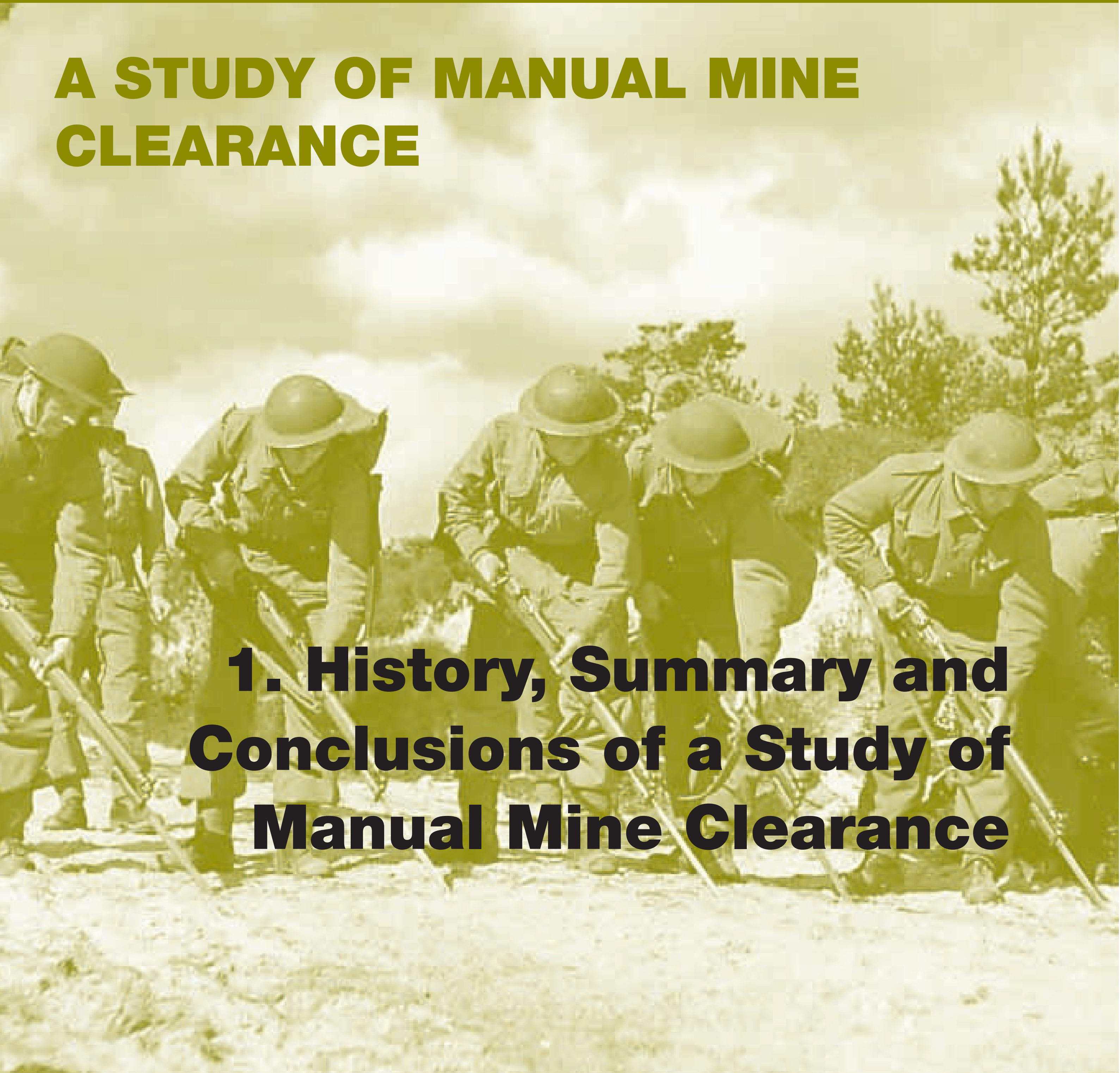
A STUDY OF MANUAL MINE CLEARANCE



1. History, Summary and Conclusions of a Study of Manual Mine Clearance

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

A STUDY OF MANUAL MINE CLEARANCE

1. History, Summary and Conclusions of a Study of Manual Mine Clearance

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

The **Geneva International Centre for Humanitarian Demining (GICHD)** supports the efforts of the international community in reducing the impact of mines and unexploded ordnance (UXO). The Centre provides operational assistance, is active in research and supports the implementation of the Anti-Personnel Mine Ban Convention.

For more information, please contact:

the Geneva International Centre for Humanitarian Demining
7bis, avenue de la Paix
P.O. Box 1300
CH-1211 Geneva 1
Switzerland
Tel. (41 22) 906 16 60
Fax (41 22) 906 16 90
www.gichd.ch
info@gichd.ch

A Study of Manual Mine Clearance — 1. History, Summary and Conclusions of a Study of Manual Mine Clearance, GICHD, Geneva, August 2005.

This project was managed by Tim Lardner, Operational Section (t.lardner@gichd.ch).

ISBN 2-88487-036-9

Contents

Foreword 1

Introduction 3
- Problem statement 4
- Study objectives 5
- Study audience 5
- Study methodology 5
- Layout of the study report 6

Executive summary 7
- The origins of manual mine clearance 7
- Management of manual mine clearance 7
- Innovative manual clearance techniques 11
- Improving the cost-effectiveness of manual mine clearance 12
- The future of manual mine clearance: the need for an explicit risk management approach 13

A history of manual mine clearance 15
- The challenge of landmine clearance 17
- Moving into formal "humanitarian demining" 22

Main study conclusions and recommendations 27

Annex: Members of the Study Advisory Group 39

Bibliography 41

Glossary of abbreviations and acronyms 47

Foreword

The global effort against landmines and unexploded ordnance (UXO) has progressed for many years, and the industry has been developing rapidly for much of this time. But how much do we really know and understand about the fundamental element of mine action — manual mine clearance? This study, which is long overdue, tries to give answers to these questions and looks at the development of manual mine clearance since the process of removing mines began after the 1939-45 war, through to today's situation. At present, national authorities, non-governmental organisations and commercial companies operate in many of the 90 or so mine-affected countries in the world. While there is growing use of machines and animals, manual mine clearance is still the predominant clearance methodology.

The study reviews the legacy of military mine clearance — something that impacts on all clearance operations today — and notes that operational safety has improved significantly over recent years. It then considers the impact of management on demining operations, followed by a detailed consideration of the basic techniques and processes used in the field. Several case studies of countries and programmes are included where innovation has meant that productivity and efficiency have been significantly improved. Finally, the study looks at the costs of demining, and also into the issue of risk to both the deminers themselves and to the end users of the cleared land.

One of the main objectives of the Geneva International Centre for Humanitarian Demining is to help make mine action cheaper, faster and more effective. This study provides another incremental step forward in the development of more efficient and effective mine clearance programmes, and provides useful guidance to practitioners.

The study was informed by a broad section of the mine action community. I would like to thank the Study Advisory Group and all those who provided comments and input to the study. I would also like to express my appreciation to the Governments of Denmark, Finland, Italy and the United Kingdom for their financial support to this work.

Ambassador Stephan Nellen
Director
Geneva International Centre
for Humanitarian Demining

Introduction

According to the United Nations (UN), mine action is

> *"not just about demining; it is also about people and societies, and how they are affected by landmine contamination. The objective of mine action is to reduce the risk from landmines to a level where people can live safely; in which economic, social and health development can occur free from the constraints imposed by landmine contamination, and in which the victims' needs can be addressed. Mine action comprises five complementary groups of activities:*
>
> *a) mine risk education;*
> *b) humanitarian demining, i.e. mine and UXO survey, mapping, marking and (if necessary) clearance;*
> *c) victim assistance, including rehabilitation and reintegration;*
> *d) stockpile destruction; and*
> *e) advocacy against the use of anti-personnel mines.*
>
> *A number of other enabling activities are required to support these five components of mine action, including: assessment and planning, the mobilisation and prioritisation of resources, information management, human skills development and management training, quality management and the application of effective, appropriate and safe equipment."*[1]

The most prominent component of post-conflict mine action is manual mine clearance (or manual demining, as it is often called). Manual mine clearance has been undertaken in various forms over many decades. Although it is still sometimes debated exactly when a formalised process of manual mine clearance was first undertaken, most observers credit this to the clear-up immediately following the end of the 1939–45 war.

In most programmes around the world today, manual mine clearance is the "core" activity: the one that employs the most staff, uses the most resources, and clears the most mines. The early UN-sponsored mine action programmes, such as Afghanistan, Cambodia and Mozambique, generally relied on international military expertise to teach processes derived from military mine clearance drills to locally engaged deminers.

1. *Glossary of Mine Action Terms*, IMAS 04.10.

A number of international mine clearance non-governmental organisations (NGOs) also train deminers, often using ex-military expatriate staff.

Since its formation in 1998, the Geneva International Centre for Humanitarian Demining (GICHD) has carried out studies on the use of dogs and mechanical equipment, as well as on many other aspects of mine action. However, until now, no formal study has been undertaken on the fundamental element of mine action— manual mine clearance — although an earlier GICHD study of global operational mine action needs analysed the process of clearance in general and provides a good baseline for further research.[2]

Problem statement

Manual mine clearance equipment and techniques have evolved over the years by adapting what were basically military skills to the needs of a specialist, largely civilian, activity. But manual clearance is still perceived as slow, repetitive, potentially dangerous and overly expensive, and opinions differ widely on the best ways to conduct clearance operations.

In particular, there are differences of opinion as to the equipment and techniques that should be used. There is therefore scope for closer examination of procedures and techniques to see if improvements can be made to operational efficiency and safety.

At the management level, there are wide variations in the recording of clearance rates (in various soil or vegetation types) and no standardised methodology to calculate the costs and rates of manual mine clearance. Moreover, as Box 1 indicates, there are serious questions as to whether, in some cases, clearance assets are being deployed in the most cost-effective manner.

Box 1. A minefield clearance site in Cambodia

The study team visited a clearance site in Cambodia. The area was marked by a technical survey team as a suspected hazardous area (SHA) and ran from the edge of the main road between Cambodia and Thailand to approximately 10 metres short of the railway line running parallel to the road. The distance between the road and a railway line was approximately 300 metres and the width of the SHA was approximately 700 metres.

A team of 35 personnel had been working on the site for approximately six months and had cleared around 40 per cent of the eastern part of the site and during that time had found some 30 mines. All the mines had been found in a precise straight line leading from the centre of the cleared area out to the edge of the SHA close to the railway line. Clearance was continuing out to the western side of the site and, based on the rate of progress, it was expected that clearance operations would last a further nine months.

It was apparent to the study team and from the results of technical survey that the likelihood of mines being found in the remaining sector of the SHA was minimal. Thus, expensive assets were being used on a site on which the risk of mines being found appeared negligible, while at the same time there were other, high-priority sites waiting for clearance.

2. GICHD (2002).

In sum, although the deminer equipped with a detector and some kind of prodding excavation tool is present in just about every clearance programme throughout the world, to date no systematic international assessment has been conducted on the appropriate management of, and methodologies for, manual clearance. This study aims to fill that gap.

Study objectives

The *Study of Manual Mine Clearance* sets out to clarify some of the basic issues at the heart of the manual mine clearance process. The study examines in detail the drills, techniques, equipment and procedures used for manual mine clearance, and reviews the management of operations. It seeks to define a set of parameters that affect the efficiency of manual mine clearance and to develop a series of benchmarks or planning figures for operations, including clearance rates and costings. It also analyses the issues of risk in relation to both the *process* and the *product* of manual mine clearance.

