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Minefield Indicators and Analytical Mine Contamination Assessment in Scientific Projects and in Practice

Milan Bajić¹, Andrija Krtalić², Čedo Matić³, Dejan Vuletić⁴

Abstract

The key factors of the application of the airborne remote sensing technology for humanitarian demining are the minefield indicators [1] or the indicators of mine presence and the indicators of mine absence [2] and the analytical assessment of the contamination by the landmines [3]. The basic simple concept of the minefield indicators was given in [1], where it was related to the ordinary physical features of the artificial and natural objects in the mine suspicious area. Similar concept was used in other works, while in [2] were introduced signatures of the minefield indicators and additional contextual features. The signatures depend on the sensors used for the remote sensing and this aspect was thoroughly considered in [2]. The contextual features can be derived by the analytical assessment of the terrain contamination by the land mines [3], addition of the formalized knowledge enables efficient use of the indicators for the support of the decision making and for suspicious area reduction [4].

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1 Introduction

The key factors of the application of the airborne remote sensing technology for the humanitarian demining are the minefield indicators [1] or the indicators of mine presence and the indicators of mine absence [2] and the analytical assessment of the contamination by the landmines [3]. The basic simple concept of the minefield indicators was given in [1], where it was related to the ordinary physical features of the artificial and natural objects in the mine suspicious area. Similar concept was used in other works [4], while in [2] were introduced signatures of the minefield indicators and additional contextual features. The signatures depend on the sensors used for the remote sensing and this aspect was thoroughly considered in [5], [2], and [6]. The contextual features can be derived by the analytical assessment of the terrain contamination by the land mines [3]; addition of the formalized knowledge enables efficient use of the indicators for the support of the decision making and for suspicious area reduction [2]. The development of the concept of the minefield indicators is the main topic of the paper, aimed to encourage further development and advancement. We consider the time period from 1999 to 2009, e.g. from [1] to [7], [8]. In [7] was for first time applied the operational project the concept of the minefield indicators and the analytical assessment of the contamination by landmines, whereas the formalization

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of the expert knowledge was for first time introduced in [8]. The experience and the lessons learnt are briefly commented in following text.

The phases of the development of the minefield indicators from initialization to the application are:

- ✚ definition of the initial list of the indicators, expected to be suitable for the considered environment, mine contamination status and the war history,
- ✚ estimation of the expected detection characteristics of the minefield indicators in dependence on the applied sensors and wavelengths of the airborne or space borne acquisition of images, [5],
- ✚ collecting the minefield indicators in the ground truth field missions, [9], [10], [11], [12],
- ✚ processing of the imagery and extraction of the signatures of the minefield indicators, [6],
- ✚ estimation of the confidence of the minefield indicators,
- ✚ definition of the strong (military) minefield indicators of mine presence (IMP),
- ✚ definition of the non military minefield indicators of mine presence (IMP),
- ✚ definition of the indicators of the mine absence (IMA),
- ✚ estimation of the confidence of the minefield indicators,
- ✚ definition of the relative importance to each class and to each particular minefield indicator, in dependence to the context, made by expert,
- ✚ definition of the membership functions to each class and to each particular minefield indicator, in dependence to the context, made by expert,
- ✚ evaluation of the influence of the minefield indicators on the results of interpretation, mainly by the confusion matrix and its derivatives (commission and omission errors), [14],
- ✚ validation of the project results by the comparison with the results obtained by the conventional mine action technology, [15].

2 Minefield indicators in the scientific projects SMART and ARC

In the frame of the project SMART was realized a whole process of the development of minefield indicators and at the end was used two groups of them: the indicators of mine presence (IMP) and the indicators of mine absence (IMA). Four regions in Croatia were analyzed, a total area was 48 km²: Glinska Poljana, Pristeg, Čeretinci and Blinjski kut. Both groups of the minefield indicators were identified, checked by ground truth mission, approved by experts, furnished with attributes (confidence, relative importance, membership function), and used in the interpretation. Although the goal of SMART project was decision support for the mine suspicious area reduction, only two classes of the indicators of mine absence (IMA) were identified and approved. Thus, in the future application of the minefield indicators more efforts should be focused on the IMA due to their importance.

Indicators of mine presence (IMP)

Mine records – polygon or line or points of minefield.

Confrontation zone reconstructed analytically.

Dominant slopes and heights at location that enable visual surveillance and gun fire protection of minefields.

Houses used by the military, between first lines of warring parties.

Bunkers.

Concealed paths to trenches or bunkers.

Damaged, destroyed houses.

Shallow river and creek locations, suitable for crossing.

Irrigation, drainage channels.

Shelters for tanks, heavy weapon.

Trenches (T) and man-made embankments (E).

River shores, at mean water level.

Bridges, inclusive destroyed bridges.

Tracks not longer in use.

Agricultural areas no longer in use.

Crossroads, crossings of main roads with tracks no longer in use.

Forest edges.

Power supply poles.

Soft edges of hardtop roads.

Mine accidents and incidents.

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Indicators of mine absence (IMA)

Cultivated land.
Asphalt roads.

Strong minefield indicators

The minefield indicators can be further divided into two classes:

-  the land cover and the land use,
-  the strong indicators (indicators related with military activities and mine laying process).

The identification and detection of the land cover and the land use minefield indicators can be made by various methods of the unsupervised or supervised classification and processing, at the pixel level or at the region level, [2]. The success of the detection of these indicators depends on subtle differences of the vegetation that should be determined. Therefore for this type of minefield indicators are needed different sensors and wavelengths. In SMART [2], [5] were used multispectral scanner with eleven channels, four wavelengths SAR (two bands with full polarization, interferometry) and color infrared aerial photography. The strong minefield indicators are remnants of the war activities and their contribution to the success of the project is more significant than the influence of the land cover and the land use minefield indicators. The identification and the detection of the strong indicators require high spatial resolution and the most important is the time lag between the emergence of the object that is strong minefield indicator and the time when it was detected. In accordance to experience in first operational project in which the minefield indicators are used, Deployment of the Decision Support System for Mine Suspected Area Reduction [7], the combined time and spatial resolution are more important than the spectral resolution. In [7] was analyzed area of nearly 150 km² in the regions of the communities Gospić, Bilje and Drniš. Types of the minefield indicator are similar to that in SMART but new indicators of the mine absence were identified. They are: water areas (in mine suspected area in community Bilje) and the very steep terrain of the mountain Velebit.

Analytical mine contamination assessment

The use of the minefield indicators is meaningless without the understanding of the actual status and the history of the process contamination by landmines in the particular region. While the ordinary practice in the mine action centers has weak this aspect in their project planning, we have introduced analytical assessment of the contamination by landmines [3], as an important part in the scientific projects [2], [4]. At the current status [16], the analytic assessment of the contamination by landmines has reached an advanced level if compared with [3] and [8]. The new kinds of outputs of the analytical assessment in [16] are general requirements and special requirements for the acquisition and providing the data and the information of the considered mine suspected area.

Conclusion

The ten years history of the minefield indicators that started by [1], was advanced by [2], reached in 2008./2009. the operational use for first time.

The indicators of mine presence, indicators of mine absence, strong indicators were recognized as useful paradigm and they are in further use in operational projects.

Further development of the concept of the minefield indicators is expected.

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Fusion of Data, a Priori Information, Contextual Information and Experts' Knowledge for Support of the Decision Making About Mine Suspected Area Reduction

Milan Bajić⁵, Luka Buhin⁶, Andrija Krtalić⁷, Tomislav Cvetko⁸, Zlatko Čandar⁹, Hrvoje Gold¹⁰, Davor Laura¹¹, Čedo Matić¹², Nikola Pavković¹³, Dejan Vuletić¹⁴

Abstract

Some of the main problems in humanitarian demining are indeterminacy and lack of knowledge about current situation inside a mine suspected area (MSA). The borders of MSA are determined on the basis of information from mine information system (MIS: detected mines, mine incidents, interviews with population, minefield records, geodetic basis (maps, orthophoto maps),...). However, MSA in Croatia is a 'live matter' and changes in years after the conflict (people come back and use land in different ways). Because of that, the main idea of fusion of data, a priori information, contextual information and experts' knowledge is analyze, interpret and combine all type of data about some MSA for getting information on current situation inside this particular MSA. These information are presented on danger maps [3] and support experts for humanitarian demining in the decision making about mine suspected area reduction or confirm suspicions in MSA [3]. In data fusion the images of airborne acquisition are used for detecting and enhancement of indicators of mine absence (IMA) [1] [4] and mine presence (IMP) [1] [4]. Furthermore, in data fusion a priori information, contextual information and experts' knowledge are used for linking indicators with their impacts on environment and on each other within MSA. These impacts and levels of danger are shown on the danger maps [4]. The confidence map [4] is also an important product of data fusion, because it gives confidence (analytical assessment) of every statement on a danger map.

1. Introduction – The Problem

Humanitarian demining community in Croatia assumes that the mine suspected area (MSA) can be significantly reduced. Big problems in these actions are indeterminacy and lack of knowledge about current situation inside of MSA. The borders of MSA are determined on the basis of information collected within general survey and information from mine information system (MIS: minefield records, mine incidents, interviews with population, geodetic basis (maps, orthophoto maps)). Risk of danger was reduced by the enlargement of MSA. So, in order to make the decision about MSA reduction easier the analytic assessment of the situation inside of MSA needs to be done. Additional collecting of the data about current situation is desirable for quality assessment. The purpose of collecting additional data is to fill "gaps" in the "data chain", or in other words, to collect missing data for precise estimation of the MSA.

2. SMART solution

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Solution for above mentioned problem was found in the SMART project, in SMART methodology [1]. SMART project based on fusion of all available multisensor data, expert knowledge, data from geographical and mine information systems (GIS and MIS) and contextual information. Before the fusion, airborne acquisition with multisensor system was done. Airborne acquisition has the purpose to complete, check and approve incomplete information and data from depth of MSA where access is danger and repeated general survey and revision did not provide improvement. This is a very important step in demining because MSA is "live matter" and has become different in the years after the war (people come back and use land in different ways). The next step is searching and mapping strong indicators of mine absence (IMA) and indicators of mine presence (IMP) [1]. The mine scene interpreter is crucial for this actions. The mine scene interpreter interactively extracts the strong IMA and IMP from the images, and formalize expert knowledge. This knowledge is used for imaging of impacts of these indicators on environment and on each other within MSA. This images are danger maps [4] and will be described later on.

3. Decision Support System

The decision support system (DSS) [3] was created on the basis of SMART methodology. DSS was designed for analyzing and processing all accessible compatible data, information and expert knowledge (figure 1) about some particular phenomena on it. In this case, the particular phenomena is mine contamination area. The purpose of DSS is to provide end-users methodological tools for processing multi-spectral, hyper-spectral, contextual data and expert knowledge, and help decision makers to make decision about reduction of MSA and demining. Input data for DSS are: image data (multi-spectral, hyper-spectral, thermal and aerial photogrammetric images, digital orthophoto (DOF), digital terrain models (DTM) geographic maps of different scales), contextual data (specific contextual data about mined area based on expert knowledge), expert knowledge (about history of conflict and mined actions), ground truth (figure 1).

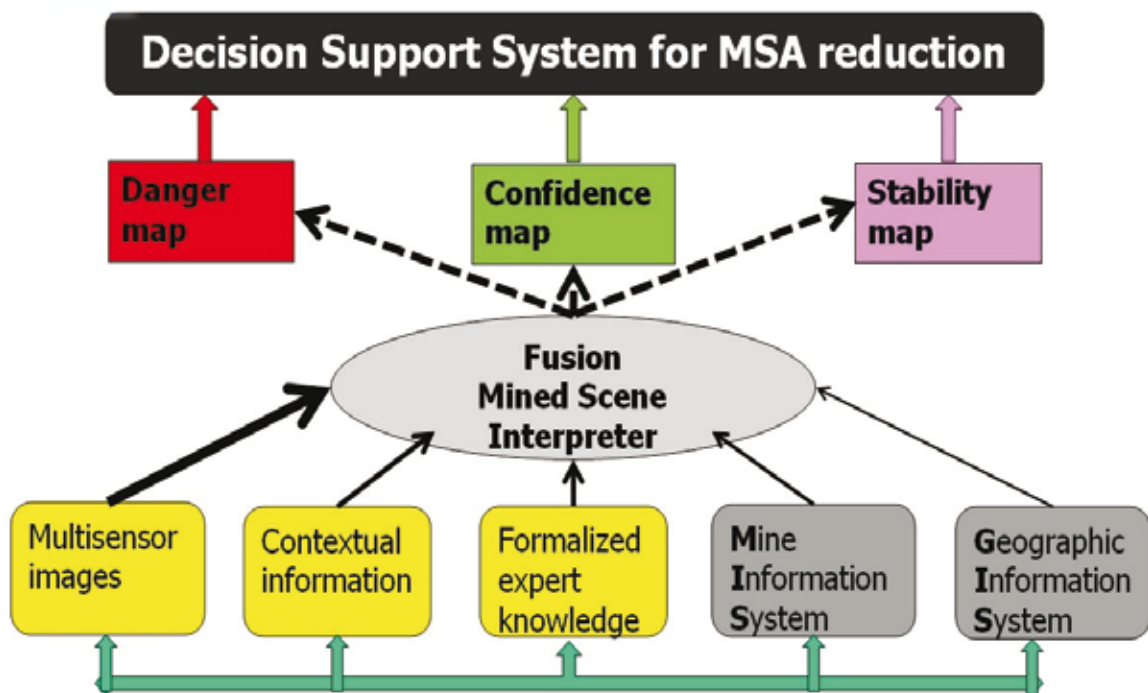


Figure 1. – The concept of decision support system for reduction of mine suspected area

4. Validation, Pre-processing, Processing and Validation data

All data and results must be validated. All input data must be validated before their use in fusion or DSS. Someone who manages with DSS needs to know the accuracy and source of all information entered in data fusion process. It is the same with all result. Validation is mandatory because various kinds of information entered in DSS (multi-sensor, multi-spectral, hyper-spectral and multi-resolution images, contextual knowledge,...) and manager (decision maker) need to know level of their accuracy and confidence.

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The purpose of data pre-processing is detection and enhancement of indicators on input images. For that purpose the registration of all input images regarding one reference image is mandatory. The quality assessment of overlapping of geographic bases and multi-sensor and multi-resolution images needs to be done after registration of images.

Data processing consists of the following actions: classification, data fusion and produced thematic images. The purpose of data processing is to detect and separate IMA and IMP from other objects on the scene. Mine scene interpreter [1], as it has been mentioned before, is an important person in this step.

The final results of data fusion and DSS are thematic images, danger (figure 2) and confidence maps [1] [4] (figure 2). Danger map shows impacts of all indicators on the other objects on the scene and impacts on each other. Confidence map give a levels of confidence of statements on danger maps. This second map is some kind of accuracy assessment of danger map. These images are made in order to help decision makers and reacting managers in decision making. Danger map (figure 2) is used for the purpose of reducing of MSA or confirming of suspicious in MSA.

Danger map should be evaluated for the purpose of testing the efficiency of DSS. Validation of danger map is give through confidence image and parameters of confusion matrix.

Glinska poljana : Danger map 2
Continuous location map

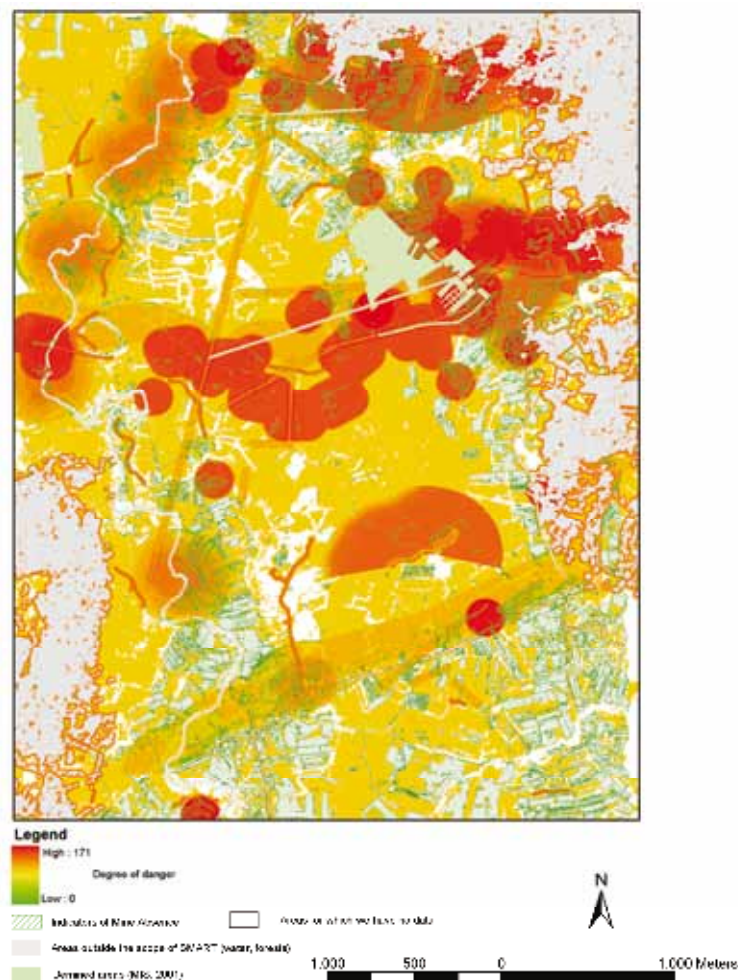


Figure 2 – Danger map shows impacts of IMP on other topological objects (red areas - the more red the great danger, green areas - the more green the smaller danger)

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5. Conclusion

The result of data fusion can give better perspective in the existing data (MIS information) through the danger map. Data fusion can also yield some new data (PCA, synthetic images with better resolution) and reduce imperfection of input data. Furthermore, with additional collecting of the data about current situation in MSA, data fusion can even better reduce imperfection of input data. After airborne data acquisition experts have better perspective in current situation in MSA. Time detection can also be done in this case. So, in data fusion a priori information, contextual information, experts' knowledge and additional collecting of the data use for linking indicators with their impacts on environment and on each other within MSA.

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Minefield Record Status and Reduction

Tomislav Ban¹⁵

Abstract

This paper elaborates the process of minefield record analysis (MR) upon the completion of demining operations, criteria and process of awarding the status to the record (confirmed-unconfirmed) and the role of minefield record status in reduction.

All minefield records possessed by the Croatian Mine Action Centre (CROMAC) are positioned as polygons in CROMAC Mine Information System (MIS). In order to position the minefield record in form of a polygon, the quality of the record and the reliability of data from the record are crucial. According to CROMAC's minefield record registry, over 50% of records consist of incomplete information, especially about turning points (nonexisting landmarks), due to which reliable positioning is impossible.

The analysis carried out upon the completion of demining operations i.e. comparison of data from the records with locations of mine detection and types of mines found confirmed that minefield records (MR) consisting of incomplete information were most often not found (confirmed).

According to that and in line with characteristics of surrounding area, the analysis of remaining suspected hazardous area (SHA) is performed with the purpose of reduction. If minefield record is impossible to position in space, but it has already been included into the SHA, there exist the elements required for the additional analysis and area reduction.

Key words: minefield record, analysis, reduction, humanitarian demining

Introduction

Mine problem in the Republic of Croatia is a consequence of an armed conflict that now represents a safety problem as well as an impediment to social and economic development.

Mines were being placed with aim to block the territory in front of combat deployment of troops. Records were made for most minefields as documents providing information on the location of placing mines, landmarks, structure and positioning of mines.

Information on placing minefields (minefield record) is an integral part of project documentation of demining projects and serves as information to the contractor regarding what type of danger to expect. During the conduct of demining operations aiming at detection, deactivation and/or destruction of mines, positions of mines, UXO (unexploded ordinance) and their fragments detected are being entered into records. Information collected this way is important for the analysis of presumed minefield records and awarding the status to the minefield record upon completed demining operations. When demining operations are completed, records can be awarded the following status: confirmed and demined, confirmed and partially demined and unconfirmed records. Unconfirmed minefield records are the subject of additional analyses in terms of new positioning or deletion from minefield record registry.

1. MINEFIELDS

The purpose of minefields is protection and obstruction of passing through a certain territory. According to tactical classification, minefields can be:

- Protective minefields
- Defensive minefields
- Barrier minefield
- Booby trapped area
- Phony minefield

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Protective minefields are used for protection of smaller troops. Defensive minefields are placed as part of defence system of a certain territory. Barrier minefields block the passage or access to a particular territory, e.g. dominant points heliports etc. Booby trapped areas are intended to create a surprise and they are placed in front of expected minefields or in possible passageways. Records on booby trapped areas are usually being made at the highest commanding levels, but most often there are no minefield records. Therefore, upon military conflicts no information on minefield placing is available. Phony minefields are usually the ones in which no mines are placed or only the small number of mines is placed. Visible indicators of minefield placing are left on the land and minefield records are made.

2. MINEFIELD RECORDS

Minefield record is a document consisting of information on placing minefields on a certain territory and information on:

- location and type of minefield
- type, quantity and positioning of mines placed
- information on passageways left
- other information

Information on location includes turning points, co-ordinates and a sketch. Type of minefield implies information on the type of mines in the minefield placed. In that respect, minefields can be: AP minefields (antipersonnel), AT minefields (antitank), mixed minefields and groups of mines. Information on the type, quantity and positioning of mines placed include information on the number of rows of mines placed, number of mines in a row, distance between the rows and distance between the mines in the row.

Information on passageways left is mentioned if there are any passageways left in the minefield. Other information include data on the troop that placed the minefield, head of the minefield placing process, time of minefield placing, number of records made and whom they had been delivered to.

3. MINEFIELD POSITIONING

With regard to the quality of the documentation made, minefield records can be positioned in space in the following manner: reliably positioned (with certainty), partially reliably positioned and supposed minefield records.

Minefields positioned with certainty (reliably positioned) are the ones with easily recognisable landmarks (AB passage on a railway track), see figure 1.

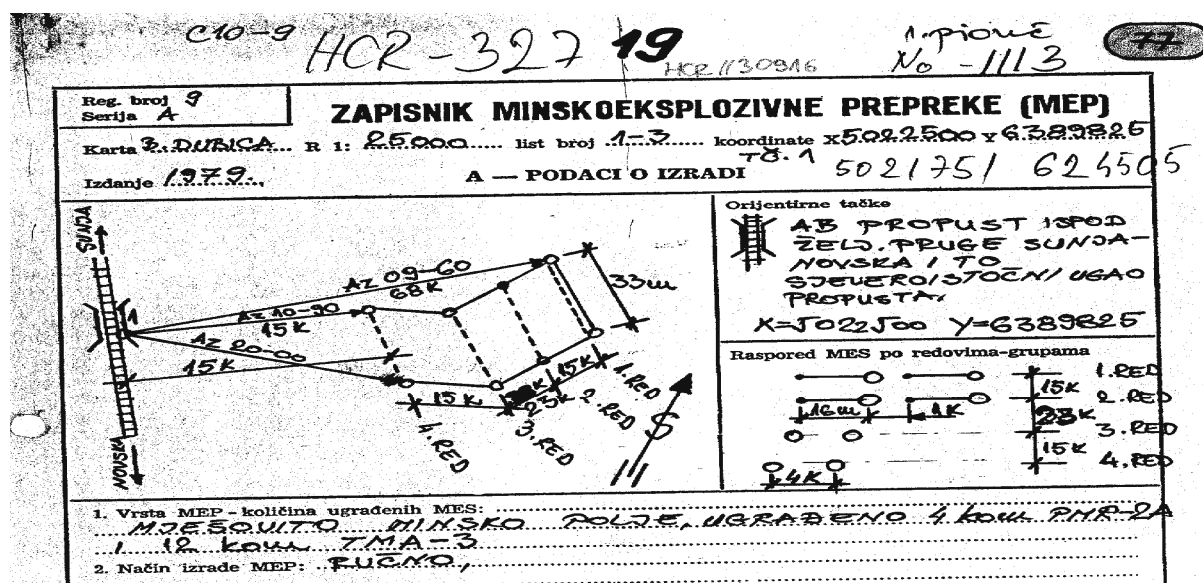


Figure 1 Reliably positioned minefield

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Information on co-ordinates and turning points are comparable and azimuth and distance measured in steps given. Due to data collected, the number and positioning of mines is known as well. Such minefields can be reliably positioned in the minefield record registry.

Partially positioned minefield is a record with recognized landmarks or co-ordinates or information is mistyped. The records bring unreliable information such as seasonal culture (corn, wheat etc.). Sometimes, it is impossible to recognize with certainty, according to sketches, the area of minefield placed (forest, vineyard).

Deployment of mines and direction of stretching cannot be confirmed with certainty or type of mines placed identified.

Supposed minefield is a record for which there is no any authentic document but there is some data collected by survey from the participants in war operations or the existence of minefield is assumed somewhere in the interspace between known minefields.

4. MINEFIELD RECORDS STATUS UPON COMPLETED OPERATIONS

Upon completed demining operations there are a number of activities undertaken with the purpose of defining new SHA (suspected hazardous area) status what, among other things, also implies awarding the status to minefield records. In order to carry out said activity, it is required to enter the data on mines found during the conduct of demining operations into the database. Considering the fact that we already have the information on minefield polygons at our disposal, it is possible to start with data comparison and awarding the status to minefield records.

Defined minefield record statuses are as follows: confirmed and demined, conformed and partially demined and unconfirmed. Unconfirmed minefield records are subjects of special analyses due to the fact of them being of crucial importance for new definition of SHA status.

Confirmed and demined minefield record, figure 2. The type, number and structure (deployment) of mines found match the minefield record i.e. not all mines were found but there were indicators of types of mines found (poles, wire, fuse etc.), structure and position of detection are confirmed; or the structure was disturbed or mines crashed during the work of demining machines.

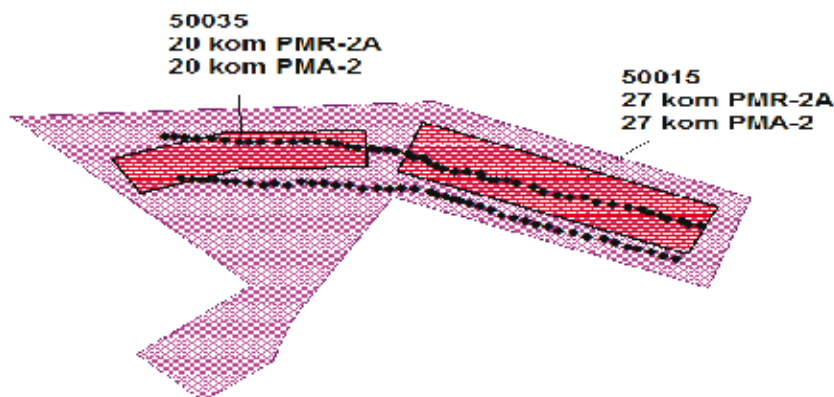


Figure 2 Confirmed and demined minefield record

Confirmed and partially demined minefield record, figure 3, mostly relates to the cases when the existing project covers only the part of minefield i.e. it is possible for additional types of mines to be detected; or some types of mines were not found at all; or bigger or smaller number of mines than expected were found.

Unconfirmed minefield record is a record that was not found on an expected territory upon the completion of demining operations. No mines or any indicators of minefield placing were found as well. Such minefields are the subjects of further analyses aiming at establishing the potential new positions. These are mostly the records that could not have been reliably positioned.

