

A Guide to



Road Clearance



GICHD | CIDHG





The Geneva International Centre for Humanitarian Demining (GICHD) works for the elimination of anti-personnel mines and for the reduction of the humanitarian impact of other landmines and explosive remnants of war. To this end, the GICHD, in partnership with others, provides operational assistance, creates and disseminates knowledge, improves quality management and standards, and supports instruments of international law, all aimed at increasing the performance and professionalism of mine action.

A Guide to Road Clearance, First Edition, GICHD, Geneva, July 2008.
ISBN 2-940369-11-9



Acknowledgements

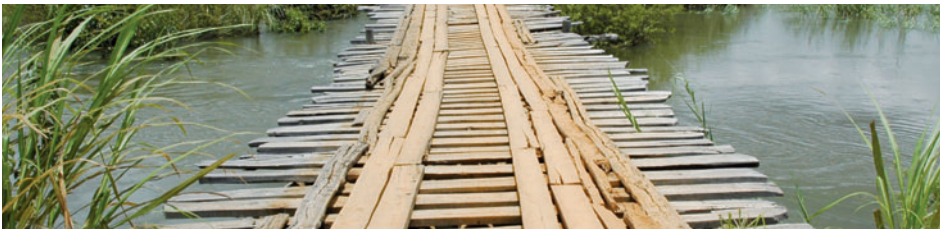
The GICHD would like to thank the four mine action programmes whose work and experience is particularly reflected in this Guide – Afghanistan, Angola, Mozambique and Sudan; the Governments of Germany, Norway and Sweden for their financial support; and individuals who contributed to this GICHD review of road clearance techniques and procedures: Håvard Bach, Al Carruthers, Rune Engeset, Roger Hess, Maxwell Brent Jones, Klaus Koppetsch, Pehr Lodhammar, Alan Macdonald, Stuart Maslen, Sharmala Naidoo, Landon Shroder, Ted Paterson and Peter Renwick.

The GICHD would also like to thank the many professional, commercial and non-governmental organisations, and individuals, who generously contributed their time and expertise to help with this project.

This project was managed by Erik Tollefsen | Operational Methods Section, GICHD (e.tollefsen@gichd.org).

A GUIDE TO ROAD CLEARANCE

JULY 2008



CONTENTS

INTRODUCTION	4
DEFINITIONS	4
SUMMARY OF ROAD CLEARANCE GUIDELINES	5
CHAPTER 1	
DEFINING THE CLEARANCE REQUIREMENT	11
WHAT IS A ROAD?	12
THE IMPORTANCE OF ROAD CLEARANCE	13
CHALLENGES OF ROAD CLEARANCE	13
> BASIC PRINCIPLES OF ROAD RELEASE	15
> TYPES OF ROADS AND THE IMPLICATIONS FOR CLEARANCE	16
> UNDERSTANDING THE NEEDS OF THE ROAD USER	18
> COORDINATE WITH THE ROAD CONSTRUCTOR	19
> INTEGRATION WITH RECONSTRUCTION AND DEVELOPMENT	20
> CONTRACTING FOR ROAD CLEARANCE	23
CHAPTER 2	
MANAGING INFORMATION IN SUPPORT OF ROAD CLEARANCE	25
BASIC PRINCIPLES OF INFORMATION MANAGEMENT	26
DATA COLLECTION AND STORAGE	27
GENERAL SURVEY	29
TECHNICAL SURVEY	30
SAMPLING	32
CHAPTER 3	
APPLICATION OF MACHINES TO ROAD CLEARANCE	35
AN OVERVIEW OF DEMINING MACHINES	36
TO FLAIL OR TO TILLER?	38
GROUND PREPARATION MACHINES	40
DETONATION TRAILERS AND MINE ROLLERS	42
MINE PROTECTED VEHICLES	43
INTEGRATED SYSTEMS	45
> THE VOODOO SYSTEM	45
> THE EFFECTIVENESS OF THE VOODOO SYSTEM	46

CONTENTS

CHAPTER 4

MINE DETECTION METHODOLOGIES FOR ROADS	49
BASIC PRINCIPLES OF MINE DETECTION METHODOLOGIES	50
WIDE AREA DETECTION SYSTEM (WADS)	50
VEHICULAR ARRAY MINE DETECTION SYSTEM (VAMIDS)	51
THE USE OF MINE DETECTION ANIMALS	53
REMOTE DETECTION	55
SAMPLING IN MEDDS & REST	57
DIRECT DETECTION BY MINE DETECTION ANIMALS	58
USE OF MINE DETECTION ANIMALS FOR QUALITY MANAGEMENT	59

CHAPTER 5

APPLYING LAND RELEASE PRINCIPLES TO ROAD CLEARANCE	61
BASIC PRINCIPLES OF APPLYING LAND RELEASE TO ROAD CLEARANCE	62
LAND RELEASE METHODOLOGY AND ITS APPLICATION TO ROADS	62

CHAPTER 6

CONCLUSION: FIVE GUIDELINES FOR ROAD CLEARANCE	67
---	----

LIST OF REFERENCE DOCUMENTS ON THE CD-ROM

1. THE VOODOO SYSTEM, MPV, WADS AND VAMIDS
2. THE USE OF ANIMALS AND ENVIRONMENTAL FACTORS
3. ANALYSIS PHASE IN MEDDS AND REST
4. DETONATION TRAILERS AND MINE ROLLERS
5. CONTRACT MANAGEMENT
6. CHECK-LIST FOR ROAD CLEARANCE
7. CEN WORKSHOP AGREEMENT 28 AND 29
8. IMAS 09.50 (AND IMAS 07.10 ADAPTED TO ROAD CLEARANCE)
9. IMSMA ROAD CLEARANCE FORM
10. DATA NEEDS
11. BOW WAVE, SLIPSTREAMING, SKIPPED ZONES AND SOIL EXPANSION
12. CATEGORISATION OF MINE CLEARANCE MACHINES
13. PERFORMANCE TESTING

INTRODUCTION

Clearing roads prior to the deployment of peacekeeping units, or in support of humanitarian, reconstruction or development work, is a prerequisite to a safe and successful operation.

However, road clearance is expensive and time-consuming. Equipment costs are high, especially in remote areas such as in Afghanistan, Angola and Sudan, where many roads remain contaminated by mines.

Confronted by these challenges, mine action operators are working to develop safer, more efficient and cost-effective road clearance systems. This Guide aims to contribute to that process by providing recent examples, data and methodologies from the field.

Methodologies and approaches used as examples in this guide were observed during field visits during 2006 and 2007. These should be considered to be snapshots: some procedures and equipment might have changed since then.

For the purpose of the guide we have generalised various methods and examples. However, in the field every scenario is unique and should be carefully assessed and interpreted within its own particular context.

Along with the information presented in this Guide, the GICHD has gathered supplementary technical data through visits to road clearance projects in four countries. This has been compiled in reference documents included on the accompanying CD-ROM. It is also published on the GICHD website (www.gichd.org).

DEFINITIONS

A wide range of terminology is currently in use to describe the elements of clearance or release of a road. While the aim is not to impose a set of terminology, it has been necessary to follow a standard set of definitions in this Guide. Readers may choose to adapt these terms or use alternative terms to describe the same process. It is, however, important to clearly define what each term means within the context of this Guide.

The term “*road clearance*” refers to tasks or actions taken to eliminate the hazard from landmines or ERW on existing and planned roads. “*General survey*” and “*technical survey*” are processes, together with “*road release*”, that are sometimes included in the road clearance terminology.

A “*suspected hazardous area*” (SHA) refers to an area or segment of road that has been identified as potentially containing landmines or explosive remnants of war (ERW).

INTRODUCTION

In this Guide the term “*danger area*” reflects the terminology used in the field to describe the part of a road subject to clearance, after survey has been carried out.

“*Land release*” is a generic term used to describe the process of freeing land previously suspected to be hazardous. This suspicion is eliminated by either some form of assessment or survey, or by full clearance. “*Road release*” is the application of certain land release principles to the clearance of roads. It should be noted that the concept of land release, and its application to road clearance, remained under discussion when this Guide was published in June 2008.

The term “*general survey*” is the process of collecting accurate and relevant information about the type and extent of explosive hazards in a SHA. A general survey does not involve the use of clearance or verification assets.

The term “*technical survey*” is used to describe a detailed physical intervention into a SHA, or part of a SHA, once all feasible general assessment activities have been implemented. A technical survey involves the use of clearance or verification assets. Terms like “*road proofing*” and “*risk reduction*” are also commonly used to describe the same process. Much of what, in the past, has been labelled as clearance is more correctly described as technical survey.

The term “*sampling*” is used to define a procedure whereby part, or parts, of a segment of a *cleared road* is taken as a representation of the whole road.

SUMMARY OF ROAD CLEARANCE GUIDELINES

Research for this Guide took place over a period of two years. During that time we investigated road clearance techniques and procedures worldwide. Particular attention was paid to road clearance operations in four countries – Afghanistan, Angola, Mozambique and Sudan. Detailed discussions were also conducted with road clearance operators in those countries. The following conclusions were drawn from the study.

1. Road clearance needs a layered approach

Road clearance needs a layered approach – a series of responses that together form a system designed to meet the various clearance challenges. The elements of such a system are:

- > gather and analyse data on mine-laying so it can be fed back into planning
- > select an appropriate mix of tools for different survey and clearance tasks

- > combine demining technologies and methodologies that complement each other
- > test them under realistic field conditions before finalising the approach

Many operators have already achieved important elements of such a coherent road clearance system, but (often despite bold claims) few individual operators have yet perfected such a system.

2. Road clearance is a highly specialised undertaking

Road clearance requires specialised technical, logistical and managerial skills, and tasks need to be executed in the correct order. For that reason, an accreditation regime should be in place for *all* assets engaged in road clearance, including mine detection animals, demining machines and applied detector systems. Road clearance is a *niche* activity – not one that all operators could (or should) undertake.

3. Operators should clear only what is needed

It is important to seek only to release or clear what is actually needed for road constructors and users. Defining the minimum road clearance requirement increases efficiency and effectiveness. This means the clearance operator should start, and maintain, a dialogue with the road constructor and with the potential beneficiaries (ie the future users).

4. Operators need to learn more from previous road clearance

Recording, analysing and sharing contamination data, (eg which mines were found, where they were found and how they were laid), should be given greater priority. Such information will ensure that clearance remains focused on contaminated areas and that decisions are based on evidence, rather than instinct.

5. Criteria are needed to release roads without clearance

Criteria to release roads without clearance should be agreed on the basis of internationally recognised standards and guidelines, (especially the IMAS), taking account of local realities. Whatever criteria are used, all decisions, (including the decision to release segments of road without clearance), must be carefully documented. Wherever general or technical survey finds clear evidence of contamination, follow-on clearance is always required.

6. Good information management is key to an effective road clearance system

The GICHD has found that, in general, Programmes pay insufficient attention to information management. All activities, decisions and information gathered should be recorded, analysed, shared and fed

back into future planning. The logical – and systematic – way of sharing relevant information is to use a map. Modern technology has greatly facilitated this task, in particular through Geographic Information Systems (GIS).

Survey plays a critical role in this process. The purpose of general survey is to release roads or identify requirements for technical survey/clearance. This means that surveyors should be experienced and trained personnel who understand what information is required to release a segment of road. They should also be able to use Global Positioning System (GPS) technology. GPS has contributed to more effective general survey over the past five years.

Technical survey is the way to identify mined areas and then to focus scarce clearance resources on contaminated land. In the case of roads, full clearance can sometimes be as cost-effective as a technical survey, when working in a confirmed danger area. However, technical survey can be an efficient method to gather contamination data in areas where no other information is available.

7. Mechanical demining assets play an important role in road clearance

Road clearance will undoubtedly become cheaper, faster, more effective and safer if demining machines are applied on suspected or hazardous roads. In general, the better the general survey and technical survey processes, the more effective the deployment of mechanical equipment will be.

An important advantage of flails and tillers is that they also destroy minimum-metal mines, which are harder to locate using metal detection equipment. However, their potential for effective use is not universal. The following four principles should be observed when considering their application for road clearance:

- > only machines with sufficient power to penetrate the road surface to the required depth should pass accreditation (but these machines have high running costs)
- > only machines that can survive blasts from Anti-Vehicle Mine (AVMs) without the machine being damaged, or its capability degraded, should be used for road clearance
- > machines should only be applied on dangerous segments of roads, as defined by general survey, or where it is impossible to disprove an area by non-intrusive means
- > the road will need to be reconstructed or surface-repaired, as these machines destroy the surface of the road

The effectiveness of pneumatic-tyred roller systems in road survey or clearance is highly doubtful. However, there is some benefit from using a solid tyre or steel wheel roller. The use of steel wheels at wheel loads in excess of 3,000 kilograms of force will, in theory, when of similar width, improve the margin of safety of detonation of a mine, significantly above that of truck wheels. Where steel wheels are not acceptable (such as where they have to pass along tarmac roads), solid rubber tyres will give a lesser, but still worthwhile, improvement over pneumatic tyres.

8. Animal detectors are generally well-suited for road clearance

Normally roads contain little or no vegetation to hinder animals from effectively searching the surface. Animals also have the advantage of operating on the basis of scent rather than metal detection, or mechanical intervention. Animals, particularly dogs, may even find it easier to detect minimum-metal, rather than metal-cased, AVMs because of the greater seepage of odour through plastic.

The Remote Explosive Scent Tracing (REST) system provides a potentially flexible detection system that can be tuned to a wide variety of targets. REST systems are best viewed as methods for eliminating areas of road suspected of being mined, rather than for close-in detection of mines. They are therefore best applied on road lengths where there are no known minefields and information is being sought to support the hypothesis that the road is clear. Detection systems involving animals can also be used to quality assure part of an organisation's work with other survey or clearance tools.

9. Manual mine clearance is reliable, but slow and costly

Manual mine clearance is commonly used as a component in most road clearance projects. It is slow and costly but, depending on mine types, it can be a reliable method.

Manual mine clearance has been used as the only method to open complete roads, mainly because of the absence of more appropriate assets for road reopening. While manual mine clearance will always play an important role in reopening roads, an effort should be made to minimise the use of manual mine clearance to limited sectors and spots where there is a proven mine/ERW contamination, or where it is difficult to deploy other, more appropriate, assets.

10. Beware migrating mines

As a part of general survey it is important to assess the topography in relation to known mined areas. Mines and ordnance from higher ground can potentially be washed out from their original location and travel relatively long distances. Normally heavy seasonal rains form creeks and

wadis, in which mines and ERW can travel. It is important to identify the correlation between higher lying minefields close to roads and water channels. If there is a possibility for washouts, actions should be taken to clear and take measures to prevent recontamination of the cleared area.

The obvious solution to this problem is to clear the source of the hazard. If short on resources or time, mitigating measures such as a grille or heavy duty metal mesh in culverts and trenches can be used to catch washouts. Such mitigation systems should be monitored to avoid clogs and subsequent wash-outs over the road.

11. Test all approaches in realistic conditions

All approaches must be tested in realistic field conditions in an environment similar to the roads to be cleared. A performance test should be carried out on applied equipment, operators and processes as a key part of accreditation, to ensure that the equipment and methods are fit for purpose. For further information on performance testing see Reference Documents 8 and 13.

12. Technology challenges for future road clearance

The layered road clearance methodology described in this Guide would certainly benefit from new detection technologies to further improve overall performance. Such technologies should focus more on cancellation of larger areas than the classical close-in detection capabilities, and can be either tailor-made for road clearance or fielded as part of broader land release.

New detection technologies must fit in as an additional component to existing approaches. They need to be of rugged, modular design, cost-effective and fast. Any new detection unit should be able to be fielded as a stand-alone system or as an integrated part of other road clearance systems. What will be key, however, is the ability to detect minimum-metal AVMs and possibly smaller anti-personnel mines (APMs) – the mines that current detector systems are struggling to find.

New technology is needed to:

- > detect the explosive filling, the casing or other materials that make up a minimum metal AVM; or
- > be able to react to the lowest common denominator that distinguishes the AVM or other munition from the materials used in road construction.

Preferably, the technology should not physically engage the ground as this would inevitably reduce efficiency and increase cost. The highest accuracy level in detection might not be needed as long as it is complemented by other systems.

CHAPTER 1

DEFINING THE CLEARANCE REQUIREMENT

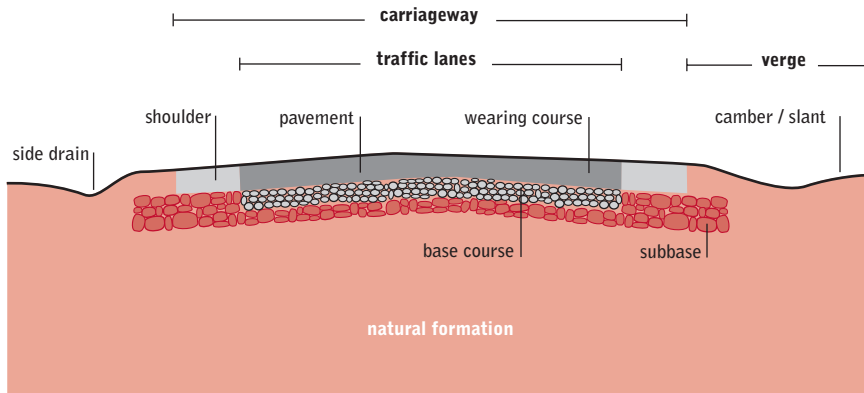


DEFINING THE CLEARANCE REQUIREMENT

WHAT IS A ROAD?

Understanding the usage and features of a road is integral to effective road clearance.

Figure 1 | The features of a road



A road typically comprises the following features, as illustrated in Figure 1:

- > traffic lane or lanes, over which people and/or vehicles travel
- > shoulder, where people and/or vehicles pass or stop
- > side drains, into which water on the carriageway (i.e. the traffic lane and the shoulder) drains and is carried away. A road would normally have a camber, which means the carriageway is highest in the centre of the road and slopes away on each side towards the drains.



Example of a road in Angola

CHAPTER 1

DEFINING THE CLEARANCE REQUIREMENT

In essence there are four typical road types:

- > asphalt/paved
- > gravel (paved)
- > dirt (earth)
- > degraded

Different road types may require different responses, survey or mine clearance.

IMPORTANCE OF ROAD CLEARANCE

A road, as a line of communication, is generally critical to the communities it serves. From governance and commerce perspectives, the network of roads that make up the infrastructure of a country is vital for economic development and prosperity. It therefore follows that when a road is blocked by mines the consequences are usually greater than when an area of land is blocked.

Landmines, especially minimum-metal anti-vehicle mines (AVMs), can be a major problem during, and following, armed conflict. They endanger emergency relief operations, block rehabilitation projects and impede development. Ensuring that roads are accessible - or can be rebuilt - is a priority immediately after conflict, during the most intense period of international intervention and humanitarian assistance.

Post-conflict road clearance is therefore urgent and important.

CHALLENGES OF ROAD CLEARANCE

Despite its importance, road clearance remains one of the least understood and least developed aspects of mine action. When clearing land, the integration of manual deminers, mine detection dogs (MDDs) and demining machines is well understood, and guided by long-established norms (see Box 1 for a discussion of some of the differences between road clearance and clearance of land). However, there are no universally accepted methods for rapid and efficient demining of roads.

DEFINING THE CLEARANCE REQUIREMENT

Box 1 | Road clearance and clearance of land:
two sides of the same coin or two different coins?

Clearing a road is different to clearing an area of land. This is due to the scale of the function of length and width of the area potentially to be cleared, the type of ordnance typically encountered and its impact, and decisions on the depth of clearance needed.

In terms of size, the areas of road suspected to be hazardous are potentially vast – amounting to thousands of kilometres in length and thousands of square kilometres, if the width is factored in. The linear length of a road presents a challenge – in terms of square metres, a road of 60 kilometres long x 24 metres wide is 1,440,000 square metres – i.e. just short of 1.5 km² of area. The length factor means that the survey of a road as an entity cannot be treated as a single hazardous area.

Consider the road in its entirety. Then divide it into a series of manageable segments with an identifiable start point, eg a junction, or the edge of a town, and an identifiable end point – A to B. This has important implications for how to survey it, report the findings, plan and conduct work, and record what has been done.

There are two elements to consider regarding the width of the road: the width of the actual features of the road, and how wide to employ demining resources.

AVMs are the type of ordnance most often encountered on roads. Their explosive effect can cause multiple victims and have very significant social and economic impact (including on circulation of goods and labour, peacekeeping operations and delivery of food aid or emergency medical supplies) – as will any mistakes in clearance. Determining the impact is usually much harder than it is for suspected land. It also means additional precautions must be taken when surveying a road.

During survey, find people or organisations with particular knowledge of any segment to try to understand the challenge of the road along its total length. (Clearly there will be overlap of informants between segments.)

A final consideration is depth. But depth of what? Do we mean depth in terms of the construction of the road or in terms of what hazards might be found in the road? The answer is both. Ignoring depth as a dimension of the road will inevitably have negative consequences.

Addressing road clearance requires a wider variety of technologies (some specific to roads), a greater level of coordination and discussion, (ie with the construction company as well as future users), and a more complex set of decisions than is normally the case with land clearance.

Clearing a segment of road can be relatively straightforward, but clearing or opening an entire road or significant length of road is more complex. When there is limited time available for clearance, demining programmes often struggle to meet the demands of road constructors, while attaining clearance standards.

There are five main challenges in road clearance:

- > cost
- > speed
- > safety

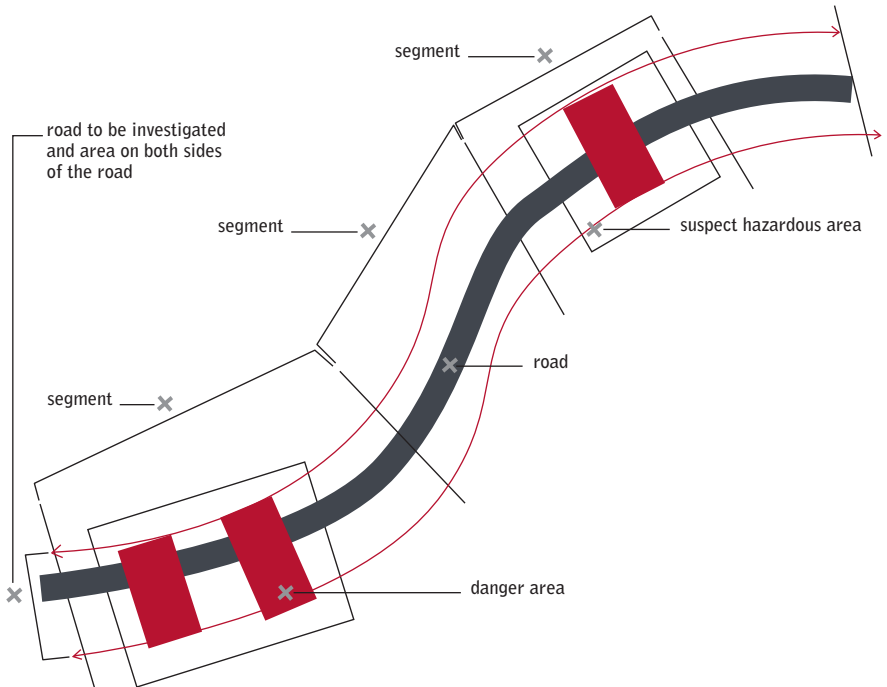
CHAPTER 1

DEFINING THE CLEARANCE REQUIREMENT

- > coordination with road construction programmes
- > current available technology and its suitability for road clearance.

This Guide suggests ways to meet and overcome these challenges.

Figure 2 | Segment SHA



Basic principles of road release

1. view the “mine-contaminated” road as a single entity. The road will have an identifiable start point, and an identifiable end point – A to B. This concept of complete linear length is important when considering the impact of a road being blocked because of mines, and also because of the implications for the planning and conduct of survey, clearance, recording and reporting.
2. decide on the width of clearance required, based on the intended future use of the road (eg is it for trucks, peacekeeping operations, emergency access, etc.?) and its current features.
3. define depth of clearance: it is necessary to decide the depth of excavation based on what will actually be needed for construction or reconstruction of the road.

DEFINING THE CLEARANCE REQUIREMENT

4. record the impact of vegetation on, and beside, the road, noting any constraints it will impose on the clearance operation.
5. establish a common terminology between the various stake holders: for example, a road reconstruction company tasked with “rehabilitating” the road after it has been demined. Box 2 discusses the semantic differences between a road and a route.

Box 2 discusses the differences between a road and a route.

Box 2 | Roads and routes: a brief discussion of terminology

A **road** is an open, generally public way for the passage of vehicles, people, and animals.

The definition of a route encompasses a road, but also refers to a course or way for travel from one place to another. The concept of a route is generally considered to be broader than that of a road. It is also used widely in military contexts.

Generally, contracts are issued for road clearance rather than route clearance. In Sudan, however, UN contracts have been issued for the clearance of routes.



An asphalt or tarmac/paved road

Types of roads and the implications for clearance

As mentioned above, there are four basic road types: asphalt or tarmac/paved, gravel (paved), dirt (earth) and degraded. The characteristics of each have particular implications for the clearance requirement.



A gravel road

With an **asphalt or tarmac/paved road**, it is normally clear where (a) the course of the road is, and (b) where the features of the road are. Thus it is possible to define the traffic lanes and the shoulders (which together make up the carriageway) as well as the side drains.

CHAPTER 1

DEFINING THE CLEARANCE REQUIREMENT

With a **gravel (paved) road**, it might be less clear where the traffic lanes and shoulders meet. Paved roads can present challenges in terms of clearance, but there is no problem defining where the road is, unless vegetation has grown up over many years.



A dirt (earth) road

On a **dirt (earth) road**, it is probably less clear where the traffic lanes and shoulders meet – and the physical course of the road might not be clear. This is partly because there may be “*spread*”, i.e. lateral movement of the carriageway across a wider area than would be normal for a typical paved road. This may result from road users creating deviations or detours because of flooded or soft ground. This sort of road presents a number of problems in survey, clearance and reporting, the central issue being “*where exactly is the road?*”



A degraded road

A **degraded road** is one where the carriageway and drains are completely blocked by vegetation, (possibly as a result of mines rendering the road impassable, restricting its maintenance and repair), or where much of the original road structure has disappeared due to erosion, washouts or other natural occurrences. When this type of road was constructed it was probably a dirt road or a gravel/paved road.

Vegetation brings further complexity to the demining of all road types. The major challenge is to match resources to the amount of vegetation needing to be cut, since this can significantly affect the speed of the operation. For example, if manual deminers are required to clear the shoulders of a road to a width of two metres beyond each side of the traffic lane, along a length of 50 kilometres, then there are 200,000m² of vegetation to be cut.

SETTING THE ROAD CLEARANCE REQUIREMENT

A vegetation cutter, mounted on an armoured tractor, requires prior clearance of the traffic lane to be used by the tractor. This could involve significant extra costs. Additional mechanical assets will also require maintenance and support.

Vegetation should only be cut if it hinders the ability to remove a hazard or obstructs movement. This will typically result in a road released for use to a width of eight metres (four metres either side of a centre line, which allows two trucks to pass each other).

Understanding the needs of the road user

It may appear obvious, but operators must understand the intended use of the road before road clearance operations commence. In essence, three uses of a road potentially require a mine action response:

- > **emergency access** on an existing known road
- > **improved access** through the reconstruction of an existing or previously known road
- > **new access**, through the building of a completely new road

In each of the three cases the mine action response may be different. For example, if the intention is to **allow emergency access** to demobilisation sites, to provide food and shelter to former soldiers, there is little point in clearing hazards out to eight metres or more from the centre line of the road, (sometimes requested in the context of peacekeeping operations).



A bridge in need of reconstruction

Similarly, if the aim is to **rehabilitate key bridges** between two towns, (or even two countries), to foster trade or enable displaced people to return to their homes, then the clearance response is again about access along the road's traffic lanes to facilitate bridge-building. However, this work must be supplemented by localised clearance at the bridge sites, and the bridge engineer should be consulted, to understand exactly what his/her needs are.

SETTING THE ROAD CLEARANCE REQUIREMENT

If, on the other hand, the operational intent is to **rebuild** the road then it is likely that the whole width of the road (traffic lanes, shoulders and drains at a minimum) will need to be demined. Clarify to what width (and measured from where!) clearance needs to take place. The road constructors might also have other requirements, such as specific locations of borrow pits, (a pit created to provide earth and gravel that can be used as fill for the construction of the road), for the construction material needed.

Another aspect to consider is the potential difference between the needs and wishes of the various stakeholders. For example, if a road is cleared to an eight-metre width to facilitate the movement of peacekeepers (as occurs, for example, in Sudan) this will help the peacekeepers but may not help cattle herders who traditionally move their cattle on the shoulders of the road. All potential usage of the road must be considered as it is being surveyed.

Coordinate with the road constructor

There may also be a requirement to clear borrow pits for road rehabilitation material, or to clear a construction camp site. This again calls for dialogue between the road constructor and the demining operator and/or funder. Try to agree a reduction in the width of area to be demined, for example in return for an increased number of cleared borrow pits. Minimising the width of road to be cleared will significantly speed up the process. For instance, reducing the width subject to clearance of five kilometres of road from 50 to 16 metres will reduce the total area to be surveyed and cleared from 250,000 to 80,000 square metres, (a reduction of 68 per cent).

Another issue is the setting of the centre line of the road. Common sense suggests that the course of the road will be set by the road construction company's civil engineers – and that any required demining will be measured out from that centre line.

However in one country (where funding for clearance and reconstruction have previously been uncoordinated), the centre line, from which clearance was occurring, was set, in at least one case, by the demining agency. This meant that any follow-on reconstruction could deviate slightly from cleared areas, if the engineer designated a different line. The driver of a grader or bulldozer following the line designated by the engineer, would be put at risk.

In sum, close coordination between the demining effort and the civil engineers is critical to efficient – and safe – road reconstruction operations. In practice, this has not always occurred, as Box 3 illustrates with an example from Afghanistan.

SETTING THE ROAD CLEARANCE REQUIREMENT

Box 3 | The dangers of poor coordination in road reconstruction:
an example from Afghanistan

During the course of clearance in support of road rehabilitation in Afghanistan a demining agency surface-cleared an area adjacent to the road, which had been selected as a borrow pit by road reconstruction engineers. The perimeter of the area was marked with painted stones.

A construction crew was then dispatched by the road construction contractor to begin excavating base materials for the road. These materials were trucked to the part of the road being rehabilitated. When workers began manually spreading the material anti-personnel mines were discovered.

The subsequent investigation into the incident discovered that the construction crew had misidentified minefield markings as the borrow pit area, and had therefore begun excavation in a minefield. Had the crew driven a further 500m they would have seen another marked area, the designated borrow pit area.

What went wrong? Although demining and construction were essentially ongoing on the same road at the same time, coordination between the contractor and the demining agency was weak. Such risks are even greater where demining precedes reconstruction by months and physical coordination between those directly involved is not feasible.

Integration with reconstruction and development

Effective communication and coordination between mine action actors, national, regional and sector government authorities, and relevant humanitarian and development agencies, is vital to improving cost-effectiveness. To further enhance the developmental effectiveness of mine action, programmes need to ensure that mine action planning and priority setting are aligned with national, sub-national and/or sector development priorities and plans. In practice, this can be a major challenge for the mine action programme. Box 4 illustrates the example of road clearance in Mozambique.

SETTING THE ROAD CLEARANCE REQUIREMENT

Box 4 | Integrating road clearance into reconstruction and development: the case of Mozambique

Mozambique is an example of a country that has actively sought to integrate road clearance into its national reconstruction and development programme. Mozambique's National Administration for Roads (ANE) first encountered serious problems with landmine and unexploded ordnance contamination during its Emergency Road Programme (1994–1996). Under intense time pressure, it worked with the UN Development Programme and donors to make arrangements for stand-alone demining services – typically mechanical “treatment” followed by survey and clearance - so as not to delay the work of the civil engineering firms selected as prime contractors for each rehabilitation project. This proved extremely unsatisfactory, as many explosive devices were missed, causing the road work to stop, with ANE bearing the cost of delays.

As a result, ANE has developed a system in which the prime contractor assumes complete responsibility for demining services. Tender documents make it clear that the bidders must include a specialised sub-contractor for mine/ERW survey and clearance. After the award of contract, the prime contractor is not allowed to mobilise the road-works crews until the demining sub-contractor produces a certificate from the country's National Demining Institute (IND) that the roads, bridges, gravel pits and other worksites relating to the roads rehabilitation project have been cleared. Subsequently, any missed devices incidents are the responsibility of the prime contractor and, after mobilising the heavy equipment and work teams, delays due to missed devices would be extremely costly. ANE does not require external quality assurance – it leaves this responsibility to the prime contractor.

Financing for the requisite demining works is provided in the budget for the road rehabilitation project. A provisional two to five per cent of the total budget is allocated for demining services, but ANE pays for actual and reasonable expenses. ANE's planned work programme over the next decade is US\$1.7 billion, implying that the budget provisions for demining should be between US\$3.4 million and US\$8.5 million per year on average.

ANE maintains close contact with IND, with two of its engineers serving in a liaison role. It sends all its project plans to IND and requests all the relevant contamination and clearance records. However, even if IND certifies that a road segment has been entirely cleared, ANE still requires the prime contractor to sub-contract a demining firm to complete another survey and clearance operation. Given its costly experiences with missed devices in the past, ANE wants to put all responsibility for clearance on the prime contractor.

¹ This section is adapted from GICHD, A Review of Ten Years Assistance to the Mine Action Programme in Mozambique, October 2005.

SETTING THE ROAD CLEARANCE REQUIREMENT

Where feasible, road clearance assessments should be undertaken in collaboration with other stakeholders, especially the road constructor or contractor, representatives of affected communities and (where relevant) peacekeepers. It is also desirable that the results of assessments be disseminated to humanitarian and development organisations working in mine-affected areas, to ensure that communities are provided with the skills, inputs and support required to effectively and productively use cleared roads.

Where appropriate, post-clearance assessments should also be conducted to monitor post-clearance road use, and ensure that cleared roads meet the needs of the target beneficiaries. Such a process strengthens accountability to communities, mine-affected states and donors, for the achievement of developmental results and the proper use of funds. It also allows valuable lessons to be learned and incorporated into future planning.

Contracting for road clearance

Contracting road clearance has been problematic in the past because decisions about whether to survey, clear or release, need to be taken during implementation and obtaining the necessary approvals may entail considerable bureaucracy. It is important for the contracting agency (for example, the United Nations) to ensure that high levels of safety are maintained, while still allowing demining operators sufficient flexibility to define the clearance requirement based on the changing circumstances. An appropriate balance has not always been achieved in the past.

Road clearance contractors often complain that the contract is all penalties with no incentives. A more positive approach could be to promote speed and safety with carrots (i.e. financial bonuses) as well as sticks (i.e. financial penalties).

In terms of the technical aspects of a contract for road clearance, the process is normally initiated through a Request for Proposals (RFP). This might consist of the following documents:

- > the RFP itself
- > a Statement of Work (SOW), which normally divides responsibilities and reporting requirements under the contract
- > a Proposal Submission Form
- > a Sample Contract in draft, including the General Conditions used by the contracting agency

SETTING THE ROAD CLEARANCE REQUIREMENT

The technical component of a proposal should be concisely presented and normally structured, in the following order. Including, but not necessarily limited to:

- > a description of the bidder and the bidders' qualifications
- > the requirements for services, including assumptions
- > the proposed approach, methodology, timing and outputs
- > the proposed team structure

The bidder should include a detailed implementation plan in the technical proposal. Failure to carry out thorough logistical planning has probably been the single biggest cause of project failure in the past. Bidders are normally required to demonstrate that they are able to meet the deadlines indicated in the SOW. A field trip to the site is often required to provide the necessary inputs for proposals.

CHAPTER 2

MANAGING INFORMATION IN SUPPORT OF ROAD CLEARANCE



MANAGING INFORMATION IN SUPPORT OF ROAD CLEARANCE

A road is rarely cleared over its full length: more usually it will be surveyed and cleared in a combined operation. Road clearance is mainly a process of general and technical survey, with some limited clearance requirements. Effective operations therefore depend on *survey* to gather data and *effective analysis* of the data recorded during clearance or stockpile destruction operations.

In most countries where roads have been cleared, data collection and analysis has often been inconsistent. If a survey only captures a small percentage of the required information, (typically because of a perception that there is no time for proper data collection during the emergency stage), a valuable opportunity to facilitate future planning has been wasted. This chapter looks at how to manage information to make planning more efficient.

BASIC PRINCIPLES OF INFORMATION MANAGEMENT

Data collected during road survey and clearance should be structured in such a way that it can be incorporated into the database and analysed adequately. Some argue that collecting too much information slows the demining process. However, the time taken to collect information can reduce the need for clearance and enable efficient survey and clearance approaches. It is normally better to collect too much information than leave out information that may prove vital later.

To support effective general and technical survey, it is important to analyse the original tactical reasons for laying mines on the road, as well as available historical records and relevant empirical experience. When this process has been completed, it may be possible to make assumptions that can be used in survey. So be careful not to be seduced by “urban mine myths” (see Box 5). All hazard claims must be verified.

CHAPTER 2

MANAGING INFORMATION IN SUPPORT OF ROAD CLEARANCE

Box 5 | Mine myths!

As with other aspects of mine action, many claims have been made about the type and location of hazards confronted in road clearance operations. Some of these are myths.

Claim: several AVMs are stacked on top of each other.

Reality: although this has happened, it is very rare that several mines are double or triple stacked.

Claim: wooden sticks are set above AVMs, emplaced 70-100cm below the surface, to detonate the mines.

Reality: in rare cases and only in a few countries, deep buried mines with sticks have been found. It is normally possible to predict when this is likely to occur on the basis of survey or empirical experience. They may, however, be difficult to detect.

Claim: AVMS and APMs are equipped with anti-handling devices.

Reality: AVMs and APMs may indeed be equipped with anti-handling devices, although this is much rarer than generally believed. Care is obviously needed when dealing with hazards so that the risks of this occurring are taken into account.

The IMSMA template for recording data linked to road contamination and clearance is attached as Reference Document 9. For a non-exhaustive list of data that needs to be collected for road clearance, see Reference Document 10.

DATA COLLECTION AND STORAGE

A range of information about the road is collected from relevant actors, such as local authorities and individual informants. There are many other primary and secondary sources of information, such as the military (all parties to a conflict), police, hospital professionals, hunters, herders, villagers and pedestrians. Of course, attention has to be paid to the credibility of both the informants and the information they are providing.

The state of the road will dictate how information can be gathered along it. The factors to be considered are:

- > the surface of the road
- > weight classification
- > bridge status (complete, collapsed, bypassed, etc.)
- > vegetation

MANAGING INFORMATION IN SUPPORT OF ROAD CLEARANCE

Technology can assist in the collection of quality data (see Box 6). Basic digital cameras and GPS recorders are inexpensive and now readily available for most survey and clearance teams. The value of pictures in planning or preparing road clearance operations should not be underestimated.

Box 6 | The application of Geographic Information System (GIS) technology to general survey.

GIS technology is extremely useful for all mine action, but especially for primary road assessments. Maximising efficiency requires developing a sequence for GIS/GPS technology, which can be integrated into any standing operating procedure for advanced survey or area reduction.

It is essential that roads be mapped by waypoints (points between major places on a road, which are recorded digitally). Waypoints are streamed by a hand-held receiver at an interval determined by the user (distance, time, or frequency). This process can begin as soon as the GPS hand-held receiver can obtain a satellite fix.

A Garmin GPS, for example, comes loaded with the appropriate mapping software (MapSource), which can be integrated, both in application and process, with the receiver itself. For example, through use of the "Track" function the user can track the road being verified, mapping all subsequent targets, and have all of the information uploaded onto mapping software for analysis at the click of a button ("receive from device" button).