Study audience

The study has been requested by the United Nations Mine Action Service (UNMAS), located within the Department of Peacekeeping Operations (DPKO), and the findings will be of direct relevance to them. In addition, the study will be of use to mine action operators, national mine clearance bodies (including the military), NGOs, commercial companies and donors.

The conclusions and recommendations will also be of interest to international military forces that have traditionally provided instructors to teach manual mine clearance skills to military and civilian staff in mine-affected countries.

Study methodology

The study brings together a series of assessments and sub-studies of key aspects of manual mine clearance, namely:

1. The history of manual mine clearance;
2. The management of manual mine clearance programmes;
3. Operational systems in manual mine clearance: case studies and experimental trials;
4. Risk assessment and risk management of mined areas; and
5. Manual mine clearance costings and sensitivity analysis.

The study as a whole was managed by Tim Lardner from the Operational Methods Section at the GICHD. Field research for the study was undertaken in Cambodia, Croatia, Iraq, Lebanon, Mozambique, Somaliland, Sudan and Sri Lanka. Input was provided by Nikki Heath, Robert Keeley, Dr Ian McLean, Dr Franco Oboni, Ian Passingham, Dr Rebecca Sargisson and Andy Smith.

To assist the study, a Study Advisory Group (SAG) was established, comprised of mine action programme managers, United Nations mine action agencies, concerned NGOs, commercial mine clearance organisations, donors, and representatives from mine-affected nations. A list of members of the SAG is included in the Annex to this Section.

Finally, the study could not have been undertaken without the significant support from the many mine clearance organisations that supported it, in particular, Accelerated Demining Programme in Mozambique; BACTEC in South Lebanon and the United Kingdom (UK); Bundesanstalt für Materialforschung und -Prüfung (BAM), the Cambodian Mine Action Authority; the Cambodian Mine Action Centre; Cranfield University Humanitarian Resilience Unit; the Croatian Mine Action Centre; Danish Demining Group in Somaliland and Sri Lanka; DOK-ING d.o.o.; European Landmine Solutions; the HALO Trust in Cambodia, Somaliland and the UK; the National Demining Institute, Mozambique; the Lebanese Armed Forces Engineer Regiment; MineTech; Mines Advisory Group (MAG) in Cambodia, Iraq and the UK; the National Demining Office in Lebanon; Norwegian People's Aid (NPA) in Mozambique and Sri Lanka; the Somaliland Mine Action Centre; Qinetiq; the UNDP Mine Action Project in Sri Lanka. and the UN MACC South Lebanon.

The study was funded by contributions from the Governments of Denmark, Finland, Italy and the United Kingdom; their support is gratefully acknowledged.

Layout of the study report

This first section of the study includes an **executive summary** of the complete project, sketches a history of manual mine clearance since the 1939–45 war and the historical legacies that the industry bears and, finally, sets out the main conclusions, findings and recommendations of the study as a whole.

Section 2 addresses the **management** of manual mine clearance operations and organisations. The sub-study on which the chapter is based was conducted over a period of seven months and involved NGOs, commercial companies and military personnel from several countries. The scope of the sub-study includes all aspects of a demining organisation, from the individual deminer through to the headquarters level.

Section 3 sets out the results of an analysis of **operational systems** sub-study into the way clearance organisations carry out their work, and considers whether that work is undertaken in the most effective way possible given the available resources. Following the initial research for this sub-study, comparative trials were undertaken in Mozambique and Sudan to look at the impact of different techniques in different environments.

Section 4 focuses on the assessment and management of **risk**. It considers the level of risk to the deminers while undertaking their work, and then the residual risk to the returning population. Are we clearing every mine? Should we even aim to do so? How does mine clearance compare to other hazardous industries?

Section 5 looks at the **costings** of manual mine clearance, assessing how this links with the risk and management, and how inputs into a programme affect outputs in terms of both costs and productivity. It conducts a sensitivity analysis on different aspects of programme expenditure, and suggests ways to improve efficiency and cost-effectiveness.

Executive summary

The origins of manual mine clearance

Manual mine clearance — the backbone of what is now termed humanitarian demining — finds its origins in the massive clearance operations engaged to address the explosive legacy of the 1939–45 war.

But the genesis of modern humanitarian demining is generally regarded as being in Afghanistan in 1988, around the time of the withdrawal of Soviet forces. The programme's first attempts were well-intentioned but ill-thought-out, foreshadowing some of the challenges that would face all clearance efforts around the world in the years to come.

After the creation of the Afghanistan demining programme came programmes in Cambodia, Angola and Mozambique. Today, there are more than 42 programmes worldwide, assisted by a strong support system within and outside the UN, which has developed a framework of support ranging from the development and implementation of international standards, to technical and logistical support for the implementation of mine action programmes.

Management of manual mine clearance

Organisational management

A number of studies have been conducted on various aspects of the demining community over the past decade. Although demining is an international and multi-million dollar industry, it appears that its culture still encourages a "small-business" approach to management.

The GICHD sub-study on the management of manual mine clearance concluded that the main areas for improvement were not at the individual deminer level, but at middle and senior management levels, where significant wastage of time and resources were observed. These include the management of minefield clearance sites and the decision-making associated with designated areas for clearance.

Apart from a few commercial companies, the sub-study found continuing and clear evidence of poor project management skills, with considerable focus on micro-management. This results in the implementation of *process-driven* rather than *task-focused* management style.

The study notes the military background of the majority of personnel, both international and national, engaged in mine clearance in one capacity or another. It is increasingly understood that **the skills and experience that serving or former soldiers bring to mine action are invaluable in the emergency phase of an operation, but different skills are required in the more developmental-focused period.** What is often missing today is project and programme management experience acquired in the development and/or the commercial sectors, bringing a corresponding drive for efficiency, innovation, creativity and flexibility.

Recruitment

Problems are particularly acute at middle manager level. Although middle managers are ostensibly responsible for running a particular area of responsibility, in many cases they are not equipped with the resources to undertake this task and are often not given the necessary autonomy to do so.

Decision-making needs to be delegated downwards from senior management to middle management for day-to-day issues, such as running a clearance site. However, the middle managers concerned also need to be recruited and trained to be able to take the necessary decisions — and have the support of the senior management in those decisions.

Issues of concern are identified with respect to the recruitment and training of deminers engaged in locating mines and items of UXO, whose work is overseen by middle managers. In particular, manual mine clearance is routine and monotonous, and is often carried out in unpleasant conditions. It requires high levels of motivation for individuals to overcome boredom, to remain alert and to sustain high levels of attention to detail. The employment of ex-military personnel, who are used to living away from home and to more stringent working conditions, may be appropriate. But their motivation may not be suitable for the mundane tasks that continue day-in, day-out. Personality type plays a significant role in the ability to sustain attention, and soldiers recently demobilised after extended time in combat may find such mundane, routine work hard to sustain and therefore tend to lack motivation.

Training

Many organisations have recruited deminers, put them immediately on a salary and sent them on a training course supplied in-house. The average training period is around two to four weeks for completion of a basic demining training course. A recruit seldom fails, even if required standards are not achieved.

Training of deminers on full pay with no standards of entry is generally inappropriate for three reasons: cost, motivation, and the potential for corruption.

In contrast to initial training, refresher training appears not to take place systematically, only on an *ad hoc* basis as and when it is deemed necessary — which appears to be seldom.

Maintaining deminer performance

Many organisations stated that "skill fade" was not an issue as the deminers were doing their task every day. This is a dangerous assumption as each site has different demands and deminers become complacent when working in low-risk areas. **It may be beneficial to provide a short refresher course to all deminers when they start a new site, to raise their awareness of the particular issues relevant to that site.** A number of organisations visited did have refresher training which led towards positive results.

Motivation

In addition to ongoing training requirements, maintaining motivation is of obvious importance. When individuals have no sight of, or feedback on, their performance, and cannot see the benefits or long-term gains, they quickly become disillusioned.

Productivity

The study team found discrepancies at several levels in the quoted figures for square metres cleared. All organisations, without exception, quoted an average clearance rate per deminer of about 50 square metres a day. However, when calculations at individual sites were made on the presented data for total area cleared, divided by days worked, the figures appeared to be closer to 15–20 square metres per deminer per day. This coincided closely with the figures developed during the earlier GICHD study *Mine Action Equipment: A Study of Global Operational Needs*.[1]

Combating dehydration

Dehydration has the potential to impact significantly on performance yet is seldom considered. **Greater emphasis should be placed on hydrating deminers, and thermal and physical comfort to aid their performance.** Ways to combat the effects of dehydration include acclimatisation, hydration, loose and lightweight or porous clothing, the application of cold water on skin, air-cooled personal protective equipment (PPE), and drinking water and electrolytes.

Personal protective equipment

The introduction of mandatory PPE has been one of the major safety innovations in recent years. Although PPE plays an important role in protecting the individual, certain factors should be considered when purchasing a particular type, as it can impair performance affecting the wearer in several ways.

For instance, there is an increased risk of error through visual distortion caused by the visor, particularly if it is poorly maintained, scratched or otherwise damaged. **Greater care should therefore be devoted to the storage of facial PPE: ultra-violet (UV) degradation should be kept under control.** PPE also accelerates perspiration and increases the risk of dehydration, which has negative implications on performance.

Broader questions are addressed about the need for, and appropriateness of, PPE. Body protectors are used primarily for **protection** against **fragmentation** rather than blast injuries, which can be best prevented by good lane drills, site management and adherence to the safety procedures in standing operating procedures (SOPs). **The size**

1. GICHD (2002).

and purpose of body protectors should be further examined for effectiveness, and international standards should be reviewed in order to give greater flexibility to operators over which PPE is required and when it should be worn.

Maintaining deminer safety

The role of standards and standing operating procedures (SOPs)

Standards and SOPs are generally believed to have vastly increased deminer safety, as well as the reliability of clearance, in manual mine clearance operations. Although today it is very difficult to extrapolate detailed information on casualties from many programmes, it appears that the average casualty rates for deminers have become much lower in respect of hours worked since 1945.

However, during observations of operational systems of ongoing clearance operations in several countries, the subject of Section 3 of the Study, no demining group was found to be working in complete compliance with their own written SOPs, and some even worked in a manner that was in direct conflict with them.

Clearance methods

The clearance method most likely to involve an accident to the deminer performing it was prodding from the surface of the ground.

The methods most likely to leave mines undetected were *area excavation*, when the required clearance depth was not maintained. Also prone to miss mines were techniques undertaken at *excessive speed*, meaning that deep signals were missed during metal-detector-based clearance.

Clearance drill and lane deployment

The development of clearance techniques has generally been evolutionary. However, in terms of safety, if SOPs are adhered to, the generally accepted clearance techniques do appear to be robust and well proven.

If organisations employ specialist multi-tasked teams, then more downtime is likely. This is particularly the case when clearance sites are spread far and wide, and teams are part of the technical survey team and may be travelling in remote areas. Keeping personnel alert when they are involved with technical survey appears to be harder than if they are dealing with mines on a daily basis.

Working and rest periods

The length of each demining period recommended between rest breaks varies considerably from one organisation to another. **In general, any work requiring sustained concentration benefits from frequent, short breaks.** If, however, the breaks are too long there is a risk of concentration and motivation decreasing.

If workers spend long periods without stimulation between working periods (as in two-man-lane drills) they are more likely to be “out of the loop” when they return to work and will have more frequent lapses and mistakes.

