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UNDAC landslide advisory visit to Serbia June 2014

Engineering Geology Programme

Open Report IR/14/043

BRITISH GEOLOGICAL SURVEY

ENGINEERING GEOLOGY PROGRAMME

OPEN REPORT IR/14/043

UNDAC landslide advisory visit to Serbia June 2014

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Foreword

This report is the principal output of the British Geological Survey (BGS) in response to the offer to provide technical and scientific help to UNDAC in the aftermath of the flooding and landslide events that happened in northern-central Serbia, concentrating in the Sava catchment, and its tributaries the Drina and Kolubara, during 13-16 May 2014.

The report describes the outcomes of four site visits, that were carried out between the 30th May and the 12th June 2014, by Dr Helen Reeves, and subsequent discussions with Serbian counterparts.

Acknowledgements

A large number of individuals have contributed to the information that is documented in this report. Dr Reeves would particularly like to thank the following:

Assoc. Prof Biljana Abolmasov (Vice-Dean, Faculty of Mining and Geology, University of Belgrade)

Prof Dr Dragoman Rabrenovic (Director, Geological Survey of Serbia)

Mr Predrag Mijatovic (Deputy Director, Geological Survey of Serbia)

Ms Aleksandra Gulan (Geochemist - Geological Survey of Serbia)

Ms Isidora Vukadinovic (Engineering Geologist - Geological Survey of Serbia)

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Ms Ana Mitić (Advisor - Ministry of Construction, Transport and Infrastructure)

Mr Momir Kocović (Head of Section for State Road Inspection - Ministry of Construction, Transport and Infrastructure)

Vladan Branković (Inspector for State Roads & Road Safety - Ministry of Construction, Transport and Infrastructure)

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1 Introduction

Following Cyclone Tamara flooding and landslide events occurred in northern-central Serbia, from May 13-18th 2014. These events were concentrated on the Sava River and its tributaries the Drina and Kolubara. Following these events the British Geological Survey (BGS) offered (through the UK Government) to provide technical and scientific help to UNDAC. UNDAC invited Dr Helen Reeves (Director of Science for Engineering Geology and Engineering Geologist) to Serbia for a 12 day visit to meet Serbian scientists and ministerial staff and to provide technical support.

The 12-day visit included an initial briefing from UNDAC and EU Civil Protection staff; four site visits (Mali Zvornik, Umka, Krupanj & Vinca); discussions with Serbian scientists at the Geological Survey of Serbia & Belgrade University and discussions with Civil Engineers from the Serbian Ministry of Construction, Transport & Infrastructure.

This report provides a description of the four site visits, presents observations made in the field during the site visits, and summarises the key conclusions and recommendations from the visit.

2 Background

The large number of landslides (reports of over 1000) that occurred in Serbia following Cyclone Tamara, between May 13-18th 2014, in the Sava River catchment (Figure 2.1, Appendix 1) and its tributaries (the Vrbas, Bosna and Drina) have developed primarily because of the relief that is present to the south of the Sava River Catchment (ISRBC 2009) and the geological conditions; although inappropriate land use and modifications of the landscape in places are contributing factors. To the south of the Sava catchment the terrain is more undulating and prone to rapid runoff, which is capable of mobilising soil and soft (weathered) geological deposits and causing debris slides and flows (Figure 2.2, Appendix 1). Where water penetrates into soft (weathered) geological deposits and stronger bedrock larger, rotational landslides have formed (Figure 2.2, Appendix 1).

The Republic of Serbia's Ministry of Natural Resources, Mining and Spatial Planning Department for Geological Research provides an access portal to the geological maps of Serbia at a 1:100,000 scale (Anon, 2012).

The geology of the Sava catchment is characterised by a Palaeozoic oceanic suture that strikes roughly NNW to SSE. The rocks within this area, contained within the Pannonian basin, are very diverse metamorphosed rocks consisting of metamorphosed sedimentary rocks such as schists and granitoids. These rocks are covered in the north by Tertiary Neogene sediments (Anon, 2012). On the Serbian engineering geological map the Palaeozoic rocks are generally shown as poorly lithified to hard rocks (green units) that are highly fractured and altered rock masses (Lazic & Bozovic, 1995) and hence are susceptible to landsliding. The Neogene sediments are generally shown as cohesionless, poorly cohesive, soft and poorly lithified (brown units). A distribution of landslides (Lazic & Bozovic, 1995) is shown in red dots on the engineering geology map of Serbia showing most events located in upland relief.

3 Site visits overview

3.1 MALI ZVORNIK

Mali Zvornik is situated along the Serbian banks of the River Drina (Figure 3), and boarders Bosnia-Herzegovina in a valley (Figure 1, Appendix 1 & Figure 3.1) with steep relief (slopes varying between 10-45°). The geology locally is dominated by massive and brecciated limestones, with some quartzites, clays, schists and greenstones. The rocks have a general dip 20° towards the north-north-west (Anon, 2012).

On the Mali Zvornik site visit Dr Reeves was accompanied by colleagues from the Ministry of Construction, Transport & Infrastructure, Miss Ana Mitić (Special Advisor), Momir Kocović (Head of Section for State Road Inspection) and Mr Vladan Branković (Inspector for State Roads & Road Safety). We were kindly hosted by the local Major for Mali Zvornik.

Figure 3.1 - View South down the River Drina from pedestrian bridge by Mali Zvornik.

3.2 UMKA & DUBOKO

The Umka and Duboko sites are situated on the banks of the River Sava (Figure 1, Appendix 1) with shallow to moderate hummocky relief (slopes approximately 10°). The geology locally is dominated by weathered Neogene Miocene laminated soft marls and clayey marls, which are variably weathered to depths of between approximately 10 – 25 m (Abolmasov & Milencovic, 2012). The sites described above were not activated during Cyclone Tamara, but are ancient active landslides that are typical of this area around the Riva Sava.

