Impact of Flooding on Mine Action in Bosnia and Herzegovina, Croatia, and Serbia

Devastating floods swept through Bosnia and Herzegovina, Croatia, and Serbia in May 2014. The destructiveness of the floods, landslides and sediment torrents on minefields resulted in significant environmental and security issues. These three countries' mine action centers launched a joint project cofunded by the Republic of Croatia's Ministry of Foreign and European Affairs to develop effective and efficient methods and technologies that might improve the situation. Their research seeks to provide reliable assessments of the flood damage to minefields and generate accurate implications for potential hazardous areas.

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In May 2014, Cyclone Tamara caused the worst floods in Bosnia and Herzegovina, Croatia, and Serbia in 120 years.[1] Heavy rainfall, landslides, sediment torrents and floods destructively impacted the minefields in these three countries, abruptly changing the mine action situation and resulting in negative environmental and security consequences.[2]

A scattering of mines in the numerous minefields threaten the large, disaster-affected area.[3] The Bosnia and Herzegovina Mine Action Centre (BHMAC), the Serbian Mine Action Centre (SMAC) and the Croatian Mine Action Centre (CROMAC) joined efforts to combat the issue. Several institutions, including Copernicus Emergency Mapping Service, Copernicus Emergency Management Service, MapAction, Esri, Humanitarian Open Street Map and NASA Earth Observation, provided satellite maps of the flooding for initial flood analysis.[4]