Data gathering

A wide range of issues affect deminer safety. One of the keys to increasing safety is to fully understand why accidents are taking place. There is a need for the demining community to collect, more systematically, data on deminer accidents and injuries. This should build on the work that has already been done in the context of the Database of Deminer Accidents (DDAS), which is being maintained by the GICHD for the UN. In particular, **organisations should collect data related to "casualties per hours worked" and/or "lost hours** (because of accidents) **per hours worked"**, similar to any other hazardous industry in the world.

Innovative manual clearance techniques

The demining industry is demonstrating a willingness to employ innovative techniques in a number of countries, but some of these techniques were only informally adopted as their use was constrained by written SOPs.

Most innovations were made in order to increase speed, which — cynics might suggest — impresses donors with better clearance figures. For example, several groups reduced the depth of metal-detector search and were prepared to leave small metal indications in the ground.

One of the most effective way of increasing the speed with which suspect land could be released was seen in South Lebanon and Iraq, where the use of post-clearance area reduction (PAR) turned the convention of pre-clearance area reduction upside down and led to a dramatic reduction in the number of square metres cleared for every device found. This appears to work well in relatively predictable situations, such as patterned minefields, but is unlikely to be of significant advantage in more random situations.

Trials were undertaken in south Sudan to test the speculation that there may be alternative innovative techniques that might give more efficient rates of progress for manual mine clearance. Two alternative drills — the "Hybrid" and the "Crab" drill were trialled and a more detailed description of the trials and results are given later in the study. It appears however that the Crab drill does offer some significant advantages by presenting more than one open workface and reducing changeover times between activities.

When clearing land, fragmentation and false alarms are significant contributing factors to clearance rates and costs. Thus, **to improve the efficiency of manual mine clearance using a metal detector, the main area for improvement is the speed with which metal fragments can be identified and removed**. The sub-study assesses the effect of a simple system of magnets on demining efficiency and agrees with a finding of the GICHD *Mine Action Equipment: Study of Global Operational Needs* that, in trials conducted for the study: *"... in a heavily fragmented area, the most efficient method of clearance among eight different options was using a metal detector and a magnetic brush-rake."*

Improving the cost-effectiveness of manual mine clearance

Clearance is expensive to undertake but there are very significant differences in quoted costs: these range between US$0.60 to US$8.73 per square metre. A number of independent cost-benefit studies have suggested that demining may only be of marginal net benefit unless costs are controlled. This means that the industry should generally develop a clear benchmark of what a deminer should be expected to achieve given a set of criteria, and at what cost.

There is a considerable problem within the demining industry in reporting on areas cleared. Some reports of performance may be considerably overestimated, and confusion abounds between the definitions of areas cleared, reduced and cancelled.

Costings and sensitivity analysis

There is inconsistency within the mine clearance industry on estimating costs. A model that would simulate the costs involved in the operation of a Mine Action Centre (MAC) was used. This "Model MAC" (MMAC) makes a number of assumptions, which are based on real-life examples wherever possible.

To try to determine which elements of the demining process really make a difference to overall costs, the most appropriate economic technique to use was deemed to be sensitivity analysis. Within the specific context of demining, sensitivity analysis can be defined as: *"The measurement of the variation in output of demining processes as a result of variation(s) in inputs, particularly in terms of cost."* Sensitivity analysis is an economic technique that allows programme managers to measure the potential effect of change. It allows users to focus on those items that are likely to make a difference, even when they are not immediately apparent.

Economists use a number of "average" costs: average fixed costs, average variable costs and average total costs, which are measured over the life of a project. The reason for taking an average cost in mine action is that, if an observer looked hard and long enough they would find that every square metre of land took a slightly different amount of resources to clear. However, the capture of such infinitesimal differences is recognised as being more trouble than it is worth. This means that a "total cost per square metre" averaged over an accounting year is probably the most appropriate cost measure in mine clearance, providing that all appropriate factors are included.

This does not allow the calculation of a global, "standard" cost: the sensitivity analysis conducted in this study reveals that, even in one programme, a change in any one of several major factors would result in a significant change in the average total cost of a square metre of land. It would therefore be little use to try to identify any figure that could act as anything more than a very rough estimate in a particular country, and it could be very inappropriate to use the same estimate anywhere else.

Explosives

Explosives are often supplied free by donors. Sensitivity analysis of explosives shows that the provision of free explosives has a very significant effect on price, reducing the undiscounted price per square metre in a "model" mine clearance programme from US$1.46 to US$1.26. This suggests that significant benefits accrue from researching alternative explosive supply methods or other, non-explosive, destruction techniques.

Deminer productivity

The MAC model is also sensitive to changes in productivity: this is because the model is designed to isolate costs accruing to particular activities, and can isolate the effect on the cost of demining of a change in productivity. If clearance productivity for a team increases by 5 per cent (i.e. from 1.5 to 1.575 hectares per month per team), there is a 5 per cent decrease in output price.

The future of manual mine clearance: the need for an explicit risk management approach

Sensitivity analysis, although a useful tool, will not address the heart of the challenges that demining faces. The aim of manual mine clearance is the clearance of every mine, and every item of unexploded ordnance (UXO) or abandoned explosive ordnance (AXO), from a given area. So, if a given area of land is declared to have been cleared, then it should, to the best available knowledge, be clear of all explosive ordnance. In this respect, the International Mine Action Standards (IMAS) should remain fixed. Indeed, there are many situations in which such a level of clearance is necessary or is demanded.

But this full clearance standard is not necessarily universally applicable, nor is it by any means universally achieved. For this reason, **the mine action community and its stakeholders need to urgently consider moving to a more explicit risk management approach**, as Section 4 of this Study argues. Moreover, spending months clearing an area and finding no mines — but a lot of pieces of miscellaneous and harmless metal — is a waste of resources, as well as being potentially unrewarding for those engaged in it. Yet, this is exactly what the demining community still does far too often. Area reduction may well form the key to this process, yet is not well understood.

Similarly, in Western Europe a residual risk in areas contaminated by mines and UXO and subsequently released for public use after the 1914–18 and 1939–45 wars persists today. The reality is that mine-affected countries will probably always remain affected to some degree and will always need to apply some level of capacity and resources to the problem. Indeed this Study as a whole argues that **the current "all-or-nothing" approach to manual mine clearance is inappropriate and unsustainable**.

The treatment of land released by methodologies other than the physical processing of land needs to be addressed. Currently, land is declared "clear" only after a physical process is undertaken on it. A process should be implemented that "releases" land which has been determined to have "no known risk" without a formal clearance process. What is important is not to tie up precious resources while lives and limbs are being lost elsewhere.

We have seen how incremental improvements can be made to existing processes for, and management of, manual mine clearance, from the recruitment and treatment of the deminer up through the decision-making chain of command to the senior management level. But the most significant change in demining would be to turn to an explicit risk management approach for clearance — basing operations and operating procedures on an assessment of the risk and accepting that, even after carefully planned demining interventions, some tolerable degree of risk will still remain. For the mine-affected countries and its people, this would result in greater economic benefit and fewer casualties sooner.

A history of manual mine clearance

Although there is some debate as to when landmines were first used, the general history can be traced with reasonable certainty. Modern landmines are explosive traps, but their lineage derives from non-explosive predecessors such as spikes and stakes used by ancient armies as far back as 2,500 years ago. The four-spiked caltrop, usually made of iron, joined at the centre and arranged so that when thrown on the ground, one spike always points upwards with the other three forming the base, was used as far back as the third century BC and can be closely compared to the present-day landmine in their design and use as a defensive tactic. Caltrops are still used in modern conflicts.

Explosives were introduced at a later stage to make use of their inherent properties in order to improve the destructive capabilities of mines. The earliest explosive-based mines appear to have been used in southern Italy in the 14th century,[1] although these were initiated by a powder trail, which was inherently problematic. In addition, the gunpowder was hygroscopic and therefore could be rendered inert after just a few days, depending upon the weather.

The first pressure-initiated landmine was recorded in 1726 by the German military historian, Freiherr von Flemming, who described the use of a *Fladdermine* (flying mine): "*It consisted of a ceramic container with glass and metal fragments embedded in the clay containing 0.90 kilos of gunpowder, buried at a shallow depth in the glacis of a fortress and actuated by someone stepping on it or touching a low strung wire*".[2]

Although noted here in 1726, the concept does not seem to have taken hold until the American Civil War, when Confederate Brigadier-General Gabriel J. Rains ordered his troops to prepare artillery shells so they would explode when stepped on. On 4 May 1862, a Union soldier activated one of these devices close to Confederate lines near Yorktown and gained the dubious epitaph of being the first person recorded to be killed by a landmine.

1. Croll (1998)
2. Flemming, cited in Croll (1998).

Although crude versions of later landmines were used primarily by the German Army on the Western Front in the 1914–18 war (such as buried and "fuzed/timed" artillery shells and pipe mines), the main mining effort was underground — the tunnelling and mining of trench systems in true "sapper" or siege-warfare style. The real evolution in the development of landmines, in the form of both anti-tank and anti-personnel mines, came during the 1939–45 war. It has been claimed that 300 million anti-tank mines were used during that war, with millions more anti-personnel mines being deployed to protect the anti-tank minefields.[3]

It soon became apparent that anti-personnel mines were much more effective in maiming rather than necessarily killing their victims. This had two distinct advantages as a weapon of war from the user's viewpoint: the considerable psychological impact on the enemy, and the fact that the severity of the wounds demanded a great deal of treatment and care, thereby putting more strain on the victim's unit (because of the need for casualty evacuation — CASEVAC) and on the army's medical services in general. Landmines had the dual "benefit" of both psychological and attritional effects.

By 1945, the United States of America (US) Army recorded that mines had inflicted 2.5 per cent of troop casualties and 20.7 per cent of tank losses.[4] Within two decades, the US Armed Forces would also discover — to their cost — that landmines, improvised explosive devices (IEDs) and UXO could be a "double-edged sword." In Korea and Vietnam, US and Australian troops would be confronted by the considerable internal attrition rate and psychological effect of these devices, many of which had been emplaced by their own forces. As an example, mines and booby-traps caused 65–70 per cent of US Marine Corps casualties in Vietnam during 1965, and a significant proportion of these casualties resulted from their own explosive ordnance.[5] Some 12 per cent of Australian casualties in Viet Nam from May 1967 to the withdrawal in 1971 were caused by their own M16 mines laid in one specific minefield.[6]

It was during this indiscriminate bombing and landmine deployment that the humanitarian tragedy began to unfold. Although the explosives dropped along the Ho Chi Minh trail and the air-delivered mines dropped by the Soviets over the mountains of Afghanistan may have had some effect tactically against the *Viet Cong* and the *Mujahadeen* respectively, the victims were more frequently civilians. When hostilities ceased, civilian casualties mounted rapidly as much of the land in Vietnam, Laos, Afghanistan and Cambodia had not begun to be cleared of landmines. Anti-personnel mines, together with cluster munitions, became the most insidious legacies of the wars, as they were the most liberally scattered and difficult to detect. Worse, being "victim activated" it was civilian workers in the paddy field or children playing in a field who were far more likely to detonate them than were military personnel.

From those beginnings, a global landmine threat has emerged that remains today. There are said to be more than 90 countries and other areas affected by landmines or UXO.[7] However, classification of the severity of the problem is not straightforward. For example, the UK is on the list because of the mines laid during the Falklands conflict in 1982. Although these have caused no civilian casualties since the conflict, the nation is still categorised as mine-affected.

3. US Defence Intelligence Agency (1992).
4. Croll (1998).
5. US Defence Intelligence Agency (1992).
6. *The Australian*, 13 August 2005.
7. Landmine Monitor (2004: 27).

