Defence Research and Development Canada
Recherche et développement pour la défense Canada

MineWolf Tiller Test and Evaluation

W.C. Roberts and J.L. Eagles

Defence R&D Canada

Technical Report

DRDC Suffield TR 2007-164

November 2007

MineWolf Tiller Test and Evaluation

W.C. Roberts and J.L. Eagles
Defence R&D Canada – Suffield

Canadian Centre for Mine Action Technologies

Le Centre canadien des technologies de déminage

Defence R&D Canada – Suffield

Technical Report
DRDC Suffield TR 2007-164
November 2007

Author

William Roberts

Approved by

Dr Chris Weickert

Director, Canadian Centre for Mine Action Technologies

Approved for release by

Dr. P. D'Agostino

Chair, Document Review Panel

© Her Majesty the Queen as represented by the Minister of National Defence, 2007

© Sa majesté la reine, représentée par le ministre de la Défense nationale, 2007

Abstract

A test of the MineWolf tiller (which is part of the MineWolf tiller and flail system) was performed in a cooperative International Test and Evaluation Program trial in September 2006 at the Croatian Mine Action Center (CROMAC) Centre for Testing, Development, and Training (CTRO). Canada and Croatia cooperated to conduct these trials. The project was conducted in accordance with the methodology specified in the European Committee for Standardisation (CEN) Workshop Agreement 'CEN Workshop Agreement 15044; Test and Evaluation of Demining Machines' available at the International Test and Evaluation Website (www.itep.ws).

Résumé

On a effectué un essai, en septembre 2006, sur le sarcleur MineWolf (une composante du système du sarcleur MineWolf et du fléau), durant un essai coopératif du Programme international d'essais et évaluation, au Centre d'action antimines Croate (CROMAC) d'essais, de développement et de formation. Le Canada et la Croatie ont conduit ces essais en coopération. Le projet a été conduit conformément à la méthodologie spécifiée par « l'Accord du groupe de travail 15044 du Comité européen de normalisation (CEN); Essais et évaluations des machines de déminage » disponible sur le site Web d'Essai et évaluation internationaux (www.itep.ws).

This page intentionally left blank.

Executive summary

Canada and Croatia, as test partners, conducted a performance trial of the MineWolf tiller, a mine clearance machine certified for use in Croatia. The project was sponsored by the International Test and Evaluation Program (ITEP), employed the methods outlined in the 'CEN Workshop Agreement 15044; Test and Evaluation of Demining Machines' and was held in September 2006 at the Croatian Mine Action Centre (CROMAC) near Karlovac, Croatia. The MineWolf Machine is provided with both tiller and flail attachments to be used as part of a System, interchangeable dependent upon conditions. Only the MineWolf with the tiller attachment was evaluated for this report due to testing resource limitations.

Three different soils – compacted sand, compacted gravel and compacted topsoil – in parallel test lanes were used in these trials. Wirelessly Operated Reproduction Mines (WORMs), developed by the Canadian Centre for Mine Action Technologies (CCMAT) at three different depths of burial – 0 cm, 10 cm and 15 cm – provided the major test markers.

The machine had sufficient power for the task of ground penetration. In addition, the tiller configuration removes the possibility of the type of skip zones experienced by a chain flail where the hammers are free to move laterally. While a flail may experience skip zones around harder pieces of ground or rocks, the tiller cannot. While the entire tiller head must move up if the ground cannot be penetrated, the manufacturer claims that this can be monitored and corrected by the operator.

The depth control on the MineWolf appears to be effective ***when used***.

The overall effectiveness of the MineWolf would likely have been higher with a lower forward speed. The average speed for these trials was 956 m/hr, which may be adequate to prepare the soil for follow-on operations, but should be reduced for 'clearance' operations.