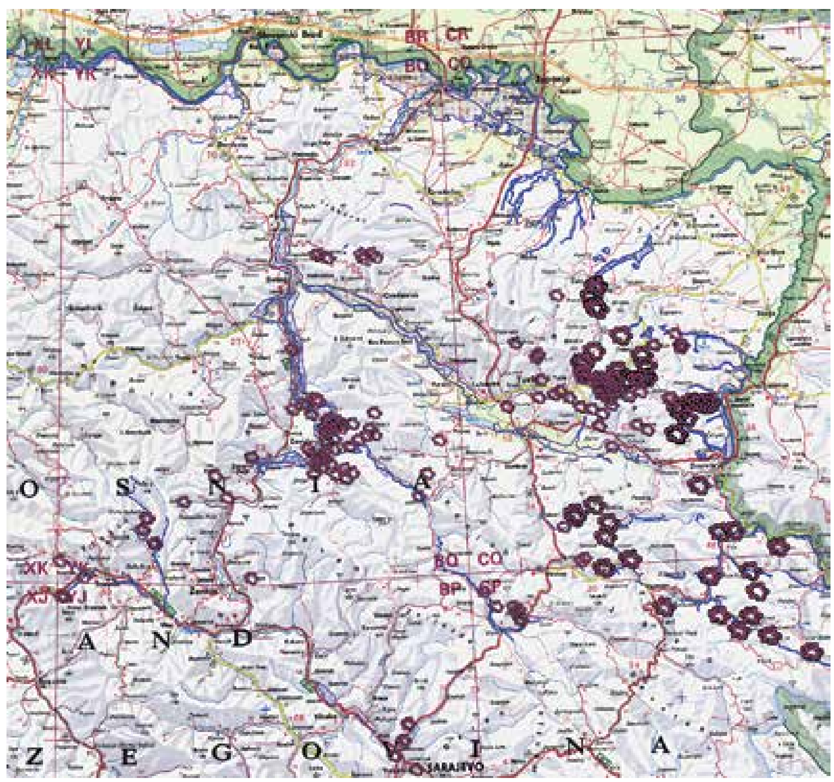

Figure 1. Geographic distribution of landslides (violet symbols) and floods (blue polygons) in Bosnia and Herzegovina, based on initial estimation by BHMAC. The light green strip shows the border lines.
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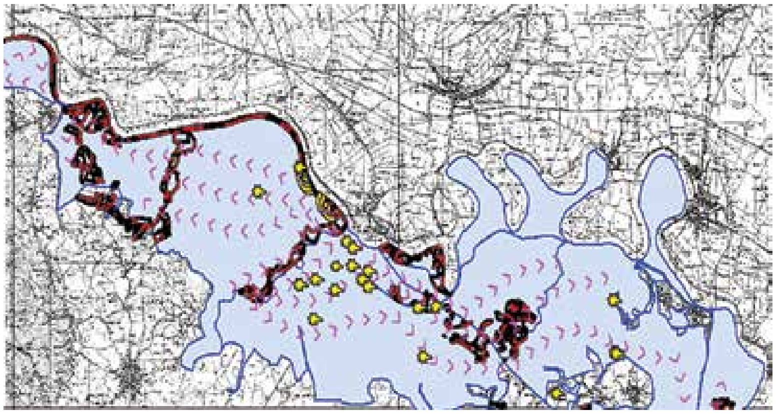


Figure 2. After the floods, a new area in the region near the town of Samac, Bosnia and Herzegovina, is now potentially hazardous due to the destructive impact of sediment torrents. Legend: flooded area - light blue, direction of torrents - >>, yellow arc – breach of dam, yellow star – detected explosive remnants of war.

Determining the Damage

The preliminary estimation showed that the worst destruction occurred in Bosnia and Herzegovina (Figure 1, page 43). The collaborating MACs decided to focus on Bosnia and Herzegovina and to apply lessons learned to address the problems in Croatia and Serbia.[5]

Taken in 2013 at a scale of 1:1000, digital orthophoto maps (DOFs) of the contamination in Bosnia and Herzegovina before the flooding are available only for BHMAC's previously defined minefields and suspected hazardous areas (SHAs), which are included in BHMAC's Mine Action Information System. The cyclone affected known minefields, moving soil, sediments and landmines to new locations not covered by BHMAC's DOFs, which further complicated the problem. Initial projections for Bosnia and Herzegovina show that:

- The total flooded area was 831.4 sq km (321 sq mi).
- More than 35 landslides occurred inside and in the immediate vicinity of the minefields in Bosnia and Herzegovina.
- Landslides, sediment torrents and floods directly impacted minefields covering 37.48 sq km (14.47 sq mi).
- A new area of 80 sq km (30.8 sq mi) became potentially hazardous due to the cyclone's impact (Figure 2).

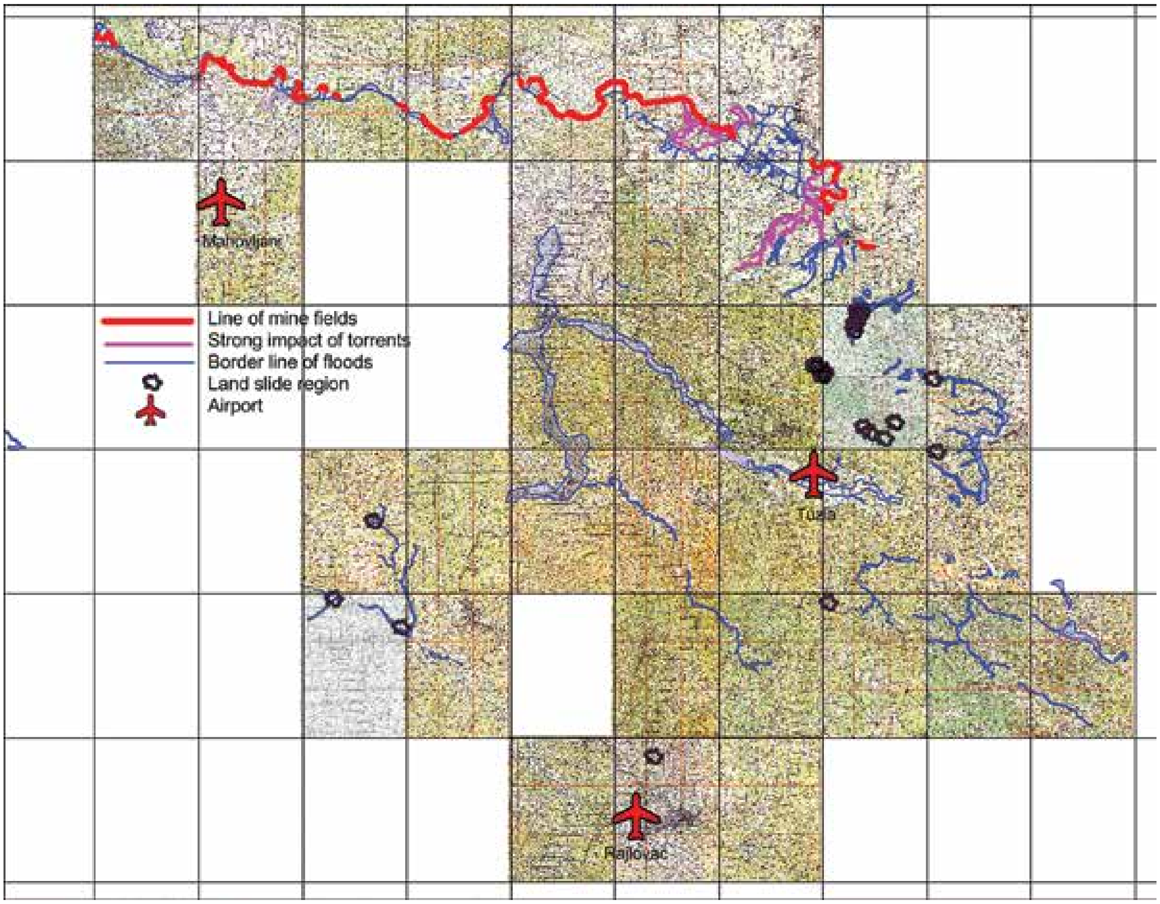
Previously known minefields spanning a length of 140 km (86.9 mi) on the banks of the Sava river bordering Croatia in Bosnia and Herzegovina may have moved as a result of the flooding. After processing and interpreting the collected images, the joint team developed a plan to assess the contaminated area. In this riverbank area, the team detected and documented landmines and unexploded ordnance (UXO) that shifted as a result of the cyclone.