In recent years political progress has helped to address the scale of the problem. Under the terms of the Anti-Personnel Mine Ban Convention, which became international law on 1 March 1999, anti-personnel landmines are now illegal in more than two-thirds of all countries in the world. States Parties "in a position to do so" have pledged to commit resources to mine clearance, mine awareness and the care of and assistance to victims, although the extent of these legal obligations is not specified in the Convention. In addition, the Convention has had an influence on non-States parties, and a number of them also make a significant contribution to mine action.

The challenge of landmine clearance

The first formal process of clearance developed immediately after the end of the 1939–45 war when the huge number of mines that had been laid during the conflict stood in the way of meaningful reconstruction in Europe. The clearance work was based on a pragmatic approach involving the use of the large amount of available manpower, and in many cases the victorious Allies used prisoners of war (POWs) to carry out the work (in possible violation of the 1929 Geneva Conventions).[8]

Figure 1. British Army mine clearance of a road in 1945. Soldiers using their rifles and bayonets to detect mines. This is called the 'prodding' method and the ground is prodded with the bayonets to clear a lane the width of six or seven men. White tapes are used to mark the boundary as it is cleared.

In France, 49,000 German POWs were employed; in Germany, the allocation of deminers was done through a system of labour units involving POWs (*Dienstgruppen)*. Supervised by the occupying armies in Germany, and by the British Army in the UK, these POWs were responsible for clearing millions of landmines.[9] As an example, in March 1947, 81,000 German POWs were reported as being employed in mine clearance, tree-felling, transport and supply administration.[10]

In the Netherlands, a total of 1,162,458 mines were lifted and cleared by the German Engineer *Draeger* Brigade and the Dutch 1st Netherlands Mine Clearing Company (a

8. Following concern about the use of POWs in clearance, Article 52 of the Third Geneva Convention of 1949 specifically prohibits the use of POWs for mine clearance activities unless they are "volunteers".
9. Some Ukrainian POW assistance was also provided at this time.
10. UK Public Records Office (PRO)/National Archives: Document PREM 3/792 – *Civilianisation of the* Dienstgruppen*: Report on the activities, organisations and [planned] release of German POWs and Para-Military formations used for Mine Clearance: 1947 to 1948*.

company of locally employed civilians) between the summer of 1944 and the end of 1945. German casualties were "fairly heavy" according to the post-action summary report: of a total of 543 casualties, 162 were killed and 185 were severely wounded from a total of 3,244 men in the Unit. The Dutch Mine Clearing Company suffered 89 casualties, of whom 26 were killed and 42 severely wounded in a similar period.[11]

Table 1. Estimates of mines cleared and casualties sustained during clearance operations after the 1939–45 War.

Country/area	Period	Mines cleared (millions)	Deminers killed	Deminers injured	Total	Mines cleared per casualty	Comments
Austria	1945-75	0.046	18	23	41	1,122	—
Belgium	1945-46	0.4	—	—	286	1,398	—
Denmark	1945-47	0.75	190	250	440	1,704	—
England	1944-57	0.35	155	55	210	1,666	—
Finland	1945-76	0.066	—	—	—	—	No casualty data available
France	1945	13.0	2,127	3,630	5,757	2,258	—
Germany	1945-47	0.76	108	113	221	3,439	Op. TAPPET only
Guernsey	1945	0.067	8	14	22	4,786	—
Netherlands	1945-46	1.162	205	407	613	1,762	—
Italy	1945-46	3.0	—	—	1,100	2,727	—
North Africa	1943-90	Est. 1.0	—	—	Est. 600	1,667	Approximate figures
Norway	1945-47	0.75	192	252	444	1,689	—
Poland	1945-56	14.76	404	571	975	15,138	Extrapolated figures
USSR	1945-46	58.5	—	—	—	—	No casualty data available
Average total		**94.53**				**3,279**	

Source: Adapted from Croll (1998).

By 1948, more than 90 per cent of the clearance work in Europe had been completed. The remainder was undertaken at a much slower pace and generally by nationals of their own countries. Much of this clearance was undertaken using simple techniques adapted from the military doctrinal handbooks and experience of that time. The techniques of prodding and using simple metal detectors formed the basis of the processes and, although there were some innovative methodologies introduced, these were complementary to the core manual mine clearance procedures. Once again, the structure of these organisations was based generally on the military structure that many of the managers and implementers had come from and with which they were familiar or experienced.

The number of mines cleared per casualty for the post-war period range between 1,122 and 15,138, but averaged one casualty per 3,279 mines cleared *(Table1)*.[12] The fundamental methodology for manual mine clearance remained largely unchanged for the next 50 years. In terms of casualties, however, it appears that the accident rate has fallen significantly.

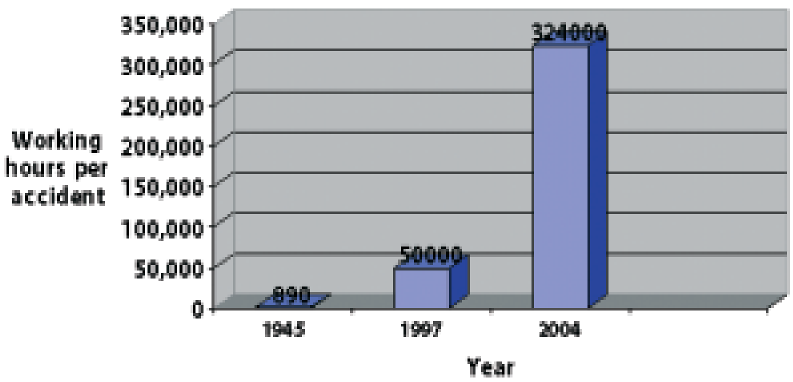
11. UK PRO/National Archives Doc WO 205/1186: *Minefield Clearance in Holland*, dated 27 November 1945.
12. Croll (1998).

Figure 2. R.Es (Royal Engineers) searching for mines with mine detectors before a bypass road is constructed around the French village of Douvres-la-Delivrande, 1945.

In the clearance of the Netherlands in 1945 and 1946, some 1.16 million mines were cleared in total. Although the historical data are difficult to interpret reliably, a British Government Report on the mine clearance operation in the Netherlands[13] outlines the details of an operation undertaken by the German *Dreager* brigade between 12 July and 19 October 1945. It used 279,325 operational man hours of work to clear 450,125 mines. The recorded casualties during the period 5 July to 10 October show 311 casualties among mine clearance personnel. From the evidence available, it appears that this was a fairly typical operation of the time. This means that there was one accident for every 890 man-hours worked.

In comparison, figures used in Section 4, *Risk Assessment and Risk Management of Mined Areas*, indicate that the risk of a deminer having an accident during work has changed significantly: from one per 50,000 working man-hours in 1997 in Afghanistan, to one per 324,000 working man-hours in more recent data from Mozambique. Both of these data sets are limited in terms of the reliability of the data and the sample size, but the underlying trend is indeed clear — that the risks to deminers during operations have reduced significantly in comparison with the immediate post-war years. While the data used in this analysis are specific to situations rather than to the global situation (because of the paucity of data), this general trend can be considered meaningful.

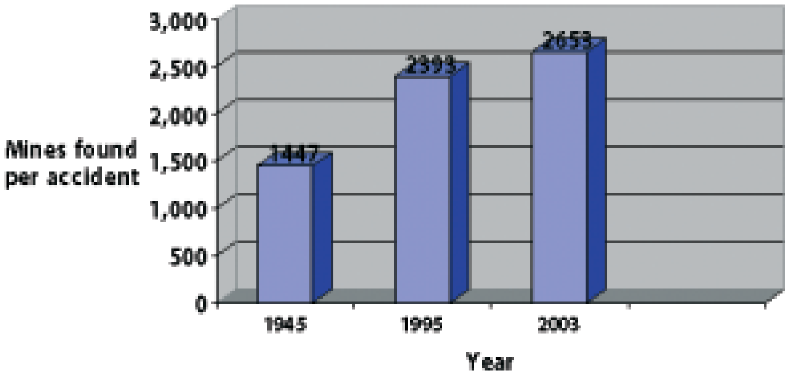
Figure 3. An illustration of the increase in hours worked per casualty during clearance operations



Source: 1945, *Draeger* Brigade, Netherlands; 1997, MAPA (best estimate); 2004, NPA & ADP combined data, Mozambique.

13. UK PRO/National Archives Doc WO 205/1186, *op cit.*

Figure 4. Number of mines found per accident



Source: 1945, *Draeger* Brigade, Netherlands; 1995, UNOCHA Afghanistan Mine Clearance Programme Annual Report; 2003, All Mozambique data.

Evidence of the evolution of manual mine clearance procedures, administration and techniques demonstrates the inevitable links, based on experience, between military manual mine clearance and civilian/humanitarian demining. Six decades ago, POWs and civilians were used or formally employed to assist in the massive task of demining in Italy, Libya and north-west Europe (not to mention the Russian soldiers and civilians on the Eastern Front risking life and limb to clear minefields after the German withdrawal from Russian territory).

Table 2. A comparison of clearance during different periods

Factor	Post 1939-45 war clearance	Post 1989 clearance
Technology	Most mines having significant metal content.	Many minimum-metal mines used.
Laying	Tended towards disciplined armies and good recording. Pattern laid.	Often undisciplined guerrilla forces without record keeping capacities.
Risk acceptance	Some risk acceptable.	Perception now that tolerable risk should be extremely low.
State structures	Usually undertaken under umbrella of functioning State.	Often begun in stateless or loose administrative States.
Time between laying and clearing	Often a matter of months.	Often a matter of decades.

Having said that, the extant situation in Germany (and indeed the rest of Europe) is entirely manageable. Of the States affected during the 1939-45 war that ended more than 60 years ago some landmines remain, although they have little impact on day-to-day life. This does not mean that there is no need for further operations, merely that the skills and capacity required to deal with the latent threat are small in scale and within the budgets of these States.

For manual mine clearance in the West between 1943 and 1948, although greater risks were acceptable by today's standards, the principle was still to clear 100 per cent of a given area of mines. This is to be contrasted with minefield breaching in combat, which accepted that only 70–80 per cent would be cleared, and this in only narrow sectors or "lanes" across minefields in order to maintain the momentum of the attack.

The principles in Box 2 for post-conflict manual mine clearance, laid down and applied during the early days of landmine clearance in the mid- to late-1940s, were drawn from wartime documentation reviewed as part of the study[14]. What is striking is that so few of the fundamental principles have changed, although they have been refined, revised and reapplied by the military in theatres of combat such as Korea, Vietnam, the Falklands, Kuwait and Lebanon — and, finally and increasingly, for humanitarian purposes from Afghanistan onwards.

Box 2. 1940s principles of demining

1. All activity will take place in "safe" areas, where Allied troops are in full control, (especially in Italy in 1943–44), even though hostilities may be continuing elsewhere, or hostilities have ceased.
2. The type and method of mine clearance will be determined by the nature of the problem.
3. The need is for systematic, 100 per cent clearance of affected land, which generally results in a decision to conduct manual mine clearance.
4. Manual mine clearance is, by nature, slow (and therefore extremely time-consuming), dangerous and expensive, but is believed to be the only guaranteed method of 100 per cent clearance.[a)]
5. For the purposes of non-military manual mine clearance, training and supervision of the locally employed force will be by experienced US Engineer/UK Sapper or equivalent unit personnel. However, locally employed demining personnel will select team or group leaders, who will be given more specialised training. (As Public Records Office/National Archive documentation underscores, German POWs had a proportion of experienced combat engineers who were already trained in mine clearance and who were particularly familiar with their own and Allied landmines and their usage.)
6. Regardless of political or higher-military-authority pressure to complete clearance operations in the swiftest practical time, all mine clearance activity will take place in daylight hours (there being no tactical requirement for night operations).
7. Casualty rates among manual mine clearance personnel are to be kept to a minimum by first-class training, teamwork (usually a clearance "pair" with a more experienced supervisor for each clearance lane) and good immediate medical support on site and full medical facilities within easy distance for CASEVAC.

a) Despite this laudable principle, few experts or commentators on manual mine clearance would unequivocally declare that 100 per cent clearance rates are always possible — for a multitude of reasons.