The MineWolf is a capable machine that displayed good but not exceptional performance, likely due to some relatively minor and easily fixed problems. Correcting the problems with the mechanical vulnerability of the depth control system will allow this feature to be employed by the user. Changing the operator training and understanding of the importance of maintaining a lower forward speed should also improve performance.

Roberts, W.C., and J.L. Eagles (2007). MineWolf Tiller Test and Evaluation. (DRDC Suffield TR 2007-164). Defence R&D Canada – Suffield.

Sommaire

Le Canada et la Croatie ont conduit, en partenariat, un essai de rendement sur le sarcleur MineWolf, une machine de déminage, homologuée pour la Croatie. Le projet était organisé par le Programme international d'essais et évaluations (PIEE) et employait les méthodes soulignées dans « l'Accord du groupe de travail 15044 du CEN**;** essais et évaluation de machines de déminage » et a eu lieu en septembre 2006, au Centre antimines Croate (CROMAC), près de Karlovac en Croatie. Un sarcleur ou un fléau peut être attelé à la machine MineWolf et peut être utilisé comme composante d'un système interchangeable selon les conditions. Les ressources étant limitées, on a seulement évalué le sarcleur attelé au MineWolf.

On a utilisé trois sols différents durant ces essais : le sable compacté, le gravier compacté et la couche arable compactée, dans des voies d'essais parallèles. Des mines de substitution opérées par le réseau sans fil et mises au point par le Centre canadien de technologie de déminage (CCTD) ont servi de repères principaux, à trois profondeurs différentes : 0 cm, 10 cm et 15 cm.

La machine avait suffisamment de puissance pour effectuer la tâche de pénétration du sol. De plus, la configuration du sarcleur annule la possibilité de zones non couvertes produites par la chaine du fléau dont les marteaux peuvent se déplacer latéralement. Le fléau peut produire des zones non couvertes autour des morceaux de sol plus dur ou de roches mais le sarcleur ne peut pas. Il faut que la tête entière du sarcleur se déplace vers le haut quant le sol ne peut pas être pénétré et le manufacturier affirme que ceci peut être surveillé et corrigé par l'opérateur.

Le contrôle de la profondeur du MineWolf semble efficace ***quand on l'utilise***.

L'efficacité générale du MineWolf aurait sans doute été supérieure avec une vitesse de marche avant plus lente. La vitesse moyenne durant ces essais était de 956 m/h, ce qui est adéquat pour préparer le sol des opérations de suivi mais elle devrait être réduite pour les opérations de « déminage. »

Le MineWolf est une machine efficace faisant preuve d'un bon rendement qui n'est toutefois pas exceptionnel, à cause de problèmes relativement mineurs, pouvant être facilement résolus. La correction des problèmes de vulnérabilité mécanique du système de contrôle de la profondeur permettra à l'utilisateur d'employer cette caractéristique. Des changements relatifs à la formation de l'opérateur et comprendre l'importance de maintenir une vitesse plus lente, en marche avant, devrait aussi améliorer le rendement.

Roberts, W.C., and J.L. Eagles (2007). MineWolf Tiller Test and Evaluation. (DRDC Suffield TR 2007-164). R & D pour la défense Canada – Suffield.

Table of contents

List of figures

List of tables

Acknowledgements

Any trial of this type takes a significant investment of time and resources, much of which occurs in the background. Administration and a host of logistic support issues must all be handled effectively for a trial to take place successfully. Additional CTRO personnel, while not listed by name, played a crucial, if largely unseen, role in the trial.

This page intentionally left blank.

1. Introduction

With Canada and Croatia as test partners, an International Test and Evaluation Program (ITEP) sponsored trial of the MineWolf tiller was conducted. The project was guided by the methodology outlined in ‘CEN Workshop Agreement 15044; Test and Evaluation of Demining Machines’ available at the International Test and Evaluation Website (www.itep.ws).