Image 1. RMA's remotely piloted aerial system.

Image 2: Geoarheo Ltd.'s remotely piloted aerial system.

Image 3. The team of HCR-CTRO will collect images and data from multisensory system from the Gazela helicopter (Air Forces of Bosnia and Herzegovina).

In Croatia, floods covered 2.4 sq km (0.92 sq mi) of SHAs, but shifting landmines were not detected. Floods in Serbia covered SHAs and minefields, including 17.3 sq km (6.67 sq mi) of high-risk areas, 40 sq km (15.4 sq mi) of medium-risk areas and 106 sq km (40.9 sq mi) of low-risk areas, but new landmine locations, again, were not detected.



Targets for imagery acquisition from the Gazela helicopter: 140 km (87 mi) line of minefields along the Sava river, more than 30 landslides, 37.48 sq km (14.47 sq mi) of minefields, which were under direct impact of landslides, sediment torrents and floods, 80 sq km (30.88 sq mi) of new potentially hazardous areas.

Creating a Plan

The collaborating MACs invited the HCR Centre for Testing, Development and Training Ltd. (HCR CTRO) to determine what methods and technologies could be used to assess current contamination and predict new SHAs. This initiative's outcome is a joint project supported by the three MACs that is cofunded by Croatia's Ministry of Foreign and European Affairs.[5]

BHMAC began with a statement of need defining the project's parameters, which BHMAC and its regional offices developed from May through July 2014. Next, the mapping phase began. Remotely piloted aerial systems (RPAS) (Images 1 and 2) and a multisensory system mounted on a lightweight helicopter (Image 3) created an aerial mapping of the affected minefields and new SHAs—this phase of the project was completed in November 2014.

Problems to Overcome

Several factors, including endurance, maximum altitude, distance from a ground-based control station and required visual contact, limit the use of RPAS. RPAS can be used on smaller targets over open ground or area characterized by rough terrain. This part of the project requires close cooperation between collaborating MACs and the survey team comprised of RPAS aerial survey operators, researchers and deminers. In addition to collecting necessary images, this activity is used for on-the-job training of future BHMAC RPAS operators.

The sensors on light helicopters are suitable for large areas and hilly terrain with changeable relief, which the Croatian aerial survey team previously approved.[6] The operational experience gained from using both kinds of aerial remote sensing platforms will be one of the outcomes of the project.