This flow of information and data is not impaired by one-way operation, but can support the mutual exchange of data from the information already intrinsic in MapSource. Through desktop analysis of the information available on MapSource Tracks, maps and waypoints can be created and downloaded from the mapping software straight to the GPS hand-held receiver.

For example, MapSource provides basic base maps, which have been overlaid with shape files delineating roads, rivers, lakes, towns, etc. If a road is to be surveyed a Track can be overlaid on the mapping software by inserting waypoints at whatever interval is conducive to the user. Any additional waypoints, which have already been catalogued along a specific road, can be added to this base map and downloaded straight to the GPS handheld receiver.

The most effective way to analyse and manipulate the data captured is in an intermediate mapping programme, such as ArcView GIS. A simple conversion to a DXF (*.dxf) file will allow users to export the MapSource Track data and import it into ArcView. Waypoint information should be catalogued in Excel spreadsheets. Each piece of information captured should have its own Excel spreadsheet, which can be converted into a DBF 4 (dBASE IV) file and exported into ArcView as a data-set. Every piece of information thus becomes a layer, which can be analysed and cross-referenced in ArcView.

CHAPTER 2

MANAGING INFORMATION IN SUPPORT OF ROAD CLEARANCE

Box 6 | The application of Geographic Information System (GIS) technology to general survey.

This data, once exported into ArcView can be overlaid on a plethora of different maps, such as base, detailed, topographical and satellite imagery, etc. Once the user is comfortable with the data-sets that have been layered into ArcView, the data and information can be manipulated to fit the specification of the analysis. Maps can be put to scale for distance, polygons can be overlaid to delineate dangerous areas/suspected hazardous areas or reduce their size by “footprinting” community-based development data and cross-referencing with an IMAS standard. Vector based data can also be added to determine distance/extent of path and road based networks with targets mapped to specification. The visual representation of these data-sets, which are geo-referenced and built to scale, will provide the most accurate and reliable format for analysis and cross-reference.

* Information provided by Landon Shroder, Community Liaison Manager MAG, Angola.



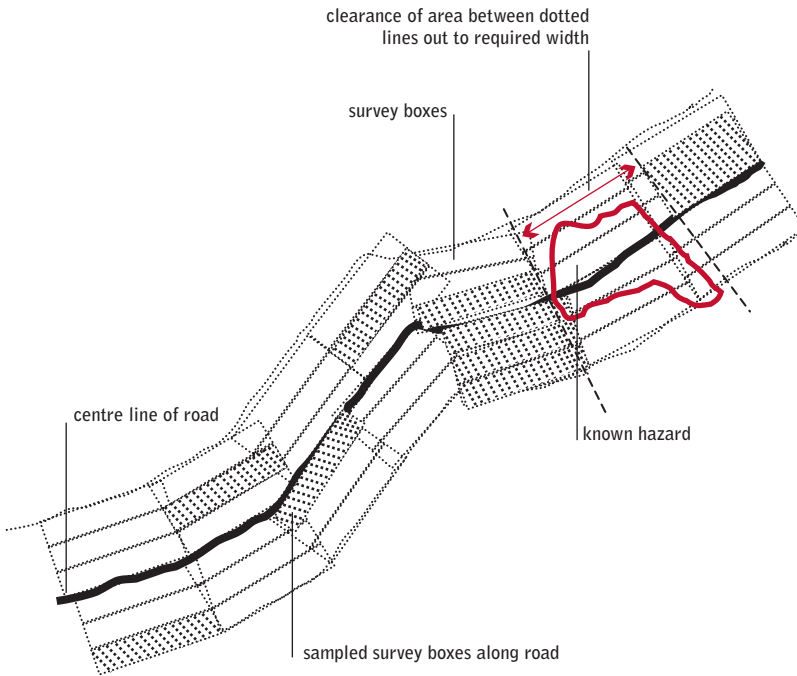
A GPS in use on roads in Angola

GENERAL SURVEY

A general survey typically combines information gathering from available literature and key informants at national, regional or district level. The outcome will be enhanced if the survey team contains representatives of a mine action agency, the local community, the road constructor or contractor and perhaps police and/or the military. This requires more organisation and coordination but results in improved information.

As mentioned in Box 1, a road should always be subdivided into logical segments, defined by the natural features of the road. Each segment should be treated as a single subject or a single suspect hazardous area. The approach is not one of segmenting the road for purely geographical purposes, but rather to find informants with particular knowledge of the segment and identify which areas require technical survey and which require clearance. Clearly there will be an overlap of informants between segments.

Figure 3 | Segments, suspect hazardous areas and dangerous areas on roads



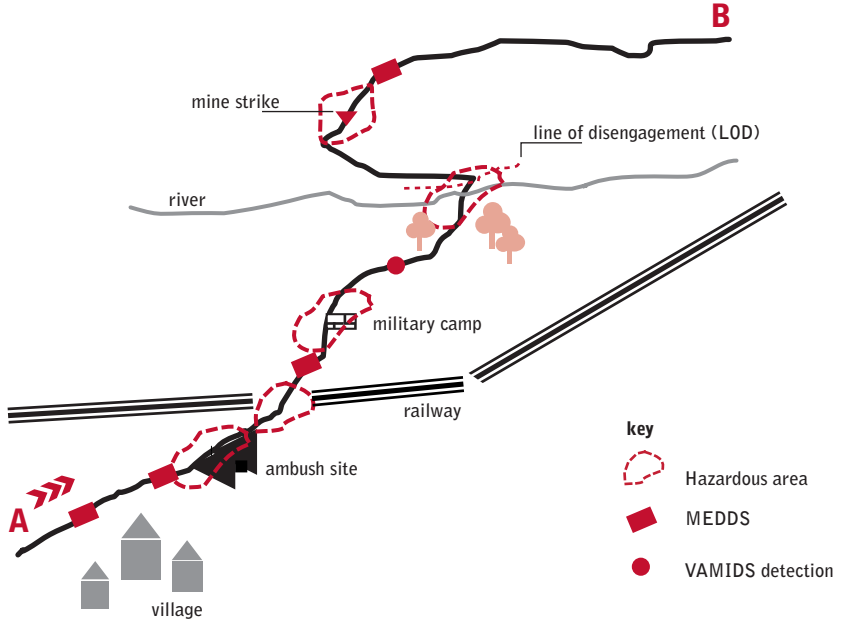
TECHNICAL SURVEY

Technical survey of roads, in comparison to general survey and full clearance, seeks to identify the location of mines and other explosive ordnance, as well as the technical information necessary for clearance. Experience, focused through good information management, should direct technical survey towards identifying the most likely locations of landmines and ERW. So if there is no evidence that plastic-cased AVMs have been used, it makes sense to look for metal-cased AVMs during technical survey. Likewise, if there is no evidence that AVMs are buried deeply, a technical survey may first look for shallow buried AVMs.

This approach can be expanded. If it is thought unlikely that mines are laid in isolation on shoulders, technical survey may look for mines in the road lane first and only check shoulders where mines have been found in the lane.

Additional data may be obtained by using a Remote Explosive Scent Tracing (REST) system (see Chapter 4 for details), such as the Mechem Explosives and Drug Detection System (MEDDS – see www.mechemdemining.com/MEDDS.htm). If this layer of sensory data is added, the results of general survey and another layer of sensory survey can be mapped, as shown in Figure 2.

Figure 4 | Stylised general survey results incorporating REST data



Assume that Figure 2 represents an 80 kilometre road suspected to be mined. After a general survey, supported by additional layers of information, it has been converted from a single linear SHA into 11 designated dangerous areas. The other areas have been released because there does not appear to be evidence of mines or ERW. If each of these dangerous areas is 200m long and 26m wide, the clearance requirement is 57,200m² (or 2.75% of the original SHA). This provides a potentially huge saving in time and costs.

Remember also that a general survey is normally based on both discussion and observation. If a road is not used by vehicles and is heavily overgrown, it is clearly inappropriate to force a passage without a mine-protected vehicle. If, on the other hand, the road is regularly used by cars, trucks and buses, a vehicle survey may be appropriate, but there will be staff health and safety considerations. In particular, it may not be acceptable to use an unprotected vehicle on a road that might still have mines in the traffic lanes, even though it is in regular use.

MANAGING INFORMATION IN SUPPORT OF ROAD CLEARANCE

The length of the road will also affect decisions. If a blocked road is an overgrown, tertiary dirt road, walking the road on an existing footpath may be a reasonable action if the road is not too long. If the road is very long, some sort of transport will be required.

Box 7 describes one approach to technical survey, which has been developed by Norwegian People's Aid (NPA) in Angola.

Box 7 | An approach to technical survey in Angola: Norwegian People's Aid

NPA has been clearing landmines in Angola since 1995. NPA's focus has gradually shifted to reopening the tertiary road network between isolated smaller communities and the larger access networks. This box describes the method NPA plans to use.

A joint team produces a detailed task order and an implementation plan based on a general survey report and a detailed task map. The road is divided into segments on the map. A segment is defined based on specific geographical or demographical characteristics. The plan details the requirements for personnel and equipment as well as a proposed time schedule.

NPA uses several technical survey and clearance approaches. A mine-protected vehicle with steel or rubber wheels was used in the past but has now been abandoned for road clearance work. NPA now uses the Aardvark flail, wide-array detectors, or manual deminers, depending on the type and location of road and the available assets. During technical survey, the flail may be followed by visual inspection.

If the flail or the visual inspection does not indicate the presence of mines, this typically justifies release of the segment. If mines are found, full manual mine clearance is required behind the machine. The wide-array detector may be used in cases where there is a high probability that most of the AVMs are metal-cased. If the wide-array detector does not find any mines, the segment of road may be reclassified for release by technical survey, but this depends on the initial classification in the general survey report.

In pocketed areas around trees and boulders, in trenches, ditches and potholes, manual deminers are often easier and more effective to deploy than a machine. Verges and terrain that cannot be easily cleared by mechanical means are cleared manually.

NPA's teams often operate far away from the nearest operations base and machine breakdowns occur regularly. NPA has eight Aardvarks but they aim to keep four of them operational at any time under a rotation scheme. The field teams are supplied by a central logistics base. The timing of fuel and food delivery is critical to productivity.

SAMPLING

In a number of countries, a sampling approach is applied to the technical survey process and to the clearance of roads. For example, in Afghanistan, a road is subject to *both* clearance within the identified SHAs and to a process of 33 per cent sampling. In contrast, in Sudan, suspected areas appear to be cleared systematically, with no sampling being conducted of those lengths of road surveyed as having “no evidence of mines”.

Sampling has obvious benefits for efficiency. Perhaps a good generic approach would be to complete a random sampling process, so that an unadulterated data set is collected, and then to conduct an additional layer of “skewed sampling” on top. This effectively becomes a layer of internal quality control.

CHAPTER 3

APPLICATION OF MACHINES TO ROAD CLEARANCE



APPLICATION OF MACHINES TO ROAD CLEARANCE

Appropriate application of mechanical demining equipment leads to cost-effective road clearance and, ultimately, to returning safe roads to communities.

An additional benefit is that mine clearance machines destroy or excavate all types of AVMs and APMs, whether plastic or metal cased. Machines do not differentiate between metal-cased and plastic-cased mines.

A variety of assets can be used for road clearance. But a well-managed mechanical component is essential for an effective road clearance programme. This chapter reviews the use of mechanical demining equipment for road clearance, including some of the major mechanical systems currently in use.

AN OVERVIEW OF DEMINING MACHINES

In general terms, demining machines are used for three purposes in a mine action programme: to find and destroy mines; prepare ground, including vegetation cutting (while often, but not always, also destroying mines); and to act as a platform for another application. These three tasks are also applicable to, and can be assigned for, road clearance. (See Reference Document 12.)

Mine clearance machines are those machines whose stated purpose is the detonation, destruction or removal of landmines. For example, a front-end loader, armoured and adapted to excavate mined ground, can be designated as a mine clearance machine because the definition includes the removal of all mines to a certain specified depth.



Bozena 5 in action

The use of a mine clearance machine may mean that follow-on processes can be reduced or eliminated. Not following-on a mine clearance machine with a secondary process, to finish the removal and destruction of all targets is unusual, but circumstances do exist where the machine used will have cleared all mines.

CHAPTER 3

APPLICATION OF MACHINES TO ROAD CLEARANCE

Rigorous testing against target mine types in specific conditions will help to establish whether a machine is capable of clearing all mines. For example, a flail, engaging a specific mine type may detonate or destroy all functioning mines of this type without the machine being damaged or its capability degraded. If it is known that the contaminated site, or road, contains only the specific mine type which the machine is known to detonate, there may be no requirement to follow-on with a secondary clearance process. A simple visual inspection of the road may be sufficient.

The main mine clearance machine designs are:

- > flails
- > tillers
- > combined tiller and flail systems, or those with interchangeable flail or tiller tools
- > civil or military plant, agriculture or forestry machinery adapted for mine clearance or removal (such as the grill bucket on a front-end loader)



An example of a mine clearance machine | the Scanjack 3500



An example of a combined tiller and flail system | the MV10

All of these machines can be used for road clearance. Mine clearance machines always destroy the road surface. Road reconstruction will be required after clearance has been completed, to make the road useable again.

APPLICATION OF MACHINES TO ROAD CLEARANCE

TO FLAIL OR TO TILLER?

In ground processing and clearance of SHAs and technical survey tasks, the most commonly used mechanical tools are flails and tillers. Similarly, in road clearance, these assets have been applied more and more often as their reliability and effectiveness have gradually increased over the last five years. An important advantage of these machines is that they will also destroy minimum-metal mines. However, their potential for effective use is not universal. The following four principles should be observed when considering their application for road clearance.

- 1.** Only machines with sufficient power to penetrate the road surface to the required depth should pass accreditation.
- 2.** Only machines that can survive blasts from AVMs without the machine being completely damaged, or its capability degraded, should be used for road clearance.
- 3.** They should only be applied on dangerous segments of roads, as defined by a general or a technical survey.
- 4.** Coordination with a road constructor will be needed as the road will have to be rebuilt or surface-repaired, as these machines destroy the surface of the road.

In general, the better the general survey and technical survey process, the more effective the deployment of mechanical equipment will be.

Both flails and tillers have their strengths and weaknesses. In most scenarios the preferred option is to use a combination of both, depending on the road surface and the hazard. Typically, a tiller system might be more cost effective when there are no mines encountered, while a flail demands less repair and downtime when detonating mine targets. Table 1 summarises the strengths and weaknesses of the two mine clearance systems.

CHAPTER 3

APPLICATION OF MACHINES TO ROAD CLEARANCE

Table 1 | Advantages and disadvantages between flails and tillers

Advantages of tillers	Advantages of flails
> Lower operating cost when no AVMs are encountered.	> Lower operating costs when AVMs are encountered.
> Higher production rate due to less downtime for maintenance and repair.	> Lighter prime movers can be used as the base vehicle which often results in a lighter machine.
> Easier to control and to measure penetration depth.	> More target impact in loose soil and sandy conditions due to no "slipstreaming"* phenomena.
> Less maintenance needed.	> Less expensive to buy.
> Generates less dust, which increases operator's visibility and reduces wear and tear on engine and moving parts.	> Demands less engine power to operate the tool.
> Easier to ensure overlap with previously cleared lanes.	> Less likely to be blocked by debris, such as concrete elements and vehicle parts, encountered during operation.
> Uses commercially available steel teeth that last longer than chains and hammers and are easier to replace with new ones.	> Chains and hammers can be locally manufactured in countries with a steel industry capacity.
Tiller disadvantages	Flail disadvantages
> Larger repairs often required when detonating AVMs.	> Higher replacement costs of hammers and chains compared to tiller teeth.
> Often based on heavier prime movers.	> Generates more dust, which leads to decreased visibility and more wear and tear on engine and moving parts.
> Demands more engine power, which often leads to higher fuel consumption.	> Demands slow operating speed to break through tough surface layers of ground.
> Larger elements of worksite debris and rocks can block, and potentially damage, the clearance tool.	> Can throw out mines, in particular polycarbonate/ ABS plastic-cased APMs like the VS-50.
> The tiller tends to be blocked by mud when working in sodden conditions.	> Not as effective as tillers when deployed on hard ground.
> Particular types of tillers are subject to "bow wave" and "slipstream"* phenomena.	> Can generate "skip zones"* when not properly operated.

* For an explanation of the reported phenomena of bow wave, slipstreaming, ridges/skipped zones and soil expansion, see Reference Document 11.

APPLICATION OF MACHINES TO ROAD CLEARANCE

Table 2 summarises the advantages and disadvantages of flails and tillers over other mechanical clearance tools like rollers and loaders.

Table 2 | Advantages and disadvantages of flails and tillers over other mechanical clearance tools

Advantages

- > when well-managed, flails and tillers are the most cost-effective clearance tool for larger sites or demining tasks
- > fast and reliable
- > the performance of many machines has been tested and evaluated in accordance with the protocol described in CEN Workshop Agreement 15044
- > performance and output is easy to measure, quantify and document

Disadvantages

- > "soil expansion" (overburden) can be a problem for follow-on activities (manual or MDD)
- > demands a professional logistical set-up to ensure productivity
- > high initial capital investment costs – and relatively high running costs

GROUND PREPARATION MACHINES

Ground preparation machines (light, medium and heavy systems) are primarily designed to improve the efficiency of demining operations by reducing or removing obstacles. Ground preparation may or may not involve the detonation, destruction or removal of landmines. Ground preparation machine tasks in road clearance might include:

- > vegetation cutting and clearing
- > removal of tripwires
- > loosening the soil for follow-on activities
- > removal of metal contamination
- > removal of building debris, boulders, rubble, defensive wire obstacles
- > sifting soil and debris
- > repairing the surface of the road following a ground engaging machine

CHAPTER 3

APPLICATION OF MACHINES TO ROAD CLEARANCE



An example of a ground preparation machine | the MineWolf Bagger

Vegetation cutters are used to assist manual clearance, mine detection dogs and other detector systems on roads. Vegetation cutting commonly occurs where the road is overgrown by vegetation, or vegetation partly blocks traffic lanes. If the clearance contract states that the clearance task has to clear the road up to an extended width on both sides of the road, vegetation cutting may be required before manual or MDD clearance operations can start.

In most cases machines used as vegetation cutters are based on commercial off-the-shelf equipment which has been adapted for demining operations. The most commonly used configuration is to install a cutting tool, such as a slasher or a mulcher, on the arm which normally has a backhoe bucket fitted to it. The chassis can be a medium size, wheeled tractor with a protective operator cab or fitted with a remote control. Such machines provide a flexible, mobile platform which can be used for a variety of functions and tasks.



An example of a vegetation cutter

APPLICATION OF MACHINES TO ROAD CLEARANCE



An example of a soil loosener, attached to a Pearson Minefield Tractor

Graders are successfully used in ground preparation roles in road clearance. The graders are well suited to surface preparation of roads and to assisting other clearance activities. MDDs will have easier working conditions following a grader operation, since the removal of the top layer will enable odour from the mine to evaporate, and other demining tools will be guided by the cut made by the grader's blade on the road surface. A grader can also be used to improve the road surface after other machines have worked on it. Graders in a standard configuration need an armoured cab to protect the operator from an AVM blast. (See the *Voodoo* description (page 45) for an example of graders used for road clearance as part of an integrated system.)

DETONATION TRAILERS AND MINE ROLLERS

Mine rollers or detonation trailers are used to prove the safety of roads that have been cleared of AVMs. There have been a variety of rollers used on roads, varying from the (rarely used) steel rollers, through to the solid-tyred rollers, the pneumatic tyres used on the Chubby system and the HALO Multidrive.



The Chubby system

The towing vehicle is fitted with low pressure tyres (to avoid setting off a mine) and detector arrays (shown stowed at an angle to the side of the engine). Towed behind are a series of trailers fitted with pneumatic truck tyres and ballasted to load each wheel with approximately 1.8 tonnes.

This type of vehicle was originally deployed during earlier conflicts in Southern Africa. They are now being used by demining operators, principally in Angola. There is concern as to how effective these detonation trailers are

CHAPTER 3

APPLICATION OF MACHINES TO ROAD CLEARANCE

when employed in humanitarian mine clearance operations because they have not yet detonated any mines. It is not certain whether this is because there have been no mines in the road or because the Chubby has developed insufficient force to activate the fuse. It is unfortunate that the wheels of these detonation trailers have only been loaded to about 36 per cent of the typical wheel loads of the heavy trucks.

Research has concluded that:

- > the benefit of adding extra weight to pneumatic tyres is disappointing, as much of the additional force is lost due to the tires distributing the load more widely: but there is significant benefit to using a wheel that is harder than a pneumatic tyre
- > using steel wheels at wheel loads in excess of 3,000 kilograms force, will improve the margin of safety of detonations significantly above that of truck wheels
- > where steel wheels are not acceptable, solid rubber tyres will give a lesser, but worthwhile, improvement
- > the effectiveness of mine rolling diminishes with depth

MINE PROTECTED VEHICLES

Mine-protected vehicles (MPVs) are vehicles specifically designed to protect any occupants, and equipment from the effects of a mine detonation. In mine action, the designation MPV is normally associated with vehicles originally designed as armoured military personnel carriers. MPV are commonly used during survey and detection operations, often on roads. They can carry equipment such as detector arrays or vapour sampling devices, or push or pull a roller. They are often equipped with steel wheels that can be used for hazard reduction, technical survey and area reduction on roads.



An example of a mine protected vehicle | the RG31 Mk6

APPLICATION OF MACHINES TO ROAD CLEARANCE

A variety of vehicle-mounted detector systems have been developed over the years. The South African military developed a number of vehicle-mounted systems, eventually producing the Meerkat vehicle as part of the Chubby system. This vehicle also used an under-body detection array and was followed by engineers to clear any suspect signals.



The Meerkat

HALO Trust acquired a Chubby system and employed the Meerkat in Eritrea. Recognising drawbacks with the under-body mounted detection system, HALO contracted Ebinger to design a front-mounted system, incorporating the UPEX-740 detector that could be operated by one person. The system incorporated a single detection loop mounted on a wooden fold-up frame, wired to a control and warning box in the cab.



The Chubby Meerkat LLD front detector

After calibration, the operator would simply drive at a pace of between five and seven kilometres per hour until the warning bell sounded. The operator would immediately stop the vehicle and try to centre the front-mounted coil over where the signal would be the strongest, without driving over that point. Once the spot was identified, a clearance team could be brought forward to clear that point.

CHAPTER 3

APPLICATION OF MACHINES TO ROAD CLEARANCE

INTEGRATED SYSTEMS

There are a remarkably small number of integrated road clearance systems in operation today. The best known is the Voodoo System.

The Voodoo System

Developed by MgM (Menschen gegen Minen), the Voodoo System has been used successfully in Angola for about ten years.

The Voodoo System is *not* designed to be used on all-weather paved or asphalt/tarmac roads. In the provinces of Angola where MgM is conducting clearance, the hazard exists on roads where their use can be expected to be interrupted by wet weather and the rainy season. These roads simply make use of the local soil and – during good dry weather – can be used by heavy transport vehicles, buses and lighter vehicles. Nevertheless, these roads are part of the national secondary road network, and their clearance does have a large impact on the local population.



A motor grader used on roads

In Angola, the major mine hazard on the roads is from AVMs. The most difficult mine to deal with is generally said to be the South African No. 8 minimum-metal mine. This was designed with all its metal components in the base of the mine, which makes it undetectable by metal detectors under most circumstances. The density of mines laid is extremely low – usually only a few AVMs and APMs in an entire length of road of 50 kilometres or more. The location of these mines can often be predicted by experienced technical survey teams and by the assistance of the local population.

In spite of the very low density and the predictability of the location of the mines, the work agreed between the National Inter-Sectoral Commission for Demining and Humanitarian Assistance (CNIDAH) and MgM will stipulate that the entire length of the road should be graded. This is to ensure that the entire road is processed by the blade of the grader during the process, and that the road surface is considerably improved, allowing much more effective use of the road.

APPLICATION OF MACHINES TO ROAD CLEARANCE

Statements of work further stipulate that the road must be left in such condition that the mine action authority can easily traffic the road to conduct quality assurance inspections. This means that road construction becomes a significant part of the road clearance process. Culverts and expedient bridges are built, and so on, all at the expense of efficient mine clearance.

However, this work means the road can be used immediately. Movement of displaced persons, humanitarian aid and normal transportation of goods and people can take place as soon as road clearance is completed. The economic and social benefit of this process is considerable and therefore this “road construction” element is an integral part of the road clearance work.



The HEC Rotar sifter

The Voodoo system is a process that combines many elements including planning; survey; clearance using machines, dogs and manual deminers; quality assurance/control; and record management. (Operating procedures for the system are detailed in Reference Document 1 on the CD-ROM with this Guide.)

The effectiveness of the Voodoo System

The motor graders are the key element in the Voodoo System. This is the equipment which sets the pace for the entire operation and will have the greatest effect on productivity. It is the preferred vehicle for road clearance, most notably when mine clearance goes hand-in-hand with road construction.

The grader will perform well if it operates on a flat, sandy road. The grader/Voodoo system also works well on highland roads, jungle tracks or just about any secondary road surface, except rocks. Rainfall can be a limiting factor but not a debilitating one. Team leaders always seek solutions to any challenges that may prevent operations from continuing.

APPLICATION OF MACHINES TO ROAD CLEARANCE

The berm (a ridge, or mound of earth) that is created provides a distinctive marking method for defining the edges of the cleared area. Deep potholes (filled with rain) and large obstacles on the road require particular investigation, and slow down the mine clearance process. But, deep potholes on asphalt/tarmac roads are not generally filled with water for the whole year. Dry potholes can quickly be checked by the MDDs.

Roads with a low density of expected mine hazards are preferable for the Voodoo system. However, MgM reported that the density of mines is sometimes very high in hot spots. In one case, the Voodoo system found nine AVMs within 100m of each other.

The Voodoo system is not designed to work on the traffic lanes of a paved asphalt/tarmac road. The threat along an asphalt/tarmac road that has been undisturbed is negligible. But the Voodoo system, including the grader, can work effectively along the sides of paved roads, where hazards are most prevalent. Culverts are easily checked for explosive charges set under roads. Clearance of the sides of the roads will also reveal planted mines, emplaced directional mines and command cables, set to charges or pipe mines laid in holes from the side to lie under the asphalt/tarmac road. Therefore there is no need for a system to dig up the entire asphalt/tarmac road in order to find charges set under it.

The Voodoo system performs well if the combination of tools is operated in accordance with the conditions on the ground. The possible time-lag between the grader in use and the follow-on MDD, as well as manual mine clearance can become the main weakness of the system. A high density mine threat can dramatically slow the process of road clearance. The right combination of tools and their appropriate application on the ground are the key contributors to good performance.

CHAPTER 4

MINE DETECTION METHODOLOGIES FOR ROADS



MINE DETECTION METHODOLOGIES FOR ROADS

BASIC PRINCIPLES OF MINE DETECTION METHODOLOGIES

Technical intervention on roads is a mix of technical survey and clearance. The latter should be limited to small segments, or spots, where hazards are likely to be found. There are, of course, a variety of detection tools, some of which are specifically designed for roads. No system has proved to be either foolproof or universal in application; therefore the toolkit principle of demining is especially applicable to road clearance.

Given the typical length of roads to be cleared – many kilometres – manual demining using traditional detectors needs to be focused on confirmed or localised high-risk areas, such as bridge heads and junctions. Of far more widespread application are mobile detection systems, such as the Wide Area Detection System, the Vehicular Array Mine Detection System or the use of mine detection animals. These are described below.

WIDE AREA DETECTION SYSTEM (WADS)

Based on the experiences of UXB (a commercial demining company) with a similar road clearance system in Eritrea in 2001, DanChurchAid (an NGO) contracted Regis Trading (South Africa) to construct a modular wide area system for road clearance tasks in Angola. The system was completed in late 2004 and named the Wide Area Detection System.

WADS can be used effectively on roads where metal-cased AVMs are suspected. Standard metal AVMs, such as the TM-46/57 series, can be consistently located at depths of one metre or more, as can common UXO items. However, its application for detecting minimum-metal AVMs is less efficient and there are a high number of false positive readings that result from a more sensitive setting.

WADS employs the Ebinger UPEX-740 large loop as the detection system. The synchronisation of the UPEX coils is controlled through standard Ebinger hardware and software, and fed into a standard laptop computer. Tracking of the detection and vehicle progress is done by an OmniStar wide area DGPS system. The WADS is mounted on a Mine Protected Vehicle (MPV) (South African Samil 20 “Rhino”) as the prime mover.



The WADS

A modular mounting system has been constructed that allows the WADS to use up to eight UPEX coils in various configurations and sensitivities. A series of electric winches raises and lowers the unit with minimal effort. The mounting system is quickly adjusted to cover search widths as small as 3m, or up to 8m if needed, including extending the detection swathe into a road verge. Search speed ranges between five and 10 km/h, depending on the terrain and vegetation.

The system can be retracted into a travel position in approximately 30 minutes, as illustrated below, which allows self-transport at speeds up to 80 km/h on improved roads and 30-50 km/h on unimproved roads. This has greatly reduced the transport time between survey sites, and so improved the productivity of the system.



The WADS in travel position

VEHICULAR ARRAY MINE DETECTION SYSTEM (VAMIDS)

As part of a United States demining research and development project in the mid-1990s, Schiebel detection systems developed the Vehicular Array Mine Detection System (VAMIDS). The original version was mounted to a skid-steer vehicle for prototyping and has since been mounted on MPVs. The system works on electromagnetic principles, incorporating PSS-19/2 mine detector heads in a modular array.

MINE DETECTION METHODOLOGIES FOR ROADS

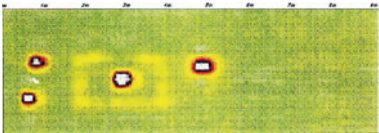
Early versions were mounted to the front of a vehicle, with the data from each detector head fed into an on-board computer. The hardware assembly can accommodate between eight to 48 detector heads in the array, allowing it to be expanded or reduced as needed. The system underwent considerable testing and upgrades, both at the US Army R&D organisation of night vision and other sensor technologies called NVESD, and with Mechem.



The NVESD version was mounted to a skid-steer for prototyping

Earlier versions of the geophysical mapping were quite cluttered and difficult to discriminate between clutter and a suspect item. Considerable progress on data processing was made on later versions and the maps became much easier to understand (see Figure 3).

Figure 3 | More recent VAMIDS mapping results



The measurements at the side of the map makes progress easy to follow, once the baseline was correctly established. This allows for an effective area reduction process that accelerates the clearance, with less labour. The software and data-recording system requires specialised training to operate, but does not require a trained geophysical specialist to analyse the survey results - a substantial benefit.

CHAPTER 4

MINE DETECTION METHODOLOGIES FOR ROADS

Mechem adjusted the power supply to the detection coils and mounted them on a two-metre-wide piece of durable rubber matting (expandable up to eight metres if needed). The entire detection array is mounted on a well-designed swing-arm assembly that allows employment to either side or directly behind the vehicle.

This system offers many advantages, such as contouring to the road surface and minimising the stand-off between the detection coils and the ground. This provides better reception of the eddy currents being returned, and therefore increased sensitivity when searching for smaller items. Search speed ranges between five and 10 km/h, depending on terrain. The disadvantage is that, because the handheld detector heads are used as the coils, the detection depth is limited to between 50 and 70 centimetres against larger items such as metal-cased AVMs.



Both Mechem and NVESD have mounted the VAMIDS on protected vehicles. The Mechem system has been working in Eritrea, DR Congo and in Sudan for several years.

THE USE OF MINE DETECTION ANIMALS

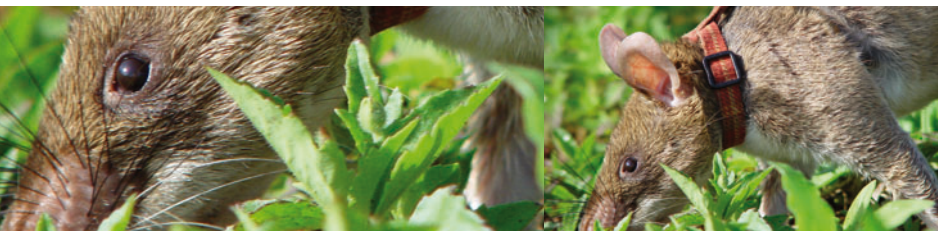
This section describes indirect and direct use of mine detection dogs (MDDs) during road clearance. This includes Remote Explosive Scent Tracing (REST) and Mechem's Explosive and Drug Detection System (MEDDS). These last two are systems suitable for technical survey, to release roads without undertaking clearance, whether with MDDs, manual deminers or demining machines.



A mine detection dog

When animals are used for detection of explosives, defined changes in the animals' behaviour indicate the presence of odours that correlate positively with the presence of that ordnance.

A number of animal species have been used in the detection of landmines. The list includes dogs, rats, goats, pigs, and bees, although dogs are by far the most commonly used. The remainder of this section focuses on the use of MDDs in both direct detection and remote detection roles. There is also a brief discussion of the use of mine detection rats (MDRs).



A mine detection rat

Dogs and rats have been preferred over other animals in mine detection. Both animals are known to possess a keen sense of smell. Given that mines in minefields cannot be seen, heard or touched, sensing their odour is the only way they can be detected by animals. A dog's ability to detect an odour against a background bouquet has been estimated at between 10,000 and 100,000 times that of a human's. The sensory abilities of both animals for the odours emanating from mines are far better than those of any existing electronic device.

Training techniques used in the military, police, civil defence and customs have also been used to train mine detection animals. Both dogs and rats are relatively easily socialised with humans, meaning that most aspects of their behaviour can be managed by people.

Animal detectors are generally well-suited to the demining of roads because roads contain little or no vegetation to limit the surface area that can be searched.

REMOTE DETECTION

There continues to be a need for a detection technology that can improve the efficiency of demining. Few technologies rival the potential efficiency of remote detection by animals, and MDDs in particular. This approach involves systematically collecting samples of air or dust/sand from defined sectors of road and presenting those samples to animals trained to emit a clear response when they sense mine-related odours. As the term 'remote detection' implies, these animals inspect the samples in a laboratory that is remote from the sites from which the samples were taken.

REST describes a set of procedures which evolved from Mechem's Explosives and Drug Detection System (MEDDS). The system was originally developed to detect conventional explosives, small-arm weapons and illicit drugs at border-crossing checkpoints. In the mid-1990s, Mechem applied their system to the detection of landmines. The general method was subsequently used by NPA, who called it *Explosives Vapour Detection*, and organisations from the US, where it was known as Checkmate. The two systems are based on the same operating principles and used for the same purposes. For the sake of clarity, the generic term, REST, (which has also been adopted in IMAS), is used to refer to all methods of remote sensing using animals.

REST is not a method in itself, but a set of methods for identifying areas of land that are contaminated with the explosive ingredients of mines/ERW, and areas that are not. Therefore, REST is better viewed as a sub-system within an organisation's overall detection system, because numerous complex phases are involved:

- > surveying and marking
- > sample collection (*sampling*)
- > sample *analysis* and *follow-up* in the field

REST is to be used as a technical survey system and is not intended for direct detection, or as a primary clearance tool.

The first phase in REST (surveying and marking) generally involves the following:

- > dividing the roadway into equal-sized segments (e.g. 100-200 metre portions)
- > marking the boundaries of each sector with semi-permanent distinctive stakes and/or coloured rocks
- > recording the GPS coordinates of each marker so that the sectors can be drawn on maps

MINE DETECTION METHODOLOGIES FOR ROADS

It is assumed that operators have previously defined and mapped the centre-line of the road at regular intervals, using a GPS. This step not only facilitates any later follow-up searching but also defines the area the organisation has searched, and declared safe at project completion.

In the second phase of REST, samples of air and dust are collected from each sector. This phase is known as *sampling*. Organisations are using different methods for sampling (eg vehicle-mounted suction pumps or manual versions). Coded containers holding either filters or dust samples from each sector are then transported to remote laboratories, where they are presented to MDDs that have been trained to emit a defined response when they detect mine-related odours in a filter or container of dust. This phase is known as *analysis*.

Samples are then designated as either *positive* or *negative*. Positive samples are those that were indicated either by a minimum number of animals, or by one animal a minimum number of times (depending on the organisation's SOPs). These represent road sectors that are suspected of containing landmines. The sectors from which those samples came are searched in a *follow-up* phase by field operators using a different method, (or *layer*), of detection and a method that has finer resolution than REST (e.g. MDDs, MDRs or manual deminers with metal detectors).

Negative samples are those which either none of the animals responded to, or those which occasioned the indication response from less than a minimum number of animals. The road sectors represented by these samples are generally declared free of mines and no further searching is undertaken in them. However, a small proportion of them might be searched more thoroughly during a quality control process.

REST systems are best viewed as strategies for eliminating areas of road suspected of being mined, (i.e. a technical survey approach), rather than as strategies for pinpointing locations of mines. They are therefore best applied on road lengths where there are no known minefields and information is being sought to ensure that the road is mine-free. To be used efficiently, REST should follow general survey, but precede the more thorough searching offered by MDDs or manual deminers.

REST systems have several major advantages over more conventional methods.

1. By seeking to identify negative sectors of road, REST has the potential to reduce, substantially and quickly, the area of road that needs to be inspected by more expensive and slower detection methods, or cleared, either manually, or by machine. This potential for rapid *area reduction* offers a guaranteed improvement in operational efficiency because detection and clearance resources can be deployed in areas where actual hazards exist.

MINE DETECTION METHODOLOGIES FOR ROADS

2. By using MDDs as the primary detection agents, REST provides a potentially flexible detection system that can be tuned to a wide variety of targets. The set of targets that the MDDs are trained to respond to might include a set of landmines that are common in that area, or a mix of landmines and IEDs. Whatever elements make up the set, it is relatively straightforward to capture and present to MDDs the odour signatures of each element. The MDDs can quickly learn to distinguish and indicate different targets.
3. The most common AVMs are metal cased (e.g. the TM57) and are relatively easy to detect by systems involving arrays of metal-detectors mounted on armoured vehicles (e.g. VAMIDS). However, some AVMs are largely plastic (i.e. minimum-metal mines) and cannot easily be detected using metal detectors. Fortunately, chemists have discovered that plastic mines are more likely to leak their explosive-compound ingredients into surrounding soil than metal ones: it is the odour of these compounds that animals can detect and be trained to indicate. REST can, therefore, potentially fill a gap in an organisation's detection system when they are tasked with clearing AVMs from roads.

Whereas the use of MDDs in the field is constrained by environmental factors, (particularly hot and dry climates or very rocky terrain), the use of a laboratory for REST analysis greatly enhances the accuracy, reliability and endurance of animal detectors. The animals can work most days and for longer periods each day. REST animals can be less likely to miss positive samples, can be more stable in their detection accuracies and can sustain that stability for longer periods of time than their field-operating counterparts. (Environmental conditions on the road itself are, however, important variables determining the effectiveness of sampling, and so must be considered relevant factors in the REST SOPs of any organisation.)

SAMPLING IN MEDDS & REST

The manner in which samples of air and/or dust are collected from suspect roads is critical to the overall effectiveness of the REST system. Different collection techniques result in different quantities of target compounds (e.g. soil contaminated with explosives) being taken to the analysis phase, and the accuracy of animal detectors is unavoidably limited by the strength of the target odour in a sample. The overall aim of any sampling technique is to maximise the collection of explosive compounds in positive samples taken from mined sectors – and minimise any transfer of these compounds to the negative samples taken from non-mined sectors.