On the Umka and Duboko site visits Dr Reeves was accompanied by colleagues from the Geological Survey of Serbia, Prof Dr Dragoman Rabrenovic (Director), Mr Djordje Trbojevic (Project leader for Landslide Catastrophe project) & Ms Aleksandra Gulan (Geochemist). These sites gave insight into ancient landslide activity in Serbia and the work that the Geological of Survey of Serbia had previously done on the landslides encountered at these sites.

3.3 KRUPANJ

Krupanj is situated in the bottom of an alluvial river valley that has four main tributary rivers (Bogostica, Krzava, Cadjavica & Brstic), converging in the centre of Krupanj town (Figure 1, Appendix 1). These tributaries enter into the Likodra River in the centre of Krupanj. The valleys have steep relief (slopes varying between 20-45°) that contain many small streams and gullies. The valleys are generally heavily vegetated with trees (Pine and Beech - Figure 3.2). The local geology is dominated by Palaeozoic metamorphosed sedimentary rocks, which are variably weathered to depths of between approximately 1-6m.

Figure 3.2 - View looking down the Cadjavica tributary towards the town of Krupanj.

For this site visit I was accompanied by colleagues from the the Geological Survey of Serbia, Prof Dr Dragoman Rabrenovic (Director) & Ms Isidora Vukadinovic (Engineering Geologist), and the Ministry of Construction, Transport & Infrastructure, Mr Lazar Lekic (Special Advisor), Mr Aleksandar Seizovic (Republic Civil Engineering Inspector) and Mr Zeljko Todorovic (Building Directorate of Serbia) & Francesco Galante (Water Engineer – Maccaferri Environmental Solutions. We were kindly hosted by the local Major for Mali Zvornik, Mr Rade Grujic.

3.4 VINCA

Vinca is situated on the southern bank of the Danube (Figure 1, Appendix 1) with shallow to moderate hummocky relief (slopes approximately 10-15° - Figure 3.3). The geology locally is dominated by Pleistocene aeolian sands and weathered Neogene Miocene laminated soft marls and clayey marls. The rocks have a general dip 15° towards the south-west (Anon, 2012).

On the Vinca site visit Dr Reeves was accompanied by Assoc. Prof Biljana Abolmasov from the University of Belgrade and offices from the Municipality of Belgrade's Urban Spatial Planning Department.

Figure 3.3 - View looking north from the Belgrade Municipal waste site towards the Danube.

4 Site visit observation

At each of the site visits observations were made to enable an initial observational assessment of the landslide type. The field observations were made at each of the locations of the site visits at: i) Mali Zvornik, ii) Umka , iii) Krupanj iv) Vinca are detailed below.

4.1 MALI ZVORNIK

At Mali Zvornik a complex landslide (Figure 2, Appendix 1) was encountered that had a multiple rotation slide mode (Figure 2, Appendix 1 & Figure 4.1, 4.2 & 4.3) at the top of the landslide with a debris flow (Figure 2, Appendix 1 & Figure 4.2) at the bottom of the landslide (toe).

Figure 4.1 - Scarp features seen in the middle of the landslide mass at Mali Zvornik showing typical features for multiple rotational slides.

Figure 4.2 - Scarp features seen in the middle of the landslide mass at Mali Zvornik showing the typical features for multiple rotational slides with small pools of water observed.

Figure 4.3 - Scarp features seen at the top of the Mali Zvornik landslide mass showing typical features for multiple rotational slides.

Figure 4.4 - View from pedestrian bridge looking west to the debris flow at the toe of the Mali Zvornik landslide.

At the bottom of the slope there is a band of strong limestone that is approximately 10m high with a slope angle of ~45°. The landslide debris flow (mixture of rock, soil, trees in a clayey matrix) came down and over the limestone band, flowing down a pre-existing stream line. Above this streamline the meta-sedimentary rocks (schist and phyllites) are heavily weathered to a clay soil and have a number of large continuous scarp features (cracks in soil), with vertical displacements of between 1.0 – 5.0 m and apertures of 0.1 – 0.5 m (Figures 4.1-4.3). Slope angles in the middle of the landslide's meta-sedimentary rocks are 10-15° (Figure 4.2) and at the top of the landslide are 20-25° (Figure 4.3).

The Mali Zvornik landslide covered and damaged the road at the bottom of the landslide, as well as severing the utilities services at the side of the road, by the Drina River (Figure 4.4). At the top of the slope small agricultural buildings had been damaged by the landslide moving. There is also evidence of there having been sustained damage from the movement of the landslide for a number of years (Figure 4.5). The agricultural practices, of growing vegetables, at the top of the slope and the associated watering and storage of water have also contributed to enhancing the movement of the landslide (Figure 4.5).

Figure 4.5 - Top of the Mali Zvornik landslide showing evidence of damage to buildings and agricultural use of land.

4.2 UMKA & DUBOKO

At Umka and Duboko large slow moving rotational landslides were observed in the weathered Neogene Miocene laminated soft marls and clayey marls. A number of continuous scarp features (cracks in soil), with vertical displacements of between 0.2 – 5.0 m were observed (Figures 4.6).

Figure 4.6 - A view of the slow moving rotational landslide observed at Duboko. Damage to road from the slow moving landslide can be observed.

4.3 KRUPANJ

In Krupanj and the surrounding valleys a number of varying sized debris flows and debris slides were observed. These ranged from flows and slides that were a few 10's m^3 in size to 10,000's m^3 (Figures 4.8 – 4.10). The debris flows and debris slides (Figure 2, Appendix 1) have formed in the weathered (1-6 m deep) Palaeozoic metamorphosed sedimentary rocks (mainly schists).

Figure 4.7 - Debris slides seen in the Cadjavica valley that have damaged houses.

Figure 4.8 - Debris slides seen in the Ogradjenica valley that have damaged agricultural land.

