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LANDSLIDE RISK MANAGEMENT STUDY IN BOSNIA AND HERZEGOVINA

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This study has been produced within the Project Landslide Disaster Risk Management in BiH, funded by the Government of Japan and implemented by the United Nations Development Programme (UNDP).The contents of this publication are the sole responsibility of the author and can in no way be taken to reflect the views of the Government of Japan nor UNDP

Contents

1. INTRODUCTION

The experiences with floods and landslides in 2014 in Bosnia and Herzegovina, but also in the wider area of the Balkans, clearly indicate the need to improve regulation and practices in disaster risk management. In this context, landslides and other instability events have proven especially problematic given the lack of clearly defined responsibilities of various institutions that primarily deal with them, coupled with the absence of strategies, lack of information and data (inventory), forecasting maps (hazards and risks), and ultimately the low level of awareness of the general public on landslides and their impacts, as well as various levels of government. Decentralised management of resources in Bosnia and Herzegovina is an additional complexity in addressing problems related to landslides in the broader sense. In addition, the experience shows that local governments differ significantly in terms of equipment and capacities to address this issue.

On the other hand, it is clear that the events of May 2014 represented an extreme that would have challenged the organisation and preparedness of far more developed countries. As a reminder, these were record-breaking rainfall, record water levels and unprecedented mass-scale activated landslides, while certain types of events were extremely unusual for the region (debris flow, lateral spread). It has been estimated[1] that as many as one million inhabitants of Bosnia and Herzegovina were affected by the consequences of floods and landslides in one way or another, with 90,000 evacuated, 25 casualties, and the total damage estimated at around 2 billion Euros, or 15% of Gross National Product. It is estimated that due to rainfall in April and May of 2014, more than 3,000 landslides were activated, damaging or destroying as many as 2,000 housing units, traffic interrupted at over 150 sites on the main road network, and 51 landslides activated in mine contaminated

1 Recovery Needs Assessment following floods in Bosnia and Herzegovina May, 14 to 19, 2014.

areas. In order to reduce these figures even in such extreme events, and to ensure better risk management, a landslide risk management study is needed, as is the application of those recommendations across all levels. The aim of the Landslide Risk Management Study (hereinafter referred to as the Study) is to provide a detailed assessment of the current situation in the field of landslide risk management in Bosnia and Herzegovina, and suggest guidelines and recommendations which could improve different segments of the process based on international experience, and create the conditions for the application of risk management of landslides within the existing system of government and its institutions. Development of the Study is based on the analysis of the current situation across all levels of risk management and throughout the entire process - from collecting data on landslides and creating databases (inventory) of landslides, collecting population data and other elements of the risk assessment methods across hazards and risks, model risk treatment and finally risk management. In addition to the analysis of the relevant legislation, a comparative analysis was also carried out for legislation relating to all levels of the process in risk treatment in the Federation of Bosnia and Herzegovina, Republika Srpska and the Brčko District. Comparative analysis of the situation in BIH and international standards has brought about recommendations for real improvements at certain levels, and the landslide risk management process in Bosnia and Herzegovina as a whole. Meeting the objectives of the Study includes the following necessary steps, thoroughly explained in the following sections, namely: consistency with other related initiatives, terminological consensus, review and analysis of existing laws and bylaws, results of users surveys, review and analysis of international documents and best practices in the field of landslide risk management, proposed methodology for landslide hazard and risk assessment from the national to the local level, as well as the proposal of the institutional framework for the implementation of risk management.

Figure 1 Geographical position of Bosnia and Herzegovina

1.1 GENERAL CHARACTERISTICS OF THE STUDY AREA

In terms of geographical position, Bosnia and Herzegovina is located in south-eastern Europe on the Balkan Peninsula (Figure 1). The total land area is 51,209.2 km2, while the length of the state border of Bosnia and Herzegovina with neighbouring countries (Croatia, Serbia and Montenegro) is 1,538 km. Bosnia and Herzegovina consists of two entities (Republika Srpska and the Federation of Bosnia and Herzegovina) and the Brčko District. The FBIH has 10 cantons and 79 municipalities, while Republika Srpska has 64 municipalities. According to the 2013 Census, Bosnia and Herzegovina has the population of 3,791,662.[2] In orographic terms, the territory of Bosnia and Herzegovina mostly consists of steep mountainous area (Figure 2). The Dinara Mountains stretch from the west and border with Croatia to the south-eastern border with Serbia and Montenegro. Maglić is the highest peak in BIH (2386 m). The Sava River is the longest (331 km) in Bosnia and Herzegovina, which runs along the northern border of the country, with its largest tributaries of Drina, Bosnia, Una and Vrbas (Black Sea basin). The Neretva River (218 km) and its tributaries are a part of the Adriatic basin. The Sava River with its vast alluvial plains is the most susceptible to flooding, while flash floods are more frequent in higher terrain and smaller streams, flowing into the Sava River together with tributaries of Black Sea basin.

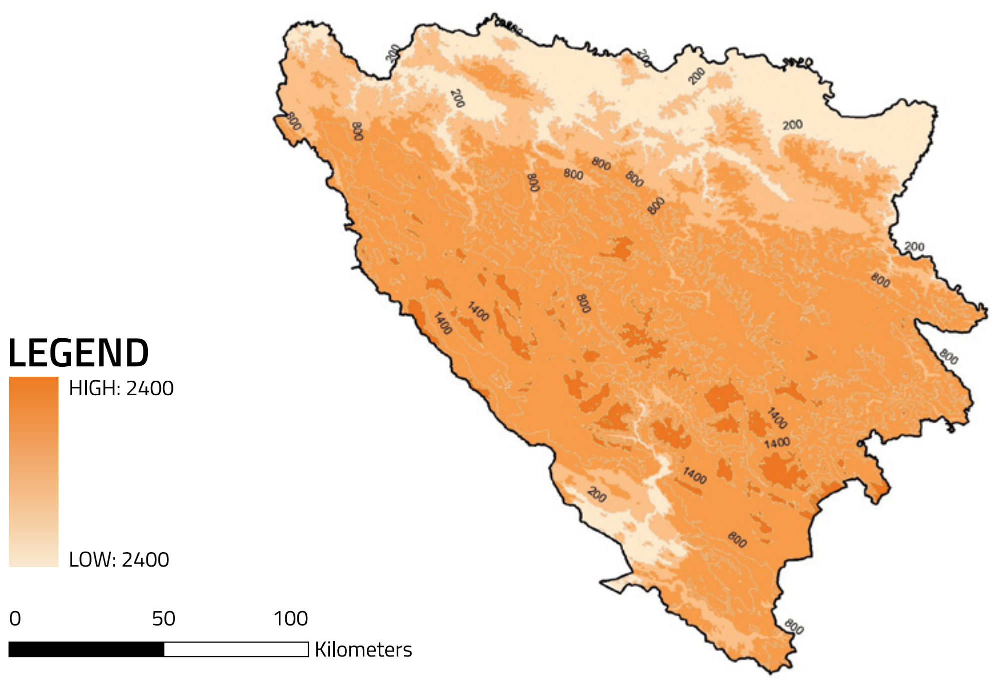


Figure 2 Hypsometric map of Bosnia and Herzegovina

2 Bosnia and Herzegovina Agency for Statistics www.bhas.ba

Different climatic impacts felt in Bosnia and Herzegovina are a result of natural elements and principles of the general circulation of air masses over a wider area. The northern peri-Pannonian part belongs to moderate continental climate zone. Mountainous and mountainous-valleys (pre-mountainous) variant of the climate impact is felt on the greatest part of Bosnia and Herzegovina. The southern part of Bosnia and Herzegovina has a modification of the Adriatic climate. Overall, rainfall is generally evenly distributed and, as a rule, rainfall decreases going from the West (1500 mm2/year) to the East (700 mm2/year) due to the influence of western air currents, except in Herzegovina, where the amount of rainfall goes up to 2500 mm2/year.

As for the geological and geotectonic structure, Bosnia and Herzegovina is dominated by two belts, namely the Dinaridc and Sava-Vardar zone, stretched between the African and Eurasian plates as a result of tectonic compression in different tectonic phases, until the very day. The most striking is certainly the Dinaric belt that covers regional NNW-SSE direction and which can be divided into External Dinarides represented by a carbonate platform and Internal Dinarides with very complex composition. It is also possible to single out a flysch belt along passive margins of Internal Dinarides, then a broad belt of Paleozoic-Triassic complex, and the ophiolite belt that permeates the entire area, partially over the active margin, presented through the Sava-Vardar zone. This zone along the Sava trench abuts the Tisijska platform in the North, and is characterised by different formations of younger flysch up to intrusive and volcanic complexes. The youngest structures lie along the dominant regional structures, represented by Neogene and Quaternary basins: South-Pannonian, the Sarajevo-Zenica and the Tuzla basin. From the perspective of instability, these youngest basins are the most sensitive, just as are tectonised zones such as the Paleozoic Internal Dinarides and flysch formations of the Dinarides and the Sava-Vardar Zone (Hrvatović, 2006).

Bosnia and Herzegovina has had a history of devastating earthquakes. Based on the actual earthquakes in the past 100 years, there are several seismic zones in BIH, and over 60 seismic structures with the expected magnitude >4M. Going from southwest to northeast, the zones are as follows: the Adriatic zone, the zone of External Dinarides, the zone of the Central Dinarides and the Sava-Vardar zone (Hrvatović, 2009). Since 1901, being the start year for recording seismic activity, the strongest recorded earthquake was in Banja Luka on October 27, 1969, of 6.6 M and the intensity of the epicenter I_0=9oMCS (Trkulja, 2009). Within BSHAP NATO SfP Project "Harmonization of Seismic Hazard Maps for the Western Balkans", a map of epicentres of major earthquakes was made (Glavatović, 2009), available on the website http://www.wbseismicmaps.org. Information on the new catalogue of earthquakes in Bosnia and Herzegovina may also be found in Cvijić and Radovanović (2009).

1.2 OVERVIEW OF BASIC DATA ON LANDSLIDES IN BIH

An analysis of spatial representation of the instability processes is important for the Study, that is, regional distribution, frequency and characteristics of landslides on the territory of Bosnia and Herzegovina, as well as their impact on population, assets and environment.

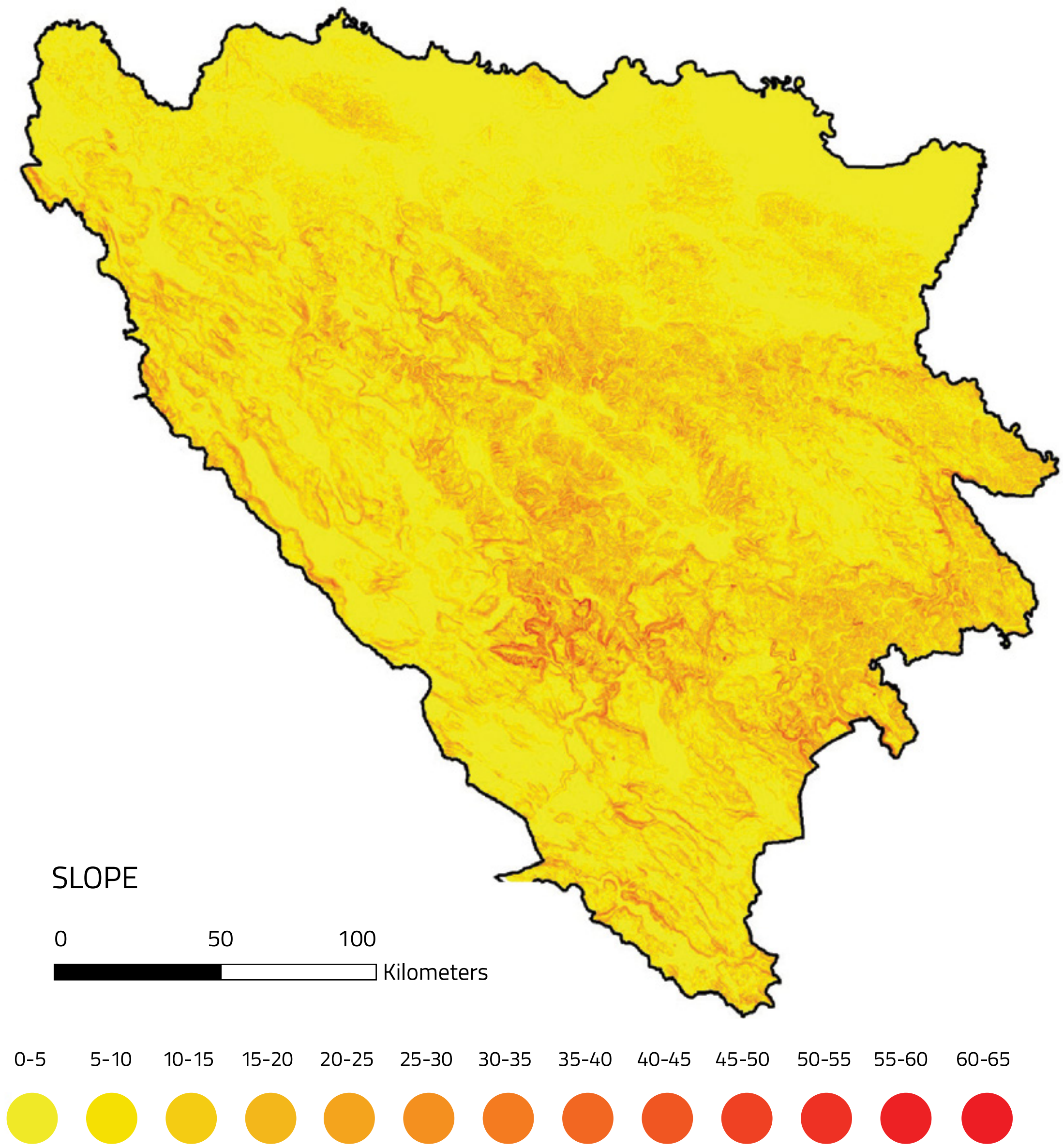
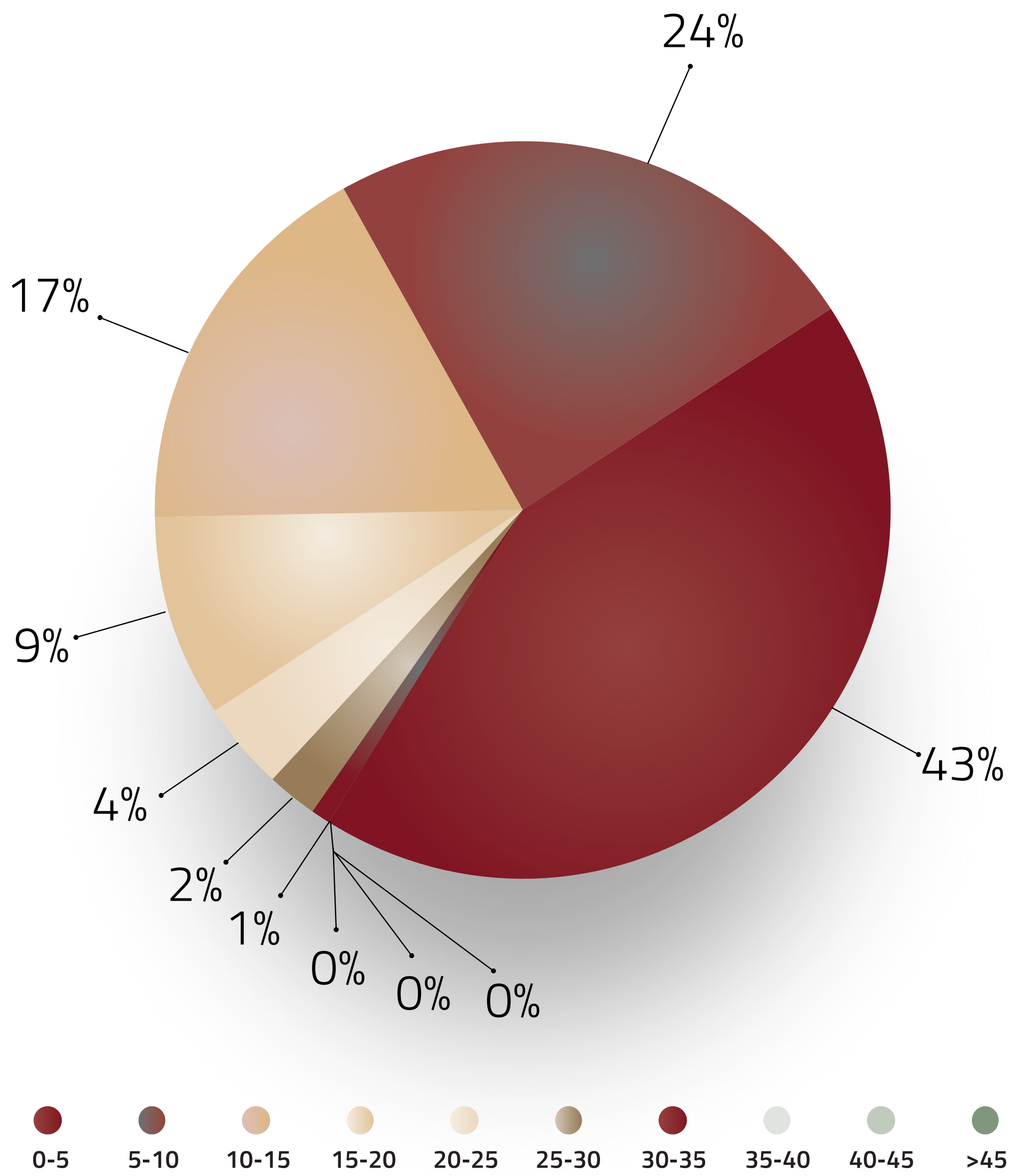


Figure 3 Map of angle of slopes in Bosnia and Herzegovina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35-40
40-45
>45

Sliding processes and landslides as events are largely predetermined by morphological features and complex geological settings of a terrain (primarily its lithological composition, as well as tectonic structure) of Bosnia and Herzegovina, climatic characteristics, but also anthropogenic impacts to a large extent and as of recently. Anthropogenic factor has had a major impact on changes in the stability of the terrain since 1990, given the large population migration and illegal construction not in line with the existing land-use planning documents. It is estimated that the main cause of landslides and other instability events in Europe is precipitation, namely rain and rapid snowmelt (69.4), while the direct impact of anthropogenic factor accounts for around 7.8% (SafeLand, 2012). In Bosnia and Herzegovina, there is no reliable data on direct causes of landslides, although, based on experience from 2006, 2010 and 2014, it can be said that precipitation, as is the case in Europe, is one of the most important triggering factors. However, complex geological settings in the most parts of Bosnia and Herzegovina is indeed one of the most causative environmental factors, crucial both in terms of lithological composition, structural characteristics, susceptibility to processes of weathering, and thus the changed physical-mechanical properties of rock mass. In regional terms, landslides in Bosnia and Herzegovina occur most frequently in terrains made of volcanogenic-sedimentary formations (diabase-chert series, Jurassic ophiolitic melange), followed by Neogene clastic sediments, sediments of the Lower Triassic in clastic development, clastic sediments of the upper Cretaceous, flysch sediments (from Jurassic to Eocene) to Paleozoic shales (Fig 4).