Historically, these principles represent "best practice" for manual mine clearance and have been observed in both military and civilian circles (including among POWs) since the latter part of the 1939-45 war.

14. Drawn from UK PRO National Archives document reference WO 205/801, *Disposal of Allied Unexploded Bombs*.

Moving into formal "humanitarian" demining

The more recent platform for the humanitarian[15] sector came from action in Afghanistan in the late 1980s. Following the withdrawal of the Soviet troops from Afghanistan in February 1989, it was realised that the country faced a huge problem frrom the presence of landmines. Initially, military personnel trained Afghans who had been displaced to Pakistan in clearance techniques to help the process of mine eradication in Afghanistan. The techniques taught were based firmly on the procedures used by the Western Allies to clear Europe in the 1940s. Then, before and during *Operation Salam*,[16] serving military trainers[17] developed a formal training programme for Afghans. This was the foundation of what is now the largest mine clearance programme in the world, the Mine Action Programme for Afghanistan (MAPA).

In 1989, the UN Office for the Coordination of Humanitarian Affairs (UNOCHA) in Afghanistan planned to train 15,000 Afghans in basic manual mine clearance. Although the plan was rather naïvely produced, given a general lack of knowledge of how to deal with such an issue, it did have the merit of being the first serious attempt to carry out and run a humanitarian mine clearance programme.

The initial plan was for various military contingents to train large numbers of community deminers in Afghanistan, with a view to the Afghan trainees then working as unpaid volunteers to demine areas around their own villages. These deminers would receive an attendance allowance during the short training period but once training was completed no salary was to be paid. No protective equipment or material was supplied other than a prodder and explosives for mine destruction. Explosives and detonators would be replenished if and when the deminers returned to the demining training facilities in Pakistan. At the same time, MAG and the HALO Trust were setting up small-scale programmes to attempt to survey or clear specific areas in Afghanistan.

Figure 5. Mine clearance in Afghanistan in 1992.

This approach to clearance relied heavily on persuading volunteers that minefield clearance would be a continuation of the *Jihad* (holy war) against the Soviet forces, which by then had withdrawn from the country. Many thousands of deminers were trained,[18] but the programme quickly ran into a number of problems. Military

15. Of course, in addition to humanitarian demining, manual mine clearance is also carried out for reconstruction, development and commercial purposes.
16. *Operation Salam* was the UN programme set up to assist refugee return and the rehabilitation of Afghanistan following the Soviet withdrawal in February 1989.
17. From countries including Australia, Canada, New Zealand, Norway, the UK and the US. Pakistan provided training and support.
18. The exact figure is not known although the operations manager of one Afghan NGO, OMAR, suggests that it was around 12,000.

contingents were not allowed into Afghanistan to oversee activities; there was no prioritisation, survey or record keeping, and thus no clear picture of what was being done. For the deminers, the lack of enforcement of SOPs and the absence of protective equipment and medical support made the job extremely dangerous. Although no reliable information is available on the casualty rate, anecdotal evidence suggests that this was very high.

Following a number of reviews, the UN changed the concept and oversaw the establishment of specialist Afghan NGOs so that demining work could be done on a more organised and controlled basis. In the absence of a recognised government, the UN provided the central coordination, training, quality assurance and funding, while the NGOs undertook clearance, survey or mine awareness projects in regions of the country assigned to them. Emphasis was placed on the standardisation of procedures, techniques and equipment, and priority setting was mainly driven by predicted refugee return.

Over the next decade or so, the Afghan programme grew to become the biggest mine action programme in the world and currently employs around 8,000 Afghan staff with a budget in the Afghan financial year 2004–05 of more than US$97 million. The MAPA coordinates all mine action activities in Afghanistan and is beginning a process of planning for a full transfer of responsibility for coordination of national mine action activities, primarily manual clearance assets, but also including dogs and mechanical equipments to the Government of Afghanistan.

Kuwait

In 1991, following liberation from Iraqi occupation, the oil-rich State funded a huge mine and UXO clearance operation resulting from the conflict. Around US$700 million of Kuwaiti reconstruction money was allocated to commercial organisations from the US, UK and France (many of which were set up specifically for the operation) as well as troops from Bangladesh, Egypt, Pakistan and Turkey on a semi-commercial basis, to clear the debris of the war.

Many mistakes were made and many deminers' lives were lost in the ensuing operation. This was perhaps the catalyst for significant developments in manual mine clearance operations, and many of the basic tenets of manual mine clearance came into being during this period, particularly on the commercial side.

Figure 6. Mine clearance in Kuwait in 1991.

In the aftermath of the Coalition conflict with Iraq, many retired military specialists and an equal number of then-serving military personnel left their armies to work as mine clearance contractors in Kuwait, with the incentive of extremely high salaries. Kuwait was the first operation where commercial organisations were formed specifically for the purposes of mine clearance.

Unfortunately, in this unsavoury "free-for-all", inexperience and poor management exacerbated by commercial secrecy and competition often overrode common sense and best practice in manual mine clearance. As a result, the accident rates in clearance operations in Kuwait were very high. Nevertheless, the more enlightened organisations realised that there were important moral issues involved, not just in Kuwait, but also across the many other countries affected, and in recent years international standards (*Box 3*) have been developed to bring some regulation into what had previously been an unregulated industry.

Beyond Kuwait

After the creation of the Afghanistan humanitarian demining programme came Cambodia, Mozambique, Angola and many others. Each of these operations was established in a broadly similar manner, but with limited lessons being passed on between programmes. There were two distinct groups of expatriate advisers and operators who worked in the industry at this stage. First, serving military personnel from Western armed forces were operating sometimes within, sometimes outside, the scope of UN peacekeeping operations. The second group was made up of former and serving military personnel typically working for NGOs.

Teams were organised and structured in the manner of the military, even to the extent that some teams were called "platoons" and "sections": deminers were issued uniforms and instructed to parade in formation at the beginning of each day. This ethos was developed because there was a belief that military discipline was the bedrock of an efficient and safe organisation. There were no benchmarks at this time and nothing against which to compare the operations.

This expansion in capacity was additionally supported by the growth of a number of specialist NGOs who provided mine clearance in parallel with the UN operations. MAG, NPA and HALO Trust were at the forefront of this rapid expansion.

The industry has rapidly professionalised and probably the most significant development has been the production and expansion of international standards (*Box 3*). In 1997, a group of NGOs and UN staff developed the first set of international standards which, although with hindsight flawed, paved the way for further development of what is now the accepted norm of International Mine Action Standards (IMAS). IMAS today provides a comprehensive framework of standards to assist the wider community, in particular to help countries develop their own national standards.

In 1998, the GICHD was established as an initiative of the Swiss government, with the aim to support the fight against anti-personnel mines by seeking practical and concrete solutions to the problems posed by landmines and UXO.[19] The GICHD has subsequently developed into a independent and neutral resource centre for mine action internationally, and is now financed by more than 20 countries. It is active in research, operational assistance and supports the implementation of the Anti-Personnel Mine Ban Convention.

For the first five to ten years of mine action after 1988, continuity in encouraging and executing demining programmes came from the management, administration,

19. Fact Sheet, Secrétariat Général du DMF Politique de Sécurité et Politique Militaire, Bern, 4 September 1997.

supervision and training by individuals and groups with a strong military background. Indeed, given the historical precedents, it is likely that many key personnel working in the mine clearance industry will continue to be former military.

Box 3. The development of international standards for mine action

International standards for humanitarian mine clearance programmes were first proposed by working groups at an international technical conference held in Denmark, in July 1996. Criteria were prescribed for all aspects of mine clearance, standards were recommended and a new universal definition of "clearance" was agreed. In late 1996, the principles proposed in Denmark were developed by a UN-led working group and the *International Standards for Humanitarian Mine Clearance Operations* were developed. A first edition was issued by the UN Mine Action Service (UNMAS) in March 1997. The scope of these original standards has since been expanded to include the other components of mine action and to reflect changes to operational procedures, practices and norms. The standards were re-developed and renamed as *International Mine Action Standards* (IMAS).

The United Nations has a general responsibility for enabling and encouraging the effective management of mine action programmes, including the development and maintenance of standards. UNMAS, therefore, is the office within the United Nations responsible for the development and maintenance of IMAS. The IMAS are produced with the assistance of the GICHD.

The work of preparing, reviewing and revising IMAS is conducted by technical committees, with the support of international, governmental and non-governmental organisations. The latest version of each standard, together with information on the work of the technical committees, can be found at *www.mineactionstandards.org.* The IMAS are evolving documents which are progressively reviewed to reflect general changes and developments in the implementation of mine action activities and to incorporate changes to international regulations and requirements.

The International Mine Action Standards follow the internationally accepted ISO format and build up a series of individual "standards" that aim to cover the scope of mine action. IMAS illustrate and specify best practice and are available for use and application to fit individual programme situations.

The principles of the past "best practice" of humanitarian manual mine clearance should continue to stand the test of time for the very reason that they have their roots firmly planted in the experiences of the 1939–45 war, and the bridge between military and non-military approaches to the solution of the worldwide mine clearance problem. Although society has evolved significantly since 1945, within mine action, little appears to have changed and the problems we are dealing with today are very similar to those encountered two generations ago. The current principles of most clearance organisations have been significantly influenced by the military legacies endowed to them.

There are some form of coordination and planning bodies in place in 42 mine-affected countries.[20] The mine action community has developed into a largely competent body of professionals, "operating in around 65 countries and seven non-recognised States",[21] with resources of more than US$250 million a year.

20. Landmine Monitor (2004).
21. *ibid*.

Main study conclusions and recommendations

Conclusion 1

Manual mine clearance has been undertaken in various forms since at least the end of the 1939–45 war. Based on the data available, the level of injuries to mine clearance personnel has decreased significantly since that period.

Findings

Manual mine clearance is routine and monotonous and is often carried out in unpleasant conditions. It requires high levels of internal motivation for individuals to overcome boredom, to remain alert and to sustain high levels of attention to detail.

Today, many organisations recruit deminers, put them immediately on a salary and send them on a training course supplied in-house. The average period is around two to four weeks for completion of demining training. A recruit seldom fails, even if standards are not achieved.

In contrast to initial training, refresher training appears not to take place systematically, often only on an *ad hoc* basis as and when it is deemed necessary — which appears to be seldom. Many organisations stated that "skill fade" was not an issue as the deminers were doing their task every day. This is a dangerous assumption as each site has different demands and deminers become complacent when working in low-risk areas.

The length of each demining period recommended between rest breaks varies considerably from one organisation to another. In general, any work requiring sustained concentration benefits from frequent, short breaks. If, however, the breaks are too long there is a risk of concentration and motivation decreasing. If deminers spend long periods without stimulation between working periods (as in "two-man-lane" drills) they are more likely to be "out of the loop" when they return to work and will have more frequent mistakes.

Deminers are usually only operational for five hours per day and many organisations stipulate this. At the individual deminer level, it appears that dehydration is a significant factor in the performance and safety of the individual deminer and managers should be aware of rehydration for their deminers.