Figure 4.9 - Debris flow seen in the valley above the Antimony Mine Waste Tailings Dam where damage to the road and road infrastructure was observed.

The debris slides and failures seen in the valleys around the town Krupanj have damaged buildings (Figure 4.8), agricultural land (Figure 4.9), as well as roads and road infrastructure (Figure 4.10).

In addition, to observing the landslide sites in the valleys around Krupanj, the Stolice Antimony Mine Waste Tailings Dam was visited. The embankment of this dam was observed to have been breached and water from the mine waste is discharging into the river below the site.

Figure 4.10 - Stolice Antimony Mine Waste Tailings Dam showing breached embankment and discharge of mine waste water.

4.4 VINCA - THE BELGRADE MUNICIPAL WASTE SITE

At Vinca a complex landslide (Figure 2, Appendix 1) was encountered that had a multiple rotation slide mode (Figure 2, Appendix 1 & Figure 4.11) at the top of the complex with debris flow (Figure 2, Appendix 1 & Figure 4.12) at the bottom of the landslide (toe) in the Belgrade Municipal Waste site.

Figure 4.11 - Scarp features seen in the middle of the landslide mass at the Belgrade Municipal Waste site showing typical features for multiple rotational slide.

Figure 4.12 - View looking south-east back over the debris flow at the toe of the Vinca Municipal Waste site landslide.

Slope angles around the edge of the Belgrade Municipal waste site range from 25 - 30° (Figure 4.14).

The Belgrade Municipal Waste site landslide has damaged the perimeter road and the utilities around the waste site (Figure 4.15). Leachate was observed to be seeping out all over the site, but particularly towards the toe of the landslide (Figure 4.15).

Figure 4.13 - View looking south of the slope around the edge of the Belgrade Municipal Waste Site.

Figure 4.14 - View looking north of the damage to the infrastructure and road around the edge of the Belgrade Municipal Waste Site.

5 Conclusion and recommendations

The flooding and landslide events that happened in northern-central Serbia, following Cyclone Tamara, (between May 13-18th 2014) are concentrated on the Sava river and its tributaries the Drina and Kolubara, resulted in damage to property and infrastructure and the inundation of agricultural land.

Following the flooding and landslide events the British Geological Survey (BGS), through the UK Government, offered to provide technical and scientific assistance to UNDAC. UNDAC invited Dr Helen Reeves (Director of Science for Engineering Geology and Engineering Geologist) to Serbia to meet Serbian scientists and ministerial staff to provide technical support. The principal aims were to i) undertake a primary assessment of the landslide events and record observations ii) discuss current understanding with Serbian counterparts and iii) propose recommendations for future technical and scientific assistance.

The Serbian authorities, with the assistance of UNPD and the EU Civil Protection, have mounted an impressive clean-up operation. In Serbia it was found that generally, there is a good scientific and engineering understanding of the problems, but as yet no active plans for remediation to deal with the landslides have been determined.

Within Serbia, at the moment, the techniques used for landslide assessments follow a traditional approach. This is evident in the Serbian Geological Survey where years of under investment in training and improved technology (especially IT hardware & software and surveying equipment) has contributed to the slower development and advancement of an integrated national approach to landslide mapping (geomorphologically, geologically & geotechnically based), assessment, databasing and the production of a digital national landslide inventory and the development of a national landslide hazard susceptibility assessment. As a result there are a number of areas within the scientific and engineering community that would greatly benefit from investment in training and improved technology (especially IT hardware & software and surveying equipment) within the specific fields of:

1. Surveying (dGPS, Terrestrial LIDAR, digital field capture of geomorphological geological data/observations)
2. Remote sensing (digital orthophotographs, Digital Elevation/Terrain Models, Radar)
3. Landslide monitoring (especially remote monitoring techniques)
4. Landslide remediation

Within Belgrade University there are experienced and highly skilled landslide experts that could undertake elements of the above training.

For the site visits with colleagues from the Ministry of Construction, Transport & Infrastructure, a number of specific recommendations have already been put forward to the Ministry through email correspondence. The outlines of these recommendations are described in more detail below.

5.1 MALI ZVORNIK

Suggested program of work recommend for the landslide at Mali Zvornik:

Phase 1: Accurate baseline survey of the landslide area

Survey should accurately map the geomorphological, hydrological, and geological features of the landslide, ideally using a differential GPS system &/or detailed surveyed points, interpretation of orthophotographs and satellite imagery. This dataset can then be used as a baseline to monitor movement on the landslide, which will help to understand the on-going movement of the landslide. Additionally, it would be recommended to monitor the volume and flow rates of water that is currently being diverted away from the landslide through the temporary diversion.

Phase 2: First conceptual ground model of the landslide

Using the baseline survey an initial conceptual ground model of the landslide can be developed

Phase 3: Design ground investigation of the landslide

Using the conceptual ground model of the landslide developed in Phase 2, design and undertake a ground investigation (e.g. boreholes, trial pits). Incorporate into the ground investigation the installation of piezometers (monitor pore pressures in soil/rock) and inclinometers (monitor lateral movement) to enable the landslide to be monitored.

Phase 4: Second ground model of the landslide

Using all the data collected from the landslide from Phase 1-3 develop a second ground model.

Phase 5: Design remediation solution using the second ground model of the landslide developed in Phase 4.

Phase 6: Install remediation solution

5.2 KRUPANJ

Recommended program of work at Krupanj is:

Phase 1: Survey of the key landslide events around the Krupanj river catchment

Survey should accurately locate and map both the geomorphological, hydrological, and geological features of the landslide events through the use of orthophotographs, satellite imagery and field based observations. From the data collection create a landslide event database (both of landslide information and landslide spatial polygon data).

Phase 2: Prepare landslide susceptibility maps

Using the baseline landslide event data, collected in Phase 1, develop a landslide susceptibility map using knowledge on the engineering geological properties of the rocks and soils in the area.