The Process

Initial plans for aerial image acquisition with RPAS were optimistic. However, as the project progresses, the team is finding that limitations caused by varying elevations, limited access and reduced visibility decreases the area that can be mapped to a smaller-than-predicted size and number of

Image 4. Example of the landslide, which crosses the minefield in the upper part. A digital orthomosaic derived from aerial image collected by RPAS.

Image 5. The landslide Olovske luke, a digital orthomosaic derived from the aerial images collected 27 August 2014 by RPAS after floods, overlaid on digital orthophoto map produced in 2013, before floods.

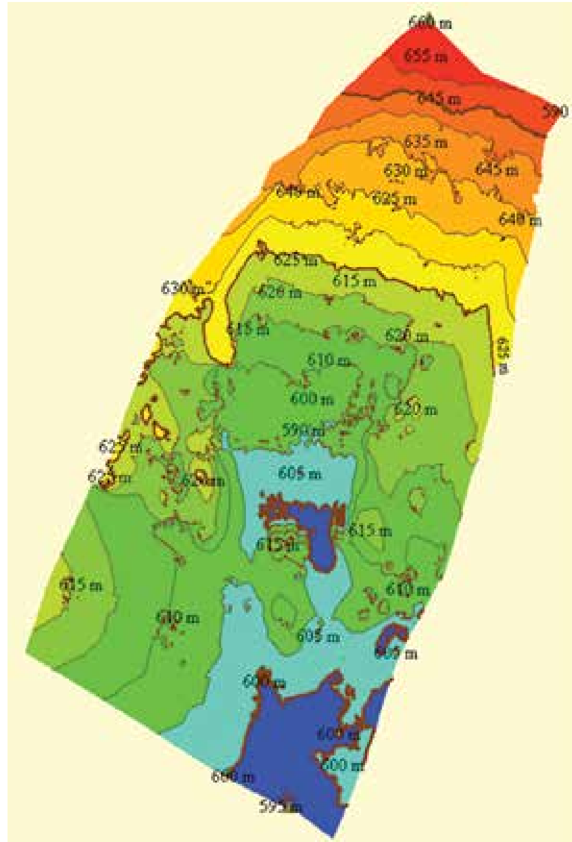


Figure 4. The landslide Olovske luke, a new digital surface model, derived from images collected 27 August 2014 by RPAS.

affected areas. The image-acquisition process with the Royal Military Academy's (RMA) RPAS was applied to 12 landslides (estimated area 3.217 sq km [1.242 sq mi]), and the image-acquisition process with Geoarheo Ltd. RPAS was applied to nine landslides (estimated area 2.899 sq km [1.1194 sq mi]). Due to RPAS' capacity limitations, a helicopter acquired additional aerial images (Figure 3).

After images are collected, digital orthomosaics (Images 4 and 5) and surface-terrain models of affected areas are developed (Figure 3). The workload in this phase is large due to the need for additional location data using geocoding from ground control points (GCP). When the orthomosaics and surface-terrain models for the target location are produced, they are delivered to researchers who are responsible for examining the consequences of landslides, sediment torrents and floods, and to BHMAC and its regional offices for their operational tasks. This phase is in its initial stage and aerial image acquisition will continue until all target locations are mapped. The researchers, comprised of experts in hydrology, geology and geomechanics, use the new input data to conduct the field survey at each target location.[7] In the case of landslides, the experts report on the following:

- Possibility of future landslides (low/medium/high)
- Estimated depth of new soil layer where landmines can appear
- Projected minefield or SHA border changes
- Urgency of landslide remediation (low/medium/high)
- Suggested prioritization of area clearance

This landslide field-survey mission awaits outcomes of aerial imagery processing. A similar process will be used to map and survey sediment torrents and flooding impact. Assessment is under way, and preliminary results were presented at the 12th International Symposium and Equipment Exhibition in Biograd, Croatia (27-28 April 2015).