A wide range of issues affect deminer safety. One of the keys to increasing safety is to fully understand why accidents are taking place. There is a need for the mine action community to collect, more systematically, data on deminer accidents and injuries. This should build on the work that has already been done in the context of the Database of Demining Accidents, which is being maintained by the GICHD for the UN. In particular, organisations should collect data related to "casualties per hours worked" and/or "lost hours per hours worked", in a similar way to any other hazardous industry in the world.

Although today it is still very difficult to extrapolate detailed information on casualties from many programmes, it appears that the average casualty rates for deminers have decreased since the 1940s. Casualty rates for deminers per hour worked in 1945 were at one accident per 890 hours worked and more recently, in 2004, in two well established programmes, was assessed to be in the region of one accident per 324,000 operating hours. This figure is marginally lower than the forestry industry rates in the US.

Recommendation 1

a. Criteria for selection of staff need to be established and the practice of full salary payment during training should be re-considered by management.

b. Operators should actively consider providing a short refresher course to all deminers when they start working at a new site, to raise their awareness of the particular issues relevant to that site.

c. Greater emphasis should be placed on rehydrating deminers, and providing thermal and physical comfort to aid their performance.

d. Deminer accident reporting needs to be improved and formalised. Deminer accident reporting may benefit from being centralised. The DDAS is a good basis for such centralised reporting, but should be accorded more attention so that lessons from accidents can be learned and mistakes corrected.

Conclusion 2

Manual mine clearance appears not to be as dangerous a profession as it is often perceived to be.

Findings

Since the first "serious" manual mine clearance operations were undertaken towards the end of the 1939–45 war, significant improvements have been made in the safety of the mine clearance profession. From the early days, where mine clearance was an extremely high risk occupation, the industry today has developed into one where it appears, given the limited amount of data available to analyse, to be as safe, or safer, than many other comparable industries. If data were to be collected more rigorously, this could well be used to further improve safety for workers. Small policy changes can have significant impacts on the risk workers are exposed to. For example, if malaria is prevalent, a realistic risk reduction measure would be to provide nets for all workers.

Recommendation 2

a. Data should be collected in a more standard, thorough and rigorous manner in order to undertake a more effective risk reduction analysis. This data should include working hours, and open and honest accident reporting from all organisations.

b. Detailed discussions should be held with insurers to explain the relative risks of mine clearance activities to attempt to reduce premiums.

c. Managers should consider the inclusion of a risk management policy as an integral part of their management tools and processes.

Conclusion 3

The International Mine Action Standards requirements for personal protective equipment (PPE) is not always appropriate to the protective needs of the deminers. Current IMAS do not allow operators sufficient flexibility in the use of personal protective equipment. In addition, current IMAS are too prescriptive in the definitions of safety distances.

Findings

The introduction of mandatory personal protective equipment has been one of the major safety innovations in recent years. Although PPE plays an important role in the protection of the individual, certain factors should be considered when purchasing a particular type, as it can have a negative influence on performance, and the wearer can be affected in several ways.

For instance, there is an increased risk of error through visual distortion caused by the visor, particularly if it is poorly maintained, scratched or otherwise damaged.

The advisory default safety distance of 25 metres between deminers is not always applied — with good reasons. But the risk assessment required in IMAS 09.20 is often not carried out, and when it is, it tends to be done in an informal manner.

Recommendation 3

a. There is a good case for downgrading PPE requirements and giving operators more flexibility not to use some or all PPE as and when appropriate. The PPE and safety distance requirements laid down by IMAS should be reviewed.

b. Greater care should be devoted to the storage of facial PPE: it should be stored with care in order to avoid deformations, and UV degradation should be kept under control.

Conclusion 4

Improved management of manual mine clearance operations could lead to significant gains in productivity. Although perceived by some to have reached maturity and an optimal point of development, this appears not to be the case.

Findings

The Section on the management of manual mine clearance found, apart from a few commercial companies, continuing and clear evidence of poor project management skills, with considerable focus on micro-management. Decision making processes and capacity are also weak. This results in the implementation of a *process-driven* rather than *task-focused* management style.

The majority of personnel engaged in mine clearance have a military background in one capacity or another. It is increasingly understood that the skills and experience that serving or former soldiers bring to mine action are invaluable, but other skills are also required in the development phase. What is often missing today is project and programme management experience acquired in the development and/or commercial sectors, bringing a corresponding drive for efficiency, innovation, creativity, and flexibility.

Problems are particularly acute at middle manager level. Although middle managers are ostensibly responsibly for running and managing their particular area of responsibility, in many cases they are not equipped with the resources to undertake this task and are often not given the necessary autonomy.

Recommendation 4

a. Manual mine clearance organisations need to move towards a task-focused management style. One way to achieve this is by bringing in project and programme management experience acquired in the development and/ or commercial sectors.

b. In all cases, decision-making needs to be delegated downwards and away from senior management to middle management for day-to-day issues, such as running a mine clearance site. At the same time, middle managers need to be recruited and trained to be able to take the necessary decisions as well as having the support of the senior management in those decisions.

c. Donors should assist NGOs to be more proactive in their resource planning by offering longer term funding.

Conclusion 5

Average rates of clearance appear to be in the region of 15 to 20 square metres per deminer per day.

Findings

Although the feedback from many operators on the ground suggested that they believed they were clearing much higher rates, on the evidence of the data gathered and after consultation with several well-documented mine action programmes, the rates for manual mine clearance (as opposed to area reduction, technical survey, battlefield area clearance, etc.), were close to the figures identified in the GICHD study *Mine Action Equipment: A Study of Global Operational Needs*, which were generally less than half of the rates quoted by organisations.

The most effective work is produced from a deminer when he/she is taking frequent short breaks and operating with comfortable PPE, when and where appropriate.

Recommendation 5

a. Programmes should be more vigilant about effectively recording clearance rates and develop a series of benchmarks to work to.

b. Discomfort is inevitable in harsh climates, but can be ameliorated by well-designed PPE. Managers should consider this when purchasing PPE.

c. SOPs should be developed to ensure working deminers take frequent short breaks and field management should ensure deminers are maintaining hydration.

Conclusion 6

Observation of ongoing clearance operations suggest that parts of the mine clearance industry is demonstrating a willingness to employ innovative techniques in a number of

countries. But some of these techniques were only informally adopted as their use was constrained by written Standing Operating Procedures.

Findings

The development of clearance techniques has generally been evolutionary. However, in terms of safety, if SOPs are adhered to, the generally accepted clearance techniques do appear to be robust and well proven.

Research conducted for the study found that most mine clearance programmes included innovative advances, some of which had been adopted only informally. Indeed, the fact that a number of these advances involved procedures that fell outside the perceived or stated requirements of national and international standards led a number of operators to call for revision of the standards to incorporate the flexibility required by an emergent discipline.

Most innovations in manual mine clearance techniques are made in order to increase speed. For example, several groups reduced the depth of metal-detector search and were prepared to leave small metal indications in the ground. Procedures for incorporating innovative procedures into SOPs and having them improved by the national authorities were not streamlined, and were often ignored.

The approach to quality management activities varies between organisations but is generally conducted in-house, as external assessors are few and far between. Within clearance organisations, supervisors seem to be more subject to accidents than deminers. Key to understanding the nature and application of an innovative procedure is a clear description of the situation in which it is being used. For example, formalising the process of reducing areas originally suspected of being mined after the clearance of *known* mines has proven to be very effective in patterned minefields. The follow-up procedure described in Iraq of having a team visually inspect areas after post-clearance area reduction is likely to be perceived as too hazardous in many situations. However, the procedure is acceptable when an appropriate risk assessment has been undertaken.

When clearing land, fragmentation and false alarms are significant contributing factors to clearance rates. Thus, to improve the efficiency of manual mine clearance, the main area for improvement is the speed with which metal fragments can be identified and removed. Indeed, in trials conducted for the purposes of the study, it was found that in a heavily fragmented area the most efficient method of clearance among eight different options was using a metal detector and a magnetic brush-rake.

Recommendation 6

a. Local innovation in mine clearance techniques should be actively encouraged, not discouraged, as long as deminer safety is not put at unnecessary risk. This innovation needs to be rigorously trialled and documented and implementation should only follow careful assessment of the results of such trials. Where this requires changes to national standards or organisational Standing Operating Procedures, such changes should be countenanced.

b. Mine clearance agencies do not routinely have personnel with the skills needed to design and undertake carefully controlled trials. Support from organisations such as the International Test and Evaluation Programme (ITEP) and the GICHD can and should be requested as a part of the trial process.

c. The results of trials of innovative techniques are a valuable resource for the mine clearance community, even if the trials are a failure. Results of trials should be made widely available, for example through placing trial reports onto websites and reporting them at workshops and conferences.

d. There is a need to streamline the approval process for innovative techniques, including developing procedures for having them written into SOPs.

Conclusion 7

The use of magnets and brush rakes as additional tools to the standard manual mine clearance "toolbox" will increase manual mine clearance efficiency in many circumstances.

Findings

Trials undertaken in Mozambique supported operational experience in several countries, that simple magnets and brush rakes can increase rates of clearance. Most mine clearance is undertaken using simple tools, and any opportunity to add a new simple (and cheap) tool to the toolbox should be widely encouraged. In Sri Lanka, one mine clearance organisation eventually rejected metal detectors in preference for a procedure using rakes.

Recommendation 7

a. Mine clearance programmes should be less bound by tradition and consider the integration of "non-standard" tools in order to improve clearance rates in manual mine clearance programmes.

b. Integration of these tools should initially be tempered with a robust full quality management system to ensure safe clearance methodologies.

Conclusion 8

The methods most likely to leave mines behind or lead to accidents are:

- **Area excavation in which the required clearance depth was not rigorously maintained;**
- **Use of metal detectors that are only marginally able to do the required task, because of either design or age; and**
- **Prodding from the surface.**

Findings

All mines missed in the Mozambique trials were buried at a depth of 12 centimetres. Two of the procedures using metal detectors missed mines because of a combination of search speed and the use of metal detectors inadequate for the task. Metal detectors appear to have a four-year lifespan when used regularly. Recent trials of metal detectors suggest that they routinely do not achieve stated manufacturers' specifications. Mines were also missed using an excavation technique that was not being applied rigorously to the required depth standard. Prodding from the surface could not supply the required detection depth, especially in hard soils.

Recommendation 8

a. Mine clearance agencies presumably only use metal detectors that are inadequate to a task because they have no other options. Regular replacement of metal detectors should be a part of budget planning. Also, metal detectors that are functional in one deployment location may not be

adequate in another. Sponsors need to be made more aware of the limitations of metal detectors and the replacement requirements.

b. Use of prodding from the surface as a standard mine clearance procedure should be reviewed, with a view to minimising use of this potentially dangerous and limited tool.

Conclusion 9

Established procedures tend to become self-maintaining as a result of training and experience, building in extra resistance to change. Mine clearance agencies have little opportunity to compare notes and discuss alternative options. Field managers are in a difficult situation: on one side they are required to adhere rigorously to established procedures (laid down in an approved SOP) yet, on the other side, as a result of experience they can often see options for improving productivity without compromising safety. Although some lag is expected between innovation and the development of SOPs, the evidence in the case studies was that updating of SOPs was viewed as a difficult and low priority task.

Findings

Trials in south Sudan and Mozambique clearly identified opportunities for improving procedures and equipment. Any agency adopting new procedures or equipment will need to do small trials and training, make adjustments as a result of local conditions, and modify and rewrite SOPs. However, the benefits to be gained in terms of productivity appear to be much more significant than the costs involved in making changes.