Fig 4. Regional distribution of landslides on the territory of BiH

As for volcanogenic sedimentary formation, the highest number of landslides was registered in the area north and south of Višegrad, followed by the wider Kladanj and Olovo surroundings. According to the morphometric characteristics, it can be concluded that these are commonly quite sizable, and apart from products of weathering, also include the bedrock, and have complex movement mechanisms.

Landslides in the Neogene clastic deposits are somewhat smaller in scale, occurring mostly on contacts between weathered Neogene sediments and fresh rock mass or contacts of areas with different hydrogeological characteristics, often caused by anthropogenic activities. These were registered in nearly all Neogene basins. Most events were registered in the Sarajevo-Zenica basin, surroundings of Jajce, Mrkonjić Grad, Tuzla, Doboj, Zvornik, Gračanica and other areas. Landslides in the Lower Triassic sediments are also common and may be significant in size and with complex movement mechanisms. Event of landslides is the result of specific structural relations of Triassic sediments, with clastic limestones covering Lower Triassic. Groundwater from limestone drains on contact and sodden the Lower Triassic Werfenian surface with a relatively thick weathering crust. Landslides of this type are found in the valley sides of the Prača River, the Drina River, the upper course of the Una River, around Sarajevo etc.

Landslides in the lower Triassic and Permian-Triassic are often related to events of gypsum (Popov Most, Prozor surroundings, the Una River and the Sana River valley, etc.). A certain number of landslides is related to the development of the Middle Triassic clastic (massive crystal limestones) between Podrašnica and Ključ.

The marl-clay development of Cretaceous (Gosau Facies) have also hosted major landslides in the area of Kladanj, Vlasenica and Višegrad.

Flysch developments of Mesozoic and Tertiary with frequent clay-marl sequences (Jurassic-Cretaceous), and in particular Eocene flysch are all abundant in landslides. The most significant events were registered in the areas of Čemerno, Majevica and the wider Doboj surroundings. Terrains made of Palaeozoic schist of low crystallinity have frequent landslides, but are also considerably less widespread than the former. They are formed mainly in the area of weathering zone of schist. Depending on the thickness of the weathering zone, these can be of different sizes, but also the movement mechanism. Most of these events have been found in the area of Bosnian Schist Mountains, the Drina and the Sana Paleozoic (Tokić, 1985). More recent publications have papers with images of landslides Lapišnica (Jelisavac et al., 2001), Bogatići (Zekan et al., 2011, Begić, 2011) and Čemerno (Sandić and Mitrović, 2011), but also an overview of many other smaller landslides which were thoroughly investigated for rehabilitation purposes. Review of the regional distribution of landslides in Republika Srpska is given in Sandić and Mitrović (2011), while the characteristics and distribution of landslides in the Sarajevo Canton can be found in Rokić (2001a, 2001b), or Mulać (2015, unpublished) for the Tuzla Canton. There is no data on a comprehensive analysis of the consequences of landslides at the regional level, nor is there documentation available on the impact of landslides on population, property and natural resources for both entities and the Brčko District.

1.3 COMPLEMENTARITY OF THE STUDY AND OTHER INITIATIVES

Within its flood recovery initiative, the European Union supported the project Development of the Floods and Landslide Risk Assessment for the Housing Sector in Bosnia and Herzegovina, with a preliminary assessment of the risk of landslides in the housing sector for the entire territory of Bosnia and Herzegovina. The methodology used corresponds to the regional level (see Chapters 3 and 4), or Tier 1 approach (the regional scale 1: 100 000), and then the local level for the cities of Tuzla and Doboj, which corresponds to the second phase of the project, or Tier 2 approach (detailed scale 1: 5000), (Günther et al., 2013).

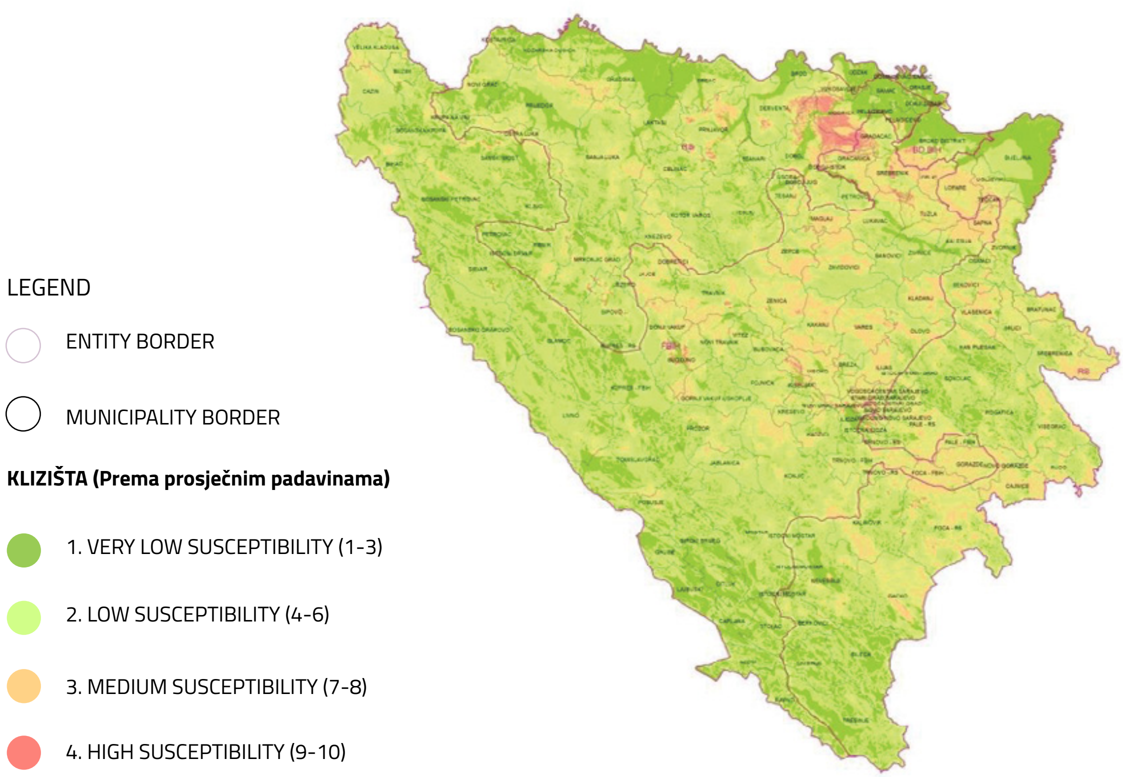
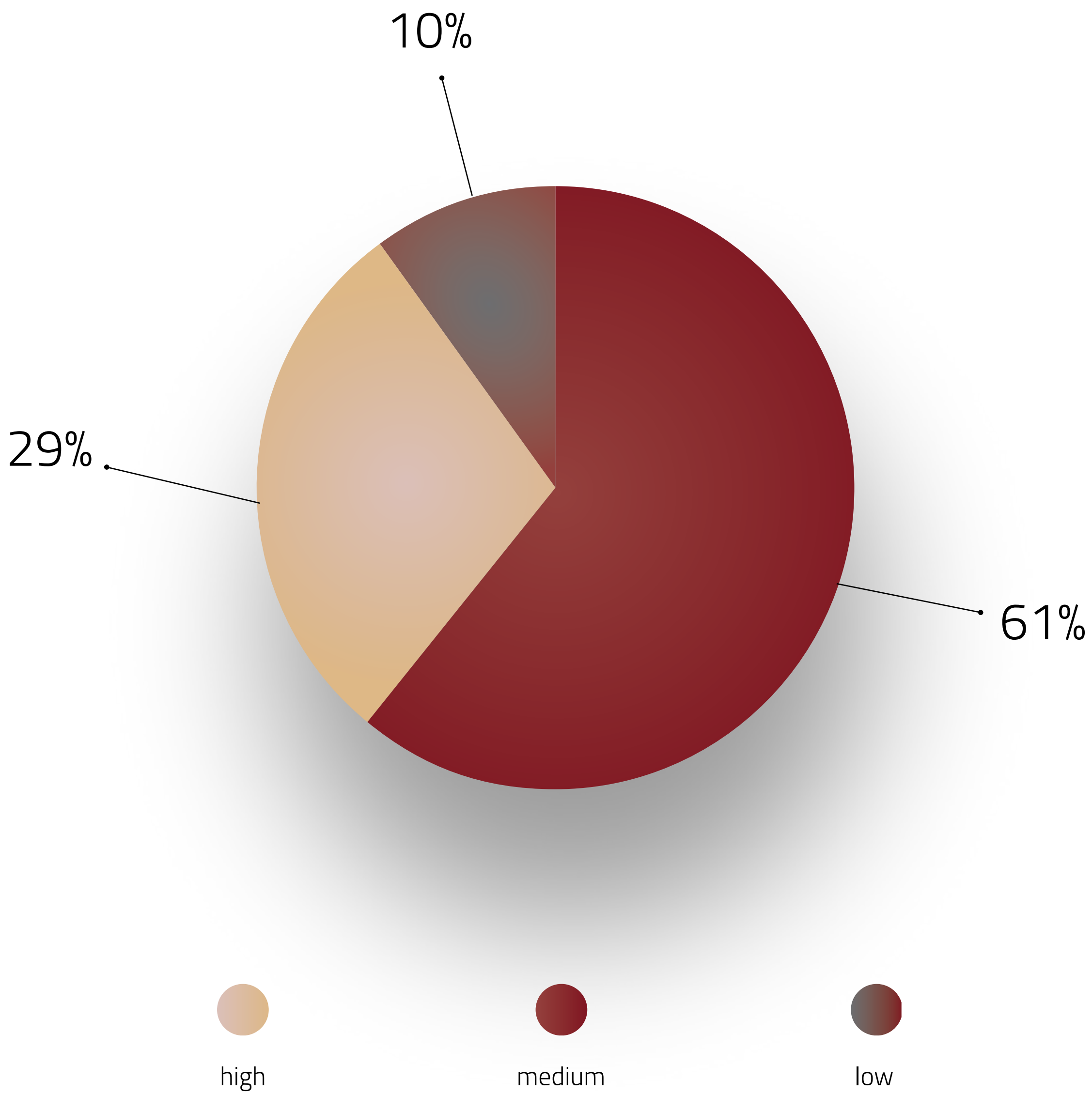


Figure 5 Distribution of landslide susceptibility classes in Bosnia and Herzegovina

Landslide Susceptibility



In the first phase of the project, based on available surfaces, an expert AHP[3] procedure was conducted to rank the selected influencing factors in order to assess the susceptibility to landslide on the territory of Bosnia and Herzegovina. Causative parameters that were taken into consideration in the analysis are: geological structure, slopes, average precipitation and land use. The AHP analysis resulted in a final map of areas with different landslide susceptibility classes (Figure 5). The assessment identified municipalities with the highest percentage of territory with high landslide susceptibility. According to the Assessment, Table 1 lists top 15 municipalities with the highest landslide susceptibility.

Table 1 Top 15 municipalities with the highest landslide susceptibility in BIH

Municipality	Entity	Area (km2)	Very Low Susceptibility (km²)	Low Susceptibility (km²)	Medium Susceptibility Risk (km²)	High Susceptibility (km²)
DOBOJ	RS	656,3	85,63	256,88	166,01	147,78
FOČA – RS	RS	1118,4	0,53	613,18	384,74	116,94
MODRIČA	RS	326,7	93,01	36,085	90,33	107,29
KALINOVIK	RS	679,5	0,40	412,16	206,77	60,15
PRIJEDOR	RS	834,0	137,50	494,13	148,73	53,69
GRADAČAC	FBiH	215,2	25,27	86,97	59,858	43,15
GRAČANICA	FBiH	215,3	16,89	71,48	87,39	39,55
PRNJAVOR	RS	629,9	75,73	225,77	289,02	39,45
DERVENTA	RS	516,6	63,39	260,07	157,03	35,94
BANJA LUKA	RS	1238,8	35,01	844,53	323,43	35,91
VIŠEGRAD	RS	449,0	3,09	288,29	121,90	34,82
LOPARE	RS	297,8	24,20	43,81	195,03	34,79
GRADIŠKA	RS	761,6	351,89	283,05	94,21	31,28
ZAVIDOVIĆI	FBiH	555,6	4,20	327,36	193,41	30,71
OLOVO	FBiH	409,3	0,9	302,54	75,90	30,57

3 AHP method of multiple criteria analysis and procedure to conduct this analysis is further elaborated in Chapter 4.1.

This model was further used for relative risk assessment based on the population density, while also considering different scenarios related to different precipitation. The model was developed based on the reference precipitation period from 1971 to 2000. Preliminary Landslide Risk Assessment for the Housing Sector in BiH has selected the following municipalities with the largest percentage of area under a high risk of landslides (Table 2).

Table 2 Top 15 municipalities according to the landslide risk for the housing sector in BIH

Municipality	Entity	Area (km2)	Very Low Susceptibility (km²)	Low Susceptibility (km²)	Medium Susceptibility Risk (km²)	High Susceptibility (km²)
TUZLA	295,86	FBiH	7,18	7,64	8,79	272,25
CENTAR SARAJEVO	32,92	FBiH	5,58	0,25	1,02	26,07
KLADANJ	335,64	FBiH	3,98	2,93	1,78	326,95
NOVI GRAD SARAJEVO	47,31	FBiH	3,94	4,29	1,52	37,56
MOSTAR	1164,95	FBiH	3,92	8,83	15,56	1136,64
STARI GRAD SARAJEVO	49,46	FBiH	3,05	1,6	1,17	43,64
ZENICA	550,41	FBiH	2,64	6,07	4,62	537,08
VOGOŠĆA	71,69	FBiH	2,5	0,97	1,48	66,74
KAKANJ	376,98	FBiH	2,47	2,48	5,39	366,64
ŠIPOVO	549,97	RS	1,89	0,14	0,87	547,07
BANJA LUKA	1238,89	RS	1,8	12,9	15,3	1208,89
NOVO SARAJEVO	9,2	FBiH	1,63	3,15	1,1	3,32
SREBRENIK	247,93	FBiH	1,27	2,72	3,55	240,39
GORAŽDE	253,6	FBiH	1,2	1,81	2,34	248,25
GRADAČAC	215,25	FBiH	1,19	5,34	4,78	203,94

The first phase of the project made a significant step forward in many aspects. Firstly, this initial stage gives a reference and solid grounds for all further and more detailed assessment, but it is also an important instrument to raise awareness about landslide processes and its consequences, good and poor practices, and other aspects, whether in entities or among various beneficiaries, representatives of local governments, professional and general public and others. Given the scale of preliminary assessment, it was technically impossible to make recommendations for appropriate structural measures, nevertheless recommendations for the implementation of non-structural measures were provided. Finally, the actual spatial data obtained as a result of the first phase of the project represent the first concrete, quantitative data on the distribution and categories of susceptibility to landslides, and also relative landslide risks for the housing sector at the national level, which is a good example for the region. The Study also followed the development of the methodology for the second phase of the Project Development of the Floods and Landslide Risk Assessment for the Housing Sector in Bosnia and Herzegovina and accordingly (see Chapter 4), proposed a data-based approach (Tier 2 approach). In any case, the coincidence of this study with the second phase of the project Detailed Floods and Landslide Risk Assessment in Urban Areas of Tuzla and Doboj is important in view of successfulness of implementation for at least two reasons: (i) all specific administrative or institutional problems in the implementation are being identified, (ii) direct feedback on the feasibility of the proposed approach is obtained for the methodology of landslides hazard and risk assessment and risk management. The procedure of detailed assessment of landslide risks in Tuzla and Doboj is shown in the diagram in Figure 6.

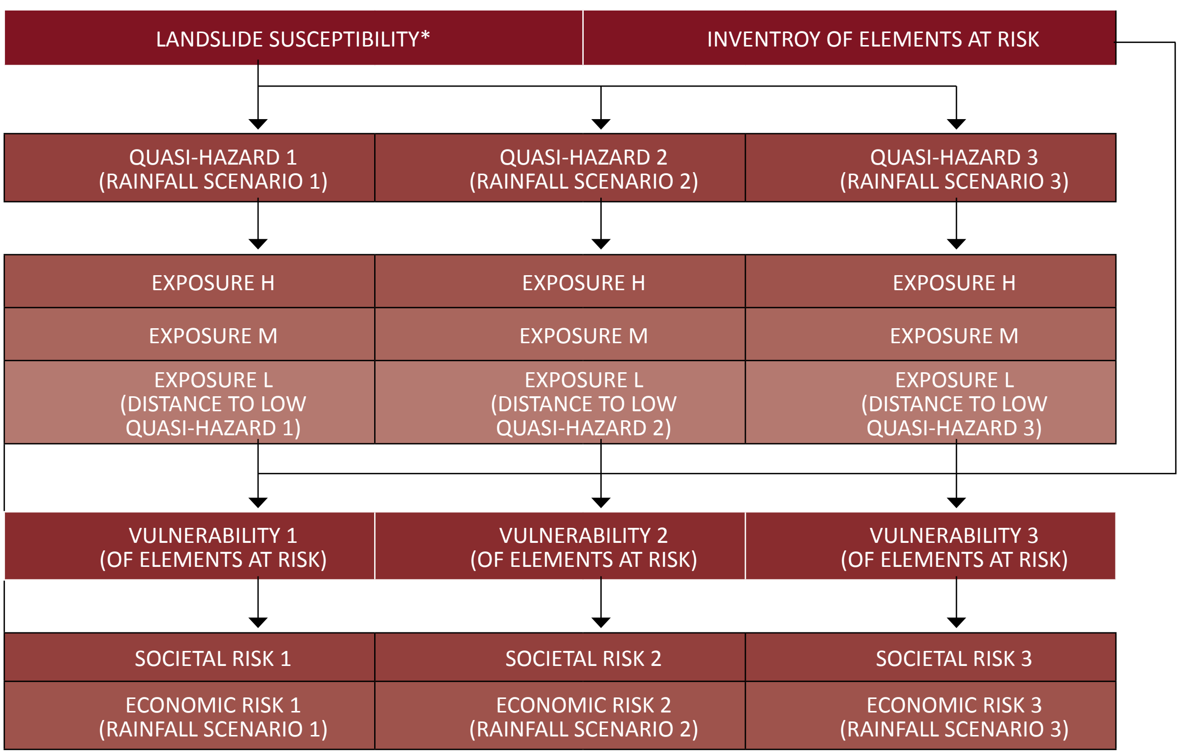


Figure 6 Procedure for Landslide Risk Assessment

According to the results obtained through a detailed assessment of landslide risks in the urban area of Tuzla, there is a very high risk of landslides for 354 ha or 14.56% of the territory of the housing sector (Table 3, Figure 7). In the urban area of Doboj, results of the risk assessment showed that a very high risk of landslides for 190.12 ha or 19.74% of the territory (Table 4, Figure 8).