Phase 3: Highlight remediation options

Using the data and information collected in Phases 1 & 2 identify potential options for remediation measures that could be undertaken (e.g. installation of catch fences, development of debris ditches and/or the clearing of gullies/streams/rivers).

Colleagues from the Geological Survey of Serbia have produced a short visit report (Appendix 2), which highlights some of the points I have highlighted above. In addition, on June 9th 2014, as a result of our visit Prof Dr Dragoman Rabrenovic (Director of the Geological Survey of Serbia) has sent a team of 6 engineering geologists to Krupanj to survey the key landslide areas in the Krupanj river catchment assess the damage to building and infrastructure and enable some recommendations to be made.

At the Stolice Antimony Mine Waste Tailings site, due to the nature of the mined mineral Antimony (http://en.wikipedia.org/wiki/Antinomy), potentially harmful fluids to human health, are discharging into the river. This site needs to be investigated with a full hazard and risk assessment by experts in the field of Mine Waste/Tailings Engineering and Mine Water Geochemistry as a matter of urgency. The representatives from the local municipality said that the dam had been inspected and water had been sent away for testing and that they were waiting for results. It is also recommended that until this is done, as a precaution, local people are evacuated from the local vicinity.

5.3 VINCA - THE BELGRADE MUNICIPAL WASTE SITE

Suggested program of work recommended for the landslide at the Belgrade Municipal Waste site:

Phase 1: Accurate baseline survey of the landslide area

Survey should accurately map both the geomorphological, hydrological, hydrogeological, geochemical and anthropogenic features of the landslide, ideally using a differential GPS system &/or detailed surveyed points, interpretation of orthophotographs and satellite imagery. This dataset can then be used as a baseline to monitor movement on the landslide, which will help to understand the on-going movement of the landslide. Additionally, it would be recommended to monitor the geochemistry, as well as the volume and flow rates of leachate that is currently seeping out of the landslide.

Phase 2: First conceptual ground model of the landslide

Using the baseline survey an initial conceptual ground model of the landslide can be developed

Phase 3: Design ground investigation of the landslide

Using the conceptual ground model of the landslide developed in Phase 2, design and undertake a ground investigation (e.g. boreholes, trial pits). Incorporate into the ground investigation the installation of piezometers (monitor pore pressures in soil/rock) and inclinometers (monitor lateral movement) to enable the landslide to be monitored.

Phase 4: Second ground model of the landslide

Using all the data collected from the landslide from Phase 1-3 develop a second ground model.

Phase 5: Design remediation solution using the second ground model of the landslide developed in Phase 4.

Phase 6: Install remediation solution

Appendix 1 Oversized Figures

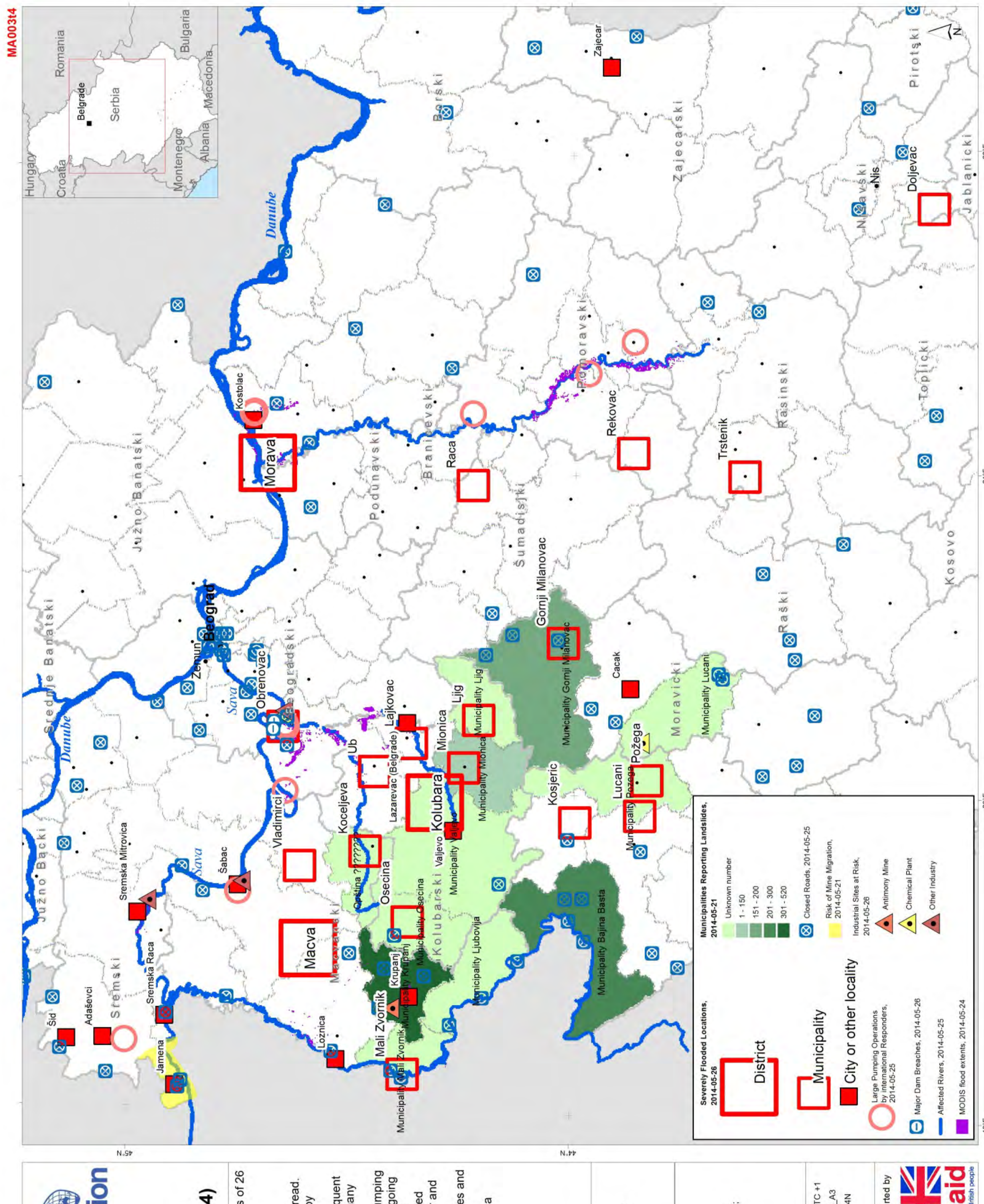

Figure 2. 1 - Map showing the location of the landslide effected areas and the site visits (black dots)