From 8-13 September 2006, the MineWolf tiller was tested at the Croatian Mine Action Center (CROMAC) for Testing, Development, and Training (CTRO) facilities outside of Karlovac, Croatia. The machine and operator were provided by MKA Demining, a demining company based in Croatia and conducting operations throughout the Balkans. Only a performance test was conducted since this machine is already certified for use in Croatia and survivability tests had already been performed by CTRO and the German Federal Armed Forces Technical Center for Weapons and Ammunition.

The MineWolf machine is available with both a tiller or flail attachment. As the flail is not commonly used in Croatia by MKA Demining, and due to testing resource limitations, it was agreed that only the tiller would be evaluated. MKA Demining has both the flail and tiller attachments, but has used the tiller attachment for a significantly larger area than the flail.

An overall description of the test facilities, the test targets and the test methods is given in Annex A. This information is relevant to almost any machine tested at this site. It is summarized briefly in Section 3 along with information that is specific to this particular evaluation of the MineWolf. Annex B provides descriptive information about the machine and contact information for the manufacturer.

Annex C contains representative photographs taken during the performance and survivability tests, and the test data sheets used during the trial are reproduced in Annex D.

2. Machine Description

2.1 MineWolf Tiller

The MineWolf tiller is reported to weigh 25.5 tonnes. It has an overall width of 3.48 metres and an active width (the width across the ground engaging section of the tiller head) of 2.8 metres. A machine this size is generally classed as a heavy machine. Figure 1 and Figure 2 provide general views of the MineWolf and the tiller head.

The machine is equipped with a Deutz diesel engine rated at 270kW (367hp). The tiller head is fitted with 72 chisels along a shaft rotating at up to 480 rpm. The chisels are arranged around the shaft on 12 plates.

Figure 1. *MineWolf tiller*

A remote control system is available for the MineWolf to enable operation from a distance, however the operator is generally inside the armoured cab. Tests carried out by the German Federal Armed Forces Technical Center for Weapons and Ammunition WTD 91 [1] indicated that the operator experienced no injury from a variety of anti-tank mine detonations under the tiller or flail.

Annex B contains a brochure from the manufacturer describing the MineWolf in detail.

Figure 2. *MineWolf Tiller Head*

3. Trial Description

3.1 Test Team

The core of the trial team for this portion of the project included the following personnel:

- Canada – William Roberts (CCMAT); Les Eagles (CCMAT)
- Croatia – Ivan Steker (CTRO); Tomislav Blašković Vondraček (CTRO)

3.2 Trial Conditions

The MineWolf Tiller trials were conducted using the techniques and procedures specified in CWA 15044. Mine targets were placed at three depths in each of three prepared soil conditions. The burial depths were 0cm, 10cm, and 15cm. The three soil conditions were sand, gravel, and a local topsoil. Three fiberboards were placed across each of the nine test lanes at the start, middle, and end of the test section in order to determine the digging profile of the machine at these intervals.

CCMAT has developed a type of target called the Wirelessly Operated Reproduction Mine (WORM) that was used for these trials. Additional detail on these test targets is provided in Annex A . These test targets were evaluated based on four categories; ‘live,’ ‘live damaged,’ ‘mechanically neutralised,’ and ‘triggered.’

As it takes special skills and experience to operate a machine properly, it is appropriate to have a qualified operator from the manufacturer or end user rather than having the machine operated by a member of the test team. Typically the machine operator will be told what the tests will involve (speed, depth, neutralization rate, skip zones, etc), and will be asked to operate the machine in the manner necessary to achieve the best results. It is expected that a competent, experienced operator will be able to use the necessary judgement to achieve the balance between these factors for the desired ‘best’ results. In this case the operator was provided by MKA Demining, and the instructions would have reflected the practice described.

A complete description of the test areas, the facilities and tools, and the test procedures can be found in Annex A.

A summary of soil conditions for the MineWolf tiller test are shown in Table 1.

Table 1. Trial soil conditions.