Table 3 Frequency of certain risk categories for the housing sector of the urban area of Tuzla

Risk Scenario 1	No of Units	Area (km2)	Area (ha)	Percentage %
Very Low	124495	3,112375	311,2375	12,79
Low	472147	11,803675	1180,3675	48,51
Medium	135696	3,3924	339,24	13,94
High	99124	2,4781	247,81	10,18
Very High	141709	3,542725	354,2725	14,56
Total	**973171**	**24,329275**	**2432,9275**	**100**

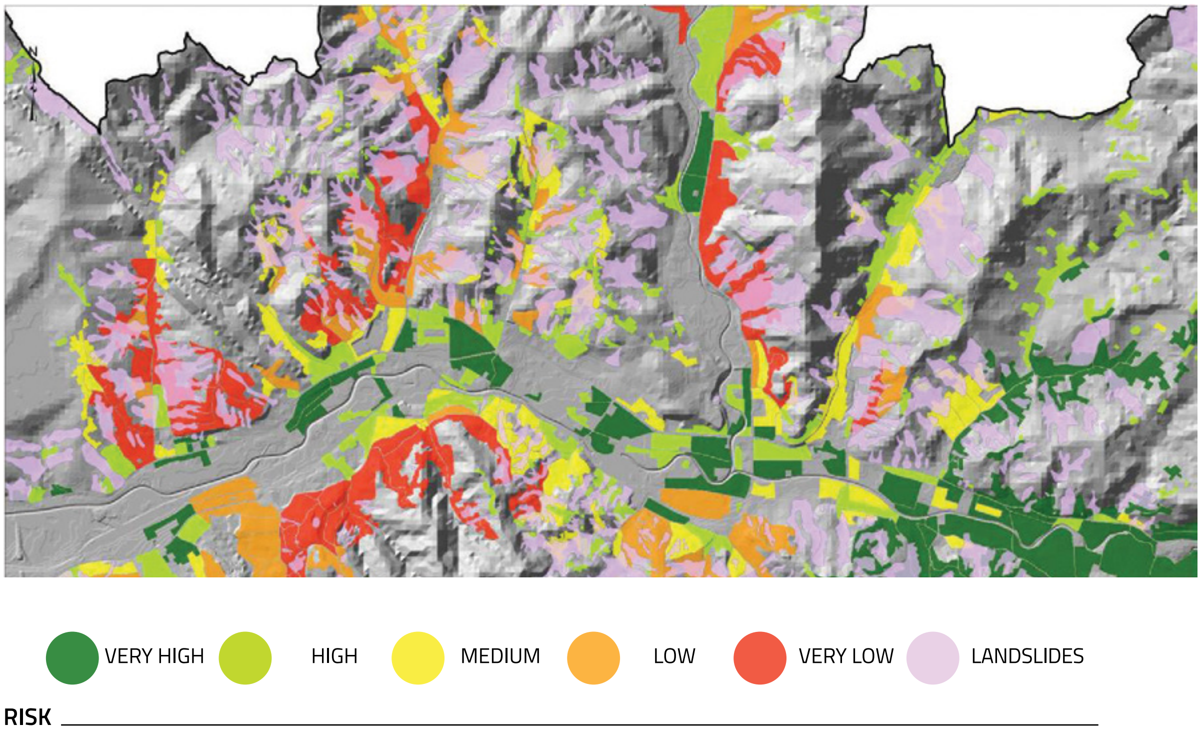


Figure 7 Detail of Landslide Risk Maps for Tuzla for the first scenario (historical precipitation 1971 to 2000)

Table 4 Presence of certain categories of risk for the housing sector of the urban area of Doboj

Risk Scenario 1	No of Units	Area (km2)	Area (ha)	% territory
Very Low	75008	1,8752	187,52	19,47
Low	79395	1,9848	198,48	20,61
Medium	76972	1,9243	192,43	19,99
High	77828	1,9457	194,57	20,20
Very High	76048	1,9012	190,12	19,74
Total	**385251**	**9,631275**	**963,1275**	**100**

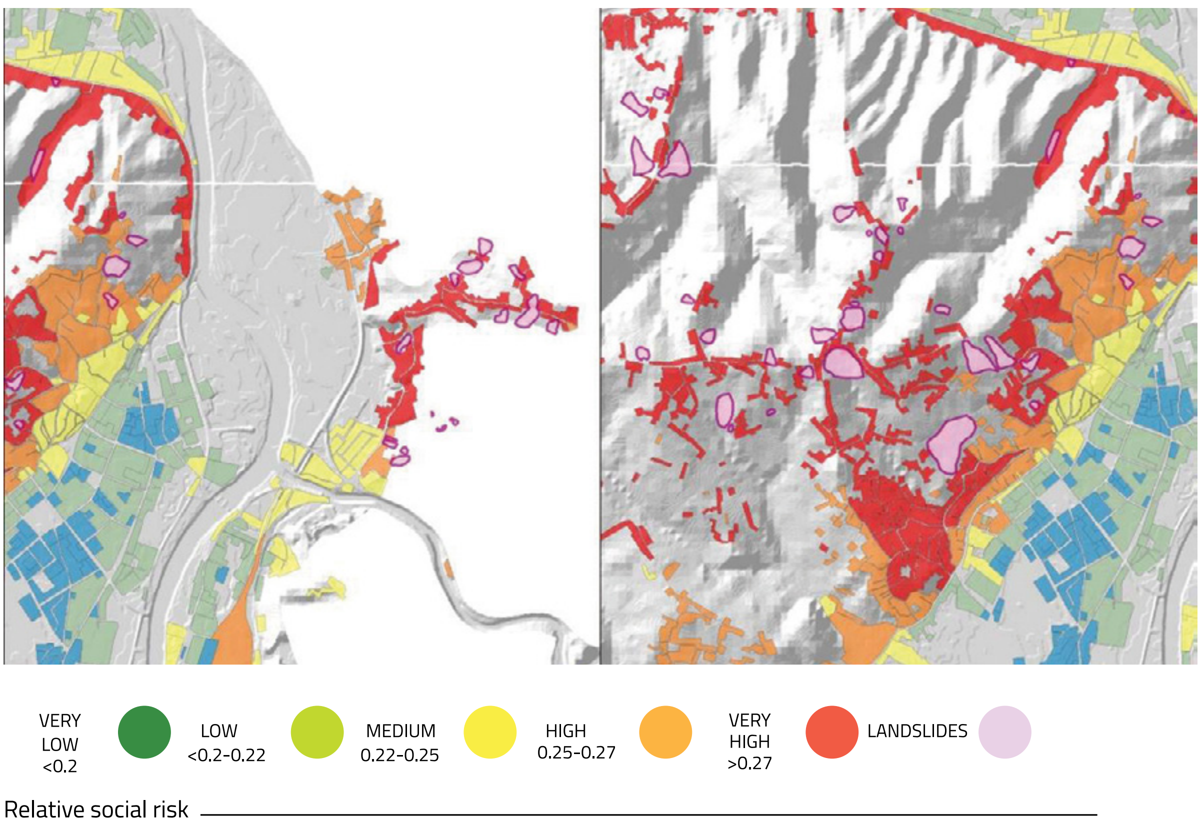


Figure 8 Details of Landslide Risk Maps for Doboj for the first scenario (historical precipitation 1971 to 2000)

Based on estimates of relative risk for the housing sector in Tuzla and Doboj, non-structural and structural measures have been proposed. Structural measures specifically target sites (landslides) where rehabilitation is needed, coupled with geotechnical monitoring on site.

2. GENERAL CONCEPTS AND TERMINOLOGY

The whole issue of terminology is a special and important one, and will hence be given particular attention, including a brief discussion, followed by definition of some basic concepts to be observed in this Study.

The biggest problem is the consistency in the use of terms in an appropriate manner and in the proper context, and even within the same line of profession. The root of the problem lies in the interdisciplinary feature, which is highly desirable in risk assessment and management, but can lead to disagreements in terms of terminology and various other problems, unless competence is clearly outlined in legislation. Thus, the problem goes much deeper into division of responsibilities and institutional frameworks, lack of uniformity in a decentralised system and so on. Extreme examples included cases of virtually unrelated professions, for example, engineering and security, where it is difficult to establish a consensus. Interdisciplinary teams of experts with different backgrounds should have a well-defined role in the process of risk assessment and management, with the consistency of terminology as an imperative, bearing in mind that these two segments are inseparable and overlapping in some aspects. Another dimension of the problem is generational, and it affects even individuals of the same profession. The reason lies in the fact that risk assessment and management is a relatively new initiative (last 25 years), resulting from an awareness of natural processes in the interaction between living and technological environment, all against a backdrop of climate changes and the expanding world's population. Thus there is a terminology conflict between the old and new schools of tought, certainly requiring consensus. Finally, there are linguistic difficulties related to direct translation of the adopted international standards, since literal translation of certain terms creates additional confusion, illogic and non-acceptance. It can be concluded that it is necessary to give it some time for hazards and risks terminology to come to life and be accepted throughout the country, while in the meantime insisting on the consistency of its application, at least at the level of professional public documents.

Basic concepts and terms used in drafting the Study, gathered from various international instruments and standards (see Chapter 3) are given below, while general terms are given in the attachment of the Study (Annex 1). It should be noted that terms are given in two languages and in the terms of the quantitative approach to landslide risk management. They can be classified in terms related to the process itself and event (landslides), risk assessment and risk management.

TERMINOLOGY

Rock

Any solid, coherent aggregate of one or more minerals.

Soil

Loose or coherent material composed of varying amounts of clay (<0.002 mm), dust (0.002 to 0.05 mm), sand (0.05 to 2.0 mm) or gravel (> 2.0 mm).

Debris

Any loose material with a greater amount of larger fragments of rocks (greater than 2.0 mm), in the narrow sense, any material with 20 to 80% of fragments larger than 2.0 mm.

Slide[4]

In the broadest sense, recent geological process of separation and movement of rock masses along slopes and inclines over stable surfaces under the influence of gravity.

Landslide

In the broadest sense, the creation of the instability process, i.e. terrain with active or suspended sliding process.

Landslide Classification

In the broadest sense, classification involves a whole range of gravitational processes and is based on the movement mechanism and the type of displaced material (Varnes 1984, Cruden & Varnes, 1996; Cruden & Van Dine, 2013). Accordingly, based on the movement mechanism, the practice frequently distinguishes between the following:

4 According to international terminology, it is noteworthy that *Landslides* in English encompasses the entire group of gravitational processes of different mechanisms of movement that do not imply only sliding as a process or landslides as an event. A closer general term, also frequently used is ‘mass movements’. Neither the Bosnian nor the Croatian and the Serbian language have a sufficiently precise and comprehensive linguistic term.

- Slide in the narrow sense - the movement of soil, debris or rocks down the slope along the defined sliding surfaces or a clear zone of expressed sliding deformations by rotation, translation or a combination.
- Fall - sudden separation and gravitational movement of rock, less frequently of soil or debris by free fall, roll or bouncing down a steep slope.
- Flow – rapid movement of debris or soil, less frequently of rocks due to water saturation and dynamic effects, without shear deformation but across it, yet with a well-defined zone of direct erosion and material accumulation.
- Topple - rotational movement of rocks (less frequently of debris and soil) where the rotation centre is located below the centre of the moving rock mass.
- Lateral spread - specifically expansive movement of coherent soil types of low thickness or thicker soil with collapsible, expansive or liquefaction soil as its base.

Conditioning Factors

Factors inducing landslide by creating favourable conditions for their development, such as unfavourable geological settings, unfavourable morphology of the terrain, poor physical and mechanical parameters of rock masses making up the terrain, unfavourable hydrological conditions, inappropriate land use, etc. A set of unfavourable conditioning factors makes specific area a subject to the event of slide.

Triggering Factors

Factors such as heavy rainfall, rapid snowmelt, dynamic impacts (e.g. earthquakes.), which directly lead to landslides and other instability events.

ASSESSMENT

Susceptibility[5]

Spatial probability of an event (e.g. landslide) in an area expressed in qualitative terms (scale from low to high susceptibility) or quantitatively.

Risk / Hazard

In general terms, a space-time probability of occurrence of an event, substance, human activity or condition that can lead to loss of life, injury or other health impacts, property damage, loss of livelihoods and work, social and economic disturbances and damage to the environment. Landslide hazard is a probability of processes in a certain area of a specified magnitude / intensity in a given time period.

5 In the spirit of local language, the term *Susceptibility* can be translated as sensitivity, proneness, susceptibleness.

Elements at risk

People, assets, systems or other elements present in hazard zones that are affected or subject to potential losses.

Vulnerability

Characteristics and conditions of exposed elements that make them susceptible to the harmful effects of danger. Vulnerability is expressed as the potential extent of the loss of value of a given element or set of elements exposed to landslide processes of a corresponding intensity or magnitude.

Risk

The combination of the probability of a hazardous event and its negative consequences on the exposed elements over time.

Risk Assessment

The methodology for determining the nature and extent of risk by analysing potential hazards and the assessment of existing conditions (threats) of elements at risk.

MANAGEMENT

Risk Management

Systemic access and practice of risk probability management, so as to reduce potential damage and losses.

Structural Measures

All physical construction to reduce or avoid possible effects of hazards and application of construction techniques to build resilience to danger and resilient structure or a system.

Non-structural measures

Any measure not involving physical construction, while using knowledge, practice or agreement to reduce risks and impacts, in particular through policies and laws, public awareness, training and education.

3. OVERVIEW AND SITUATIONAL ANALYSIS

3.1 OVERVIEW AND ANALYSIS OF RECORDS

The overview of records aimed to highlight the history of the study of instability processes in Bosnia and Herzegovina in the period leading up to 1991, and after 1991 likewise. Unfortunately, papers published in both periods are very scarce, although, obviously, the process of studying landsliding at the regional research was institutionally defined as the activity of the Institute of Geological Research in Sarajevo (until 1991). Internal reports in both entity Geological Surveys are records available in analogue form, split after the war between the Federal Geological Survey of the Federation of BiH and the Geological Survey of Republika Srpska. In addition to basic research, detailed studies for landslides rehabilitation and other instability processes have been conducted for a number of sites, but such documents only give an insight into individual cases, and not the regional overview. Further, most of these studies were never publicised in professional and scientific events; instead, these are generally inaccessible analogue records of the Geological Survey of the Federation of BiH, including studies on detailed surveys of individual landslides that are records kept with the client-investor or contractor. It is also likely that previous studies are also in analogue form. There is, unfortunately, no uniform documentation for the Federation of BiH, nor for Republika Srpska, and the Brčko District.

As for records covering the period up to 1991, in short, the conclusion is that in terms of basic research in the area of Bosnia and Herzegovina, the most important are geological engineering research, conducted by the Institute of Engineering Geology and Hydrogeology of Sarajevo in the period from 1966 to 1984. Apart from the overall engineering geological issues, these studies also analysed slope stability, including recording and description of a number of landslides. The actual investigations of active landslides, for the remediation measures, are indeed numerous, especially in the period after 1967 in Bosnia and Herzegovina. From 1968 to 1985, geological engineering studies were carried out for the Southern coastal area, northern Bosnia, the Sava River, the Gomjenica River and the Drina River basin. In the eighties, a study was finalised with a general overview of landslides and unstable slopes for areas of Bosnia and Herzegovina (LJ. Rokić and S. Tokić), but is also available only as records.One of the objectives of the analysis and overview of records was to rely on published documents and papers to examine the complexity of the problem of instability processes in Bosnia and Herzegovina, but also to analyse the state of technical and scientific literature related to some of the segments of landslide risk management. Of all the published papers after 1991, merely a few have been singled out (Rokić Lj. and Vujanić V., 2004, Rokić Lj., 2004a, 2004b, Tadić Z., 2011, Mulać M., 2011) addressing only some of the segments of landslide risk management. All other technical documents (published and unpublished) do not deal with any segments of landslide risk management.

3.2 REVIEW AND ANALYSIS OF LEGISLATION IN BOSNIA AND HERZEGOVINA

The aim of the review and analysis of legislation was to study the legal framework in which it is possible to institutionally define and implement landslide risk management. The analysis included laws in the field of planning and construction, geological research, environmental protection, water management, forestry and agriculture, organisation and operation of civil protection, local governance, procedures in emergency situations, documents related to action plans and strategies, laws and by-laws, procedures, competences, enforcement, and other, in the Federation of BiH, Republika Srpska and the Brčko District.

The list of analysed legislation is provided in the following sections. Possible improvements to legislation in the form of comments to existing Articles are provided in the section on recommendations how to improve institutional framework (5.2.), Annex 4.