MINE DETECTION METHODOLOGIES FOR ROADS

Considerable resources have been spent on developing procedures and equipment to optimise the sampling component of REST. Perhaps the most important finding is that the concentration of explosive compounds and their by-products in the surface sand/soil above a mine is around one million times higher (and considerably more stable) than the concentration of these chemicals in an adjacent odour plume. This has led a number of organisations to develop equipment and protocols for collecting dust samples from roads. This work is still in progress, but it is likely that the sampling phase of REST systems will change dramatically. The aim will be to bring representative samples from road sectors into the laboratory for close inspection by animals.

Similarly, the analysis phase of REST has undergone dramatic changes and differs markedly across organisations. Variations in method include: how the samples are arranged for inspection by animals, how the samples differ from, and might be interspersed with, training samples, (i.e. known positive and negative samples), how rewards are arranged for indications on operational and/or training samples, how an animal's performance is measured and analysed, and how the responses of individual animals are used in the categorisation of operational samples.

For further information on procedures used in REST and MEDDS, see Reference Document 5 on the CD-ROM included with this Guide

DIRECT DETECTION BY MINE DETECTION ANIMALS

Direct detection is the use of detection technologies in the field to identify areas of ground containing signals that correlate positively with the presence of buried landmines or concealed IEDs. MDDs can be used for intensive searching of a suspect road. The resolution of this searching is generally fine enough to enable the animal's indications of a mine to be followed up by manual searching by a deminer.

The efficient use of MDDs generally requires that they are deployed following the use of a wide array detector system, or REST, to reduce the search area. This position in a detection system means that MDDs can also serve as a useful quality assurance function. Specifically, by systematically selecting areas of road to be searched by MDDs, the detection accuracy of the technology before it in the sequence (i.e. VAMIDS or REST) can be assessed. This requires that all sectors of road declared positive, and some negative, by the preceding detection technology must be searched by the animals.

MINE DETECTION METHODOLOGIES FOR ROADS

MDDs searching areas declared positive by REST provide opportunities for identifying hits and false-alarms of that technology. In contrast, MDDs searching areas that have been declared negative provide opportunities for identifying correct rejections and misses of that technology.

USE OF MINE DETECTION ANIMALS FOR QUALITY MANAGEMENT

Detection systems involving animals can be useful for quality control. By deploying REST occasionally on roads that were declared safe by other surveying techniques, (such as interviewing locals), their accuracy and reliability can be assessed. The logic behind this process is that the follow-up detection system is applied to more sectors of road than declared necessary by the detection system under scrutiny.

This might seem like a waste of time and resources. However, without accurate and informative assessments of each component of an organisation's detection system, deploying components that add no value to the overall system wastes more time. Even worse, if one component is systematically missing mines or providing false-alarms at a high rate, then that component could be reducing the accuracy of what could otherwise be a reliable overall system.

MDDs can also be used effectively in a follow-on role behind mechanical demining machines to ensure that all mines have been cleared. The MDDs can also be deployed for direct detection in support of a mechanical demining operation, to cover areas that were not accessible to the machines, such as areas around buildings, bridges, trees, etc.

CHAPTER 5

APPLYING LAND RELEASE PRINCIPLES TO ROAD CLEARANCE



APPLYING LAND RELEASE PRINCIPLES TO ROAD CLEARANCE

BASIC PRINCIPLES OF APPLYING LAND RELEASE TO ROAD CLEARANCE

As mentioned earlier, roads are best released by applying a “layered” approach. There is, however, a need for clear criteria to define when roads can be released by general and technical survey. These criteria should comply with internationally recognised standards and guidelines, taking local realities into account. The basis of any decisions made to release segments of road without clearance must be carefully documented. Wherever general or technical survey finds evidence of contamination, follow-on clearance is *always* required.

LAND RELEASE METHODOLOGY AND ITS APPLICATION TO ROADS

The vast majority of suspect roads demined today are proven, in retrospect, to contain no landmines or other explosive ordnance. Efficiency requires investing more time and resources in the activities undertaken prior to clearance, including general and technical survey.

There is, today, a set of broad generic principles and requirements that are widely understood throughout the mine action sector. Their application to roads has yet to be fully explored in practice, but land release methodology offers useful insights on how to maximise efficiency in road clearance. The following five elements would comprise a road release methodology.

1. Start a formal, well-documented investigation process into any mine problem

A precondition for any release of roads using general approaches is to establish a credible investigation into the risk of the presence of mines or ERW. In some countries, land has been released as a result of re-analysing old survey information more thoroughly. However, it is more common to undertake a new survey.

There are several types of survey. The general survey is a hazard identification process. Its output is based purely on the collection of information from a variety of sources, coupled with visual field inspection. General survey is the first step for mine action organisations to build an approach and make decisions on whether a particular segment of road can be released.

APPLYING LAND RELEASE PRINCIPLES TO ROAD CLEARANCE

For a road to be released through general survey there needs to be a documented high level of confidence in the collected information. Factors that will influence this process include:

- > a thorough and well described methodology ensuring objective assessments
- > sufficient number of credible informants (with names and contact details recorded)
- > survey information quantified if possible

A general survey should ensure that not only are major informants with knowledge of the conflicts or community leaders involved, but that other relevant respondents are also included in the process of data collection and information cross-checking.

2. Set well-defined and objective criteria for reclassification of roads

The criteria used for the reclassification of suspected roads need to be clear and universally understood. If a road is released as a result of a general survey, the detailed process allowing that release should be described and, to the degree possible, quantified.

Reclassification can be based on qualitative and quantitative measures. The first implies clear criteria for measuring the confidence in survey information. Information provided by soldiers who laid the mines may be considered more credible than information provided by a villager who recently moved back into an area. Quantitative measures may involve the type of information and the number and variety of information sources.

3. Ensure a high degree of community involvement

There needs to be a high level of confidence in the process, which should be genuinely accepted and agreed between the operators and the population with the local authorities. Effective local participation in major decisions will ensure that a road is effectively used after it has been released. Local participation should be fully incorporated into the main stages of the process in order to render the entire process more accountable, manageable and ultimately cost-effective. The community should ideally be involved in any handing over process or procedure.

4. Ensure ongoing monitoring after release

Post-clearance and post-release monitoring must be properly planned and agreed between the different parties. This will help measure the impact that road release has had on local life – and clarify issues related to liability in case of accidents. This approach is important especially when it effectively uses current social and political structures to carry on the work of monitoring and information updating.

5. Support a formal national policy on liability issues

The absence of a national policy that addresses issues related to liability is likely to impede the process of effectively releasing roads. It is therefore important that the national mine action authority, on behalf of the national government, develops a policy that details the shift of liability from the survey organisation to the government or local authorities.

The shift in liability may be tied in with the requirements for an open survey and assessment process. An organisation failing to demonstrate that it has followed the national policy may, for example, be liable in the case of accidents or evidence of mines in previously released land. If it is demonstrated that the organisation undertaking the survey and assessment has used a methodology which has been endorsed by the government, liability in case of later mine accidents typically lies with the government.



CONCLUSION: FIVE GUIDELINES FOR ROAD CLEARANCE

This final chapter summarises the lessons of the guide in five key points.

1. Only areas that are absolutely necessary for the road constructor and end user should be cleared.

This is the first step in any road clearance project – defining as restrictively as possible the clearance requirement. It is essential to clearly understand the intended use of the road before starting operations, as this can help to reduce the width and depth of clearance. Dialogue with the road constructor may, for example, enable the operator to agree to a reduction in the width of area to be demined, in return for an increased number of cleared borrow pits.

2. Road clearance needs a layered approach.

Survey, allied to a systematic analysis of all data gathered, is crucial to the success of a road clearance project. A mixture of appropriate tools, combining different suitable demining technologies and methodologies, should be used for survey and clearance of roads. Prior to fielding any equipment, their performance should be field tested under realistic conditions.

3. Agreed criteria are needed to release roads without clearance.

It will always be possible to release segments of road without undertaking clearance of the road surface. This demands prior agreement on the standards and guidelines for information gathering, documentation and adjustment to local realities that must be followed. But when general or technical survey finds clear evidence of mine contamination, follow-on clearance is always required.

4. The difference between road clearance and clearance of land needs to be understood by demining operators.

Not all demining operators have the necessary capacity and knowledge to undertake survey and clearance of roads. For instance, standard manual demining drills and the use of rollers, which are usually used to clear land, may not be appropriate when clearing roads. Specific road conditions and time pressures need to be taken into consideration when determining approach and technology. Mine clearance operators are encouraged to further develop methods and technologies that are specifically suited to the survey and clearance of roads.

5. Quality management is an important element during road clearance

As with any demining task, quality assurance and quality control are integral to each operation. It is essential to document the various processes in an auditable document trail (starting with the survey report and leading up to the handover documentation of the road cleared and released).

Quality assurance should be carried out on all aspects of the road clearance operation. Quality assurance and quality control should not only be internal but also conducted by an external partner, or the contracting agency, if possible. Quality assurance and quality control should ideally be carried out while the operation is ongoing.

LIST OF REFERENCE DOCUMENTS ON THE CD-ROM

1. THE VOODOO SYSTEM, MPV, WADS AND VAMIDS
2. THE USE OF ANIMALS AND ENVIRONMENTAL FACTORS
3. ANALYSIS PHASE IN MEDDS AND REST
4. DETONATION TRAILERS AND MINE ROLLERS
5. CONTRACT MANAGEMENT
6. CHECK-LIST FOR ROAD CLEARANCE
7. CEN WORKSHOP AGREEMENT 28 AND 29
8. IMAS 09.50 (AND IMAS 07.10 ADAPTED TO ROAD CLEARANCE)
9. IMSMA ROAD CLEARANCE FORM
10. DATA NEEDS
11. BOW WAVE, SLIPSTREAMING, SKIPPED ZONES AND SOIL EXPANSION
12. CATEGORISATION OF MINE CLEARANCE MACHINES
13. PERFORMANCE TESTING





Geneva International Centre for Humanitarian Demining
Centre International de Déminage Humanitaire | Genève

7bis, av. de la Paix | P.O. Box 1300 | 1211 Geneva 1 | Switzerland
t. + 41 (0)22 906 16 60 | f. + 41 (0)22 906 16 90
info@gichd.org | www.gichd.org



REFERENCE DOCUMENT 1

THE VOODOO SYSTEM, MINE-PROTECTED VEHICLES (MPVS), WIDE AREA DETECTION SYSTEM (WADS) AND VEHICULAR ARRAY MINE DETECTION SYSTEM (VAMIDS)

Road clearance using the Voodoo System

Developed by MgM (Menschen gegen Minen), the Voodoo System in Angola has been used successfully for approximately ten years. From May to September 2006, the combination of mechanical demining machines and mine detection dogs accounted for 93.1 per cent of the total area cleared by the operator of the system in Angola.

It must be understood from the outset that the Voodoo System is not designed to be used on all-weather paved or tarmac roads. In Angola, where MgM is conducting clearance, the hazard exists on what could best be described as tracks, the use of which can often be interrupted by wet weather and the rainy season. Typically the “roads” are meandering tracks. These roads simply make use of local soil material and in good dry weather they can be used by heavy transport vehicles, buses and lighter vehicles. Nevertheless, these roads are a part of the National Secondary Road Network and their clearance does have a large impact on the local population.

In Angola, the major mine hazard on roads is from anti-vehicle mines. The most difficult mine to deal with is generally the South African No. 8 minimum-metal mine. This mine was designed with all of the metal components in the base of the mine which makes it undetectable by most metal detectors. The mine density is extremely low – usually just a few anti-vehicle and anti-personnel mines in 50 km or more of road. The location of these mines can often be predicted by experienced technical survey teams and by the assistance of the local population.

In spite of the very low density and the predictability of the location of the mines, the statement of work agreed between the National Inter-Sectoral Commission for Demining and Humanitarian Assistance (CNIDAH) and MgM stipulates that the entire length of road will be graded. This is to ensure that the entire road is covered during the process and that the road surface is considerably improved, allowing much more effective use.

The statements of work further stipulate that the road must be left in such condition that the mine action authority can easily traffic the road to conduct QA inspections. This means that road construction is a significant part of the road clearance process. Culverts are constructed, expedient bridges are built, and so on, all at the expense of efficient mine clearance. This does, however, immediately provide an important road link for the area. Movement of displaced persons, humanitarian aid and goods and people can take place as soon as road clearance is completed. The economic and social benefit of this process cannot be overlooked and therefore this “road construction” element is an integral part of the road clearance work.



Picture 1. A cleared dirt track.

The Voodoo system is really a process that combines many elements, including: planning; survey; clearance using machines, dogs and manual deminers; quality assurance/control; and record management. Basic operating principles include the following:

General priorities are established annually by the national mine action authority for Angola, CNIDAH. One of the high priorities recently has been to provide road access to the many population nodes without access to primary roads. This is so that the Election Commission has access to the maximum number of people for forthcoming elections. Opening of these secondary and tertiary roads are an ideal job for the Voodoo clearance system.

Provincial mine action authorities play an important part in selecting priority tasks. A strong relationship has been formed between MgM and the authorities and effective liaison between the two helps coordinate clearance plans and priorities.

Planning future operations makes some use of the Landmine Impact Survey but the most detailed information comes from the provincial authorities for technical survey.

Execution of operations depends largely on local conditions and there is a strong reliance on individual demining team leaders conducting the clearance. The team leader is responsible for determining which equipment, personnel and resources are used for a particular clearance task. He/she also has the authority to apply changes on the ground and to request additional assistance if needed. SOPs provide guidelines but the detailed execution is left to the demining team leader.

Decisions made by the team leader include what mix of personnel, equipment, and resources will be used and what follow-on procedure will be used to ensure the ground is clear, i.e. mine detection dogs, manual deminers or a combination both.

The motor grader

The motor grader is the primary piece of equipment used in the Voodoo road clearance operations. It provides the largest increase in productivity and has proved itself over the years as a safe and effective machine. Under normal conditions, MgM uses a planning figure of 3 to 5km per day for an 8m-wide road. This does not include follow-on procedures with dogs and/or manual demining teams. When conditions are good for grading, the limiting factor is usually the number of dogs available for follow-on.

The grader's armour aims to ensure absolute protection of the operator, and to guarantee the integrity of the engine from a detonation blast. Numerous anti-vehicle mine detonations have occurred over the years and there has been no serious injury to any operator. Some minor armoured of vulnerable components has been done, such as rerouting hose lines and occasionally, providing small armoured protective enclosures. The vast majority of detonations during operations are at the rear tandem wheels of the grader.



2. A motor grader used in the Voodoo System.

Operator vision was carefully considered with the placement and size of vision ports. Large openings allow the operator to easily observe the blade, the movement of the soil in contact with the blade, and the berm that is created when the soil moves off the end of the blade.

The ROTAR sifter

The ROTAR sifter is used in the Voodoo System to process the windrows of soil cast to the side of the road by the grader operation. It can also be used to process soil piles or windrows that have been created by bulldozers and other earth-moving equipment in suspect areas.



3. A ROTAR sifter in the Voodoo system.

Mulchers

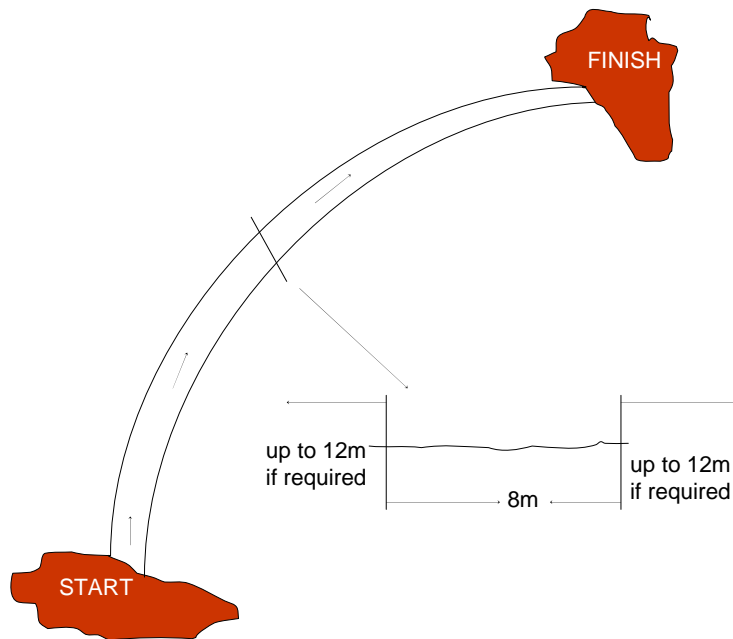
The Mulcher HEC MAXX 2 is used by the Voodoo System to assist manual clearance, mine detection dogs and mechanical operations. This is another piece of commercial off-the-shelf equipment, adapted slightly for demining operations. The most effective configuration to date has been installing the mulcher on the arm which normally has a backhoe bucket fitted to it and installing the sifter where a front-end loader bucket is normally installed (*see Chapter 3*).



4. The MAXX v2 machine with mulcher attachment.

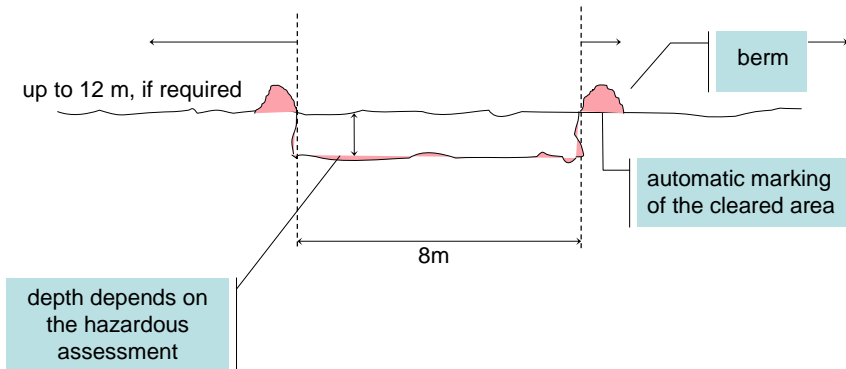
Operating procedures for the system

Picture 5 gives a general view of a typical road project. The start and finish are recorded using a GPS and progress is recorded by simply maintaining a log of the distance travelled along the road or track. The statement of work will define the area that must be cleared (typically an 8m width of road) and the distance to be investigated left and right of the road or track. The investigated area is also defined in the statement of work and might be specified when an additional width must be covered to cater for activities such as follow-on road construction project.



5. A stylised 'typical' road project.

Picture 6 shows a typical cross-section of a road after the grader has made its passes along the road. The depth that the grader scrapes to depends on the hazardous assessment for the particular segment of road and can be varied according to the hazard. Where the likelihood of mines is low, the grader will scrape shallower. Where the likelihood of mines is high the grader will scrape deeper. The berm on each side of the road was created by the spoil scraped from the road surface and cast to the side of the grader blade. This berm automatically creates a very effective marker for the cleared area of the road. The berm is not permanent but is reported to remain clearly visible for approximately one year and can withstand most erosion that occurs during the rainy season.



6. Typical cross-section of a road after grader passes.

The eight steps typically followed when using the Voodoo System for road clearance are:

Step One: Technical survey is conducted using fairly standard methods and equipment. A mine-protected vehicle is the preferred mode of transport.

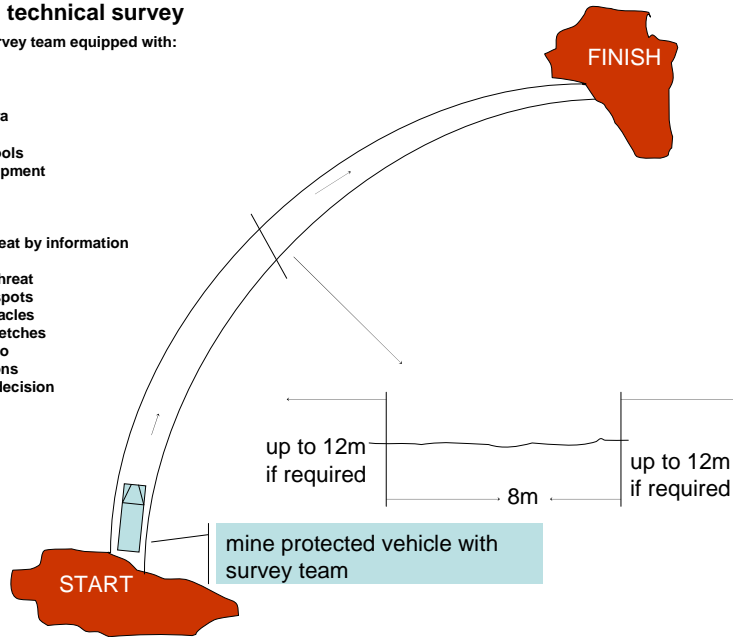
Step one: technical survey

done by a survey team equipped with:

- computer
- GPS
- binoculars
- digital camera
- compasses
- measuring tools
- drawing equipment

given task:

- find the road
- verify the threat by information gathering
- identify the threat
- identify hot spots
- identify obstacles
- draw map sketches
- collect data to make decisions
- prepare the decision



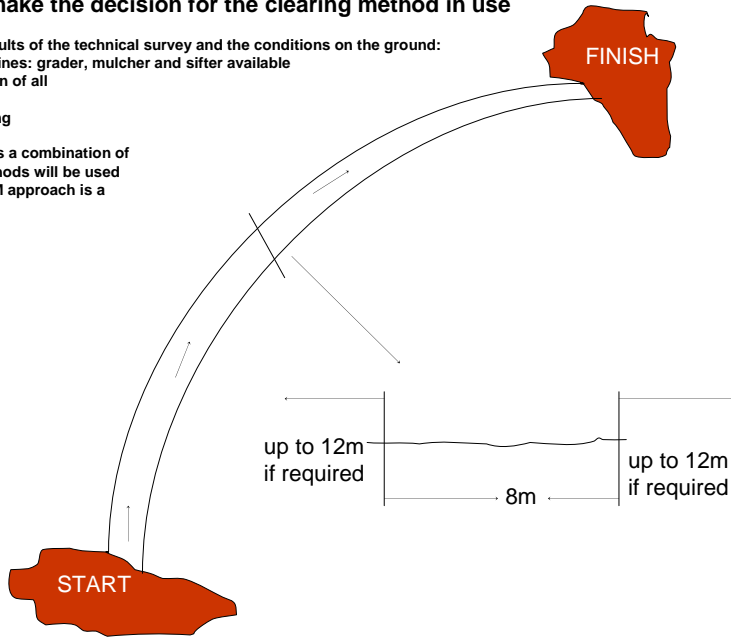
7. Step One

Step Two: A decision is made, based on the technical survey, on what the composition of the road clearance team should be, the equipment required, and any logistical, administrative, or medical requirements for the operation (*see picture 8*).

Step two: make the decision for the clearing method in use

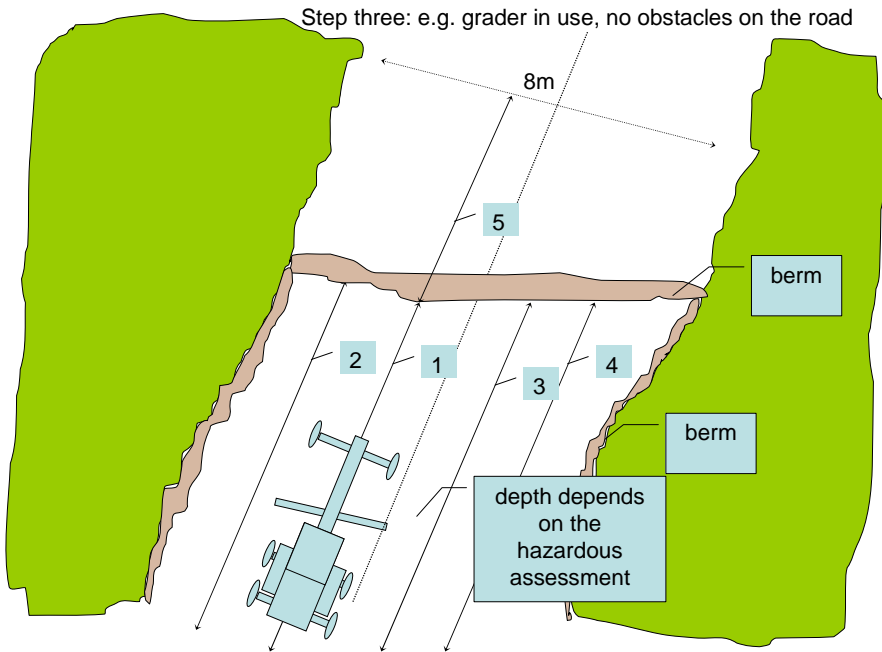
- based on the results of the technical survey and the conditions on the ground:
- choice of machines: grader, mulcher and sifter available or a combination of all
 - MDD
 - Manual demining

In the most cases a combination of all available methods will be used because the MgM approach is a modular one.



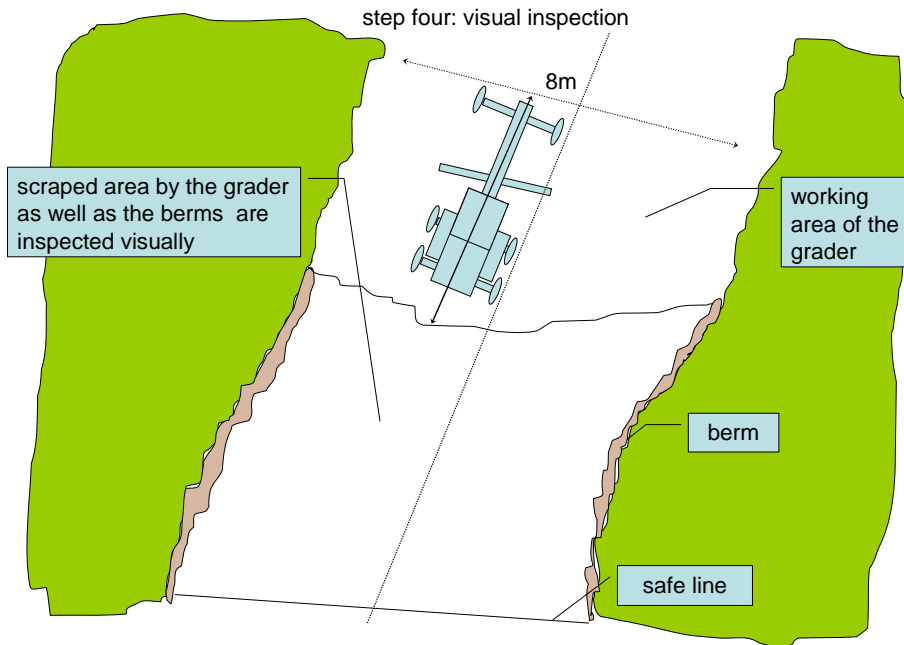
8. Step Two

Step Three: Typically the grader is used initially. It normally makes four passes with the blade to create a nominal 8m-wide track. The berms created leave a clear mark of where the grading has taken place.



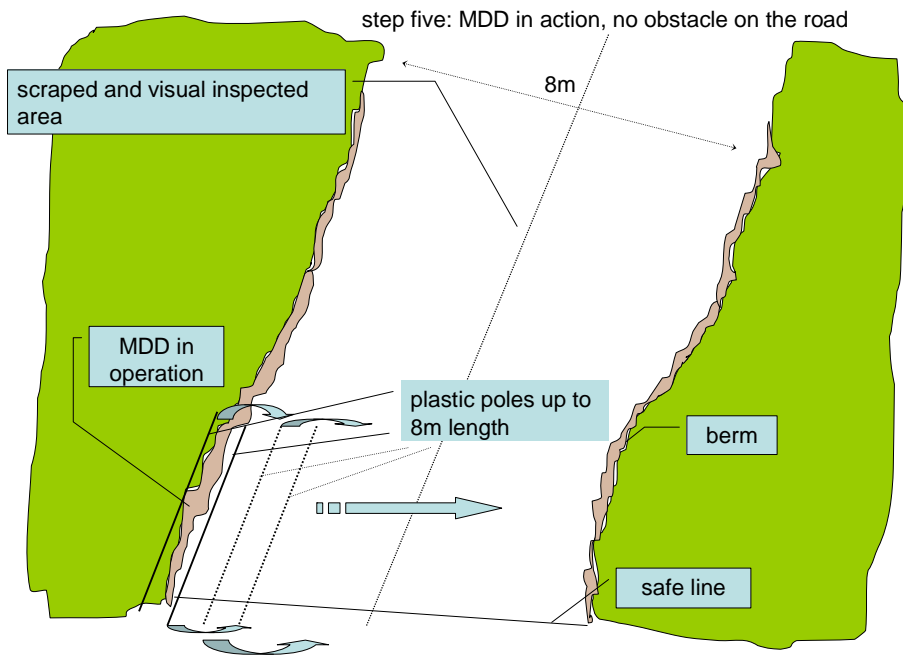
9. Step Three

Step Four: If no mines have been encountered during the grading process, a further visual inspection is made by deminers on foot. They follow the wheel tracks of the grader for an added degree of safety.



10. Step Four

Step Five: Normally dogs are used to follow-on the visual inspection. They follow the grader's work by two or three days to allow the disturbed soil to stabilise and permit any mine scents to migrate to the surface. Two plastic poles, approximately 8m long, laid 1m apart in the direction of the road clearance, are used to guide the dogs and to keep track of the areas checked by the dogs.

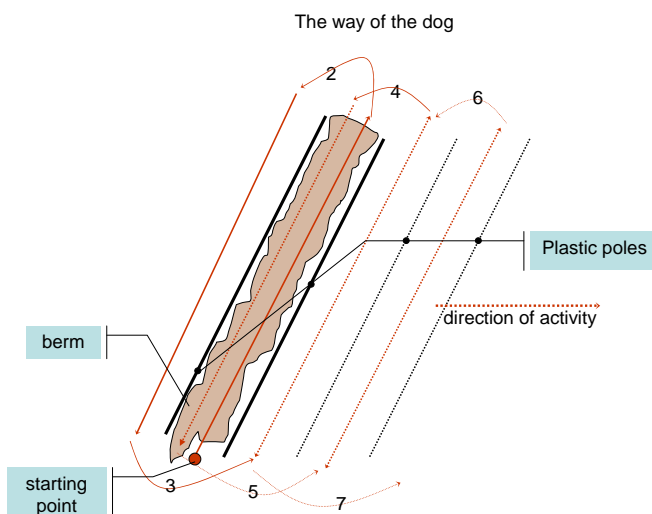


11. Step Five

Each dog (*see picture 12*) is kept on a 10m leash and under the constant supervision of a handler. The path followed by the dog is illustrated in picture 13. The plastic poles are moved in leap frog fashion after each area between the poles is cleared. The left berm of the track is investigated first and then the dog proceeds across the road until the entire road surface has been checked. If a dog encounters a suspected mine he sits and waits until the handler marks the area that the dog has indicated.

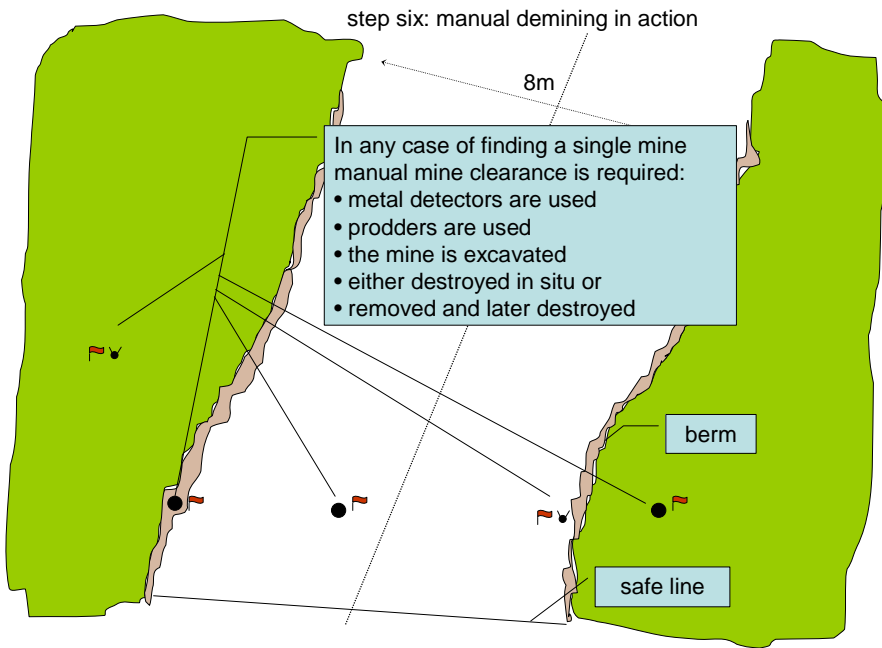


12. A mine detection dog searching.



13. The path of the MDD.

Step Six: A manual deminer then typically checks the area with a metal detector and prodder and will excavate any suspect items. When it is stipulated that the verges are to be investigated, heavy vegetation will be removed with a mulcher working from the road surface previously cleared. The width of the verge to be investigated will be stipulated in the statement of work. This will require the additional steps of Steps Seven and Eight.



14. Manual checking of the area.

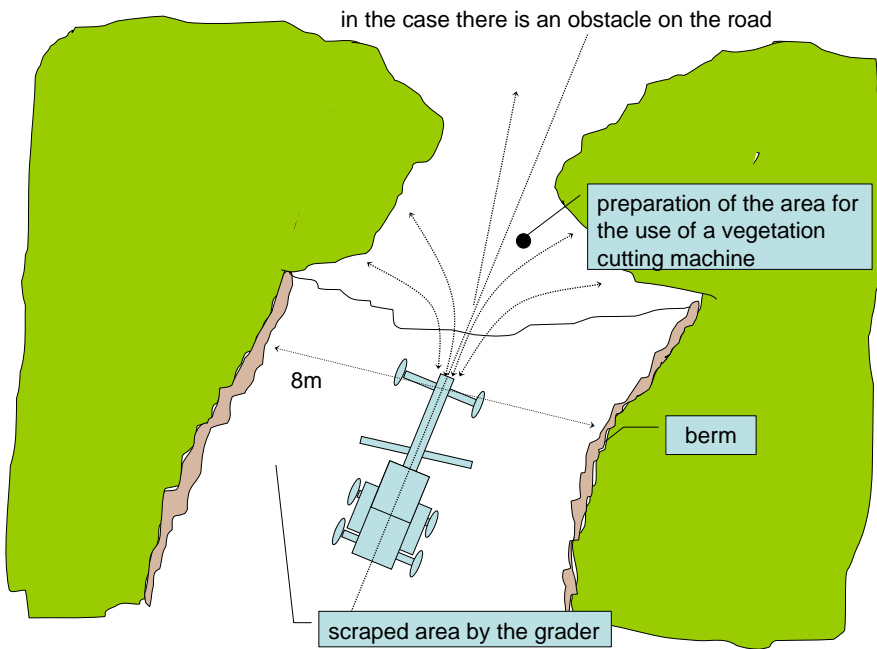
Step Seven: Vegetation is removed, if necessary, by a mulcher working from the cleared area.

Step Eight: Mine detection dogs then investigate the verges beyond the berm. Note that they work at right angles to the cleared road.



15. Investigation of verges.

There are variations in the above procedure. For example, picture 16 illustrates what happens if an obstacle, in this case heavy vegetation, is encountered. The grader proceeds to scrape the full 8m width of road as far as possible. It then scrapes the road in a series of passes to the maximum extent possible. The area scraped is then visually inspected. The area is further investigated by mine detection dogs.



16. Procedural variation in case of obstacles.

After the area to the obstacle has been scraped, inspected visually, and investigated by the dogs, a mulcher can be deployed to remove the obstacle. After the vegetation has been removed to permit grader operation, the grader continues to clear the road to the normal 8m width, and the process continues.

Concluding remarks

Motor graders are the key element in the Voodoo System. They are the preferred vehicle for road clearance. Notably, mine clearance goes hand in hand with road construction.



17. MgM road clearance in Angola.

The Voodoo system performs well if the combination of tools is operated in accordance with the conditions on the ground. The possible time-lag between the grader in use and the follow-on MDD as well as manual mine clearance can become the main weakness of the system. A high density of mine threat can dramatically slow road clearance. The right combination of tools and their appropriate application on the ground are the key contributors to good performance.

MINE-PROTECTED VEHICLES

Mine-protected vehicles (MPVs) are vehicles specifically designed to protect the occupants and equipment from the effects of a mine detonation. In mine action, the designation MPV is normally associated with vehicles originally designed as armoured military personnel carriers. MPVs are commonly used during survey and detection operations often on roads, where they can carry equipment such as detector arrays or vapour sampling devices, or push or pull a roller. They are typically equipped with steel wheels that can be used for hazard reduction, technical survey and area reduction on roads.

A variety of vehicle-mounted detector systems has been developed over the years. In the 1970s, the South African and Rhodesian militaries developed some of the earliest functional vehicle-mounted detection systems, which contributed greatly to the ability to detect mines on roads, thereby increasing safety on these roads. As effective data-recording of the detection signals was not yet developed, all of the systems were based on a direct reading, or “locate and immediately remove” methodology.

The Rhodesian military designed a prime mover that provided a footprint light enough to drive over anti-vehicle mines without detonating them. They prototyped a system called the “Pookie” (see picture 18), which was successfully employed to locate metallic anti-vehicle mines during the decolonisation war. As the detection system was mounted directly beneath the armoured vehicle, a considerable amount of nullifying of the detector system would be required to exclude the vehicle hull from interfering with the detector arrays. The sensitivity would be sufficient to locate larger metal mines such as the Russian TM-46 and TM-57, but smaller mines and minimum-metal mines would be missed.



18. The Pookie vehicle

The South African military developed a number of vehicle-mounted systems, eventually producing the “Meerkat” vehicle) as part of the “Chubby” system. This vehicle also used an under-body detection array and was followed by engineers to clear any suspect signals. As with the system used on the Pookie, the detection capability was primarily towards larger, metallic mines due to the under-body coils.



19. The Meerkat vehicle.

This shortcoming and a system to follow up, or “proof” the road was incorporated. The lead vehicle for this system, called the “Husky”, towed a column of weighted detonation trailers with off-set tyres. The Chubby system became standard issue for the South African National Defence Force and is still in use. The Chubby system has been adopted by the militaries of various countries.



20. The Chubby system.

HALO Trust also acquired the Chubby system and employed the Meerkat in Eritrea. Recognising the drawbacks of the under-body mounted detection system, HALO contracted Ebinger to design a front-mounted system incorporating the UPEX-740 detector that could be operated by a single person. The system incorporated a single detection loop mounted on a wooden fold-up frame, wired to a control and warning box in the cab.



21. The Chubby Meerkat LLD front detector.

After calibration, the operator would simply drive at between 5 and 7 km/h until the warning bell sounded. The operator would immediately stop the vehicle and try to centre the front-mounted coils over where the signal would be the strongest, without driving over that point. Once the spot was identified, a clearance team could be brought forward to clear that point.

WIDE AREA DETECTION SYSTEM (WADS)

Based on UXB's experiences with a road clearance system in Eritrea in 2001, in 2004 DanChurchAid contracted Regis Trading (South Africa) to construct a modular wide area system for road clearance in Angola. The system was completed in late 2004 and named the **Wide Area Detection System (WADS)**. The system was deployed to Angola in early 2005 and has since been moved to Denmark for minefield clearance on the Skallingen peninsula.

WADS employs the Ebinger UPEX-740 large loop as the detection system. The synchronisation of the UPEX coils is controlled through standard Ebinger hardware and software, and fed into a standard laptop computer. Tracking of the detection and vehicle progress is done by an OmniStar wide area DGPS system. The WADS is mounted on an MPV (South African Samil 20 "Rhino") as the prime mover.