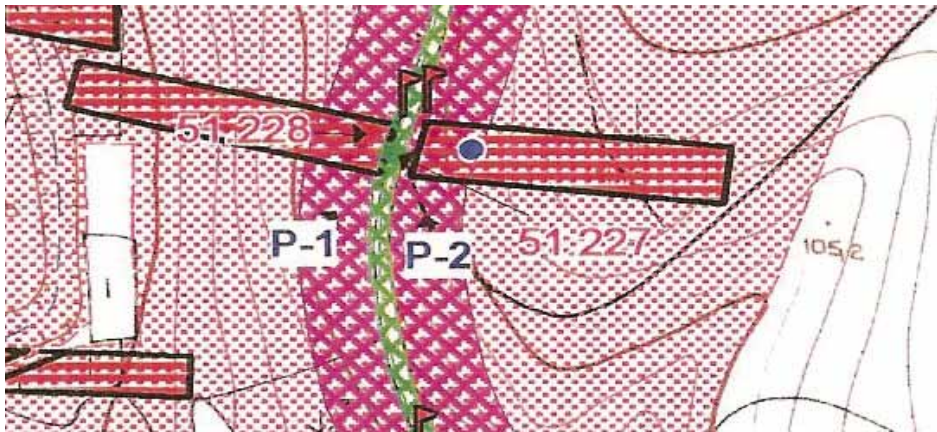


Figure 3 Confirmed and partially demined minefield record

5. STATUS OF REMAINING AREAS (REDUCTION)

Data collection for awarding the status to the remaining areas upon completed demining operations is conducted through all phases of project conduct. Data collection is conducted during quality assurance undertaken during the execution of demining operations by collecting new information from the local population, monitoring the work of the demining company in terms of detection of mines and UXO. Upon the completion of the project there are the analysis of company's final report and final analysis of reports carried out.

Final analysis of the project is performed upon quality assurance carried out over completed demining operations and geodetic measurement implemented by an authorised geodetic company.

The following facts are being analysed: remaining SHA, remarking of the new SHA status and minefield records. A new application within CROMAC database has been made for the purpose of performing the above-mentioned analyses.

Remaining SHA is being analysed in relation to the deviation from the project area, realized and geodetically measured area. The status of remaining SHA can be to: cancel from SHA, join the remaining SHA or additional work needed.

Remarking implies placing mine warning signs on the boundaries of the remaining SHA. It is performed upon quality assurance carried out over completed demining operations and registered into the database as part of final project analysis.

Minefield Record Analysis

In order to perform the analysis, it is required to enter the positions of mine and UXO findings into the database. After that, data is compared to the minefield record polygons from CROMAC database. The analysis is performed as per flow diagram, figure 4:

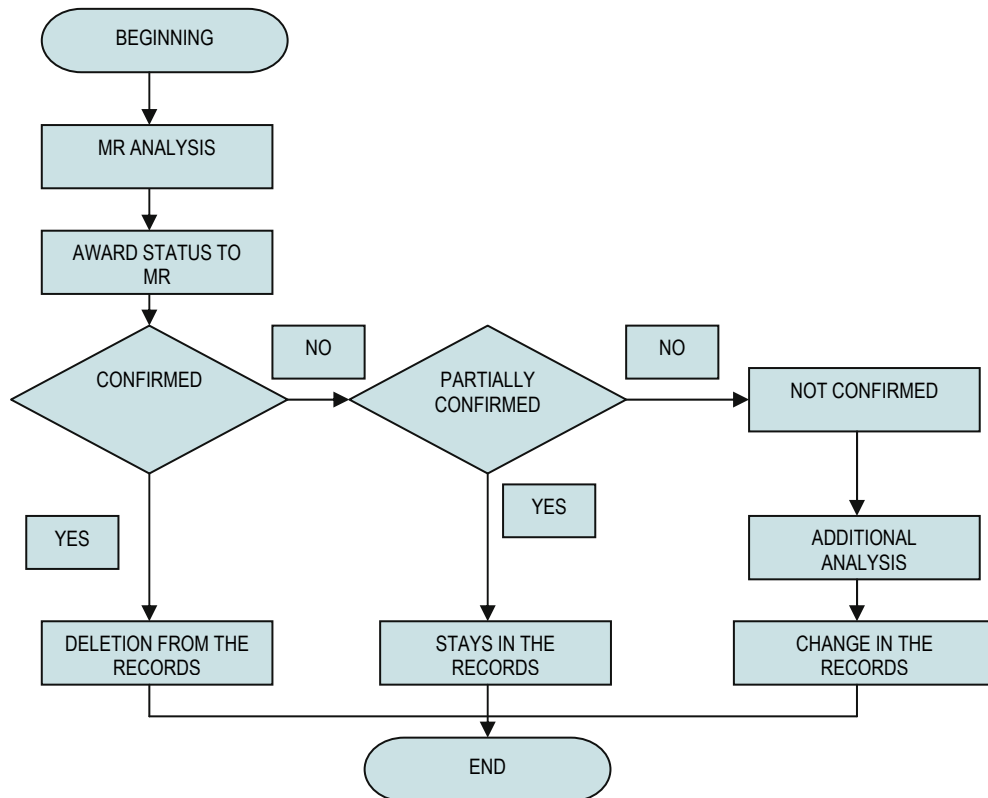


Figure 4 Flow diagram; awarding the status to the MR

Effect of results of MR analysis on modification of SHA

Results of analyses performed have an effect on the existing SHA status, especially information on MR analysis carried out. New SHA status is further analysed putting special emphasis on minefield records classified as unconfirmed. They are being

re-analysed and potential new positions that might have an effect on change of SHA status checked.

When confirmation of new positions for the unconfirmed MR is impossible, one should analyse the criteria for cancellation or remaining areas from the SHA. Criteria are being discussed by the committee and if the criteria for cancellation have been met, the proposal for the reduction of remaining areas can be made. If not, additional information is required or additional demining aiming at status confirmation of MR and remaining areas.

Awarding the status to the MR upon completed demining operations is of crucial importance for further demining activities and possible reduction of remaining areas from the SHA.

Metal Detectors with Enhanced Efficiency

Jürgen Braunstein¹⁶, Markus Sautter, Armin Merz, Gerhard Vallon

Abstract

Vallon GmbH pursues two different approaches to increase the efficiency when searching mines and UXO. Both approaches have the objective to reduce the number of non-relevant alarms, which are frequently referred to as "false alarms". These are the alarms from other metal objects but not from the searched ones. One approach is to use dual sensor systems, especially metal detectors and ground-penetrating radars (GPR). Another approach is to use intelligent detectors with metal discrimination allowing distinguishing between some UXO and scrap metal. Both approaches will be described in the following paragraphs.

Introduction

When searching anti-personnel mines or anti-tank mines a second criterion can be used to analyse an alarm from a metal object. The second piece of information can be the information retrieved from a ground-penetrating radar, which is set up in a manner only to give alarms when the found object has at least the dimensions of a small anti-personnel mine. Vallon and ERA from the UK developed a dual sensor detector, the VMR2-Minehound, comprising of a metal detector and a ground-penetrating radar (GPR).

In many regions the dominant problem with explosive remnants of war is submunitions or bomblets. They can be detected easily by conventional metal detectors, but only with a high false-alarm rate due to metallic clutter. Consequently, clearance work is tedious, frustrating and time-consuming. To facilitate the work in affected areas, Vallon developed a new UXO detector, the VMXC1, especially for the efficient detection of submunitions (e.g., BLU's). The VMXC1 has a built-in programmable metal-discrimination option, which can be adapted to the local threat scenario.

Dual sensor systems: The VMR2 is a handheld system without any external cables and weighs less than 4 kg. The easy to learn man machine interface requires only a single operator for the search tasks. Eight hours of operation can typically be achieved with the specially designed low-weight high-performance rechargeable battery. The VMR2 is designed for all climatic conditions in mine-affected countries, including desert heat and extended rainy seasons. The VMR2 uses a state-of-the-art metal detector, which is similar to the VMH3CS, as a primary search tool. Subsequently, the alarms from metal objects are investigated with the GPR. If both, the metal detector and the GPR, give an alarm then the probability having identified a mine is quite high because a mine with its metal content triggers an alarm of the metal detector and an alarm of the GPR as the size criterion is fulfilled. Typical efficiency enhancements reported from field tests in Angola, Cambodia, and Bosnia are around a factor of 5 to 7 in comparison to using only a metal detector.

Detectors with metal discrimination: The VMXC1 has an operation mode with metal discrimination. The digital signal processing allows the detector to analyse the received signals and to identify the metallic nature of the object from which the signal was picked up. In this mode, the VMXC1 distinguishes between the alarms from submunitions or bomblets and metallic clutter, hence the operator hears and sees on an LED bar graph different alarms for the searched objects and for the insignificant objects. The customized firmware can be optimized also for ammunition with different kind of metals like the MK-42, BLU-26 or BLU-63, therefore, the operator has the option to neglect alarms from, for example, aluminium cans and bottle caps, and concentrate on the alarms from ferrous objects and selected submunitions. Typical efficiency enhancements reported from field usage in Laos are around a factor of 3 to 5 in comparison to using only a metal detector.

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VMR2 with GPR and MD



Mode selector of the VMXC1



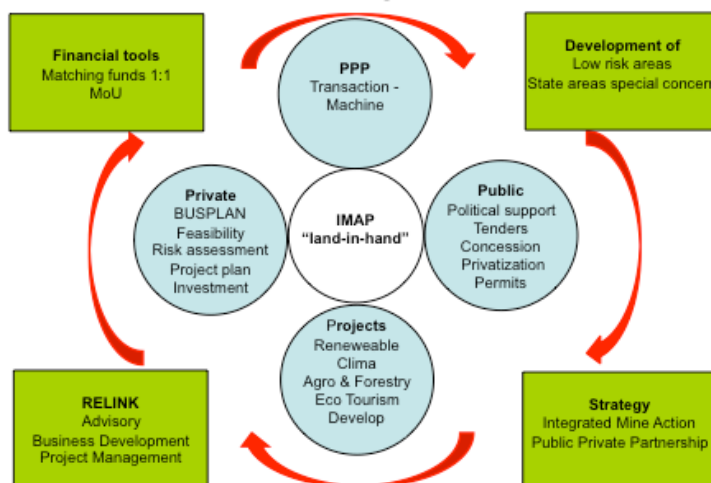
VMXC1

PUBLIC PRIVATE PARTNERSHIPS INTEGRATED MINE ACTION

- a regional LINK in South East Europe

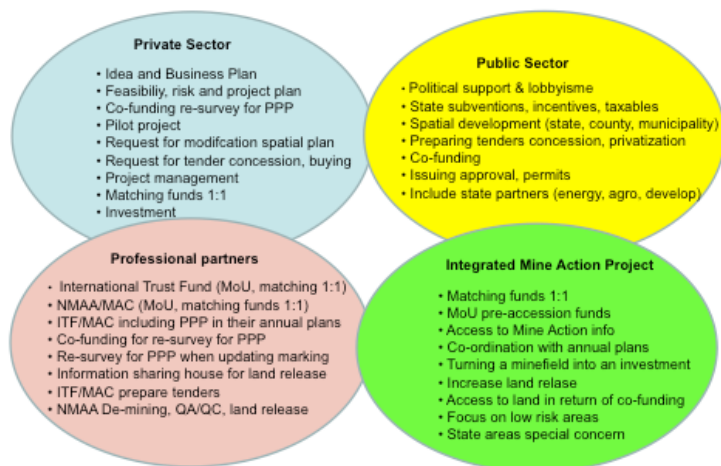


Public Private Partnership in Mine Action



The idea of **Public Private Partnership in Mine Action** was created in 2006. During 3 years of work with the Danish company Aresa trying to develop a landmine plant for Technical Survey and QC in Mine Action the idea turned into a business strategy based on PPP in Mine Action. During 2007-2009 feasibility studies, risk assessment and pilot projects were developed and tested in Croatia, Bosnia and Serbia.

Who is doing what in PPP Mine Action?



Private investors in Scandinavia and Germany are especially interested in providing **matching funds** with donors such as ITF and NMAA in return of concession or privatization of msa. In 2008 Croatia adopted a new land legislation for agricultural land including the options of **free concession for 10 years in return of funds for demining** and investment. ITF signed an MoU based on matching funds 1:1 with Aresa in 2008. This is one **example of Public Private Partnership in Mine Action**. (the option was never used by Aresa due to the global financial crisis) but other investors are willing to invest in Europe's mine suspected areas!

It is especially in the **renewable energy** (wind, solar and biomass), **agro**, **forestry** and **clima** sectors you find investors who are interested in PPP Mine Action.

RELINK – a regional link in Mine Action in South East Europe was founded in Croatia in 2009. The idea is to improve the concept of socio-economic Mine Action, Land Mine Impact Survey, General Survey and none Technical survey to include a more economic development approach based on Public Private Partnership motivating private investors to join the work of releasing mine suspected areas, reducing risk initiating investment in mine suspected areas, often known as state areas of special concern. The ambition is to develop the concept into most of the region including Serbia, Kosovo and Bosnia Herzegovina. In a second phase the concept could be exported to other parts of the world. **RELINK was founded by Mr Kim Bretting, www.relink.hr, GSM +385 - 91 - 1122790 or +45 - 40640665**

Experimental and Numerical Study of Soil Stress Induced by Dynamic Loads Applied on Soil Surface

*Michel Grima*¹⁷

Abstract

The purpose of this paper is to present experimental results related to pressure induced in soils by different loads on soil surface.

Many studies have been led to estimate soil stress, in the agricultural area in order mainly to prevent soil compaction, and in the demining area in order to assess the performance of mechanical demining systems.

In this last area, tests have been carried out in the field with a force measurement sensor, in a French DGA test laboratory. The aims of these tests are to identify the physical interaction process between mechanical demining devices and mines laid or buried in soils, and to calibrate models based on experimental data, obtained on natural soils for conditions encountered in operational cases.

Apart from experimental results obtained in the field, a theoretical model, based on Boussinesq theory, is presented.

This paper presents results which are parts of a global approach aiming at the assessment of mechanical demining system performances.

Keywords: soil stress, soil, impact loading.

1. Introduction

Mechanical demining systems are used in military operations and humanitarian landmine clearance operations in order to neutralize mines on paths or areas. These systems are designed to apply mechanical actions, directly or indirectly on mines laid or buried in the superficial layer of the soil. In the field, there is a need to predict the success of clearance operations which can be hampered mainly by soil conditions depending on water content and compaction for a given type of soil.

2. Experimental approach

Stress has been measured in natural soils using a force measurement sensor, with a 0 - 20 kN measuring range. This sensor, shown in Fig 1, is a cylinder which has been buried in the soil. Forces are measured on its upper part, which is a 13 cm diameter disk.



Figure 1: force sensor

Series of experiments have been conducted, in ETAS, to assess forces and stress induced in natural soil while applying loads at the soil surface. Examples of measured forces in the same soil at 10 cm depth, for three types of promptings are presented in the following figures.

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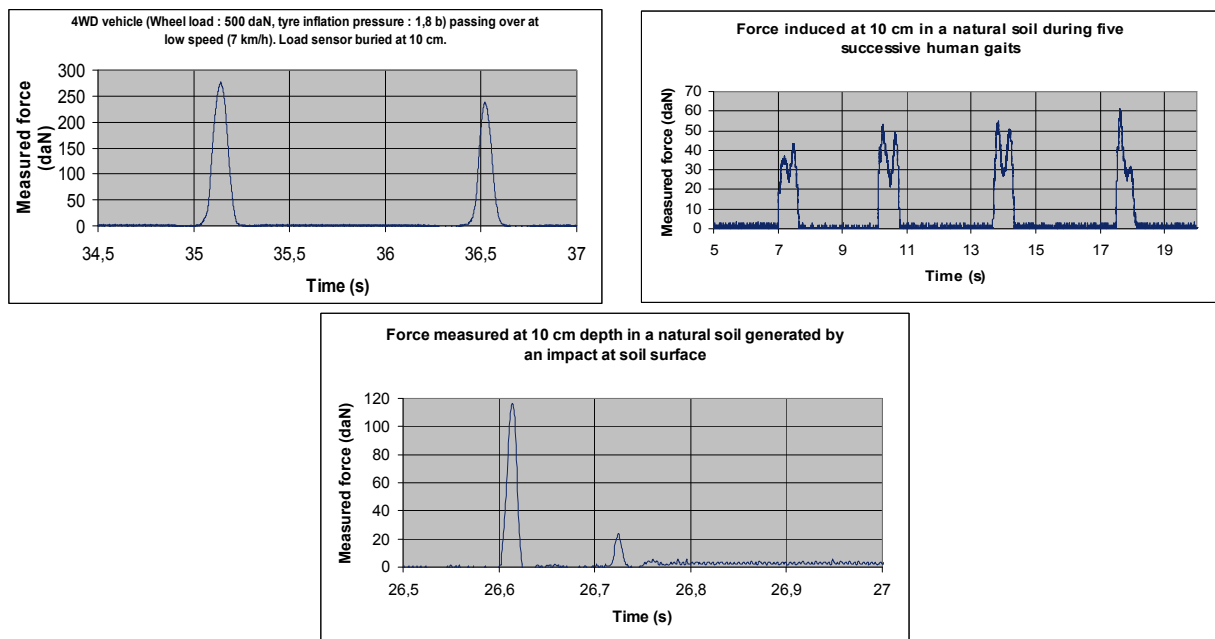


Figure 2, 3 and 4 : time plots of force measured in a natural soil, in ETAS, at 10 cm depth

Two recent papers [1] and [2], related to soil stress distribution from impact mechanisms at soil surface, give information on maximum stress level measured using a laboratory device.

The first one presents stresses induced in a sand cushion with a 10 cm thickness. Stresses are recorded at the bottom of a laboratory device.

The second one is related to an interesting study carried out at the University of Saskatchewan on a sandy clay loam. Impact loading tests carried out on a soil box show the maximum stress level as a function of depth and impact level.

Experimental results from these two papers complemented with results obtained on natural soils in ETAS, have been gathered in the following figure.

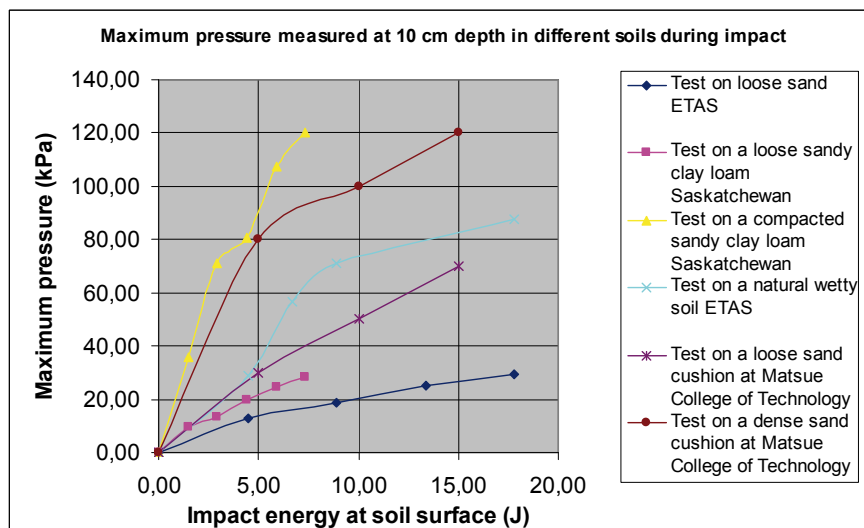


Figure 5

These results put in evidence that the impact transmission is higher in dense soils than in loose soils.

In conclusion, impact loading tests are important to predict soil response and efficiency of non intrusive demining tools.

3 Numerical approach

For estimating stresses induced in the soil by a distribution of forces applied on its surface, Boussinesq analytical solution has been used, adding all the elementary contributions of these forces on a soil surface mesh. Assumptions are then :

- continuous distribution of forces applied on the soil surface are distributed on each node of the previous mentioned mesh ;
- dynamic effects are ignored, forces are applied in a quasi static way ;
- superficial soil layer is considered as a semi-infinite homogeneous and isotropic elastic medium.

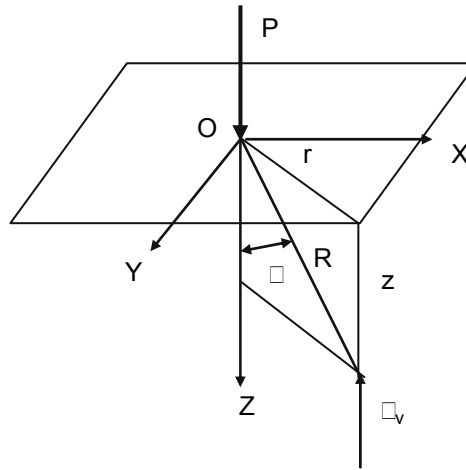


Figure 6

In the soil, at a depth z , the vertical Boussinesq stress induced by a concentrated load P at the soil surface, takes this analytical form :

$$\sigma_z = \frac{3 \cdot P \cdot z^3}{2\pi \cdot R^5} = \frac{3 \cdot P}{2\pi \cdot R^2} \cdot \cos^3 \beta$$

Frölich has modified this equation in order to take into account soil hardness, with this formula :

$$\sigma_z = \frac{\nu \cdot P}{2\pi \cdot R^2} \cdot \cos^\nu \beta$$

Where ν is a parameter whose value depend on soil hardness.

When $\nu=3$ the stress correspond to vertical Boussinesq analytical solution.

For a given load distribution applied on the soil surface, vertical soil stress can be computed by adding the contribution of all elementary concentred loads.

This numerical model has been applied to impact load tests, assuming there is no speed effect on the propagation of impact in the soil (Boussinesq solution is valid for static loads). Comparisons have been made between the analytical solution and ETAS experimental results and impact loading tests results obtained at Saskatchewan University [2].

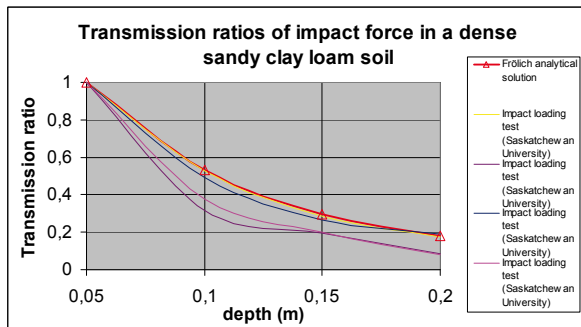


Figure 7

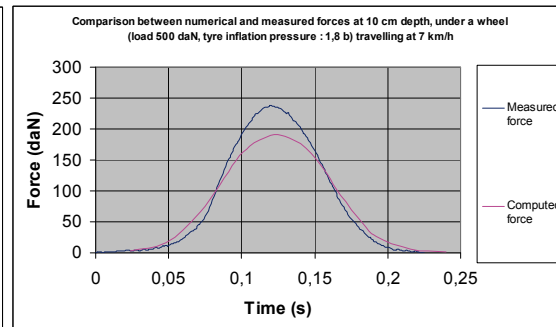


Figure 8

Assuming that impact is fully transmitted in the upper soil layer (5 cm thickness), the transmission ratio between stress at various depths and stress at 5 cm, decreases with depth (figure 7). Discrepancies between numerical and experimental values of the transmission ratio put in evidence dynamic effects on stress propagation in soil. Measured force at 10 cm depth, under a 4WD vehicle travelling at 7 km/h, is compared to numerical result in figure 8.

4 Conclusion

- For a same load and a same depth, the maximum pressure measured, varies significantly, with the type of soil, soil water content and soil density.
The harder the soil, the lower must be flails speed. But Kushwaha et al. [2], have shown that the impact load transferred in soil will increase with soil compaction level.
- Before choosing which mechanical system should be employed for clearance, there is a need to collect soil mechanical properties of the zone to be treated in order to make effective clearance works.
Impact load tests cannot be carried out in the field, so a solution to assess soil hardness, could be, for instance, to correlate transmission ratio of impact force (ratio of earth pressure to impact pressure) to cone index.
- To evaluate Mine clearance efficiency, effort should be focused on a few critical parameters :
 - mine depth ;
 - size of mines ;
 - size of the tool part in contact with soil ;
 - type of soil ;
 - density and water content of soil ;
 - soil relief.

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Soil Parameters Measurements in Mechanical Demining Area

Michel Grima¹⁸

Abstract

The aim of this paper is to present soil measurement techniques that have been used by the French Ministry of Defence, at the Angers Technical Establishment (ETAS) over the last 10 years in the mechanical demining area. Soil parameters are useful for the study of mechanical soil properties which are important in this area. Both laboratory and in-field tests are carried out, at ETAS, in order to identify and characterise soils in order to obtain soil mechanical and state parameters. This paper gives an overview of different techniques that have been used at ETAS.

1. Introduction

Characteristics and mechanical properties of soil put in evidence many variations in the field. These variations depend on space in three dimensions ; horizontally, vertically and in time. Principally they depend on :

- soil nature which can be identified in laboratory mainly by its granulometry (grain size distribution) obtained using sieves ;
- water content which can be identified in the field or in the laboratory ;
- compactness or dry density mainly identified in the field.

Ground temperature may also have an influence on mechanical properties of soil particularly on shear strength. Comparisons have been made by Czurda and all [1] (1997) between frozen and unfrozen soil, showing that frozen soil has higher cohesion values. Soil compactness is the result of natural or artificial process, artificial processes being related to agricultural soils and soils subjected to human activities. Therefore the mechanical state of soil and its mechanical parameters needs to be measured in the field for predictions of the performance of soil engaging implements, such as demining tools : flails, ploughs...

Soil mechanical behaviour presents a wide variety of parameters and results due to variations in soil composition and condition. Many different soils can be encountered in the field, depending on the amount of sand, silt clay gravel and stones present in the top soil layer. When using the term soil, it is the superficial layer of soil which is pertinent to our military studies in the mechanical demining area.

The mean depth of interest being 30 cm (~ 12 in), and intrusive test methods have been used in order to identify mechanical behaviour and pertinent characteristics of the soil.

For demining performance prediction, tines have been designed to measure forces acting on soil engaging implements such as ploughs (Grima and all.[2], 2000).

2. Measurement tools used for the determination of demining tool-soil interaction performances in ETAS

For the evaluation of equipment such as ploughs, many measurement devices need to be used in the field in order to identify the soil state. These include gamma densitometer for water content and density of natural and disturbed soils and penetrometer (figure 1) for cone index evaluations.

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Figure 1 Static penetrometer used in the field

As studied by Desbiolles et al.[3] (1999), single tine draught as measured in situ, can help the prediction of tillage tool draught requirements. Mechanical tools such as ploughs need this soil-tool interaction information. An original measurement of soil resistance acting on a tine has been designed at ETAS. As shown in Figure 2, a tine fixed to a chassis, equipped with skis, is pulled by a vehicle. Traction force measurement from this device, called 'sclerometer' enables an evaluation of soil horizontal hardness, for the evaluation of performance. Another experimental device which has been developed in ETAS, is shown in figure 3, this one can be transported and fixed on the soil, then a measurement of the horizontal force is made with a tine tracted manually with a cable and a winch.



Figure 2 : Sclerometer



Figure 3 : Manual sclerometer

Soil failure using a tine has been studied leading to an understanding of the magnitude of soil forces measured in the field, with a single tracted tine, for different soils textures and soil conditions.

An example of results is given as evidence in figure 3 below. It shows the influence of tine depth in the soil on horizontal force acting on a 45° rake angle tine, on a sandy loam soil.

The interest of such a measurement is that sensitivity studies can be carried out to quantify the influence of :

- depth ;
- rake angle ;
- speed ;
- type of soil

in order to obtain correlations for prediction models.