SERIES	DATE	LANE & SAMPLE	WORM DEPTH OF BURIAL	MOISTURE %	WET DENSITY KG/M³	DRY DENSITY KG/M³
1	07-Sep-06	gravel	10cm	4	2731	2621
2	07-Sep-06	gravel	10cm	4	2653	2541
3	07-Sep-06	gravel	10cm	3	3140	3035
4	07-Sep-06	sand	10cm	8	2312	2144
5	07-Sep-06	sand	10cm	7	2336	2176
6	07-Sep-06	sand	10cm	7	2500	2333
7	8-Sep-06	topsoil	10cm	16	2120	1832
8	8-Sep-06	topsoil	10cm	16	2055	1765
9	8-Sep-06	topsoil	10cm	17	2135	1830
10	11-Sep-06	sand	15cm	7	2019	1890
11	11-Sep-06	sand	15cm	8	1817	1688
12	11-Sep-06	sand	15cm	8	1900	1759
13	11-Sep-06	gravel	15cm	5	2444	2335
14	11-Sep-06	gravel	15cm	5	2413	2307
15	11-Sep-06	gravel	15cm	4	2646	2542
16	11-Sep-06	topsoil	15cm	14	2108	1850
17	11-Sep-06	topsoil	15cm	15	1512	1315
18	11-Sep-06	topsoil	15cm	13	1473	1298

4. Test Results

4.1 Effects Against Mine Targets

This section summarizes the performance of the machine as tested using the mine targets. In addition to simply tabulating numbers, the data is given a statistical treatment as recommended by the CEN Workshop Agreement.

4.1.1 Tabular Data and Explanations

Table 2 shows the number of mines triggered, mechanically neutralised, live damaged, or live at each depth, and in each soil condition. This table also indicates the number of untriggered fuzes which were found separated from their main charges. The notes following the table provide additional, amplifying information for each case.

The aggregate neutralisation effectiveness (triggered and mechanically neutralised) is shown in Table 3.

The worst performance achieved is 41/50 at 15cm in sand. The reasons for the poorer performance in these conditions were not fully examined during these trials. The manufacturer indicated awareness of this issue and has increased the tiller rotation speed for operation in sand conditions such as Jordan and United Arab Emirates.

Table 2. *Mine Target Results Summary*

Soil Type	Depth (cm)	Emplaced	Triggered	Mechanically Neutralized	Live Damaged	Live
sand	0	50	32	12	4	2
sand	10	50	35	8	2	5
sand	15	50	38	3	3	6
gravel	0	50	26	18	4	2
gravel	10	50	37	8	4	1
gravel	15	50	45	5	0	0
topsoil	0	50	34	13	3	0
topsoil	10	50	43	4	0	3
topsoil	15	50	47	3	0	0

This material is taken from the data sheets contained in Annex D. There were 50 targets in each test condition.

Table 3. Mine Targets Neutralized

Soil Type	0 cm	10 cm	15 cm
Sand	44/50	43/50	41/50
Gravel	44/50	45/50	50/50
Topsoil	47/50	47/50	50/50

This material is taken from the data sheets contained in Annex D. This table includes mines both mechanically neutralized and triggered. There were 50 targets in each test condition.

4.1.2 Statistical Treatment of Data

As limited numbers of test targets were employed for these types of trials, some variation between the apparent performance and field performance with a large number of mines will occur. That the machine test results are merely an estimate of the actual performance of the machine is suggested by Figure 1 of the CEN Workshop agreement. A statistical analysis using the binomial distribution was conducted to provide some indication of the confidence with which these results could be interpreted. Note that a significance level of 5% was used. This means that if two machines are found to have a statistically similar (or different) performance, there is a 95% probability that this is the case.

Since a relatively small number of test targets were used in each condition, machines with different measured performance may not be statistically different. This can be illustrated intuitively by comparing a machine that neutralised 3/3 test targets (100%) and a machine that neutralised 950/1000 test targets (95%). While the machine that neutralised 100% (3/3) of the test targets appears to have been more effective, clearly the user would need significantly more data to assess the potential performance of this machine.