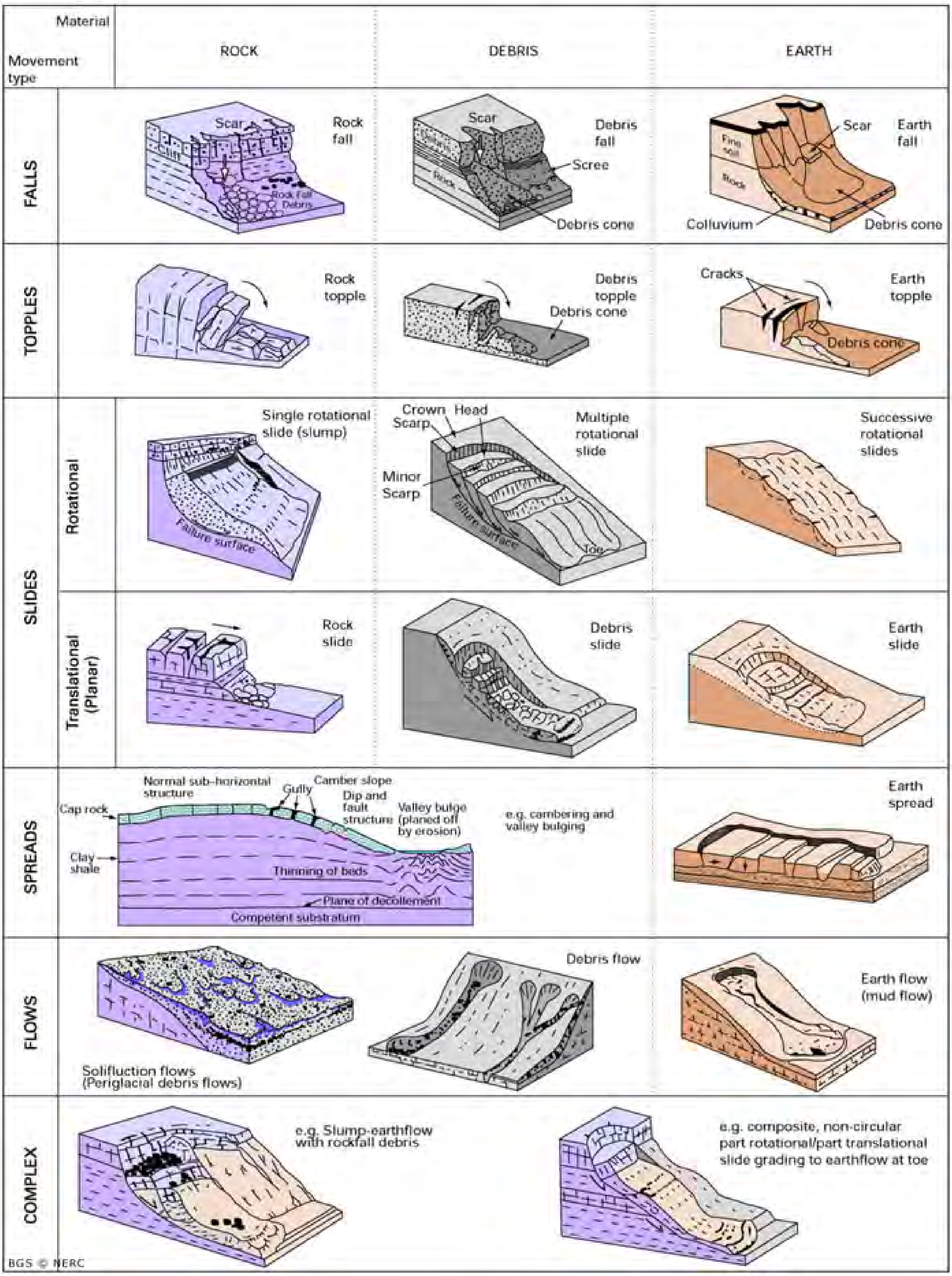

Figure 2. 2 - Landslides types.

For more information on what causes a landslide and what is a landslide:
http://www.empr.gov.bc.ca/MINING/GEOSCIENCE/SURFICIALGEOLOGYANDHAZARDS/LANDSLIDES/Pages/Whatcauseslandslides.aspx
http://www.bgs.ac.uk/landslides/whatIs.html

Appendix 2 The Geological Survey of Serbia's visit report from Krupanj

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ИЗВЕШТАЈ СА ОБИЛАСКА ТЕРЕНА ОПШТИНЕ КРУПАЊ

БЕОГРАД јун 2014.г.

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ДИРЕКТОР

Проф.др Драгоман Рабреновић

БЕОГРАД јун 2014.г.

Екипа у саставу:
За Геолошки завод Србије,
Проф. Др Драгоман Рабреновић, дипл.инж.геол
Исидора Вукадиновић, дипл.инж.геол
За Геолошки завод Велике Британије,
Др Хелен Ривс, дипл.инж.геол

Дана 6.6.2014. екипа у наведеном саставу имала је састанак са председником општине Крупањ, Радетом Грујићем, председником Скупштине општине Крупњу Александром Зељићем, представником из геодетске службе Милорадом Пуртићем и екипом Кризног штаба.