22. The WADS

A clever modular mounting system has been constructed that allows the WADS to use up to eight UPEX coils in various configurations and sensitiveness. A series of electric winches raise and lower the unit with minimal effort. The mounting system is quickly adjusted to cover search swaths as small as 3m, or up to 8m if needed, including extending the detection swathe into a road verge. Search speed ranges from 5 to 10 km/h, depending on terrain.

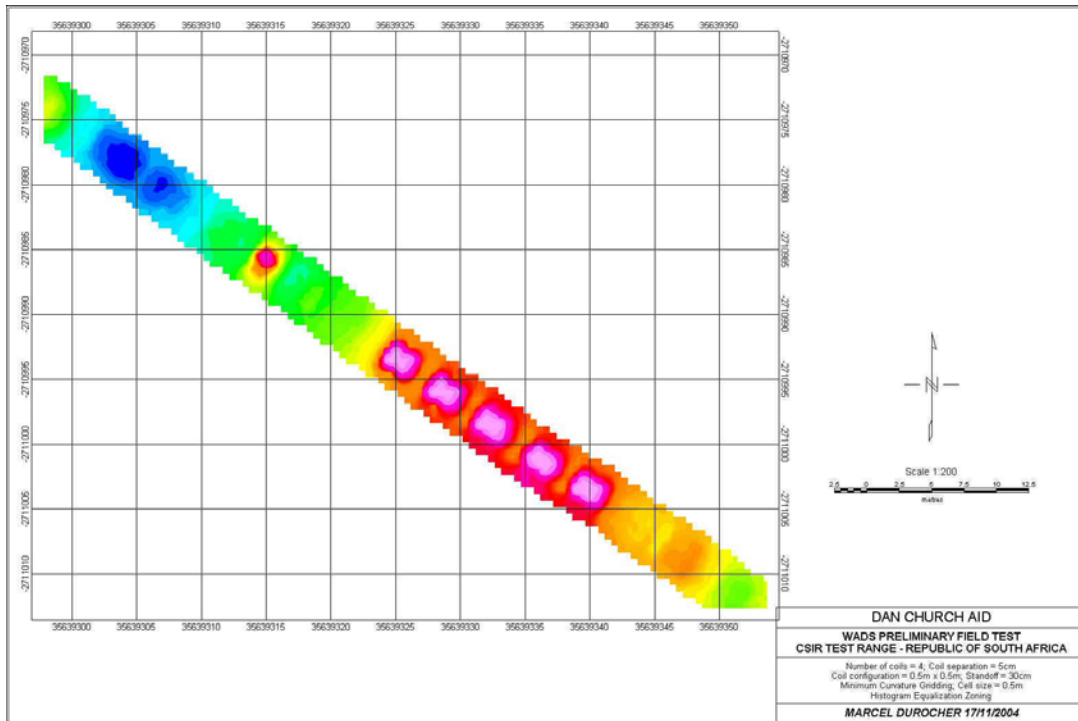


23. The WADS in travel position.

The system can be retracted into a travel position in approximately 30 minutes, which allows self-transport at speeds up to 80 km/h on improved roads and 30-50 km/h on unimproved roads. This reduces transport time between sites, and boosts productivity.

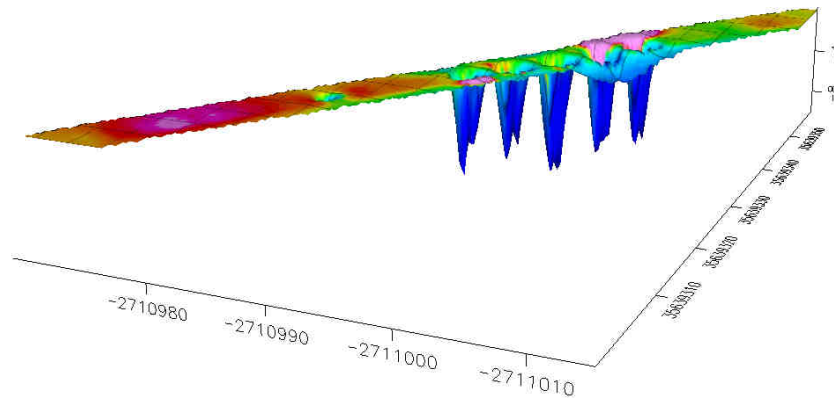
When using the UPEX coils in 50x50cm configuration combined with the upgraded software, the sensitivity is substantially increased and some minimum-metal mines can be located. During tests in South Africa, the WADS reliably generated strong signals against a surrogate Chinese Type 72 anti-vehicle fuze and the ITEP LO test source. However, other minimum-metal targets such as the South African R2M2 anti-personnel mine and No. 8 anti-vehicle mine were not located. DanChurchAid did, however, abandon the set-up and coil configuration designed to locate minimum-metal mines because of the huge number of false positives generated by the system.

Standard metallic anti-vehicle mines, such as the TM-46/57 series, can be located at depths of 1m or more with every configuration of the coils, as can common UXO items. Smaller items, such as PMN series anti-personnel mines, are reliably located at depths between 10 and 20cm using the smaller 50x50cm coil configuration.



24. Reading of five surrogate AVMs, 2D view.

The generation of clearance maps has been improved with upgraded data processing and GIS software. Highly accurate 2D and 3D maps are possible, making it easier to locate and estimate the depth of the suspect signal. The diagrams here are of five surrogate metal anti-vehicle mines and another suspect is shown approximately 10 metres to the north-west of the mines. The mapping system allows for an effective area reduction process that accelerates the clearance with less labour.



25. Reading of five surrogate AVMs, 3D view

Reacquisition of the signals is accomplished with a hand-held GIS system similar to other systems. The method for employment is improved by use of a handcart to mark the suspect signals. The antenna has been forward-mounted on the cart, allowing it to be positioned closer to the signal. Once located, a coloured flag is dropped through chute to mark the spot.

The advantage of the WADS system is its flexible width search path with the ability to increase sensitivity for smaller items like anti-personnel mines, or expand the coils and for deep-buried anti-vehicle mines. The system provides an accurate geophysical map with coordinates as part of the permanent record and extra channels have been included in the operating system to incorporate other sensors as technologies develop.

VEHICULAR ARRAY MINE DETECTION SYSTEM (VAMIDS)

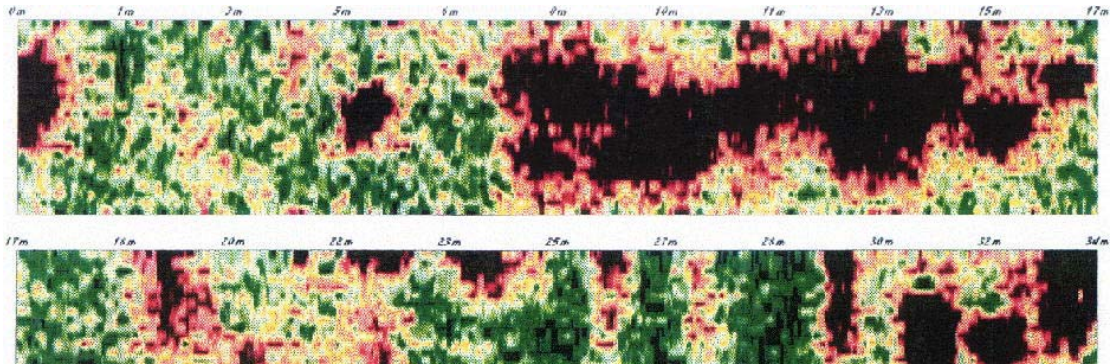
As part of a United States demining research and development project in the mid-1990s, Schiebel detection systems developed a system called the Vehicle Mounted Mine Detector (VMMD) and developed it into the Vehicular Array Mine Detection System (VAMIDS). The original US Army Night Vision and Electronic Sensors Directorate (NVESD) version was mounted to a skid-steer for prototyping and has since been mounted on MPVs.

The system works on electromagnetic principles; incorporating an array of PSS-19/2 mine detector heads in a modular array. Early versions were mounted to the front of a vehicle, with the data from each detector head fed into an on-board computer. The hardware assembly can accommodate between eight to 48 detector heads in the array, allowing it to be expanded or reduced as needed. The system underwent considerable testing and upgrades, both at NVESD and with MECHEM.

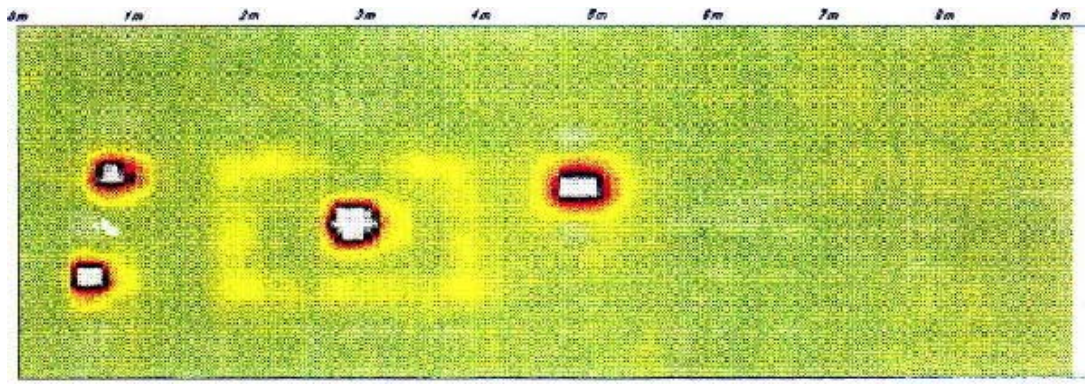


26. The NVESD prototype version mounted to a skid-steer.

Earlier versions of the geophysical mapping were quite cluttered and difficult to discriminate between clutter and a suspect item. Considerable progress was made on future versions and the maps became much easier to understand.



27. Early VAMIDS geophysical mapping.



28. More recent VAMIDS mapping results.

The measurements at the side of the map made progress easy to follow once the baseline was established at the correct location. This allows for an effective area reduction process that accelerates the clearance with less labour.

The software and data-recording system does require specialised training to operate, however it does *not* require a trained geophysical specialist to analyse the survey results, a substantial benefit when highly trained staff are few.



29. VAMIDS mounted on a mine-protected vehicle, in service with MECHEM.

Mechem adjusted the power supply to the detection coils and mounted them on a 2m-wide durable rubber matting (expandable to 8m if needed). The entire detection array is mounted on a well-designed, swing-arm assembly that allows employment to either side or directly behind the vehicle. This system offers many advantages, such as contouring to the road surface and minimising the standoff between the detection coils and the ground, which provides better reception of the eddy currents being returned and therefore increased sensitivity when searching for smaller items. Search speed ranges between 5 and 10 km/h, terrain dependent.

The disadvantage is that as handheld detector heads are used as the coils (PSS 19/2), the detection depth is limited to between 50 and 70cm against larger items such as metal-cased anti-vehicle mines. The system currently being employed does not have a GPS/DGPS interface system and relies on an odometer tracking unit for time/distance recording. This method simplifies the generation of the clearance maps: but it limits the use of the mapping data from the survey, and alignment of parallel search paths must be done visually.

The VAMIDS map is based on a straight linear-distance measurement and does not contain any global positioning coordinates: to relocate the signals the clearance team must start from the same “known point” where the VAMID started and accurately measure the distance travelled between signals. Loss of a measurement during the course of the clearance involves returning to the known point and starting again.

The final clearance map and road data cannot be imported into the national GIS database. While this is not a requirement, it has proved extremely useful when available. Both Mechem and

NVESD have mounted the VAMIDS on protected vehicles. The Mechem system has been working in Eritrea, the Democratic Republic of Congo and Sudan for several years.



REFERENCE DOCUMENT 2

THE USE OF ANIMALS FOR THE DETECTION OF MINES LAID ON ROADS AND ENVIRONMENTAL FACTORS AFFECTING AN ANIMAL'S DETECTION ACCURACY¹

The use of animals for the detection of mine laid on roads

This document describes two components that sometimes exist as layers in the detection systems used by some demining organisations working on roads: *remote detection* by animals and *direct detection* by animals. Generic applications of each method are described as are recommendations for effective and efficient use and sequencing of the methods. However, the material presented here is expected to be supplemented with the guidelines offered in future IMAS and in other relevant publications.²

When animals are used for the detection of explosive ordnance, defined changes in their behaviour indicate the presence of odours that correlate positively with the presence of that ordnance. A number of animal species have been used to varying degrees in the detection of landmines. The list includes dogs, rats, goats, pigs and bees, although dogs and rats are by far the most commonly used. (The use of insects is still largely in a research and development phase.) These latter two animals have become known as mine detection dogs (MDDs) and mine detection rats (MDRs). The remainder of this document will focus on the use of these two animals in both direct detection and remote detection roles.

Dogs and rats have been preferred over other animals for three important reasons. First, both are terrestrial animals that are known to possess acute olfactory perception or *a keen sense of smell*. Given that mines cannot be seen, heard or touched, sensing their odour is the only remaining means by which they can be detected by living organisms. A dog's ability to detect an odour against a background bouquet has been estimated at between 10,000 and 100,000 times that of a human's. Furthermore, the sensory thresholds of both animals for the odours emanating from mines are still far more sensitive than any existing electronic device.

¹ This document was drafted by Dr Brent Maxwell Jones, Associate Professor (Research), Behavioral Technology Group, E.K. Shriver Center, University of Massachusetts, Medical School, Waltham, USA.

² See for example GICHD, *Training of Mine Detection Dogs in Bosnia and Herzegovina: NPA Global Training Centre*, December 2004 & *Mine Detection Dogs: Training, Operations and Odour Detection*, June 2003.



Mine Detection Dog



Mine Detection Rat

Second, in the case of dogs, their use in the military, police, civil defence and customs has meant that training techniques existed which could be (and have been) applied to train for mine detection. Third, both animals are relatively easily socialised with humans, meaning that most aspects of their behaviour can be managed by people. Finally, it is worth noting that animal detectors generally are well suited to the demining of roads because, by definition, roads contain little or no vegetation which limits the surface area that can be searched.

Remote Detection

The need for a detection technology to add efficiency to the operational activity of a demining organisation is clear. Few such technologies rival the efficiency that is potentially available with effective use of remote detection by animals. This approach involves systematically collecting samples of air or dust/sand from defined sectors of road and presenting those samples to animals trained to emit a clear response when they sense mine-related odours in those samples. As the term *remote detection* implies, these animals inspect the samples in a laboratory that is remote from the sites where the samples were taken.

Remote Explosive Scent Tracing (REST) describes a set of procedures which have evolved from Mechem's Explosive and Drug Detection System (MEDDS). Mechem, a South African subsidiary company of Denel (Pty) Ltd., originally developed MEDDS to detect conventional explosives, small-arm weapons and illicit drugs at border-crossing checkpoints into South Africa. However, in the mid-1990s, Mechem applied their system to the detection of landmines. The general method was subsequently used by Norwegian People's Aid (NPA), who called it *Explosives Vapour Detection*, and organisations from the USA who called it *Checkmate*. For the sake of brevity, the term REST will be used here to refer to all methods of remote sensing using animals.

REST is not a method in itself, but a set of methods for identifying areas of land that are contaminated with the explosive constituents of mines and ERW, and areas that are not. Therefore, REST is better viewed as a sub-system within an organisation's overall detection system because numerous complex phases are involved: surveying and marking, sample collection (*sampling*), sample *analysis*, and *follow-up* in the field. The first phase in REST (surveying & marking) generally involves the following:

- Dividing the roadway into equal-sized sectors (e.g. 200m portions);

- Marking the boundaries of each sector with semi-permanent distinctive stakes and/or coloured rocks; and
- Recording the GPS coordinates of each marker so that the sectors can be drawn on maps.

It is assumed that the operators had previously defined and mapped the centre of road at regular intervals using a GPS device. This step not only facilitates any later follow-up searching but also serves to define the area that the organisation has searched and so declares safe at project completion.

In the second phase of REST, samples of air and dust are collected from each sector. This phase is known as *sampling*. (As considerable differences in sampling methods exist across organisations, more detail regarding this phase is presented below.) Coded containers holding either filters or dust samples from each sector are then transported to remote laboratories, where they are presented to animal detectors (typically dogs or rats) that have been trained to emit a defined response when they detect mine-related odours in a filter or container of dust. This phase is known as *analysis*. (The manner in which samples are presented to the animals, and the way in which the prior training has been conducted, also vary considerably across organisations and so will be described in more detail below.)

The outcome of this analysis phase is that samples are designated as either *positive* or *negative*. Positive samples are those that were indicated (responded to with the defined response) either by a minimum number of animals, or by one animal a minimum number of times (depending on the organisation's SOPs), and so represent road sectors that are suspected of containing landmines. The sectors from which those samples came are then searched in a *follow-up* phase by field operators using a different method (or *layer*) of detection and a method that has finer resolution than REST (e.g. MDDs, MDRs or manual deminers with metal detectors).

Negative samples, on the other hand, are those which either none of the animals responded to, or those which occasioned the indication response from less than a minimum number of animals. The road sectors represented by these samples are generally declared free of mines and no further searching is undertaken in them. A small proportion of them might, however, be searched more thoroughly in some quality assurance process.³

REST systems are best viewed as strategies for eliminating areas of road suspected of being mined (i.e. an approach to *area reduction*) rather than strategies for pinpointing locations of mines, and so are best applied on road lengths where there are no known minefields and information is being sought to support the hypothesis that the road is clear. Therefore, to be used efficiently, REST should occupy quite a high position in an organisation's detection system: following general survey (e.g. analysis of information provided by the tasking agency, interviews with local people) but preceding the more thorough searching offered by MDDs, MDRs or manual deminers. Efficiency can also be added if it is used *before* mechanical clearance assets are applied because more information regarding priority areas is provided to programme managers and logistics staff. As described below, REST systems can also serve a useful role in an organisation's quality assurance process.

³ The definition of negative samples in an organisation's SOPs constitutes an important feature of their system because a third category of samples – those that were indicated by some animals but not the required minimum – might have been constructed, and the subsequent treatment of road sectors corresponding with those samples will have to be specified.

When used in a primary detection role and quite high in an organisation's detection system, REST systems have four major advantages over more conventional methods.

First, by seeking to identify negative sectors of road (and perhaps the ends of positive sectors) REST has the potential to reduce substantially and quickly the area of road that needs to be either inspected by more expensive and slower detection methods (e.g. MDDs, MDRs or manual teams with metal detectors), or cleared by applying machines such as tillers, flails and rollers. This potential for rapid *area reduction* gives the using organisation a guaranteed improvement in the efficiency of their operations because accurate area reduction enables limited other detection and clearance resources to be deployed in areas where real threats exist. Thus, not only is less valuable time wasted after effective use of REST, but time is devoted earlier to road sectors that actually require that time.

Second, by virtue of using animals as the primary detection agents, REST provides a potentially flexible detection system that can be tuned to a wide variety of targets. The set of targets that the animals are trained to respond to might include a set of landmines that are common in that area, or a mix of landmines and IEDs that are prevalent. Whatever elements make up the set, it is relatively straightforward to capture and present to dogs the odour signatures of each element. With repeated pairings of reward and each odour alone, or some common feature between them (e.g. the odour of explosives), the animals will learn to indicate the different targets.

Third, animal detectors have a special advantage in detecting plastic-cased mines. The most common mine used on roads is an anti-vehicle mine (AVM). Those cased in metal (e.g. the TM57) are relatively easy to detect by systems involving arrays of metal-detectors being towed behind armoured vehicles (e.g. VAMIDS). However, AVMs that are largely plastic (i.e. minimum-metal mines) cannot be so easily detected. Fortunately, chemists have discovered that the plastic mines are more likely to leak their explosive-compound ingredients into the surrounding soil than are the metal ones. It is the odour of these compounds that animals can detect and be trained to indicate. REST using animals, therefore, can potentially plug a gap in an organisation's detection system when they are concerned with clearing AVMs from roads.

The **fourth** advantage of REST with animals relates to the conditions under which the animals are used. Whereas the use of animal detectors in the field is constrained by environmental factors – particularly hot and dry climates, or very rocky terrain– the use of a laboratory for REST greatly enhances the accuracy, reliability and endurance of the animal detectors. The animals can work most days and for longer periods each day. More importantly, REST animals can (at least in theory) be less likely to miss positive samples, can be more stable in their detection accuracies, and can sustain that stability for longer periods of time than their field-operating counterparts.⁴

SAMPLING IN MEDDS AND REST

The manner in which samples of air and/or dust are collected from roads suspected of being mined is critical to the overall effectiveness of the REST (or MEDDS) system because different collection techniques result in different quantities of target compounds (e.g. soil contaminated with explosives) being taken to the analysis phase – and the accuracy of animal detectors is

⁴ Environmental conditions on the road itself are, however, important variables determining the effectiveness of sampling, and so must be considered relevant factors in the REST SOPs of any organisation. See section below on *Environmental factors affecting an animal's detection accuracy*.

unavoidably limited by the strength of the target odour in a sample. The overall aim of any sampling technique is to maximise the collection of explosive compounds in samples taken from mined sectors (positive samples) and minimise any transfer of these compounds to the samples taken from non-mined sectors (negative samples). This component of REST is so critical to the overall effectiveness of the system that organisations usually devote the majority of their SOPs to describing the sampling phase.

The actual methods used in the sampling phase of REST have varied considerably over the past ten years. Rather than describing that history here, the reader is referred to the publications listed in endnote 2 and to IMAS 09.43 (draft version 7.0) for a description of procedural requirements that seem most important in the sampling phase. Here, we will describe only the basic principles applied in two working models. One model is currently being used by Mechem (MEDDS) in their road clearance projects in Southern Sudan and the Democratic Republic of Congo. The other was recently used by NPA for opening roads in Angola.



MEDDS at work in Southern Sudan.

The approach to sample collection taken in MEDDS is extremely automated and aims at being as efficient as possible. A sampling team (at least a driver and one technician) and all the necessary equipment travel in an MPV, such as the Casspir. (This use of an armoured vehicle can sometimes obviate the need for a breaching team to travel ahead of any detector system.) Behind each rear wheel of the vehicle, a filter cartridge dangles from the vehicle hanging about 10 centimetres above the ground. As the vehicle moves forward at around 5 km/h, air is drawn through the filters in each cartridge at a constant and monitored rate by two independent vacuum pumps mounted inside the vehicle. These filters are made of a plasticised netting wrapped around a central rod of PVC and are expected to trap airborne molecules of the explosive compounds that emanate from mines (or molecules attached to dust particles).

At regular intervals, defined by either GPS coordinates or road markings, the vehicle stops and the technician in the rear of the vehicle removes the filters, places them in coded plastic containers, washes the filter cartridges, and puts new filters in their places. The interval between

filter changes varies and usually depends on the predicted density of mines along the road. On recent projects, this distance has been 200m.⁵ By virtue of attempting to drag air from odour plumes above mines through the filters, the SOPs for MEDDS state a maximum wind velocity over which no sampling should be attempted. However, as will be discussed below, other climatic variables are also likely to determine the amount of explosive molecules in the soil and air above mines, and so should probably also be considered in the organisation's SOPs.

NPA has taken a different approach to the collection of samples for REST. Rather than mounting filters on vehicles, their approach has been to have a sampling team (five to seven people) walk in the tracks of an MPV. This team includes two pairs (a sample collector and an assistant) and a supervisor responsible for ensuring that the procedures defined in the SOPs are followed. The two sample collectors and his/her assistants walk in different tracks of the armoured vehicle.

Each sample collector carries on his/her back a portable vacuum pump, usually driven by a small two-stroke petrol engine. The filter (made of either plasticised netting or polyester wool) is fixed at the end of a long metal tube (1.5 to 2m) that is attached via a hose to the vacuum machine. While walking at a slow and steady pace, the sample collector holds the hose-end of the tube and swings the tip and filter from side to side in arcs as close as possible to the ground surface. He/she tries to sample as much area as possible within that defined by the midpoint between the vehicle's tracks and about 3m from the track onto the road verge.

At regular and predefined intervals (specified in the SOPs for a particular task), the sample collector stops, lifts the tube over his/her shoulder and rests it there while the assistant following about 3m behind performs a filter change. This involves removing the filter, placing it in a coded container, placing that container in a hip bag, washing the filter cartridge and fitting another filter. It is a demanding and tiring task to be manually collecting samples for REST. Searching for the tracks of the vehicle while also attempting to sample thoroughly half of the road's width with continual movement of the filter head requires long periods of concentration and smooth and rhythmic whole-body movements. Consequently, the sample collector and his/her assistant switch roles after a specific number of filters have been changed.

Considerable resources have been spent in recent years developing procedures and equipment to optimise the sampling component of REST. For example, the filters through which air and dust are drawn in the sampling phase have been optimised, as have the materials used for the storage of these filters. Similarly, bar-code readers and small GPS devices have been integrated with hand-held computers to automate the coding component of sampling.

Perhaps the most important finding from this research is that the concentration of explosive compounds (e.g. 2-4-6 TNT) and their by-products (e.g. 2-4 DNT) in the surface sand/soil above a mine is around one million times higher (and considerably more stable) than the concentration of these chemicals in an adjacent odour plume.⁶ This finding has led a number of organisations (e.g. APOPO and Swedish Rescue Services Agency) to develop equipment and protocols for collecting dust samples from roads. Although this work is still in progress, it is likely that the sampling phase of REST systems will change dramatically. The aim will be to bring representative samples of surface soils (or sands) from road sectors into the laboratory for

⁵ It is important to note that the efficiency of MEDDS or REST cannot be judged solely on this sampling distance because, when positive filters are identified, shorter sampling distances become shorter sectors of road that receive the next layer of the detection system.

⁶ See Phelan & Barnett, 2001.

inspection by animals, thus literally bringing a piece of the land suspected of being mined into the laboratory for close scrutiny.

Just as the sampling component of REST has undergone dramatic changes and differs markedly across organisations, so too the analysis phase has varied and continues to do so. The variations in method include: how the samples are arranged for inspection by animals; how the samples differ from, and might be interspersed with, training samples (i.e. known positive and negative samples); how rewards are arranged for indications on operational and/or training samples; how an animal's performance is measured and analysed; and how the responses of individual animals are used in the categorisation of operational samples.

Direct detection

Direct detection is a term coined to describe the use of detection technologies in the field to identify areas of ground containing signals that correlate positively with the presence of buried landmines or concealed IEDs. That is, these methods aim to pinpoint as precisely as possible the exact location of buried (or concealed) landmines. Both MDDs and MDRs provide intensive searching of a section of road suspected of containing landmines. The resolution of this searching is generally fine enough to enable the animal's indications of a mine to be followed up by a deminer using excavation of the ground around the indication spot. (However, manual deminers sometimes follow up an animal's indications with a handheld metal-detector. See the section below on Accreditation, Quality Assurance and Quality Control).

Consequently, the efficient use of MDDs or MDRs generally requires that they are deployed following either the use of vehicle-mounted detector arrays (e.g. VAMIDS) or Remote Explosive Scent Tracing (aka MEDDS, *see below*) to reduce the search area. This position in a detection system also means that MDDs and MDRs can (and should) serve a useful quality assurance function. Specifically, by systematically selecting areas of road to be searched by MDDs or MDRs, the detection accuracy of the technology before it in the sequence (i.e. VAMIDS, REST or MEDDS) can be assessed. This of course requires that sectors of road declared positive and negative by the preceding detection technology must be searched by the animals.



A mine detection dog searching during road clearance.

MDDs or MDRs searching areas that have been declared positive by the preceding technology provide opportunities for identifying hits and false-alarms of that technology. In contrast, MDDs or MDRs searching areas that have been declared negative provide opportunities for identifying correct rejections and misses of that technology. Obviously, the higher the hit and correct-rejection rates, and the lower the miss and false-alarm rates of the preceding detection technology, the higher is its overall detection accuracy and the more value it adds to the overall detection system.

A range of different search strategies are used when MDDs or MDRs are deployed in road clearance. In both cases, the tracks of an armoured vehicle are usually used to provide safe lanes to a search site (a sector of road) because such a vehicle will have previously travelled along the roadway in the process of applying VAMIDS, REST or MEDDS.⁷ Sectors of road targeted for search are then generally split into smaller areas known as boxes by manually checking areas on either side of the box. (This manual checking is usually achieved by deminers using hand-held metal detectors.) Each box is generally searched successively by an MDD or an MDR, or separately by different MDDs or MDRs. The size of these boxes varies across organisations but often measure 10m by 10m. (The width of the box varies with the width of the roadway being searched and can sometimes be as much as 25m.) From this point, the search strategies vary considerably.

Perhaps the most significant difference between methods of deploying MDDs or MDRs concerns how handlers behave once their animal has emitted the indication response. Operational methods fall into one of two categories: those which reward indications in operational scenarios and those which do not. (Opportunities to play with a ball or toy – e.g. a kong – are the rewards most commonly used with dogs, whereas food – bites of banana – is generally used for rats.) Those who refrain from rewarding operational indications generally argue that they are avoiding a risk of retraining the animal to indicate in the absence of mine-related odours (and perhaps in the presence of some other specific odour) because, until manual deminers inspect the indicated location, they cannot be sure that the presence of a mine cued the indication. However, this approach requires devising strategies that reduce the likelihood of animals learning to discriminate training scenarios where rewards are available from operational scenarios where rewards are never provided.

If the animals learn such a discrimination, then their search intensity and, consequently, their detection accuracy in operations would very likely decrease. (Unfortunately, this drop in detection accuracy may well go unnoticed by the animal handlers if quality-control assessments are not thorough because accuracy in training would remain high.) One such strategy has been to intermittently reward correct indications (i.e. hits) in training situations where the positions of mines are known, in order that the dogs don't expect rewards for every hit and so tolerate no rewards in operations. Another strategy is to continue training the animals on constructed minefields between operational sessions (*see, below, the section on Maintenance Training*). This maintenance training should be conducted in environments as similar as possible to those where operations are occurring, again to reduce the chance of a discrimination being learned.

Although preventing animals from learning to discriminate between training and operational scenarios is achievable (and so renders the absence of rewards in operational activity unproblematic), it is not altogether straightforward and requires attention to many seemingly minor details such as the times of day at which the two activities are scheduled, different routines

⁷ The visibility of vehicle tracks implies a need for MDDs or MDRs to follow the preceding detection technology closely in time especially when wind and/or rain is likely.

before each type of activity, etc. Advocates of the alternative approach (i.e. of rewarding indications in operations) accept the risk of rewarding indications without knowing whether it was a hit or a false-alarm and so can arrange continuous reinforcement of indications and also avoid the need to disguise training scenarios from operational ones. However, this approach requires careful monitoring of an animal's accuracy during operations and does not circumvent the need for maintenance training, especially when mine-density is low and so hits are very infrequent. Suffice to say, each approach has its pros and cons. Furthermore, this difference between procedures has not yet been identified as responsible for different degrees of detection accuracy, although the appropriate research has not yet been conducted.

By far the most common response trained as an indication response in MDDs is sitting. That is, MDDs are usually trained to sit, remain still and stare at the position on the ground where they sense the strongest odour of mines. Thus, MDDs are believed to detect mine odour(s) and then follow gradients (increasing signal strengths) of that odour until its source is located. (Source here implies no more than that position where moving away in any direction produces a decrease in odour strength.) Statistically speaking, the ground position where the odour of mines is strongest (the odour's source) is more predictive of the mine's position than any other position chosen at random. Put another way, although the strongest odour of a mine at ground surface (the hot spot) is frequently not immediately above the mine, the average hot spot over many mine types and in many locations is directly above the mine. This tendency does not, however, exclude the possibility of halos of highly contaminated soil sitting on the surface above a mine – a phenomenon that field operators and chemists alike agree sometimes occurs.

Search strategies used with MDDs

One of three strategies is generally applied when MDDs are used to directly detect landmines. Either the MDD is free-running or it is tethered on a long leash (up to 11m) or it is tethered on a short leash (around 1.5m). Free-running MDDs roam freely within the box being searched. They have either been trained to search boxes in a “figure 8” pattern, or are directed by their handlers via vocal commands or to the spot on the ground projected by a laser pen. These dogs search a box until such time as they indicate (sit) or the handler decides that sufficient area has been searched thoroughly. Advocates of this approach argue that it is better than tethering a dog because it allows the dog the freedom to follow odour plumes (or odours attached to dust particles) along a gradient of increasing intensity until the odour's source (i.e. the buried mine) is found.

MDDs working on a long leash usually search a box in a very uniform manner; namely, within straight lanes around 30cm wide and from a baseline (one of the edges of the box that is perpendicular to the road and declared safe) to the opposite end of the box. The search lanes generally start from the left corner of the box and move right along the baseline after each successive lane has been searched. On completing the search of a lane, the MDD is either trained or commanded to turn left into the previously searched area and return to the baseline where the handler stands. (Some organisations, however, require their dogs to turn right at the end of each lane and search on the way back to the handler.) With this method, a handler might require that a dog searches a lane a second time if he/she judges that the first search was insufficient. Searching of boxes terminates when the dog either indicates a mine, or has searched all of the lanes within the box without indicating. Unlike the free-running method, however, dogs on long leashes have been trained to refrain from indicating when they detect mine-related odour if that odour is not at

its strongest within the lane they are searching. This is often a controversial feature of the long-leash method.

Short-leashed MDDs also search a box in successive straight lanes around 30cm wide but are accompanied by a handler who walks on one side of the dog holding the leash during the entire search. This method allows the handler to closely monitor his/her dog's behaviour and control the dog's searching if need be by vocal commands or light movements of the leash. (The application of such control is sometimes viewed as problematic because inadvertent cuing of a mine's position can sometimes occur in training.)

The confidence of end users of the roadway is often increased when they witness (or are informed of) a search being conducted via this method. Similarly, many people believe that requiring handlers to immediately walk over the ground rejected by their dogs results in more thorough training of MDDs. It is clear, however, that each method (free-running, long-leash and short-leash) has its own advantages and disadvantages. No one method is clearly superior to another when the advantages of each are exploited fully.

Search strategies used with MDRs

The search patterns used when MDRs are deployed in direct-detection roles also vary, but not to the extent with MDD methods because MDRs are currently being used by only one organisation; a Belgian non-profit organisation called APOPO. APOPO use a rat known as the African Giant Pouched Rat (*Cricetomys gambianus*), a species endemic to sub-Saharan Africa and so able to withstand the climate and diseases of that region and similar ones. All of their operational strategies involve a short leash tethered to a rat searching a box of some dimension. Furthermore, in all cases, rats have been trained to scratch vigorously at a focused spot on the ground when they sense the odour of chemical constituents of mines. (This training is described briefly below.)

In one method, the leash is attached to a glider under a 6m bar with a set of spokes at each end (like spoked wheels without the rims joined by an axle). The rat is able to move back and forth in a lane under the bar and between the two spoked ends. This lane is 50cm wide and is, therefore, 3m² (6m x 0.5m). Once two handlers at either end of the bar decide that this area has been thoroughly searched, each gently turns their spoked ends to move a rat to the adjacent 3m² search area. The rats would then search the entire box in successive 3m² sections. Unlike some of the methods using MDDs, the ends of boxes must be searched and cleared earlier before this two-person method can be used because two safe lanes are required. This addition of gridlines can increase significantly the requirement for either human deminers with metal detectors and prodders or other animal detection teams, and so reduces the efficiency of this strategy for frequent deployment on large road projects.

A second method of deploying MDRs involves a simple modification of the first. Instead of using the spoked bar, this method involves allowing the rat's leash to slide along a rubber cord attached around the knee of each of two handlers positioned at each end (or side) of the box. As before, the rat is free to move back and forth between the handlers but is restrained by the leash and cannot search outside of a lane that is about 30cm wide. The search lanes are adjusted simply by the two handlers simultaneously stepping sideways and thus moving their knees with the cord is attached.

A third search pattern used by APOPO, but one that is still under development, involves rats being tethered to the end of a fishing pole held by a single handler. (By eliminating a second handler per rat, this strategy aims to increase the efficiency of the programme so that more rats could potentially be deployed by the same workforce.) The rat starts in one corner of the box and is led by the leash to search in lanes around 20cm wide from the baseline to one side of the box and back again. As searching proceeds in non-overlapping lanes that resemble arcs, the radius of the arcs increases until the rat is essentially travelling from one side of the box to the other searching a zigzag of lanes.

Initially the handler would stand quite some distance from the box so that the tip of the rod was in the corner, but once the rat proceeded a distance through the box, the handler follows them into the box. As with the other methods, the moment the handler judges the rat has indicated a spot, he/she gently withdraws the rat and marks the indicated location in some way so that manual deminers can search the location more thoroughly.

Maintenance training

Maintenance training is the term used to describe that aspect of training that continues after initial training (not described here) and between periods of operational activity: the aim is to keep the appropriate learned behaviours in the animal's repertoire during operations. In the case of animals serving direct-detection roles, a range of behaviours are practiced and occasionally rewarded in maintenance training because all these behaviours are required for accurate and reliable indication of mines. For MDDs, the list includes such things as: walking nicely on a leash; standing still when commanded; searching thoroughly straight lanes of an appropriate width; turning in a small radius after completing a lane search; and remaining in a sitting position until released by a handler. For animals serving remote-detection roles, the list is similar but often shorter. However, the precise exercises undertaken in maintenance training generally differ across organisations (in accordance with their initial-training protocols) and often across animals within one organisation.

Organisations using animals in either role should have clear and detailed SOPs regarding the nature and frequency of maintenance training sessions, and careful records of those sessions should be kept. This information should relate to the training and performance of each individual animal working in the system and should be regularly analysed to inform and plan further maintenance training. These files will also need to be submitted to a national authority that regulates and accredits demining organisations and their techniques (*see Assessment and Accreditation below*).

In addition to serving as refresher training, maintenance training can (and indeed should) serve to provide regular assessments of the accuracy with which the animals are detecting the target odour(s). (Such information is critical for an organisation's internal quality control.) Informative and frequent tests in turn require the setting up of a number of sites where mines of the type that are prevalent in that area are buried in a typical manner but in known locations and without a fuze mechanism. These sites are known as test fields. There should be sufficient mines spaced appropriate distances apart and in a sufficient number of test fields that a dog cannot learn, and later recall in a subsequent test. A dog's performance in every test session must be independent of its performance in previous test sessions.

It is also extremely important that the odour emanating from the mine in the test field is as close as possible to the odour of mines being sought in operations. This implies a need to take great care when handling, storing and laying mines in a test field. The protocols for establishing test fields should be described in an organisation's SOPs. For example, a minimum period of time between setting up a test field and using it for maintenance training (termed soak time) should be specified in the SOPs and strictly adhered to in practice. These times will depend on the soil and weather conditions in the area (e.g. test fields in arid environments probably require longer soak times) but should be at least three months.⁸

The need for careful planning and construction of test fields along sections of the road to be demined (or in areas adjacent to the road) poses a challenge for logistics staff because considerable forward planning is required. Some amount of preliminary demining might be required to access sites before the actual clearance operation has reached those sites. However, the need for maintenance training and appropriate test fields is clear and mandated in the IMAS. Therefore, organisations cannot avoid finding effective and efficient ways to establish these test fields.

Acclimatisation of detection animals and systems

An obvious implication of the above discussion of environmental variables is that animals (be they direct detectors or remote detectors) will usually require some practice and experience with finding mines in new environments before their accuracy is maximal and they can be deployed in operations. In the case of MDDs and MDRs, if the climate in a new operational environment differs markedly from that in a previous one, the animals will also require some time to adjust to the new climate. This period of practice and adjustment is known as *acclimatisation*.

Unfortunately, there is no simple answer to how long direct-detectors should be given for this acclimatisation. Nor is there any simple rule for when acclimatisation should be scheduled. The answers to both of these questions should be found in analyses of a dog's (or rat's) performance in maintenance training. Acclimatisation periods and suspension of operational activity should be scheduled whenever moving to a new operational site produces a decrease in detection accuracy, a decrease in the amount of area covered per session, or any other significant change in the animal's behaviour (e.g. loss of appetite). And acclimatisation should last as long as it takes for measures of the animal's behaviour to recover to previous levels, or to stabilise at a new and acceptable level.