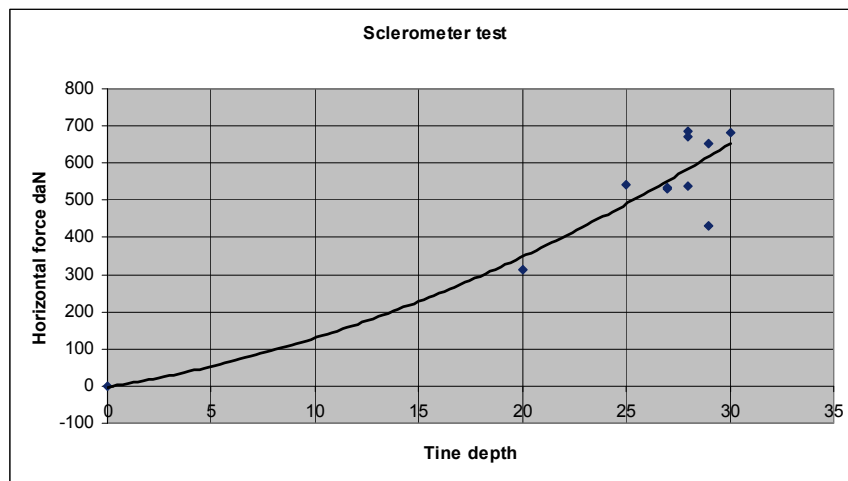


Figure 3 : Influence of depth on soil cutting resistance

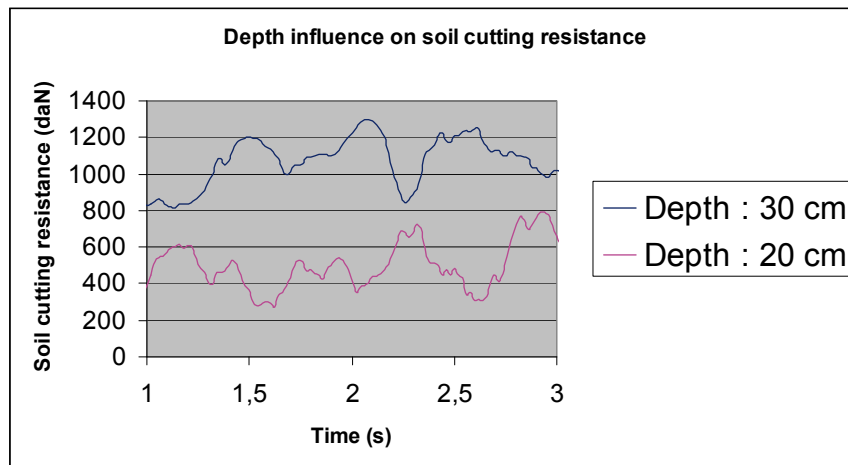


Figure 4 : Soil cutting resistance

Figure 4 shows field variation of soil cutting resistance over a distance of about 2 meters. Variability in soil properties is an important parameter that must be measured in order to obtain minimum and maximum parameter values. It is impossible to ignore that both natural and anthropogenic superficial soils are not homogeneous and that soil properties vary around mean values up to minimum and maximum boundaries. These boundaries depend on many parameters

3. Soil Database

Apart from the tests, a soil data base has been developed at ETAS in order to capitalize on all data measured in laboratories and in the field for a given soil.

Organization of this database is based on three parts :

- laboratory measurements, with mainly, granulometry, Atterberg limits, water content and dry density, cohesion and friction angle resulting from shear box tests ;
- field observations that give primary information ; slope, vegetation, estimated type of soil ;
- field measurements such as cone index profiles and mean values up to given depths, cohesion and friction angle resulting from tests using an annular shear ring, load-sinkage relationship resulting from plate penetration tests and cutting force on a tine.

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For each test on a given terrain, an overview of main characteristics of soil can be produced. Then research and treatments can be made on stored data allowing statistics and comparisons.

4. Conclusion

Soil characterization is an important topic which needs to be addressed for performance of soil engaging implements used in demining devices. Necessary in situ and laboratory tests are to be managed with accurate and constant procedures. This is essential in order to be able to compare performances of mechanical demining systems.

Mechanical characterization of superficial soils is a necessary process for estimating soil – mechanical demining tools interaction performances.

The terrain environment presents natural and artificial characteristics depending on its history. Appropriate measurement tools, deforming the soil as close as tools does, are to be used in the field, at different time of the year, in order to estimate influence of soil moisture content and density.

For the future, it will be important to standardise each type of measurement device in order to make meaningful and easy comparisons between results. This will be a necessary condition to compare performances of different mechanical demining systems used in different test sites.

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Measurement of Impulse Generated by the Detonation of Anti-tank Mines by Using the VLIP Technique

Pieter Marius de Koker¹⁹, Nikola Pavković²⁰, Jacobus Theodorus van Dyk²¹, Ivan Šteker²²

Abstract

The impulse generated by the detonation of anti-tank mines is an important characteristic of the mine used to design and develop protective countermeasures and to define the threat in terms of scientific and engineering terms. CSIR in collaboration with CTRO conducted explosive testing to determine the impulse generated by anti-tank mines. Testing was conducted in two phases. Phase 1 occurred during September 2008 in Croatia. The Vertical Launched Impulse Plate (VLIP) technique was used to measure the impulses generated by the TMA-3 and TMRP-6 anti-tank mines. The test data resulting from these tests were used to establish empirical formulas to determine the impulse generated by anti-tank mines. These formulas were used to predict impulse values for a number of anti-tank mines. Phase 2 was completed in the RSA during March 2009 where the impulse values of these mines were established by using the VLIP technique. The measured values correlated closely with the predicted values.

Introduction

The impulse of an anti-tank mine detonating underneath a target at a given distance is an important characteristic used to assess the threat that anti-tank mines pose to vehicles. Impulse values can not be calculated accurately with current computational and simulation methods—especially when the effects of soil on top of the mine and other mine debris have to be considered as well. Empirical test data have to be accumulated and used in the design of protection systems to counter the threat.

CSIR Landwards Sciences (LS)²³ identified and defined the following threat levels that mines and UXO pose to Landward Forces and Humanitarian Demining entities.

Table 1: Mine and UXO Threat Level definition.

MTL	Description	Typical examples
MTL-01	A/P mine blast type	PMN, PMD-6, Type 72
MTL-02	A/P mine shrapnel type	POM-Z, OZM-4, OZM-72, PROM-1
MTL-03	UXO small size	Hand grenades, rifle grenades a/c bomblets
MTL-04	A/T blast type	
MTL-04A	A/T blast under wheel	TM46, TM57, TMA-3
MTL-04B	A/T blast under hull	TM46, TM57, TMA-3

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²³ Landwards Sciences is a competency research area within the Defense Peace Safety and Security Research Unit within the CSIR.

MTL	Description	Typical examples
MTL-05	UXO medium size (mortars and artillery rounds)	60-120 mm Mortar. Artillery rounds up to 155mm
MTL-06	A/T HC	AT-4
MTL-07	A/T SFF	TMRP-6, TMRP-7, TMK-2, UKA-63
MTL-08	UXO heavy size	250-500 kg a/c bombs, sea mines

LS has developed the VLIP method to conduct such tests in order to characterize the various mine types and gain some understanding of the impulses that is imparted on to targets above detonating mines. [1]. Of particular interest is the impulse generated by SFF type anti-tank mines (Threat Level 07). It is expected that the detonation of these mine types would result in higher impulse values than those of the normal blast type anti-tank mines (TMA-3, Threat Level 04). Typical examples of the SFF type mines are the TMRP-6 (Yugoslav) and UKA-63 (Hungarian). LS has further established international cooperation with HCR-CTRO in Croatia in order to conduct collaborative testing due to the availability of TMRP-6 anti-tank mines in Croatia as well as the availability of suitable test facilities and technical support rendered by CTRO and Croatian Industry.

The VLIP method

The VLIP method for measuring impulse uses a thick steel plate with a steel mast that is accelerated as a unit vertically by the detonation of an anti-tank mine underneath the plate. (Figure1). The velocity of the plate during its vertical displacement and the mass of the plate are required to determine the impulse that is imparted to the plate.

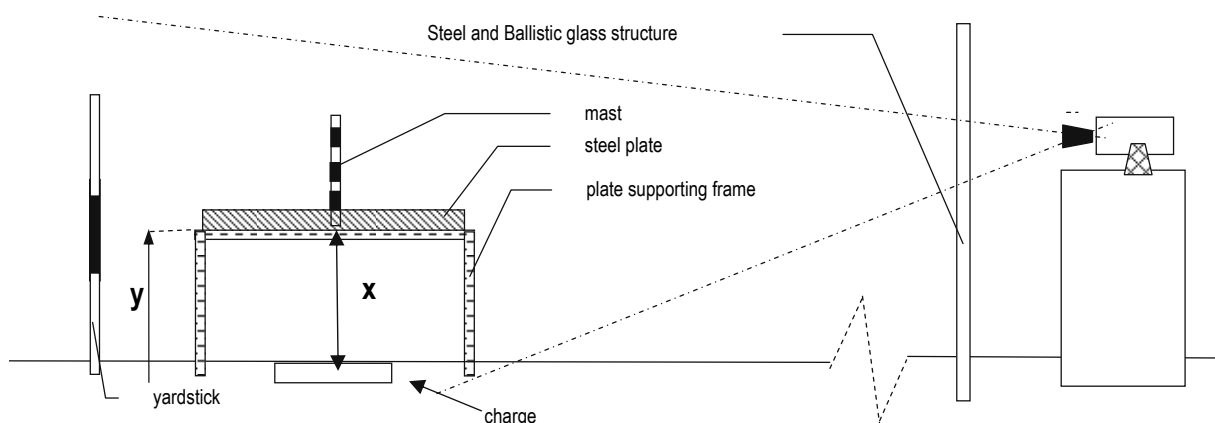


Figure 1: Schematic layout of VLIP method.

Impulse equals a change in momentum and the initial momentum is zero, therefore the following formula is valid:

$$I = mv \quad (i)$$

Where m is the mass of the plate [kg] and v , the velocity [m/s] of the plate at any given position. The mass of the plate is known as it is weighed for each of the experiments prior to the tests in the workshop. The velocity of the plate is determined using video footage from a medium speed camera. The tip of the mast is used to track the upward distance traveled in order to create a distance (x) vs time (s) curve. Velocity is obtained by differentiation of this curve.

PHASE 1 Testing (Croatia)

Testing was conducted at the HCR-CTRO test facility at Cerovac on the outskirts of Karlovac in Croatia on 3 and 4 September 2008. Technical support and manufacture of the VLIP test plates were conducted by Dok Ing D.o.o. All tests were conducted in accordance with the Test Instruction issued by HCR-CTRO. A medical team consisting of a medical doctor, nurse and ambulance driver as well as an ambulance was present on the range during testing. An Olympus D medium speed camera was used to record the movement of the vertical pole during and directly after the detonation. Recording was done at a speed of 5 000 frames per second. Normal digital cameras were used to capture still images of the test procedure. TMRP-6 and TMA-3 anti-tank mines were used during testing.

Figure 2 shows typical high-speed film extracts from one of the explosive events.

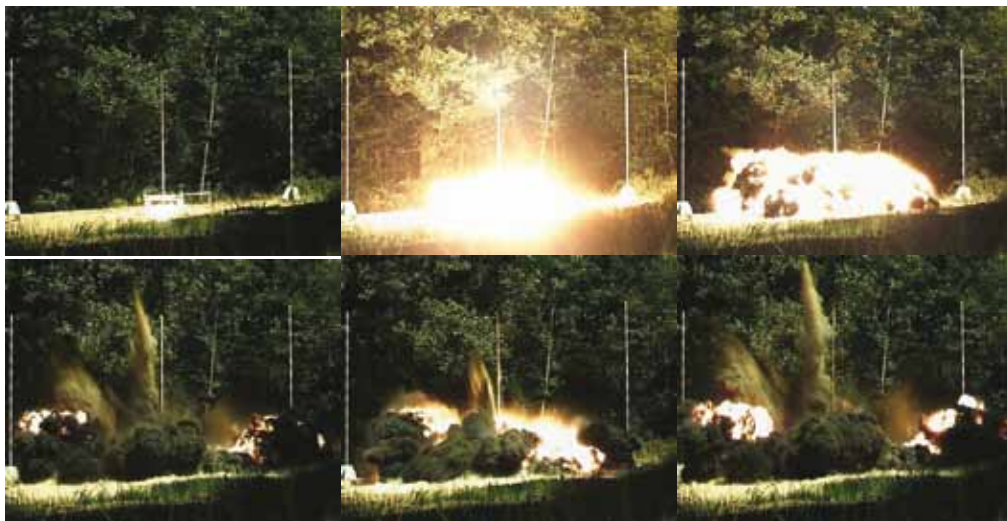
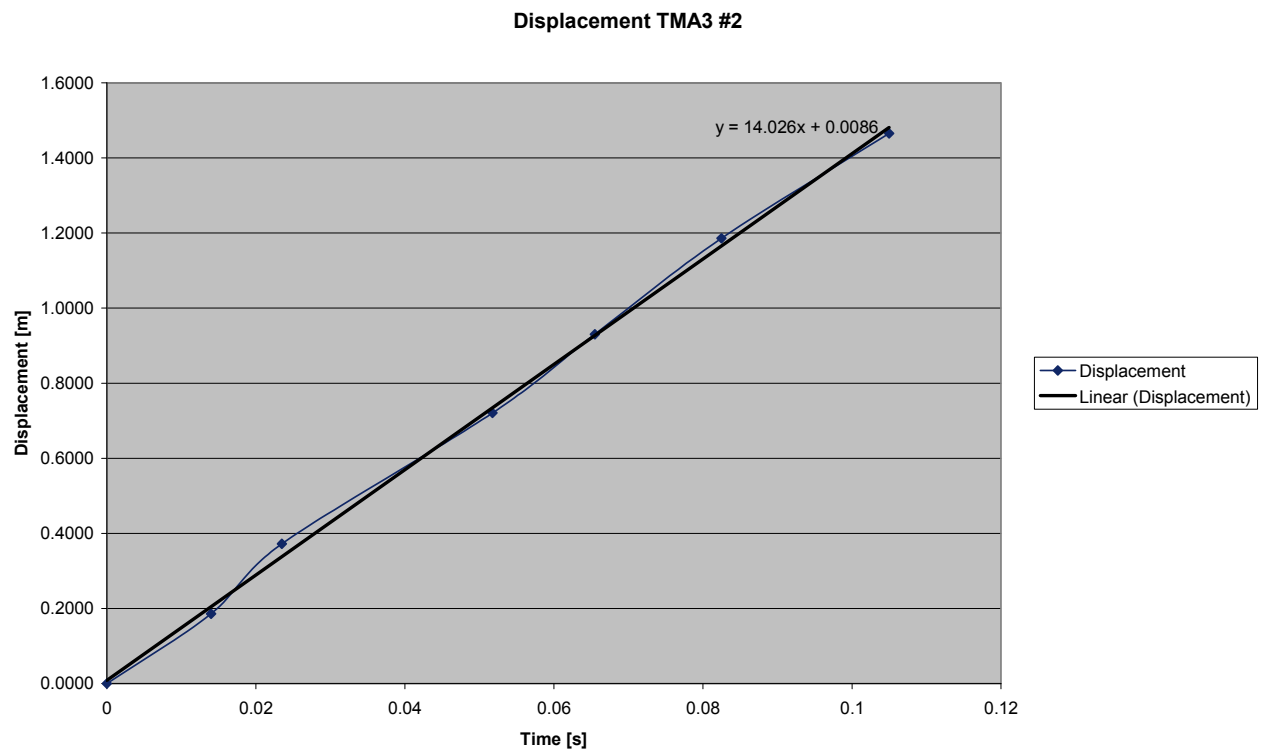
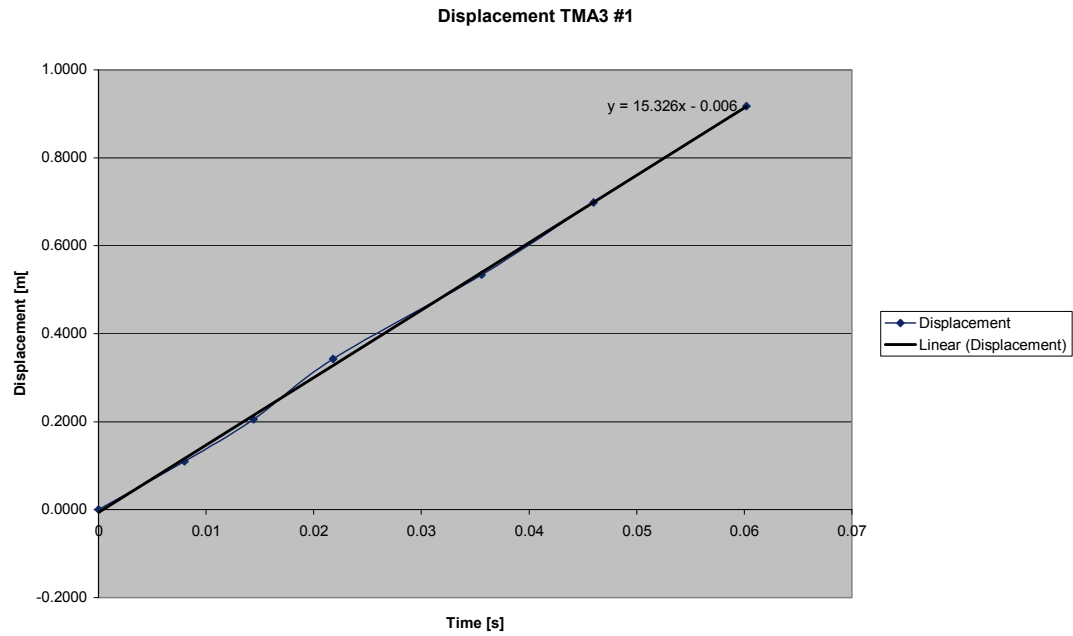


Figure 2: High speed extracts from explosive event.

The distance-time curves that resulted from these tests are shown in Figure 3.

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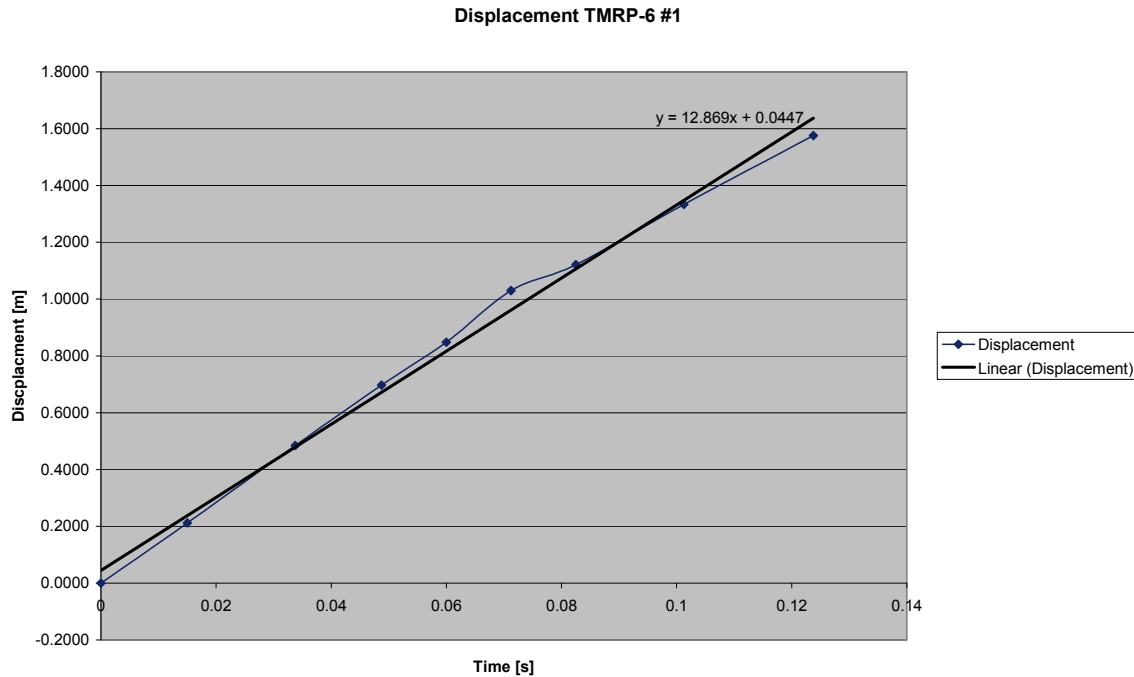


Figure 3: Displacement (x)-time (t) curves for TMA-3 and TMRP-6 mines.

The test results are summarised in Table 2.

Table 2: Summary of test results.

Test event	Explosive charge		VLIP Mass (kg)	Measurements	
	Type	NEC (kg)		Velocity (m/s)	Impulse (kNs)
1	TMA-3	6.5	1310	15.32	20.33
2	TMA-3	6.5	1310	14.026	19.96
3	TMRP-6	5.1	1310	No recording	No recording
4	TMRP-6	5.1	1310	12.869	16.86

The values in Table 2 shows that the average impulse value (20.15 kNs) for the TMA-3 mine is considerable higher than the impulse measured for the TMRP-6 mine (16.86 kNs). However, while the TMA-3 generates a higher impulse than the TMRP-6 during detonation, it only causes damage to a target (vehicle) in the 500 mm region above the target through the combination of shock and blast effect. The TMRP-6 causes more damage to unprotected targets (vehicles) in the same region due to the ballistic effect associated with the SFF generated during the detonation of the mine as well as the associated shock and blast effect. The TMRP-6 is therefore rated as a higher threat (Level 07) than the TMA-3 a/t mine (Level 04).

Thus, in order to compare the different impulse values more accurately, the effect of explosive contents should be considered as well. Thus if weighted impulse is defined as the netto impulse value divided by the NEC (netto explosive contents), the weighted impulse values are summarised in Table 3.

Table 3: Summary of weighted Impulse values.

Mine Type	NEC (kg)	Impulse (kNs)	Weighted Impulse (kNs/kg)
TMA-3	6.5 (TNT)	20.15	3.1
TMRP-6	5.1 (TNT)	16.86	3.3

The values in Table 3 can be used to establish the following relationship between NEC (TNT based) of a particular mine type to give a rough estimate of the impulse expected against a target (vehicle) within the 500 mm region above the mine (mine not covered with soil):

For blast type mines: $I = 3.1 M$ (ii)

Where I is the impulse (kNs)

M is the NEC (TNT) in kg

For SFF type mines: $I = 3.3 M$ (iii)

Where I is the impulse (kNs)

M is the NEC (TNT) in kg

Where the mine is filled with explosives other than TNT, the TNT equivalent values as determined by Petes [2] can be used. Thus equations (ii) and (iii) are adapted to include the TNT equivalent value as follows:

For blast type mines: $I = 3.1 M A$ (iv)

Where I is the impulse (kNs)

M is the NEC (TNT) in kg

A is the TNT equivalent value

For SFF type mines: $I = 3.3 M A$ (v)

Where I is the impulse (kNs)

M is the NEC (TNT) in kg

A is the TNT equivalent value

Equivalent values (A) for some explosive types are summarised in Table 4.

Table 4: TNT equivalent values.

Explosive type	TNT equivalent for impulse (A)
TNT	1.00
RDX/5% wax	1.16
Comp B	1.06
Torpex	1.28
Pentolite (TNT/PETN: 50/50)	1.15
Minol ii	1.22

Thus the following impulse values are predicted for the mine types listed in Table 5.

Table 5: Prediction of Impulse values for various mine types.

Mine Type	NEC (kg)	Predicted Impulse (kNs)
TM-46 (blast)	5.3 (TNT)	16.43
TM-57 (blast)	6.5 (TNT)	20.15
	7 (Torpex)	27.78
TM-62B (blast)	7.01 (TNT)	21.73
	7.57 (Torpex)	30.04
TM-62M (blast)	7.46 (TNT)	23.10

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	8.06 (Torpex)	31.98
UKA-63 (SFF type)	6 (TNT)	18.60

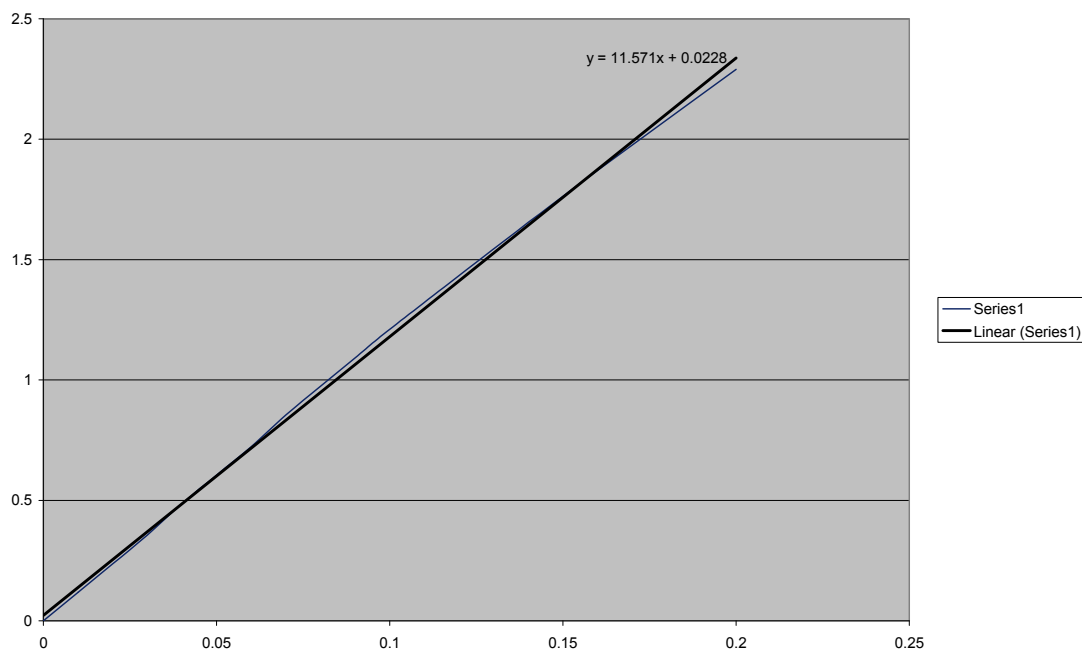
Phase 2 Testing (Rep. of South Africa)

Testing was conducted at LS explosive test range at Paardefontein outside Pretoria on 9 and 10 March 2009. Testing was conducted with the TM-46, TM-62M and TM-62B blast anti-tank mines. The VLIP method was used in a similar fashion as the tests conducted in Croatia. The test results are summarized in Table 6.

Table 6: Summary of test results.

Test event	Explosive charge		VLIP Mass (kg)	Measurements	
	Type	NEC (kg)		Velocity (m/s)	Impulse (kNs)
1	TM-46	5.3 (TNT)	1262	11.57	14.6
2	TM-62M	7.46 (TNT)	1250	17.67	22.1
3	TM-62B	7.01 (TNT)	1247	16.99	21.2

The displacement (x)-time (t) curves for the various tests are shown in Figure 4.