Након разговора извршен је обилазак терена заједно са представницима локалне власти и екипом из Министарства за инфраструктуру.

Г-ђа Др Хелен Ривс је Директор сектора за инжењерску геологију у Геошком заводу Велике Британије (British Geological Survey - **BGS**). Такође је Технички саветник за Геохазарде везане за појаву клизишта при уједињеним Нацијама (Landslide Geohazard Senior Technical Advisor for the UN OCHA Field Coordination Support Section in Serbia). Упућена је у Геолошкии завод Србије од Стране Г-ђе Ирене Војацкове Солорано која је Главни Координатор Уједињених нација у Србији како би извршила преглед клизишта и штете насталих у Србији након догођених поплава и за Уједињене Нације направила извештај последицама.

Локације које смо обишли су биле репрезентативне за сагледавање штете која се догодила наком поплава и предложене као такве од стране представника локалне самоуправе:

- Долина реке Кржаве
- Долина реке Чађавице
- Долина реке Бистрице
- Столице – јаловиште из рудника Антимона
- Липеновић
- Сам центар Крупња

Након обиласка предметних локација и сагледавања топографије терена, геолошке грађе, положаја објеката и насеља, може се закључити следеће:

Насеље Крупањ – градско језгро лоцирано је у алувијалној равни, тј. на самом ушћу река Бистрица, Чађавица, Кржава и Бистрица, тј. на месту њиховог спајања у реку Ликодру.

Ове речне долине усечене су у палеозојским метаморфитима, које су алтерисане и површински распаднуте у просеку од 1-2м дубине. Распаднути материјал је слабо везан, склон покретању и спирању под утицајем вода и гравитације. Честе су бочне јаруге са повременим токовима.

Долинске стране су средњег до стрмог нагиба, покривене густом шумском вегетацијом. Доминира буква и сађена јела. Стабла су висине од неколико до преко 10м.

Објекти у самом центру се налазе изнад нивоа линијских водотокова на висини од максимално 2,0м. Удаљавањем од центра ова висинска разлика се смањује. Реке су биле уређене са обложеним коритом. Делимично је око њих био насип.

При поплави која се десила током маја 2014.г сви речни токови су набујали и издигли своје нивое изнад максимално очекиваних. Снага бујице уништила је насипе и обалоутврдне конструкције, као и многе стамбене објекте. Такође је оштећена саобраћајна мрежа. Штете су видне и разликују се од тачке до тачке. При томе је, на великој површини (око 2000ха) формиран талог у некадашњим алувијалним равнима дебљине и преко 20цм. Ово је посебно оштетило усеве кукуруза и засаде малина и купина од којих људи претежно и живе.

Поплављена долина реке Чађевице

Констатовано је да су реке се делом вратиле у своја речна корита, али су алувијалне равни и даље у водозасићеном стању и део вода покушава да формира нове токове. Јасно су уочљиви делови формираних мањих каскада висине 20-30цм низ које се слива вода.

У исто време формирана су бројна тецишта у распадини стена на падинама, те су постојећи објекти на више локација били двојако угрожени. Према речима представника из општине од 27 мостова који су били у општини Крупањ 21 мост је оштећен у већој или мањој мери.

Тециште формирано у распадини шкриљаца

Угрожени објекти у долини реке Чађевица

Долина Ликодре –објекат у насељу Липеновић

Након обиласка терена договорено је да се у Крупањ из Геолошког завода Србије пошање екипа од 6 чланова како би се детаљније испитале најугроженије локације и дефинисале у погледу сигурности објеката са геотехичког аспекта.

Прелиминарни предлог даљих мера:

- У речним долинама предлаже се уклањање бујичног материјала.
- Када се водостај река устали потребно је регулисати очистити и речна корита. Неопходно је да речна корита и у даљој будућности остану проходна.
- Делове терена који су већ под обејктима, заштитити прописним насипима за глиненим језгром, као би се спречио даљи утицај површинских вода на исте. Како би се обезбедили објекти од високих подземних вода потребно је предвидети обимне дренажне захвате.
- Делове терена који су предвиђени у оквиру алвијалних равни за градњу потребно је издићи изнад максималног догођеног поплавног таласа насипањем.

На падинама се предлаже да се у догледном временском року изврши постепена делимична замена вегетације биљкама са дубљим кореном.
Такође се предлаже примена адекватних мрежа за прихват осулинског материјала.
Могуће је урадити и канале за прихват "одроњеног материјала" и чиме би се материјал из зоне тецишта уклонио и усмерио у правцу који није опасан за објекте.

За детаљнију анализу заштите угроженог подручја потребно је урадити адекватне инжењерскогеолошке подлоге, које захтевају детаљно инжењерскогеолошко картирање терена, анализу слива Ликодре са притокама, начине пуњења и пражњења издани, а затим утврдити геомеханичке карактеристике тла.Тек на основу наведених истраживања може се кренути у даље предлоге мера коришћења простора на подручју општине Крупањ.

У Београду, 10.06.2014.