- *Law on Geological Researches of the Federation of Bosnia and Herzegovina (Official Gazette of the Federation of Bosnia and Herzegovina, Nos. 10/09 and 14/10),*
- *Law on Spatial Planning and Land Use in the Federation of Bosnia and Herzegovina (Official Gazette of the Federation of Bosnia and Herzegovina, Nos. 02/06, 72/07, 32/08, 4/10, 13/10 and 45/10),*
- *Law on Waters (Official Gazette of the Federation of Bosnia and Herzegovina, No.12),*

- *Law on Forests (Official Gazette of the Federation of Bosnia and Herzegovina, Nos. 20/02, 29/03 and 37/04),*
- *Law on Mining of the Federation of Bosnia and Herzegovina (Official Gazette of the Federation of Bosnia and Herzegovina, No.10),*
- *Rules of Geotechnical Surveys and Tests and Geotechnical Engineering (Official Gazette of the Federation of Bosnia and Herzegovina, Nos. 2/06, 72/07 and 32/08),*
- *Law on Geological Research of Republika Srpska (Official Gazette of Republika Srpska, No. 13),*
- *Law on Spatial Planning and Construction (Official Gazette of Republika Srpska, No. 10),*
- *Law on Waters (Official Gazette of Republika Srpska, No. 50/06 and 92/09),*
- *Law on Environmental Protection (Official Gazette of Republika Srpska, No. 50/02),*
- *Law on Forests (Official Gazette of Republika Srpska, No. 75/08).*

3.3 ANALYSIS OF ENTITY INSTITUTIONS, LOCAL GOVERNMENTS AND EDUCATION

The study foresees interviews with institutions in both entities and the Brčko District, as well as with relevant ministries, local governments and respective entity geological institutes, and both Hydrometeorological Institutes. Interviews aimed to gain insight on the state of play in institutions involved in landslide risk management in line with their competence. A list of interview visits is provided in Annex 2.

ANALYSIS OF GEOLOGICAL SURVEYS IN ENTITIES AND THE BRČKO DISTRICT

The main task of Geological Surveys in the process of landslide risk management is to gather, create and maintain a database of landslides,,[6] but also to estimate susceptibility, hazards and risk at the level of basic research (1:25 000 scale and smaller), including the preparation of other necessary data for the aforementioned assessments (required analytical maps with appropriate scale, such as, an engineering geological map).

6 *Landslide Database* is a more comprehensive data collection than Landslides Inventory, which includes registration of landslides, which is not most precisely defined in BIH content-wise. Landslide Database is usually a part of the national geological information systems.

Also, it is desirable to take part in the estimates for the level of detailed research (larger scale than 1: 25,000), given the capacity of personnel for gathering and creating a database of landslides and other instability events, preparation of engineering geological basis as required for spatial and urban plans and others. In addition, geological surveys in the world are in charge of setting up a geological information system and its Internet presentation. Database on landslides and other instability events is an integral part of a geological information system.

Table 5 Survey results on resources of geological Surveys of entities and the Brčko District

Question	FGZ BiH	GZ RS	BD
Do they have a license for ArcGIS and ArcGIS Server (if yes, which version)?	10.3.1.	No	No
Server infrastructure			
Virtualised servers	No	No	No
Operating systems	No	No	No
Server’s internet connection	No	No	No
External static links	No	No	No
Which system is used to manage databases?			
SQL Server, PosgeSQL, ORACLE	Yes	No	No
No system - Access	No	Yes	No
Which format is used to record the current database?			
Shape	Yes	No	No
Personal geodatabases	Yes	Yes	No
Server geodatabases	Yes	No	No
How many landslides are described at the level of polygons?	Significant No.	2500	-
How many landslides described at the level of their characteristics?	-	1200	-
How many are processed electronically?	Significant No.	2500	-
Availability of geological maps?			
Via web service	No	No	No
In geodatabases	Yes	Yes	No
Total sum* (see Figure 5.)	65	51	0

** Total sum is obtained by adding columns in the table, wherein an affirmative response in each major data column is assigned 10 points, and 5 points for smaller columns.*

The Brčko District does not have a geological survey or a department with similar assignments, hence the competence for development of landslide inventory falls under the Public Safety Sector. The service is yet to be established, despite having a part-time/ volunteering geologist (BSc, geological engineering, hydrogeology study programme). There are no full-time employees for geology. In terms of professional and technical equipment, additional adequate professional training and support are needed, as is hardware and software, and appropriate training in the field of landslide risk management (Table 5).

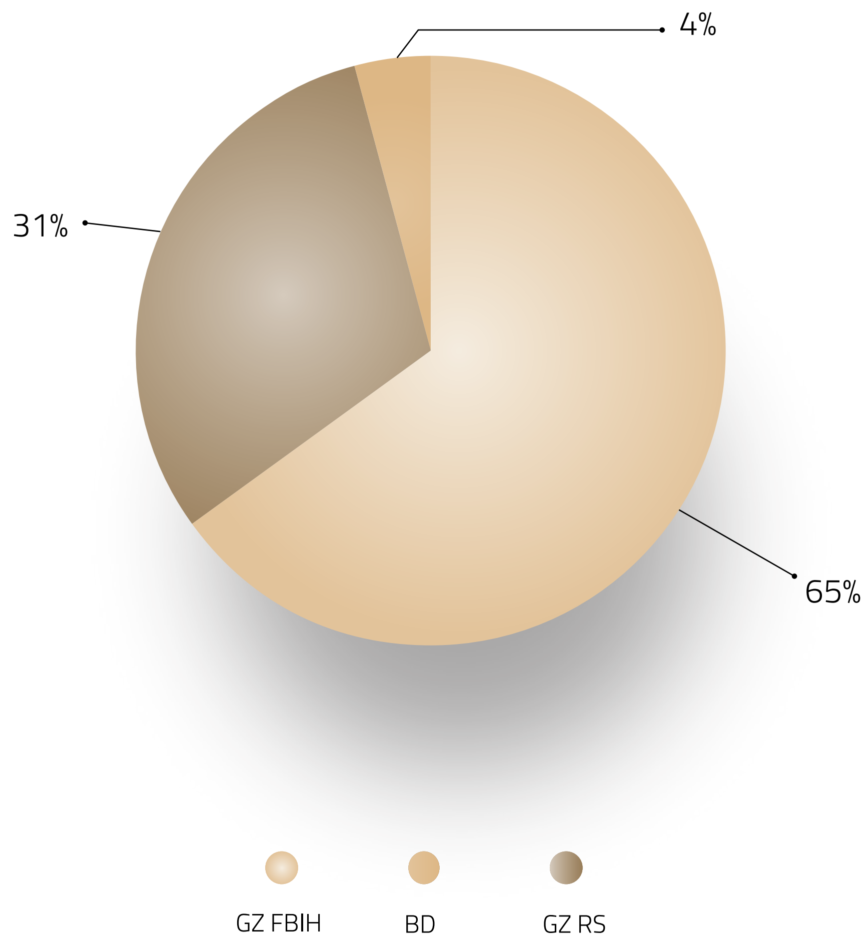


Figure 9 Ratio in terms of human resources in respective Geological Survey Institutes of entities and the Brčko District

The Federal Geological Survey of the Federation of BiH – The Federal Geological Survey Institute is an entity institution of the Federation of BiH, employing 17 engineers of various backgrounds in the field of geology. Engineering geology and the problems of landslides and other instability events at the level of basic research are directly handled by two engineers, and indirectly could engage additional two, which suggest serious understaffing when it comes to the establishment of an entity landslide database. In this regard, it is necessary to strengthen the capacity of the Institute, primarily the Sector for Engineering Geology, so as to deliver on its role of the landslide database holder. The process of landslide risk management and all its phases by international standards are not sufficiently known, hence the need for additional training on assessment methods for susceptibility to landslide, hazards and risks of landslides.

The methodology of collecting data on landslides and other instability events is reduced to fieldwork, in the framework of annual plans and research programmes, without the use of recent methods of remote sensing, which is the actual standard for the level of basic research. The largest drawback is a non-standardised inventory format of events, as well as non-compliance of content of process descriptors with the international classification of processes and events. Creation of a landslide database based on the existing concept of inventory forms and reports does not provide for searchability by selected parameters for potential users. A large body of data (reports on individual events, landslides, etc.) is still in analogue, and not digital format. The website of the Institute offers no transparency of existing data. There is also inconsistency in communication between the Federal Geological Survey Institute of the FBiH and the duty of cantons to provide information, as they also have information on landslides and other instability events. Cooperation with geological counterparts in the region has been established and is at a satisfactory level. Equipment of the Institute is rather good, yet additional steps are needed in ICT terms (Table 5). Recommendations for improvement of the Institute are given in Section 5.1.

Geological Survey Institute of Republika Srpska - Geological Survey Institute of Republika Srpska is an entity institution of Republika Srpska, employing eight engineers of various backgrounds in the field of geology. Engineering geology and the issue of landslides and other instability events at the level of basic survey is directly handled by two engineers, but indirectly it could engage another one. Just as in the Federation of BiH, there is a serious lack of staff when it comes to establishing and maintaining the entity landslide database. In this regard, it is necessary as soon as possible to strengthen the capacity of the Institute to deliver on its role of holder of the landslide database at the entity level. The process of landslide risk management and all its stages according to international standards are sufficiently known, considering that one of the employees had participated in a prestigious international workshop on the assessment of landslide hazards and risks in 2014 (LARAM School, http://www.laram.unisa.it/). There is no need for additional training on assessment methods of landslide susceptibility, hazards and risk. The short and long term plan of the Institute foresee for the landslide inventory and mapping of hazards and risks, also adopted by the competent ministries of Republika Srpska. The methodology for collecting data on landslides and other instability events is reduced mainly to fieldwork, in the context of annual plans and survey programmes (or in the case of emergencies), without the use of modern methods of remote sensing, which is the actual standard for the level of basic research. Inventory form is standardised and in use (more than 2500 events recorded according to this form), however there is a discrepancy in content descriptors and processes, on the one hand, and the international classification of processes and events on the other. Also, the establishment of landslide database based on the existing inventory form does not provide sufficiently for searchability by selected parameters for potential users. A bulk of data is available in digital form (Table 4). Website of the Survey has no transparency on the existing data on landslides. The delivery on municipal obligation to submit data is satisfactory. Cooperation with geological counterparts in the region has been established and is at a satisfactory level. Equipment of the Institute is adequate, but when it comes to ICT, additional steps and investments are needed in terms of hardware and software to achieve full functionality of the already prepared digital data (ArcGIS Server license). This includes direct investment in the equipment of the Survey, but also a permanent arrangement of skilled personnel (engineering geology, geotechnics), as well as personnel in the field of information technology (Table 5, Figures 9, 10).

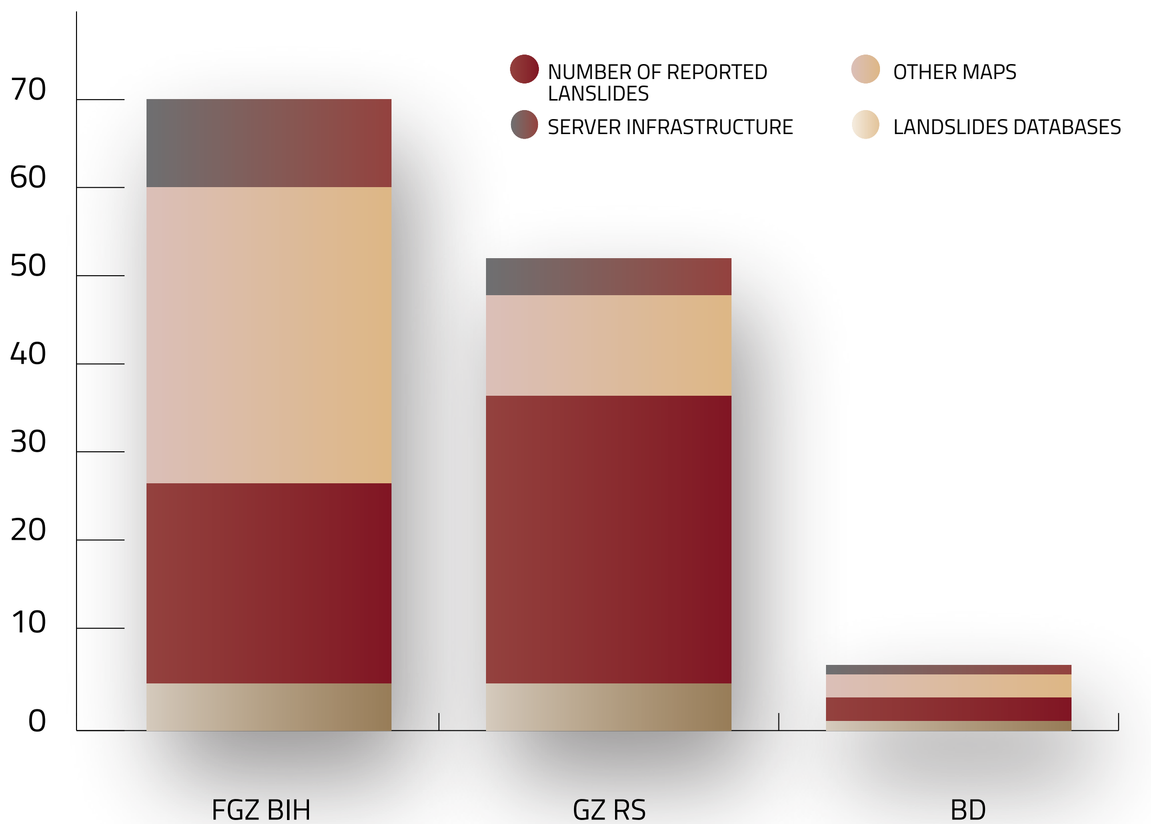


Figure 10 Ratio in different resources of Geological Survey Institutes of entities and the Brčko District

In conclusion, capacities of both entity Geological Survey Institutes and the Brčko District should be strengthened as soon as possible, being primarily in charge of basic geological survey research, and thus also the landslide databases at the entity level, which will in return create the institutional preconditions for the primary segment of risk management.

Chapter 5 outlines recommendations made concerning the role of the entity Geological Surveys and the Sector of Public Safety of the Brčko District, while Annex 3 gives a minimum indicative budget for implementation.

ANALYSIS OF SITUATION IN LOCAL GOVERNMENTS

As a part of the Study, visits to local governments aimed to gain insight into the situation and problems on the local level, or in fact into capacities to overcome problems in all aspects of landslide risk management. Visits and interviews were conducted with representatives of a certain number of municipalities (Annex 2).

During the events of May 2014, local governments faced problems for which they primarily lacked preparedness in terms of professional and technical equipment, with insufficient manpower and basic opportunities for communication (mobile networks down due to electricity outage and destroyed infrastructure). This was overcome during 2014 thanks to maximum personal engagement of local population, employees in the administration and volunteers. In most municipalities affected by floods and massive landslides in 2014, the extent of economic damage had by far exceeded the municipal budget, and local governments faced financial problems that could not be overcome without the assistance of donors, entities, state and international institutions and others. The greatest need among local governments was that for qualified personnel and technical equipment, not only in similar situations, but also in the implementation of legal regulations and obligations at the local level in situations apart from a state of emergency (landslide inventory, preparation of planning documentation, inspectorate). In most municipalities, the work on spatial data in a GIS environment is minimal and is not related to the recording of landslides and other instability events, but only on maintaining a surveying inventory. Entity Geological Survey Institutes provided professional assistance to individual municipalities in 2014 and 2015, but the assistance was insufficient primarily due to lack of financial resources and inadequate number of professional staff of Geological Survey Institutes (as already mentioned). Certainly, this model is not acceptable for local governments in the long run, particularly in municipalities where a large percentage of the area is subject to instability processes. Training by the UNDP in BIH in 2015, financed bz the Government of Japan, was conducted for nine (9) local authorities to record landslides. This training is the initial step towards the establishment of communication between the entity institutions and local governments, training of members of local governments on their active role, as well as raising the general awareness on the landslide risk management process. In addition, it is necessary to review the planning documentation in all municipalities that were threatened by floods and landslides in 2014. In financial and technical terms, local governments cannot do this on their own – and this is the conclusion of analysis of most local governments.

The situation is somewhat more specific in the Brčko District, although there is also the need for qualified staff, additional training, technical equipment, etc., but also quality communication with institutions across different levels in BIH, given the specific administrative position of the Brčko District. In the process of adoption of the new 2017 spatial plan, corrections are expected as to the intended use of land in accordance with the data on the spatial distribution of landslides to be prepared by the Sector of Public Safety.

The City of Tuzla is a positive example of a local authority which is largely implementing landslide risk management, primarily thanks to the organisation of the Civil Protection and the presence of appropriate skilled personnel, as well as previous experience with instability processes in the city itself, and the whole of the Tuzla Canton. The situation is far above the average for other local governments and the biggest step forward has been made in the process of landslide risk management. The records on instability processes are up to date as well as records of material damage, coupled with the analysis of causes and triggers in landslides, non-structural measures have been implemented in the planning and spatial documentation. If needed, emergency structural measures and permanent stabilisation measures are being carried out, and there is good communication with the administration at the cantonal level. There is a need and an initiative to establish an automatic monitoring system, as well as early warning systems, and there are already some initiatives in place. Additional training is required only in part of the assessment methodology for susceptibility, hazards and risks according to the international methodology, with all the prerequisites and professional staff available.

In general, the situation in local governments in Bosnia and Herzegovina related to the process of landslide risk management is such that there is a huge imbalance between local governments in terms of their capacities to implement the process in every sense of the way. Due to the existing administrative setting in Bosnia and Herzegovina, recommendations for the implementation of landslide risk management are given in Chapter 5, whilst taking into account all specificities.

3.4 OVERVIEW AND ANALYSIS OF THE EXISTING INTERNATIONAL BIBLIOGRAPHY ON LANDSLIDE RISK MANAGEMENT

The last decade of the last century (1990 to 1999) was declared the International Decade for Natural Disaster Risk Reduction by the UN General Assembly.[7] The last 25 years in many professional and scientific organisations and institutions had been marked by intensive engagement, both in theoretical and practical terms, on harmonising methodologies and the development of methods for risk assessment of natural hazards, including landslides as a natural geological hazard, and methodology for landslide risk management as a process. On the other hand, a number of global and European social, political and financial organisations have adopted documents which approximate, require, finance or promote different aspects of management of natural hazards and risks, including landslides. Extensive bibliography is available, both in professional and scientific publications, as well as in many other articles and bylaws of world associations and institutions (UNISDR, UNESCO, ICL, IAEG, IUGS). The parties to Hyogo[8] (2005) and Sendai[9] (2015) Declarations, Bosnia and Herzegovina included, undertook to implement the goals of these declarations. Overview and analysis of the existing international literature in the field of landslide risk management for the purpose of the Study has included the relevant general and technical documents that provide specific measures and recommendations in the field of landslide risk management, internationally recognised procedures with examples of good practice, which, above all, is applicable in Bosnia and Herzegovina.

International literature is divided into several groups according to the type of information that can be of practical use for different levels of landslide risk management: (1) strategic global documents, (2) strategic national documents, (3) professional publications and instructions, (4) examples of best practices and (5) state-of-the-art publications and books.