TM-46

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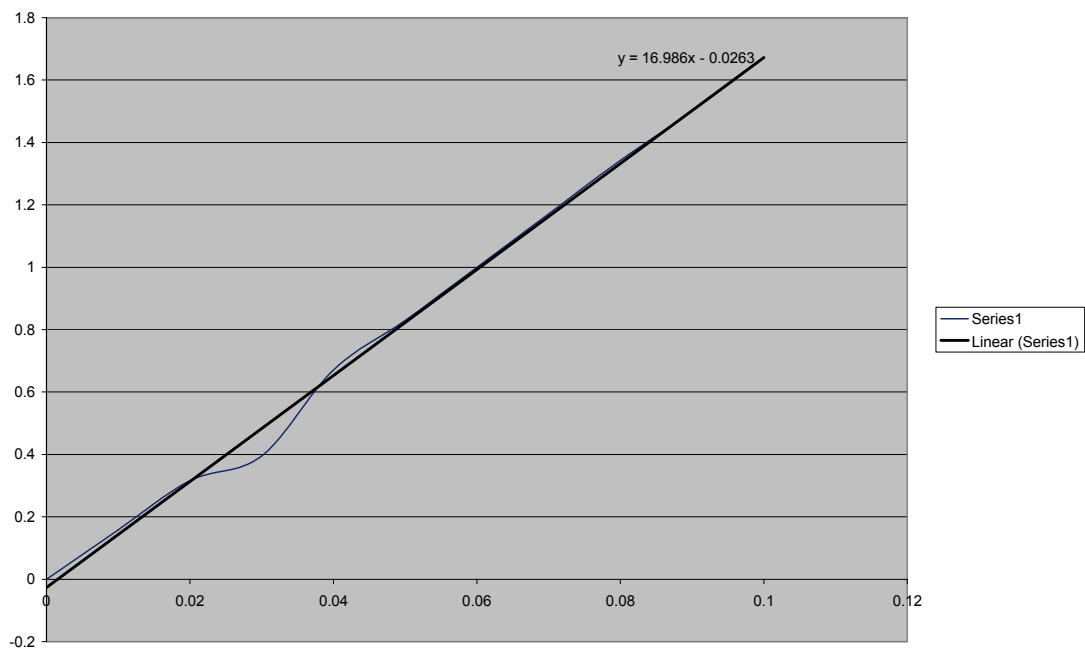
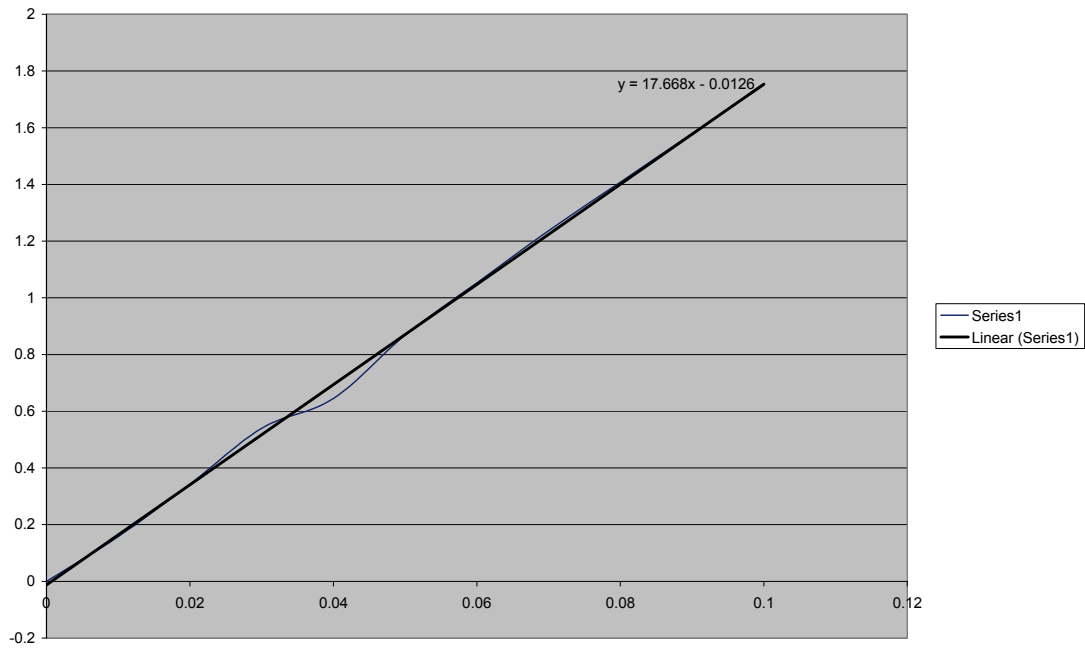


Figure 4: Distance-time curves for the TM-46, TM-62M and TM-62B mines.

Table 7 shows the comparison between the calculated and measured impulse values for the TM-47, TM-62M and TM-62B anti-tank mines.

Table 7: Comparison between calculated and measured impulse values.

Mine Type	Impulse (kNs)	
	Calculated	Measured
TM-46	16.43	14.6

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TM-62M	23.10	22.1
TM-62B	21.73	21.2

Conclusions

The calculated impulse values for the mines as shown in Table 7 correlates sufficiently with the measured values to validate the use of the empirical equation for the calculation of impulse generated by blast type anti-tank mines.

This test programme must be extended to include testing of SSF type anti-tank mines in order to validate the second empirical equation.

Testing should also be conducted with mines buried at various depths in the soil to determine soil factors that should be added to the existing equations.

References

- [1] Smith P, Mostert F, Snyman I M. Comparison of methods to measure the blast of an explosive charge. 24th International Symposium on Ballistics, New Orleans. 2008.
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Implementation of General Survey in the Republic of Croatia

*Davor Laura*²⁴

Abstract

General survey consists of activities of SHA data collection, data processing, data analysis, data interconnection and making conclusions about SHA situation

1. Organisational forms of general survey

In the Republic of Croatia, general surveys as continuous cyclic activities are implemented through two interconnected organizational forms:

- *General survey of SHA inside administrative boundaries of towns and municipalities*
- *Additional general surveys of territorially narrower suspected hazardous areas*

2. Phases of general survey implementation:

- *Analytic preparation*
- *Logistic preparation*
- *Collection and verification of data in the field*
- *Reconstruction of SHA*
- *Preparation of General Survey Report*
- *Registration of General survey into CROMAC MIS*
- *Control, analysis and verification of general survey*

3. The main factors that had an affect on precision in definition of SHA in the Republic of Croatia using general survey method:

- *Non-existence of mine records and other military documents that are essential for defining of SHA at certain battlefield locations;*
- *Inaccuracy and non-precision of available mine records, military maps and other military documents regarding mining*
- *Inaccessibility of the terrain and/or limited visibility of terrain, and impossibility to position battle deployment of the military units, and impossibility to define mined routes;*
- *Inefficiency when collecting data from persons that have information on mining;*
- *Collecting of data exclusively from safe areas – without possibility to enter SHA.*

Key words: *General survey, suspected hazardous area (SHA), analytic preparation, verification of survey results, reconstruction of mine situation, mine information system.*

Part I

STATUS OF SUSPECTED HAZARDOUS AREA IN THE REPUBLIC OF CROATIA

Final estimates of suspected hazardous area based on UN MAC's estimate from 1996 of 13 000 km² and 1.000.000 antipersonnel and antitank mines placed were rough and incorrect. According to those indicators, ca. 23% of the total territory of the Republic of Croatia was under suspicion of being contaminated with mines and UXO, i.e. out of 21 counties in the Republic of Croatia, 14 were contaminated by mines.

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The actual estimate of suspected hazardous area (SHA) could not have been made without relevant documentation on minefields and field information from the occupied territory i.e. systematic implementation of general survey on the entire territory of the Republic of Croatia. That is why the estimate only based on information on the occupied territory, lines of separation of forces and combat operations was so big.

Aware of the facts mentioned above, in the period from 2004 to 2008, the Croatian Mine Action Centre performed systematic general survey (survey of wider proportions) of the entire territory of towns and municipalities affected by mine problem. After that, we no longer spoke of SHA in terms of an estimate but in terms of a defined status, meaning, the total suspected hazardous area was finally precisely defined.

Today, suspected hazardous area amounts to 954 km² (1,6%). It covers the territory of 12 counties in the Republic of Croatia out of 21 with 110 towns and municipalities.

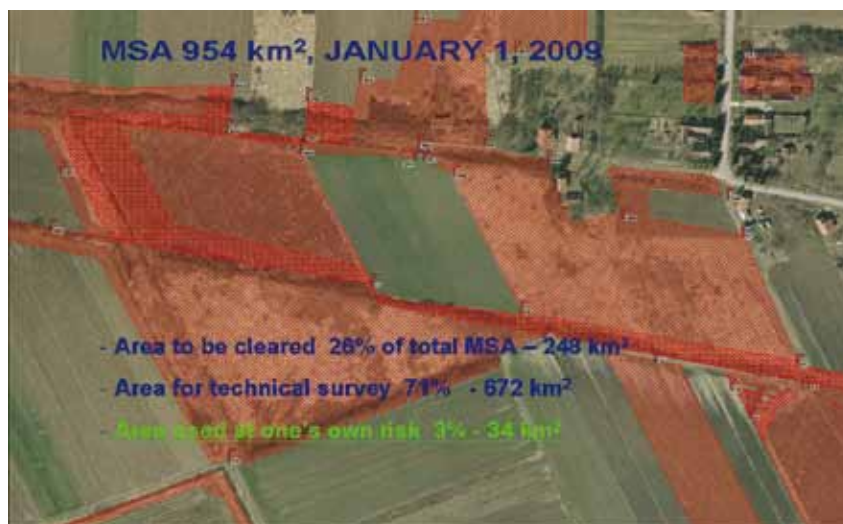
Taking into consideration the activities of technical survey and demining carried out, implementation of general survey and reconstruction of minefields, there are 4174 minefield records and 103.000 antipersonnel and antitank mines registered in CROMAC Mine Information System.



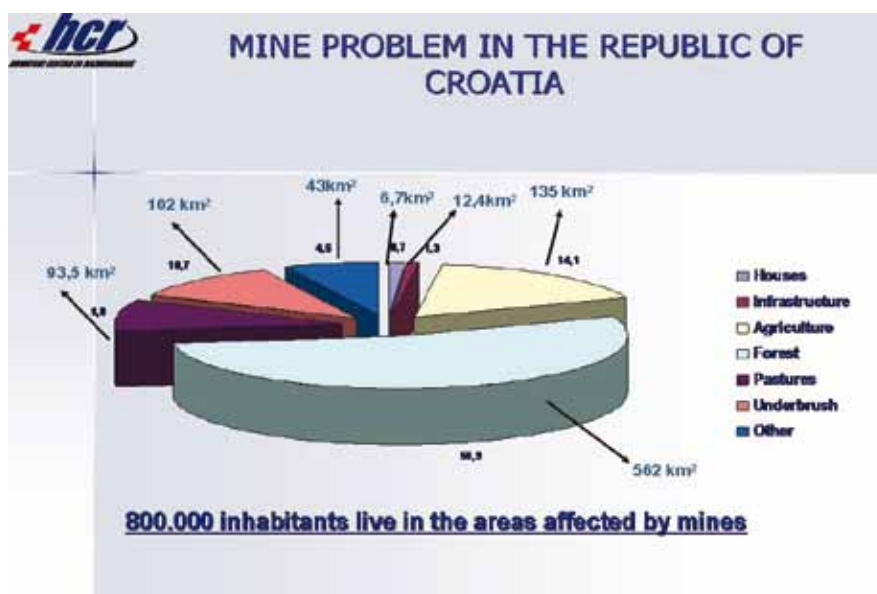
According to the size of suspected hazardous area, Lika-Senj County, Osijek-Baranja County, Sisak-Moslavina County, Karlovac County, Vukovar-Srijem County and Zadar County are considered to be the most mine contaminated counties.

Out of defined 954 km² of SHA, according to current indicators, areas for demining as separate entities make 248 km² or 26% of suspected hazardous area; areas for technical survey as separate entities make 672 km² or 71% of SHA. Areas used at one's own risk make 34 km² or 3% of suspected hazardous area.

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Taking into account the structure and intended use of suspected hazardous areas, forest areas make 562 km² or 58,9% of the total SHA. Agricultural areas make 135 km² or 14,1%, underbrush and karst make 102 km² or 10,7% of SHA, meadows and pastures 93,5 km² or 9,8%, houses and house yards 6,7 km² or 0,7%, infrastructure makes 12,4 km² or 1,3%. Other areas with 43 km² make 4,5% of the total SHA.

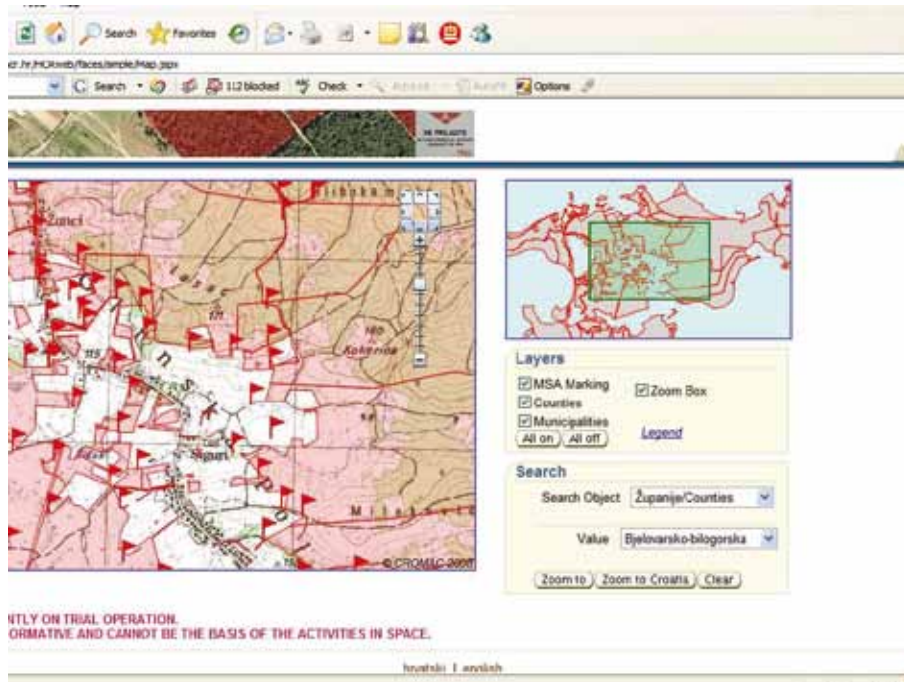


The entire suspected hazardous area of the Republic of Croatia is marked with 15 000 mine warning signs. Good quality and continuous marking of suspected hazardous areas resulted in informing and warning the SHA users and overall population in due time about the danger threatening from landmines.

Aiming at raising the quality and level of population awareness of the status and marking of suspected hazardous area, in February this year, CROMAC put into operation its Mine Information System portal (MISportal).

MISportal is a web application that enables each Internet user an insight into suspected hazardous areas in the Republic of Croatia. This type of display of suspected hazardous areas through web application is unique in the world. Detailed cartographic background maps provide insight into suspected hazardous areas displaying the locations of mine warning signs placed. MISportal improves interaction between users of potentially suspected areas and CROMAC and, at the same time, users are provided with more up-to-date information about the situation on the terrain. The portal also makes the distribution of cartographic background maps a lot easier.

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Part II

IMPLEMENTATION OF GENERAL SURVEY IN THE REPUBLIC OF CROATIA

1 ORGANIZATIONAL FORMS OF GENERAL SURVEY

General survey is a set of interconnected and harmonized operations by which the verification of existing data is made and new one about mine danger on a particular territory is collected without applying pyrotechnical methods (demining methods). Information about the position, appearance and basic characteristics of the area suspected of being contaminated with landmines is collected during the implementation of general surveys.

General surveys as continuous cyclic activities are conducted through two interrelated organizational survey forms:

- General survey of suspected hazardous areas inside administrative boundaries of towns and municipalities
- Additional general surveys of narrower suspected hazardous areas, in territorial sense, as part of total suspected hazardous area of the municipality-town.

General Surveys of Suspected Hazardous Areas of Towns and Municipalities

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General surveys of suspected hazardous areas of towns and municipalities are surveys of a wider extent and they are conducted with an aim of systematic definition of the status of the entire suspected hazardous area in the Republic of Croatia.

Additional General Surveys of Suspected Hazardous Areas

Additional general surveys of suspected hazardous areas represent target surveys of narrower areas, as part of the overall suspected hazardous area of a particular town or municipality.

Additional general surveys are a quantitative continuation of previous surveys of wider extent carried out. This means that the extent of said surveys will primarily depend on the quantity and quality of previously collected data.

Additional surveys are planned and conducted with the purpose of:

- additional collection of SHA status-related information based on new original data on mine contamination and/or demining
- additional collection of data on suspected hazardous areas for which it was estimated not to have enough relevant information collected
- data collection upon report on detection of mines
- data collection on mine incident
- collection of data on changes in the SHA status on the area of humanitarian demining project to be made

2. ORGANIZATION OF GENERAL SURVEY IMPLEMENTATION

At the Croatian Mine Action Centre, general surveys are conducted based on monthly operative activity plans. Operative planning, implementation control, final analysis and verification are conducted in the central office – operations department - while the immediate implementation of general surveys is under the authority of CROMAC's regional offices i.e. survey departments in regional offices.

General surveys are conducted by CROMAC surveyors, personnel fully trained for general survey conduct. The work of surveyors is managed directly by the head of Survey Department in the regional office. Department head is responsible for direct preparation of surveyors for general survey. He/she continuously monitors and controls the work of surveyors and together with a surveyor performs the analysis of general survey carried out. Upon paperwork control, the head verifies the report on general survey carried out with his signature.

The head of regional office monitors and co-ordinates general survey activities and confirms the report on general survey carried out with his signature.

3. PHASES OF GENERAL SURVEY IMPLEMENTATION

ANALYTIC PREPARATION

Analytic preparation covers detailed in-depth analysis of previously collected information from different sources and production of an initial analytic background map on SHA status for the field general survey.

Documentation that is a subject of the above-mentioned in-depth analysis is as follows:

- ◆ Combat-related documents:
 - Written commands, reports and maps as part of engineering logistic support to combat operations and operative deployment of troops
 - Maps showing military facilities (lines of trenches, bunkers, combat shelters, observation posts, artillery positions, command posts, depots and other logistic support facilities, roads and routes for the movement of troops inside the zone of combat deployment, ...)
 - Demining records

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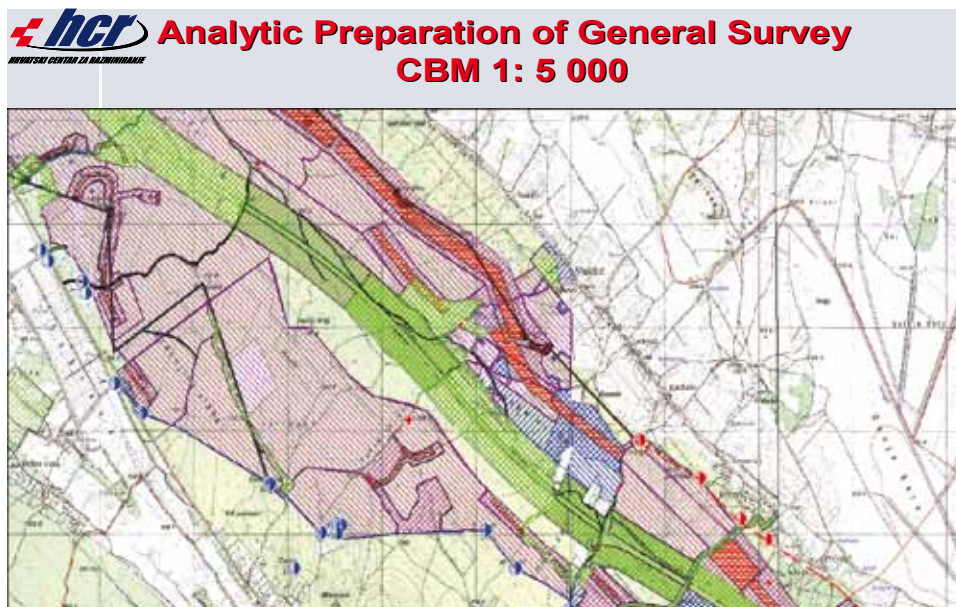
- Written commands and minefield maps
- Minefield records
- ◆ Documents, information and facts on placing minefields in possession of associations and individuals, participants in war events, local population and other individuals
- ◆ Documents from police investigations and other mine incident-related information
- ◆ Reports and corresponding maps on general and technical surveys carried out
- ◆ Reports with corresponding maps upon demining operations carried out

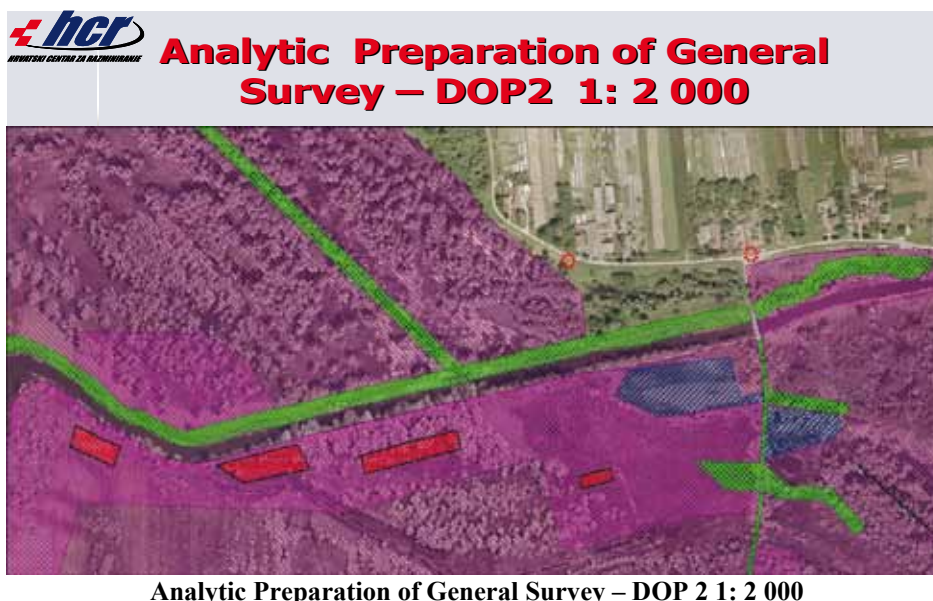
There were 7 922 minefield records analysed through the conduct of general surveys. The analysis established 2 659 minefield records to have been demined, the existence of 1 087 duplicates and 4 174 active (not demined) minefield records. Almost 50% of minefield records are impossible to position on the map in form of a polygon without conducting general survey on the terrain due to the fact of records being incomplete, inaccurate or imprecise. In addition, almost 900 military maps have been analysed through general surveys. The maps have been scanned, **geo-coded** and digitalized. The process of vectorization of military signs and symbols is currently underway. Minefield records have also been scanned and digitalized as well as data from the records entered to the Mine Information System (MIS). This enables prompt access to the data as well as performance of different statistic analyses and data processing.

Results of analytic preparation are presented via following documents:

- ◆ Working topographic maps S 1: 25 000, CBM S 1: 5 000 and DOF 2 1: 2 000 with marked already defined suspected hazardous areas, information on minefields placed, mine incidents, operative deployment of troops with fortification facilities and barriers, information on locations of mines detected during technical survey and demining etc.
- ◆ List of missing information and unknown facts on SHA that need to be updated, verified by general survey in the field or collect new relevant information.
- ◆ List of individuals having original information on placing minefields and other SHA status-related information that are missing.
- ◆ Activity plan of general survey in the field

Analytic preparation is made by surveyor with instruction and control of the head of survey department.





COLLECTION AND VERIFICATION OF DATA IN THE FIELD

Methods of on-site general survey are planned ways of taking actions by the surveyor aiming at collecting information on suspected hazardous areas solely from safe areas without using pyrotechnic methods.

Goals and Tasks of On-Site Survey

- a) Verify the existing information and collect additional information on war operations, minefield placing during the war and demining in post war period through interviews with contact persons.
- b) Compare geographic and topographic data from the maps and the actual situation in the field.
- c) Collect information on basic topographic features of the area as well as soil characteristics
- d) Note down the existence of indicators of mine danger observed (traces of explosions, fragments of mine and UXO packaging, remains of animals killed, residual mine warning signs etc.)
- e) Precisely establish the existence of safe roads and areas that can be used for visiting and field work purposes.
- f) Verify and correct information from the analytic preparation working map and harmonize it with the situation in the field.
- g) Define or estimate the positions of minefields according to incomplete information from the original documents and data collected through conversations with contact persons and draw them onto the working maps.
- h) Identify areas and facilities that need to be included into the SHA and precisely mark them on the maps.
- i) Identify areas and facilities that can be cancelled from the SHA and precisely mark them on the maps.
- j) Identify SHA boundaries and categories of areas and buildings according to the method of conducting demining operations inside the SHA and precisely mark them on the working maps S 1: 5 000 and DOP2.
- k) Collect information on SHA structure as per type and intended use.
- l) Perform necessary marking of SHA with mine warning signs.

Stated goals and tasks are being realized using the following methods:

- a) Collecting data using conversation method – 1 400 interviews with persons familiar with mine situation.
- b) Collecting data in the field using the measurement method – topographic map S 1: 25 000, CBM S 1: 5 000, DOP2 and onsite measurement.
- c) Onsite data collection using observation method.

RECONSTRUCTION OF SHA

Upon the completion of field work, final in-depth analysis of data collected by on-site general survey is performed, data connected with the ones from the initial analytic background map and relevant conclusions made using the process of interpretation of SHA status-related information.

Final reconstruction of mine situation i.e. definition of SHA status on the area that is the subject of survey is made by research and in-depth analysis of all data collected and their comparison, systematisation, linking and interpretation.

3.3.1. Definition of Suspected Hazardous Areas

Final reconstruction of SHA status covers:

- ◆ Definition of boundaries of suspected hazardous areas
- ◆ Classification of suspected hazardous areas as per method of conducting demining operations:
 - areas for demining
 - areas for technical survey – mine search
 - areas used at one's own risk
 - areas for cancellation from the SHA

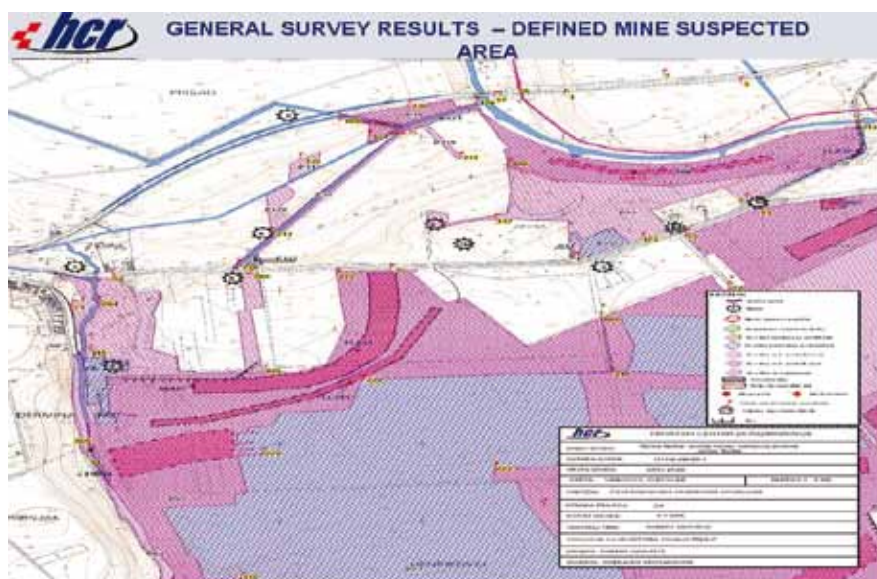
Areas for demining are areas inside the SHA for which there is no any doubt in being contaminated with mines what is confirmed by original data on placing minefields and data collected by general survey.

Areas for mine search are the ones for which there is no original information on placing minefields, but there is a reasonable doubt in being contaminated by mines due to the position of the area in space in relation to the operative deployment of troops, minefield placing tactics and organization of placing minefields in the wider surrounding area.

Areas used at one's own risk are defined based on information on the use of areas inside the defined SHA despite of the fact that the users have previously been informed about the existence of mine danger.

- ◆ Classification of suspected hazardous areas as per intended use:
 - forest areas
 - fire-fighting roads and fire lines
 - agricultural areas
 - meadows and pastures
 - underbrush and karst
 - houses and house yards
 - infrastructure facilities
- ◆ Reconstruction of minefield placing process with vector and polygon display of the positions of minefields placed.
- ◆ Positioning of mine incidents and detections or activations of mines in situ.
- ◆ Marking of SHA with mine warning signs.