The three processes (aerial survey, processing of imagery and field survey) are consecutive. Aerial survey and field survey depend on weather conditions, with completion expected in spring 2015. Data and images collected with RPAS 1 and RPAS 2 are processed and delivered to BHMAC and its regional offices, and to researchers at the faculty of civil engineering at Sarajevo University. Images and data collected by the Gazela helicopter are in the processing phase. Interpretation of delivered data is underway, and field survey is planned for spring 2015. The field survey is the most intensive part of the project and is unique in mine action, providing a treasure trove of empirical data. The acquired knowledge and experience will be directly applied to mine action processes in Bosnia and Herzegovina, Croatia, and Serbia, and it is expected to prompt additional research in several scientific fields, including methods and technologies for assessing mine areas after a disaster, impact of landslides and torrents, and landmine detection.

Future Steps

The next part of the project focuses on research methods and developing models for estimating the impact of the natural disaster on mine action. It is mainly based on information acquired from the project's second phase. A variety of methods were considered, such as analysis of watershed boundaries, flow lines, flow path parameters, flood/torrents and erosion hazards. The locations of detected landmines will be used as the seed points for estimating the downstream flow paths along which the landmines could be dispersed. The opposite case will be analyzed also; the seed points serve for upstream watershed analysis and to determine regions where the landmines may have been displaced. Special efforts focus on research and development of hazard-distribution maps based on the spatial, multi-criteria, multi-objective decision-support methods. The goals of this phase are:

- Acquiring new data and information
- Sharing collected experiences
- Documenting lessons learned
- Deriving new approaches for the prevention, preparation and response of landslides, sediment torrents and floods

Aside from scientific results, this part of the project will assist with the development of the recommendations and standard operating procedures (SOP) for mine action behavior in similar kinds of natural disasters.

Additional aspects of the project will be advancing regional and cross-border cooperation, developing suitable technology, building capacity in the three MACs, and creating amendments to existing demining SOPs in the respective countries.

In addition to landslides, sediment torrents and floods within Bosnia and Herzegovina happened near rivers bordering the three countries. The right bank of the Sava river in Bosnia and Herzegovina has many minefields, which were exposed to the destructive flooding. There is a 140-km (87-mi) long line of minefields along the Sava river that may be affected by future natural disasters. Therefore these areas are of elevated importance in the project.

The three MACs agreed to establish resources for the aerial survey, prepare for quick and immediate reaction in case of emergency or disaster, and create a regional information network.[8] As part of the project funding, the RPAS system will be provided to BHMAC, and operators will be trained.

Training is composed of three parts: (1) on-the-job survey training of RPAS teams (currently underway); (2) product training by the RPAS manufacturer; and (3) a 10-day seminar on aerial survey for mine action use in cases of natural emergency and disaster. The Aerial Survey Regional System for Mine Action Needs in Emergency and Disaster will be established in HCR CTRO. The nine-day workshop and on-the-job-training was completed from 18 to 27 February 2015 in Vogosca, Bosnia and Herzegovina. The regional information network of the three MACs will be accomplished using cloud technology. The network will establish links to the European Emergency Response Centre service, the Copernicus Emergency Management Service, and the Global Monitoring for Environment and Security Initial Operations, if possible, as an authorized user or associated user.[8]

See endnotes page 66

Acknowledgments

The authors and project participants thank the Croatian Ministry of Foreign and European Affairs for recognizing and supporting the contribution of the project to mine-action cooperation in disaster and emergency response, technology development, and capacity building. We also thank BHMAC, CROMAC and SMAC for supporting the project concept and its realization. We extend especially cordial acknowledgments to the regional offices and BHMAC, and to the many people who contributed and participated in the project's realization. BHMAC Assistant Director Ahdin Orahovac and HCR CTRO Director Nikola Pavkovic were key people in defining goals, concepts, conditions, support and realization of the project. For technical contributions, we would like to particularly thank the University of Sarajevo's civil engineering faculty, RMA (Brussels, Belgium), Geoarheo Ltd. (Zagreb, Croatia) and University of Zagreb's (Croatia) geodesy faculty. Several subjects and institutions expressed interest in participating as observers in later phases of the project. We invite mine action and scientific communities to support the project's evaluation phase, and development of recommendations and SOPs for mine action operators working in mine-affected countries exposed to natural disaster.

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