(1) Strategic global documents include directives, decisions, declarations of the UN and its institutions, which apart from ensuring the uniformity of approach and guidelines in the fight against natural hazards, these also have a binding role for all State Parties and the UN Member States. These documents should be translated into local languages, especially those relating to terminology issues and the strategy against natural hazards and the risk management process (and hence landslides). Thus, the global approach is brought closer to an individual, which increases overall awareness.

7 International Decade for Natural Disaster Reduction, Resolutions 42/169 and 44/236, http://www.un.org/en/sections/observances/international-decades/

8 Hyogo Framework for Action 2005 - 2015: Building the Resilience of Nations and Communities to Disasters. http://www.unisdr.org

9 Sendai Framework for Disaster Risk Reduction 2015 - 2030. http://www.unisdr.org

Apart from the Hyogo and Sendai Declarations, UNISDR documents on the general terminology of natural hazards are also useful.[10] The documents are translated into local language and are the basis for long-term national strategy of risk management of natural hazards in the entire territory of Bosnia and Herzegovina (and hence landslides). More specifically, these documents provide the minimum requirements for the understanding of all participants in the process of risk management. Also, UNESCO publication,[11] although promoted more than 30 years ago, remains the basis for the concept of hazards and risk, not only for landslides. This set of documents also includes a publication promoted by an International Consortium on Landslides (ICL) as a manual for a better understanding of the slide process in a broader sense. Publishers are two major geological societies USGS (US Geological Survey) and CGS (Geological Survey of Canada).[12] With all the illustrations and annexes, this is an extremely interesting material, especially for national institutions tasked to manage the risk of landslides (line ministries, sectors of public safety / security, civil protection, etc.).

(2) When it comes to strategic national documents, the focus is on the National Platform and the accompanying documents published by the Geological Survey of Canada (http://www.nrcan.gc.ca/).

A very useful document, with practical, simple and understandable classification of landslides and other instability events (meaning, processes understood under the English term Landslides) is Open File 7359 (Cruden D. & VanDine, 2013).[13] This classification allows for setting up a landslide database based on seven descriptors of events that are easily searchable once the database is in place, which is one of the goals of open government database of landslides and other instability events. As a part of the Canadian national platform, another useful document is Open File 6996 (VanDine, 2012)[14] addressing the risk of slides. Geological Institutes of both entities, as well as the Sector of Public Safety of the Brčko District should be familiar with this document. Suggested reference is a good basis for harmonisation of the inventory form, data and databases between the entity Geological Surveys and the Sector of Public Safety of the Brčko District.

10 Proposed Updated Terminology on Disaster Risk Reduction: A Technical Review Facilitated by The United Nations Office for Disaster Risk Reduction, August 2015. http://edition.www.unisdr.org

11 Varnes D.J. 1984. Landslides hazard zonation: a review of principles and practice. *Natural Hazards* 3. UNESCO Press, Paris. 63 pp

12 Highland, L.M., and Bobrowsky, Peter, 2008, The landslide handbook—A guide to understanding landslides: Reston, Virginia, U.S. Geological Survey Circular 1325, 129 p. http://www.nrcan.gc.ca/

13 Classification, Description, Causes And Indirect Effects-Canadian Technical Guidelines and Best Practices related to Landslides: a national initiative for loss reduction, D. Cruden and D.F. VanDine, Geological Survey Of Canada Open File 7359, 2013. http://www.nrcan.gc.ca/

14 Risk Management-Canadian Technical Guidelines and Best Practices related to Landslides: a national initiative for loss reduction, D.F. Van Dine, Geological Survey Of Canada Open File 6996, 2012. http://www.nrcan.gc.ca/

(3) As for professional publications and instructions, documents of the Australian Geomechanical Society was selected, and also one of the first guidelines for the assessment of hazard and risk of landslides (Australian Geomechanical Society http://australiangeomechanics.org/), which in addition to the classification of landslides (same classification as in Cruden & VanDine) and other instability events (i.e. process understood under the term landslides), gives an extremely detailed and practical instructions for a qualitative and quantitative assessment of hazard and risk of landslides,[15] but also an overreview of structural and non-structural measures that can be implemented depending on the mechanism of the process, and events (landslides, pour point) in order to reduce risk.[16] Guidelines of the Australian Geomechanical Society are the basis for assessing susceptibility, hazard and risk of slide for the teams that will be conducting these activities. Professional associations should have these documents translated into the local language and given as a reference literature to their membership (such as the Geotechnical Association of BIH).

Finally, a long-time project of the EU FP7 programme gave an overview of current issues related to the landslide processes in a broader sense, starting from the basic terminology, through survey and monitoring methods, and the quantitative assessment of hazard and risk,[17] with concrete examples and experiences. Experts with the entity Geological Surveys tasked with landslide inventory and hazard and risk assessment should become familiar with both these documents.

(4) Examples of best practice exist in many countries in the world where there is an institutionally defined Natural Hazards and Risk Management. In some countries, somewhat more attention is paid to the most common natural hazards and risk management process specifically associated with a particular type of process - for example, Japan for earthquakes, tsunamis and landslides, New Zealand for landslides, earthquakes, volcanoes, and tsunamis, Italy for landslides and floods, Switzerland for avalanche and landslide. Examples of best practice in local communities are given through examples where the spatial planning process involved risk reduction[18] or at higher administrative levels[19], that is, where risk

15 Guidelines for landslide susceptibility, hazard and risk zoning for land use planning, Australian Geomechanics, Vol 42 No 1, March 2007. Landslide Zoning Guideline AGS (2007a) http://australiangeomechanics.org/

16 Practice Note guidelines for landslide risk management, Australian Geomechanics, Vol 42 No 1, March 2007. Practice Note 2007 AGS (2007c). http://australiangeomechanics.org/

17 SafeLand-Living with landslide risk in Europe: Assessment, effects of global change, and risk management strategies, 7th Framework Programme, Grant Agreement No.: 226479, 2012.

18 Hazard Mitigation: Integrating Best Practices into Planning. James C. Schwab, American Planning Association, Planning Advisory Service, Report Number 560, 2010.

19 Guidelines for Legislated Landslide Assessments for Proposed Residential Developments in BC. Association of Professional Engineers and Geoscientists of British Columbia, Revised May 2010. APEGBC.

management process was conducted with non-structural and structural measures in underdeveloped communities.[20] Aside experts in geology, these examples of good practice can be used by planners.

(5) Scientific and professional community is also involved in the risk management process through research and finding of optimal solutions to scientific and technical knowledge in the most appropriate way so as to take advantage of the risk management process through training[21], providing guidelines for the best possible application of the susceptibility assessment, hazard and risk zoning,[22] the methodology of quantitative landslide risk assessment,[23] and recommendations for different levels of risk management.[24] These publications provide not only the basic, but also the most advanced understanding of the entire international community on the methodology and process of landslide risk management, and training institutions should use and implement the recommended methodology for the training of future professionals.

All selected international publications, save for publications under 5), are the essential bibliography that all relevant stakeholders should be familiar with, given their role in the process of landslide risk management, but most of all entity Geological Survey Institutes and the academia. Most of these documents have not been translated into local language, but documents are open, publicly available and simply accessible by searching keywords, titles or links already provided in the Study. Publications under 5) are available to the academia in BIH and represent advanced literature, which together with the documents (1-4) are used in training of qualified personnel to perform certain procedures in landslide risk management. Additional training of the academia is also required, as well as its active participation in the process of landslide risk management.

20 Anderson, Malcolm G., and Elizabeth Holcombe. 2013. Community-Based Landslide Risk Reduction: Managing Disasters in Small Steps. Washington, D.C.: World Bank. doi:10.1596/978-0-8213-9456-4. License: Creative Commons Attribution CC BY 3.0

21 Turner AK, Schuster RL (eds) Landslide investigation and mitigation, Special Report 247, Transportation Research Board, National Research Council, National Academy Press, Washington, D.C. 1996.

22 Fell R. et al. (2008). JTC-1. Guidelines for landslide susceptibility, hazard and risk zoning for land use planning. Engineering Geology 102. 85-111.

23 J. Corominas et al. (2014). Recommendations for the quantitative analysis of landslide risk. Bull Eng Geol Environ 73:209–263, DOI 10.1007/s10064-013-0538-8.

24 Günther et al. (2013). Tier-based approaches for landslide susceptibility assessment in Europe. Landslides10 (5): 529-546, DOI 10.1007/s10346-012-0349-1.

4. LANDSLIDE RISK MANAGEMENT

The following Chapter outlines and elaborates on the procedures for the assessment of landslide hazard and risk, as well as the methodology of risk management. As already mentioned, it relies on the international terminology and classification of processes and events, as well as the existence of basic knowledge in this field, including work in the GIS environment. Depending on the level of detail and scope of view, there are significant differences in the methodological approach. Therefore, all recommendations will be given at the level of the state or regional assessment of hazards and risks, and the level of detailed evaluation, thus being readily implementable as such procedures.

4.1 METHODOLOGY OF LANDSLIDE HAZARD ASSESSMENT

The landslide hazard assessment is the most significant segment. Its quality and results condition all other segments of further landslide risk management in a broader sense. Hazard assessment requires a wide range of spatial data on conditioning factors, which may differ in terms of spatial and temporal variability. Certain factors are practically stationary, such as geological and geomorphological conditions, but there are those whose volatility can be traced in the longer or shorter periods, even on a daily basis, such as meteorological factors (for example, intensity of precipitation). In addition to factors that are directly associated with the process, it is necessary to know the spatial distribution and frequency of the event, which often represents the biggest problem. Due to the uneven promptness in recording and dating of landslides, the practice has often seen the need to exclude the time dimension of the analysis and instead of dealing with hazard, we are addressing susceptibility to slide, which only considers the spatial probability mostly based on stationary factors (see Chapter 2).

From the perspective of recording of events (landslides, rock falls, debris flow), the situation in Bosnia and Herzegovina is similar, and further describes the methodology that is based on the assessment of susceptibility to slide, but not the hazard. In order to assess the hazard of landslides, according to international literature and practice, it is necessary to establish a single landslide database with dated stages in the activity process and triggers. This requires time and a systematic approach to managing the inventory. Therefore, it is first necessary to provide a sufficiently accurate, up-to-date and reliable inventory, or database of processes/events of landslides and other instabilities, according to the international classification. Methodology for the preparation of inventory depends on the scale used, but also the types of processes/events, hence the procedure for recording events at all levels of assessment will be summarised in the following sections.

THE HIGHEST (REGIONAL) LEVEL OF INSTABILITY INVENTORY

This level implies a scale of 1: 100,000 and less (1: 300,000). It primarily involves the entity Geological Survey Institutes, but it can also be collected by local authorities and public enterprises, for example, following the model of the BEWARE project, http://geoliss.mre.gov.rs/beware/ in the event of massive events. This is often a long process, but the example of the BEWARE project showed that in emergency situations, it is possible to record from 1000 to 2000 landslides in an area of about 15 000 km^2 in only a couple of months. The recording involves single standardised procedures, including at the very least the following activities:

- locating and dating the event at least as point data (each instance is a single point in space, with clearly defined coordinates), and if technical conditions permit, in the form of polygons (each landslide outlined with a unique polygon)
- assessment of basic elements of the event: type (debris flow, landslide, rock fall etc.), type of displaced material (rocks, debris, soil), water content, activity, velocity of movement, style of movement, trend of movement, volume, damage and the like.
- Photo documentation (photos of the elements of the event and details, such as damaged facilities and infrastructure with the appropriate scale).

Format of the inventory should be in vector format, preferably in the form of spatial database, and as noted, the level of data related to individual event is reduced to a minimum point of a uniform level of information. If there is a basis to improve data quality at the regional level (polygons, geometry, etc.), it is necessary to standardise a minimum set of harmonized data. Further, there should be a consensus at the national level and to adopt a standard to be followed by all departments responsible for the inventory in both entities and the Brčko District (Chapter 3.3.). This would create the preconditions for setting up a single database of landslides for the whole territory of Bosnia and Herzegovina.[25]

25 During the preparation of the preliminary landslide risk map for the territory of Bosnia and Herzegovina in the Phase

THE LEVEL OF DETAILED INVENTORY

This level implies the scale of 1:25 000 and larger (e.g. the level of municipality or smaller territorial units) and falls solely under the jurisdiction of the entity Geological Survey Institutes, which have the staff needed to carry out recording in a satisfactory manner. If cantons or municipalities have the appropriate personnel for the establishment of a registry scale larger than 1: 25,000, they can take part in the recording of the event, but according to the unique classification and methodology as agreed with the entity Geological Surveys.

Recording is performed according to the pre-agreed, unified and standardised inventory which is more detailed than the highest level of landslide, and provides information on:

- location and the date of appearance, which is presented by using a polygon on the corresponding topographic base,
- type of event with a detailed classification according to the international standard of materials and type of movement, to a water content, activity, velocity of movement, type of movement and trend of movement,
- detailed geometry (depending on the type of event) and morphometry of the event,
- properties of geological settings (geological, geomorphological and hydrogeological settings on the terrain),
- the cause of the event through the assessment of the most important conditioning factors and triggers,
- damage caused by the event categorised according to local and international standards,
- photo documentation (photographing the elements of the event and details of damaged facilities and infrastructure with the appropriate scale),
- additional sketches and forecasting sections,
- data on completed studies and their results.

It is noteworthy that the preparation or additions to the inventory are especially important if linked to a massive event like the one from May 2014, but it is necessary to make further efforts to perform mapping in the best way possible. Compiling with the past data is recommended only if each polygon is added a relative time determination so as to distinguish new from reactivated events.

1 of the project, sensitivity map according to the AHP method was prepared, and the existing available data obtained from the entity Geological Institutes were used for validation of the model. This highlighted the differences in recording the event of instability, which must be overcome, and as indicated in Section 3.3.

The format of the inventory should be that of a spatial database, which can be transferred from the vector to the raster format for further the purposes. The choice of resolution of such a raster depends on the minimum and maximum dimensions of the majority of recorded events. As before, the basis for setting up is having harmonised data, overcoming the problems in technical support, as well as in staffing (Chapter 3.3.).

THE LEVEL OF THE HIGHEST (REGIONAL) SET OF DATA ON CONDITIONING FACTORS

Furthermore, in the process of susceptibility assessment, it is necessary to identify those factors that have the most impact on the landslide process in its broader sense and select the appropriate data sources in order to model it. In practice, the factors can be classified as geological, geomorphological, environmental and anthropogenic factors.In the group of geologic factors, the most influential factor is lithologic composition of the terrain, since different mechanical properties are distinguished depending on the type of rock. The ideal approach would be to use a thematic geological map as a basis, such as engineering geological maps, where the criterion of parameters of the rock mass is already incorporated. For BIH, such maps are available in the scale of 1: 500,000 from the period of the former Yugoslavia. Given the stationarity of these conditioning factors, these maps are quite useful. An ideal map would be the engineering geological map of 1: 100,000 and 1: 300,000 (counterpart of OGK 1: 300,000 for the entity level).These materials are available mainly in analogue form in the entity Geological Survey Institutes, and it is necessary to have these transferred into a digital form. Subsequently, due to their stationary nature, these data will always remain usable for any further desired step.

For this level of assessment of landslide susceptibility, the above maps still need to be changed, firstly by simplifying the units so that eventually about a dozen are left, and each unit should be assigned an arbitrary weight e.g. 0-100, so that unfavourable units have a higher weight, and the favourable ones a smaller weight. In selection of the weight, one should be mindful of the general physical and mechanical properties of rock masses in individual units, and also of the character of their substratum, which can be of significant thickness, even if not shown on the map (so-called, open map). It is also possible to use other thematic maps or derive these from the basic geological map, such as hydrogeological maps. The borders of hydrogeological units are contacts where there is a change in hydrogeological features of rocks, and these are very common indications of instability.

For this level, it is also possible to include the soil base of small proportions, with raw data on the individual parameters of the soil, among others gravity near the surface, as well as the types of soil according to the international classification. These maps are derived from samples usually 1x1 km and although having a rough resolution, these can nevertheless be used, especially for the level of assessment at the highest level. Available bases are free of charge: http://soilgrids.org/. Numerical soil data needed to be classified for this level and score a weight class, while for nominal soil maps, to score only weight classes.

Geomorphological factors mainly include the impact of various morphometric parameters such as slope, relief, form of terrain, slope aspect, curvature index, distance from watercourses, elevation etc. Physical dependence of these parameters is brought into close contact with instability processes, because it is intuitively clear that steeper slopes are more prone to instability, just as those more spread out slopes or those facing the humid north side. All parameters can be obtained from the Digital Terrain Model (DTM) by using appropriate GIS tools. The main source of DTM may be different, but for this level, a DTM of some global missions would be quite sufficient, such as SRTM and ASTER provided in raster format with a resolution of 30 to 100 m, while being at the same time free and publicly available (http: //earthexplorer.usgs.gov/).

Environmental factors are closely related to anthropogenic factors and are commonly presented as maps of land use, containing the arrangement of vegetation, water resources, but also the layout of urban areas, infrastructure, etc. Their impact must also be made general and then scored by respective weights, similar to geological soils. As a source of data, it is sufficient to use CORINE maps of 2006 or 2012 (http://gis.epa.ie/GetData/Download), which give the distribution of land use at three levels of detail for BiH in a resolution of 100 m. These are also completely free of charge and available to the public.

All data prepared for this level must be brought into raster format of the same resolution, usually 30 to 100 m resolution, for this is the very resolution of most of the original data. Also, numerical factors must be subsequently classified to five to ten classes with arbitrarily assigned different weights, while nominal factors (geological or soil units, land use) go through this procedure as described earlier.

THE LEVEL OF A DETAILED SET OF DATA ON CONDITIONING FACTORS

This level is mostly using the same conditioning factors as the previous level, but their preparation is different. Geological factors must be prepared by using a detailed geological map of 1:25 000 or geological engineering maps 1:25 000 and plans > 1:10 000. These can be followed by lithological maps with interpolated groundwater depth, paleorelief, depth of weathering crust, if available. The preparation remains the same as in the previous level that is, simplifying units with the reduction to 10 classes but without assigning weight. Instead, arbitrary values of 1 to 10 are assigned.

Geomorphological factors must also be prepared on the basis of DTM of higher resolution, which can be obtained on the basis of detailed topographic maps, through contour line interpolation for smaller equidistances (1:25 000 - 1: 5000) or in the ideal case, through aerial-photogrametric or LiDAR aerial survey with resolution of min 1 to 5 m. Lately, aerial survey of small areas (5 to 10 km radius) can be done with drones (UAV). Such detailed DTM bases require an additional specialised software and hardware.