The term acclimatisation has a slightly different meaning for animals working as remote detectors in REST or MEDDS systems. In the process of detecting minute traces of explosive odour on filters or in samples of dust, these animals need to learn a discrimination between background odours (any odour other than that from mines) and mine-related odours. Alternatively, they might need to learn to detect the mine-related odours against a background of irrelevant odours. Unlike their direct-detection counterparts, however, REST and MEDDS animals don't have the advantage of being in and living around the odours that might be unique to that environment (e.g. the odours of indigenous plants). Therefore, any shift of operations to new environments will usually require that REST and MEDDS animals are systematically exposed to filters or samples

⁸ The failure to wait a minimum amount of time before using a test field could result in the dogs indicating only recently excavated sites in the field. Rewarding such indications could subsequently lessen – if not eliminate – the control that mine-related odours had over the indication response, and so render the dog useless for operations.

from known negative and known positive sites in that new environment (i.e. filters or samples taken from test fields).

It is this period of exposure to potentially new odours and fine-tuning of detection that is known as acclimatisation. As with direct-detection animals, the need for and duration of any such acclimatisation should be judged by those working in the REST or MEDDS system, in accordance with performance data from maintenance training sessions.

Accreditation, Quality Assurance and Quality Control

When the change in operational environments is significant (e.g. MDD teams are moved to a new country) and/or a new regulatory authority is responsible for monitoring the quality of demining operations, animal-detection systems might require a formal and thorough assessment before permission for operational deployment is granted by the regulatory authority (e.g. a National Mine Action Authority). Such assessments leading potentially to formal endorsements are known as *accreditation* episodes.

These assessments should involve a complete and thorough examination of all components of a detection system, and the organisation using the system should need to demonstrate that the system is effective, efficient and appropriately monitored. Detailed SOPs for every important aspect of the system should be examined by the regulatory authority, and operations should be observed to ensure that the SOPs are being followed accurately and are complete.

Most importantly, the user of the animal detection system(s) should be required to demonstrate how they monitor the quality of the process defining the system (i.e. how they undertake *quality assurance*) and how they assess the quality of the final product (i.e. how they undertake *quality control*). This is particularly important for REST and MEDDS where there is a long chain of complex steps involved. Flaws at any point in the chain will result in a flawed final product.

The regulatory authority should then conduct their own tests of detection accuracy and reliability by applying the organisation's system in test fields that the authority itself has established and so has exclusive knowledge of. Qualitative judgements regarding the apparent intensity of an animal's search, or the bond between a handler and his/her dog, are insufficient in such tests. Instead, quantitative assessments that involve objective and reliable measurements of various aspects of an individual animal's behaviour (e.g. hit rate, false-alarm rate, area searched in a defined time period) provide the acid test of performance and ought to be conducted.

Specific criteria defining what constitutes a hit and a false-alarm (e.g. sitting within a 1m radius from the buried mine) and defining the minimal accuracy (and perhaps endurance) that must be achieved by a direct-detection animal, need to be made clear to the organisation before the tests commence. Opportunities to acclimatise to the environment and practice in test fields should also be provided before the tests. On many occasions, such assessments might well mean that regulatory authorities engage the services of impartial third-party expert(s) familiar with scientific approaches to training and testing animals.

In addition to regulatory authorities conducting quality assurance and quality control checks, the organisation using the detection system should have valid and reliable methods for assessing quality and efficiency themselves. As mentioned above, this self-assessment can be accomplished

by arranging specific degrees of overlap between the layers of detection systems with a view to identifying the number of hit, miss, false-alarm and correct-rejection rates of each layer.

Furthermore, a genuine attempt should be made to assess each detection-system layer alone and independent of another. Take the quality-control assessment of an MDD system as an example. If this system is being followed-up by manual deminers using metal detectors and excavation tools, then checks on the accuracy of a dog's indication should involve the deminer occasionally and unknowingly searching around positions that were *not* indicated by the dog. Searching only those positions that were indicated provides information regarding the dogs hit and false-alarm rates. However, searching around randomly selected positions that were not indicated completes the picture by giving us information with which to calculate the dog's miss and correct-rejection rates.

The same logic can be applied to assessing the accuracy of a REST or MEDDS system except that the next layer in the organisation's detection system, and that which should be used to assess it, is often direct-detection animals. Thus, a proportion of the road sectors that REST (or MEDDS) returns as negative should be checked by MDDs (or MDRs) as if they were returned as positive. These sectors should be randomly selected and interspersed unpredictably between sectors that really were returned as positive by the laboratory. All the staff involved in the MDD system should be blind as to whether a sector was defined as positive by the animals or by the quality-assurance staff.

The organisation's quality-assurance staff must themselves also maintain clear and fair principles when conducting the checks and interpreting the results. For example, if the absence of mines in road sectors declared positive by a REST (or MEDDS) system is sometimes excused because spent munitions have been found in the sector (i.e. a false-alarm is being considered a hit but of a closely-related target), then some of the sectors declared negative by the detection system should also be searched for spent munitions (as well as mines obviously). Finding such items in negative sectors suggests either that the animals missed that sector or that the false-alarm rate of the system is high: they cannot have their cake and eat it too.

Finally, mention should be made of the remaining way in which detection systems involving animals can be used to quality assure part of an organisation's work. Specifically, by deploying MEDDS or REST occasionally on roads (or road sectors) that were declared safe by some general surveying technique (e.g. interviewing locals) the accuracy and reliability of that surveying technique can be assessed. Again the logic is simply that the follow-up layer of a detection system is applied to more sectors of road than was declared necessary by the detection system under scrutiny.

This might seem like a waste of time and resources while organisations are already struggling to complete demining projects in a timely manner. Yet, without accurate and informative assessments of each component of an organisation's detection system, more time might be being wasted with deploying component systems that add no value to the overall system. Even worse, if one component is systematically missing mines or providing false-alarms at a high rate, then that component could be reducing the accuracy of what could otherwise be an accurate and reliable overall system.

Environmental factors affecting an animal's detection accuracy

Various detection systems available to demining organisations do not detect landmines themselves. Instead, each system detects signals that are generally predictive of landmines buried under the ground surface. (For example, hand-held metal detectors provide a method of direct detection by registering electronically the presence of materials with metallic properties on or under the ground surface.) Therefore, the accuracy with which some method of direct detection locates landmines depends on the accuracy of the detector for the specific signal *and* the correlation between that signal and the presence of landmines.

This point is particularly pertinent to our understanding of landmine detection by metal detectors. It is well known that the efficiency of metal detectors can be severely compromised by the presence of metallic (or metallic-like) fragments in the soil, or soil with high concentrations of naturally occurring iron, because false-alarm rates can climb to unacceptably high levels. In such cases, it is the correlation between the searched-for target and landmines that has decreased, rather than the ability of the metal detector to find those targets. However, the same principle applies to detection systems involving animals. That is, at times the correlation between the odour signals of a landmine and the presence of a mine can also decrease such that those mines cannot be detected by animals.

Either of two scenarios is possible. Either the environmental conditions (or the mine itself) limit the availability of the odorous compounds (some component of the explosive inside the mine) or those compounds are present in the absence of mines. The first situation can be addressed by understanding the effects of weather conditions, soil types, vegetation, and so on, and accommodating those effects when MDDs, MDRs and/or REST/MEDDS sampling teams are deployed.

The second situation (i.e. an area contaminated with explosive material) is more difficult to accommodate in animal detection systems and may render these systems too inefficient to be applied. It is important, therefore, for those managing operations to assess the degree to which portions of road might have become contaminated by explosives (e.g. by spent artillery and/or small-arms shells in previous battle areas) prior to selecting detection systems.

Despite research into the use of animals for landmine detection still being in its infancy, a number of important findings have already emerged. First, although a range of materials are often used in the construction of landmines (e.g. plastics, metals, rubber, explosives) research conducted at the Institute for Biological Detection Systems at Auburn University in Alabama, USA, has suggested that accurate MDDs are most likely detecting the odour of the explosive content. TNT (trinitrotoluene) is the most common explosive found in landmines – occurring in around 80 per cent of mines. However, numerous other compounds either exist with, or are by-products of, military-grade TNT (e.g. plasticizers, waxes, dinitrobenzene - DNB, dinitrotoluene - DNT, etc.).

Unfortunately, exactly which constituent of buried TNT is being sensed by animals remains unclear (and may depend on mine type and/or initial training) although the evidence is presently in favour of 2,4-DNT.⁹ That animals are detecting the DNT from landmines is also supported circumstantially by the fact that this compound frequently occurs in high concentrations in the soil above landmines. DNT also has one of the highest vapour pressures of all the compounds

⁹ Cicoria, 1999.

above a mine meaning that it moves from solid to gaseous states quite readily and so might often be present in odour plumes above mines.

A second finding that is relevant to using animals as detection tools has emerged from research into the transportation of explosive compounds in soil. This research has been conducted by environmental chemists.¹⁰ Such chemists have discovered that explosive compounds migrate away from buried landmines and travel to the surface soil by becoming dissolved in water that continually travels through soils. Part of their research, therefore, has focused on understanding the variables that determine water flow through soils.

A brief description of the process they propose will suffice here. Imagine that a mine has just been laid in dry soil. If the first following episode of rain is sufficient, water will infiltrate the soil and soak down to where the mine resides. This water around the mine results in any explosive compounds that are leaking from the mine becoming dissolved in water. Once the rain ceases, water in the top layers of soil begins to evaporate and the surface dries. This drying causes the downward flow of water to gradually slow, then stop and then reverse direction. That is, the water begins travelling upward to the surface carrying the explosive compounds with it. (The dry surface layer also acts as a trap for the explosives because adsorption of explosives is much stronger in dry soils than in moist soils.)

The process is further complicated, however, because an invisible *water divide* develops inside the soil. Water below this divide will continue falling deeper into the soil: it is only the water above this divide that will creep upwards to the soil surface. The height of this water divide lowers with further drying of the soil and rises with further rain (it is above ground level when the water is pooling on the ground surface) and the transport of the explosive compounds toward the surface can begin only once this divide has reached the level where these compounds are residing.

The task facing organisations using MDDs, MDRs or REST, therefore, is to judge the position of this water divide in order to work under conditions where the availability of explosive compounds at the ground surface (the strength of the signal for the animals) is close to maximum. At present, we have only *rules of thumb* for identifying these conditions. (For example, following rain, a certain depth of dry sand/soil – e.g. 5mm – may indicate upward movement of water and explosives.) Current research is, however, aiming to develop and validate such simple rules and identify simple ways of measuring soil humidity with inexpensive instruments.

The rules of thumb that can be applied during operational planning for MDD, MDR, REST and/or MEDDS each involve factors that either directly or indirectly affect the movement of water (and, therefore, explosive compounds) through soil. What follows is a brief description of the environmental conditions that favour effective and efficient use of animal-detection systems.

Air temperature

It is well known within user organisations that MDDs and MDRs must be used cautiously in very hot environments. The animals must be given frequent breaks, plenty of water and opportunities to cool their bodies. Operational activity might also need to be limited to the early morning hours when air and ground temperatures are lower. Even then, however, the animals are unlikely to

¹⁰ See, for example, Goss, 2008; Phelan & Webb, 2003.

maintain accurate performance for the same period per day as they would under cooler conditions. This is unfortunate because the transport speed of water and explosives to the ground surface increases as air temperatures (and consequently, soil temperatures) increase. In addition, the degradation of TNT into its by-products (e.g. DNT) increases as temperatures increase in moist soils. (Little – or no – degradation is expected to occur in dry soils.)

A compromise must, therefore, be sought between the animal's welfare and waning accuracy, and increased signal availability. That said, the range of temperatures over which accuracy is high and signal strength is sufficient is probably quite wide. Also, the effect of temperature should not be considered without consideration of rainfall patterns.

Rainfall patterns

Roads in locations where it rains frequently are not conducive to being searched by animals (either directly or remotely) because the water divide is too often likely to be too high in the soil, meaning insufficient upward transporting of the explosive compounds. However, if air temperatures are high and the intervals between precipitation events are sufficiently long, then these environments can also be good for animal detectors because water transportation in the soil is generally rapid.

The issue is whether the time available for MDDs, MDRs or REST/MEDDS sampling should occur at longer intervals after rain in order to capture occasions when TNT/DNT concentrations at ground surface are at their highest. In many countries where roads require demining, the climate limits effective use of animal detectors to a few days per month. Such limited application would probably mean that the cost of maintaining the system(s) outweighs the benefits of its use, and therefore that the system is not cost effective.

The effect of precipitation on the movement of explosives through the soil highlights another consideration for organisations using animal detectors on roads. In many countries, the roads themselves have often not been properly engineered and so trap water for much of the year. In many cases, the roads contain more puddles than the neighbouring areas. Although it is possible that odour plumes from buried mines are able to emerge from the water over a mine, this plume must contain considerably less signal strength than that to be found in plumes above mines under dry soil.

It is also clear that there is considerably less explosive compound in the air above a mine than in the soil above it. This implies that MDDs, MDRs and REST/MEDDS sampling should not be deployed over pools of water. Taken one step further, these systems might not therefore be cost-effective on roads where a significant proportion of its length is flooded. This limitation points again to the need for systematic and thorough checking of road and weather conditions in the early stages of planning operational activities.

Vegetation

Plants, grasses, shrubs and trees significantly decrease the evaporation of water from the soil surface. Although evaporation may still be occurring, the shade thrown by vegetation and the

roots of plants within the soil keeps the surface layers of soil cooler than they would be in direct sunlight and slows the drying out of the surface. (Slower wind speeds at ground surface in vegetated areas will also slow drying relative to open areas and higher wind velocities.) This in turn slows the upward movement of water and explosives to the soil surface because the sponge-like qualities of dryer soils at the surface are diminished.

However, an additional effect of vegetation compensates for some (if not all) of this effect, which results from the fact that plants draw water from the surrounding soil through their roots. They pump it through their stems and leaves, where it can be evaporated. This water processing induces water flow (and so explosives transport) toward the plant's root zone. Consequently, although there may be little drying of soils immediately under vegetation, there are potentially higher concentrations of explosive compounds under isolated plants on roads if they are growing close to mines.

By definition, roads are often free of thick vegetation. In situations where vegetation covers large portions of the road, it is probably best to cut that vegetation close to ground level and leave it, and the ground surface beneath it, to dry in the sun for a period. Clearing vegetation before searching seems to be more important for direct-detection animals than for people collecting MEDDS or REST samples. This is because plants, shrubs and grasses will often limit how close an MDD or an MDR can get its nose to the ground surface. Field operators often report that closer searching frequently yields higher detection accuracies.

Also, clearing isolated plants and grasses from roads might well be counter-productive for REST and MEDDS if there has been drawing of water and explosives toward those plants. Some scientists have proposed that dust with high concentrations of TNT and DNT often sits on the underside of leaves and around the stems of plants. Such dust is probably of little use to the MDD or MDR because they will generally keep their noses close to the ground, but it could be valuable to people collecting dust samples (or filters) for REST (or MEDDS). Those sample collectors might need only to disturb the plant with their equipment before some of the dust falls from leaves and lands where it can be collected.

Soil types

It is well known that different soil types have different water retention and water flow properties. Some soils permit water to flow easily through them (e.g. sandy soils) while others tend to trap water (e.g. clays). Therefore, soil type should also be a variable that determines the availability of explosive compounds at the ground surface (i.e. signal strength). Unfortunately, however, the relationship between soil type and signal strength is not straightforward because at least three other variables are thought to interact with soil type: the organic-material content of the soil, the size of the soil particles and precipitation patterns.

With respect to organic content, higher amounts of organic material in a soil (e.g. more humus on a forest floor) allow greater micro-bacterial activity that will speed the degradation of TNT into its by-products. More degradation of TNT over time can at times help, but at other times hinder, the amount of explosive compound at ground surface, depending on the period of time that the mine has been underground. (However, low rates of – or no – degradation is predicted to occur in dry soils even if the organic content is high.)

With soil-particle size, the smaller the particle the greater the surface area to which the relevant molecules of TNT and DNT can attach and remain when the soil is dry. There is, therefore, an irony in the case of clays. While clay-type soils often retain water, they also have small solid particles (but very small spaces between those particles – hence they don't drain well) and so retain the explosive molecules relatively well. The problem with clay is that its drying time is relatively slow and so there may be limited time when the soil is sufficiently dry for the TNT and DNT molecules to sorb to the dry soil particles.¹¹ There may also be limited time when sufficient dry soil is able to be collected either by an animal's nose or a REST sampler's hose. Under the right wetting and drying conditions, clay can be among the best soils for animal detection systems to work on.

It is clear that the effects of soil type on the strength of mine-related odours are complex and probably cannot be considered without reference to other environmental conditions. It is hoped, however, that further research by environmental chemists might result in simple and efficient tests of soil conditions being made available to field operators at little cost. The results of administering these tests on selected pieces of road would then guide the decision making of those engaged in planning demining operations, especially the use of animal detection systems.

Finally, it is worth noting that research by environmental chemists will provide essential information but not all the information we require in order to refine and optimise the use of animal detection systems. In particular, there is a need for further behavioural research with the animals used in detection systems. Some of this research should be focused on identifying the effects (if any) of the environmental variables described above on aspects of their detection performance (e.g. detection accuracy, search speed, endurance). After all, the strength of a signal when measured by a chemist's instruments may not equate to the strength of a signal registered by an animal's sensory apparatus. In addition, there are quite likely to be effects of extreme environmental conditions on an animal's general physiology, and that, therefore, affect its sensitivity to the target odour indirectly.

¹¹ The number of these molecules in solid form and attached to dry soil particles is probably just as important as - if not more important than - the concentration of these molecules in the air above contaminated soil.



REFERENCE DOCUMENT 3

ANALYSIS PHASE IN MEDDS AND REST¹

For the sake of brevity, I will describe here only those procedural differences that are most apparent in analysis phases between two organisations: Mechem and Norwegian People's Aid (NPA). We will also describe some recent research and development work on analysis phases conducted by the Belgian APOPO organisation and Swedish Rescue Services Agency (SRSA). A lot of important details regarding an organisation's analysis procedures appear in their SOPs because the accuracy and reliability of the animals depend so heavily on the details involved in this phase.



Rest analysis

Mechem

With their Explosive and Drug Detection System (MEDDS), Mechem use a dedicated building for the analysis phase. This building is maintained like a laboratory and various measures ensure that the building remains uncontaminated by even tiny traces of explosives. Between 10 and 12 stands are placed at 1 to 1.5m intervals against a long and solid wall inside the building. At one end of the wall, solid screens obstruct a view between a dog-holding area and the set of stands. Each stand supports a filter cartridge around nose height for the dog. One dog at a time is led on a short lead from the holding area and past the ten or so stands. The lead is always kept slack and dogs are given time to sniff at each filter and perhaps sit afterward. The consequences delivered to the dog for sitting at a stand depend on exactly what type of filter was loaded there.

¹ This document was drafted by Dr Brent Maxwell Jones, Associate Professor (Research), Behavioral Technology Group, E.K. Shriver Center, University of Massachusetts, Medical School, Waltham, USA.

At times, training filters of known assignment are loaded into stands. Sitting next to stands that contain positive training filters occasionally earns the dog an opportunity to chase a tennis ball thrown by the handler. In contrast, sitting at stands containing either negative training filters or operational filters are never rewarded: a dog is simply led away back to the holding area after sitting for between one and three seconds. Exactly when training or operational filters are presented on stands is varied systematically, to be unpredictable by the dog.

Every day of operational work begins with a set number of training filters with which a dog's accuracy and readiness for inspection of operational filters is assessed. (For example, 40 training filters consisting of 35 negatives and five positives might be presented in four runs of ten filters.) If a dog's accuracy on these runs (measured in terms of a minimum hit rate and a maximum false-alarm rate) exceeds a pre-set criterion, the dog is used for operational work that day. Further positive training filters are then interspersed quasi-randomly between operational filters in the remainder of the work session.

Runs on which an operational filter has been replaced with a positive training filter are known as *motivation runs*. The aim of arranging these runs is to maintain searching for, and subsequent detection of, the target odour on operational filters in the absence of rewards on those operational filters. It is extremely important, therefore, that the odours on positive training filters are not categorically different from the odours on operational filters. To disguise the difference between these odours, operational filters previously rejected by dogs (and thus are very likely to be negative) will have the odour of explosive compounds (TNT and DNT) laid over them. Mechem achieve this by drawing air from a cardboard box containing a tiny amount of TNT (a so-called vapour strip) over a filter that has previously been collected in the field.

Mechem usually operate their dogs in pairs where one searches a set of ten filters (training or operational) immediately after the other. This minimises the handling of filters and so minimises the risk of adding extra odour cues to filters, and allows a comparison of each dog's responses toward particular filters. Operational filters are deemed to be positive – and so worthy of follow-up in the field – if either dog sat next to it (i.e. indicated it). Consequently, operational filters are considered negative only if neither dog indicated it. The daily assessment of accuracy with training filters, combined with this definition of negative filters, is expected to keep the rate at which the system misses mines at a very low level.

NPA

NPA took a different approach in the analysis phase when they were using Remote Explosive Scent Tracing (REST) on roads in Angola. The procedure used later in their Angola work was shaped largely by a consultant from Norsk Kompetansesenter for Spesialsokshund AS (NOKSH AS) in Norway. The procedure involved presenting filter cartridges on a device known as a *carousel* (or *Apparatus for Discrimination of Source Material*). On this device, filters were clipped at the ends of each of 12 arms that extended from a central hub much like spokes on a wheel. This carousel sat in a laboratory room about 60cm above the floor so that the filters were at about the height of a dog's nose. An axle was fitted between the hub of the carousel and a base that supported the unit, allowing the arms to be spun. This spinning allowed quick and easy repositioning of filters relative to the internal features of the room, a routine that was performed regularly in training and operational sessions to remove any position cues. Dogs were trained to examine each filter on the carousel in a counter-clockwise direction and while being off a leash.

NPA required each set of 12 operational filters to be examined by at least three dogs. In addition, each dog was required to examine each set of filters twice. Therefore, each filter was examined a minimum of six times. The procedure went as follows. A technician would begin by placing filters at each arm of the carousel. A dog would then be led into the room and commanded to search the carousel. Between each visit to the room and carousel search, the carousel was rotated to move the filters a variable but known distance. Consequently, if the dog sat after sniffing a filter on the first occasion it encountered that filter, then it would be led from its seated position out of the room, and the position of that suspect-positive filter would be changed for the second search. If the dog indicated that filter on the second search also, then the dog is removed from the room, and the filter is removed from the carousel and replaced with another.

If filters remain to be examined a second time, then the dog is brought back into the room to search those remaining. Otherwise, a second dog starts searching that set of 12 filters (minus any indicated by the first dog). Those filters indicated by the first dog are temporarily put aside and later inserted between filters in positions with which the dog handler is unaware. If they are indicated by a second and/or a third dog, or indeed both, then greater confidence in the accuracy of the dogs develops. However, any filters that were indicated at least once and by at least one dog were considered positive filters and were followed-up by field operators.

As with Mechem, NPA also refrained from rewarding indications on operational filters, preferring instead to periodically insert training filters (of known assignment) between operational ones, and reward intermittently hits on training filters. Their procedure also meant minimal handling of filters and so less risk of adding odour cues for the dogs. Unlike Mechem's procedure, however, NPA started constructing training filters using methods similar to those used in the sampling phase. That is, they would make positive filters by having their sampling teams use their vacuum pumps while walking over an area that contained at least one mine that they themselves buried and defuzed earlier. By using this method, training filters would likely be very similar to operational ones, and the dogs might have received training to indicate odours other than just those emanating from the explosive contents of mines (e.g. the odour of plastic casings or rubber seals).

APOPO and SRSA

Recent research by APOPO and SRSA has been pursuing the development of effective and efficient methods of analysis in REST systems. Experimental psychologists (trained in applied behaviour analysis and familiar with the research literature on learning in animals) have attempted to validate empirically the various components of the analysis procedures used by Mechem and NPA. This validation process involves conducting carefully-controlled experiments where a single procedural feature is isolated as the sole difference between conditions being compared.

A large number of procedural differences turned out to be trivial, in so far as they had little effect on an animal's detection accuracy. But various other differences had significant and reliable effects on the animals' accuracy. The research has attempted to identify variables that (if left uncontrolled) will produce variance in an animal's detection accuracy, and to identify methods for assessing whether the animals are discriminating positive from negative samples using the cues that trainers intend them to use.

A notable feature of SRSA's model for analysing operational samples is that rewards are provided intermittently and at a high rate on both operational and training samples. The system they propose for this has been called *reinforcement for agreement*. As the name suggests, this involves rewarding an animal's indication response on an operational sample if it agrees with the response to that sample made by a previous animal. The principle is that if each animal's hit rate is high, then its false-alarm rate is low; and if its false alarms are independent of the other animal's false alarms, then the probability of rewarding an error on operational samples in the second dog is very low. Being able to reward indications on operational samples as well as on training samples reduces the likelihood of animals learning to discriminate between the two sample types, and so keeps detection accuracies on operational samples high.



REFERENCE DOCUMENT 4

DETONATION TRAILERS AND MINE ROLLERS

Detonation trailers and mine rollers

Mine rollers or detonation trailers (*see picture 1 for an example*) are used to prove the safety of roads that have been cleared of anti-vehicle mines. There have been a variety of rollers used on roads, varying from the (rarely used) steel rollers, through the solid-tyred rollers to the pneumatic tyres used on the Chubby and the HALO Multidrive. They were initially developed in South Africa and Rhodesia in the 1970s in response to the mining of roads by independence movements.



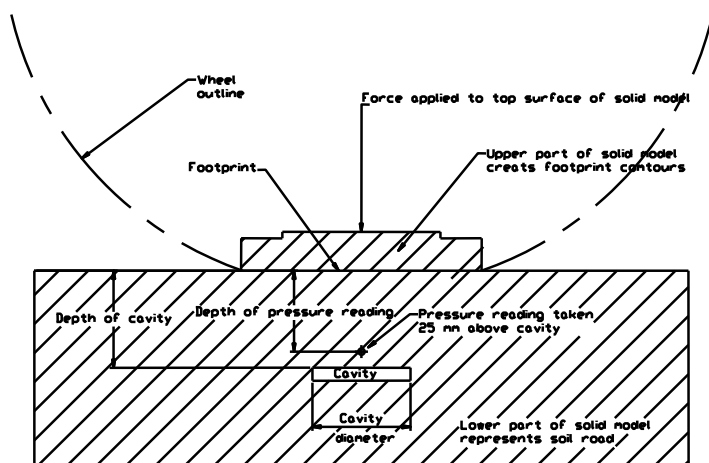
The Chubby system

The towing vehicle is fitted with low pressure tyres (to avoid setting off a mine) and detector arrays (shown stowed at an angle to the side of the engine). Towed behind are a series of trailers fitted with pneumatic truck tyres and ballasted to load each wheel with approximately 1.8 tonnes.

This type of vehicle was originally deployed during the conflicts in Southern Africa. They are now being used by demining operators, principally in Angola. There is some concern as to how effective these detonation trailers are when employed in humanitarian mine clearance operations. They have not as yet detonated any mines. It is not certain whether this is because there have been no mines in the road or because they have developed insufficient force to activate the fuze. It is unfortunate that the wheels of these detonation trailers are only loaded to about 36 per cent of the typical wheel loads of heavy trucks.

Are there ways of increasing the effectiveness of proofing rollers without using impossibly heavy rollers? Finite Element Analysis (FEA) has been used by Renwick¹ to investigate how much more effective harder rollers would be at detonating mines. Comparison is made between an actual pneumatic tyre loaded with 1,800kg, an actual pneumatic tyre loaded with 5,000kg, and a hypothetical steel wheel of similar dimensions, loaded with 1,800 and 5,000kg. Models were created for each wheel type/load conditions where the block representing the soil was a uniform medium.

The bridging effect is mimicked in FEA, by creating a cavity in the medium whose diameter is similar to the fuze of a mine. The diameter of the cavity has been varied from 100mm to 150mm to 200mm and it is set at 100 and 200mm depths. The picture below summarises the layout of a cross section of the road profile, detailing dimensions and showing the point chosen to represent soil pressure. FEA showed the different way pressure is distributed through the soil by pneumatic tyres and steel wheels.



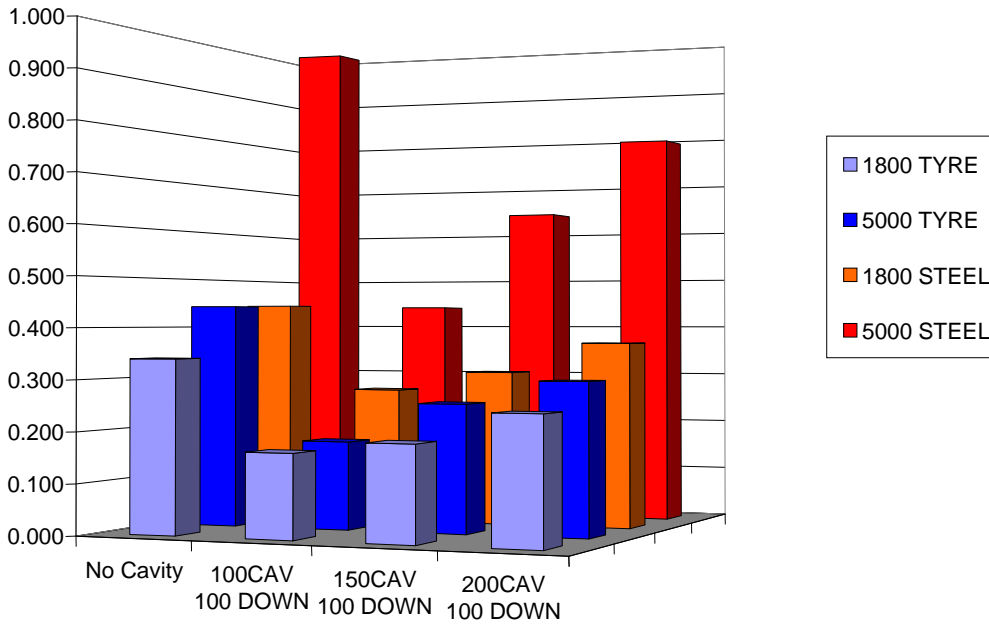
Cross sectional view of model showing dimensions

Soil pressure with a cavity set at 100mm deep

The picture below shows a three-dimensional plot of the data for the 100mm-deep cavity, with pressure measured at 75mm depth.

¹ P.J. Renwick, “Stresses induced by wheels below the surface of a soil road”, Paper to be published in the *Journal of Mine Action* in 2008.

Soil pressure (Mpa) at 75mm deep above cavity 100mm deep

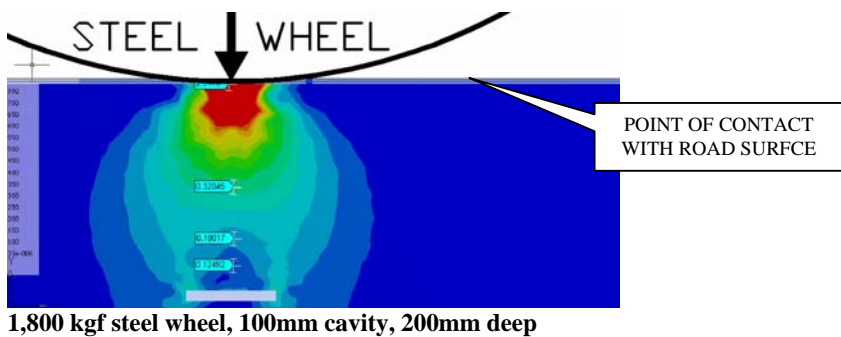
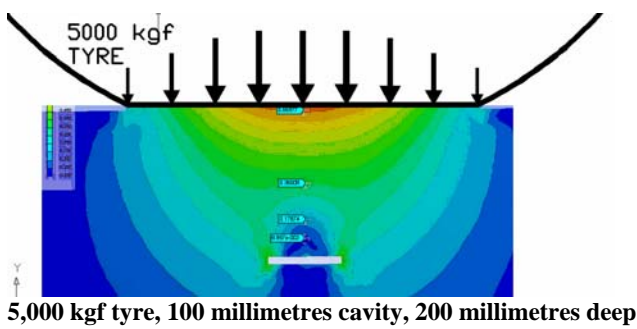
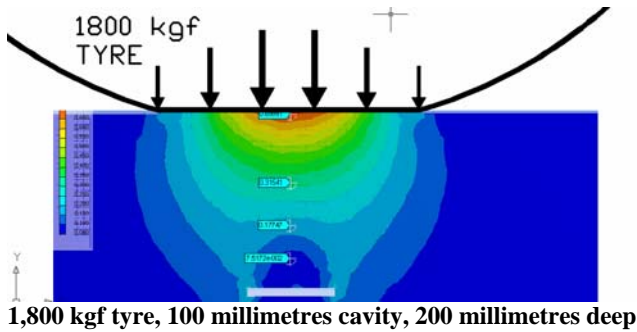


A big increase in tyre load from 1,800kg of force (kgf) to 5,000kgf gives a disappointing 30 per cent improvement in soil pressure at 75mm depth in plain soil. The effect of bridging over the various cavities at that depth reduces that advantage to 20 per cent improvement on average.

Switching from pneumatic tyres to steel wheels (both at 1,800kgf) gives a more worthwhile improvement, 31 per cent in plain soil and an average of 60 per cent over the three cavity sizes. It is also significant that the 1,800kg steel wheels created the same pressure at 75mm depth in plain soil as the 5,000kgf pneumatic tyre. Where the effect of cavities was examined, the 1,800kgf steel wheel had advantages averaging 35 per cent over the 5,000kgf tyre.

At 75mm deep, steel wheels loaded at 5,000kgf showed significant advantage over other wheels, being more than two-and-a-half times better than 5,000kgf tyres, thus having a safety factor of 2.5 over heavy trucks.

Comparing the pictures below one sees how the extra load is spread more widely with the 5,000kg of pneumatic tyre, resulting in little extra benefit from the extra force.



However the stress from the steel wheel is much more concentrated above the cavity, transmitting load more effectively.

A big increase in tyre load from 1,800kgf to 5,000kgf gives a disappointing 30 per cent improvement in soil pressure at 75mm depth in plain soil. The effect of bridging over the various cavities at that depth reduces that advantage to 20 per cent improvement on average.

Switching from pneumatic tyres to steel wheels (both at 1,800kgf) gives a more worthwhile improvement, 31 per cent in plain soil and an average of 60 per cent over the three cavity sizes. It is also significant that the 1,800kg steel wheels created the same pressure at 75mm depth in plain soil as the 5,000kgf pneumatic tyre. Where the effect of cavities was examined, the 1,800kgf steel wheel had advantages averaging 35 per cent over the 5,000kgf tyre.

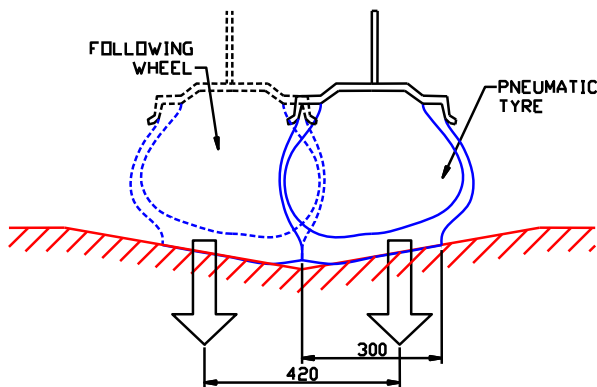
At 75mm deep, steel wheels loaded at 5,000kgf showed significant advantage over other wheels, being over two-and-a-half times better than 5,000kgf tyres, thus having a safety factor of 2.5 over heavy trucks.

Breaking the crust

The road material above recently buried mines has difficulty bridging. Such mines are easily detonated by passing vehicles. Soil that has covered a mine for many years on an unused road is subject to wetting and drying cycles which cement the road material together. The swelling and shrinking thus caused also leads to fissuring of the road crust. Each segment is locked into its neighbour in a jigsaw fashion. Breaking the crust by studs or cleats on a solid wheel will disrupted bridging and make mine detonation more likely.

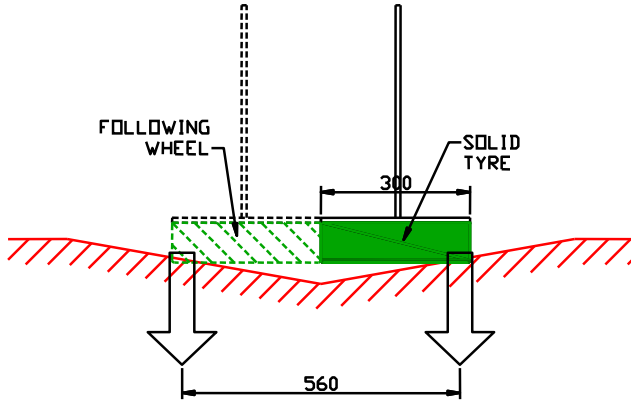
The effect of depth

Pressure decreased with cavity depth. The advantage of steel wheels over tyres became less significant with a 200mm deep cavity. These simulations indicate that it would be desirable to move from a pneumatic tyre to a stiffer solid tyre. There are, however, drawbacks to using a solid tyre. One drawback is the inability of the solid tyre to adapt to changing contours of the road as viewed across the road. The picture below shows how the profile of pneumatic tyres adapts to the profile of the road and that there is some distance between the centres of pressure. This allows for the possibility of missing a mine in the centre of the pothole.



A pneumatic tyre adapting to the road profile

Substituting solid tyres makes matters worse with the gap between the centres of pressure being even further apart.

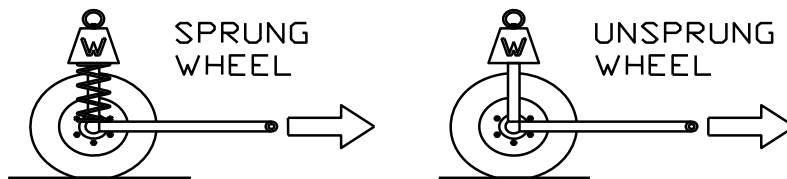


A solid tyre on the road

There is therefore a need for caution in using harder wheels on seriously potholed roads. Slower speeds and deliberate overlapping would be needed.

The effect of speed

A sprung wheel is able to move down rapidly when encountering a pothole, while still maintaining a strong down force.



Un-sprung wheels are fine at low speeds. Higher speeds will need sprung wheels if bounce and skip zones are to be avoided.

Concluding remarks

1. The benefit of adding extra weight to pneumatic tyres is disappointing, much of the additional force being lost. There is significant benefit using a wheel that is harder than a pneumatic tyre.
2. Using steel wheels at wheel loads in excess of 3,000kgf will improve the margin of safety of detonation trains significantly above that of truck wheels.

3. Where steel wheels are not acceptable, solid rubber tyres will give a lesser, but worthwhile, improvement.

The effectiveness of mine rolling diminishes with depth. This reduction is inversely proportional to the depth raised to the power 1.5.



REFERENCE DOCUMENT 5.

CONTRACT MANAGEMENT

The International Mine Action Standards (IMAS) include guidance on the development and management of mine action contracts.¹ IMAS identifies seven principles:

1. The contract must recognise the environment and conditions in which the activity is to be undertaken;
2. It must recognise the capabilities and capacities of the parties;
3. It must be realistic in its performance requirements and other obligations and must specify them as completely as possible;
4. It must be fair and equitable to all parties;
5. It should assign specific risk to that party most able and best-motivated to control it;
6. The wording of the contract should be clear, concise and unambiguous; and
7. It should encourage cooperation rather than confrontation between the parties.