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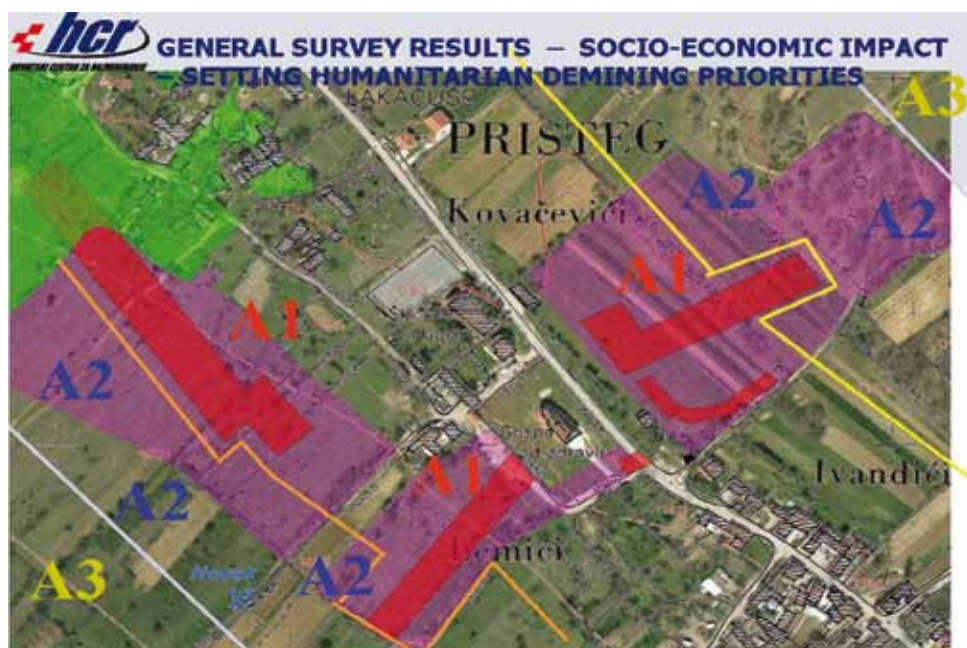
3.3.2. Socio-Economic Aspect

It is important to mention that general survey is conducted for the purpose of collecting information based on which the impact of mine problem on the safety, socio-economic development and ecology is identified. General survey results enable definition of humanitarian demining priorities.

 PRIORITIES				
Group	I Subgroup	II Subgroup	III Subgroup	
SAFETY	Schools, hospitals, playgrounds	Areas near settlements	Forests near settlements	
	Settlements			
	Turistic destinations			
	Safety area near factories			
	All known minefields			
SOCIO-ECONOMIC	Houses for reconstruction	Agricultural land II category	Agricultural land III category	
	Agricultural land	Infrastructural objects II category	Infrastructural objects III category	
	Infrastructural objects	Parts of forests	Parts of forests	
	Parts of forests			
ECOLOGY	National parks	Parts of parks of nature	Parts of parks of nature	
	Wild depos	Forests for special purposes		
	Fire protection			

Priorities are classified into three main groups: safety, socio-economic and ecological.

Until 2014, it is aimed to completely remove mine danger from the areas classified into group I and partially into group II. This makes 1/3 of the overall mine problem in the Republic of Croatia. Upon demining of these priority areas, mines will no longer represent an impediment for the economic development of the country or a direct threat for the population.



This map shows an area on the territory of Benkovac with marked priority areas from the safety aspect. This is a safety zone along houses and a local road that also covers minefields located nearby.

3.4. DRAFTING OF REPORTS AND KEEPING RECORDS IN CROMAC MIS

Reports on result of SHA survey is a final document in which all-SHA-related information has been systematized.

The report is made by surveyor and consists of the following information:

- a) on chronology of war events on survey area
- b) information on collective SHA status
- c) separate information for each area defined and classified by general survey
- d) estimate of remaining quantity and type of mines and positions of minefields on the area
- e) information on mine incidents
- f) information about the impact of mine problem on socio-economic development
- g) detailed overview of SHA status on the maps S 1: 25 000, CBM S 1: 5 000 and DOP2.

The report from general survey together with maps enclosed is stored and registered in CROMAC Mine Information System.

General survey data entered into CROMAC MIS in a form suitable for practical use for the purpose of implementation of further mine action activities are also suitable for different forms of statistic analysis and processing.

3.5. CONTROL, ANALYSIS AND VERIFICATION OF GENERAL SURVEY

Control and analysis of the results of general survey carried out at the regional office level are performed by the head of survey department and head of regional office. The aim of the analysis and control carried out by the head of survey department, database advisor and head of regional office is to study and analyse the data collected, establish their conformity with relevant standard operating procedures and verify the general survey report.

Final control, analysis and verification of general survey is carried out by CROMAC Operations Department in CROMAC headquarter upon submission of relevant technical documentation on general survey by the regional office.

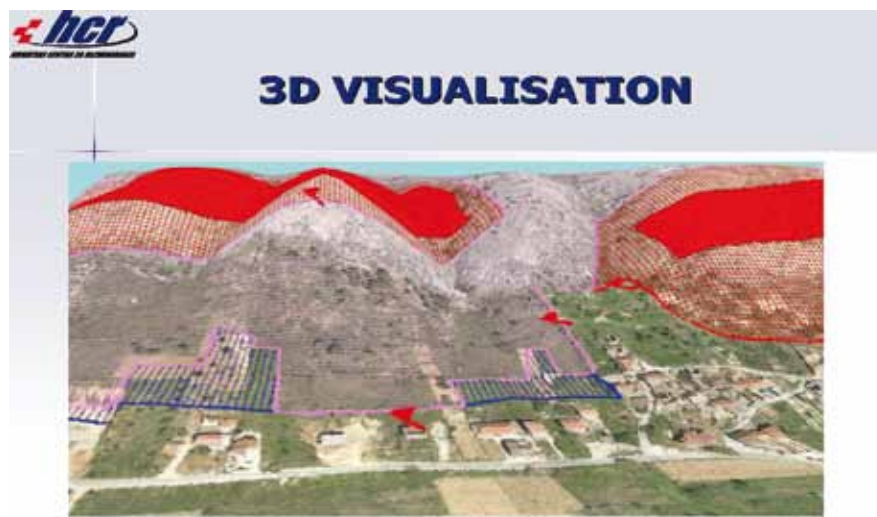
4 UPGRADE OF EXISTING GENERAL SURVEY METHODOLOGY

One of key issues we who work in mine action are forced to face is how to define suspected hazardous area as precise as possible and positions of minefields placed inside the hazardous area. Solving this problem is not important only from the aspect of safety but also from the aspect of spending financial means for solving it. Precision of SHA definition by general survey following the current methodology is conditioned by many factors.

The main factors that had a negative impact on the precision of SHA definition using general survey method on certain parts of the territory of the Republic of Croatia are as follows:

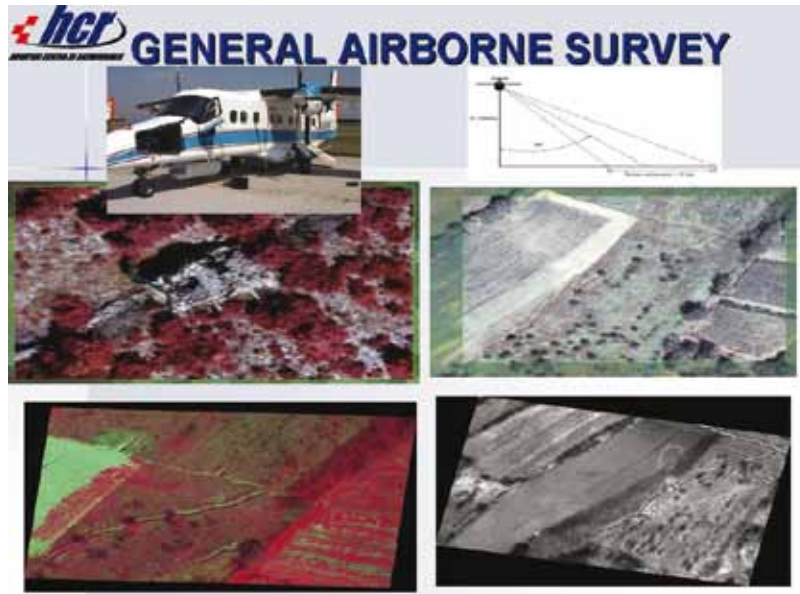
- ◆ Lack of minefield records and other military documents relevant for definition of suspected hazardous areas on certain parts of a battlefield;
- ◆ Inaccuracy or impreciseness of available minefield records; military maps and other military documents relating to placing mines;
- ◆ Terrain inaccessibility and/or limited terrain layout resulting in inability to position combat deployment of troops and precise definition of mined routes;
- ◆ Inefficiency in collecting information using conversation method from the people informed about placing minefields;
- ◆ Collecting information solely from safe areas – without possibility of entering SHA

Right for the purpose of reaching as better precision of SHA definition as possible, by the end of this year, Croatian Mine Action Centre will put a three-dimensional DOP 2 component in operative use.



For the same purpose, there was the project entitled “General Airborne Survey – Deployment of the Decision Support System for Mine Suspected Area Reduction” Initiated in the Republic of Croatia. The project holder is CROMAC CTDT and it is financed by the US Government through ITF.

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General airborne survey consists of the following phases: implementation of general and special requests for multi-sensor airborne survey, multi-sensor shooting, data processing and interpretation. Airborne collection of shots is focused on parts of target areas that are not available from the ground and for which only the airborne survey can ensure the information needed. Targets are: strong indicators of mine presence, indicators of lack of mine presence, especially in forest and mountainous parts of SHA. Shots are collected in visible, infrared part of spectrum (four channels), in infrared thermal part of spectrum and by airborne hyperspectral technique (95 channels).

The project is currently in its final stage. In the period ahead of us, we expect this method to be verified and put into operative use. This will result in further increase of efficiency and economical quality of work on the problem of precise definition of suspected hazardous area.

Results of General Survey of Areas with Unexploded Cluster Submunitions in Serbia

*Darvin Lisica*²⁵

Abstract

The general survey in Serbia was carried out by Norwegian People's Aid (NPA) between 9 November 2007 and 30 November 2008. The Mine Action Programme of the NPA in Bosnia and Herzegovina took on responsibility for this project because of its years of experience with general survey. Implementation of the project involved staff from Bosnia and Herzegovina and from Serbia. The project was carried out in three phases: (1) project preparation, (2) preliminary assessment of the situation of unexploded cluster submunitions, and (3) field surveys and general assessment of the situation regarding unexploded cluster submunitions. The general assessment of the situation included assessment of unexploded cluster submunitions hazards and of their socio-economic impact. According to the latest results of the general survey, 105 cluster-ordnance deployment zones are located in the territory of Serbia, in 15 municipalities. Into these deployment zones, 196 cluster ordnances had been fired, involving a total of 37,032 pieces of cluster submunitions. The database on the total suspected areas contains 390 polygons, in all 30.7 km². The hazard of cluster submunitions is not evenly distributed, affecting 28 local communities in 16 different municipalities in Serbia, and a total of 12 out of 30 districts. Some 162,000 people live in the affected local communities. According to the latest assessments, 88,000 are living in the immediate vicinity of suspected areas, and can thus be considered as exposed to daily risk. Analysis of blocked resources confirmed that the hazard of unexploded cluster submunitions, in combination with the blockage of resources, seriously affects the local socio-economic situation. The extent of risk area still to be cleared of unexploded cluster submunitions in Serbia has been calculated to be approximately 15 km². The Serbian Mine Action Centre has taken over the general survey database along with all the documents collected, for use in future surveys and preparing terms of reference for clearance tasks.

Key words: *general survey, cluster submunitions, risk management*

Project timeframe and objectives

The general survey in Serbia was carried out by NPA between 9 November 2007 and 30 November 2008. The immediate objectives were to assist the Mine Action Centre and the Government of the Republic of Serbia in defining the scale of the problem, identify contaminated areas and assist in capacity building to enable the Mine Action Centre to manage operations of surveying and clearing areas contaminated by unexploded cluster submunitions. The long-term objective of the project has been to create a secure environment for the local population, free of hazards of unexploded cluster submunitions.

Process of General Survey

The core process of general survey of areas of cluster ordnance deployment consists of three sub-processes: (1) identification of areas suspected of cluster ordnance hazards, (2) Field activities of general survey, and (3) risk assessment and project design.

Identification of areas suspected of cluster ordnance hazards is the first sub-process of general survey, during which all available data are analysed, without any additional field collection of data. Hazard is assessed from the levels of local communities to the general hazard assessment for the country. At the local community level, the perimeters, area and other characteristics of suspected areas are defined, for later use in the preparation and organization of general survey field activities. In addition, these data, statistically processed and sorted by higher-level administrative areas, are used to complement the general assessment of mine action. Identification of areas suspected of cluster ordnance hazard involves six process steps: (1) collection and processing of available data, (2) sorting the documents collected, estimating their quality and entering them into the database, (3) classifying information by micro-location and mapping, (4) comparative analysis of data and the reconstruction of cluster-ordnance deployment zones, (5) mapping the areas suspected of cluster ordnance hazards, and (6) monitoring of process and results.

Field (on-site) activities are the second sub-process of general survey. The collection and processing of missing data is performed as well as detailed measurements related to the area where a hazard of unexploded cluster submunitions has been identified. This work is performed at each individual location by the survey team, in line

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with the priorities and plan of the national mine action body. It consists of five process steps: (1) analysis of missing data, (2) preparation for field visits, (3) collecting data in the field and control of their quality, (4) corrections of deployment zone and cancellation of hazard-free land from the list of suspected areas, and (5) topographic measurements at hazardous locations.

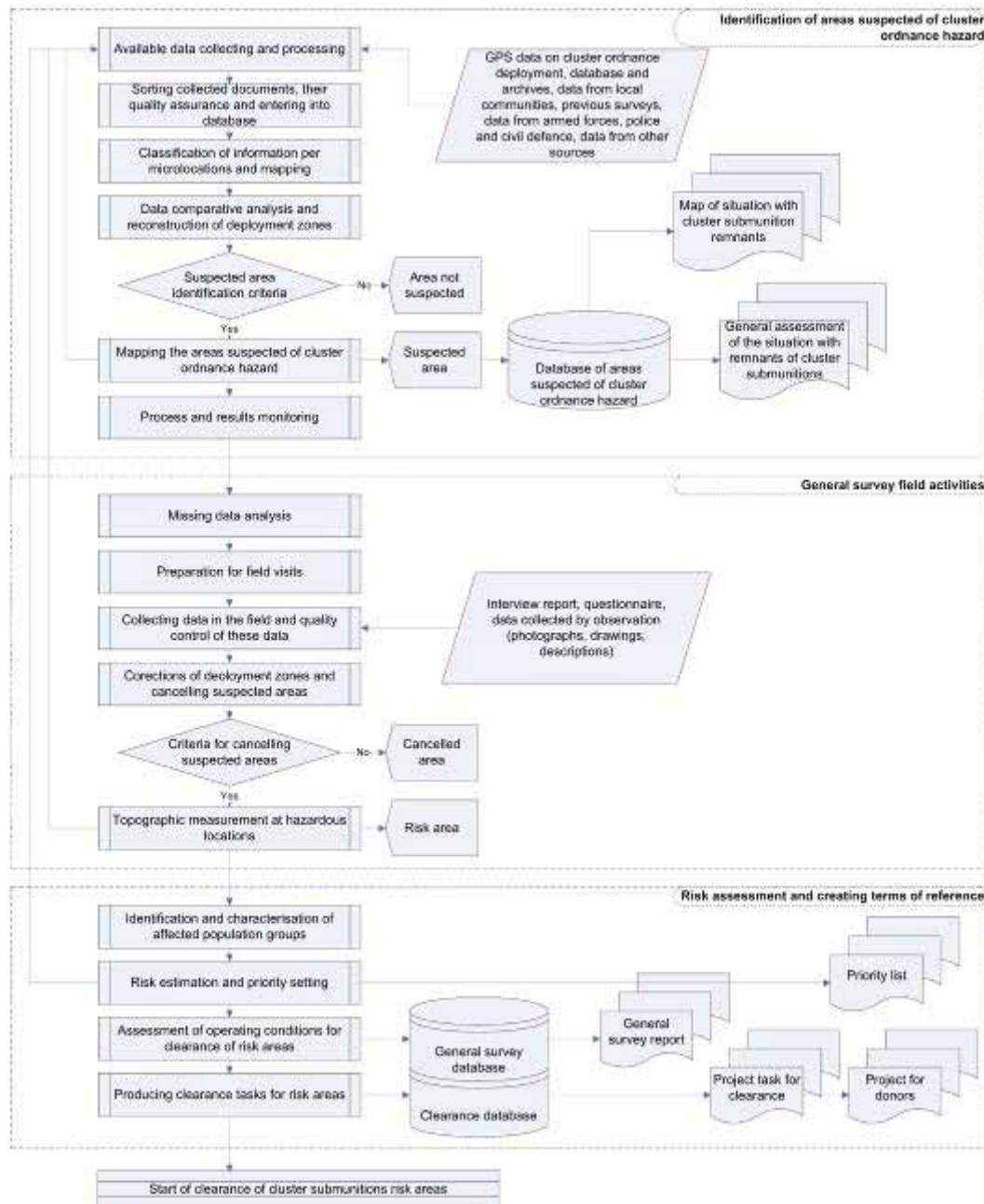


Figure 1: Flow chart of the process of general survey of cluster-ordnance deployment areas

Risk assessment of unexploded cluster submunitions and preparing terms of reference for clearance (including technical survey and marking) constitutes the third sub-process of the general survey. The scale of the problem is assessed (risk magnitude), as well as the priorities and plan for managing the risk at given locations contaminated by unexploded cluster submunitions. This involves four process steps: (1) identification and characterization of affected population groups, (2) risk evaluation and priority-setting, (3) assessment of operating conditions for clearing risk areas, and (4) preparing clearance tasks for risk areas.

The results of the general survey process represent input for the process of risk reduction, which may involve clearance, reduction, marking of contaminated area or/and education of the local population. The results of the risk management process, like the satisfaction of direct and indirect users of the land released to them for use, will depend on the quality of general survey management, the quality of its results and the selection of priorities.

Results of the reconstruction of cluster-ordnance deployment zone

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Identification and reconstruction of cluster-ordnance deployment zones were carried out based on the data obtained from available sources, and by collecting and verifying data in the field. The state authorities of the Republic of Serbia had received some data on the areas of cluster ordnance deployment from NATO Headquarters. However, the data on deployment zones proved incomplete, containing only the coordinates of the deployment locations and the number of ordnances deployed, without any particulars as to which type(s) of ordnance had been used. Data were submitted for 217 deployment zones, as follows: 142 deployment zones in Kosovo, 3 deployment zones in Vojvodina and 70 deployment zones in central Serbia. The Serbian Mine Action Centre provided data on previous surveys and records of earlier clearances, and prepared the terms of reference. Data on accidents and incidents caused by cluster submunitions were also used as a source for identifying deployment zones. All these data were not sufficient for the reconstruction of deployment zones, so the survey teams of the NPA had to perform additional field collection and verification through questionnaires and on-site visits. The teams collected data by filling in questionnaires for each affected municipality and by visiting 76 cluster-ordnance deployment areas in order to get an overview of the situation.

On the basis of available data and time-constrained field activities, the survey teams were able to reconstruct the location and extent of deployment zones, identify which cluster ordnance had been used and in which numbers, and estimate the quantity of unexploded cluster submunitions. At that time it was estimated that NATO forces had deployed five types of cluster bomb units with a total of seven types of cluster submunitions. It was assessed that there were a maximum of 177 deployment zones, in which 298 cluster bomb units were used. A more detailed assessment of deployment zone characteristics was carried out in the second phase of the general survey. After new data had been collected and existing data had been verified in the field, it was possible to cancel 98 deployment zones, since they were found to be deployment zones not of cluster ordnance, but of other bombs or cluster ordnance without explosive payloads. Furthermore, during the general survey field activities, 26 new deployment zones were identified. The latest results of the general survey show that, in all, 105 cluster-ordnance deployment zones have been located in the territory of Serbia, in 15 municipalities. In these deployment zones, 196 cluster bomb units were used, containing 37,032 pieces of cluster submunitions.

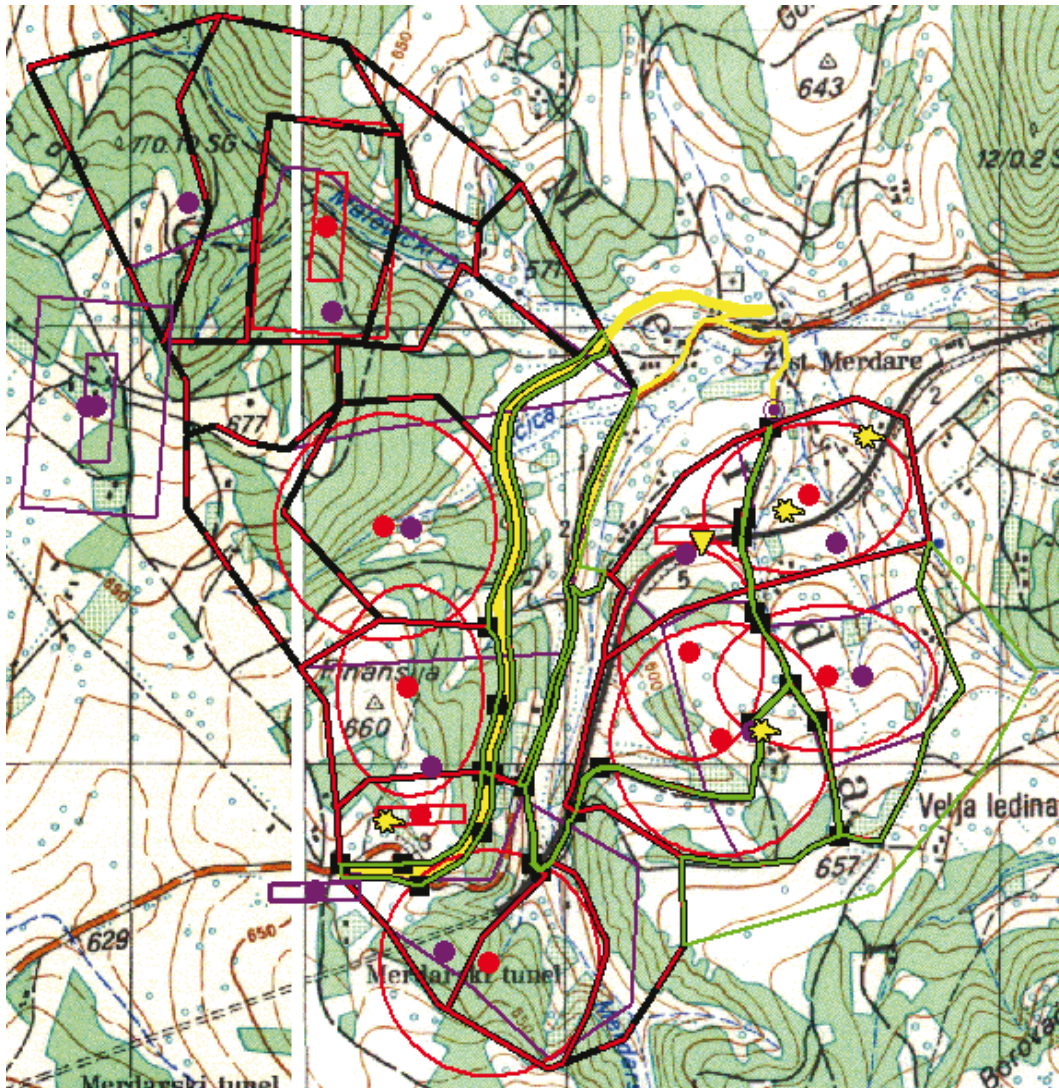
Cluster Ordnance Type	Number of Identified Deployment Zones	Number of Ordnance Projected	Munitions Type	Number of Munitions Projected	Assessed Number of Unexploded Cluster Submunitions
AGM 154/A	4	6	BLU 97	882	112
CBU 87	61	82	BLU 97	16,564	1,061
CBU 87	9	42	BLU 97 A/B	8,484	644
CBU 99	5	14	Mk-118	3,458	290
RBL 755	2	2	Mk-1	294	21
RBL 755	24	50	Mk-4	7,350	419
	105	196		37,032	2,547

Table 1: Estimate of the number of cluster ordnance used and remaining unexploded cluster submunitions

Immediately after deployment, the cluster submunitions and bomb remnants were typically collected by military, police and civil defence units. However, records on the removal of unexploded ordnance were not available to the survey teams of the NPA. It is estimated that there are still 2,547 pieces of unexploded cluster submunitions scattered in 105 deployment zones.

Hazard, economic impact and accidents caused by cluster contamination

The characteristics of the suspected areas¹ were assessed on the basis of the reconstructed deployment zones, other data collected, and sketch drawings made by the survey teams during field visits. Each suspected area is a vector polygon with its perimeters defined in the map on the scale of 1:25,000. The perimeters of each suspected area were defined on the basis of the assessed hazard level, land-use, and topographic characteristics of the land. During December 2007 and January 2008, NPA survey teams processed and entered into the database drawings of 790 sites with a total area of 77.13 km². Areas with graphite munitions deployment are not considered to be a hazard for the population. There were a total of 60 such identified sites, with an overall area of 7.02 km². Accordingly, it was assessed that 720 sites are suspected of unexploded cluster submunitions hazard, some 70.11 km² in total.



Map 1: Assessment of suspected area in the community Merdare

The initial status of the suspected area changed during the general survey field activities carried out from February till November 2008. The field activities of the general survey, including the collection of additional data in the field, measurements, recording data and the mapping thereof, were of twofold importance. Firstly, they enabled an evaluation of the situation and the preparation of project documents for risk areas of priority for clearance. Secondly, they ensured sufficient data for a more precise assessment of the total suspected area and its reduction after non-hazardous portions had been cancelled. By early November 2008, general survey field activities were completed. All the results were processed and entered into the database. The database on the total suspected area contains 390 polygons, in all 30.7 km², with an average size of 0.079 km². The total suspected area could be reduced in comparison to the initial assessment of February that year for two reasons: (1) reduction in the number of deployment zones after cancellation of non-existent deployment zones of cluster ordnance, and deployment zones of graphite cluster submunitions; and (2) more precise assessment and ensuing cancellation of previously suspected area.

It is mostly agricultural land that is blocked due to the presence of unexploded cluster submunitions: 29.7% of the suspected locations relate to agricultural land, or 33.4% of the total area suspected. The second largest barrier caused by unexploded cluster submunitions is the impossibility of reconstructing the infrastructure of settlements and utility facilities (19.9% of the total suspected area). The third largest problem is the impossibility of renovating or restoring housing units (14.2%). The analysis confirms that the hazard of unexploded cluster submunitions in combination with blocked resources has a significant impact on the socioeconomic situation of the communities affected. The likelihood of fatalities has been reduced, but the number and frequency of incidents is such that the probability of activating unexploded submunitions will rise with the growing needs of the population to use the blocked land.

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Structure of resources blocked due to presence of unexploded cluster submunitions	Extremely high hazard	Very high hazard	High hazard	Medium hazard	Low hazard	Total	%
Forest exploitation and maintenance	0,057	0,120	0,739	0,899	0,884	2,699	8,78%
Tourism development	0,000	0,000	0,515	1,240	1,202	2,957	9,62%
Employment incentives	0,000	0,000	0,000	0,000	0,094	0,094	0,30%
Reconstruction of educational, religious and cultural facilities	0,000	0,001	0,000	0,319	0,091	0,411	1,34%
Passability of transport communications	0,000	0,000	0,610	0,907	0,446	1,963	6,38%
Construction of communications facilities	0,000	0,000	0,000	0,000	0,000	0,000	0,00%
River regulations, reconstruction of canals and embankments	0,000	0,000	0,000	0,000	0,000	0,000	0,00%
Water supply	0,000	0,000	0,000	0,080	0,097	0,177	0,57%
Starting industry production	0,000	0,000	0,057	0,543	0,678	1,278	4,15%
Reconstruction of power transmission lines and power facilities	0,000	0,149	0,000	0,098	0,000	0,247	0,80%
Restoring agricultural land use	0,402	0,563	1,648	3,014	4,645	10,272	33,40%
Reconstruction of settlement infrastructure and utilities	0,000	0,155	0,961	2,345	2,650	6,111	19,87%
Reconstruction of housing units	0,133	0,000	0,323	2,320	1,581	4,357	14,17%
Other	0,035	0,152	0,000	0,000	0,000	0,187	0,61%
Total	0,627	1,140	4,853	11,765	12,368	30,753	100,00%
%	2,04%	3,71%	15,78%	38,26%	40,22%	100,00%	

Table 2: Extent of suspected areas with regard to hazard levels and blocked resources

Accidents and incidents have been caused by four types of cluster submunitions: BLU 97, BLU 97 A/B, Mk-4 and Mk-118. Cluster submunitions of the type BLU 97 are the most frequent cause (46.6% of instances), followed by submunitions of the type Mk-4 (in 34.3% of cases). Accidents recorded to date have resulted in 191 victims: 31 fatalities (16.2%) and 160 persons injured (83.8%). The hazard of cluster submunitions is not evenly distributed, affecting 28 local communities in 16 different municipalities in Serbia, and a total of 12 out of 30 districts. Some 162,000 people live in the affected local communities. According to the latest assessments, 88,000 are living in the immediate vicinity of suspected areas, and can thus be considered as exposed to daily risk.