In all of the case studies, SOPs were found to be out of date or in need of work. There was little motivation to improve them, presumably because this was not seen as a priority at a management level. SOPs are often too rigid and inflexible which prevents innovations and potentially useful changes. SOP changes often require approval from national authorities which may be a bureaucratic and time-consuming process. SOPs should thus allow minor changes without the need to consult mine action authorities on every occasion.

Recommendation 8

a. Current manual mine clearance techniques, although appearing to exist as a result of long experience and trials, can be challenged to achieve a higher degree of efficiency. Trials in this study suggest a significant potential productivity gain. Field managers should investigate the potential for increased clearance rates by carrying out trials and implementing change if appropriate.

b. Field managers and technical advisers should have the opportunity to meet and exchange ideas in a workshop format on a regular basis.

c. Support for trials and modifications should be made available by the wider community in order to assist implementation.

d. Updating SOPs needs to be given a higher priority in order to ensure ongoing compliance with national standards and IMAS. Support from external agencies may be required to ensure that such updating proceeds regularly. National agencies should be more proactive on this issue, perhaps through providing an updating support service.

e. SOPs should be written in less rigid forms which will facilitate a less bureaucratic process of making changes to them.

Conclusion 10

Standard manual mine clearance drills appear to be implemented in a similar fashion in most countries. This is in part due to a perception that the technique is too well proven to be challenged. Two experimental drills show that it is possible to significantly increase the speed of manual mine clearance by adopting an approach allowing multiple working faces to be open at the same time.

Findings

The Hybrid and Crab techniques both proved more efficient than the standard manual mine clearance drills during the trials in Sudan. This appears to be because the technique opens up more operating faces and reduces changeover times. In wet soils, the difference between the Crab and Standard drills were significant, which suggests that the Crab drill may be used permanently both during wet and dry conditions (provided there is a requirement for vegetation cutting). Dry soil conditions where watering is required amplifies this difference significantly. Programme managers should realise that the standard drills do provide inbuilt security and safety measures, whereas Hybrid and Crab drills will need extra procedures introduced to achieve the same levels of security.

The Crab drill is particularly promising and appears to be 30 per cent more effective in wet conditions. In dry soil, however, the potential gain is significantly higher. This technique, or variations of it based around the principle of minimising the time for tool handling, vegetation cutting and watering/soak time, is worth considering by field managers.

Recommendation 10

The Hybrid and Crab techniques should be considered as alternatives or substitutes for the traditional manual mine clearance techniques as they may offer a significant increase in clearance efficiency during most conditions.

Conclusion 11

Modelling the costings of mine action programmes can provide managers with guidance on where expenditure is best used within a programme.

Findings

The link between expenditure in a programme and cost per square metre of clear land might be expected to be directly linked, but in many circumstances, this is not the case. For example, a manager would probably assume that increasing productivity will decrease the cost of the output per square metre (i.e. of cleared land). However, the implications of purchasing more expensive equipment — for example PPE — may well not result in a proportionate decrease in the output costs. If the programme manager takes the time and effort to understand the relationship between the inputs and outputs, it may well provide a clearer indication of the benefits that may be obtained from more efficient expenditure.

Recommendation 11

a. Programme managers should attempt to understand in more detail the relationship between inputs and outputs into their programmes.

Conclusion 12

Manual mine clearance is the most prevalent — and costly — component of mine action. It also appears that there is a considerable problem within the mine clearance industry in reporting on areas cleared.

Findings

Multi-skilled deminers who are on site appear to be a more practical and time-efficient approach. Incentives, such as pay increases and bonuses for conducting successful EOD tasks, may be a useful means of persuading deminers to become multi-skilled.

To determine which elements of the mine clearance process really make a difference to overall costs, an appropriate economic technique is sensitivity analysis. Sensitivity analysis on the impact of various costs and overheads on the price of clearance per square metre of land has found that:

- A 75 per cent reduction in **vehicle** purchase price (i.e. a reduction from a new price of US$20,000 to a used price of US$5,000) only leads to a US$0.05 reduction in the undiscounted price of clearance per square metre, even though there is a huge reduction in initial costs. This indicates that, given such issues as reliability and warranties, it may not be appropriate if a programme has sufficient cash flow, to buy second-hand vehicles.
- A 50 per cent reduction in **battery** usage rate reduces the undiscounted output price by US$0.03 per square metre. This suggests that there is a case for encouraging the adoption of either cost-effective battery charging systems or reducing the electricity consumption of mine detectors.
- **Medics** (if employed solely as such) can be regarded as "overheads" in mine clearance, and, like the provision of PPE, are a fixed cost of meeting safety regulations. Removing the medic from the platoon organisation chart results in a significant reduction in price, from US$1.46 to US$1.44. Some organisations are attempting to overcome this problem by adding "dual-role" medics: individuals who operate normally as deminers, but in the event of an accident, step in as a medic. With enough of these dual-role medics, an IMAS-compliant operation can still be undertaken and cost-effectiveness will be significantly increased.
- If **deminer productivity** increases by 5 per cent (i.e. from 1.5 to 1.575 hectares per month per team), there is a 5 per cent decrease in output price.

Recommendation 12

a. If mine clearance is to prove cost-effective, costs need to be carefully controlled. The use of sensitivity analysis can be an important element in efforts to control operational costs.

b. Performance must be reported accurately and honestly, if confidence in the mine clearance industry is to be maintained: exaggerated clearance statistics are wholly unacceptable.

Conclusion 13

Most land cleared contains no explosive ordnance. The current "all-or-nothing" approach to manual mine clearance is inappropriate and unsustainable.

Findings

Mine clearance is still largely "input driven" rather than "output driven", i.e. it is based around the money available, rather than an assessment of how much is needed to reduce risk in a given area to an "tolerable" level. However, it needs to be recognised that there are practical difficulties in establishing a contractual mechanism that allows an organisation to clear to lower standards, without allowing less scrupulous organisations to take advantage of the situation.

The aim of manual mine clearance is the clearance of every mine and every item of unexploded or abandoned explosive ordnance from a given area. So, if a given area of land is declared to have been cleared, then it should, to the best available knowledge, be clear of all explosive ordnance. In this respect, IMAS 09.20 should remain fixed. Indeed, there are many situations in which such an absolute level of clearance is necessary or is demanded.

But this full clearance standard is not necessarily universally applicable, nor is it by any means universally achieved. For this reason, the mine action community and its stakeholders need to urgently consider moving to a more explicit risk management approach. Moreover, spending months clearing an area and finding no mines — but a lot of pieces of miscellaneous and harmless metal — is a waste of resources, as well as being unsatisfying for those engaged in it. Yet, this is exactly what the mine clearance community still does far too often.

Area reduction may well form the key to this process, yet is typically misunderstood. Area reduction is defined within the IMAS but there is no agreement on how it is best conducted. There is an urgent need to identify appropriate methodologies for quickly and efficiently focusing the scarce manual mine clearance resources on those areas where they are truly needed. Technical survey is not well defined.

Recommendation 13

a. The mine clearance community should move explicitly towards a risk-management approach to addressing explosive ordnance contamination and impact. In doing so, a new standard for the treatment of land contaminated by explosive ordnance should be considered – "released land". The type of approach to such "area risk reduction" will depend on the context, including the views of the different stakeholders.

b. Further research should be undertaken into the appropriate methodologies for conducting area reduction and technical survey.

c. The depth at which mines are located should be recorded systematically. This has never been done, but would provide valuable information in order to development a professional risk management approach.

Conclusion 14

Cost benefit analysis as part of the risk management process may provide a useful tool for making the best use of limited resources.

Findings

There may be merit in considering a "less than perfect" clearance option. The model proposed in Section 4 is just that — a model — but the concept needs to be carefully considered by the community and a clearer model for "tolerable risk" needs to be defined. Data collection is key to allow informed decisions to be made about where and how to approach mine clearance tasks.

Recommendation 14

a. Data collection should be standardised and improved to allow clearer oversight of cost-benefit issues related to mine clearance. This data should enable detailed analysis of the costs of the land cleared to be drawn.

b. A discussion should be initiated in the community about a more realistic approach, in terms of the acceptance of land that may not be completely "cleared" of mines and UXO.

c. Terms such as "cleared land", "released land", "mine-free" and "impact-free" need to be more clearly defined.

Annex

Members of the Study Advisory Group

The Geneva International Centre for Humanitarian Demining would like to thank the individual members of the Study Advisory Group for their time and effort in the guidance and review of the work as it developed throughout the study.

The Study Advisory Group consisted of the following individuals:

- Noel Mulliner, United Nations Mine Action Service (UNMAS);
- JJ van der Merwe, United Nations Office for Project Services (UNOPS);
- Kent Paulusson, United Nations Development Programme (UNDP);
- Guy Willoughby, HALO Trust;
- Damir Jaksic, Norwegian People's Aid;
- Per Breivic, Norwegian People's Aid;
- David Hewitson, European Landmine Solution;
- Lionel Dyck, MineTech;
- Hugh Morris, MineTech;
- Hemi Morete, Independent Consultant;
- James Trevelyan, University of Western Australia;
- Robert Keeley, Independent Consultant;
- Andy Smith, Independent Consultant;
- Khair Sharif, Independent Consultant;
- Alistair Craib, UK Department for International Development (DFID);
- Jacky D'Almeida, UN Accelerated Demining Programme, Mozambique, and
- Taz Khaliq, Cranfield University, UK.

Bibliography

This study consists of five separate stand-alone publications, each of which has its own bibliography. The bibliography in this overview document details all references throughout each of the five separate publications of the whole study

Ale, B.J.M. (1991)
"Risk analysis and risk policy in the Netherlands and the EEC", *Journal of Loss Prevention in the Process Industries*, No. 4, pp. 58–64.

Anderson, P. (1999)
"Seven levers for guiding the evolving enterprise", in J.H Clippinger III (ed.), *The Biology of Business*, Jossey-Bass, San Francisco.

Angel, H.A. and D.W. Tack (2001)
Human Factors in Humanitarian Demining: A Scoping Study, Canadian Centre for Mine Action Technology, Medicine Hat.

Anonymous (2004)
Residual Liability for Cleared Land, draft.

BARIC Consultants Ltd. (1996)
Minutes from a meeting to Discuss Humanitarian Mine Clearance Equipment Requirements, UK.

Blagden, P.M. (1997)
The Evolution of Mine Clearance Operations since 1991, SusDem '97, Zagreb.

Brown, S. (1999)
"Mine Action – The Management of Risk", *Journal of Mine Action*, James Madison University, Mine Action Information Center, Spring 1999, Vol. 3, No. 1.

Bruce, I.G. and F. Oboni (2000)
Tailings Management Using Quantitative Risk Assessment. In Tailings Dams 2000, Proceedings of the Association of State Dam Safety Officials, US Committee on Large dams, 28–30 March 2000, Las Vegas, Nevada.

Campion, M.A. and C.L. McClelland (1993)
"Follow-up and extension of the interdisciplinary costs and benefits of enlarged jobs", *Journal of Applied Psychology*, 78: 339—351.

CMAA (2004)
National Assessment of Mine/UXO Contamination, Phnom Penh, February.

Croll, M. (1998).
History of Landmines, Leo Cooper, Barnsley.

Dixon, N. (1976)
On the Psychology of Military Incompetence, Jonathon Cape, London.

DoD (US Department of Defense) (2000)
"Landmine Casualty Data Report: Deminer Injuries", *Office of the Assistant Secretary of Defense for Special Operations/Low Intensity Conflict*, US/07.