The price component in a contract depends on whether the contract is a fixed price, cost-plus² or a combination of both. Regardless, it should include:

1. The total contract price or the unit rates, including the units of measurement for each rate;
2. The frequency and methods of payment, including advanced payments and recovery mechanisms if relevant;
3. The milestones or triggers for payment; and
4. Performance bonds or similar control measures and details of how these may be applied, including penalty clauses if relevant.

A contract for road clearance is normally initiated through a Request for Proposals (RFP), normally consisting of the following documents:

- > The RFP itself;
- > A Statement of Work (SOW), which will normally divide responsibilities and reporting requirements under the contract;
- > A Proposal Submission Form; and
- > A Sample Contract in draft including the General Conditions used by the contracting agency.

¹ IMAS 07.20 (Guide for the development and management of mine action contracts), First Edition, 1 August 2005, available at www.mineactionstandards.org.

² A written agreement with the contracting agency under which the contractor is reimbursed for his/her direct and indirect costs and, in addition, is paid a fee for his/her services. The fee is usually stated as a stipulated sum or as a percentage of the total cost.

The technical component of a proposal should be concisely presented and normally structured in the following order to include, but not necessarily be limited to, the following information:

- > **Description of the bidder and the bidders' qualifications:**
A description of the bidding firm and an outline of recent experience (normally for the last three years) on projects of a similar nature.
- > **The requirements for services, including assumptions:**
Assumptions and comments on the data, support services and facilities to be provided by the contracting agency as provided in the SOW, or any other necessary information.
- > **Proposed approach, methodology, timing and outputs:**
Comments or suggestions on the SOW as well as a detailed description of the manner in which the bidder will respond to the SOW. This should include the number of person-months in each specialisation that is considered necessary to carry out the required work.
- > **Proposed team structure:**
The composition of the team and the team structure used by the bidder in the country of assignment, at the home office (including supervisory). A description of the organisation of the team structure, should support the proposal. Normally the bidder will also be requested to provide CVs of its management staff.

Project timelines

The bidder should include a detailed implementation plan in the technical proposal. Failure to carry out thorough logistical planning has probably been the single biggest cause of project failure in the past. Bidders are normally required to demonstrate that they are able to meet the deadlines indicated in the SOW. A field trip to the country in question is often required in order to provide the necessary inputs for proposals.

- > A contract is normally carried out in the following phases;
- > Phase 1: Mobilisation
- > Phase 2: Preparations;
- > Phase 3: Operation;
- > Phase 4: Demobilisation.

These phases normally include the following activities:

Phase 1: Mobilisation

This phase commences on signature of the contract and includes all the preparatory activities and the transport of the capacity and equipment from the home country to the country of operation (if the contract has been awarded to a contractor which is not local). Contractors will be given a date when the phase is to be completed.

Phase 2: Preparation

Include preparations prior to becoming operational, including being accredited and carrying out all planning activities to develop a works programme for Phase 3 for approval of the Contracting

Agency. The contractor will be given a date when the phase is to be completed. In addition, the Contractor may be required to carry out the following during the phase:

1. Contractors must normally plan on deploying an advance party followed by a main body,
2. Meet with the Programme Manager of the Contracting Agency to go over the SOW and the Contract to ensure that both the Contractor and the personnel of the Contracting Agency are familiar with the work to be carried out and the manner in which the services need to be delivered.
3. Amending the Contractor's standing operating procedures (SOP) to conform to national standards.
4. Complete all training of local and international personnel.
5. Receive accreditation to become operational.
6. Finalizing an inventory of all equipment loaned to the Contractor and purchased by the Contractor for use during the contract.
7. Arrange for the reception of the mechanical systems in country as well as the movement of equipment and personnel to the area of operations. These arrangements will normally include;
 - a) Identification and establishment of suitable maintenance/repair facilities. The proposal should normally include an explanation of how the machine will be maintained/repared.
 - b) Recruitment and training of staff required by the Contractor. A final date for this will normally be given.
 - c) Preparation of a works programme through the identification of sites suitable for the deployment of the ground preparation teams.

Phase 3: Operation

The Contractor will be required to deploy operationally in accordance with the approved plan and to start clearance work. Failure to commence, or finish, with operational activities within timeframes normally constitutes a penalty, which will be described in the draft contract.

Phase 4: Demobilisation (normally 1–2 weeks)

The Contractor should plan for time at the end of the contract for demobilisation. Any activities that extend beyond one or two weeks will normally be at the Contractor's own expense. During this Phase the Contractor must finalise all outstanding reports, including a final substantive report and carry out a stock-take and handover of equipment to the Contracting Agency.

Tasking

The Contractor will receive tasking and priorities of work to be performed in accordance with a work plan developed by the Contracting Agency. Multiple tasking orders for one or several months may be provided to the Contractor. The Contractor will be required to conduct a pre-deployment site reconnaissance for each task and to present an implementation plan for the site or cluster of sites prior to commencing operations. The Contractor's Site Reconnaissance Report and Implementation Plan must normally contain a priority order and description of the tasks, a

list of assets required for the completion of the task, anticipated duration of the task and clearance methods to be used.

The Contracting Agency will review and approve the Contractor's implementation plan for each task or group of tasks. The Implementation Plan will be used as the basis of the Final Tasking Order to be issued by the Contracting Agency. Progress on completion of the sites in each cluster will be reported in the Contractor's daily, weekly and monthly reports, including the Contractor's plan to take corrective action for any predicted or actual shortfalls in achievement. The Contractor is to achieve production targets as agreed with the Contracting Agency in the Implementation Plan. The plan may be amended in consultation with the approval from the Contracting Agency in writing based upon new information or changes in circumstances.

Standards and reporting

The Contractor will be required to adhere to the IMAS and the National Standards for the country in question that have been derived from the IMAS. The SOW will, in most cases, make reference to the applicable parts of IMAS. The SOW will also outline the reporting requirements and formats for reporting under the contract.

It is essential that the principal (contracting agency) incorporates any requirements for the Contractor to comply with IMAS and/or the national mine action standards of the country involved, in the contract. These standards are too voluminous to attach to the contract, so they should be incorporated by reference, indicating the website or location where they can be found. It is also strongly recommended that those IMAS most relevant to the contract be specifically referred to in the SOW.



REFERENCE DOCUMENT 6

CHECKLIST FOR ROAD CLEARANCE

- What are the requirements for road clearance at the country and local level, and is road clearance part of the country's mine action strategy?
- Is road clearance linked with the country's development goals, and with local aims?
- What are the social, economic and environmental impacts from roads blocked with mines?
- Are the roads to be cleared prioritised and selected by all the mine action stakeholders involved, including affected communities at country and local level?
- Are funds available for road clearance?
- Are there national standards for road clearance?
- Have you got SOPs for road clearance?
- Is there a specific accreditation process related to road clearance methodologies and the demining assets required for road clearance?
- How and when will the accreditation for road clearance operations be carried out?
- Will a contractor be used, and what are the contractual arrangements for road clearance?
- What are the timelines if a contract will be issued for the road clearance task?
- Are there appropriate contractors for road clearance available in-country or will external contractors be required?
- If external contractors are to be used, which contractors are capable of carrying out the road clearance required?
- Has road clearance been carried out previously in-country and how was this done?
- If machines were used for road clearance previously in-country, which machines were used?
- Will machines be tested and, if so, how will the machines be tested?
- What are the key information requirements for road clearance during the survey phase?
- Are rules and regulations for land release established in country?
- What activities will follow road clearance and what are the requirements in terms of width and depth?
- Should the road clearance organisation only operate during certain seasons of the year?
- If the road clearance organisation is from outside the country, what permissions are needed?
- Does an operator need permissions and clearances to carry out road clearance and move personnel and assets freely in-country?
- What are the appropriate demining assets for detection, removal or destruction of all mine and ERW hazards for future use of the road?
- Will several different types of machines be needed during the road clearance?
- Are rules and regulations for QA established for use during the planning, preparation and clearance process?
- If the road will be reconstructed after clearance, how is liaison with the road construction/rehabilitation contractor ensured?
- What are the recording and reporting requirements?
- Are land release procedures after clearance activities established, and how will the handover documentation be prepared?
- Are the rules and regulations for conducting a post-project review established?

CEN

CWA 15832

WORKSHOP

April 2008

AGREEMENT

ICS 95.020

English version

Humanitarian mine action - Follow-on processes after the use of demining machines

This CEN Workshop Agreement has been drafted and approved by a Workshop of representatives of interested parties, the constitution of which is indicated in the foreword of this Workshop Agreement.

The formal process followed by the Workshop in the development of this Workshop Agreement has been endorsed by the National Members of CEN but neither the National Members of CEN nor the CEN Management Centre can be held accountable for the technical content of this CEN Workshop Agreement or possible conflicts with standards or legislation.

This CEN Workshop Agreement can in no way be held as being an official standard developed by CEN and its Members.

This CEN Workshop Agreement is publicly available as a reference document from the CEN Members National Standard Bodies.

CEN members are the national standards bodies of Austria, Belgium, Bulgaria, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland and United Kingdom.



EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

Management Centre: rue de Stassart, 36 B-1050 Brussels

© 2008 CEN All rights of exploitation in any form and by any means reserved worldwide for CEN national Members.

Ref. No.:CWA 15832:2008 D/E/F

Contents

Page

Foreword.....	3
Introduction	4
1 Scope	5
2 References.....	5
3 Terms and definitions	6
4 The use of demining machines	6
4.1 General.....	6
4.2 Ground preparation	6
4.3 Ground processing.....	7
4.3.1 General.....	7
4.3.2 Off-site	7
4.3.3 On-site – survey	7
4.3.4 On-site – technical survey	7
5 Follow-on requirements in areas where no hazard has been encountered	8
5.1 General.....	8
5.2 Scenario 1: Use of a demining machine in technical survey operations.....	8
5.3 Scenario 2: Use of a machine in areas outside, or adjacent to, a known minefield	10
5.4 Scenario 3: Verification	11
5.5 Scenario 4: Clearance operations.....	11
6 When follow-on is not required after hazards are encountered	12
7 Summary.....	13
8 Agreement statement	13
Bibliography	15

Foreword

This CEN Workshop Agreement has been drafted and approved by a Workshop of representatives of interested parties, the constitution of which was supported by CEN following the public call for participation made on 27 November 2006.

Participants in the process were drawn from the following sectors with interests in humanitarian demining: non governmental organisations, other international organisations, national mine action authorities and manufacturers and users of demining machines. The following organisations have been actively participating in the process: Geneva International Center for Humanitarian Demining (GICHD), Switzerland. Active contributions have also been received by representatives from ANAMA, CMAC, CTRO, INTERSOS, PNDHD, SWEDEC, UNMACA, UNMAS, Norwegian People's Aid, Idea Group, Cranfield, DOK-ING, MineWolf Systems AG and Scanjack AB.

The formal process followed by the Workshop in the development of the CEN Workshop Agreement has been endorsed by the National Members of CEN but neither the National Members of CEN nor the CEN Management Centre can be held accountable for the technical content of the CEN Workshop Agreement or possible conflict with standards or legislation. This CEN Workshop Agreement can in no way be held as being an official standard developed by CEN and its members.

The final review/endorsement round for this CWA was started on 2007-12-21 and was successfully closed on 2008-02-21. The final text of this CWA was submitted to CEN for publication on 2008-03-27.

This CEN Workshop Agreement is publicly available as a reference document from the National Members of CEN: AENOR, AFNOR, ASRO, BDS, BSI, CSNI, CYS, DIN, DS, ELOT, EVS, IBN, IPQ, IST, LVS, LST, MSA, MSZT, NEN, NSAI, ON, PKN, SEE, SIS, SIST, SFS, SN, SNV, SUTN and UNI.

Comments or suggestions from the users of the CEN Workshop Agreement are welcome and should be addressed to the CEN Management Centre.

The development of this CWA has benefited from an EC - EuropeAid Co-operation Office, financial contribution allocated in the context of the EC Mandate M/306.

Introduction

Demining machines are essentially used for two functions, ground preparation or ground processing. To operate effectively in either role it is fundamental that the machine must be “fit for purpose”. For example, a vegetation cutter that does not engage the ground/soil cannot effectively be used to process ground if the intent of the operation is to disrupt the soil to a depth of 20 cm.

The concept of “intent” is very important and, before the application of any machine, it must be agreed /decided exactly what is expected/anticipated of the machine in the specific operation, i.e. what is intended to be achieved.

In *ground preparation* operations intent can be relatively straightforward: vegetation cutting and/or clearing, removal of tripwires, loosening of soil, removal of metal contamination, removal of building debris, boulders, rubble, defensive obstacles etc, and the sifting of soil and debris.

However, in *ground processing* the intent can be more complex. For example the demining machines can be used to:

- find mines;
- clear mines; or
- prove there are no mines.

The role against which the machine’s performance is to be measured must be decided early in the planning stages.

1 Scope

This agreement analyses the follow-on processes after the use of demining machines. It makes a general statement about follow-on processes after the use of a demining machine in a *ground preparation* role when the operation is carried out within an area of suspected hazard. More specifically, this agreement focuses on follow-on after the use of machines in the *ground processing* roles of finding mines, clearing mines and proving that no mines exist in a given area.

This document seeks to define the requirement for follow-on behind a demining machine. It does not describe the method of follow-on activities that are already well known and understood by the mine action community.

2 References

The CEN Workshop Agreement CWA 15044 established guidelines that are recommended to be considered before a demining machine is deployed in a hazardous area.

Users of this CEN Workshop Agreement should also refer, in particular but not only, to the following CEN Workshop agreement, International Mine Action Standards (IMAS)¹⁾ and standards from the International Standards Organisation (ISO):

CWA 15044, *Test and evaluation of demining machines*;
 IMAS 03.40, *Test and evaluation of mine action equipment*;
 IMAS 04.10, *Glossary of mine action terms definitions and abbreviations*;
 IMAS 07.10, *Guide for the management of demining operations*;
 IMAS 07.30, *Accreditation of demining organisations and operations*;
 IMAS 07.40, *Monitoring of demining organisations*;
 IMAS 08.20, *Technical survey*;
 IMAS 09.10, *Clearance requirements*;
 IMAS 09.20, *Guidelines for sampling*;
 IMAS 09.40, *Guide for the use of MDD (mine detection dogs)*;
 IMAS 09.50, *Mechanical demining*;
 IMAS 10.20, *Safety and occupational health (S&OH) demining worksite safety*;
 EN ISO 9000, *Quality management systems – Fundamentals and vocabulary (ISO 9000:2005)*;
 EN ISO 9001, *Quality management systems – Requirements (ISO 9001:2000)*;
 EN ISO 9004, *Quality management systems – Guidelines for performance improvements (ISO 9004:2000)*.

In addition readers should refer to the National Mine Action Standards (NMAS) and/or the National Standard and Technical Guidelines (NSTG) which are in force in their country of operation. They should also refer to any other relevant country-specific technical notes.

The guidance in this Workshop Agreement on follow-on processes after the use of demining machines should be used to augment the guidance offered in the above documents. Other useful references are the CEN Workshop Agreement CWA XXXXX²⁾ *Quality Management – Quality Assurance and Quality Control for Mechanical Demining*, and the 2004 The Geneva International Centre for Humanitarian Demining (GICHD) publication *A Study of Mechanical Application in Demining*.

1) IMAS can be accessed through www.mineactionstandards.org.

2) Result from CEN/WS 29, under publication.

3 Terms and definitions

In the context of this document the definitions in IMAS 04.10 and the following apply.

3.1

follow-on

clearance activities that are undertaken on a site that was initially worked on by a demining machine

NOTE Follow-on activities are not compulsory after a demining machine has been applied on a clearance site as the primary demining activity. In most cases however, follow-on activities are required to achieve the given performance standards.

4 The use of demining machines

4.1 General

The intended outcome of the use of a demining machine will determine what follow-on procedures are applied, assuming that the machine used is fit for purpose.

4.2 Ground preparation

Machines used for ground preparation are those machines primarily designed to improve the efficiency of demining operations by reducing or removing obstacles (see *IMAS 09.50*). In this context, “ground” refers more generally to the area of suspected hazard and not specifically to the soil/s and composition of the earth.

Operations can be carried out using both intrusive and non-intrusive methods.

Intrusive operations are those in which the demining machine (with or without an on-board operator) is deployed inside the boundaries of the suspected hazardous area. In non-intrusive operations the demining machine (or platform machine) is operated from outside the suspected hazardous area – on known safe or previously cleared ground – and an attached tool “reaches” into the hazardous area.

Ground preparation does not normally result in clear ground. Ground preparation is carried out with the *intention* and *expectation* that a follow-on clearance asset or process will clear the ground after the use of the machine. Ground preparation may involve the detonation, destruction or removal of some, but not normally all, landmines and ERW.

Typical activities carried out in order to prepare ground include but are not limited to:

- flailing;
- rotary tilling;
- raking (scratching/pecking);
- ripping;
- rolling; and
- lifting/removing obstacles, etc.

NOTE Some of the above activities can also be used in ground processing (see below).

Given that the intention to remove obstacles in a suspected hazard area is to allow follow-on clearance operations, it follows that ground preparation operations must be followed by a clearance method or a re-assessment of the situation. Which follow-on method is eventually used will be determined by the local conditions, e.g. ground, climate and expected hazard.

4.3 Ground processing

4.3.1 General

In this context, “ground” refers more specifically to the earth/sand in which the hazard is suspected to be buried and not to the general area of the hazard.

In ground processing operations the intent can be to:

- find mines;
- clear mines; or
- prove there are no mines.

Processing operations can occur both on, and off, the suspect hazardous area. Off-site operations are activities that involve the removal of the earth/sand/soil from the suspected hazardous area to an area where some other activity is conducted to remove the hazards, such as sifting and soil processing inspections. On-site operations are activities that occur in the suspected hazardous area such as use of the machine:

- in a technical survey role – where the intent is to find the general location of mines;
- to detonate mines – where the intent is to clear mines; or
- to process soil in an area suspected to be hazardous even though the evidence suggests that there are no hazards; in this case the intent is to use a machine process to “prove that there are no mines”.

4.3.2 Off-site

When a machine is used as part of an integrated off-site processing operation there is no requirement for follow-on procedures in the original suspect hazard area when the soil/sand is replaced, provided adequate QA and QC procedures are in place at the off-site location. However, it should be noted that the guarantee of clearance is restricted to the depth of the earth/sand/soil removed, processed and replaced.

4.3.3 On-site – survey

When machines are employed in technical survey operations, the information they provide is used to make an informed judgement about what to do next. This is no different from technical survey conducted using dogs, manual deminers or some other observational or sensory method.

Follow-on operations after technical survey may not be required, if the machine does *not* encounter a hazard, and has been proven capable of detecting and destroying similar expected hazards in similar conditions. If a machine *does* encounter a hazard then follow-on will be required in all but exceptional cases. The specific follow-on activity can only be determined at the site – and would normally be either by manual demining or mine detection dogs (MDD). The specific area for follow-on operations will be determined on the site on a case-by-case basis.

If optimum climatic and topographical conditions for using MDD are met and the machine has been used to process the whole area on-site, it is recommended by this agreement that only one MDD is required for follow-on because a single MDD is effectively a second tool to the machine.

4.3.4 On-site – technical survey

When machines are employed in technical survey operations, the information they provide is used to make an informed judgement about what to do next. This is no different from technical survey conducted using dogs, manual deminers or some other observational or sensory method.

Follow-on operations after technical survey may not be required, if the machine does *not* encounter a hazard, and has been proven capable of detecting and destroying similar expected hazards in similar conditions. If a machine *does* encounter a hazard then follow-on will be required. The specific follow-on activity can only be determined at the site – and would normally be either by manual demining or mine detection dogs (MDD). The specific area for follow-on operations will be determined on the site on a case-by-case basis.

If optimum climatic and topographical conditions for using MDD are met and the machine has been used to process the whole area on-site, it is recommended by this agreement that only one MDD is required for follow-on because a single MDD is effectively a second tool to the machine.

4.3.4 On-site - clearance

When machines are employed to detonate mines and where the intent is to clear mines. Follow-on operations after clearance will most likely be required in order to ensure that mines indeed have been cleared. The specific follow-on activity can only be determined at the site and would normally be through manual demining in such case the objective has been to detonate mines. If the purpose has been clearance the ground will be contaminated with explosives as a consequence of detonations and breaking up of mines. This will make employment of MDD in the area difficult unless a considerable soak time is applied.

4.3.5 On-site – ground processing (technical survey)

The purpose of ground processing in a suspect hazardous area is to prove that there are no mines present. Follow-on operations after ground processing may not be required, if the machine does *not* encounter a hazard, and has been proven capable of detecting and destroying similar expected hazards in similar conditions. If a machine *does* encounter a hazard then follow-on will be required. The specific follow-on activity can only be determined at the site – and would normally be either by manual demining or MDD.

5 Follow-on requirements in areas where no hazard has been encountered

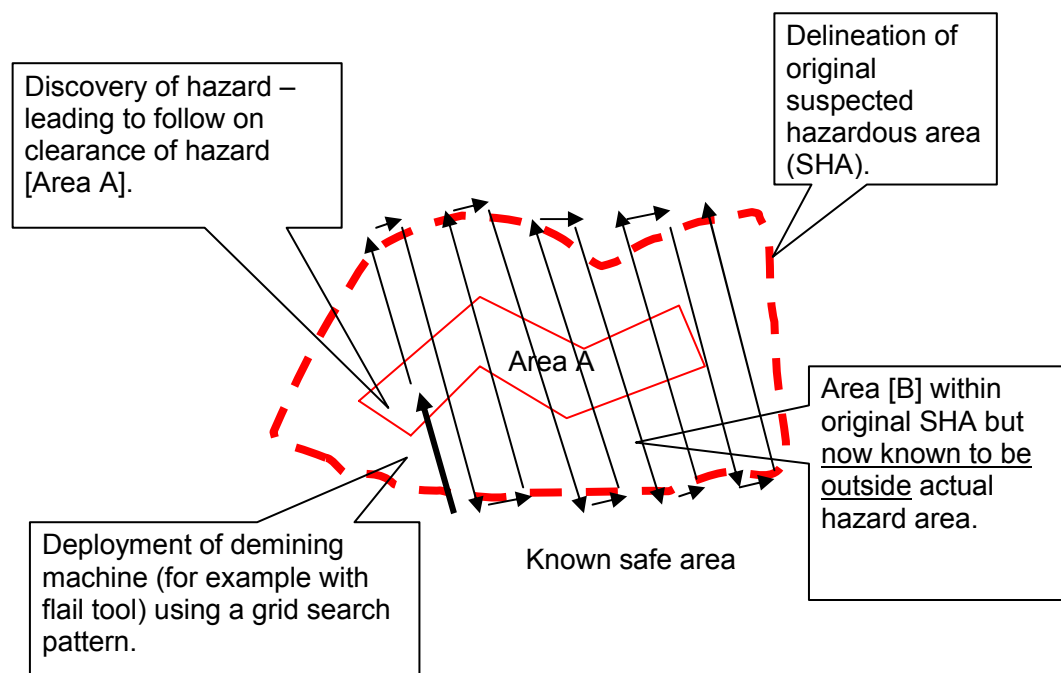
5.1 General

There are four general scenarios in which the outcome of machine use can be the discovery of no hazard. The four scenarios are the use of a demining machine in:

1. Technical survey operations;
2. Hazard mitigation procedures outside, or adjacent to, a known minefield;
3. Verification (that no mines exist) procedures;
4. Clearance operations – where a machine is used with the intent to clear ground but no hazards are found.

5.2 Scenario 1: Use of a demining machine in technical survey operations

In this scenario a demining machine with, for example, a flail tool is used to define the limits of a hazardous area. Characteristically the machine will be used to overlay a grid of search lanes over the suspected area. (See Figure 1.)



Mine detonations or evidence of mines in Area A enable the operator to define the hazard area. This area will then be subject to follow-on clearance to a specified fade out point beyond where mines are encountered.

Figure 1 —Scenario 1: Use of a demining machine in technical survey operations.

It follows that the demining machine will, if the intent of the operation is successful, process ground that is *both mined and not mined*.

When mined ground is encountered follow-on in line with IMAS 09.50 will occur, as the now-confirmed hazard will be defined and can be cleared with other assets, and subjected to QA and QC before it is released for handover as safe cleared ground.

NOTE The machine use may result in no defined area of hazard but simply confirm that there are random and sporadic mines laid to no discernable pattern within the SHA – in which case follow-on will occur on most if not all of the SHA.

Other ground in the SHA, however, that is “processed” to reach and define the actual mined area may not contain a hazard or hazards: it follows therefore that follow-on, with another machine, MDD or manual deminer, *may not be required*.

Establishing whether this is true or not must be based on:

- full knowledge of the targets likely to be encountered; and
- understanding (through QA and QC) that the demining machine and tool is working to capability (i.e. fit for purpose, for example that it is working to the specified depth).

If these conditions are met there is no requirement to apply follow-on procedures or assets. These conditions and the method to evaluate that the conditions have been met, must be defined in the operators Standard Operational Procedures (SOPs) and in NMAS or NSTG.

This workshop agreement recommends that where a demining machine has been successfully used to reduce an SHA to a definable minefield (which will be cleared with other assets) there is no requirement for follow-on in the area where mines have not been encountered.

However, although no follow-on with other assets is required, QC and a visual inspection in the area should be conducted. Also, the decision making process leading to the “not to follow-on” decision shall be fully documented in release documentation.

5.3 Scenario 2: Use of a machine in areas outside, or adjacent to, a known minefield

In this scenario an SHA has been identified as a mined area that it is accurately delineated – possibly through possession of reliable minefield records. The hazard area will normally be cleared by assets other than a machine – although a machine may be used to conduct ground preparation or ground processing. Once the delineated hazard has been cleared – SOPs or NMAS or NSTG may require a confidence procedure to check that no hazard has moved from the known mined area into the surrounding area, for example because of animal traffic or water wash. In this case, a demining machine with a tool such as a flail may be used to verify that no hazard exists. (See Figure 2.)

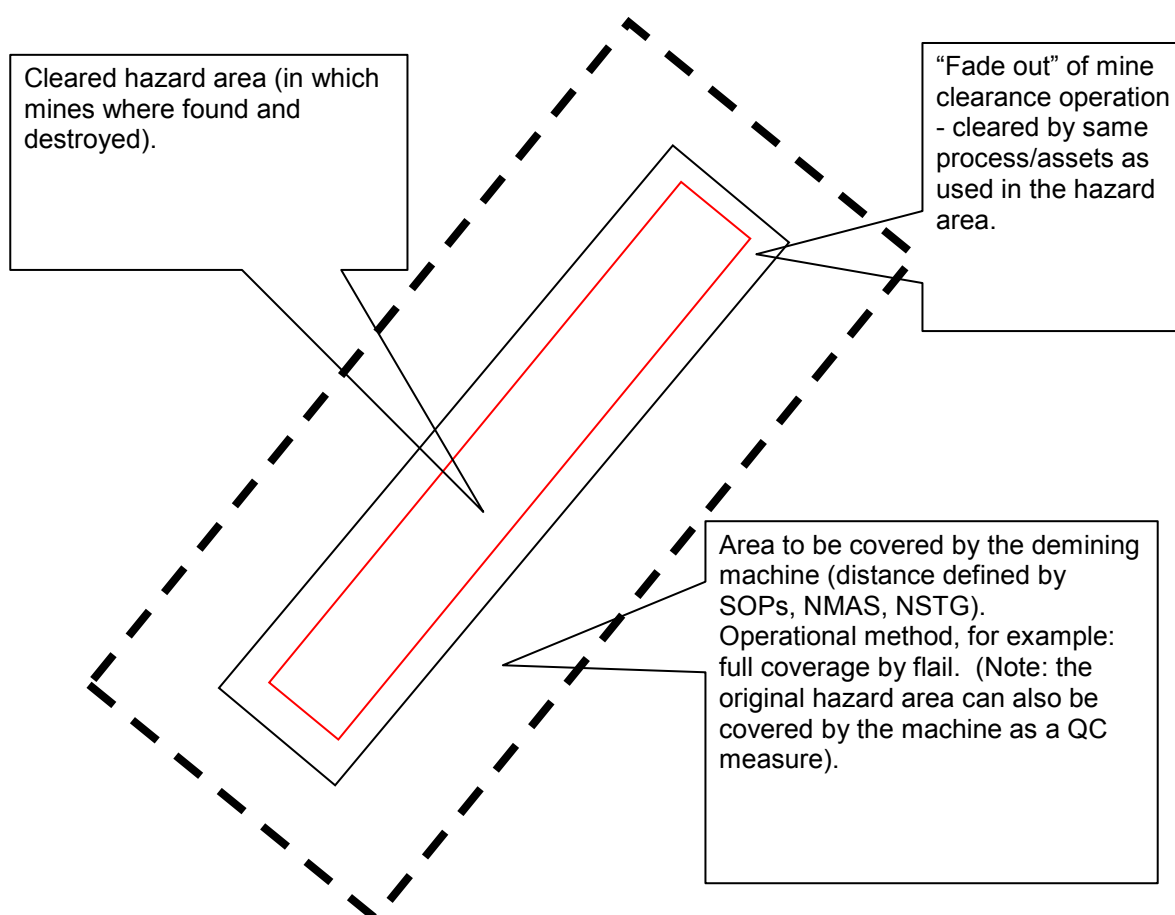


Figure 2 — Scenario 2: Hazard mitigation procedures outside or adjacent to a known minefield present a different scenario.

If a hazard is encountered in the area outside the original hazard area then follow-on shall be conducted in line with IMAS 09.50

If, however, no hazard is encountered then a follow-on process is not required.

This workshop agreement recommends that where a demining machine is used in this confidence role, and where no hazard has been encountered, there is no requirement for follow-on in that area.

However, although no follow-on with other assets is required, QC and a visual inspection in the area should be conducted. Also the decision making process shall be fully documented in release documentation.

NOTE The procedures of Scenario 2 can be used when a single mine is encountered – i.e. the mine is manually cleared and “fade out” distance/area defined and then a machine is used to mitigate outside this area and over the hazard spot for QC purposes.

5.4 Scenario 3: Verification

In this scenario, a demining machine is used to verify that an area of ground suspected to be hazardous does not in fact contain hazards. This scenario tends to occur when an implementer has more information than local people – but, for reasons of confidence building with the community, the clearance implementer (or national authority) decides to demonstrate that the area is not hazardous. (See Figure 3.)

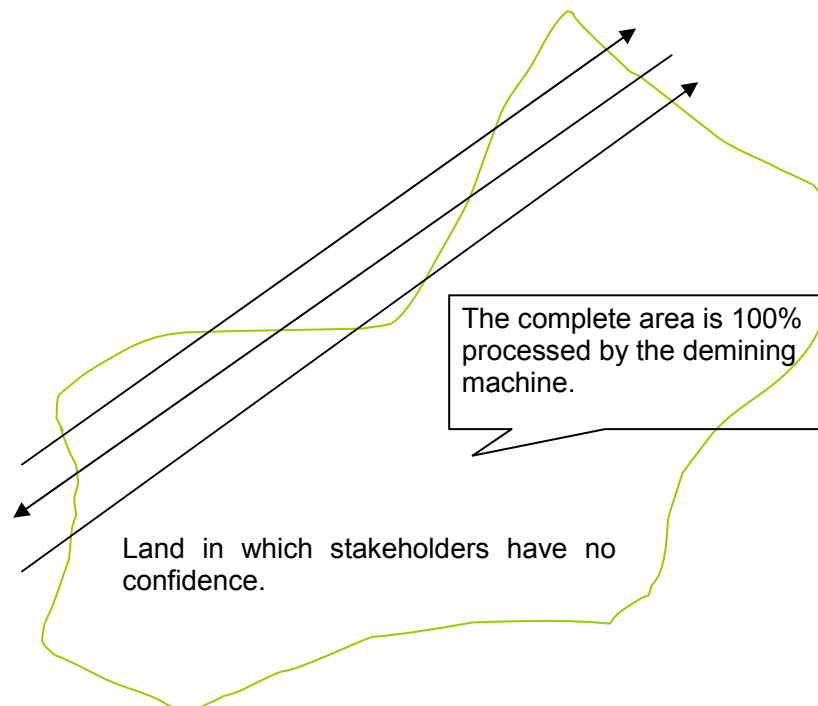


Figure 3 —Scenario 3: Verification.

If no hazards are encountered during the verification process then follow-on is not required.

However, although no follow-on is required, QC and a visual inspection in the area should be conducted. And the decision making process shall be fully documented in release documentation.

5.5 Scenario 4: Clearance operations

Unfortunately, survey data can be based on incomplete information – and uncertainty can lead to areas being assumed to be hazardous when they are not.

A demining machine may be used to process such an area with the intention of clearing it yet the result is that there is no evidence of any hazard. ***In this case – if the capability of the machine is well understood and the anticipated target was inside the capability range of the machine – a decision could be taken not to follow-on.***

However, although no follow-on is required, QC and a visual inspection in the area should be conducted. And the decision-making process shall be fully documented in release documentation.

6 When follow-on is not required after hazards are encountered

In certain circumstances a demining machine can be used as the primary clearance asset at a hazardous site. In some **exceptional** circumstances (explained below) no follow-on – beyond visual inspection – is required.

The decision whether to follow-on or not must be based on evidence. This evidence must be based on knowledge documented from:

- previous testing and evaluation of the demining machine;
- national accreditation of the demining machine;
- previous field evidence (from similar sites) of the capability of the demining machine to destroy the specific and expected target hazard;
- evidence, through QA and QC monitoring, that the demining machine is working to its optimum capability at the site; and
- evidence, through QA and QC monitoring, that the operator is working the machine correctly.

Furthermore, the criteria for this operational decision must be included in the operators accredited SOPs for the demining machine and be in line with criteria set out in NMAS or NSTG (and/or national law).

NOTE Demining law that details specific clearance operations are the exception rather than the norm.

Possible example: a machine of known capability is working to that capability in conditions similar to those in which it was tested and evaluated, and in conditions similar to other areas where a sufficient body of evidence exists to state that it is *known* that the machine will destroy all targets of a specific type, therefore no follow-on is required. Figure 4 shows this decision process.

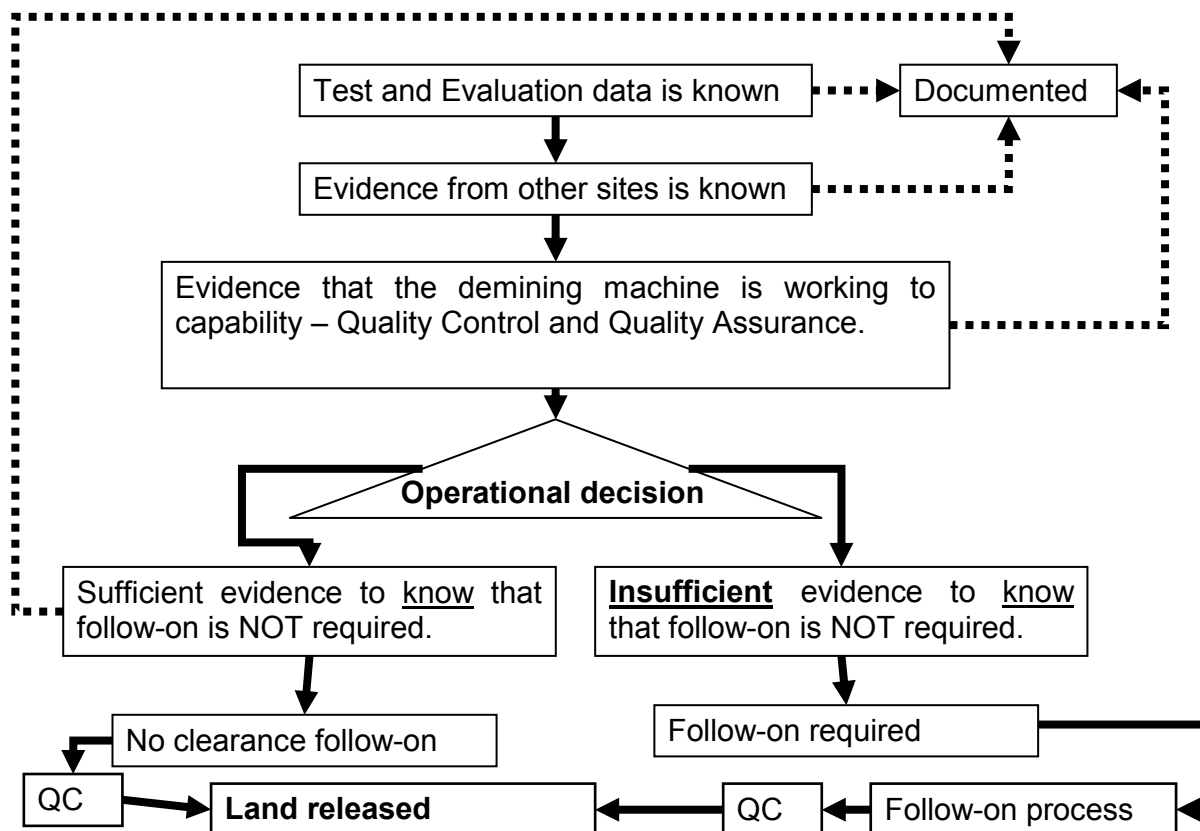


Figure 4. Follow-on decision process.

The conditions for no follow-on occur *very exceptionally* and in general follow-on will be undertaken when demining machines are used for clearance.

7 Summary

In summary, the overall guidance of this Workshop Agreement is as follows:

- a) The intended outcome of the use a demining machine will determine what follow-on procedures are applied.
- b) Follow-on is required when a machine is used for ground preparation in a hazardous area.
- c) Follow-on is not required when a machine is used for ground preparation in an area that is not hazardous.
- d) When a machine is used as part of an integrated off-site processing operation there is no requirement for follow-on procedures in the original suspect hazard area when the soil/sand is replaced provided adequate QA and QC procedures are in place at the off-site location
- e) Follow-on after survey: if the machine does not encounter a hazard, but has been proven to be capable of detecting and destroying similar expected hazards in similar conditions, then follow-on operations may not be required. If a machine does encounter a hazard then follow-on in anything other than exceptional cases should be undertaken.
- f) Follow-on is also not required in four general scenarios in which the outcome of machine use **is the discovery of no hazard**. They are the use of a demining machine in:
 - technical survey operations;
 - hazard mitigation procedures outside, or adjacent to, a known minefield;
 - verification (that no mines exist) procedures; or
 - clearance operations – where a machine is used with the intent to clear ground but no hazards are found.

In these circumstances, if no hazard is encountered no follow on is required – given that the capabilities of the machine are understood and QA and QC systems are in place.

In certain circumstances a demining machine can be used as the primary clearance asset at a hazardous site. In some **exceptional** circumstances no follow-on – beyond visual inspection – is required.

- g) Decisions about follow-on be based on documented evidence from:
 - previous testing and evaluation of the demining machine;
 - national accreditation of the demining machine;
 - previous field evidence (from similar sites) of the capability of the demining machine to destroy the specific and expected target hazard;
 - evidence, through QA and QC monitoring, that the demining machine is working to its optimum capability at the site; and
 - evidence, through QA and QC monitoring, that the operator is working the machine correctly.

8 Agreement statement

The agreement described in this document has been reached over three meetings. The workshop concluded that this agreement should be seen as an advisory document towards the development or revision of existing, International Mine Action Standards. The workshop members do not believe that this agreement should, in itself, be a stand-alone document defining specific actions within the complex considerations of the use of machines in humanitarian demining. The workshop also concluded that this agreement is of a significantly different character to those that have preceded it in the mine action sector such as CWA 14747-1 [1], CWA 15044 [2] and CWA 15464 [3].