Environmental factors must be collected on the basis of satellite images of medium or high resolution. The new LANDSAT 8 mission provides for multispectral images of 10 m resolution free of charge (https://landsat8portal.eo.esa.int, http://reverb.echo.nasa.gov, http://earthexplorer.usgs.gov/), which can be used if some of the GIS programmes for visual interpretation of LANDSAT 8 images is available. Interpretation can be further assisted with derivatives in the form of different vegetation index (NDVI, EDVI) that can be done in combinations of LANDSAT channels.

All data should be prepared in raster format in a resolution adopted at the level of detailed inventory (depending on the size of the observed events), which is usually 10 to 30 m. It should again be noted that in numerical factors, classification and scoring of class weight is not necessary, but it is necessary to normalise these in a range of 0 and 1. None of the above is needed in nominal units which are made binary in the later stages, meaning that each of their classes is used to create a new subfactor with values 1 = respective class and 0 = all other classes together.

THE LEVEL OF THE REGIONAL AND DETAILED SET OF ACTIVATORS/TRIGGERS

The most common triggers of landslides are rainfall, earthquakes, erosion, sudden fluctuations in the level of groundwater and surface water (flooding) and anthropogenic effects. Anthropogenic effects are often reduced to isolated cases with no pattern of occurrence and it is difficult to observe these in a wider area. At a more detailed level, these can be included in the analysis when there is documented intensive exploitation of mineral resources; for example, data on earthquakes as activators/triggers and temporal relations with instability processes is rare, as are similar relations with other factors either at the highest or the detailed level, and hence, will not be addressed in the Study. In the climate in BIH, precipitation stand out as one of the most common triggers of instability processes, and the focus is given to the general modelling of precipitation as triggers (on all levels). Precipitation, as a trigger, is one of the most changing factors in space and time. The density of data that can be obtained from meteorological services in this regard is generally satisfactory. It is also possible to inspect archive records and determine the return period of certain extreme precipitation. In order to identify the extremes, it is necessary to monitor cumulative and secondary precipitation. Cumulative precipitation should be monitored in a short time interval of 5-10-15 days, since this period, in case of obstructed draining, could see successive worsening of parameters of rock and soil. Identification of such extremes allows for an overview of their spatial distribution and weather frequency. Alternatively, the process can be simplified by observing the medium precipitation over a very long time interval from 10 to 20 years, which can then reconstruct the general pattern of precipitation, and accordingly, calculate susceptibility to slide, or quasi-hazard. It should be noted that it is necessary to monitor reports on climate change, in particular those relating to the precipitation regime. The latest report of the Intergovernmental Panel for Climate Changes (http://www.ipcc.ch/) indicates that the annual amount of precipitation in Bosnia and Herzegovina would generally reduce, but that local extremes would be more common and that the length of the day in excess of daily maximum precipitation would increase by 10 % by 2040. In any case, coordination with the Hydrometeorological Institutes which will be providing information on soil saturation can assist in modelling precipitation as the most important instability activator/trigger.

The introduction of precipitation in the model brings about the quasi-hazard, as it introduces time dimension, to some extent, expressed through the return period of extreme precipitation or their frequency through the medium precipitation over a long period of time. Precipitation should be introduced in the model subsequently, after the calculated susceptibility to landslide, regardless of the level of assessment in question. Modelling of precipitation is best performed by using the advanced interpolation methods (e.g. kriging and co-kriging, regression kriging etc.), as the source of information is most often a dot and obtained in the form of a network of hydro-meteorological stations. Alternatively, it is possible to use satellite images of TRMM mission, giving precipitation in very raw resolution, but this alternative relates primarily to the highest level. All analyses related to precipitation should be done in the GIS environment. Raster remains as the format, with the adopted general resolution, depending on the specific levels (30 to 100 m). It was noted earlier that a full assessment of hazards requires a clear correlation between the date of the activation of processes and triggers, that is, precipitation, which is possible for the highest level in the case of extremes, while the detailed level of assessment requires a condition. A similar model can be applied for impacts of seismic forces, especially in seismogenic zones that can generate earthquakes with a magnitude > 5M. It is known that earthquakes of > 5.4M can cause seismo-gravitational deformation on the surface, that is, it is possible to activate instability processes on slopes. The model (so-called quasidynamic model) of introducing the impacts of seismic forces in assessing susceptibility, hazards and risks of landslides can be found in Abolmasov (2009), Jibson et al. (2000) and Luzi and Pergalani (1999). For areas of Bosnia and Herzegovina that are in seismogenic zones with a history of recorded earthquakes of magnitude> 5M, it is necessary to further include leyers showing zones with different horizontal accelerations, that is, possible movements. Spatial distribution of the specified size is obtained by calculating the Arias Intensity (Abolmasov, 2009).

ASSESSMENTS OF LANDSLIDE HAZARD AT THE HIGHEST (REGIONAL) LEVEL

In assessing susceptibility for a wider area, it is usually sufficient to apply the so-called multiple criteria analysis based on expert approach, or an understanding the extent to which individual factors conditions the process. The starting point is the fact that a set of conditioning factors in their coordinated action creates conditions for the development of landslides in the most adverse conditions. Every conditioning factor is scored based on an expert opinion, and it is possible to survey several relevant experts and then use central score. Score or weight can later be split to percentage shares so that the most influential factors have the greatest value and that the sum of weights of all factors is 100% (normalisation of weight). One of the leading multiple criteria methods of quantification of experiential opinion in this context is the Analytical Hierarchy Process (AHP). With certain rules in weighing of scores, AHP can establish relations between certain factors in great detail. Based on the AHP, subjectivity is effectively reduced and controlled. For AHP method, it is necessary to firstly classify all conditioning factors to an understandably small number of classes (up to 10), with a corresponding weight assigned to each class. Thus, the multi-criteria analysis is communicated further subjectivity, which should be kept to a minimum. This objective can be achieved by calibration of conditioning factors directly before applying multi-criteria analysis. The landslide inventory, which is usually dot data type for this level, should be used to select the class and class interval of numerical conditioning factors. This is not necessary for nominal ones (classes are predefined, e.g., geological units, units of land use). Calibration is still done by checking the density of dots of landslides in selected classes (for example, if the density is large in a given class, this class is favourable for the development of landslides). In calibration for each numerical conditioning factor, it is necessary to try different variants of the number of classes and different selection of intervals of these classes (for example, if we are to divide a slope into intervals of 2°, 5° or 10°). Once a satisfactory variant is achieved, the next step is quantification of weight classes of each factor (nominal and numerical) in the range 0 to 1 or 0 to 100%. Again, the density of dots of landslides comes in hand, suggesting which class should have a higher or lower value. By multiplying each calibrated conditioning factor with its percentage weight established, for example, based on the AHP analysis, and then summing all factors, the result is the ultimate model of landslide susceptibility of an area. This is a continuous raster model with more susceptible zones portrayed in pixels with higher numerical values, and stable ones with lower. With the addition of the standard scale of colours, the regions of high susceptibility are typically indicated in red and those with lower susceptibility in green. Yellow and orange shades are in between, and it is possible that such a continuous raster is divided into several classes (e.g. low medium and high susceptibility). It is further possible to compare susceptibility model against the precipitation model (triggers). Firstly, it is necessary to normalise both models at the range of 0 to 1 (or 0 to 100%), and then multiply it. This process results in quasi-hazard scenarios dependent on the selected precipitation scenario, e.g. hazard for short-term cumulative precipitation maximums or long-term medium precipitation. In other words, it is possible to have several varieties of quasi-hazard maps depending on the scenario of our interest. Preparation, calibration and the actual modelling of susceptibility and quasi-hazard must be done in the GIS environment, by using appropriate modules for spatial analysis of rasters. During the first phase of the project Development of the Floods and Landslide Risk Assessment for the Housing Sector in Bosnia and Herzegovina, a preliminary assessment of the landslide risk for the housing sector was done for the entire territory of Bosnia and Herzegovina. One of the intermediate steps includes the preparation of Landslide Susceptibility Map 1: 100 000, with the validation of the model made based on available data (submitted by the entity Geological Surveys in a different format). Model validation and correction should be expanded following the completion of the recording of events (additions to existing inventory with new data).

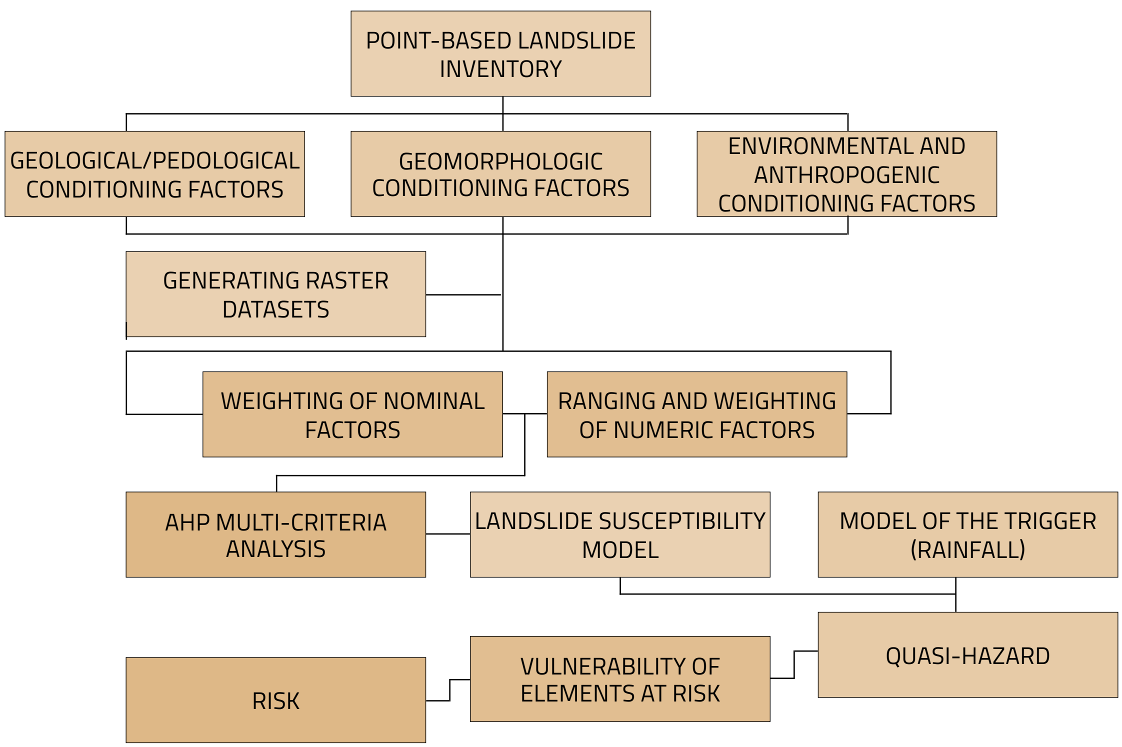


Figure 11 Flowchart of methodology for landslide hazard and risk assessment at the highest/regional level

THE LEVEL OF A DETAILED LANDSLIDE HAZARD ASSESSMENT

Susceptibility on a detailed level and in narrow area requires an approach based on data, not on experience. Here, it is necessary to establish a direct link between the landslide events and individual conditioning factors. The principle of defining these connections may be statistical (based on the spatial correlation of landslides and conditioning factors) or deterministic (based on physical models). According to the information, except for the cities of Doboj and Tuzla, none of the two types of model is available. In general, preparation of such models on the request and with the support of local government should be done by entity geological services responsible for landslide hazard and risk.

Deterministic models are usually limited to a certain type of landslides, primarily translational landslides in the weathering zone, and should be used only in cases where such a landslide was dominant in the context of the observed events. SHALSTAB and SINMAP models are such, and are based on the model of infinite slope, or landslide as an event in its narrow sense. Another type of model is a process of flow and pour point, which can be modelled and simulated in specialised programmes (e.g. RAMMS, FLO-2D, FLOW-R), with a more realistic hazard obtained in relation to landslides, given the simulation of the pour point speed, transport distance or sediment height, providing a quantitative intensity of the event. A shortcoming of all deterministic models is that these require an input of quite a number of detailed data sets, in particular the physical and mechanical parameters (bulk density, porosity, strength parameters, etc.), which are obtained through lab results and are extremely difficult to generalise, due to the impact of the extent and representativeness of laboratory and real conditions in the field. Therefore, both these analyses suggest far more specific locations or exclusively individual phenomena (site-specific). Statistical models can be very different, but essentially boil down to determining the spatial correlation of individual conditioning factors on the one hand and landslides on the other hand, by comparing the value of all the factors at locations where the landslide occurred but also on stable ground. Hereby, it is possible to obtain a function or rule that systematically separates examples that can lead to landslide from those that do not. Depending on the selection of statistical methods and machine learning methods, it is possible to have different functions and rules, ranging from simple statistical conditional index and phase method, through regression function, to rules derived from neural networks and trees, to a non-linear function. Most commonly used are Logistic Regression, Decision Trees Support Vector Machines and Artificial Neural Networks. Most of these methods require a process of training on a smaller specimen, that is, data training, whilst "learning" the rule how to distinguish a landslide from stable terrain and testing/validation process, where the "learned" rule is extrapolated to other data. According to the input data, that is, data from the landslide and conditioning factors, it is necessary to separate the two main cases, the forecast of hazard of landslides and debris flow.

- In the case of landslides, the data type from the inventory is a polygon, or in fact a raster generated from polygons, while the other raster data sets have been described in previous sections. The inventory needs not to have additional information about the zone of accumulation and separation of the rock mass. Rasters of numerical conditioning factors may not be classified. Nominal conditioning factors (geological or soil unit and land use) must be divided into several rasters, so that each class is a separate (new) raster. Training is conducted on a sample that is balanced, and composed of an equal number of examples of landslides and stable terrain.
- In the case of debris flow, the data type from the inventory is a polygon (i.e. an appropriate raster) which carries information about the zones of accumulation and separation. As for other data, it must also contain erosion and as a conditioning factor. It is necessary to make two models, one that will in training have only examples from the zones of separating rock mass and stable surface, while the other will have only examples of the zones of accumulation of rock mass and stable surfaces. The first model is used as an additional conditioning factor in the development of other models. The first model identifies areas of characteristics susceptible to the formation of debris flow, and the other a possible range of active debris flow.

These assessments and modelling are to be performed in specialised programmes for advanced statistical methods and machine learning (e.g. WEKA, R), which usually cannot be found in sufficient volume in the GIS platforms. Therefore, additional effort is needed to communicate about different data formats between GIS platforms and external software, keeping in mind that the final output data should remain raster type for the purpose of presentation.

In this way, in several iterations (not less than 10), a number of different models of landslides and debris flow susceptibility is obtained. Results cannot be superimposed, but should be viewed separately. The final models of susceptibility to slide and flow are obtained by averaging, and can be symbolised with a scale similar to the case of the regional level. Finally, similar to the previous level, maps of quasi-hazard may be obtained by overlapping the final model of susceptibility with the relevant trigger scenarios, that is, precipitation.

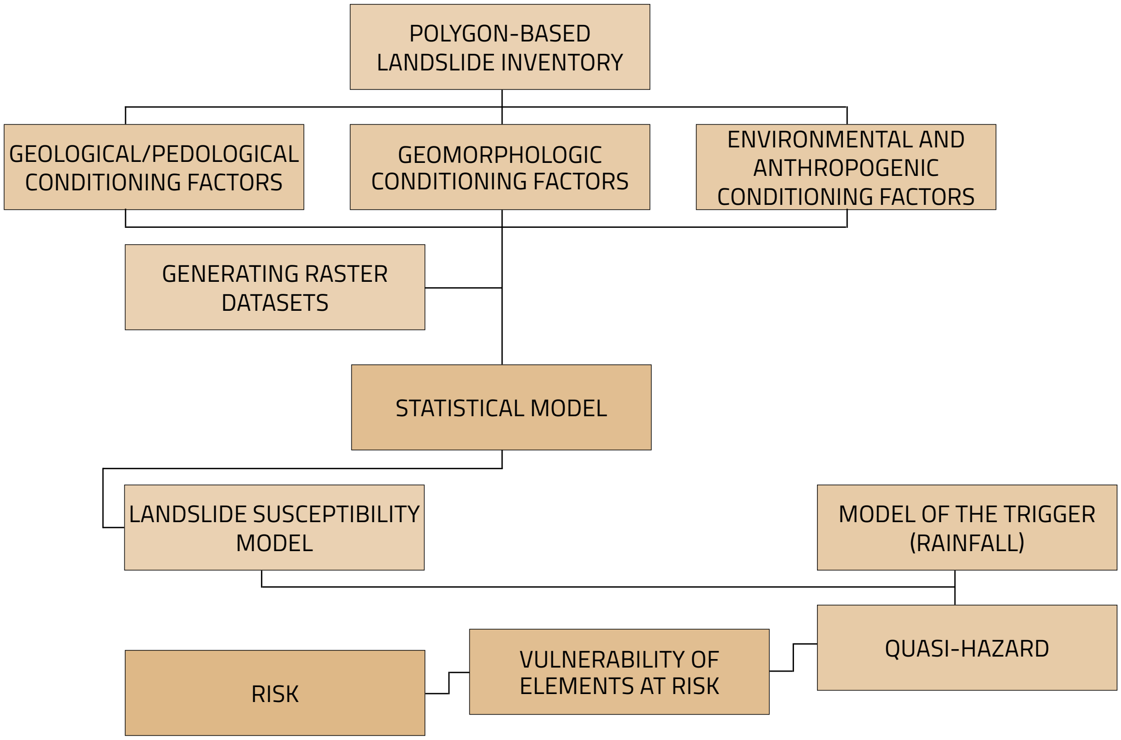


Figure 12 Flowchart of methodology for landslide hazard and risk assessment at a detailed level

4.2 METHODOLOGY OF LANDSLIDE RISK ASSESSMENT

Methodology of landslide risk assessment is given for two levels of risk assessment, primarily given that the scale or the level of detail dictates methodology and selection of additional data needed for risk assessment.

LANDSLIDE RISK ASSESSMENT AT THE HIGHEST (REGIONAL) LEVEL

Exposure is the following characteristic that predisposes the risk in relation to the hazard of landslides. The exposure is usually expressed through the proximity of the observed element in the risk of a certain class of hazard. Of course, the focus is on classes of very high and high hazard. Weighted map of proximity of hazard zones can be made by raster with a proportional deduction depending on the considered class of hazard, so as to obtain a normalised (0-1 or 0-100%) raster that gives exposure on the whole territory.