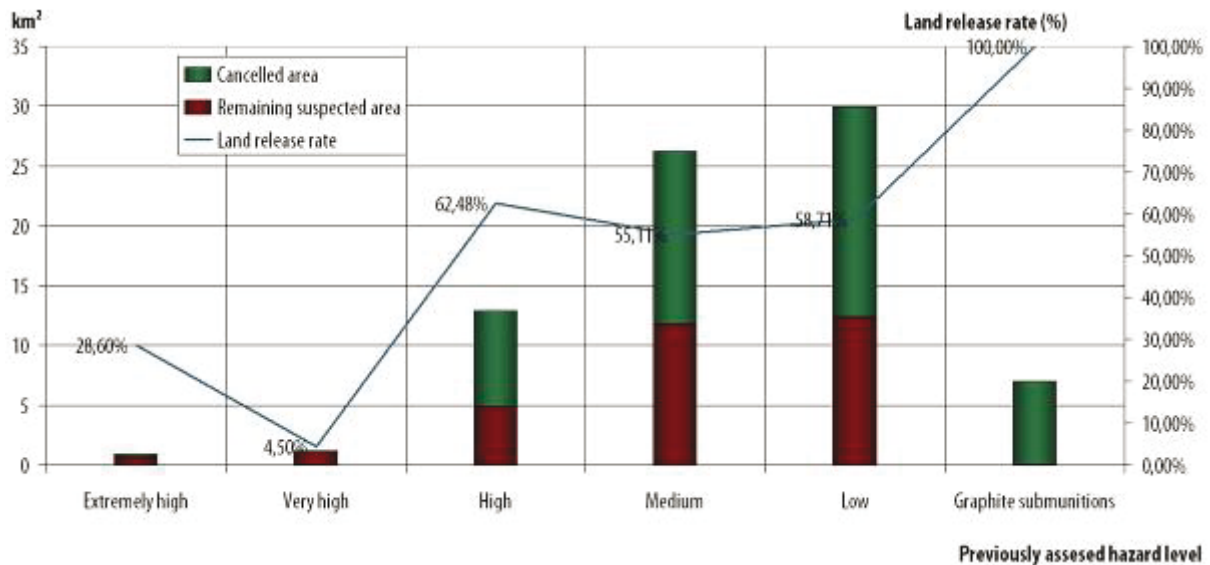
Land release

The collection of new data and the checking of facts resulted in a more accurate assessment of the situation in the micro-location under survey. The survey teams were able to assess more objectively the position and characteristics of the adjacent suspected areas. Such assessments generally led to the cancellation of certain parts of the suspected areas, as it could be positively determined that they presented no hazard. The re-assessment of the deployment zone and its suspected areas was undertaken in the manner described in the sub-process of identifying areas suspected of hazards of cluster ordnance. Land was 'cancelled' if one of the criteria for the cancellation of land from the area suspected of cluster ordnance hazard was met. The land thus cancelled was deleted from the records in the database for the relevant suspected area and, using identical perimeters, was entered into the database of cancelled land. This enabled monitoring of the timeframe and control of the land cancellation procedure.

In the period from February to November 2008, cancellation of land from the suspected area was undertaken in 593 cases. The size of the areas cancelled was 47.4 km², or 60.67% of the area previously defined as suspected.

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Graph 1: Analysis of cancelled area in relation to previously assessed hazard levels

The most difficult assessment of all concerns the final extent of the risk areas to be fully treated by international-standard procedures of cluster ordnance clearance. A statistical analysis was undertaken that included: calculation of risk areas based on the extent and number of suspected areas, calculation of the risk areas based on the land release rate according to hazard levels, calculation of risk areas for clearance based on the surveyed risk areas, and calculation of risk areas based on the deployment zones. The extent of risk area still to be cleared of unexploded cluster submunitions in Serbia has been predicted to be approximately 15 km².

Conclusions

The one year of work on the survey, the data collected and the results of the general assessment of the situation have enabled the NPA to define 10 strategic assumptions that are the preconditions for successful resolution of the problem of unexploded cluster submunitions in Serbia. Strategic assumptions and their indicators are part of the strategic and operating planning that lies within the purview of the Serbian Mine Action Centre.

Monitoring of all activities was carried out by the Mine Action Programme Manager, together with the special team for monitoring, and with monitoring by the NPA Southeast Europe Regional Director. Such monitoring contributed to improving the general survey process, the quality of the work done by the survey teams and the reliability of the results obtained.

Project was funded by the Norwegian Ministry of Foreign Affairs. The Serbian Mine Action Centre has taken over the general survey database along with all the documents collected, for use in future surveys and preparing terms of reference for clearance tasks.

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Development Challenges of Demining Machines and Vehicles

Dinko Mikulić²⁶, Vjekoslav Majetić²⁷, Tihomir Mendek²⁸, Fran Sabolich²⁹

Abstract

The article describes the current state in development of machines and supporting vehicles in humanitarian demining. Demining machine and mine protected vehicles are used for neutralization of mine obstacles in open mine contaminated areas. Evident progress is reflected in the design and demining quality for all machine categories. Alternative machine drivetrains and different tools for demining and machine detection are challenges, as well as mine protected vehicles. The combination and use of different demining tools, such as flail and tiller offers favourable results. However, problems are still present in demining on soft soil, due to soft soil trafficability which has significant influence on the use of machines.

Mine protected vehicles are used as escort vehicles in humanitarian demining. They have to provide crew protection in machine demining. Design of such vehicles is not yet defined for humanitarian demining demands. A demining machine can not be fully controlled from an escort vehicle due to various obstacles. Then the machine operator moves behind the machine.

At the end main conclusion and recommendations are presented.

Keywords: Humanitarian demining machines; Mine protected vehicles; Soil trafficability; Flail and Tiller; Teledemining machines; Active protection

1. Introduction

Today's technology of humanitarian demining successfully overcomes mine obstructions. Nevertheless, thorough researches disclose that the challenge of greater demining efficiency should reach a higher level. Therefore it is important to set a list of fresh demands for development. Today the logistic support to demining forces, especially to those in peace operations, requires lots of various equipment, and also a relevant number of supporting equipment and personnel.

Requirements for machine development are based on needs for demining in real and challenging specific conditions. Designers are often required to develop machines that should fulfill specific requirements. Requirements arise for light transport, demining in hard terrains, at high temperatures in deserts, and under heavy dust. Basic and specific requirements become every day more and more rigid. Most of demining machine design requirements is achievable, and process of humanitarian demining is more and more mechanized. Mine neutralization is done quickly and safely for deminers. Basic requirements for speeding up the demining process demand for better design of demining machines and additional demining equipment. Application of new technologies is frequent, and machine designers and manufacturers are constantly improving machines according to new requirements. Recently developed demining machines can demine large areas in short time and achieve required efficiency.

Basic requirements for development of demining machines are:

1. High soil treatment capacity
2. High quality landmine neutralization
3. Complete safety for operators / deminers
4. Long machine life-cycle, durability
5. Acceptable price of demining / sq.m.

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2. The concept with flail and tiller

Working tool with independent positioning of flail and tiller is innovative concept, where it is possible to have different technological speed of flail and tiller, as well as different digging depths. For destruction of mine threats primary role is given to the first tool – flail.

Independent position and movement (in relation to digging depth) of flails is providing higher efficiency in relation to classic fixed relative positions of flails. With this combination of flail and tiller certain advantages in digging of different types of soil can be achieved. According to demining requirements digging depth and number of rpm are adjusted in order to achieve higher technological speed for better working effectiveness. Each segment of tiller rotor can have multiple heads positioned at relative angle of 120°. Segments are phase shifted in such a way that segment cutting heads are forming three spirals. Spirals are starting from the rotor centre and are spreading symmetrically to each side.

To destroy AT mines, primary role is given to high radius flail; second role is given to the tiller that insures digging depth and soil mine clearance quality. Smaller radius of tiller in relation with flail radius is better, because it provides lower mass of machine. This insures lower machine mass and insures engine power. Removal of mine threats of great destruction power has to be performed with primary tool – high radius flail – that will not be damaged. Tiller unit, as secondary tool, is adequate for demining depth adjustment according to SOP. This way high reliability in mine destruction is achieved because with two independent and different tools hammer impact density could be quickly adjusted for different mine threat density conditions, so probability of hammer hitting the mine is high. Reliability of mine destruction is evaluated through two events:

$$P = p_1 p_2 (p_3)$$

p_1 – probability that flail hammer will hit the mine in the minefield,

p_2 – probability of mine activation

p_3 – probability of mine crashing

(p_2 and p_3 – circumstances that exclude one another)

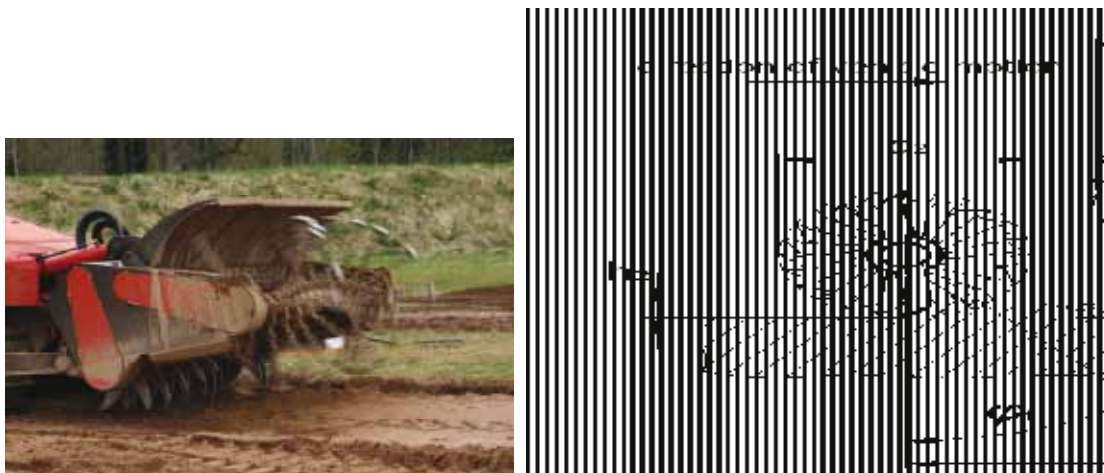


Fig. 1. Concept of working tool with flail and tiller (15 t, MV-10)

Benefits of primary and secondary tool combination, flail and tiller

- in different working conditions is better to operate with two independent working tools
- two tools / tiller and flail can provide double efficiency
- two demining tools provide high reliability of mine destruction
- the most destructive AT mines are destroyed by flail (no significant damage of machine)
- possibility to adjust digging depth and tiller's and flail's rpm; adjustment to real demining conditions
- tiller is not heavy – small tiller, materiel and engine power savings
- tiller destroys the smallest parts

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- tiller determines the final soil digging depth
- tiller protects the machine's vital parts in case of explosion under the flail



Fig. 2. Demining machine with tiller (5 t, MV-4 tiller)



Fig. 3. Demining machine with gripper (MV-4 gripper)

3. Teledemining machines

Neutralization of mine suspicious area in urban areas stagnates behind development of other countermining equipment. For demining in urban environment with limited maneuvering space, for removal of scattered and bulk UXO, and for antiterrorist actions, mobile *machine demining* mechanization is required. That required development of demining mechanization for specific conditions. *Teledemining machines*, based on tracked vehicle with telescopic arm and different tools is conceived, that will contribute to their dual use.

Beside the need for that kind of equipment, commercial justification for development of such equipment is also important. Dual requirements are determined for development of that equipment, which will be used for demining and material handling purposes. A family of *MV teledemining machines* was conceived as possible solution for urban countermining and commercial tasks, so called dual use demining technology.

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Dual use demining technology considers:

1. use of advanced *teledemining* technology in mine suspicious area in urban areas
2. use of advanced *teledemining* technology for handling of hazardous materials

Goal: to develop an advanced demining machine family for dual use:

1. DM with flail
2. DM with tiller
3. DM with flail and tiller
4. DM with rollers
5. DM with detonating grid
6. DM with mini-loader, dozer
7. DM with magnetic plate
8. DM with multi-sensor plate
9. DM with grippers
10. DM for stacking - *teleforklift*

Special attention, when development of future countermining equipment is concerned, is given to equipment for mine threat neutralization in urban areas. Basic characteristics of urban demining are:

- Mobility - problem is emphasized due to mine threats, narrow roads, concrete or wired obstacles, mines, ruins. Each crossroad is potential obstacle.
- Difficult to determine the exact position of mines and other obstacles in parks, municipal infrastructure, buildings, etc.
- Limitations to technical logistics resources – countermining equipment.

Technical development is focused on detection equipment and removal of possible threats. Development of remotely controlled vehicles and intelligent robots enables their application during peacetime, especially development of *teledemining* machine types. "Dual use" application increases the countermining actions in different humanitarian operations. Tool replacement enables application of *teledemining* machine as standard excavator, forklift or vehicle for manipulation of hazardous material. Its commercial side is highly appreciated, because instead of the use of several different machine types only one basic machine with different tools and sensors can be used.

Teledemining machine has great market dual use potential:

- (1) Demining of mine suspected urban areas and counterterrorist tasks (IED - Improvised Explosive Device);
- (2) Better safety when handling special cargo in special working conditions;
- (3) Dual use *teledemining machines* can be key to a success of safe working in special humanitarian countermining conditions.

4. Diesel - electric demining machine

Compared to hydrostatic concept, diesel-electric propulsion concept is regarded as technically more advanced. Development of the Diesel - electric demining machine and testing provide basis for analytical judgment for acceptability of technical concept. Diesel engine is connected to the generator, which produces electricity transferred to the electromotor with permanent magnets, which is providing power for machine movement and soil digging flail. Initial calculations are implying towards better performance and higher power efficiency. Technological challenges of power conversion and high temperatures are expected to be solved in near future. Demining machine traction characteristics are sufficient for effective soil digging and for destroying AP mines. It is considered that more advanced technologies will enable multi role use of machine for humanitarian demining tasks and for special tasks of removal the remains of low intensity conflict. Electrical propulsion technology is intensively developed and distributed as a future crucial factor for new capabilities. The biggest advance in demining is achieved in field of machine demining.



a



b



c

Fig. 4. a – Diesel demining machine with flail, b - Diesel - electric demining machine, c - Electric demining machine (5 t, MV-4 flail, options)

Electric demining machine

Beside industrial facilities, cars, trucks, agricultural and engineering machines are environment pollution actors, because they are using fossil fuels and lubricants for its operations and are producing exhaust gases such as carbon-monoxide (CO), carbon-hydrogen (HC), nitrogen-oxide (NO_x) and soot. According to EU directives,

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alternative fuels and lubricants are being developed. Additionally, high level of noise and vibrations is affecting human lives and work. Development and procurement of ecologically acceptable demining machines is proposed. Based on requirements and standards, model of ecologically acceptable demining machine is set up.

Perspective is given to alternative fuels and to new drive and transport technologies. *Characteristics of ECO generation* of demining machines are:

- *environmental protection* has become an important factor in the decision making of work processes and selection of means of work,
- demands requiring *humanization of humanitarian demining work*,
- many ecosystems are *protected to a various degree*.

The idea of a light electric machine was skillfully planned, albeit needs to be prepared technically and logistically to real demining conditions where it is most common to encounter mine suspected areas (undeveloped countries).

Developing problems are of technical significance and thus solvable. Capacity and service life of batteries, temperature conditions of use and need of transfer aggregate mounted on the supporting vehicle will represent logistical obstacles. With a technological solution of battery system with regard to stated 2-4 hour continued work with incorporation of a supporting engine, could create certain utilization in humanitarian demining.

Currently the machine can be used to detect mine contaminated areas and for demining of specific and smaller areas. Due to a lesser extent of such operations, autonomous application of this machine in humanitarian demining is under question. Therefore, a specific electric machine may be used in demining as a supporting vehicle in an enterprise which contracts great activities and so the machine is being utilized.

5. Soil trafficability

Use of machines and vehicles in demining depends on state of soil. On soft and moist soil, machines and vehicles move with difficulty. There exists a problem of soil trafficability.

Use of machines in demining depends on the state of soil. When weather conditions change (rain, mud), soil load capacity (soil strength) also changes. When soil is humid and the machine is too heavy, it won't move or perform demining. Machines with less pressure on soil offer greater soil trafficability.

In a study of soil trafficability often times a nominal vehicle pressure is used on soil NGP (Nominal Ground Pressure), as an easiest approach to soil trafficability estimate. However, nominal pressure on soil is a marginal tangential pressure of wheel on soil, which doesn't provide a competent soil trafficability estimate because of neglecting the impact of laden wheel pneumatics deformation while moving, or because of track chain deformation.

Mean maximum pressure (MMP) is a referent pressure of the vehicle on soft soil through the wheels. It is defined as the mean value of peak pressure magnitudes acting on the soil under the wheels. A partial empiric model (British Army Engineer Corps) for evaluation of vehicle mobility on coherent (clay) soil has been developed. Lower value of MMP decreases wheels sinkage, which provides better soil trafficability and mean movement speed, which further provides better vehicle mobility. Linking MMP and CI soil load, correlation that defines vehicle mobility is being determined (go / no go).

CI – soil cone index is a soil load capacity (soil strength) indicator, which is measured with penetrometer. Resistance to penetration of penetrometer cone into the certain type of soil is measured. *Standardized value of cone penetration measurement on depth of 15 cm (ASAE EP542 1999) is called cone index (CI)*. For example, load of very soft soil has soil cone index of $CI < 300$ kPa, medium hard soil is 300 - 500 kPa, and very hard soil more than 500 kPa.

Limiting Cone Indexes: $CI = CI_L = 0.827 \cdot MMP$ [kPa]

This expression can be used to determine the lowest soil load, where vehicle with certain MMP is mobile. In another words, soil load should be at least 83% of given MMP for certain vehicle, in order to successfully cross the passage.

Demining machine MV has NGP 0.46 dN/cm² (bar) and MMP 1.5 bar. By comparison of MMP machine with cone indeks value CI, high soil traficability is recognized and machine usage on soft soil. The same applies for other machine from DOK-ING. Based on NGP value, quality assessment of soil traficability is not possible.

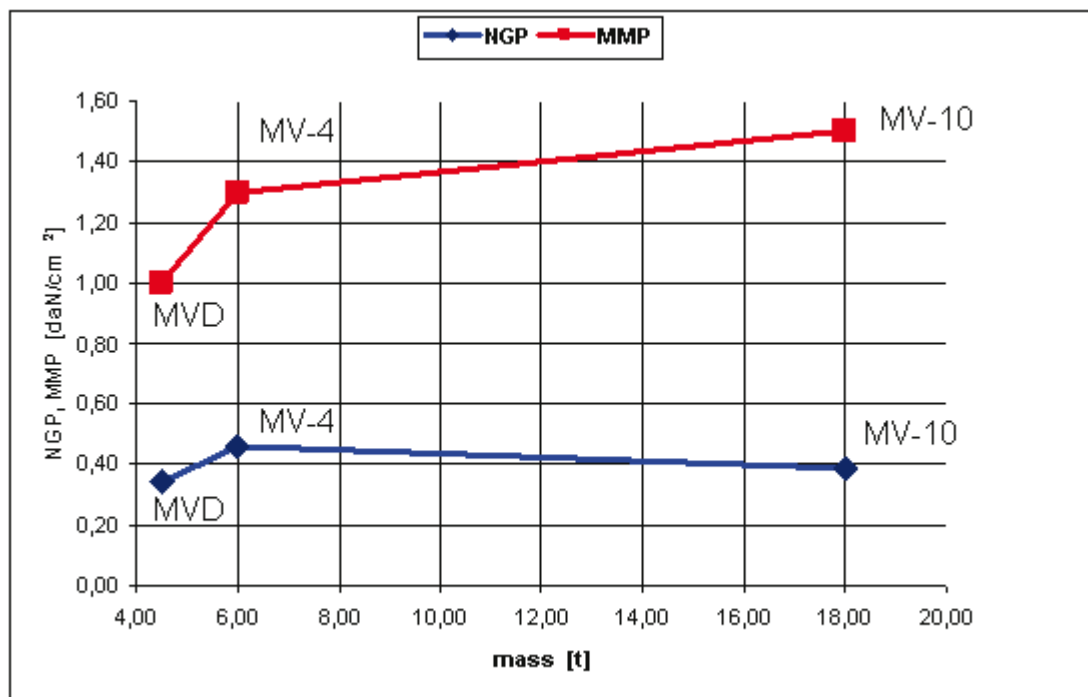


Fig. 5. NGP and MMP for Humanitarian Demining Machines by DOK-ING

6. Mine Protected Vehicles

Mine protected vehicle (MPV) is most common escort vehicle in demining operations. These vehicles are designed to protect the crew from mine threats in humanitarian demining with emphasis on cross-country mobility and countermine protection. Cross-country mobility implies high vehicle performances. Countermine protection implies full ballistic protection against bouncing – fragmentation AP mines and AT mines. Demining machine and other demining mechanization can be remotely controlled from this vehicle. Accordingly, MPV are very demanding project for designers and engineers.

Important characteristics of chassis:

- highest clearance value of 500 mm and other cross-country mobility parameters,
- highest vehicle load of 5 t,
- total vehicle weight to 10 t,
- profile chassis is acceptable for special vehicle superstructure

It is possible to equip the vehicle for different and multipurpose tasks. To transport 10 crew members, volume criteria is 1-1.2 m³ per person, meaning that volume of 10-12 m³ should be provided. *Citadel* option provide sufficient volume for 5-6 crewmembers.

Countermine protection

The goal is to test if vehicle fulfills countermine protection requirements, primarily for level 2a. To develop realistic simulation test conditions, during the design phase, section module can be developed, consisting of front wheel and related armor parts for crew protection above the wheel. Wheel section module can be prepared and tested against mine explosion, or it can be inserted into body of old, used vehicle. Wheel is lifted above the ground and chained to the vehicle body, in order to overcome suspension, shock absorber and spring resistance. This enables setting up the steel pits with mine charge under the wheels (or tracks in case of tracked vehicles).

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1. MPV mine protected vehicle have to provide crew protection at machine demining. Vehicles have to be designed end tested according to safety standards for NATO logistics vehicle.
2. The most important parameters are vehicle's clearance height, double floor, deflectors, independent wheel suspension, run-flat tires, countermine seats, impulse noise and vibration protection.

Mobile mechanic workshops for maintenance of humanitarian machines are also mine protected vehicles. A mobile mechanical workshop is to be planned also on a terrain vehicle of high soil trafficability, protected ballistically and counter-mine as escort vehicles. Due to transport height limitations of workshop vehicles the workshop ought to be projected as a variant of roof elevation. Therefore the workshop has two heights: transport height and working height. For a mechanic's work, workshop's internal height needs to be at least 2 metres. Workshop basic equipment comprises welding equipment, perforating equipment, turning equipment, cutting equipment, various tools, electroenergetic aggregates, and other.



Fig. 6. Escort vehicle and mobile mechanical workshop

The demining machine commonly can not be controlled from a escort vehicle, due to various obstacles. Then the machine operator moves behind the machine. During the machine treatment of mine-suspected area, embedded mines are destroyed or activated. However, occasionally some random AP mines or their parts may remain, presenting a threat of injuries. Therefore, the machine operator remotely controlling the machine, needs to be protected from an accidental explosion of AP blast mines. Of primary concern are legs, body (torso), neck and head. Operator legs, are at the moment of the explosion, exposed to accelerating forces that result from a combination of shock wave pressure and blasted mine fragments. According to the model "cone of destruction" of an AP mine, if an operator is too close to the explosion of an AP mine, there exists a great risk of injuries, ranging from feet and knees to hips and the genital area. Protective machine operator equipment can prevent huge injuries if legs are further away from centre of the "cone of destruction".

Except the above mentioned, protective equipment safeguards the operator from the thrown rock fragments and other debris which the working tool can blast off far away from the machine.

Kinds of machine operator's personal protection:

Passive protection refers to an organization and actions of the machine operator during the very process of demining. When control from a escort vehicle doesn't seem possible (smaller spaces for demining, cross-country, forest, and other), the operator moves outside the vehicle. In this case the operator takes on passive protection:

- keeps a safe distance from the machine in relation to the possible threat (30-100 m considering the estimate of the AP fragmentation mines),
- the operator walks behind the machine, following the rut of the machine's tracks or wheels, whereon the machine silhouette provides a shield for the operator from mine debris under the working device. This kind of operator movement provides greater operator safety than when moving outside the trail lane.

Escort vehicles and machines with direct control from its cabin, are tested for ballistic protection and safety of the machine operator. If the machine operator is located in the armored cabin (of the demining machine or the

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escort vehicle) then he is protected by the machine design (protective armor thickness and protective window glass). During demining, cabin windows have to be closed. That means drivers and operators of the machine are protected inside the vehicle, so when they work, in theory, they needn't wear the PPE gear. However, machine operator and driver often leave the vehicle and come out to the mine-suspected surface, and therefore should wear certain PPE. The level of PPE protection pack can correspond to that of PPE worn by the machine operator moving behind the demining machine.

Active protection refers to PPE of a machine operator. In practice, the level of protection is limited with the capability of machine operator movement. Due to higher equipment weight and fast machine operator weariness, his movability lapses. This is why less equipment is favored.

Depending upon the degree of possible danger in the mine-suspected area, demining companies use levels of protection in line with the threat posed. Basic PPE machine operator equipment remotely controlling, includes: protective vest, helmet with visor and protective footwear.

Vest should protect frontal upper body part, including sides, neck, shoulders and upper parts of hips with groins. Additional protection for back, arms and legs can be used by operator's choice, i.e. demining company.

Helmet with visor has to protect face and its sides, forehead and neck. It should be designed to cover the collar of protective vest or it can be set into collar. It should provide good visibility without restricting the view.

Protective footwear should be comfortable and protect against threats. It is recommended, if possible, to wear countermine boots, or army type boots.

Experiences from using the machine are likewise important. In humanitarian demining (CROMAC), a 10-year experience shows no machine operator casualties, even scoping deminers in control of machine demining. Therefore, no special attention is given to a need of research and solving this issue. Often in practice, minimal PPE operator gear is used: protective vest (according to the CWA test) and suitable light footwear (boots) and head (visor and light helmet). This type of machine operator equipment weighs usually 30-50% less than the weight of standard PPE deminer gear. At the same time still the question remains about the operator protection and effects of AP fragmentation mines. For the time being, this issue is covered by measures of passive protection (operator being at a safe reach from the machine and moving along the silhouette of the machine).

7. Main conclusion and recommendations

A. Situation on machine mobility and use

Evaluation of soft soil trafficability is important for the use of machines. There is a significant difference between the soil trafficabilities of wheeled and tracked vehicles. Tracked machines provide greater soft soil trafficability. Comparing the MMP value of a certain machine with the practically measured CI cone indeks, the possibility of usage on certain terrain can be estimated, but the quality of demining cannot be evaluated.