Eaton, R., C. Horwood and N. Nyland (1997)
Multi-Country Mine Action Study: Study Report - The Development of Indigeneous Mine Action Capacities, Department of Humanitarian Affairs, United Nations, New York.

Ehlers, H. (2003)
Mozambique farewell address, MgM demining forum.

Elizur, D., I. Borg, R. Hunt, and I.M. Beck (1991)
"The structure of work values: A cross cultural comparison", *Journal of Organizational Behavior*, 12: 313-322.

Engelhardt, F. Rainer (1999)
ENOVA Research Applications; Workshop on Remote Sensing of Anti-Personnel Land Mines, Westin Hotel, Ottawa, Canada, CA/15/I.

Fitzgerald A.M. and D.J. Neal (2000)
"Dispelling the Myth between Humanitarian and Commercial Mine Action Activity", *Journal of Mine Action*, Issue 4.3, Fall 2000, Mine Action Information Center, James Madison University, US.

GICHD (2004)
A Study of Mechanical Application in Demining, GICHD, Geneva.

______ (2004)
A Guide to Insurance for Mine Action Operators, GICHD, Geneva.

______ (2002)
Mine Action Equipment: Study of Global Operational Needs, GICHD, Geneva.

GICHD/UNDP (2001)
A Study of Socio-Economic Approaches to Mine Action, GICHD/UNDP, Geneva.

GPC Public Affairs (2002)
Humanitarian Demining, Prepared for the Government of Canada, Assessment of the International Market for Humanitarian Demining Equipment and Technology, Prepared by GPC International Public Affairs and Communications, CA/06.

Guelle, D., A. Smith, T. Bloodworth, and A. Lewis (2003)
Metal Detector Handbook for Humanitarian Mine Clearance, European Union, Luxembourg.

Gyllenhammer, Pehr G. (1977)
People at Work. Addison Wesley, Reading, MA.

HALO Trust (2003)
Cambodia, Demining Standard Operating Procedures, HALO Trust, Phnom Penh, March.

Handicap International and Cambodian Red Cross (2003)
"Towards zero victims" – National Census of the victims & survivors of landmines & unexploded ordnance in Cambodia 2002, Brussels & Phnom Penh.

Health and Safety Executive (HSE) (2001)
Reducing Risks, Protecting People, HSE decision making process.

ICBL (International Campaign to Ban Landmines) *(2004)*
Landmine Monitor Report 2004: Toward a Mine-Free World , Human Rights Watch, Washington DC.

_____(2003)
Landmine Monitor Report 2003: Toward a Mine-Free World, Human Rights Watch, Washington DC, August.

_______ (2001)
Landmine Monitor Report 2001: Toward a Mine-Free World, Human Rights Watch, Washington DC, August.

International Union of Geological Sciences (1997)
Working Group on Landslides, Committee on Risk Assessment, Quantitative Risk Assessment for Slopes and Landslides, The State of the Art, IUGS Proceedings, Honolulu, Balkema.

Keeley, R. (2003)
"The Cost Capture Issue in Humanitarian Mine Action", *Journal of Mine Action*, James Madison University, US, December 2003, at *maic.jmu.edu/journal/7.3/notes/keeley/keeley.htm*.

_____ (2003)
Development of Economic Techniques as a Means of Assessing the Cost-Effectiveness of New Potential Demining Technologies, Paper presented at EUDEM conference in September.

Keeley, R. and R. Griffin (2004)
Joint Evaluation of Mine Action in Cambodia for the Donor Working Group on Mine Action, 4 December 2004.

Lardner, T. (2002)
"Towards a Better Mine Action Programme", Master of Science Dissertation, Cranfield University, UK.

Leroi, E., C. Bonnard, R. Fell, R. McInnnes (2005)
Risk Assessment and Management, International Conference on Landslide risk Management, Vancouver quoting Whitman (1984).

_____ (2003)
Risk Assessment and Management, International Conference on Landslide Risk Management, 2 June, Vancouver.

Maslow, A.H. (1970)
Motivation and Personality, 2nd Edition, Harper & Row, New York.

MgM (Menschen gegen Minen) (1999)
"Standard Operating Procedures of MgM Mine Clearance Operations", available at: *www.mgm.org*.

Morgan, G.C., G.E. Rawlings and J.C. Sobkowicz (1992)
Evaluating total risk to communities from large debris flow, in "*Geotechnique and natural hazards*", Bi Tech Publishers, Vancouver BC, pp. 225–236.

NDRF (Nordic Demining Research Forum), ARIS (EC Action for Research and Information Support in Civilian Demining) and DANDEC (Danish Demining Centre) (2000)
Proceedings of Workshop on Management of Risk and Quality in Humanitarian Mine Clearance, Organised by NDRF and ARIS in cooperation with DANDEC, DK/01-2000.

Oboni, F. and G. Oldendorff (1998)
Uncertainties, Risk and Decision Making: Risk Management and Crisis Management Integrated Approaches, Second International Conference on Environmental Management, Wollongong.

Oboni, F., I. Bruce, M. Aziz, and K. Ferguson (1998)
A Risk Management Approach for Tailing Systems Second International Conference on Environmental Management, Wollongong, Australia.

_____ (1997)
A Risk Management Approach for Tailing Systems – Golden Jubilee Conference, Canadian Geotechnical Society, Ottawa, Canada.

_____ (1997)
Information Gathering and Analysis for Risk Assessment in Tailing Systems, 50th Canadian Geotechnical Conference.

PRIO (International Peace Research Institute (2004)
Mainstreaming Mine Action in Development, Policy Recommendations for UNDP, International Peace Research Institute, Oslo.

RCAF (2004)
Interview, Phnom Penh, 23 February 2004.

RCAF, De-mined Assignment Task and Development of Nation Society (2003)
Summarization Outcome Report on the Mine Assignment Task and 2004 Projection Forecast, Phnom Penh, Cambodia, February 2004.

Roberts S. and J. Williams (1995)
After the guns fall silent, Vietnam Veterans of America Foundation, Washington DC.

Sanders, M.S. and McCormick, E.J. (1992)
Human Factors in Engineering and Design (7th ed.), McGraw-Hill, New York.

Serco Assurance (2003)
A Risk Strategy for Mine Action, Report for DFID, UK, May.

_______ (2002)
A Risk Strategy for Mine Action in Cambodia, Report for DFID, UK, October.

Smith, A. (2003)
Risk assessment in humanitarian demining, internal document.

The Australian, 13 August 2005

Toews, J.D. (1997)
Land Mine Detector Evaluation Trials, Sus Dem '97, Zagreb.

Trevelyan, J. (2003)
Proceedings of Eudem2-Scot conference, Brussels, Belgium, pp. 242-248.

______ (2003)
"Statistical Analysis and Experiments in Manual Mine Clearance", University of Western Australia, available at: *www.mech.uwa.edu.au*.

_____ (1997)
Better Tools for Deminers, SusDem '97, Zagreb.

UK Public Records Office
Archives on post-1945 clearance, London, UK.

UN (1998)
"Mine action and effective coordination: The United Nations Policy", UN General Assembly doc. A/53/496.

UNMAS (United Nations Mine Action Service) (2003)
International Mine Action Standards, UN, New York.

US Defence Intelligence Agency (1992)
"Landmine Warfare: Trends and Projections (U)", DST-1160S-019-92, Washington DC.

Whitman, R.V. (1984)
"Evaluating calculated risk in geotechnical engineering", *Journal of Geotechnical Engineering Division*, ASCE, No. 110: 145–188.

Glossary of abbreviations and acronyms

ADP	Accelerated Demining Programme (Mozambique)
APMBC	Anti-Personnel Mine Ban Convention
AREA	Agency for Rehabilitation and Energy Conservation (Afghanistan)
AXO	abandoned explosive ordnance
BAC	battle area clearance
BAM	Bundesanstalt für Materialforschung und -Prüfung
CASEVAC	casualty evacuation
CBA	cost-benefit analysis
CBU	cluster bomb unit
CCW	Convention on Certain Conventional Weapons
CMAA	Cambodian Mine Action and Victim Assistance Authority
CMAC	Cambodian Mine Action Centre
CROMAC	Croatian Mine Action Centre
DDAS	Database of Demining Accidents
DDG	Danish Demining Group
DPKO	Department of Peacekeeping Operations (UN)
EO	explosive ordnance
EOD	explosive ordnance disposal
FCDB	full costs of doing business
FSD	Swiss Foundation for Mine Action
GICHD	Geneva International Centre for Humanitarian Demining
GRH	Ground Reference Height
HALO Trust	Hazardous Areas Life-Support Organization
HDU	Humanitarian Demining Unit
IED	improvised explosive device
IMAS	International Mine Action Standards
IND	National Demining Institute (Mozambique)
ISO	International Standardization Organization
KFOR	Kosovo Protection Force
LIS	Landmine Impact Survey
LTTE	Liberation Tigers of Tamil Eelam
MAC	mine action centre
MAG	Mines Advisory Group

MAPA	Mine Action Programme for Afghanistan
MCRA	mine clearance risk assessment
MDD	mine detection dog
MMAC	Model Mine Action Centre
MRE	mine risk education
NGO	non-governmental organisation
NMAS	National Mine Action Standards
NPA	Norwegian People's Aid
NSCMA	National Steering Committee for Mine Action
PAR	post-clearance area reduction
POW	prisoner of war
PPE	personal protection equipment
QA	quality assurance
QC	quality control
QRA	quantitative risk assessment
RA	risk assessment
RCA	root cause analysis
RCAF	Royal Cambodian Armed Forces
REDS	Rake Excavation and Detection System
RM	risk management
SAG	Study Advisory Group
SHA	suspected hazardous area
SME	Subject Matter Expert
SON	Study of Operational Needs
SOP	standing operating procedure
SPLA	Sudan's People Liberation Army
TA	technical adviser
TRO	Tamil Relief Organisation
UK	United Kingdom
UN	United Nations
UNDP	United Nations Development Programme
UNMAS	UN Mine Action Service
UNOCHA	UN Office for the Coordination of Humanitarian Affairs in Afghanistan
UNOPS	United Nations Office for Project Services
UNTAC	United Nations Transitional Authority in Cambodia
US	United States
UV	ultra-violet
UXO	unexploded ordnance

Area excavation: in this report, the term "area-excavation" is used to describe the process of removing the entire ground surface to a predetermined depth, and locating any concealed mines or ERW in the process.

Detector-signal investigation: in this report, the term "detector-signal investigation" is used to describe the process of locating metal with a metal-detector, then unearthing and recovering that metal from a discrete location.

Ground Reference Height: a measure of electromagnetic disturbance from the ground. Conventionally made using a Bartington meter or other scientific device, the GRH can usefully be measured using old Schiebel metal detectors; this was done in most minefields studied.

Post-clearance area reduction (PAR): a formalised procedure for “reducing” remaining parts of a “suspect area” after mine-belts have been located and removed. A twist on the conventional concept of area reduction, PAR involves reducing the originally suspect area as work progresses and the placement of mines becomes clear. Some of the originally suspect area may not be cleared, but will instead be declared to be “No Known Risk” and released to the community after fully informed area-reduction. Area reduction can only be fully informed after the suspected mine-belts have been located (and where mine-belts are the anticipated threat).

Rake Excavation and Detection System (REDS), as devised by NPA with the HDU in Sri Lanka.

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

Geneva International Centre for Humanitarian Demining
7bis, avenue de la Paix
P.O. Box 1300
CH - 1211 Geneva 1
Switzerland
Tel. (41 22) 906 16 60, Fax (41 22) 906 16 90
www.gichd.ch