Further, the risk at this level can easily be obtained by superimposing hazard, exposure and risk elements. If agreed that hazard maps can be approximated to sensitivity maps or quasi-hazards addressed in previous chapters, the only thing left is to define a spatial (and possibly time) distribution of elements at risk.

Elements of risk at this level can be identified by populations and/or certain classes of land use with a defined certain anthropogenic function or activity.

- Population in Bosnia and Herzegovina unfortunately is not processed in dasymetric terms. The only available census data are those generalised to smaller territorial units, namely municipalities, settlements and local communities. These can only serve as basis for the so-called choropleth maps. Their main drawback is that these generalise a one medium data on a relatively large area, far higher than the adopted scale of observation in this Study (30 to 100 m). Inclusion of the population as an element of risk requires real distribution obtained through dasymetry. A good example of this practice is a project done in Serbia, showing, at the national level, the real population density based on the 2006 Census in resolution of 100 m and publicly available at: http://osgl.grf.bg.ac.rs/ PopDensSerbia2006.html.

- On this level, it is possible to identify facilities of specific purposes from CORINE (http://gis.epa.ie/GetData/Download), where the second and third level of classification can distinguish different elements of the urban areas (continuous and discontinuous urban area, industrial and commercial zones, roads, etc.). Based on its purpose and use, it is possible to approximate elements at risk. This means that the already prepared conditioning factor of land can now be used again, by being reduced to the target class, with a possibility of conversion into a vector form. It is necessary to assign to these classes specific relative weight as a function of the material value of a specific type of urban cover, which will define the vulnerability of elements at risk (for example, industrial and commercial area is more vulnerable than discontinuous urban areas, and such area is more vulnerable than roads).

Superimposing with the exposure, and then with susceptibility or quasi-hazard, is also done in the GIS environment, resulting in values of landslide risk, for example, for the population at the national level. Based on these, it is possible to suggest general non-structural measures.

LEVEL OF DETAILED LANDSLIDE RISK ASSESSMENT

Much like at the highest level, the risk is first approached by addressing exposure. A detailed assessment of exposure may include distance from the zone of high and very high hazard, as well as a more detailed assessment, based on deterministic models, especially in the case of debris flows. In any case, the exposure is obtained as a function of the distance of the observed element at risk of category of hazard given as a raster map in the prescribed proportion, normalised to the interval of 0-1 or 0-100%. It is then superimposed with a map of hazards and finally, with inventory of elements at risk.

For the level of detailed risk assessment, it is necessary to make a far more detailed database of elements at risk based on housing units, and that information must be of a polygon type. It must be reduced to blocks or individual units in urban areas, industrial, medical facilities, religious, educational and administrative institutions, roads, parks, sports, tourism and cultural facilities, etc. For each class of adopted elements of risk, it is necessary to estimate the density and structure of the population, as well as the basic activity that is carried out. It is also necessary to give consideration to the value of facilities per unit area. Eventually, if the level is detailed to such an extent, it is necessary to enter data on the number of floors, type of construction and the type of building material. Based on these data, the function of vulnerability is defined, depending on a number of factors, and the subtype of risk that is of interest (social and economic).

- For a general social or collective risk, vulnerability function should primarily take into account the population of the individual polygons and align with the purpose of the facility or activity performed in it, so as to define the space-time vulnerability. For example, a hospital has a maximum vulnerability, since it can be assumed that it has a constant number of individuals at all times, including staff that is individually less sensitive compared to patients who are extremely susceptible to potential disaster (limited mobility and independence). Schools have lesser vulnerability, for being populated only during classes, which is a period when, for example, residential areas are less populated. Then again, residential areas as opposed to schools are populated during the night or on weekends. High-quality and detailed information must be collected to define such a complex function. To this aim, it is possible to partly utilise census data (most of these data can be found there, yet this information should be introduced into a spatial context). The risk is thus given quantitatively in relation to the space-time probability that the population will be affected by a catastrophic event.
- For material/economic risk, vulnerability function is first brought in connection with the characteristics of the facility, the standard which was used for its construction or the age of the facility, the material that was used and alike. Based on this information, it is necessary to specify the original vulnerability and then supplement it with other segments that reflect the economic value of the facility. At the city level, it is possible to perform zoning of the value of facilities per unit area (the price of a square meter), while facilities with a specific purpose must be assessed with a higher commercial price, at least tentatively. The risk is thus given by the chosen monetary unit per facility over a wide area, so it is possible to consider cost-effectiveness of undertaking structural and non-structural measures in this area, and perform a selection in the case of limited funds intended for rehabilitation and prevention (which is very often the case). The assessment of cost-effectiveness needs to be viewed through the prism of available budget or general economic indicators, such as income per capita and the like. If the underprivileged and a privileged part of the area have the same collective risk of potential catastrophic events, provided that both areas meet the economic feasibility of the measures, priority should be given to the underprivileged area. Material risk can be further assessed for natural or agricultural goods in a similar way. It takes only a step back, and instead of urban areas, as a basis for vulnerability, to prepare an inventory of agricultural or forest plots with further detailed information (price per unit area, the type and quantity of biomass for forests, that is, the price of both the forest plots and biomass).
- Individual risk would imply very detailed information and essentially should not be subject to these estimates (this is more a type of risk that is of interest to insurance companies and similar agencies).

All this data should be collected with the agreement of teams of local governments and higher institutional level (state administration, emergency situations sector, etc.), even if this is primarily a detailed level, for example, for the territory of a municipality or a city. Superimposing vulnerability to exposure and hazard (susceptibility or quasi-hazard) is performed at the level of the polygon also in the GIS environment, thus obtaining risks for individual facilities over a wide area, and it is possible to compare facilities and manage risks, and propose structural and non-structural measures or carry out further cost-benefit analysis to define acceptable risks and justification of possible measures to prevent it in the most vulnerable areas.

METHODOLOGY FOR LANDSLIDE RISK MANAGEMENT

Risk management is the responsibility of state, entity and local decision-making centres. In practical terms, these are institutions of the executive branch that adopt strategic document on the process of risk management, but also decide on the allocation of budget funds or other assets intended to reduce the risk of various types of disasters. The modern concept of risk management is focused on the elements at risk, and decreasing the sensitivity function of elements at risk. The concept of the fight against the process itself or the hazard was abandoned. Risk management is therefore based on raising general awareness, legislation that is enforceable, preparedness and response of the community and individuals to hazards. Non-structural and structural measures are therefore carried out in the last segment of risk management.

Non-structural measures include a whole set of different measures that primarily have a preventive character and are implemented through appropriate laws and by-laws depending on the level of risk management. The main documents at the highest level would be disaster risk reduction strategies, or landslides in this particular case. This document must comply with international treaties and represent a fundamental commitment of the state to implement the risk management process. The next level of documents is primarily related to the areas of society, and deals with the land use, and defining conditions for its use and protection, that is, frameworks of all levels of planning (spatial and urban) and the conditions for construction of facilities, water management, forestry and agriculture. Previous documents must contain a clear division of responsibilities and lines of implementation, as well as clear guidelines for all cases of non-compliance. Also, the highest level of documents includes and regulates activities and responsibilities of civil protection in risk management. In addition, this level establishes a clear horizontal and vertical compliance of all laws and bylaws in all segments. The next set of measures relates to education and it should ensure raising public awareness - not only in order to inform the executive authorities at all levels of landslides as a process (as well as the processes of another mechanism or type of movement), but also hazards and risks that it entails. Education provides different levels of awareness and consciousness of the individual about the risk assumed (for example, construction of a building in an area where construction is not allowed), but also the level of awareness of professional staff that is needed in all aspects of risk management. Assessment of landslide hazards and risks (in the broad sense), as a basis of risk management, is essentially a part of the non-structural measures at all levels, and depending on the level of implementation, it may be threefold in terms of its character, namely, informative, advisory and binding. Informative assessments of hazards and risks at the highest level (scale 1: 100,000 and smaller), provide the highest executive authorities with information on the spatial distribution of certain classes of hazards and risks of landslides, but are also an element in the planning documents of the highest rank. Assessment of hazards and risk at the regional level (1:25 000) has an advisory function, particularly in regional planning and development, selection of corridor infrastructure facilities, choice of space for a detailed assessment of hazards and risks, planning activities of the civil protection sector, emergency action situations and other. Their implementation is related to planning documents and spatial plans of regional or local governments. At the local level, assessment of hazards and risks has a binding function, and is the basis for the adoption of different planning and urban planning documents and their implementation, the basis for planning of structural measures, the basis for activities in the civil protection sector at the local level, planning of activities in cases of emergencies, etc.

Structural measures relate to concrete decisions of officials through investments in recovery and other measures, which include a variety of different construction activities in terms of design, construction and operation of facilities that provide temporary or permanent ground stability (retaining structures, drainage systems, physical redistribution of mass and rearrangement of slope, etc.). This group of measures, given the need and specificities of the design, also includes measures for monitoring and/or early warning systems. The difference between temporary and permanent rehabilitation measures is related to emergency response (emergency measures to provide temporary stability of the terrain, that is, to enable functionality to a certain time). Measures that provide temporary stability of the terrain must be replaced by measures to ensure lasting stability and functioning of facilities. In deciding on the implementation of structural measures and their economic justification, the value and importance of the elements at risk (material, functional, social, etc.) are taken into account.

Non-structural measures are being implemented at all levels (from national to local), while the implementation of structural measures is in most cases related to the local level only.

5. RECOMMENDATIONS AND MEASURES FOR INSTITUTIONAL FRAMEWORK FOR LANDSLIDE RISK MANAGEMENT

5.1 RECOMMENDATIONS AND MEASURE FOR IMPROVING THE METHODOLOGY FOR HAZARD AND RISK ASSESSMENT

Recommendations and measures for improving the methodology of hazard and risk assessment are given based on the analysis of the situation in the entity Geological Survey Institutes and the Sector for Public Safety of the Brčko District. The proposed set of measures and recommendations is given in several phases, which are cycles in the methodology, and thus also the phase priorities. Recommendations and measures from Phase I to III should be carried out as a priority, meaning within a maximum of two years. All remaining phases should be completed in the following five years. In the first two years of implementation, it is necessary to carry out additional training of professional staff, if and where necessary, in accordance with the needs of the respective entity institutions, and the Brčko District. Due to large differences in terms of capacity (in every sense) across local governments for the implementation of the landslide risk management, emphasis is given on entity institutions, and Geological Survey Institutes, as holders of the basic stages of the process. The methodology for the assessment of hazards and risks is described in detail in Chapters 4.1 and 4.2. This Study represents both the theoretical basis as well as a guide for the entity geological institutes and the Sector of Public Safety of the Brčko District, on how to establish the basic segment of the landslide risk management. Financial framework is given in Annex 3.

Phase 1 – Establishing a database of landslides and other instability events at the level of entities and the Brčko District

Brčko District - a database on landslides and other instability events in accordance with the principles of establishing a database (inventory) on a detailed (local) level, all in accordance with the requirements set forth in Chapter 4.1. The holder of the database is the Sector of Public Safety of the Brčko District. As there is no established standardised inventory form, there is a problem of harmonisation with the international terminology and practices, and it is possible to have it immediately established without approximation.

Republika Srpska - development of a database of landslides and other instability events in accordance with the principles of establishing a database on a detailed level, all in accordance with the requirements set forth in Chapter 4.1. The holder of the database is the Geological Survey Institute of Republika Srpska. Given that there is a standardised inventory form, it should be further harmonised and supplemented in accordance with the international classification and methodology.

Federation of BiH - establishment of a database of landslides and other instability events in accordance with the principles of establishing a database on a detailed level, all in accordance with the requirements set forth in Chapter 4.1. It is necessary to urgently establish a standardised inventory form in accordance with the international classification and methodology. Consolidate data from the cantonal level. For data that are brought to the level of a detailed inventory, it is necessary to harmonise data, also in accordance with the international classification and methodology.

In order to comply and harmonise data, it is necessary at this stage at the level of both entities and the Brčko District to adopt a minimum common set of data, or event descriptors. It is recommended to use the methodology of the Geological Survey of Canada (Cruden & Vandini, 2013). The content of the inventory form can be expanded arbitrarily, depending on the capacity of the institution or sector and in accordance with the short-term/long-term plans of institutions. As soon as possible establish the transparency of data through web services, and provide appropriate technical conditions to the entity Geological Survey Institutes and the Sector for Public Safety of the Brčko District.

Phase 2 – Preparation of accompanying basis for assessing susceptibility, hazards and risks at the entity level and the Brčko District

In assessing susceptibility, hazards and risks at the highest level, it is necessary to ensure a map - oleate containing the information necessary for the given level of assessment (4.1).

Brčko District – preparation of the basic set of maps 1: 25,000, primarily engineering-geological and hydrogeological maps, their digitization and preparation in the vector format. The holder of the data is the Sector for Public Safety of the Brčko District.

Republika Srpska – preparation of geological engineering and hydrogeological maps 1: 100 000, as well as other supporting layers of conditioning parameters for assessing susceptibility, hazard and risk at the highest level. Preparation and organisation of data fully in line with the methodology described in 4.1. The holder of the data is the Geological Survey Institute of Republika Srpska.

Federation of BIH – preparation of geological engineering and hydrogeological maps 1: 100 000, as well as other supporting oleates of conditioning parameters for assessing susceptibility, hazard and risk at the highest level. Preparation and organisation of data fully in line with the methodology described in 4.1. The holder of the data is the Geological Survey of the Federation of BiH.

Phase 3 – Landslide susceptibility assessment at the level of entities and the Brčko District

Brčko District – Landslide susceptibility assessment on the territory of the Brčko District fully in line with the methodology set out in Chapter 4.1. Once the necessary data sets are in place, it is necessary to conduct corrections in relation to the preliminary landslide susceptibility map as a result of the first phase of the project in Chapter 1.3. Also agree on levels of detail for the basis of areas of the Spatial Plan of the Brčko District. Results can be implemented through the creation of the new Spatial Plan in 2017. The activity holder is the Sector for Public Safety.

Republika Srpska - Landslide susceptibility assessment on the territory of Republika Srpska fully in line with the methodology set out in Chapter 4.1 at the highest level. Once the necessary data sets are in place, it is necessary to conduct corrections in relation to the preliminary landslide susceptibility map as a result of the first phase of the project in Chapter 1.3. The activity holder is the Geological Survey Institute of Republika Srpska.

Federation of BiH - Landslide susceptibility assessment on the territory of the Federation of BiH fully in line with the methodology set out in Chapter 4.1 at the highest level. Once the necessary data sets are in place, it is necessary to conduct corrections in relation to the preliminary landslide susceptibility map as a result of the first phase of the project in Chapter 1.3. The activity holder is the Geological Survey Institute of the Federation of BiH.

Phase 4 – Analysis of landslide triggers (in general terms)

Following the assessment of landslide susceptibility in general terms, it is necessary to analyse the triggers of the process, which is the basis for assessing the quasi-hazard at the highest level (1: 100 000), as well as the assessment of quasi-hazard, and then also hazards at the regional level (1 : 25 000). The data are obtained from the entity hydro-meteorological services and are available to the public, free of charge.

Brčko District – trigger analysis is done at the regional level. The activity holder is the Sector for Public Safety.

Republika Srpska - trigger analysis is done at the highest and at the regional level. The activity holder is the Geological Survey Institute of Republika Srpska.

Federation of BIH - trigger analysis is done at the highest and at the regional level, that is, at the cantonal level. The activity holder is the Geological Survey Institute of the Federation of BiH.

Phase 5 – Assessment of susceptibility, hazards and a preliminary risk assessment at the regional/local level

Assessment of susceptibility, hazards and risks at the regional level implies a set of harmonised data so that an assessment could be done at the local level, or level of municipalities in the scale of 1:25 000 and larger. This phase is related to entities, but not the Brčko District, other than the assessment at the local level (larger scale of 1:25 000). The priority for both entities are municipalities or administrative units (cantons) that, in previous levels of assessment, had the highest percentage of the territory (in terms of percentage of area of the administrative unit) designated with a high degree of susceptibility to landslide, or the greatest material damage and human casualties in the past 20 years. A long-term goal of both entities is the coverage of the entire territory with the assessment of susceptibility, and later on of hazards at the level of regional assessments to a scale of 1:25 000, which is the level of basic survey activities of geological institutes, and the level of planning documents of local governments. Activity holders in the assessment are entity Geological Survey Institutes, that is, the Sector for Public Safety of the Brčko District.

5.2 RECOMMENDATIONS AND MEASURES FOR INSTITUTIONAL LANDSLIDE RISK MANAGEMENT FRAMEWORK

Institutional framework for landslide risk management is the basis for consistent application of certain segments of the process, and should be defined through legislation, if necessary, with new legal provisions or amendment of laws and bylaws. Proposed amendments to specific Articles of different laws are given in Annex 4. Due to the complexity of the state structure in Bosnia and Herzegovina, the following section provides a proposal of measures that would in practice contribute to the process of risk management of landslides and other instability events. It should be noted that the process of risk management of landslides in its full extent requires time and it is possible to find rational solutions in accordance with realistic possibilities. Institutional framework for landslide risk management in Bosnia and Herzegovina is the highest level document that needs to be endorsed as the country's commitment to respect international declarations. The document provides that the entity documents and documents of the Brčko District have a framework for drafts or additions to strategies. A special segment for both entities and the Brčko District is to strengthen the capacity, or the training of professional staff of institutions within the entities and the Brčko District to conduct such activities. The project Disaster Risk Management for the period 2017 to 2019, planned as a technical support of the Japanese International Cooperation Agency (JICA), foresees a comprehensive training of professional staff of institutions, in coordination with the Ministry of Civil Affairs of BiH, the Department for Surveying, Geology and Meteorological Affairs. Given that the existing training system has no relevant courses to adequately educate qualified personnel for landslide risk management, it is necessary to find a solution for this segment of risk management, as well as for accreditation of appropriate academic courses and lecturers. At the level of entities and the Brčko District, proposed measures and recommendations are given in the following section.

Brčko District

The specificity of the administrative unit of the Brčko District resulted in the absence of an appropriate institution in charge of the organisation of data on geological environment. In organisational terms, the Sector for Public Safety is an institution that will perform tasks of keeping the register or inventory of landslides and other instability events, that is, implement risk management process for landslides. Given the complexity and responsibility for commitments, it is necessary to define the legal framework, strengthen the capacity of the people, conduct additional training, but also provide technical equipment of the Sector (minimum fulfilment given in Chapter 5.1., Annex 3).