звештај обрадили:

За Геолошки завод Србије

Директор

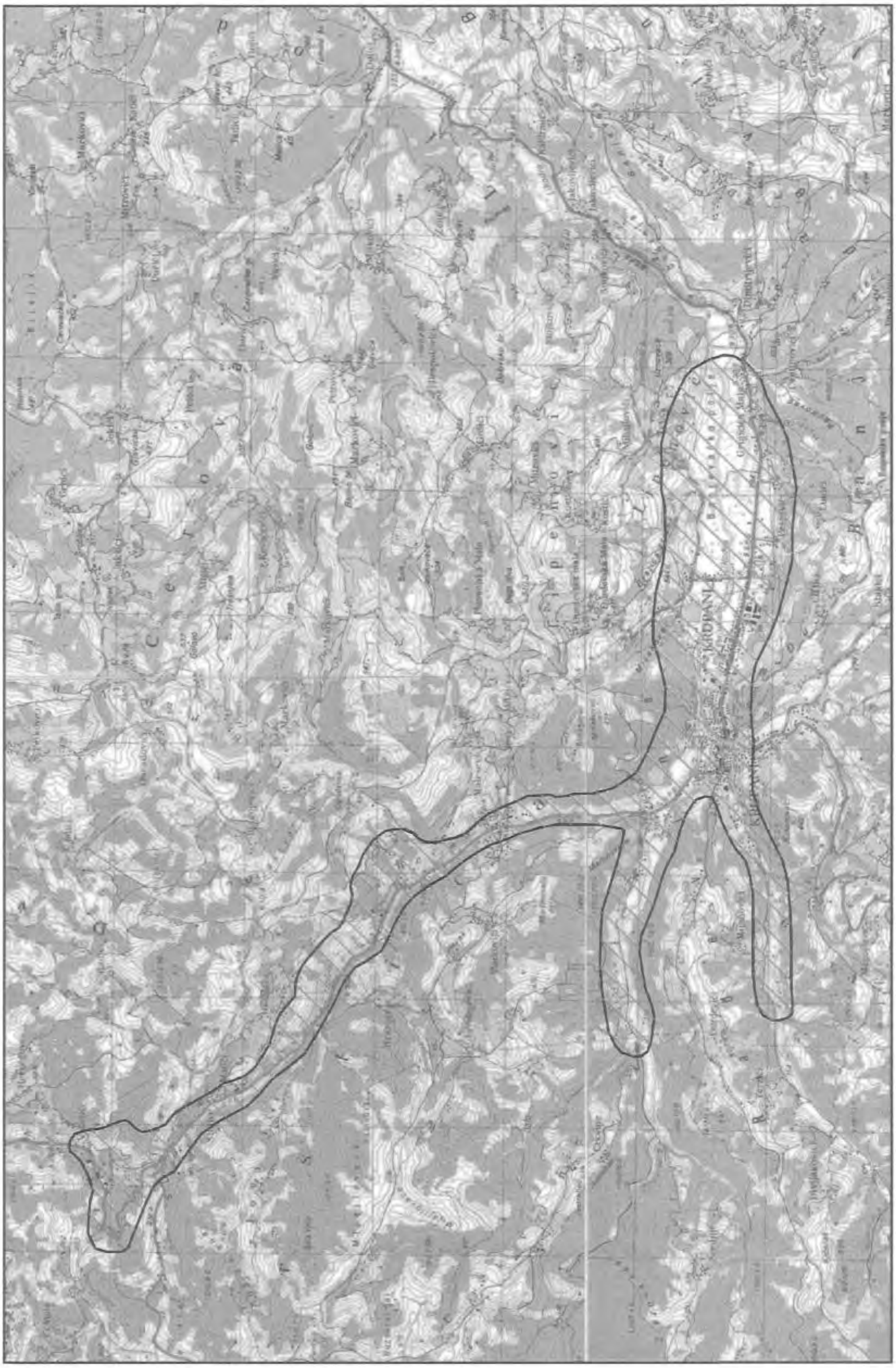
Др Драгоман Рабреновић, дипл.инж.геол

Исидора Вукадиновић, дипл.инж.геол

За **Британски геолошки завод**

Др Хелен Ривс, дипл.инж.геол

Зона града Крупња коју смо обишли



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REPORT ON OVERVIEW OF THE TERRAIN OF THE MUNICIPALITY OF KRUPANJ

BELGRADE
JUNE 2014.

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REPORT ON OVERVIEW OF THE TERRAIN OF THE MUNICIPALITY OF KRUPANJ

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GEOLOGICAL SURVEY OF SERBIA
DIRECTOR
Prof. PhD Dragoman Rabrenovic

BELGRADE

JUNE 2014.

The team members:
From Geological Survey of Serbia:
Prof. PhD Dragoman Rabrenovic, engineer of geology
Isidora Vukadinovic, engineer of geology
From British Geological Survey:
PhD Helen Reeves, engineer of geology

On the 6th of June 2014. The team had a meeting with Rade Grujic, the mayor of municipality of Krupanj, with the town mayor and with the representative from geodetics service Milorad Purtic and with the crisis staff.

After meeting the research of the terrain had been carried out with the representatives of local government and with the team from the Ministry of Infrastructure.

Ms PhD Helen Reeves is the director of science for Engineering Geology at the British Geological Survey- BGS. Also she is Landslide Geohazard Senior Technical Advisor for the UN OCHA Field Coordination Support Section in Serbia. Ms Helen came to Geological Survey of Serbia advised by Ms Irena Vojackova Sollorano, UN Resident Coordinator in Serbia. She had been asked to provide landslide expertise and to overview the damage caused by the recent Serbian floods.

Locations we visited, proposed by the local government, were representative for the overview of the damage caused by floods:

- Valley of the River Krzava
- Valley of the River Cadjavica
- Valley of the River Bistrica
- Stolice – tailing from the antimony mine
- Lipenovic
- Town center of Krupanj

After the visit of all the locations and overview of the topography of the terrain, geological structure, position of buildings and estates, it can be considered that:

Town Krupanj is located in alluvial plain, at the place where the Rivers Bistrica, Cadjavica and Krzava are merged to the River Likodra.

These river valleys are cut into the Paleozoic metamorphite, which are altered and broken on the surface at about 1 to 2 meters of depth. Weathered material is low cohessive and prone to startup and to runoff under the influence of water and gravity. Often there are also lateral gullies with intermittent stream. The sides of the valleys are from medium to steep slope, covered with dense forest vegetation. Beech and Fir are dominant. The trees are from few to over ten meters of height.
Buildings in the town center are located above the level of linear stream, at the height of 2 meters maximum. Going from center this height difference decreases. Rivers had been cultivated. Partially around them there was embankment.