Problems of usage demining machines on soft soil are forming of a new loose layer of soil under the tracks, which produces poor conditions of adhesion, and causes:

1. Unsafe hold of machine trace on loose layer of soil (direction, turn)
2. Mines being pressed deeper in the soft soil
3. Machine usage on moist coherent soil is not sufficiently determined

The demining and the scientific communities need to conduct further research into the field of terramechanics.

Goals of R&D machine usage on soft soil

1. Examine the problem of loose soil layer trafficability at which the machine moves (sinkage, adhesion,)
2. Determine the machine usage acceptability model in humanitarian demining
3. Define the machine usage evaluation procedure

Machine usage criterion is its mobility on soft soil. Mobility of the machine encompasses:

1. Soil trafficability
2. Working machine soil treatment speed (flat ground, climb, inclination)

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3. Keeping the trace (line, digging depth, manoeuvre)

- B. Special attention, when development of future countermine equipment is concerned, is given to equipment for mine threat neutralization in urban areas. Development of remotely controlled vehicles and intelligent robots enables their application in peacekeeping operations, especially development of *teledemining* machine types. There is a set of alternatives for development of future equipment.
- C. Mine protected vehicles are used as escort vehicles in humanitarian demining. They have to provide crew protection in machine demining. Design of such vehicles isn't yet defined for humanitarian demining demands.

Vehicles can be designed and tested according to safety standards for NATO logistics vehicle. The most important parameters are vehicle's clearance height, double floor, deflectors, independent wheel suspension, run-flat tires, countermine seats, impulse noise and vibration protection.

D. Personal protection equipment of the machine operator

One can distinguish the following kinds of personal operator equipment:

- PPE for the drivers of escort vehicles and machine operator controls the demining machine remotely from the escort vehicle,
- PPE of a machine operator moving behind the machine and who remotely controls the machine (light and medium demining machines),
- PPE of a machine operator who directly controls the machines from the machine cabin (usually, heavy demining machines).

Passive protection refers to an organization and actions of the machine operator during the very process of demining. When control from a escort vehicle doesn't seem possible (smaller spaces for demining, cross-country, forest, and other), the operator moves outside the vehicle.

Active protection refers to PPE of a machine operator. In practice, the level of protection is limited with the capability of machine operator movement. Due to higher equipment weight and fast machine operator weariness, his movability lapses. This is why less equipment is favored. Depending upon the degree of possible danger in the mine-suspected area, demining companies use levels of protection in line with the threat posed. Basic PPE machine operator equipment remotely controlling, includes: protective vest, helmet with visor, protective footwear.

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ALIS Evaluation Tests in Croatia and Cambodia

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Abstract - Tohoku University, Japan is developing a new hand-held land mine detection dual-sensor (ALIS) which is equipped with a metal detector and a GPR. ALIS is equipped with a sensor tracking system, which can record the GPR and Metal detector signal with its location. The Migration processing drastically increases the quality of the imaging of the buried objects. Evaluation tests of ALIS have been conducted in several mine affected countries. Tests in real mine fields in Croatia has been conducted between December 2007 and April 2008 in collaboration with CROMAC. Under different soil and environment conditions, ALIS worked well in QC (Quality Control) stage of mine clearance operations. Then ALIS evaluation test started in Cambodia in February 2009 with CMAC. We could find discrimination capability of ALIS by using GPR in test lanes, and we are planning to start evaluation test in real mine fields in Cambodia in April 2009. Through these evaluation tests in real mine fields, we will gain more experience for improvement of the system, and plan to optimize the SOP for ALIS. In 2009, ALIS will be tested in two international evaluation tests, namely Defuse to be held in Denmark and ITEP test to be held in Germany in 2009.

Keywords – GPR, Humanitarian Demining, Dual Sensor, ALIS, Sensor Tracking System, Croatia.

I. INTRODUCTION

It is expected that more than 100,000,000 landmines are still remaining buried in over 60 countries. Humanitarian demining is a very important and urgent issue not only in mine affected countries, but all over the world. Metal detectors, which is a Electro Motive Induction sensor, has been widely used for humanitarian demining. However, in order to improve the efficiency of the demining operation, identification of buried landmines and discrimination from metal fragments by Ground Penetration Radar (GPR) is believed to be useful. Although there has been some approach to use unmanned vehicles for sensor scanning in mine fields, most of the mine fields are very small and hand-held sensors are more effective.

Due to very strong clutter from the ground surface and inhomogeneous soil to GPR, combined use of GPR with metal detector is more common approach, and this kind of sensor is called "Dual sensor" for humanitarian demining. A few dual sensor systems are now available for humanitarian demining in commercial basis. We have been developing a dual sensor system, namely, Advanced Landmine Imaging System (ALIS) since

2002. The unique feature of ALIS is in its novel technique of tracking the sensor position, even though it is scanned by hand by deminers. Then, ALIS can provide 3-D GPR image and it will help to understand the subsurface conditions much better than the conventional audio signal. It leads to the higher efficiency of detection of buried landmines.



Figure 1. ALIS in operation in Croatia.

The performance and characteristics of dual sensors are quite different from conventional metal detectors. Therefore, new procedures for dual sensors must be established. CEN working group is now working for a document of soil evaluation for dual sensor, and ITEP is now planning evaluation tests of dual sensors. In this paper, we introduce the latest status of ALIS development and its evaluation in Croatia.

II. ALIS SYSTEM

Since 2002, ALIS has been developed and the current system has a few variations dependent on its applications. ALIS can select one from two different GPR systems, namely a stepped-frequency radar by using a VNA (Vector Network Analyzer) and an impulse GPR. The two systems use the same sensor tracking system and a sensor head.

2.1 GPR System

A compact hand-held VNA was developed by Tohoku University under the support from Japanese Science and Technology Agency (JST). The developed VNA is small, approximately 30×20×8 cm, and light weight, less than 1.7 kg, but it has almost the same performance as the conventional commercial VNA

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especially for the sweep speed and the measurement accuracy. VNA is a combination of a synthesizer and the synchronized receiver. It is controlled by a CPU and can store the measured data in its memory. The operation frequency of the GPR system can be adjusted depending on the soil condition by using a VNA, which is not easy for an impulse radar system. The calibration data can be stored in the memory of the VNA, and the output data can be calibrated by using this stored data. This calibration function is useful for better antenna impedance matching, and can improve the radar data quality, because it suppresses the reflection from the antenna.

On the other hand, an alternative type of ALIS, namely ALIS-PG is operated by using an impulse GPR system. This impulse GPR system was also developed in the JST project, and can generate a short pulse having approximately 200ps which covers the frequency ranging from DC to a few GHz. Compared to the VNA system, the impulse duration is fixed, and we cannot change the operation frequency dependent on the soil condition. The important advantages of using an impulse GPR system are its light weight and fast data acquisition rate.

We think, if we operate ALIS-PG in normal conditions, since the impulse GPR system is easier to operate, but if we need to use ALIS in very wet soil condition, ALIS with a VNA GPR is strongly recommended.

ALIS uses cavity back spiral antennas for transmitter and receiver. The antennas are combined with a coil sensor for a metal detector. The location of the coil and antennas were optimized to avoid the interferences. The metal detector is a differential type sensor, therefore it is insensitive to metal objects which are symmetrically placed near the metal detector coil. Electromagnetic wave is transmitted through the coil, and it has some influences, but we founds that the reflection from fixed objects can be suppressed by signal processing.

2.2 Sensor Tracking System

The most unique feature of ALIS is its sensor tracking function. During the operation, the sensor operator can observe the metal detector response image together with a picture of the ground surface displayed on the palmtop PC in real-time as shown in Fig.1. Thus, the area, which shows a high metal detector response, can be scanned thoroughly.

Signal processing and imaging of GPR data is quite common in GPR survey, however, it was not possible in conventional hand-held GPR and dual sensors for humanitarian demining, because the position of the sensor could not be obtained by a hand-held sensor. For imaging of GPR data, the sensor position information is necessary. Since the trajectory of the

sensor is unpredictable in a handheld system, therefore images cannot be constructed without sensor tracking.

ALIS uses a CCD camera fixed on the handle of the sensor head for the sensor tracking. The CCD camera captures images of the ground surface, and the relative movement on the ground surface is calculated by cross-correlation algorithm, and the sensor position can be tracked. Fig.2 shows an example of the tracked sensor position. The dots indicate the positions, where ALIS acquired the data of GPR, metal detector and the sensor position.

This sensor tracking function has significant advantages as follows:

- (1) The handheld scanning operation can be visualized, which improves the reliability of detection by a deminer.
- (2) A deminer can monitor the locus of scanning, and can avoid the scanning blank area.
- (3) The record of the locus of the scanning by the deminer can be recorded and it can be monitored in real time, and can also be checked afterward. This record can be used for quality control of the demining. In addition, it can be used for training of deminers, and can be used also for the determination of the cause of mistake, in the case of accident.

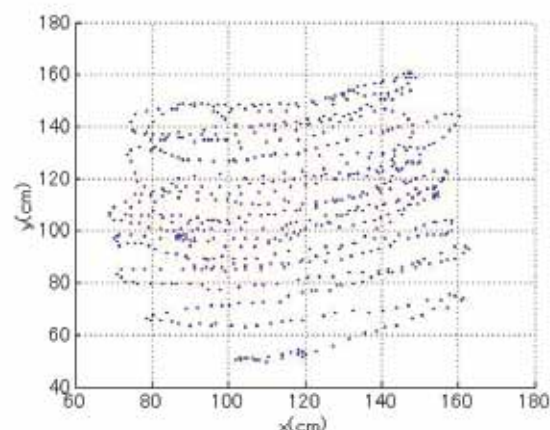


Figure 2. The locus of the sensor trace and the data sampling points.

2.3 Image Reconstruction

The GPR data acquired with the sensor position information is processed after the scanning the ALIS sensor over the area of about 1m by 1m. At first, all the acquired data set was relocated on a regular grid points. Interpolation algorithm is used for this process. After the relocation of the data sets, metal detector signal can directly be displayed in a horizontal image as shown in Fig.3.

3-D GPR image is reconstructed by the diffraction stack migration algorithm. In this signal processing, the vertical inhomogeneity of the soil is considered.

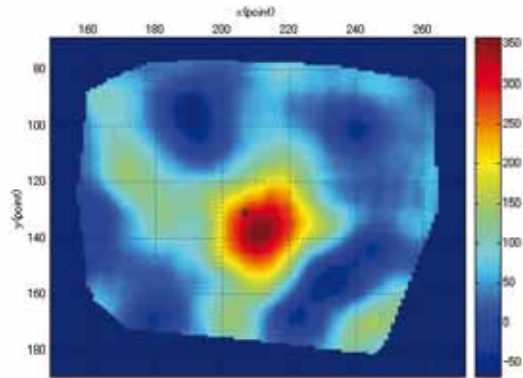


Figure 3. ALIS GPR image acquired at CDS test site (Afghanistan, 2004).

The migrated GPR data gives 3-D reconstructed subsurface image. However, we normally use only horizontal slice image (C-scan) as shown in Fig.3 for data interpretation. However, we think 3D image gives too much information to deminers for judgment, and we normally use a horizontal slice for detection of buried landmine.

III. EVALUATION TEST IN CROATIA

3.1 Evaluation Test in Test Lanes

ALIS has been evaluated in some mine affected countries including Afghanistan (2004), Egypt (2005) and Cambodia (2006). Then, systematic evaluation test of ALIS was conducted in September-October 2007 in Croatia. This test was originally planned as ITEP dual sensor test, but due to cancellation of other sensors, only ALIS was evaluated in this test. Therefore, it is not ITEP test, but ITEP sent observers in this test. The test was sponsored by JST (Japan Science and Technology Agency), and conducted by CROMAC-CTDT, and the test lanes were designed by BAM. In this test, we used ALIS-PG. We trained the operation of ALIS-PG to Croatian deminers for two weeks. It included tutorial of fundamental principle of sensors, and signal acquisition, processing and interpretation. Then, we conducted training operations in calibration lanes. We think two-week training is sufficient, however, longer experience of operation of ALIS improves the skill of the operators.

3.2 QC Test in Mine Fields

After the evaluation test carried out in the test site of CROMAC-CTDT, we agreed with CROMAC-CTDT to start evaluation tests of ALIS-PG in mine fields in Croatia. In this test, ALIS-PG has been tested in QC(Quality Control) operation. ALIS will not be used as a primary sensor, but has been used for a confirmation sensor. The first trial was conducted in December 2007. In the first test, ALIS was operated in the sites which were manually demined and machined demined. The soil in the manually mined area is normal, except the positions where anomaly was dug out, but in the machine demined area, soil was excavated and then it is very soft as shown in Fig. 4. In this area, many gravels were dug out and distributed in the soil. However, we found that the imaging capability of ALIS is not much affected by the soil conditions.

Figure 5 shows one of the buried objects which was detected by ALIS in this site. It is a stone, and a piece of metal located close to the stone. Figure 6 shows the ALIS image for this object. We can see clear response to the metal detector shown in Fig.6(a) and also can see round shape in GPR image shown in Fig.6(b). Therefore, the deminer has judged it as a possible landmine.

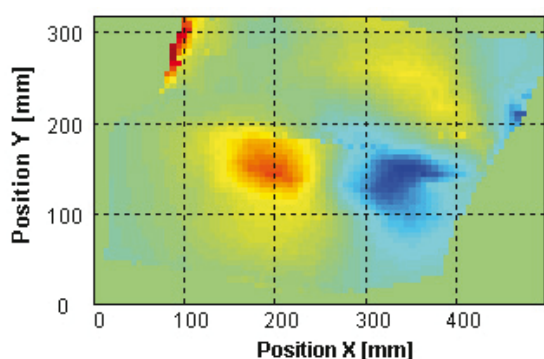
Since this is QC test, we have low possibility to detect real buried mines in operations, we will accumulate much experience of operation of ALIS in different soil conditions. The test is planned to continue for a half year.



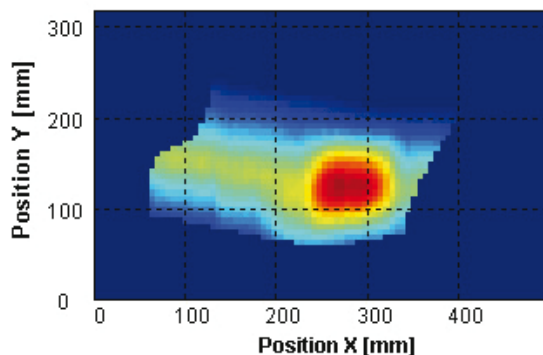
Figure 4. ALIS operated in machined demined area. The soil is very soft, because it was excavated, but we found the capability of GPR imaging by ALIS is not much affected.



Figure 5. A stone with a metal pieces detected by ALIS in QC test. (2008, December 19-PG-2-No.11)



(a) Metal detector image



(b) GPR image

Figure 6. ALIS images of the stone with a metal pieces detected by ALIS in QC test. (2008, December 19-PG-2-No.11)

IV. CONCLUSION

We developed ALIS, which has high efficiency with better reliability for landmine detection by MD-GPR sensor fusion. The developed ALIS can visualize the signal, even if it is a hand-held sensor.

In the Eleventh International meeting of Mine Action Programme Directors and United Nations Advisors was held in April 2008, In Sibenik, Croataia. ALIS was demonstrated in the field demonstration with the results of QC test held in Croatia for about a half year. We are now planning the commercialization of the ALIS systems, and it will be available by the end of 2009. After evaluation test in QC in Croatia, we will plan deployment of ALIS.

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Practical Considerations for Releasing Mine and ERW Suspected Land

Andy Smith, Reuben McCarthy³⁴

The main purpose of humanitarian demining is the release of land to civilian populations that was believed to be contaminated with landmines or Explosive Remnants of War (ERW). This must be done in a way that is cost effective, speedy and provides the best possible guarantee to communities that land is free of any known threats. This paper will discuss processes to release land in a way that increases confidence that land is not dangerous and is free of known threats without necessarily having to undertake full mine Clearance procedures.³⁵

The majority of countries severely affected by landmines and ERW have undergone some form of general survey or mine action assessment to determine the general nature, scope and impact of the mine/ERW problem. One of the main outputs (or anticipated outputs) of such surveys has been to identify Suspected Hazardous Areas or SHAs – that is, defined areas suspected of being contaminated by explosive ordnance that pose a threat to the population. Often SHAs have been categorised by land type (rural, urban, infrastructure, peri-urban, etc), compared with mine/ERW casualty statistics and overlaid with population maps to provide an indication of the impact the loss of these areas and loss of life has on local and national economic and social development. Such analysis has generally been based on primary assumptions that these areas, due to their (suspected) dangerous nature, are not used by local populations and thereby constitute a loss of productive capacity or, if they are used, pose a threat to life.

A consistent perceived shortcoming of general surveys is that they do not accurately define the perimeter of hazardous land, do not precisely identify the nature of the explosive ordnance threats in these areas and have not identified whether the areas are being used by local populations prior to being subjected to demining procedures. While it is rarely the aim of general surveys to achieve these outputs, many mine action programmes have used the findings of general surveys as the baseline or starting point for their mine Clearance operations especially in the absence of more detailed Technical Surveys. It is true that general surveys have done a lot to broadly identify and highlight the general nature of the mine and ERW problem and have enabled governments, donors and mine action operators to identify general priorities. Despite such uses, their utility in supporting the data requirements of operational mine Clearance has been of questionable and inconsistent value.

The use of general surveys to guide and inform technical operations has posed certain ongoing challenges over the years including: the discovery that certain areas defined as SHAs in the general survey are not contaminated to the extent initially thought (and in some cases not contaminated at all); areas either suspected of being mined, or actually mined, are in continuous productive use by local populations placing doubts on claims that SHAs limit local capacities; and mine clearance organisations have sometimes used the perimeter of SHAs (which are often very large) as the starting point for mine Clearance leading to the allocation of assets to sometimes low or *no* priority areas. These elements combined with the fact that mine Clearance can be a very arduous and slow process has sometimes led to the wasteful use of scarce resources and the tying down of clearance assets for

³⁴ The paper was written by Andy Smith and Reuben McCarthy, UNDP Libya and South Africa; it was adapted and presented at the Symposium by Hans Risser, UNDP Croatia. This is a working paper prepared to facilitate discussion and contribute to the debate about Land Release theory and practice. The views expressed are those of the authors and not necessarily those of UNDP.

³⁵ "Land shall be accepted as *cleared* when the demining organisation has ensured the removal and/or destruction of all mine and ERW hazards from the specified area to the specified depth". *Clearance Requirements, IMAS 09:10*, United Nations, 2003.

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months or even years with little return on investments in terms of the actual identification and destruction of explosive ordnance or indeed the return of land to communities.

It has been argued (and continues to be argued) that general surveys should not or cannot be used as a basis for technical operations. As these surveys identify SHAs, there is however a burden of responsibility on government and mine action operators to verify the nature of the threat (real or imagined) contained in these areas, release land suspected to be hazardous, and eliminate false-positives from the survey database. The end result is to provide assurances to local communities that areas identified in general survey as SHAs are safe and, in accordance with the international Mine Ban Treaty, all known mined areas have been identified and cleared of all known threats. The central challenge is that while general surveys often do not provide a solid or accurate basis for effective technical operations, they must be used as that basis because in most countries there is a legal and moral requirement to investigate and eliminate SHAs through some form of investigation.

In recent years this situation has led to the development of more efficient, faster and more strategic work processes to release the often large tracts of land identified as SHAs by the initial general survey. Sometimes known as 'Land Release' methods, these work processes include undertaking a series of evidence based assessments and physical investigation procedures to more accurately define the presence and perimeters of hazardous areas, eliminate false-positives, and release land back to communities more quickly.

The tools at the disposal of mine action operators to undertake Land Release are by no means new. They include qualitative and Technical Survey, Area Reduction techniques, mine/ERW Clearance as well as activities to eliminate errors and duplication in national mine action databases. The point of Land Release is to place a greater focus on evidence based assessment, strategic decision making at each step of the assessment process and the use of more efficient work processes rather than to rely on the full Clearance of all sites identified as SHAs.

By focusing on assessment and the allocation of appropriate demining techniques, SHAs are defined with greater accuracy, can be released more quickly and more efficiently, and affected communities can be given greater confidence that SHAs are safe - even if they have been waiting for full mine Clearance procedures. Basically, unless otherwise required by contractual obligations, demining resources should only be used on the Clearance of *genuinely* mined areas – areas confirmed to be mined. Because most of any SHA is not mined, full Clearance of the entire SHA must be the last choice of any programme as it is often the slowest of all demining procedures. While this might seem very obvious to most people, the presence of large SHAs identified by general survey that must be investigated, even cleared, has led some mine action programmes to attempt to clear all SHAs. The use of Land Release investigation and decision making processes should prevent any mine action programme from having to use the perimeters of land identified as SHAs in the general survey as the starting point for mine Clearance operations.

Making decisions about whether SHAs (or parts of SHAs) should be cleared or released through other means can have serious moral and legal implications. To ensure accountability and effectiveness, it is a minimum requirement that Land Release processes are systematic, governed by public and authorised rules and procedures, and are based on evidence. It is true in most countries that it is incredibly difficult to achieve total confidence that land is completely free of mines or ERW without searching land thoroughly and sometimes multiple times. Even after an area has been searched using approved mine Clearance procedures there is only confidence that there are no detectable mines and ERW to the depth searched and according to the limitations of the technology and search methods applied. As a result it is difficult if not sometimes impossible to achieve total confidence.

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The remainder of this paper describes basic criteria and systems for the release of land to achieve all *reasonable* confidence that an area presents no threat to the end user. Aiming at reasonable confidence acknowledges the realities in the limitations of the evidence and tools that we have to hand to eliminate a threat that, in a short space of time, is never completely knowable. The aim is to ensure that, if there are residual risks after applying Land Release techniques, then those risks are small enough to be tolerable (or nominal) to the people affected and that there are structures that can deal with any residual threats as they come to light.

A very important pre-requisite to undertaking Land Release is the development and application of national policies and standards to which all demining operators subscribe. These policies outline clear and public standards and criteria for Land Release and acceptable standards of tolerable or nominal risk. In the framework of a Land Release strategy SHAs can be released in one of four ways:

1. Using more than one demining procedure (each of which is not full Clearance), the combined results of which give confidence that an area is not actually mined or contains No Known Threat, sometimes known as *Area Reduction*;
2. Using a single procedure to raise confidence that an area is not mined or contains No Known Threat, sometimes known as *Area Verification*;
3. Cancelling areas that are not mined, and were perhaps falsely identified by the general survey as being hazardous, sometimes known as *Area Cancellation*;
4. Using efficient demining processes to clear the SHAs in their entirety.

In efficient demining, most parts of SHAs will be released using a combination of Verification, Cancellation and Area Reduction as the first resort. Most decisions about which method(s) are most appropriate to release land will develop as work on the site progresses. Findings and decisions must always be recorded in a 'task release plan' or similar task dossier. Some decisions about which land is released can even be made prior to the deployment of any assets to the site, usually through the Cancellation of duplicate or unverified records from the national mine action database.

> Releasing land by Area Reduction

Where the perimeters of SHAs are less well defined, parts (if not all) of a SHA can often be released after the ground has been processed in a way that gives confidence to believe there are no mines in that part of a SHA, even if there might be mines in other parts of the SHA. Eliminating specific areas from the record of known threats in a particular SHA is known as *Area Reduction*. Area Reduction introduces the use of selective and precise procedures and the application of agreed standards to give confidence that parts of a SHA were never mined and that no pieces of ERW are likely to be found in the area during the normal use of the land.

Area Reduction procedures used can include:

1. Percentage Clearance using manual or MDD procedures;
2. Battle Area Clearance (BAC) procedures, including sub-surface BAC; and
3. Mechanically processing the ground.

In general terms, clearing a part of an SHA and finding no evidence of explosive ordnance does not itself constitute conclusive evidence that there are no explosive ordnance in the remainder of an SHA. In situations where evidence indicates a low probability of a mine threat 'percentage Clearance' can however be undertaken to increase confidence. Percentage Clearance is a method of sampling that includes the systematic Clearance of

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an agreed percentage of an SHA using a uniform search pattern. Typically percentage Clearance includes the Clearance of at least 20% of the total suspected area using full Clearance procedures. The area to be cleared must ordinarily cut across the entire suspected area in a grid pattern that is designed to clear at least 4 of every 20 square metres. Given that many mined areas are laid in regular and sometimes predictable patterns percentage Clearance will in all probability identify any threats. Finding no evidence of mines using such techniques can go a long way to increasing confidence that there are no mines in the unsearched areas and also confidence among the local population.

While percentage Clearance does not itself constitute a guarantee that there are no mines, it can significantly increase confidence. Due to the inherent risks in applying a percentage rule, task supervisors must rigorously apply standards in the process of analysing a task. They should only make decisions on what parts of an SHA can be reduced by percentage Clearance when the following conditions prevail:

1. There are no reports of accidents to people or livestock within at least 50 metres of the area to be reduced;
2. There is no record of a minefield within 50 metres of the area to be reduced;
3. No mines have been discovered within 25 metres;
4. There is no evidence of trip wires, stakes, mine casings, packaging, fuse clips and arming pins, etc, associated with the presence of mines or mine use; and
5. The area does not include *hot-spots* that are more likely to be mined, such as military installations.

Following the 20% Clearance of the SHA, the remaining area should be processed using a ground engaging machine and/or searched using BACS (Battle Area Clearance Subsurface) procedures. Additionally, when there are features in the area that are likely to be mined (*hot-spots*) those areas must be cleared fully. Examples of such areas include places that combatants may have been expected to take cover, such as around trees, in ditches and trenches, around large rocks or abandoned buildings. Other more obvious examples include military installations of any sort.

Battle Area Clearance (BAC) is the controlled, systematic and typically fast search and surface Clearance of SHAs that are suspected or known to contain unexploded and abandoned ordnance, but do not contain mines of any type.³⁶ BAC includes a visual inspection of suspected land which can provide confidence that there is no known threat and no need to undertake Clearance or demolition. A task leader can decide that a battle area can be released without the need for full Clearance under the following circumstances:

1. There are no reports of accidents to people or livestock within 100 metres of the suspected area;
2. There is no record of a minefield within 50 metres of the area;
3. Despite being included as part of a bigger SHA, there is no evidence that the area was the site of a battle and on visual inspection there is no evidence of surface ERW;
4. The use of the area will not include construction or agriculture that requires excavation of some type;
5. The area has not been subjected to mechanical ground processing as this may bury ERW;
6. The BAC team is equipped with appropriate sub-surface detectors in case sub-surface BAC is being undertaken;

³⁶ *Battle Area Clearance, IMAS 09:11, United Nations, 2007.*

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7. When land is intended to be used for farming, construction or other activities that might require excavation of some type that BACS should be undertaken as an essential search procedure;
8. There is no evidence of ERW, their casings, packaging, fuses, etc.; and
9. There is no evidence of trip wires, stakes, mine casings, packaging, fuse clips and arming pins, etc, associated with the presence of mines or mine use.

In mined areas, land can often be released after it has been processed by mechanical equipment, such as a flail or in smaller areas an armoured back-hoe, among other such equipment. Having said this, mechanical equipment has not yet proved to provide sufficient guarantees that land is clear when used alone. Mechanical clearance should as a result always be accompanied by some form of manual mine clearance to give greater confidence that areas are likely to be free of any threats. A task leader could decide to release land utilising machines when:

1. There are no reports of accidents to people or livestock within 100 metres of the suspected area;
2. There is no record of a minefield within 50 metres of the area;
3. No mines have been discovered within 50 metres;
4. A machine has been used to process the ground to the required depth and there have been no detonations or evidence of mines;
1. There are no features in the terrain that prevent the machine processing the ground to the agreed standard;
5. The machine has processed the ground twice, moving in different directions;
6. When there are no features in the area that are more likely to be mined, such as military installations - those areas must be cleared manually; and
7. At least 10% of the total area has been cleared utilising manual techniques or MDDs, where the area processed must cut across the land in a grid pattern that is designed to clear 2 square metres of every 20 square metres; or the entire area has been processed using BACS procedures.