CWA 15832:2008 (E)

Unlike preceding CEN Workshop Agreements, this agreement does not set out a test nor does it set out any evaluation procedures or processes. Instead, this agreement is presented as a series of condition statements contributing to the wider consideration of the use of machines.

The workshop consensus was that the CEN workshop process was not ideally suited to the subject of follow-on processes after the use of demining machines. This was not at first apparent but, by the second meeting, it was clear that, within the subject matter, there was little of real contention and little that was not already covered either directly or obliquely in many IMAS, national mine action standards or operator standard operating procedures. The utility of this agreement document is, however, that the various key factors are presented in one document.

Bibliography

- [1] CWA 14747-1, *Humanitarian Demining Actions – Test and evaluation – Part 1: Metal Detectors*
- [2] CWA 15044 -2004 *Test and evaluation of demining machines,*
- [3] CWA 15464-2005 *Humanitarian Mine Action – EOD Competency Standards – Parts 1 to 5*

CEN

CWA 15833

WORKSHOP

April 2008

AGREEMENT

ICS 95.020

English version

Humanitarian mine action - Quality management - Quality assurance (QA) and quality control (QC) for mechanical demining

This CEN Workshop Agreement has been drafted and approved by a Workshop of representatives of interested parties, the constitution of which is indicated in the foreword of this Workshop Agreement.

The formal process followed by the Workshop in the development of this Workshop Agreement has been endorsed by the National Members of CEN but neither the National Members of CEN nor the CEN Management Centre can be held accountable for the technical content of this CEN Workshop Agreement or possible conflicts with standards or legislation.

This CEN Workshop Agreement can in no way be held as being an official standard developed by CEN and its Members.

This CEN Workshop Agreement is publicly available as a reference document from the CEN Members National Standard Bodies.

CEN members are the national standards bodies of Austria, Belgium, Bulgaria, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland and United Kingdom.



EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

Management Centre: rue de Stassart, 36 B-1050 Brussels

© 2008 CEN All rights of exploitation in any form and by any means reserved worldwide for CEN national Members.

Ref. No.:CWA 15833:2008 D/E/F

Contents

Page

Foreword.....	3
Introduction	4
1 Scope	5
2 References.....	5
3 Quality management and the use of machines in mine action.....	5
4 Applying QA and QC to mechanical demining	7
5 Quality assurance at the site	9
6 Quality control at the site.....	9
7 Summary.....	11
8 Agreement statement	11
Bibliography	13

Foreword

This CEN Workshop Agreement has been drafted and approved by a Workshop of representatives of interested parties, the constitution of which was supported by CEN following the public call for participation made on 27 November 2006.

Participants in the process were drawn from the following sectors with interests in humanitarian demining: non governmental organisations, other international organisations, national mine action authorities and manufacturers and users of demining machines. The following organisations have been actively participating in the process: Geneva International Center for Humanitarian Demining (GICHD), Switzerland. Active contributions have also been received by representatives from ANAMA, CMAC, CTRO, INTERSOS, PNDHD, SWEDEC, UNMACA, UNMAS, Norwegian People's Aid, Idea Group, Cranfield, DOK-ING, MineWolf Systems AG and Scanjack AB.

The formal process followed by the Workshop in the development of the CEN Workshop Agreement has been endorsed by the National Members of CEN but neither the National Members of CEN nor the CEN Management Centre can be held accountable for the technical content of the CEN Workshop Agreement or possible conflict with standards or legislation. This CEN Workshop Agreement can in no way be held as being an official standard developed by CEN and its members.

The final review/endorsement round for this CWA was started on 2007-12-21 and was successfully closed on 2008-02-21. The final text of this CWA was submitted to CEN for publication on 2008-03-27.

This CEN Workshop Agreement is publicly available as a reference document from the National Members of CEN: AENOR, AFNOR, ASRO, BDS, BSI, CSNI, CYS, DIN, DS, ELOT, EVS, IBN, IPQ, IST, LVS, LST, MSA, MSZT, NEN, NSAI, ON, PKN, SEE, SIS, SIST, SFS, SN, SNV, SUTN and UNI.

Comments or suggestions from the users of the CEN Workshop Agreement are welcome and should be addressed to the CEN Management Centre.

The development of this CWA has benefited from an EC - EuropeAid Co-operation Office, financial contribution allocated in the context of the EC Mandate M/306.

Introduction

The following definitions and notes associated with quality are taken from the International Mine Action Standard IMAS 04.10 *Glossary of mine action terms, definitions and abbreviations*. The note under the Quality Assurance (QA) definition is critical to understanding that quality in mine action is about more than checking processes during demining operations. This might be obvious but there is sufficient anecdotal evidence to suggest that it is often forgotten.

NOTE The IMAS definitions reference an earlier version of EN ISO 9000. The present EN ISO 9000 is from 2005. The cited definitions are the same except for the NOTES which are IMAS additions.

Quality Assurance (QA)

part of QM [quality management] focused on providing confidence that quality requirements will be fulfilled. [EN ISO 9000:2000]

NOTE: The purpose of QA in humanitarian demining is to confirm that management practices and operational procedures for demining are appropriate, are being applied and will achieve the stated requirement in a safe, effective and efficient manner. Internal QA will be conducted by demining organisations themselves, but external inspections by an external monitoring body should also be conducted.

Quality Control (QC)

part of QM focused on fulfilling quality requirements. [EN ISO 9000:2000]

NOTE: QC relates to the inspection of a finished product. In the case of humanitarian demining, the “product” is safe cleared land.

The note under Quality Control suggests that, in humanitarian demining, QC relates only to the inspection of safe cleared land (which is also addressed in IMAS 09.20 *Post-clearance sampling and inspections*). In this agreement, this narrow interpretation of QC is broadened to include quality control checks at stages of the process when there is something to be checked. QA and QC can, therefore, be conducted during demining operations as well as at the end when we check the quality of the final product, i.e. safe land through post-clearance sampling.

Both QA and QC are thus intrinsic parts of quality management which is defined in IMAS as:

Quality Management (QM)

coordinated activities to direct and control an organisation with regard to quality. [EN ISO 9000:2000]

This agreement looks at quality from the perspective that:

- Quality assurance (QA), either internal or external, has a primary focus on *process*;
- Quality control (QC), either internal or external, is focused on a *product*.

The product, when referring to safe cleared land ready for release, is not produced on day one. It may take weeks to clear the whole area but quality processes can start immediately. This agreement takes the position that both internal and external QA and QC are required at all stages of the process if demining machines are to be used to best effect.

This CEN Workshop Agreement should be read in understanding with the terminology used in CWA XXXXX *Humanitarian mine action – Follow-on processes after the use of demining machines*.

1 Scope

This workshop agreement considers quality management in humanitarian demining in general as well as associated with demining machines. The agreement also focuses on specific actions for quality assurance (QA) and quality control (QC) in the use of demining machines at hazardous sites.

2 References

Users of this CEN Workshop Agreement should also refer, in particular but not only, to the following CEN Workshop agreement, International Mine Action Standards¹⁾ and standards from International Standards Organisation (ISO):

CEN/CWA 15044, *Testing and Evaluation of Demining Machines*;
 IMAS 03.40, *Test and evaluation of mine action equipment*;
 IMAS 04.10, *Glossary of mine action terms definitions and abbreviations*;
 IMAS 07.10, *Guide for the management of demining operations*;
 IMAS 07.30, *Accreditation of demining organisations and operations*;
 IMAS 07.40, *Monitoring of demining organisations*;
 IMAS 09.10, *Clearance requirements*;
 IMAS 09.20, *Guidelines for sampling*;
 IMAS 09.40, *Guide for the use of MDD (mine detection dogs)*;
 IMAS 09.50, *Mechanical demining*;
 IMAS 10.20, *Safety and occupational health (S&OH) demining worksite safety*;
 EN ISO 9000, *Quality management systems – Fundamentals and vocabulary (ISO 9000:2005)*;
 EN ISO 9001, *Quality management systems – Requirements (ISO 9001:2000)*;
 EN ISO 9004, *Quality management systems – Guidelines for performance improvements (ISO 9004:2000)*.

Readers should also refer to the National Mine Action Standards (NMAS) and/or the National Standards and Technical Guidelines (NSTG) for mine action in their operating country, as well as any other relevant country-specific technical notes.

The guidance in this agreement should be used to supplement the guidance in the above documents. Note should also be taken of the CEN Workshop Agreement CWA xxxxx²⁾ *Follow-on processes after the use of demining machines*, and the 2004 Geneva International Centre for Humanitarian Demining (GICHD) publication, *A Study of Mechanical Application in Demining* is a useful reference.

3 Quality management and the use of machines in mine action

Demining machines are not used in isolation in a demining programme. They are either used in support of other assets or other assets are used in support of the machines. Therefore, a holistic approach to the management of machines and quality must be considered.

IMAS 07.10 *Guide for the management of demining operations* sets out guidance for the conduct of demining operations. For mine action to be effective, efficient and timely the overall process must be managed within the framework of a quality management system. It follows that, for demining machine use to be effective:

— all aspects of quality management must be addressed;

1) IMAS can be accessed through www.mineactionstandards.org.

2) Result from CEN/WS 28, under publication.

- QC should be seen as more than a post-clearance sampling process at a minefield site; and
- QA should be seen as more than assuring that the minefield processes are correct.

Figure 1 set out one model for a process-based quality management system.

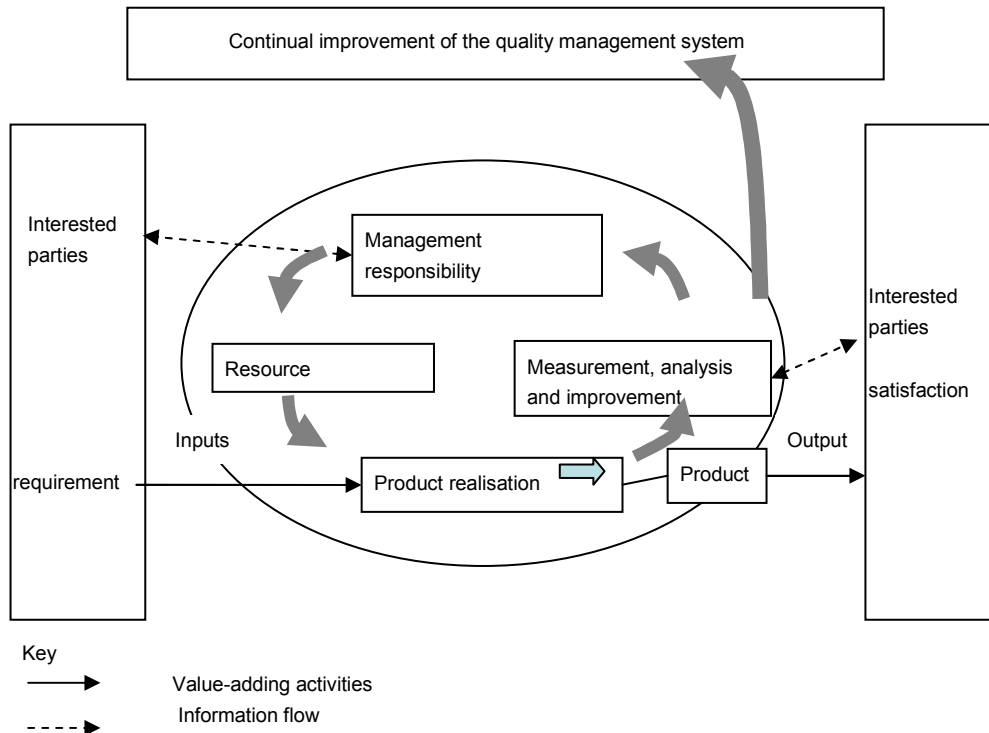


Figure 1 — Model for a process-based quality management system

The physical processes of operations in the suspected hazard areas are inside the box "Product realisation". In the case of clearance operations, clearance and follow-on as appropriate lead to the product, which is safe cleared land. As a consequence, interested parties, in this case the users of the processed land are satisfied.

The diagram is intended to show that the product can only be produced efficiently if:

- management allocates the required resources and those resources are applied correctly when allocated;
- the process of demining is measured, analysed and improved – and management seeks to learn from mistakes and takes ownership and responsibility.

It should be noted that management responsibility rests with both the national authorities (and their equivalent) and the implementers of mine action.

The process, in the context of mechanical demining, is more simply shown in Figure 2.

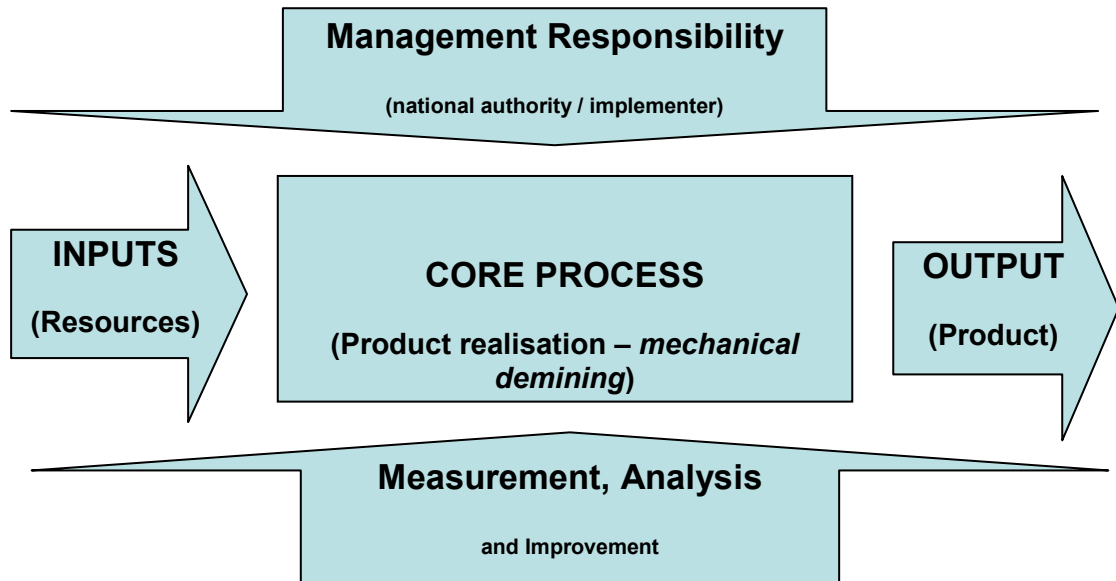


Figure 2 — The core process and influences.

4 Applying QA and QC to mechanical demining

Demining machines are essentially used for two functions, ground preparation or ground processing. However, to operate effectively in either role it is fundamental that the machine must be “fit for purpose”. For example, a vegetation cutter that does not engage the ground/soil cannot effectively be used to process ground if the intent of the operation is to disrupt the soil to a depth of 20cm.

The concept of “intent” is very important and, before the application of any machine, it must be agreed /decided exactly what is expected/anticipated of the machine in the specific operation, i.e. what is intended to be achieved?

In ground preparation operations, intent can be relatively straightforward: vegetation cutting and/or clearing; removal of tripwires, loosening of soil; removal of metal contamination; removal of building debris, boulders, rubble, defensive obstacles etc; and the sifting of soil and debris.

However, in ground processing the intent can be more complex. For example, demining machines can be used when the intention of the operation is one of the following:

- a) To find mines;
- b) To clear mines; or
- c) To prove there are no mines.

The role against which the performance of the machine is to be measured must be decided early in the planning stages.

QA is about process, thus actions to ensure quality should not exclusively focus on how the machine is being used at a particular site – and the starting point for QA is to understand machine use within the country/programme. Confidence that the machine is fit for purpose comes from:

- testing and evaluation of the demining machine;
- field analysis of results; and
- pre-testing before a site deployment.

In addition, and as part of the accreditation process, the experience of the operator must be known and the organisational SOPs fully understood. These aspects of QA – testing, analysis, pre-testing, operator

experience and SOPs – are all off-site processes that will enable an on-site QA evaluation to take place against benchmarks other than pure observation and speculation.

In Figure 3 the steps of machine use at a suspected hazardous site are shown. The first step is establishing a clear understanding of the intended outcome. (What are we trying to achieve?) Next is the mechanical process. (What is going to be done?) Then comes establishing that the objective has been achieved – for example, that the depth required has been met. (What has been done?)

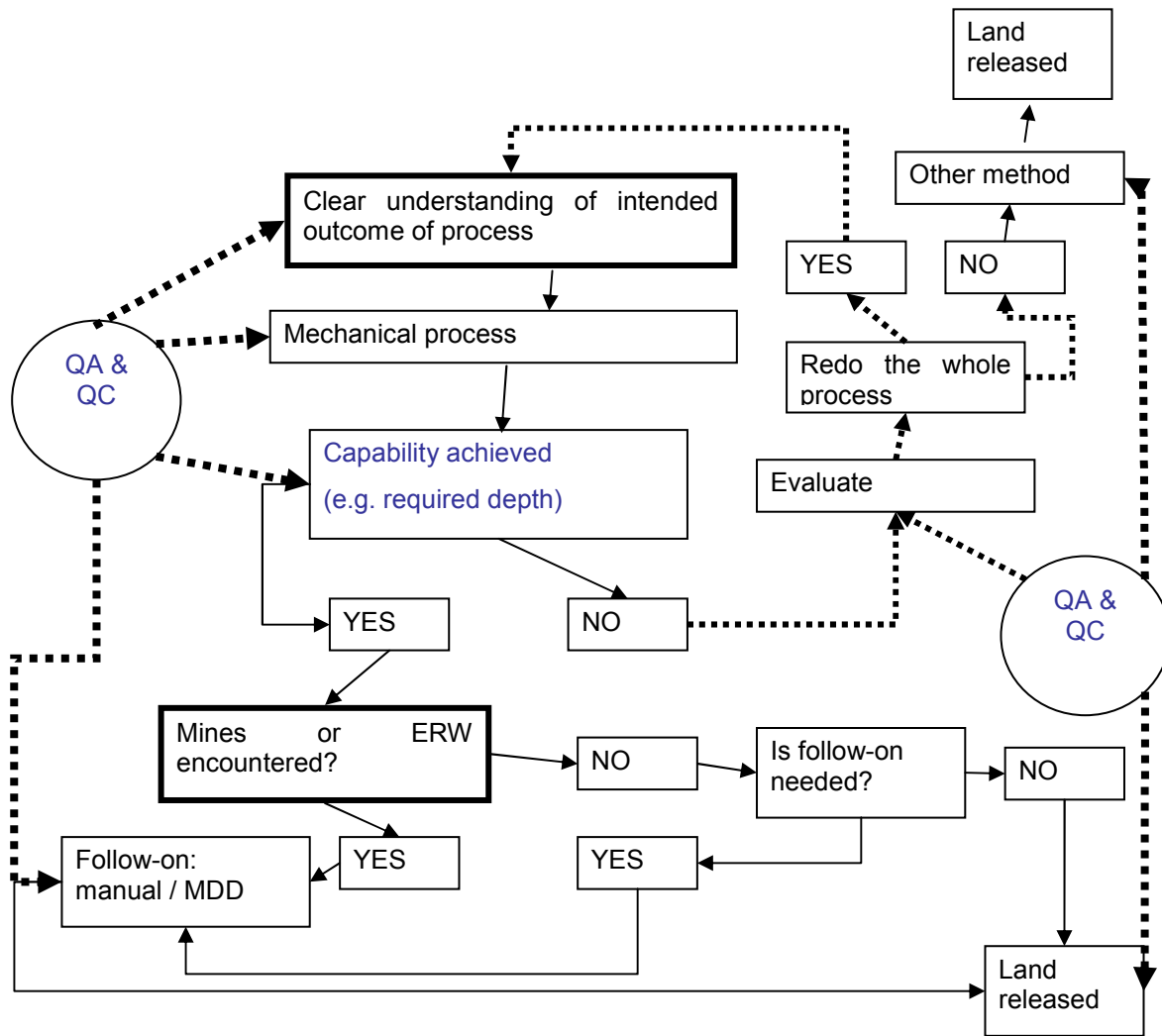


Figure 3 —The demining machine in the operational process.

Superimposed on the diagram are links shown to QA and QC. Thus it can be seen that quality is achieved by applying quality measures to understanding the intent, the process and the result. (Capability achieved)

5 Quality assurance at the site

On the demining site or suspected hazard area, quality can be directly assured by checking, among other things, records and planning: for example, by reviewing the operational site plan and by observing the work of the machine, i.e. observing the process (e.g. IMAS 09.50 Annex C).

If there are no records of hours worked, or no records of fuel use or maintenance, it becomes more difficult to make a judgement as to whether the process is going according to plan (the intent). Likewise, if there is no operational plan for the use of the machine, it is possible that the intended use of the machine is not clearly defined, therefore a judgement about whether the machine is working well becomes difficult. If vegetation is being cut, this is clear, but is it clear that the right vegetation is being cut?

Beyond records, plans and training, quality assurance of machine use is based on observation, often from a distance and is almost always conducted differently from QA of manual or dog demining. Traditionally, the QA process in manual demining has three stages – looking at the deminer, the section leader and the team leader – all of whom have a role in processing the ground in question. QA is sequential and deliberate. With a machine this process is more difficult to replicate.

Therefore, successful QA of machines relies on observation of the process but is also measured against facts established through:

- testing and evaluation of the demining machine;
- field analysis of results; and
- pre-testing before a site deployment.

Comprehensive testing and evaluation should include understanding the relationships between speed of movement and the effectiveness of the tool – for example, forward movement speed will have an effect on flails and tillers.

Pre-testing before deploying on a site can be done by simply engaging the machine and tool on an area in close proximity to, and similar to, the suspected hazard area – i.e. in similar ground conditions but in a safe area. At this “test ground” the capability of the machine is evaluated and recorded in the prevailing conditions. This gives you sufficient information against which to evaluate the actual work of the machine. A refinement in the case of tillers and flails – rather than simply engaging the tool in virgin ground – could be to introduce witness boards into the test area. Typically used witness boards are five mm wooden fibre boards that are dug into the ground prior to clearance to provide a profile of the cut achieved by the machine. (See CEN/CWA 15044 *Testing and evaluation of demining machines*). Note that one limitation of pre-testing in proximity to the site is that no live mines will be encountered. Dummy mines could, however, be introduced.

6 Quality control at the site

Normally both internal and external QC will be carried out at a given task to ensure the performance of the machine at the work site. The box “capability achieved” in Figure 3 describes where a QC check of the product can be carried out. For example, has the vegetation been cut to the quality expected, or has the depth required been achieved, or is the bucket separating material correctly?

Vegetation cutters and similar machines do not present a QC challenge as it is clear if the capability of the tool has been met when the process is paused or stopped – and it is also obvious from QA observation whether the active machine is working to standard. The same applies to any system where it is possible to inspect the working process visually from close proximity and to observe the quality of product in a pause in operations. For example, measuring the depth of cut when a front-end loader is used to excavate ground is a relatively simple process of walking onto the excavated area and establishing that soil to a specific depth has been removed. QC checks are more problematical when other ground processing operations are being conducted.

There are essentially only two ways of carrying out QC checks on the product of an intrusive demining machine.

The first method is to walk around the outside edge of the hazardous area, on known safe ground, and to take samples at the edge of the ground processed by the machine (see Figure 4).

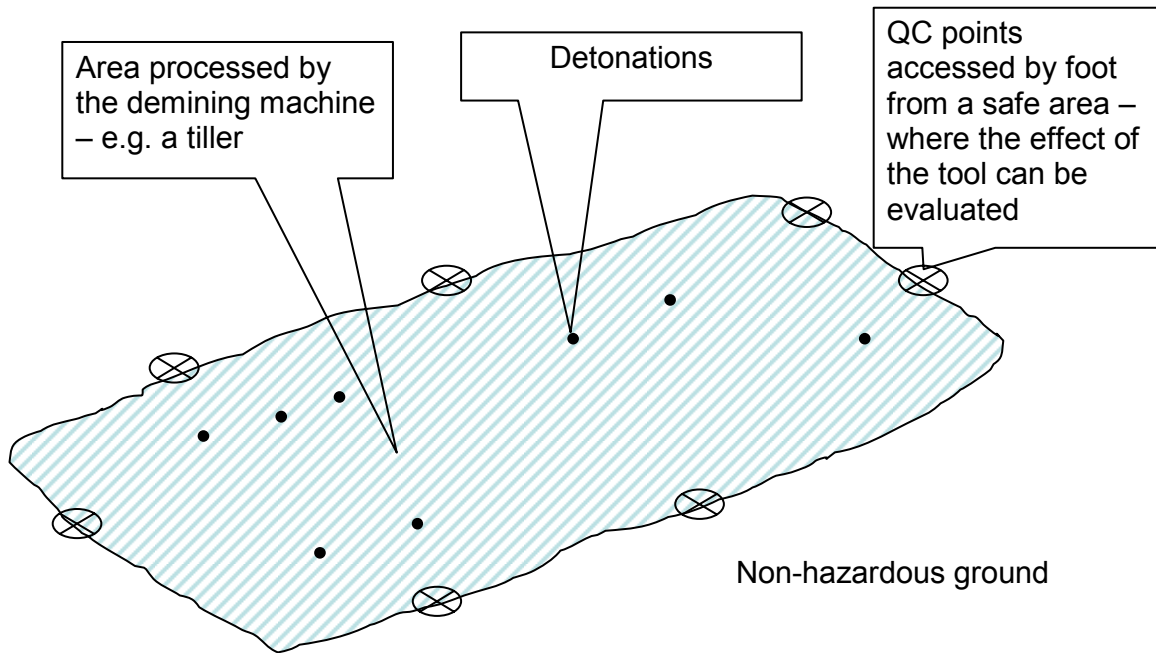


Figure 4 —QC around the perimeter of a work site processed by machine.

The second method is to run one or more deliberate QC lanes into the site. This will enable a QC monitor to evaluate the work of the machine inside the site. This process will clearly be more time consuming than the perimeter check. This is shown diagrammatically in Figure 5.

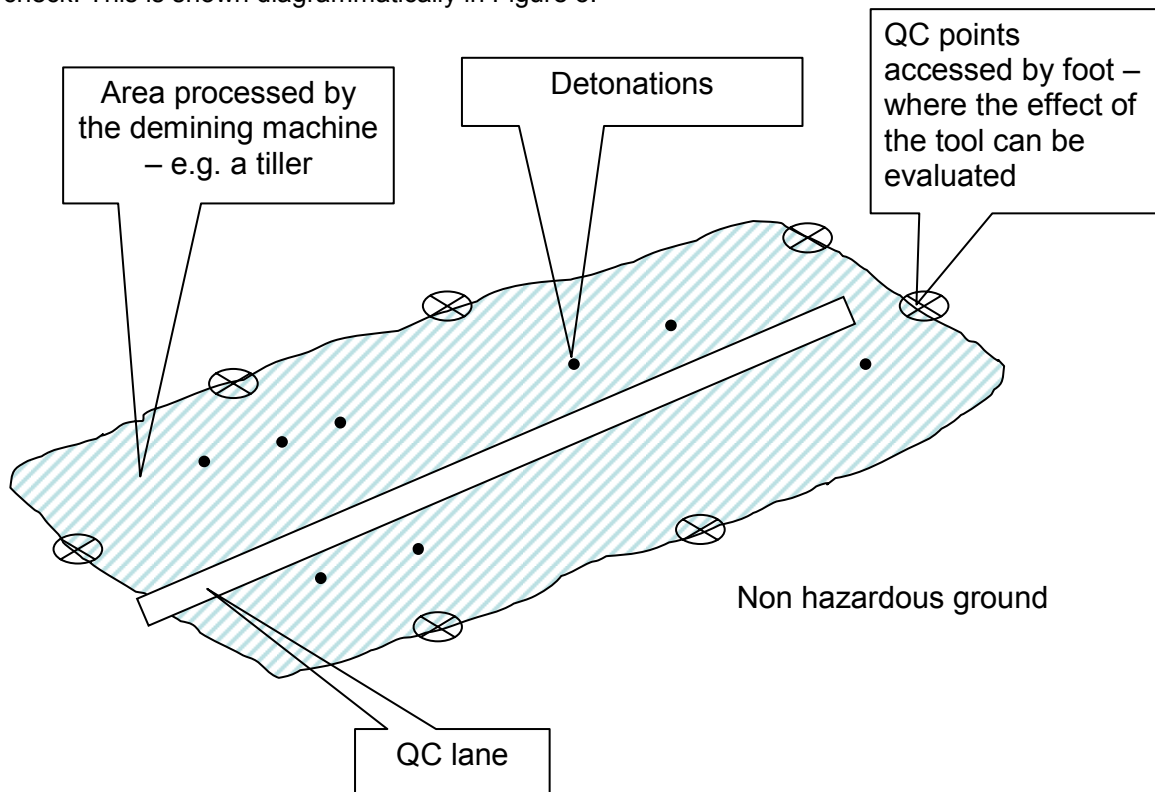


Figure 5 —Quality control lane into hazardous area.

The performance of a machine will vary over the area being worked on and achieved depths over the entire site will be different. The critical issue is to verify that the minimum intended depth is being achieved. Thereafter a view can be taken as to why a greater depth is being achieved and whether the operator is working the machine inefficiently.

As with QA, effective QC must be a check that is measurable against facts established through:

- testing and evaluation of the demining machine;
- field analysis of results; and
- pre-testing before a site deployment.

7 Summary

- a) For mine action to be effective, efficient and timely the overall process must be managed within the framework of a quality management system. This agreement recommends use of the EN ISO 9004 Model for a process-based quality management system.
- b) A quality product will only be produced efficiently if, for example:
 - Management allocates the required resources;
 - Those resources are applied effectively when allocated;
 - The process of demining is measured, analysed, and improved; and,
 - Management seeks to learn and take ownership and responsibility.
- c) Management responsibility depends on both the national authorities (or equivalent) and the implementers of mine action.
- d) The “intent” is very important. Before the application of any machine, it must be agreed /decided exactly what is expected/anticipated of the machine in the specific operation, i.e. what is intended to be achieved. If the intent is not clear it will not be clear how to QA the process or QC the product.
- e) Therefore, successful QA and QC depends on making evaluations measured against facts established through:
 - testing and evaluation of the demining machine;
 - field analysis of results; and
 - pre-testing before a site deployment.

8 Agreement statement

The agreement described in this document has been reached over three meetings. The workshop concluded that this agreement should be seen as an advisory document towards the development, or revision, of existing, International Mine Action Standards. The workshop members do not believe that this agreement should, in itself, be a stand-alone document defining specific actions within the complex considerations of the use of machines in humanitarian demining. The workshop also concluded that this agreement is of a significantly different character to those that have preceded it in the mine action sector, such as CWA 14747-1[1] CWA 15044[2] and CWA 15464[3].

Unlike the preceding CEN Workshop Agreements, this agreement does not set out a test nor does it set out any evaluation procedures or processes. Instead, this agreement is presented as a series of condition statements and a contribution to the wider consideration of the use of machines.

CWA 15833:2008 (E)

The workshop consensus was that the CEN workshop process was not ideally suited to the subject of quality management (quality assurance and quality control) for mechanical demining processes after the use of demining machines. This was not at first apparent but, by the second meeting, it was clear that, within the subject matter, there was little of real contention and little that was not already covered either directly or obliquely in many IMAS, national mine action standards (NMAS) or operator standard operating procedures (SOP). The utility of this agreement document is, however, that the various key factors are presented in one document.

Bibliography

- [1] CWA 14747-1 *Humanitarian Demining Actions – Test and Evaluation – Part 1 : Metal Detectors,*
- [2] CWA 15044 -2004 *Test and evaluation of demining machines,*
- [3] CWA 15464-2005 *Humanitarian Demining Action - EOD Competency Standards – Parts 1 to 5*

REFERENCE DOCUMENT 8.

INTERNATIONAL MINE ACTION STANDARDS; IMAS 09.50 MECHANICAL DEMINING; IMAS 07.10 THE DEMINING PROCESS ADAPTED TO ROAD CLEARANCE

Introduction

In the international effort against landmines and Explosive Remnants of War (ERW) there is a constant need to improve efficiency and safety. Machines have been used on demining operations for many years now and have already demonstrated their potential in several areas for significantly increasing output and for making demining a safer activity. However, the full potential of machines has not yet been reached. There are still opportunities to improve the use of machines and to encourage their development and application.

This standard has been produced to provide guidelines and specifications that promote the safe, efficient and effective use of machines in demining operations. It forms the introductory “standard” to a series of IMAS that relate to mechanical demining.



MECHANICAL DEMINING

1. Scope

This standard provides specifications and guidelines for mechanical demining operations.

2. References

A list of normative references is given in Annex A. Normative references are important documents to which reference is made in this standard and which form part of the provisions of this standard.

3. Terms, definitions and abbreviations

A list of terms, definitions and abbreviations used in this standard is given in Annex B. A complete glossary of all the terms, definitions and abbreviations used in the IMAS series of standards is given in IMAS 04.10.

In the IMAS series of standards, the words 'shall', 'should' and 'may' are used to indicate the intended degree of compliance. This use is consistent with the language used in ISO standards and guidelines:

- a) 'shall' is used to indicate requirements, methods or specifications that are to be applied in order to conform to the standard.
- b) 'should' is used to indicate the preferred requirements, methods or specifications.
- c) 'may' is used to indicate a possible method or course of action.

The term 'National Mine Action Authority' (NMAA) refers to the government department(s), organisation(s) or institution(s) in each mine-affected country charged with the regulation, management and co-ordination of mine action. In most cases the national Mine Action Centre (MAC) or its equivalent will act as, or on behalf of, the NMAA. In certain situations and at certain times it may be necessary and appropriate for the UN, or some other recognised international body, to assume some or all of the responsibilities, and fulfil some or all of the functions, of a NMAA.

The term 'mechanical demining operations' refers to the use of machines on demining operations and may involve a single machine employing one mechanical tool, a single machine employing a variety of tools or a number of machines employing a variety of tools.

The term 'machine' refers to a unit of mechanical equipment used on demining operations.

The term 'mechanical demining unit' may refer to a single machine or it may refer to more than one machine that works as part of a system for example, a front end loader and a screening plant.

The term ‘mechanical tool’ refers to the working component(s) attached to a machine, such as flails, tillers, sifters, rollers, excavators, ploughs, magnets etc. A single machine may utilise a number of different tools, which may be fixed or interchangeable.

The term ‘intrusive machine’ refers to those machines that are designed to work inside a hazardous area, while the term ‘non-intrusive machine’ refers to those designed to operate from a cleared or known safe area, with it’s mechanical tool working in the hazardous area.

In this IMAS the term ‘residual risk’ relates to the hazard remaining from landmines or ERW following mechanical demining in a particular hazardous area.

4. Use of machines on demining operations

Machines used on demining operations can be divided into three general categories; mine clearance machines, ground preparation machines, and Mine Protected Vehicles (MPV) when used in detection and survey operations.

4.1 Mine clearance machines

Mine clearance machines are those machines whose stated purpose is the detonation, destruction or removal of landmines. A consequence of their use is that the necessity for post-mechanical follow-up clearance is reduced to the minimum possible, or in certain cases, eliminated i.e. where the perceived hazard was non-existent, where the machines removed the hazard or where the remaining hazard forms a tolerable residual risk.

4.2 Ground preparation machines

Ground preparation machines are primarily designed to improve the efficiency of demining operations by reducing or removing obstacles¹.

Ground preparation tasks may include:

- a) vegetation cutting and clearing;
- b) removal of tripwires;
- c) loosening the soil;
- d) removal of metal contamination;
- e) removal of building debris, boulders, rubble, defensive wire obstacles etc; and
- f) sifting of soil and debris.

Ground preparation may or may not involve the detonation, destruction or removal of landmines.

4.3 Mine Protected Vehicles (MPV) used in detection and survey operations

¹. See A Study of Mechanical Application in Demining, GICHD 2004, chapter 4 page 103.

MPV are vehicles specifically designed to protect the occupants and equipment from the effects of a mine detonation. MPV are commonly used during detection and survey operations, where they may carry equipment such as detector arrays, vapour sampling devices or in some cases push or pull a roller.

While these operations are not strictly mechanical demining operations involving ‘machines’ and ‘mechanical tools’ some of the work carried out by MPV falls into the category of mechanical demining. For example:

- a) heavy MPV using their wheel tracks to provide an access path for manual sampling teams (a ground preparation role); and
- b) MPV pushing or towing rollers (a mechanical mine clearance role).

When used on demining operations, the requirements of MPV are similar to those for mechanical demining. Accordingly, the requirements of this standard shall apply equally to the use of MPV on detection and survey operations.

4.4 Operational requirements

When machines are used for mine clearance, and the machine has been assessed as potentially leaving hazards which pose an intolerable risk to the end users of the land, follow-up demining operations shall be carried out before the area is considered cleared.

When machines are used for ground preparation, they shall always be followed-up by other demining operations such as manual, Mine Detection Dog (MDD) or mechanical mine clearance.

When machines are used for detection and survey operations, the information that they provide shall be followed up as appropriate and determined by an information management process, e.g. leading to a decision to clear the area, mark the area or classify the area as non-hazardous.

4.5 Mechanical area reduction

Mechanical area reduction can be a part of a technical survey process or a part of a clearance operation. Mechanical area reduction involves a machine being used to indicate or confirm the presence or absence of landmines and/or ERW within a hazardous area. The aim is to enable the deployment of other demining assets only in areas that are proven to contain landmines and/or ERW.

The scope and extent of mechanical area reduction operations depends on factors such as the accuracy and completeness of existing information, terrain, vegetation, machine and tool type, mine and ERW types and area reduction procedures used. Generally, the less information available about a hazardous area, the more investigation is required by a machine in order to be able to confirm the location of landmines and subsequently reduce the hazardous area.

4.6 Other operations

Machines may also be used for other functions in support of demining operations. Such functions may include preparing tracks to permit access into areas for demining operations, excavation in support of deep search operations and the removal of debris to enable access to suspected hazards (e.g. under collapsed buildings etc.).

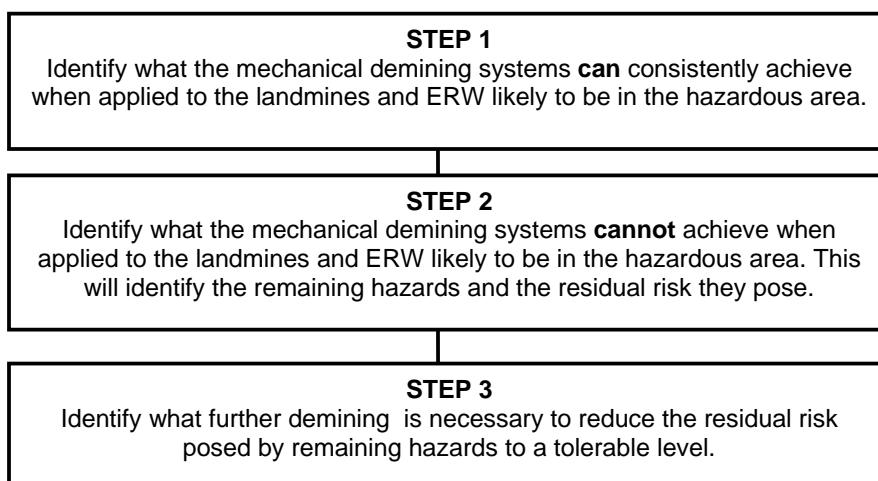
5. Systems approach to mechanical demining

While there are many varieties of machines and tools available for use in mechanical demining, machines alone are rarely able to defeat all mine types and are unlikely to detonate all ERW².

This has led to a need for a ‘**systems approach**’ to mechanical demining whereby machines with a combination of tools, or a combination of machines with different tools, are applied at different stages during the demining process to reduce the hazard to the greatest extent possible. Both ground preparation and mine clearance machines may be used in a systems approach.