During floods in may 2014. all the stream flows were over flowing and elevating their levels above the maximum of expected. The power of the flash flood destroyed embankment and fortified constructions, as well as many other homes.

The transport network is also destroyed. The damages are apparent and different from place to place. Thereby, on the big surface of 2000ha in the alluvial plains lees had been formed with thickness over 20 cm. This destroyed seed corn and the plants of raspberries and blackberries which people mostly make a living from.

Flooded river valley of the River Cadjavica

It is considered that the rivers are mainly back to their river bed, but the alluvial plains are still in the saturated state and part of water is trying to form a new stream. It can be clearly seen that part of cascades, are formed from which water flows (height from 20 to 30 cm).

At the same time the numbers of debris flows in the weathered rock on the slope are formed, therefore buildings on many locations had been doubly endangered. As the mayor of municipality said that from the 27 bridges which municipality of Krupanj had, 21 is damaged more or less.

Debris flow in the weathered shales

Destroyed buildings in the valley of River Cadjavica

Valley of river Likodra – damaged house in Lipenovic

After overview of the terrain it is arranged that the team of six members from Geological Survey of Serbia go to Krupanj in order to examine the most vulnerable locations and to define safeness of buildings from geotechnical aspect.

The preliminary proposal of further works:

- In the river valleys removal of the flood material is proposed.
- After the water level settles the river beds need to be cleaned. It is necessary for river beds to stay mobile in the future.
- Estate parts of the terrain needs to be protected with the proper embankment with the clay core, thus the further influence of the surface waters will not be able to damage them again. In order to prevent buildings from the higher level of ground waters, extensive drainage procedures need to be predicted.
- Parts of the terrain which are dedicated for construction, within the alluvial plains, need to be elevated with embankment above the recent flood maximum.

Within the timeframe, exchange of vegetation with deeper roots on the slopes needs to be done. Use of debris flow catch fence is also considered to be applied/used. It is possible to make derbis flow channels for the runoff material from the zone of debris flow and to be directed to the area which is not dangerous for buildings.

For the detailed analyze of protection of the damaged area appropriate engineering geological maps needs to be done. It consider detailed engineering geological mapping, analyze of the whole river basin disctrict of the River Likodra, the way of aquifer recharge and drainage. Afterwards geomechanical characteristics of soil needs to be determined.

After all the mentioned researches, other work proposal of usage of the municipality of Krupanj can be prepared.

In Belgrade, 10th of June 2014.

Report done by:

Geological Survey of Serbia

Director

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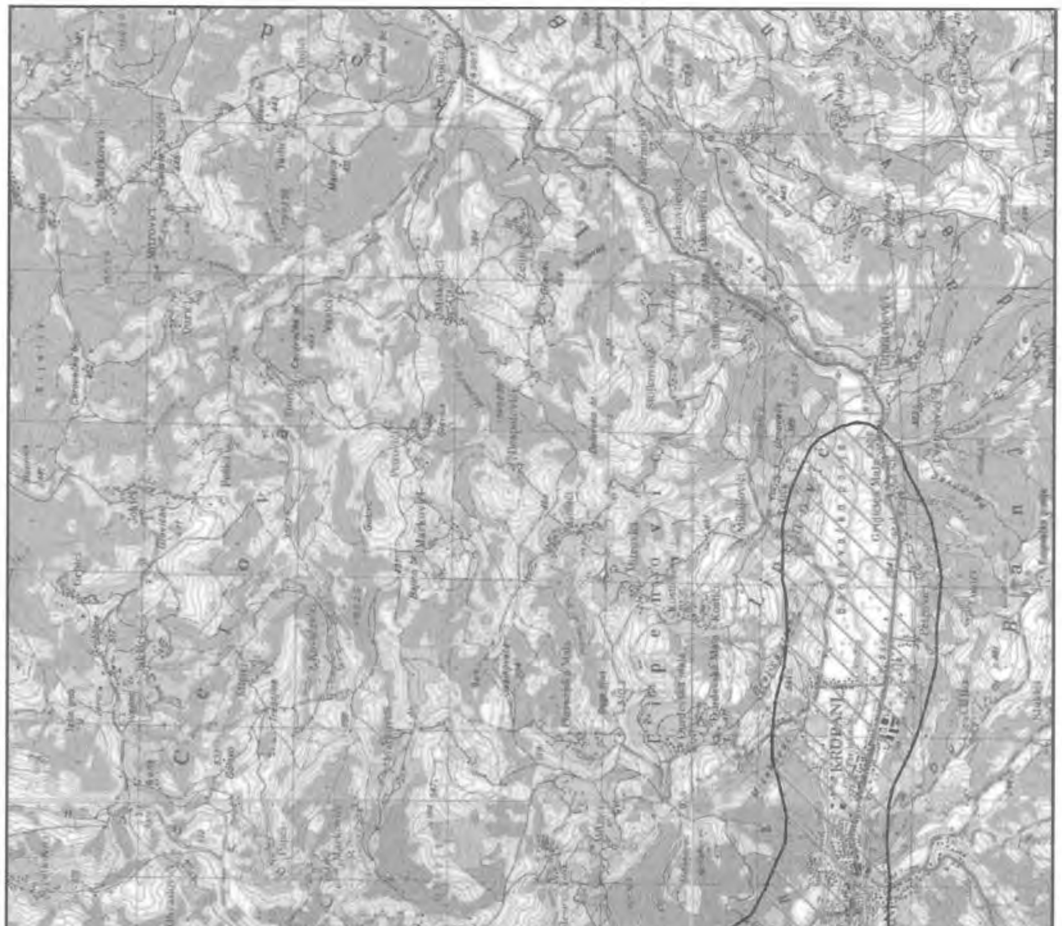
Overviewed area of town Krupanj



Appendix 3 Serbian Contacts

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