Republika Srpska

The Geological Survey Institute of Republika Srpska is an entity institution, which according to the legislative framework, is responsible for basic geological surveys, and thus the basic segment of landslide risk management, namely, keeping records of instability events, and development and maintenance of a database on landslides and other instability events. The role of the Institute in assessing susceptibility, hazard and risk of landslide must be defined in amendments to legislation, that is, the duty to provide information to the Institute, in order to establish a database. Also, in accordance with the recommendations from the previous chapter, it is necessary to define the terms for execution of certain goals, both by the Institute, as well as by other competent authorities. The law should also define the obligation on takeover of data on landslides and other instability events, as well as the appropriate analytical and forecasting maps for the development of planning documents or for the needs of the sector for emergency situations, civil protection or any other institution. The line ministry, that is, the Government of Republika Srpska should define and support the activities of the Institute in accordance with the recommendations in Chapter 5.1. (Annex 3) through short-term and long-term activities of the Institute by adopting appropriate programmes, as well as supplementing the Strategy to combat landslides and other instability events.

In terms of structural measures, it is necessary to perform correction of individual articles of several laws, but also to clearly define who can implement these through licensing in the context of professional associations (e.g. Engineering Chamber or in some other form). Non-compliance with any segment of landslide risk management must be subject to sanctions, whether fines, measures of banning from further performance in the profession or other.

Federation of BiH

The role of the Federal Geological Survey Institute in FBiH is identical to the role of the Geological Survey Institute of Republika Srpska, but the institutional framework is more complex because of the administrative structure of the Federation of BiH. The FBiH Government is directly responsible for the work of the Geological Survey Institute, and in this respect, it has the obligation to mandate under relevant legislation all lower administrative units to undertake activities referred to in Chapter 5.1., which primarily relates to the duty to provide information to the highest-level institution. Due to the specific relationship between cantons and the Federation of BiH, it is possible that the database is set up in cantons, but only on condition that there is a single database at the entity level in the Federal Geological Survey Institute (Chapter 4.1.), within time limits laid down in Chapter 5.1 (Annex 3). The long term goal of the Federation of BiH must be the establishment of a single landslide database of the Federation of Bosnia and Herzegovina, with the Federal

Geological Survey Institute as the activity holder. In this regard, the Government of the Federation of BiH is responsible for the implementation of landslide risk management at the entity level.

At cantonal level it is possible to fully implement the landslide risk management process to the level of regional and detailed assessment, only if there is adequate capacity and the needs of individual cantons, but the methodology should be harmonised at the FBiH level. In many cantons, there is no adequately trained person who could establish the most basic levels of risk management of landslides. Very few cantons have the capacity to perform the tasks of setting up a landslide database (such as Tuzla and the Sarajevo Canton for example). This also includes the obligation to harmonise legislation of cantons with regulations of the Federation of Bosnia and Herzegovina, and also to develop cantonal departments to perform similar work as the Federal Geological Survey Institute.

In terms of structural measures, it is necessary to perform correction of individual articles of several laws, but also to clearly define who can implement these through licensing in the context of professional associations (e.g. Engineering Chamber or in some other form). Non-compliance with any segment of landslide risk management must be subject to sanctions according to the laws of the Federation of BiH and cantons, whether fines, measures of banning from further performance in the profession or other.

6. CONCLUSION

The aim of the Study on landslide risk management was to provide a detailed assessment of the current situation in the field of landslide risk management in Bosnia and Herzegovina, with the proposed guidelines and recommendations how to improve the situation in different segments of the process, based on international experience. Conditions would be created for the application of landslide risk management within the existing system of government and its institutions, in the entire territory of Bosnia and Herzegovina. Preparation of the Study was based on an analysis of the current situation in the context of all levels or segments of risk management - from design of a database as the basic level of the process, through presentation of information on population and other risk elements, to assessment methods of susceptibility, hazard and risk, the model of risk treatment and finally, risk management. In order to perceive the actual situation, a review of international documents was made, regulating certain levels or the entire process of landslide risk management, coupled with examples of best practices. After the analysis of international documents, it was necessary to reach a model that would be a long-term solution in the existing administrative structure. Due to the complexity of the state structure and analysis of legislation, an analysis of possible solutions was also carried out, relating to certain levels of risk treatment process in the Federation of BiH, Republika Srpska and the Brčko District. Based on the analysis of the situation in BiH and international standards, recommendations were provided for realistic improvement in certain levels, and the landslide risk management process in Bosnia and Herzegovina in individual segments as well as in general. Solutions include specific measures and recommendations in terms of improving the work of the institutions, legislation within entities and the Brčko District, measures to implement or improve these, so as to strengthen institutions and local governments, and thus create prerequisites for the institutional framework of landslide risk management.

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ANNEX 1
LIST OF GENERAL TERMS RELATED TO RISK MANAGEMENT

Event

Rock - Any solid, coherent aggregate of one or more minerals.

Soil - Loose or coherent material composed of varying amounts of clay (<0.002 mm), dust (0.002 to 0.05 mm), sand (0.05 to 2.0 mm) or gravel (> 2.0 mm).

Debris - Any loose material with a greater amount of larger fragments of rocks (greater than 2.0 mm), in the narrow sense, any material with 20-80% of fragments larger than 2.0 mm.

Slide - In the broadest sense, modern geological process of separation and movement of rock masses along slopes and inclines over stable surfaces under the influence of gravity.

Landslide - In the broadest sense, the creation of the sliding process, i.e. terrain with active or suspended sliding process.

Landslide Classification - In the broadest sense, classification involves a whole range of gravitational processes and is based on the movement mechanism and the type of displaced material (Varnes 1984, Cruden & Varnes, 1996; Cruden & Van Dine, 2013). Accordingly, based on the movement mechanism, the practice frequently distinguishes between the following:

- ***Slide in the narrow sense*** - the movement of soil, debris or rocks down the slope along the defined sliding surfaces or a clear zone of expressed sliding deformations by rotation, translation or a combination.
- ***Fall*** - sudden separation and gravitational movement of rock, less frequently of soil or debris by free fall, roll or bouncing down a steep slope.
- ***Flow*** – rapid movement of debris or soil, less frequently of rocks due to water saturation and dynamic effects, without shear deformation but over it, yet with a well-defined zone of direct erosion and material accumulation.
- ***Topple*** - rotational movement of rocks (less frequently of debris and soil) where the rotation centre is located below the centre of the moving rock mass.
- ***Lateral spread*** - specifically expansive movement of coherent soil types of low thickness or thicker soil with collapsible, expansive or liquefaction soil as its base.

Conditioning Factors - Factors inducing landslide by creating favourable conditions for their development, such as unfavourable geological settings, unfavourable morphology of the terrain, poor physical and mechanical parameters of rock masses making up the terrain, unfavourable hydrological conditions, inappropriate land use, etc. A set of unfavourable conditioning factors makes specific area a subject to the event of slide.

Triggering Factors – Factors such as heavy rainfall, rapid snowmelt, dynamic impacts (e.g. earthquakes.), which directly lead to landslides and other instability events.

Disaster - A serious disturbance in the functioning of a community or society that includes broader human, material, economic and environmental losses and impacts, and goes beyond the ability of the affected community or society to fight it by using its own resources.

Emergency – A situation during and immediately after a disaster of such scale and intensity that it cannot be neutralised by regular activities of competent services; instead, it is necessary to use special measures, forces and resources in an intensified work mode.

ASSESSMENT

Susceptibility – Spatial probability of an event (e.g. landslide) in an area expressed in qualitative terms (scale from low to high susceptibility) or quantitatively.

Risk / Hazard - In general terms, a space-time probability of occurrence of an event, substance, human activity or condition that can lead to loss of life, injury or other health impacts, property damage, loss of livelihoods and work, social and economic disturbances and damage to the environment. Landslide hazard is a probability of processes in a certain area of a specified magnitude / intensity in a given time period.

Elements at risk - People, assets, systems or other elements present in hazard zones that are affected or subject to potential losses.

Vulnerability - Characteristics and conditions of exposed elements that make them susceptible to the harmful effects of danger. Vulnerability is expressed as the potential extent of the loss of value of a given element or set of elements exposed to landslide processes of a corresponding intensity or magnitude.

Risk - The combination of the probability of a hazardous event and its negative consequences on the exposed elements over time.

Acceptable Risk –The level of potential losses that society or community considers acceptable in a given social, economic, political, cultural, technical and environmental conditions.

Risk Assessment - The methodology for determining the nature and extent of risk by analysing potential hazards and the assessment of the existing conditions of vulnerability that together could cause damage to exposed persons, property, services, living conditions and environment that the population is dependent on.

MANAGEMENT

Public Awareness - The scope of common knowledge about disaster risks, the factors that lead to them and the activities that can be implemented individually and collectively to reduce exposure and vulnerability to hazards.

Sustainable Development - Development that meets the needs of the present without compromising the ability of future generations to meet their own needs.

National Platform for Disaster Risk Reduction - A generic term for national mechanisms for coordination and policy guidance on disaster risk reduction that are interdisciplinary in their nature, with the involvement of public, private and NGO sector in the engagement that brings together all interested parties in the country.

Resilience - The ability of a system, community or society exposed to hazards to resist, absorb, respond to the effects of hazards in a timely and efficient manner and to recover, including the preservation and restoration of its essential basic structures and functions.

Capacity - The combination of all the benefits, attributes and resources available within the community, society or organisation that can be used to achieve agreed goals.

Recovery - Restoration and improvement of facilities, livelihoods and living conditions in communities affected by the disaster, including efforts to reduce disaster risk.

Response - The provision of services in emergency situations and public assistance during or immediately after a disaster to save lives, reduce negative health impacts, ensure public safety and to meet the basic needs of the affected population.

Emergency Management - The organisation and management of resources and responsibilities for addressing all aspects of emergencies, that is, preparedness, response and initial recovery steps.

Risk Management – Systemic approach and practice of risk probability management, to reduce potential damage and losses.

Mitigation - A number of methods for reducing or limiting the harmful effects of hazards or disasters.

Residual Risk - The risk that remains in a form that cannot be managed, even when there are effective measures for disaster risk reduction, and which need to have capacities maintained for emergency response and recovery.

Retrofitting - Strengthening and upgrading of existing facilities in order to be more resilient to the harmful effects of hazards.

Structural Measures - All physical construction to reduce or avoid possible effects of hazards and application of construction techniques to achieve resilience to danger and resilient structure or system.

Non-structural Measures - Any measure not involving physical construction and using knowledge, practice or agreement to reduce risks and impacts, in particular through policies and laws, public awareness, training and education.

ANNEX 2.
LIST OF INSTITUTIONS AND RESPONDENTS FOR INTERVIEWS

SARAJEVO	
1	**FBiH Hydrometeorological Institute** Bardakčije 12 71 000 Sarajevo Director Almir Bijedić
2	**FBiH Ministry of Agriculture, Water Management and Forestry** Marka Marulića 2 71 000 Sarajevo Mr. Aziz Čomor
3	**FBiH Geological Survey Institute** Ustanička 11 71 000 Sarajevo Director Hazim Hrvatović, PhD Hamid Begić, MSc
4	**FBiH Ministry of Environment and Tourism** Marka Marulića 2 71 000 Sarajevo Assistant Minister Dr. Mehmed Cero
5	**FBiH Ministry of Spatial Planning** Marka Marulića 2 71 000 Sarajevo Assistant Minister Mr. Danijel Čapelj Ms. Hanka Mušibegović
6	**FBiH Civil Protection Administration** Vitomira Lukića 10 71 000 Sarajevo Director Mr. Fahrudin Solak
ISTOČNO SARAJEVO	
7	**RS Civil Protection Administration** Spasovdanska 3 71 123 Istočno Sarajevo Director Mr. Veseljko Elez g. Željko Janković

ZVORNIK	
1	**RS Geological Survey Institute** Vuka Karadžića 148 B 75 400 Zvornik Director Mr. Mitrović Dragan Mr. Cvjetko Sandić Mr. Boban Jolović Ms. Koviljka Leka
BANJA LUKA	
1	**RS Ministry of Agriculture, Water Management and Forestry** Trg Republike Srpske 1 78 000 Banja Luka
2	**RS Hydrometeorological Institute** Put banjalučkog odreda b.b. 78 000 Banja Luka Director Mr. Zoran Božović Ms. Vesna Šipka
3	**RS Ministry of Spatial Planning, Construction and Environment** Trg Republike Srpske 1, 78 000 Banja Luka Deputy Prime Minister and Minister Ms. Srebrenka Golić Assistant Minister Mr. Miladin Gaćanović Assistant Minister Mr. Nenad Trbić
4	**Ministry of Industry, Energy and Mining** Assistant Minister Mr. Esad Salčin
BRČKO DISTRICT	
1	**Brčko District Government** **Department of Agriculture, Forestry and Water Management** Bulevar mira 1 76 100 Brčko Mr. Adnan Pašalić Ms. Ljiljana Zaminović

2	**Department of Spatial Planning and Property and Legal Affairs** Bulevar mira 1 76 100 Brčko Ms. Ivana Blagojević Ms. Dragana Visović Ms. Nada Ljubojević
3	**Department of Public Safety** Head of Department Mr. Uroš Vojnović Miss. Vanja Piperac, graduate engineer
LOPARE MUNICIPALITY	
1	Lopare Mayor Mr. Rado Savić
CITY OF TUZLA	
1	Adviser to the Mayor Mr. Bahto Mekić Head of Civil Protection Dr. Miralem Mulać Sabid Zekan, PhD, University of Tuzla
MAGLAJ MUNICIPALITY	
1	**Civil Protection Administration** Head of Municipal Administration Mr. Anton Maglica
	Ministry of Civil Affairs of BIH
1	Mr. Haris Čengić Head of the Sector for Geodetic, Geological and Meteorological Affairs

ANNEX 3.

FINANCIAL FRAMEWORK TO IMPLEMENT RECOMMENDATIONS OUTLINES IN CHAPTER 5.1.

Financial framework for the implementation of Phase One, Chapter 5.1. in the Brčko District (Sector of Public Safety of the Brčko District) roughly includes the following:

- full-time employment of one graduate geology engineer (with adequate undergraduate or master studies) (approximately 12,000 KM annual net),
- procurement of computer components that can support the work with spatial data (around 5,000 KM),
- purchase of a licensed ArcGIS software with the appropriate extensions (around 30,000 KM).

Financial framework for the implementation of Phase One, Chapter 5.1. in Republika Srpska (Geological Survey of Republika Srpska) roughly includes the following:

- full-time employment of two graduate geology engineers (with adequate undergraduate or master studies) (12,000 KM annual net x 2),
- fieldwork on data collection - basics standard is 5 pieces of data on the event / per engineer / per day x 150 EUR gross (e.g. 1000 landslide would require 200 field days or 60,000 KM)
- procurement of computer components (price in KM or EUR),
- purchase of a licensed ArcGIS software with the appropriate extensions (around 40,000 to 90,000 KM),
- setting up a web service

Financial framework for the implementation of Phase One, Chapter 5.1. in the Federation of BiH (Geological Survey of the Federation of BiH) roughly includes the following:

- full-time employment of two graduate geology engineers (with adequate undergraduate or master studies) (12,000 KM annual net x 2),
- fieldwork on data collection - basics standard is 5 pieces of data on the event / per engineer / per day x 150 EUR gross (e.g. 1000 landslide would require 200 field days or 60,000 KM)
- procurement of computer components that can support the work with spatial data (around 5,000 KM each),
- setting up a web service.

ANNEX 4.

AMENDMENTS TO LEGISLATION

FEDERATION OF BIH

Law on Geological Researches of the Federation of Bosnia and Herzegovina (Official Gazette of the FBiH, No. 9/10, 2010)

The entire Article 20, paragraph 4 should be deleted. Such approach, in practice, allows for various technical personnel with no appropriate professional background or qualifications to perform surveys and lab soil testing, thus participating in the preparation of project documentation. This is especially true of engineering-geological surveys and geomechanical tests. Existing provisions made it possible for incompetent and unprofessional individuals to design and work on recovery of landslides.

Law on Water (Official Gazette of the FBiH, No. 70/06)

Article 91 should have a paragraph 4 added, to read "The FBiH Geological Survey Institute in Sarajevo shall establish a system for monitoring the impact of water flow on landslides with their foot in the watercourse, as well as monitoring the development of flood and torrential flows and forecasting their impact on stability of slopes in the way of floods".

Law on Forests (Official Gazette of the FBiH, Nos. 20/02, 29/03 and 37/04)

Article 4, paragraph 7 of the Act should have item g) added to read "area map - map of area stability and landslide risk assessment during and after deforestation and clearing, issued by the Federal Geological Survey Institute in Sarajevo".

Law on Spatial Planning and Land Use in the Federation of BiH (Official Gazette of the FBiH, Nos. 02/06, 72/07, 32/08, 4/10, 13/10 and 45/10)

Article 32, after item 8, add a new item 9, which should read "enter data, inventory maps of landslides and landslide and flood risks", and then proceed with the remaining items of this Article of the Law.

Article 68, after paragraph 7 should have the word "geology" added after "electrical installations".

Rules on Geotechnical Surveys and Tests and Geotechnical Engineering (Official Gazette of the FBiH, No. 2/06, 72/07 and 32/08)

It is recommended to amend Article 40 - Conditions and criteria for granting authorisation for geotechnical survey and field tests and Conditions and criteria for granting authorisation for geotechnical laboratory tests.

REPUBLIKA SRPSKA

Law on Geological Survey of Republika Srpska (RS Official Gazette, No. 13)

Article 2 and Article 5 should additionally include the terms "susceptibility, hazard and risk of landslides";

Article 51, paragraph 1, add "geological hazards".

Law on Spatial Planning and Construction (RS Official Gazette, No. 110/13)

In Article 2, add the terms hazard and risk of landslides, spatial planning segment.

Article 10, paragraph 1, add engineering and geological and management of hazard and risk,

Article 11, paragraph (v) Add "landslides" after earthquake; paragraph (lj) to add with respect to data from the Geological Information System;

Article 18, add a paragraph on the threat from instability processes;

Article 27, paragraph (dj) add the term hazard of landslides.

Law on Waters (RS Official Gazette, Nos. 50/06, 92/09 and 121/12)

A general view is that this Law is inconsistent with the Law on Geological Survey of Republika Srpska (RS Official Gazette, No. 110/13).

Law on Environmental Protection (RS Official Gazette, Nos. 50/02 and 113/08) - no comments

Law on Forests (RS Official Gazette, Nos. 75/08 and 60/13)

A general view is that this Law is inconsistent with the Law on Geological Survey of Republika Srpska (RS Official Gazette, No. 110/13).