Assuming no evidence of mines or ERW have been found, areas that have undergone percentage Clearance, BAC/BACS or have been mechanically processed must be mapped thoroughly, showing what has been cleared and the total area that has been reduced. Reports should accompany the release of such land including a description of the search procedures and an *affidavit* by the task leader that no evidence of mines or ERW was found using the agreed search procedures. Assuming compliance with standards and work processes, the team leader is in a position to release the land without having to undertake the full manual Clearance of the area, saving both time and money.

> Releasing land by Area Verification

There are some situations when the mine action programme has no evidence to believe that an area is hazardous, but local communities believe there is a threat despite all assurances. In mine action, real or perceived threats have the impact of limiting the use of productive land and effecting the wellbeing of a community. As a result, some form of verification may be required to give confidence to the community and release land that might not otherwise be used. Providing such guarantees is known as *Area Verification*.

Following detailed historical analysis of the area, its use in military operations and reviews of any past mine action surveys in the area (among other information), the two primary means of Area Verification include Battle Area Clearance or mechanically processing ground. These two methods can provide sufficient (though not

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absolute) assurances that an area includes No Known Threats. Both methods are also far quicker than traditional manual Clearance methods. The conditions for using either method to verify land are as follows:

2. No historical records or visual evidence of conflict in the area such as with abandoned fighting vehicles and equipment, conflict damaged or destroyed buildings;
3. No reports of accidents to livestock or people within 150 metres;
4. No minefields or minefield-records exist within 150 metres of the area;
5. No mines or ERW have been discovered within 150 metres of the area;
6. The machine has processed the ground to at least 15cm;
7. When using machines alone, there are no features in the terrain that prevent the machine processing the ground to the agreed standard;
8. There is no evidence of mines or ERW including trip wires, stakes, mine casings, packaging, fuse clips and arming pins, etc; and
9. The area does not include sites that are more likely to be mined, such as military installations.

Neither BAC nor mechanical methods provide the same level of guarantees of full safety as does manual Clearance. Nonetheless, assuming no evidence of a mine or ERW threat is found, such procedures can provide sufficient evidence that the area has been verified as having No Known Threats and so can be released to the community with a measurable degree of confidence. As in previous procedures, all work must be clearly documented, mapped and an affidavit signed by the team leader that due process has been followed. When undertaking Verification, task reports must state that the land has been Verified but *not* Cleared.

> Releasing land by Technical Survey

The aim of Technical Survey is to collect sufficient information to enable the Clearance requirements of an SHA identified in general survey to be more accurately defined,³⁷ including the precise area(s) to be Cleared, Reduced, Verified or Cancelled, the nature and condition of the terrain and the task and the method of demining that might be required. Technical Survey is distinguished from other survey methods by the fact that survey teams have a limited mine Clearance capacity and are thereby able to physically confirm and delineate the boundaries of a mined area. Technical Survey involves some form of Clearance to establish the boundaries of Confirmed Hazardous Areas that might exist within a larger SHA, releasing suspect land that is not confirmed to be mined during the survey. Technical Survey teams are required to mark Confirmed Hazardous Areas with official warnings and markings.

Because most recorded SHAs are much larger than the area that is confirmed to be mined, Technical Survey should always be conducted before Clearance at a SHA begins or is even considered. The results of the survey will result in an accurate Task Assessment, including land release planning requirements. The Assessment will determine *High Threat Areas*, *Low Threat Areas* and areas with *No-Known Threats* within the SHA.

High Threat Areas are parts of an SHA where there is physical evidence that there may be mines present. High Threat Areas will have been identified during the Task Assessment and must be marked on the SHA map. Manual Clearance methods used during Technical Survey in High Threat Areas include *breaching*³⁸ the hazardous areas using patterns of:

³⁷ *Technical Survey*, IMAS 08:20, United Nations, 2003.

³⁸ *Breaching* is the process whereby manual Clearance teams starting from a known safe area clear lanes into a hazardous area to a designated depth, distance and width.

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- A grid of ten metre wide breaches that are 50 metres apart, or
- A grid of two metre wide breaches that are 10 metres apart.

The wider breach pattern is often more appropriate when machines are available to prepare the ground in advance of manual demining, but the aim is always to ensure that at least 20% of the area has been cleared during breaching. At times a combination of two and ten metre breaches can be used so long as 20% of the area is cleared to provide confidence. Following the identification of the High Threat Area a five metre wide safe area should also be cleared around the perimeter, which will actually increase the area cleared to more than 20%.

The grid and breaching pattern should be designed to include any features within the area where mines are more likely to have been placed such as areas that provide cover to combatants, military installations, battle damaged equipment and buildings and so forth. If the grid does not include Clearance through such features, two metre wide breaches should be cleared to them and an area of five metres cleared around them.

If no evidence of mines is found during the breaching-Clearance the areas between breaches should be considered for Area Reduction using the methods described previously. If evidence of mines is found a 20 metre area surrounding each mine in all directions will need to be cleared fully.

Low Threat Areas are parts of an SHA where mines and ERW are not anticipated. Irrespective of the lower threat rating such areas will need to be marked on the map of the SHA and included in the Task Assessment and ultimately the land release plan. Because no regular pattern of mines are anticipated in such areas, a grid of breaches should be cleared across the area using manual demining or mine detection dogs. Such breaches can also be mechanically prepared when machines are available. The grid and breaching pattern must be designed so that at least 10% of the area is cleared. A two metre breach should also be cleared around the perimeter of the area, which will increase the area cleared to more than 10%. As in High Threat Areas the grid and breaching pattern should be designed to include features that are more likely than others to be mined and when the grid does not cover these areas a two metre breach should be cleared to them and an area five metres around them should be cleared.

If no evidence of mines is found during the breaching process but ERW is found, the areas between breaches can be processed using Area Reduction techniques previously discussed. If mines are discovered the area should be reclassified as High Threat and the conditions for High Threat Areas described above will need to be applied, including the possible need to undertake full Clearance.

No Known Threat Areas are parts of an SHA where there is no reason or evidence to believe there is a threat. Typically such areas include parts of an SHA that are regularly used by local communities and which they believe to be safe. Despite the lower threat rating such areas still need to be recorded on the SHA map and within the land release plan. Technical Survey should not be undertaken as a first order of priority in such areas until both high and low threat areas have been processed. If no evidence of mines or ERW has been found during the Technical Survey of surrounding areas within 100 metres, such areas can be *Verified* or *Cancelled* as described in this paper. If evidence of mines or ERW is found in the surrounding 100 metres the area should undergo *Area Reduction* as previously described.

Obviously, land cannot be released following Technical Survey unless no evidence of mines or ERW are found. If evidence is found, the relevant areas may need to undergo full Clearance or processing using Area Reduction techniques. If no evidence is found, the entire area can be effectively released and different parts of the SHA

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recorded and mapped according to the land release methods that were applied: *Cleared, Reduced, Verified, or Cancelled*.

> Releasing land by Area Cancellation

In certain circumstances land can be released after a process of *Area Cancellation*, meaning the area has been removed from the records of SHAs. Typically Cancellation takes place either when initial surveys have obviously created a false-positive record, have made an error in the location of a SHA, or if conditions at the site have changed so much that there is no longer any evidence to believe that there is a remaining threat - if indeed there ever was one.

Area Cancellation does not require any demining assets to be deployed, but does require the application of strict criteria. Cancellation criteria are designed to determine whether there is any reason to believe that the reported SHA contains any hazards and why the error was made. If no hazards are identified the area can be Cancelled and recorded as having No Known Threat. It is important to note that Cancelled areas should never be recorded as being Cleared because there may be a reason to revise the threat status of the area at a later stage and demining assets may need to be deployed.

Area Cancellation involves a process of information gathering, analysis, deduction, reporting and the application of criteria when making decisions. This includes:

1. Collecting all existing information about the area, including initial general survey data, any subsequent Technical Survey data, assessments and information that may have been collected by mine risk education operators, among others;
2. Deploying an Assessment Team and gathering new information about the area with a site visit, including discussions with community leaders, (ex)combatants, men and women;
3. Analysing all available information;
4. Applying the criteria for Cancellation; and
5. Reporting.

The Assessment Team may Cancel an entire area or parts of the area, depending on the information that comes to light during their assessment as long as the criteria for Cancellation are followed and a Cancellation Report is generated, which includes a map of the Cancelled area. By applying the same criteria, a task leader may Cancel a part of a task as Clearance, Area Reduction, or Area Verification work progresses. The general criteria for Cancelling a part of entire SHA include:

1. Local people use the area and do not report any mine or ERW threat;
2. There have been no reports of accidents to people or livestock within 150 metres of the area;
3. There have been no detonations of mines or ERW;
4. There are no records of a minefield within 150 metres;
5. No mines or ERW have been discovered within 150 metres;
6. There is no evidence that the area was a battle area;
7. There is no evidence that the area was used as a military position or was militarily important;
10. There is no evidence of mines or ERW including trip wires, stakes, mine casings, packaging, fuse clips and arming pins, etc;
8. No demining works, whether by villagers or organisations, have been conducted in the area, including Clearance and marking;

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9. When ground between the No-Threat Area and the nearest mine found has been Reduced and no additional evidence of mines has been found; and
10. The Assessment Team are entirely happy to walk over the area or, if the possible hazards included anti-vehicle mines, drive over the area.

Additional, more specific criteria for Cancellation can be applied and should include a more detailed analysis of how local people have been using the land (according to the type of land) and for how long. For example, agricultural land that has been cultivated by ploughing for longer than two years strongly indicates that there is likely to be no threat.³⁹ Such information added to the general criteria can give strong reasons to Cancel a suspected area, assuming all process have been followed and detailed reports have been kept. Depending on the legislative, coordination and accreditation arrangements in a particular country, it is also important that Cancellation reports are reviewed, authorised and possibly verified by a group external to the team undertaking the work, usually the National Mine Action Authority or other government authorities.

Sometimes SHAs can be Cancelled following the identification of a statistical error made during the general assessment or data entry which leads to identification of a “false positive”. This could occur when map coordinates for the SHA have been incorrectly recorded and the descriptions of the area included in the initial survey reports do not in any way match the conditions observed by the Assessment Team, or it could follow from the reproduction of duplicate records contained in the national mine action database for areas that have already been released. When this occurs the Assessment Team will need to:

1. Review task information and try to identify the real position of the recorded SHA in case the problem is one of location as opposed to false identification;
2. Determine what demining has already taken place in case the false positive was generated through a duplicate report of some type;
3. Interview local people (both men and women) and local authorities to try to identify the real position of the recorded SHA and the circumstances that led the present area to be identified as an SHA;
4. Accurately record the boundaries of the area to be Cancelled using GPS and produce a detailed map of the area; and
5. In the presence of local authorities, walk (or drive) over the SHA to be Cancelled - unless there is reason to believe that this area may itself be mine affected even if the area doesn't correspond to the initial survey reports.

If following a process of evidence gathering, consultation, observation and deduction the area is verified as a false-positive the area may be Cancelled. Cancellation must be accompanied by stringent reporting guidelines and the provision of that information to the National Authority or equivalent body, along with an affidavit by the team leader that due process and standards have been correctly applied.

The use of land released through Cancellation depends on the end-users' confidence in the approach. If end-users do not agree with the Cancellation of a task and no new evidence is presented that indicates there is a threat,

³⁹ *Special Criteria for Cancellation of Surface Areas and Buildings out of the MSA*, National Mine Action Standards, Republic of Croatia, January 2006, pg. 28. The criteria described in the Croatian standards provide very good examples of detailed and contextually appropriate criteria to Cancel areas and provide assurances that land is safe.

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additional measures may need to be undertaken to increase confidence to an acceptable level. In certain circumstances this can be achieved by using Area Reduction or Area Verification techniques previously discussed. In addition a ground processing machine alone might also be used over the land to raise confidence that there are No Known Threats in the area. During such processes if evidence comes to light that there may be a threat, the decision to Cancel or Verify the land must be revoked and the plan revised to include Area Reduction or Clearance as required.

> Releasing Land by Full Clearance

All parts of a SHA area can of course be released following a thorough process of manual demining or demining with dogs searching to an agreed depth and in accordance with methods that comply with national/international standards. This is the most obvious solution to eliminating SHAs but is often wasteful of resources because large parts of SHAs often prove not to be mined. Nonetheless, in many instances hazardous areas may be confirmed and the perimeters of the area clearly defined following Technical Survey or as a result of detailed minefield maps or markings. This is often the case in border minefields and at military installations that may sometimes contain mines laid in regular and predictable patterns. Where mines have been confirmed to be present and where the land is not in general use (because the local community know it to be dangerous) full Clearance is the only option to release the land back to communities. Clearance procedures to be used include:

1. Manual demining utilising metal detectors
2. Manual demining using area excavation procedures
3. Mine Detection Dogs (MDD) supported by manual demining.

Typically the search depth for manual demining is 13cm as this corresponds to the current maximum depth that modern metal detectors can reliably detect minimum-metal mines in electromagnetic ground conditions. In case the initial task assessment has found evidence that ordnance might be encountered at greater depths the search depth for these items should be increased. The important elements here relate to the application of agreed search depths based on the findings of the assessment, which will normally be governed by national standards. The Clearance process can be assisted by using machines to remove undergrowth or loosen the ground. Despite some claims otherwise, there currently appear to be no demining machines that have yet established their ability to clear ground to standards that are acceptable in humanitarian demining operations. As a result the use of demining machines alone should not yet be used to provide any guarantee of full Clearance.

Following full Clearance, Quality Assurance procedures are ordinarily applied to determine the success of the effort and gauge whether agreed standards have been complied with. Assuming no evidence of mines or ERW have been found following Quality Assurance, areas that have undergone full Clearance must be mapped thoroughly, showing what has been cleared. Reports should accompany the release of such land including a description of the search procedures and an affidavit by the task leader that No Known Threat remains and that due process and standards have been applied. Assuming compliance with standards and work processes, the team leader is in a position to release the land.

> Conclusion

Many of processes described in this paper are not new, but have been presented to show that the way suspected hazardous areas are approached and demining methods are applied enables mine action programmes to be more strategic in how limited demining resources are deployed. Efficient Land Release requires an intelligent combination of office based and field procedures that make the most effective use of all assets. A sequential approach needs to be followed, which starts with evidence based assessment and followed by the application of

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the most appropriate demining techniques available. Following such processes means that land should only undergo full Clearance where there is documented and physical evidence that hazards are present. What constitutes conclusive evidence is of course the subject of debate and disagreement.

This paper has tried to go some way to present certain rules that give fixed criteria for decision making such as the distance from a discovered device that must be subjected to full Clearance or the distances of dangerous areas from other areas before they can be declared as containing No Known Threat. It is necessary for the guidance of those in the field to use fixed parameters because it provides consistency in operations that will help ensure coherence and confidence in the processes and outcomes of demining operations. That being said, the parameters that have been presented here should not be adopted without assessing how appropriate they are for the country and demining context in question. The Croatian programme, for example, has very detailed criteria for the cancellation of tasks which go considerably further than the ideas presented here and are no doubt more appropriate to the legislative framework in Croatia.⁴⁰

The degree of evidence required and criteria to release land should be developed and approved by national authorities as part of a Land Release Strategy or Land Release Standards, because they take responsibility for the outcomes and the potential that any hazards might be discovered after land is released. Keeping in mind that no method of Land Release is fail-safe, national authorities should also be prepared to undertake reassessments as required and maintain demining capacities in case of residual threats. At the same time, national authorities must ensure the consistent application of the defined standards by operators through quality control and coordination.

Finally, many of the terms used in this paper have been used before, but not always with the same practical definitions. It is important that we continuously discuss our terms to ensure the best practical applications of them. The exception is the definition of 'Clearance' which is used as it is defined in IMAS 09.10: "Land shall be accepted as 'cleared' when the demining organisation has ensured the removal and/or destruction of all mine and ERW hazards from the specified area to the specified depth".⁴¹ This definition has not been altered because if Clearance is needed for Land Release operations we must aim for the highest standards possible, according to the strengths and limitations of the technology and methods that are available. Having said that, we are hopeful that the ideas, definitions and rules presented in this paper will stimulate debate and assist the process of applying the theory of Land Release in practice.

April 2009

⁴⁰ See for example: *Special Criteria for Cancellation of Surface Areas and Buildings out of the MSA*, National Mine Action Standards, Republic of Croatia, January 2006.

⁴¹ *Clearance Requirements, IMAS 09:10*, United Nations, 2003.

The Use of the MECHEM Explosives and Drug Detection System (MEDDS) as a Survey Tool

Ashley Williams⁴²

INTRODUCTION

1. The MEDDS system, also known as Remote Explosives Scent Tracing (REST), is a system originally designed and used by MECHEM as a security system for the detection of explosives and ammunition at border posts and other ports of entry into South Africa. After 1994 when the threat of illegal explosives and ammunition smuggled into South Africa subsided, or rather was expected to decrease, the system was adapted for use in mine action operations, mainly as a survey and area reduction tool.

2. MEDDS was initially designed to reduce the natural inefficiencies of dogs by taking the smell or odor to the dog instead of taking the dog to the smell/odor. MEDDS is based on the concept of drawing/concentrating the air (and the dust and impurities suspended in the air) in an area suspected of containing a specific substance, through a medium that would capture, retain and, when required, release the smell in order to allow specially trained dogs, working in a controlled environment, to identify and indicate the presence of the specified smell or odor.

3. Since 1996 MECHEM has successfully used the MEDDS technology in mine action operations in Angola, Mozambique, the DRC, Sudan and Afghanistan. Due to many factors such as MECHEM often not being contracted to do the follow up clearance and the notorious MECHEM reluctance to paperwork, the keeping of accurate statistics was not done and the success of the technology was not scientifically quantified. The MEDDS technology was greatly enhanced by a comparative study between the technology and the Nomadics Fido in a research project financed by NVESD of the USA and executed in Croatia. This study greatly enhanced the knowledge of all concerned in the leeching of explosives and ultimately in the fundamentals of the MEDDS technology.

PRESENT DILEMMA

4. The present dilemma in the demining world is the search for a fast and effective method to hand back suspected land and roads/routes without going through the laborious process of physically demining. This has led to the concepts of acceptable risks and land release which presently are still under rather intense discussion. In the process the different concepts such as survey, assessment and verification have not yet been clearly defined and distinguished. Although terminology and semantics should never become stumbling blocks it can have a large impact in the field of mine action. In the case where MECHEM is very involved in road and route clearance the difference in understanding between survey, assessment and verification can be rather drastic. A road/route assessment can mean a very subjective and flawed assessment by an individual that can lead to the road/route being declared as having "no evidence of mines and UXO's". The nature of the conflict, the demographics of the country as well as the displacement of the population make this a very dangerous and even meaningless judgement call to make. On the other hand verification will mean the use of at least two demining tools on the road/route which has obvious cost and time implications.

THE ROLE OF MEDDS

5. With the above dilemma in mind the use of MEDDS becomes an excellent option to enhance an assessment or make verification faster and less costly. Whilst MEDDS will not and cannot indicate the exact location of a mine or UXO, it will indicate large areas where there is no presence of explosive vapour, thus making the call of "no evidence of mines and UXO's" much more objective and scientific. Using MEDDS in conjunction with a trained individual's tactical and operational observation skills will make the survey,

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assessment or verification of a road/route very accurate and cost effective. Recent operations in Afghanistan, Sudan and Angola have proven the worth of using MEDDS in the road/route assessment, survey and verification role. Irrespective of the terminology used the introduction of MEDDS will ensure that subjective judgement is ruled out and that the assessment, survey or verification has a strong and reliable scientific backing.

6. Presently MECHEM surveys (the term survey is used for uniformity) roads/routes over 200m sectors. Sampling is either done on foot (only in exceptional circumstances where safety can be guaranteed) or by using a mine protected vehicle as carrier. The exact location of each sector is either physically marked or preferably recorded using a differential geographic positioning system (DGPS). The filters containing the air samples taken over each 200m sector are then sent for analysis by the specially trained MEDDS dogs. Presently MECHEM has analysis facilities in Pretoria and Menongue, Angola.

Photo 1: Sampling from a TAPIR MPV in Afghanistan



7. In the analysis facility each sampled MEDDS filter is investigated by using 3 trained dogs which are each given 2 runs over the filter; thus a total of 6 “noses” over each filter. If any of the 6 noses indicates the filter as containing explosives the particular sector where the air was drawn from is declared positive and conventional demining methods are used to clear that sector. If the dogs do not indicate any filters in a sector as containing explosives, the particular sector can be declared as having “no evidence of mines or UXO’s”. In this case the statement made will not be a subjective judgement call but will be substantiated by the MEDDS analysis.

8. The MEDDS survey that MECHEM did for UNOPS along the Kabul-Kandahar road (arguably one of the most contaminated areas in the world) delivered a 35% positive rate. Whilst this seems very high one should remember that in real terms this meant that the follow up clearance was reduced by two thirds of the time. Unfortunately MECHEM was not responsible for the physical clearance of the positive sectors and thus does not have exact statistics. However the fact that no construction machines unearthed or detonated any mines or UXO’s goes a long way in proving the effectiveness of the system.

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Photo 2: Sampling team in Afghanistan



9. In Angola MECHEM is presently busy with a MEDDS survey of the road between Menogue and Caiundo for a road construction company. This road was previously cleared by a local demining company, but after two bulldozers detonated mines MECHEM was requested to do a MEDDS survey. Many of the “cleared” areas have been indicated as positive by MEDDS and quite substantial ERW found in these areas/sectors.

Photo 3: ERW found in a “cleared” area



10 Sudan Case Study: Ngulere to Lokiline. This route of 33,6km was surveyed by MEDDS. A total of 168 sectors each 200m in length were sampled thus using 336 filters. Of the 168 sectors sampled only 14 were indicted as positive, thus only 2,8km of the total 33,6km (8,33%) had to be investigated further. In practical terms this meant that if the whole route had to be verified using one Mine Detection Dog Team (MDDT) it would have taken 56 days, whilst verifying the MEDDS positive areas with a MDDT would only have taken 5 days. In 13 of the 14 positive sectors ERW were found as indicated in the table below:

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Table 1: ERW found between Ngulere and Lokiline

Resources used	Device Type Found	Device Name	Quantity
VMMDS	UXO	F1 Hand Grenade	2
	Fragments	7.62 mm cartridge	27
MDD	Fragments	7.62 mm empty cartridge	26
	Fragments	Mortar Shrapnel	8
	Fragments	7.62 mm round	1
	Fragments	7.62 mm cartridge	4
	AT	PRBM3	1
Manual	UXO	F1 Hand Grenade	2
	UXO	60 mm mortar	1
TOTAL			72

11. Due to the fact that terrain and climatic conditions differ drastically from location to location it is difficult to determine an exact production rate for the system on roads and routes. As a rule of thumb a mobile MEDDS sampling unit can cover approximately 25km per day over a width of 8m whilst a foot team will cover approximately 5km per day. An analysis facility with 3 dogs will be able to analyze approximately 400 filters per day.

FURTHER USES OF MEDDS IN MINE ACTION

12. The use of the MEDDS technology in road and route survey by MECHEM has proven to be very successful, both from a cost and time perspective. However it is felt that the system has just as great potential for use in land release where one has huge tracts of land that are only "suspect" with no real evidence of mines and UXO's. Once again the question can be asked as who would be prepared to take the risk and put hand on paper declaring the entire area free of mines and UXO's? The innovative use of MEDDS can add credibility to any land release program at a fraction of the cost and time of traditional demining methods.

13. Furthermore the present international requirement that any ground cleared solely by machines needs to be followed up by a 10% manual sampling creates an excellent opportunity for using MEDDS as a QA tool. Especially where very large tracts of land have been mechanically cleared MEDDS could be used as a 100% QA tool and still be much faster and cheaper than manual methods. The exact mechanics of using MEDDS in this role is presently being investigated between MECHEM and DOK-ING.

CONCLUSION

14. The MEDDS (or REST) technology has matured to such a level that it should be used more aggressively in survey and other mine action roles. Unfortunately conventional demining methods are very time consuming and costly and have necessitated concepts such as land release and assessments that are highly subjective by nature. However combining these concepts with MEDDS surveys can add creditability and give a greater sense of trust in these methodologies.

15. A method must also be found to negate the fact of MECHEM ownership of MEDDS since everyone is aware of the competitive nature of the demining market. The establishment of a number of MEDDS analysis facilities strategically placed across the world to which any company can send MEDDS filters to be analyzed could be a possible solution. Unfortunately MEDDS is a very complex system that needs to be actively managed (as a number of companies have discovered) and the answer is not as simple as it seems. Any mistake, from the sampling process right through to the final analysis of the filters will lead to the system failing.

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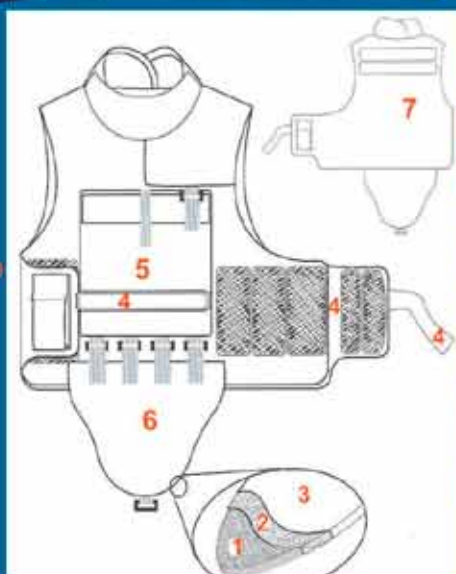
B-1



BALLISTIC PROTECTION
Protective vest against fragments B1
Protection level: STANAG 2920
 $V_{50}=480\text{m/s}$

Composition of protective vest. B-1 and B-1A

- 1 – Protective package (aramidic PPTA material)
- 2 – Covering for the protective package
- 3 – Outer cover of the vest (hydrophobic)
- 4 – Velcro tape
- 5 – Pocket
- 6 – Protector for genitals-only for B-1
- 7 – Back part



Assignment:
Protection from fragments which are from exploded missiles, grenades, rejected missiles and physical shoots primarily for demining activities. This type enables comfortable wearing with well movements during working, moving and using of military technique, armament and vehicles (e.g. for the tasks of mechanized earthy troops).



MINE & UXO DETECTION

Metal Detector VMH3CS
with pinpointing feature



60-cm-Search Head
for deep lying metal
cased mines / UXOs



UXO Detector VMXC1-3
with special firmware to
detect country-specific
submunition



Metal Detector VMC1
for special tasks



Dual-Sensor-Detector VMR2
GPR and metal detector to
detect metal and metal-free
objects



Vallon GmbH has been a manufacturer of mine detectors for more than 40 years. The own R&D division develops hand-held mine detectors, hand-held bomb locators, vehicle mounted multi sensor detection systems, navigation tools for the field work, and powerful software for automatic evaluation of the detector data and following identification of UXOs.

Vallon GmbH's engineers and technicians work closely with the users in order to integrate their requirements into the equipment.

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HCR

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With its testing capacity (test sites and equipment) and highly professional staff, the Center offers the following services:

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- testing of mine detection dogs
- testing of metal detectors
- training and issuing certificates for the use of metal detectors
- testing of demining methodologies, technologies and equipment
- training of work site managers, demining teams and monitoring personnel
- organizing workshops, conferences and other gatherings on the subject of mine action
- preparation for introducing quality management in demining companies as per ISO 9001:2000
- lease of test sites
- implementation of research and development projects in the field of mine action
- field testing and evaluation of technologies used for mine contaminated area detection and mine suspected area reduction
- scientific and professional cooperation with national and international institutions.