The systems approach is about mechanical demining being integrated with other demining assets (manual or MDD) to ensure that the most effective outcome is achieved.

On the next page is an example of the steps involved in a systems approach leading to the selection of an appropriate method to deal with a hazardous area.



5.1 Tolerable risk

The identification of tolerable risk to the end user is an important component of any demining operation, as it implies how thorough the demining process has to be to reach the required level of tolerance. After mechanical mine clearance has been completed, an assessment of the residual risk posed by remaining hazards may show that the risk is already tolerable and no further demining is required. National mine action standards should provide guidance for the process of determining tolerable risk

More information on tolerable risk can be found in the section on risk management included in IMAS 01.10.

6. Mechanical demining operations - general requirements

Machines used in demining operations shall conform to certain general requirements:

². “Machines are fairly ineffectual at detonating or breaking up all UXO” GICHD, A Study of Mechanical Application in Demining, May 2004, p.65.

- a) each machine shall be Tested and Evaluated (T&E) to determine its suitability for the task(s) it is expected to carry out in the conditions in which it will work. Further guidance on T&E is provided in clause 7 of this standard;
- b) the operation of each machine shall be assessed and confirmed as safe for the operator and any other person on the worksite. The protection level for machines shall be established through a risk assessment; and
- c) Standing Operating Procedures (SOPs) shall be developed for each machine. These SOPs should include general mechanical operating procedures, procedures specific to the machine, and where necessary, procedures for the integration of the machine with other machines or demining operations.

Operational accreditation of a machine in accordance with the requirements of IMAS 07.30, should also be based in part on fulfilling the requirements of this clause of this standard.

Machines should not be used with tools, or on tasks, or in conditions for which they do not have operational accreditation.

Prior to the deployment of any machine to a programme an assessment should be made of the in-country infrastructure and support systems to ensure that a machine can be operationally maintained in the areas where it will be used.

7. Testing and Evaluation (T&E)

T&E of machines is carried out to ensure that a machine is suitable for its intended use in the environment in which it will operate.

7.1 Scope of T&E

T&E for machines should be designed to:

- a) identify the operational limitations of the machine;
- b) identify the optimal operating conditions for the machine in its intended operating environments;
- c) [for mine clearance machines], identify the effectiveness in disrupting, destroying, detonating or otherwise removing different types of landmines or ERW from hazardous areas in different operating environments. This should only occur for landmines or ERW that a machine has been designed and developed to combat in accordance with the manufacturer's specifications;
- d) [for individual mine clearance machines, or a number of machines or tools to be used as part of a systems approach], identify the residual risk remaining from each landmine or ERW type to be targeted in the operating environments in which the machine(s) will work;
- e) identify any limitations in the employment of a machine (e.g. environmental conditions such as inclines, wet soil, hard ground, temperatures etc, or certain explosive hazards);

- f) assess and confirm the safety of the machine for the operator and any other person on a mechanical demining worksite; and
- g) identify the operating procedures required to ensure that a machine is able to achieve the specified standards.
- h) Identify any potential environmental damage caused through the use of demining machines e.g. soil erosion.

Where a machine has been through T&E or has proven to be effective in other comparable locations, additional formal T&E may not be necessary.

This should only be permitted if continued performance monitoring is carried out by the demining organisation concerned, and that the operating procedures for the machine are such that the NMAA is confident that the standards required of the machine, and any required follow-up demining, will be achieved.

Where such operational performance monitoring is undertaken, records shall be maintained by the demining organisations. The records shall be sufficient to justify any changes to the operating procedures of the machine. See IMAS 03.40 for further guidance on the T&E of mine action equipment.

7.2 CWA 15044:2004 for demining machines

The European Committee for Standardisation (CEN) has developed a CEN Workshop Agreement (CWA) for the T&E of demining machines (CWA 15044:2004). This CWA provides standardised methodology for T&E of demining machines. It gives technical criteria for the following:

- a) performance test. A test to establish whether the machine and its tool(s) is capable of performing the role for which it is intended under comparable and repeatable conditions and to evaluate the manufacturer's specifications;
- b) survivability test. A test to verify that the machine survives the explosive forces used as design criteria; and
- c) acceptance test. A test to ensure that a machine is able to work in the environment where it is intended to be used.

The CWA also establishes the requirements for the test targets to be used in the performance and acceptance tests. Further information can be found at www.mineactionstandards.org or at www.itep.ws

7.3 Mechanical records

The NMAA should require demining organisations to maintain detailed records of their mechanical and follow-up operations to establish a statistical database of information that can be used for operational decision making. This information may for example, permit NMAAs to release land after mechanical mine clearance without follow-up activities if statistical data proves sufficiently that the residual risk posed by remaining hazards is tolerable.

Reporting on operational performance indicators, such as hours worked, land cleared and landmines and ERW found, is essential in order to maintain sufficient statistical records. Reporting on non-operational time, such as mechanical breakdowns, transport between sites and logistical delays, may help understanding the operational constraints and/or visualising performance trends of particular machines, which subsequently may help organisations to improve the efficiency of their mechanical operations. See Annex C for an example of a weekly report format for a mechanical demining unit.

8. Mechanical procedures

Demining organisations shall ensure that operating procedures developed for mechanical operations include the following topics.

8.1 General

Machines are only employed within the limits of their operational accreditation as established during T&E and as documented in SOPs.

Soil expansion (the increase in volume of soil as a result of mechanical processing) is to be taken into consideration when planning follow-up demining. Depth of processing shall be referenced to the original undisturbed ground surface.

8.2 Landmines, ERW and other hazards

If during operations, a hazard is identified which a machine was not designed or approved to be used against, the mechanical operation shall cease and a review of the task shall be carried out.

Machines shall be checked prior to moving from hazardous to safe areas to ensure that no landmines, ERW or hazardous components remain in the working or moving parts of the machine or are attached to the machine.

8.3 Management of mechanical demining operations

Management of mechanical demining operations shall be carried out in a manner that ensures that adequate control is exercised over the operation and that it is possible to provide emergency support in accordance with accident response and equipment recovery plans.

8.4 Medical

See IMAS 10.20 'Safety & occupational health - Demining worksite safety' for demining response plans. In addition, accident response plans for mechanical operations involving crewed machines shall include procedures for the extraction of a casualty from the inside of a machine.

8.5 Communications

Communications between the site supervisor and the mechanical operator shall be in place at all times while a machine is working in a hazardous area.

8.6 Personnel requirements

Mechanical demining worksites shall have sufficient qualified personnel on site while operations are ongoing; to ensure that:

- a) standards for operations are maintained;
- b) where applicable, the effective integration with other demining operations is achieved; and
- c) the necessary support is provided in an emergency.

9. Machine support

9.1 Maintenance and servicing

Demining organisations should make provisions for the maintenance and servicing of machines. Such provisions should ensure that:

- a) machines are maintained and serviced in accordance with the manufacturers' recommendations;
- b) maintenance and servicing is carried out by qualified personnel and authorised agencies;
- c) routine checks are made on the working components of machines and where working components critical to the effective operation of a machine are damaged or lost, these components are repaired or replaced before further work continues;
- d) routine inspections of safety features on machines are carried out and where damage is identified, the damage is repaired before further work continues; and
- e) whenever a machine is subject to a detonation that may have affected the safety of the operation, the machine is immediately withdrawn from the hazardous area and inspected. Where damage to a machine may place personnel in danger from subsequent detonations, the machine should not return to work until the damage is repaired.

A key component of good machine maintenance is the way that a machine is operated. Mechanical operators should be qualified and experienced in the operation and maintenance of their machines.

9.2 Recovery requirements

Operating procedures for mechanical demining operations shall include provisions for the recovery of the machine and operator in the event of a machine becoming stranded in a hazardous area. Such procedure shall ensure the safe extraction of the operator as quickly as possible, and the safe recovery of the machine in a reasonable time.

9.2 Fire precautions and drills

Demining organisations employing machines shall develop procedures to be followed in the event of a fire on a machine. These procedures shall cover the immediate actions to be taken and ensure the safe extraction of an operator from a hazardous area. Where an onboard operator is present, machines shall be fitted with fire extinguisher or fire suppressing systems. On no account shall any person be permitted to enter an uncleared area to fight a fire on a burning machine.

Fire fighting equipment shall be available at all places where refuelling of machines is carried out.

10. Environmental considerations

10.1 General

The ground over which mechanical operations are carried out shall be left in a state whereby the land is suitable for its intended use when handed over.

Where mechanical operations involve the removal of vegetation, or occur on ground that may be subject to erosion, demining organisations shall ensure that measures are taken to limit such erosion.

The operation, repair, maintenance and servicing of demining machines shall be carried out in an environmentally acceptable manner e.g. by preventing ground or watercourse contamination from fuel, oil and lubricants.

10.2 Protection of property and infrastructure

Planning for mechanical operations shall take into account any possible damage to property or infrastructure. Where damage to property or infrastructure is possible, the property owners or local authorities should be consulted prior to the operations.

11. Responsibilities

11.1 National Mine Action Authority (NMAA)

The NMAA shall:

- a) operationally accredit machines in accordance with the requirements of this standard;
- b) develop and implement national standards for the employment of machines on demining operations;

- c) implement QM systems to ensure the safe, effective and efficient use of machines on demining operations;
- d) develop an environmental policy for the use and maintenance of demining machines; and
- e) provide advice to prospective machine users.

In addition the NMAA should:

- a) establish procedures to ensure the proper T&E of machines prior to their deployment on demining operations;
- b) establish reporting systems and procedures for the gathering of data on mechanical and follow-up demining operations. Such data should be made available to all stakeholders; and
- c) provide advice and assistance to demining organisations in establishing tolerable risk for demining operations.

11.2 Demining organisation

The demining organisation shall:

- a) support the NMAA with the T&E of machines to be used on demining operations;
- b) obtain (from the NMAA) the operational accreditation for each different machine (model, make, type) to be used in demining operations;
- c) comply with the national standards for the employment of machines on demining operations. In the absence of national standards, the demining organisation shall apply the IMAS standards, or such standards as are specified in their contract or agreement;
- d) apply management practices and operational procedures which aim to clear land to the requirements specified in national standards or contracts and agreements;
- e) establish and maintain reporting systems and make the information available on mechanical and follow-up demining operations as specified by the NMAA; and
- f) establish systems and procedures to ensure that machines used on mechanical demining operations operate effectively, are properly maintained and serviced and remain safe for the operator and support staff.

In the absence of a NMAA, the demining organisation should assume additional responsibilities. These include, but are not restricted to:

- a) agreeing common mechanical standards with other demining organisations operating in the same programme; and
- b) assisting the host nation, during the establishment of an NMAA, in developing national standards for mechanical demining.

Annex A (Normative) References

The following normative documents contain provisions, which, through reference in this text, constitute provisions of this part of the standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this part of the standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid ISO or EN:

- a) IMAS 01.10 Guide to the application of International Mine Action Standards (IMAS);
- b) IMAS 03.40 Test and evaluation of mine action equipment;
- c) IMAS 04.10 Glossary of mine action terms, definitions and abbreviations;
- d) IMAS 07.30 Accreditation of demining organisations;
- e) IMAS 10.20 Safety & occupational health - Demining worksite safety; and
- f) CEN 15044:2004 – CWA for demining machines.

The latest version/edition of these references should be used. GICHD hold copies of all references used in this standard. A register of the latest version/edition of the IMAS standards, guides and references is maintained by GICHD, and can be read on the IMAS website (www.mineactionstandards.org). NMAA, employers and other interested bodies and organisations should obtain copies before commencing mine action programmes.

Annex B (Informative) Terms, definitions and abbreviations

B.1 accreditation

the procedure by which a **demining organisation** is formally recognised as competent and able to plan, manage and operationally conduct **mine action** activities safely, effectively and efficiently.

Note: For most mine action programmes, the **NMAA** will be the body which provides accreditation. International organisations such as the United Nations or regional bodies may also introduce accreditation schemes.

Note: ISO 9000 usage is that an ‘**Accreditation**’ body accredits the ‘Certification or Registration’ bodies that award ISO 9000 certificates to organisations. The usage in IMAS is completely different to this, and is based on the main definition above, which is well understood in the mine action community.

B.2 area reduction

the process through which the initial area indicated as contaminated (during any information gathering activities or surveys which form part of the **GMAA** process) is reduced to a smaller area.

Note: Area reduction may involve some limited clearance, such as the opening of access routes and the destruction of landmines and ERW which represent an immediate and unacceptable risk, but it will mainly be as a consequence of collecting more reliable information on the extent of the hazardous area. Usually it will be appropriate to mark the remaining hazardous area(s) with permanent or temporary marking systems.

Note: Likewise, area reduction is sometimes done as part of the clearance operation.

B.3 cancelled area

an area previously recorded as a **hazardous area** which subsequently is considered, as a result of actions other than **clearance**, not to represent a **risk** from **landmines** and **ERW**.

Note: This change in status will be the result of more accurate and reliable information, for example from technical survey, and will normally only be authorised by the **NMAA**, in accordance with national **policy**. The documentation of all **cancelled areas** shall be retained together with a detailed explanation of the reasons for the change in status.

B.4 CEN (Committee European Normalisation)

CEN is the European Committee for Standardisation.

Note: The mission of CEN is to promote voluntary technical harmonisation in Europe in conjunction with worldwide bodies and its European partners. European standards (referred to as EN (Europe Normalisation)) form a collection which ensures its own continuity for the benefit of users.

B.5

demining organisation

any organisation (government, NGO or commercial entity) responsible for implementing demining projects or tasks. The demining organisation may be a prime contractor, subcontractor, consultant or agent.

B.6

ground preparation

preparing of ground in a **minefield** or **hazardous area** by mechanical means by reducing or removing obstacles to clearance e.g. tripwires, vegetation, metal contamination and hard soil to make subsequent **clearance** operations more efficient. Ground preparation may or may not involve the detonation, destruction or removal of landmines.

B.7

hazard

potential source of harm. [ISO Guide 51:1999(E)]

B.8

hazardous area

contaminated area

a generic term for an area not in productive use due to the perceived or actual presence of **mines** and **ERW**.

B.9

mine clearance machines

those machines whose stated purpose is the detonation, destruction or removal of landmines as part of the overall clearance process.

B.10

minefield

an area of ground containing **landmines** laid with or without a pattern. [AAP-6]

B.11

residual risk

*in the context of **humanitarian demining**, the term refers to the risk remaining following the application of all reasonable efforts to remove and/or destroy all **mine** or **ERW hazards** from a **specified area** to a **specified depth**. [Modified from ISO Guide 51:1999]*

B.12

risk

combination of the probability of occurrence of **harm** and the severity of that **harm**. [ISO Guide 51:1999(E)]

B.13

risk analysis

systematic use of available information to identify **hazards** and to estimate the **risk**. [ISO Guide 51:1999(E)]

B.14

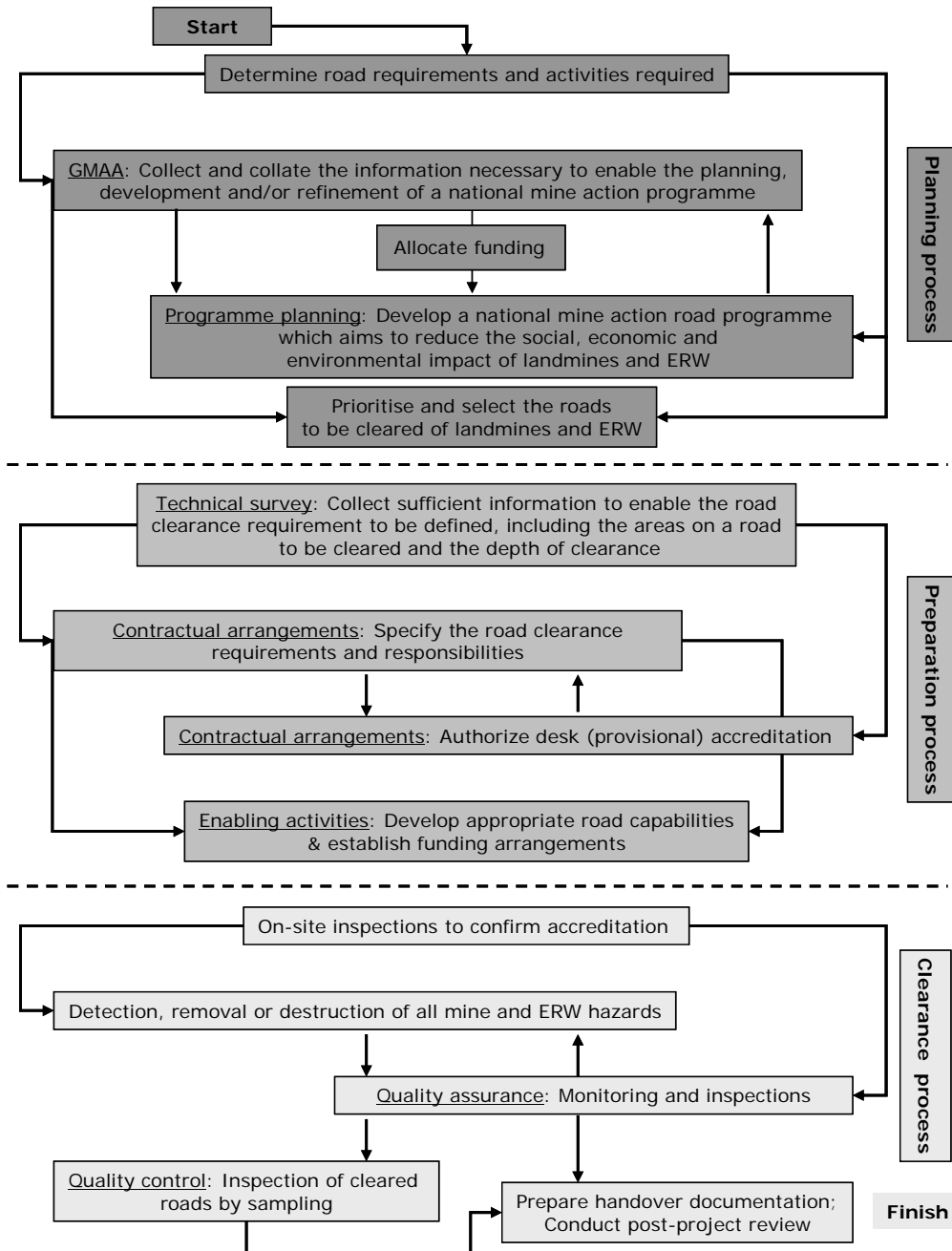
soil expansion

the increase in volume of soil caused by being mechanically processed.

Reference document 8 was developed by the International Mine Action Standards and was published as: **IMAS 09.50 Mechanical Demining**.

IMAS 07.10 THE DEMINING PROCESS ADAPTED TO ROAD CLEARANCE

Related to IMAS 07.10 the demining process adapted to road clearance



Sample Road Clearance Form

Report ID

Date of Report



Reported by

Day

Month

Year

Hazard Reduction ID

Hazard Reduction Name

Task ID(s)

Tasked By

Organisation



Name

Local ID

Start Date



Day

Month

Year

End Date



Day

Month

Year

Status

- Planned
- Issued
- Ongoing
- Completed
- Suspended
- Aborted

Type Of Activity

- UXO Removal
- Progress Report
- Battle Area Clearance
- Clearance
- Impact survey
- Technical survey
- Completion survey
- Other
- Road Verification
- Road Clearance
- Road Assessment

Reduction Method

- Combined
- Dog
- Manual
- Mechanical
- Other
- Unknown
- Not Specified
- Detector
- Prodding



REFERENCE DOCUMENT 10

DATA NEEDS

The data set described below should be required as a minimum for survey and clearance of roads.

1. **Depth of mine finds.**
2. **Generic type of mine** (i.e. metal or minimum metal).
3. **Specific type of mine.** If it is important to note variations (or series) of a specific mine type then ensure that this is done in a uniform fashion. The problem is not in recording variations or series but in how these differences are inserted into the database. To be able to sort – and thus analyse effectively – a common language is necessary.
4. **Locations of mines.** Where mines were found – on traffic lanes, on the shoulder, in the ditch, off the carriageway (at what distance from either the centre line, or an identifiable part of the road, such as the ditch). How were mines laid? What kind of patterns (if any) were used?
5. **Specific location of mines** (GPS readings so that they can be mapped).
6. **Evidence of mine strikes – craters** (with GPS reading).
7. **Evidence of mine strikes – destroyed vehicles.** Were they off-road, on-road or pulled off (with GPS reading)?
8. **Improvised explosive device (IED) evidence** (with GPS reading).
9. **Features in proximity to the mine** (distance, bearing, GPS reading or projected GPS, hill, dip in road, corner, junction, bridge, rivers, viaduct, etc.).
10. **Proximity to military features** (e.g. trenches, camps, with distance and bearing).
11. **Hot spots** (ambush sites – known /speculative, with GPS reading).
12. **Lines of confrontation** (with GPS reading).
13. **Military data** e.g. units, HQs – detachments, both extant and old positions (with GPS reading).
14. **Police posts/garrisons** – both extant and old (with GPS reading).
15. **Civil administration structures** – both extant and old: district offices, agricultural offices, and medical.
16. **Villages, towns – proximity to road** (GPS to centre or GPS all households).
17. **Inhabitants:** the number of people living in these villages.
18. **Vegetation** (on traffic lanes, shoulders and ditches and off the road).
19. **Key topography** – the degree of slope both laterally and horizontally.
20. **Road surface** (tar, gravel).
21. **Road condition.** Can the road be segmented into traffic lanes, shoulders, ditch, etc.?
22. **Road type** – paved (tar or gravel), non-paved soil, blocked (due to vegetation). It would also be useful to know about the hardness of the road – i.e. some current data with regard to soil compactness or the physical structure of the pavement.
23. **Road course stability** (directional stability).
24. **Junctions.**
25. **Bridges** (including structural state, estimated length, width, and type).
26. **Culverts** (including structural state).
27. **Embankments** (i.e. is the road on an embankment?).
28. **Bypasses** (and why?).
29. **Traffic status** (vehicles, foot, bicycle).

30. **Frequency of traffic movement** (for example, over a given day, ensuring that due consideration has been given to market days/ holidays, etc.)
31. **The course of the road.** Map the road, noting that at the stage of general survey (including any survey action described as emergency) a general centre line should be sufficient. (Defining exactly where the centre line specifically is becomes a more significant issue when reconstruction is being considered or planned.)
32. **Location of known minefields in proximity to the road** (within 1,000 metres)
33. **Infrastructure in place**, i.e. fuel stations, workshop facilities and other support for the clearance operation.

You will also need to consider:

- Number of informants;
- Credibility of informants;
- Historical detail of confrontation/fighting;
- A conflict analysis;
- How locations of individual items of ERW are recorded;
- Segmentation of the length of road surveyed;
- Gazetteer issues, i.e. what segments of roads are called what, and what are the official names of towns, villages, bridges and other significant features?;
- The contents of mine stockpiles in proximity to the road: i.e. it is important to know what mine types have been stored in a particular region or district, and who controls them;
- Who places what value on the road? Is it humanitarian access, political, security, food security, or commercial?;
- Who are the users of the road and who owns and/or is responsible for it?;
- What is the plan? Why is the road being surveyed and what happens next?;
- Turning places, i.e. where can a truck, or a track and trailer turn?; and
- Passing places, i.e. does the road have two traffic lanes, or where can two vehicles pass?

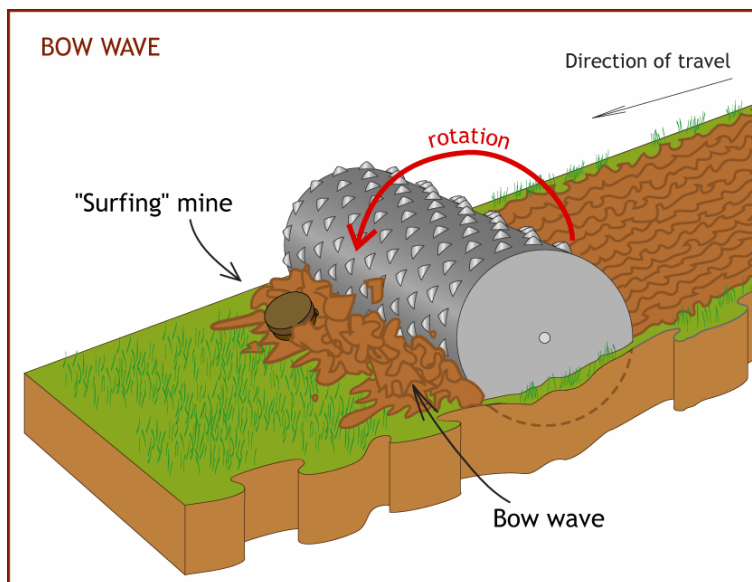


REFERENCE DOCUMENT 11

BOW WAVES, SLIPSTREAMING, RIDGES/SKIPPED ZONES AND SOIL EXPANSION

In using mechanical demining equipment for road clearance it is important to be aware of the effects of how the soil is displaced by the machines, and the implications for any ordnance in the soil.

A **bow wave** can be created by many machines, pushing the soil into a shape similar to the wave pushed in front of a ship in motion at sea. Ordnance may be situated within the bow wave at the front of a tiller drum. On occasion, ordnance caught in this position may roll continually within the bow wave and never end up between the jaws of the tiller teeth and the ground surface, thus escaping destruction even though the soil particles that comprise the bow wave are forever changing: the ordnance acts like a surfer, always keeping slightly ahead of the breakpoint.



A bow wave created by a tiller

Slipstreaming refers to the theoretical phenomenon where the rotating action of the tiller drum creates a thin layer of free space between the end surface of the tiller bits and the surface of the ground beneath. Although as yet unproven, it is suggested that this space contains aerated, loosely packed debris such as broken-up soil, small stones and mulched vegetation. On occasion – depending on the design of the teeth fixed to the drum, the soil type being engaged and the mine type concerned – ordnance may become situated within the slipstream and thereby escape destruction.

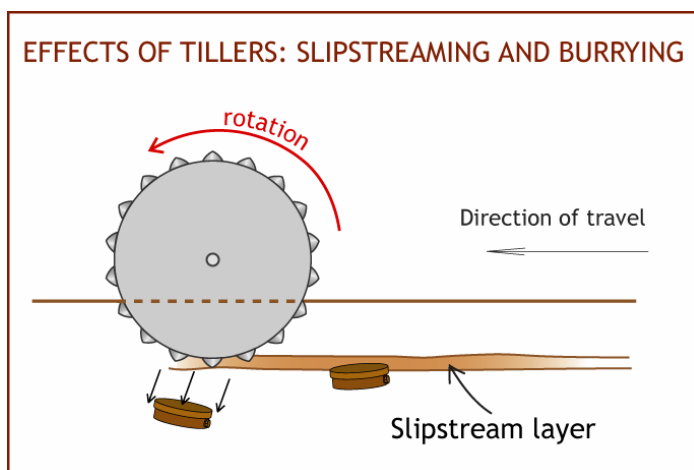
It appears that the occurrence of slipstream beneath a tiller drum is aided by increasing rotation speed. It can resemble the effect of a vehicle tyre spinning on icy ground while remaining static or the pebbled moraine left behind a retreating glacier.

The slipstream effect is also increased by dry, light soil conditions. Reportedly, where light-to-medium vegetation is present in an area worked by a tiller, slipstreaming is significantly reduced. This appears to be due to the additional “grip” on the soil provided by mulched vegetation matter. When vegetation of above medium thickness is encountered, the performance of a tiller begins to be degraded, as with any other mechanical system.

Once an item of ordnance becomes caught up in a slipstream, it may remain within the slipstream layer until the tiller drum has passed over it.

Slipstreaming does not occur in all conditions all the time. It is not known what percentage of ordnance that fails to be destroyed by tillers is because of slipstreaming. The factors that contribute to slipstreaming are not well understood. Where it occurs, its negative effects can range from severe to non-existent, depending on the size of the mine type involved. Smaller mines or fuzes may escape destruction by “hiding” in the slipstream.

Among existing tiller machines, drum rotation speed vary from approximately 100 to 700rpm. As mentioned, reducing rotation speed is believed to be one method of preventing slipstreaming. It remains to be seen, however, if drum rotation speed reduction might lead to other performance limitations.



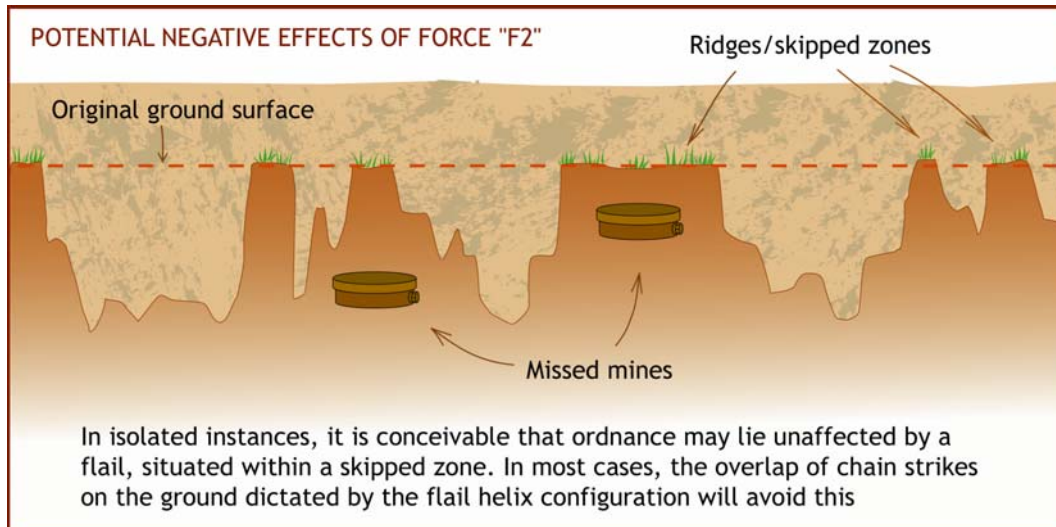
Slipstreaming with a tiller.

Ridges/skipped zones: the pattern created by the points at which chains are attached to the flail shaft is referred to as helix configuration. A flail helix configuration is usually designed so that, when chains have hammers connected which are of greater circumference than the chain links, all strikes on the ground should be overlapped by adjacent hammers. The intended result is that no section of ground is missed by the flail.

For certain flails, skipped zones remain a problem. On some flails, such shortcomings are immediately predictable due to the sparse positioning of the chains attached to a shaft. Some flail manufacturers have minimised this effect by improvements to flail helix designs and, through increased rotation speed, have achieved more strikes to the ground.

Also if the demining machine is not powerful enough the result might be an increase in ridges/skipped zones. Forward speed of the machine also plays a part. In general, the slower the vehicle is driven while flailing the ground, the lesser the likelihood of ridges/skipped zones. Unfortunately, a slower-moving vehicle also reduces productivity. Operational flail systems

should have been evaluated and tested with hammers attached to the chains. If, for cost reasons, a user removes the hammers it follows that the machine is no longer working as designed and may be under-performing.



Effects of flails – ridges and skipped zones

Soil expansion (sometimes referred to as overburden or bulking) is the expansion in volume of loosened soil created by the action of the flail dragged through and across the impacted ground or the tiller milling the soil. Soil expansion is an effect well understood by the construction engineering and agricultural industries. The measure of the bulking factor of soil is its volume after excavation divided by volume before excavation. As the flail or tiller moves along its path, a spoor of loosened soil is left in its wake. In the event of a mine being missed by the machine, overburden may serve to conceal missed mines under a depth of loosened soil, exacerbating the difficulty of locating missed ordnance after a machine has completed its sweep.

The amount of overburden created varies between mechanical systems and soil types. It has been discovered that overburden can be so significant that some current models of metal detector are unable to detect mines buried as a result of it. The amount of overburden created increases the deeper a machine is required to flail or till. A ground penetration depth of 20cm will produce roughly twice the amount of overburden created by flailing or tilling to a depth of 10cm.

*For more information on bow waves, slipstreaming, ridges/skipped zones and soil expansion see GICHD, **A Study of Mechanical Application in Demining**, 2005.*



REFERENCE DOCUMENT 12

CATEGORISATION OF DEMINING MACHINES

MECHANICAL DEMINING	
Machine category	Common machine tasks
<p>Mine clearance machines (light, medium and heavy systems) Specifically designed</p> <ul style="list-style-type: none"> > Flails > Tillers > Combined systems flail & tiller > Dual capability flail or tiller <p>Adapted</p> <ul style="list-style-type: none"> > Earth movers/front-end loaders > Rotary sifter systems 	<ul style="list-style-type: none"> > Area reduction > Cancellation > Inspection > Land release > Mechanical mine clearance > Quality control procedures > Removal of metal contamination > Removal of buildings debris, boulders, rubble, defensive wire obstacles, etc. > Risk reduction > Road clearance > Road hazard (threat) reduction > Sifting of soil and debris > Soil loosening > Tripwire removal > Technical survey > Vegetation cutting > Vegetation clearance > Vegetation removal > Verification¹
<p>Ground preparation machines (light, medium and heavy systems) Multi-tools (attachments to a tractor or excavator):</p> <ul style="list-style-type: none"> > Flail head > Tiller head > Magnet > Roller > Tree excavator > Soil disrupter > Rotary mine comb > Lift and grab > Rotary systems > Constructional engineering equipment tools > Adapted farming implements <p>Vegetation cutters (attachments on a tractor or excavator):</p> <ul style="list-style-type: none"> > Mower > Rotary mower > Reach mower > Brush cutter > Mulcher > Slasher > Flail > Tiller > Rock crushers > Sifters 	
<p>Mine protected vehicles</p>	<ul style="list-style-type: none"> > Inspection > Mine clearance

¹ Verification is the act of establishing that a suspected hazardous area is mined, thus this could also be described as technical survey.

MECHANICAL DEMINING	
Machine category	Common machine tasks
	<ul style="list-style-type: none"> > Risk reduction > Road hazard (threat) reduction > Road clearance



REFERENCE DOCUMENT 13

PERFORMANCE TESTING

Performance testing

This Reference Document looks at the testing, evaluation and accreditation of equipment and methodologies used in road clearance. In observing a number of mine clearance operators in programmes, both when coordinated by the UN or under management of national authorities, it became clear that the various tools applied in the search for mines and ERW were rarely performance tested against realistic targets in real conditions or in soil similar to the working environment. Based on these findings, there is a need to institutionalise tests that can prove the performance of methodologies and technologies of demining machines and detector systems against realistic targets in relevant soil conditions.

Mine clearance machines

IMAS 09.50: Mechanical Demining outlines the definition of machine types, responsibilities and general requirements for mechanical operations. One essential requirement is the testing, evaluation and accreditation process that each machine needs to go through to demonstrate the clearance capabilities and safe operation of the system.

Extract from IMAS 09.50: Mechanical Demining

Each machine shall be Tested and Evaluated (T&E) to determine its suitability for the task(s) it is expected to carry out in the conditions in which it will work.

The operation of each machine shall be assessed and confirmed as safe for the operator and any other person on the worksite. The protection level for machines shall be established through a risk assessment; and Standing Operating Procedures (SOPs) shall be developed for each machine. These SOPs should include general mechanical operating procedures, procedures specific to the machine and, where necessary, procedures for the integration of the machine with other machines or demining operations.

Three major requirements are:

- Operational accreditation of a machine in accordance with the requirements of IMAS 07.30 should also be based in part on fulfilling the requirements of this clause of this standard.
- Machines should not be used with tools, or on tasks, or in conditions for which they do not have operational accreditation.
- Prior to the deployment of any machine to a programme an assessment should be made of the in-country infrastructure and support systems to ensure that a machine can be operationally maintained in the areas where it will be used.

The European Committee for Standardisation (CEN) has, together with the mine action community, developed a CEN Workshop Agreement (CWA) for the T&E of demining machines (CWA 15044:2004). This CWA provides standardised methodology for T&E of demining machines. It gives technical criteria for the following:

- a) performance test: a test to establish whether the machine and its tool(s) is capable of performing the role for which it is intended under comparable and repeatable conditions, and to evaluate the manufacturer's specifications;

- b) survivability test: a test to verify that the machine survives the explosive forces used as design criteria; and
- c) acceptance test: a test to ensure that a machine is able to work in the environment where it is intended to be used.

The CWA also establishes the requirements for the test targets to be used in the performance and acceptance tests. Further information can be found at www.mineactionstandards.org or www.itep.ws.

Demining machines deployed in a mine action programme should adhere to the minimum testing requirements described in these two standards (IMAS 09.50 and CWA 15044:2004). Most demining machines have, however, already undertaken a full test by the International Test and Evaluation Program for Humanitarian Demining (ITEP) in accordance to CWA 15044:2004 and require only an acceptance test of the machine and operator by the national authorities in the country of operation.

Such an acceptance test can be easily performed under field conditions, requires limited recourses and comes at a minimum cost to the programme. The most common way to ensure the performance of a demining machine is to conduct a time and motion study (including a performance test) examining the ground penetration by carefully sweeping aside the loose soil using normal brooms/brushes being careful not to dig out additional, undisturbed soil. Then one can examine the effects or measure and decide if the performance is acceptable or not. This method works well on hard ground. In softer ground, one can use wooden fibre boards dug into the test area as witness panels.

If fibreboards are used, it is critical that they are installed using the pizza-slicer technique shown below. If the fibreboard trenches are even the width of hand-shovels, the validity of the fibreboard data is questionable. Where it is possible to simply sweep aside processed soil and measure directly, this is preferable and, in fact, quicker and easier!



Pizza slicer (cutter). © CCMAT



Fixture and fitting of the fibreboard into the ground. © CCMAT



Result after the processing by a demining machine. © CCMAT

CWA 15044:2004 also describes the use of test targets in various ground conditions. It is worth mentioning that burying simulated mine test targets in hard ground might create a situation where the soil used to cover the holes made for the test targets is softer than the test ground and thereby creates a false performance indicator of the ability of the machine to clear mines in hard ground. The hard-soil/soft-hole problem exists even when the surrounding soil is not rock hard – and should be considered when setting up a test site. Weathering the test site by spraying it with water and letting it sit for a few days might help overcome this problem.

Detector Systems

As with demining machines, it is critical that the various metal detectors, ground-penetrating radar (GPR), dual sensors and other sensor systems applied in road clearance have been tested against the targets one can expect to find on the sectors of road subject to clearance. Performance testing of detector systems has taught us valuable lessons about the impact soil characteristics have on detectors. Without being specific in regard to the various soil types and their impact on detector systems, it is nonetheless essential that the mine being searched for must be buried or tested in the most difficult (i.e. least cooperative) soil conditions likely to be confronted during clearance operations.

Below one can see two examples of performance testing methodologies of a UPEX 740M “large loop” metal detector. The first picture shows how one can build a semi permanent ramp for testing a number of detectors on a variation of targets, whereas the second shows how a confidence test of the detector system is carried out while clearing a road.



A semi-permanent ramp for testing a number of detectors on a variation of targets.



An example of performance testing methodologies of a UPEX 740M.

Accreditation and testing procedures

Conditions between countries, mined areas and roads differ, therefore it is important that options are researched. If demining machines or metal detectors are in current use or have been used before in the proposed area or country of operations it would be sensible to critically evaluate their past effectiveness. Countries apply different rules and regulations for road clearance. If the requirements exist, find out what they are, and find out what testing will be required before deploying a machine to a country.

Test reports on various machines and detectors also exist and can be found on the ITEP website. The test reports provide assessments of the performance under specific conditions. If the conditions in the area of operations are not similar to the test conditions, a performance test will be required. The machine has to show its performance under these specific conditions. The expected performance must be in line with the achieved results. Testing on the site in the area of operations is also a part of the quality assurance procedures.