To aid in understanding the confidence with which the MineWolf results can be interpreted, the confidence intervals are shown in Figure 3. The upper and lower confidence intervals illustrate the anticipated range of the actual performance of the machine. Note that the upper and lower boundaries of the confidence interval shown on the graph are valid for sets of 50 test targets only.

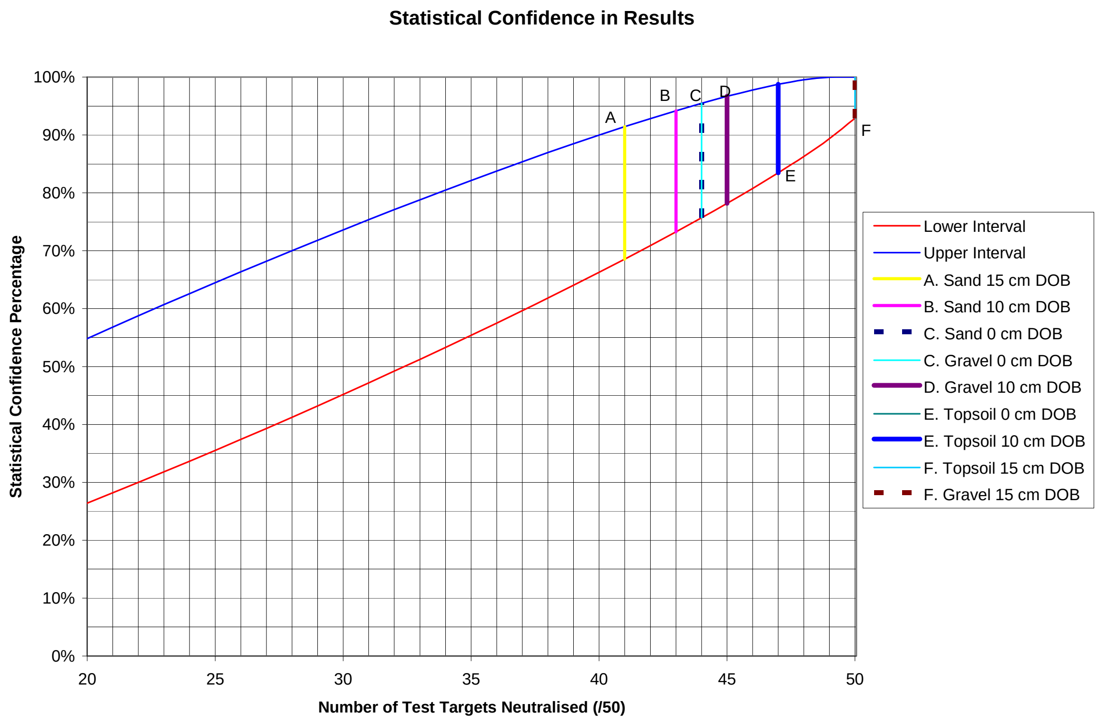

Figure 3. *Performance Data – Statistical Treatment*

To illustrate the interpretation of Figure 3, consider the data for gravel or sand at 0cm DOB (44/50). You can state that there is a 95% probability that the actual performance of the machine in sand and gravel at 0cm DOB lies between 76% and 96%.

There is often a desire to compare machines based on their performance data. Comparing the overall number of neutralised mines out of 450 total test targets does not provide useful or meaningful comparison. The results for each condition must be examined independently. The graph shown in Figure 4 has been prepared to assist in this evaluation. For each condition, Figure 4 can be used in the following way:

- For the machine which apparently has the better performance, enter the test number of mines triggered/neutralized out of 50 on the horizontal axis and draw a line vertically upward.
- For the machine which apparently has the worse performance, enter the test number of mines triggered/neutralized out of 50 on the vertical axis and draw a line horizontally to the right.

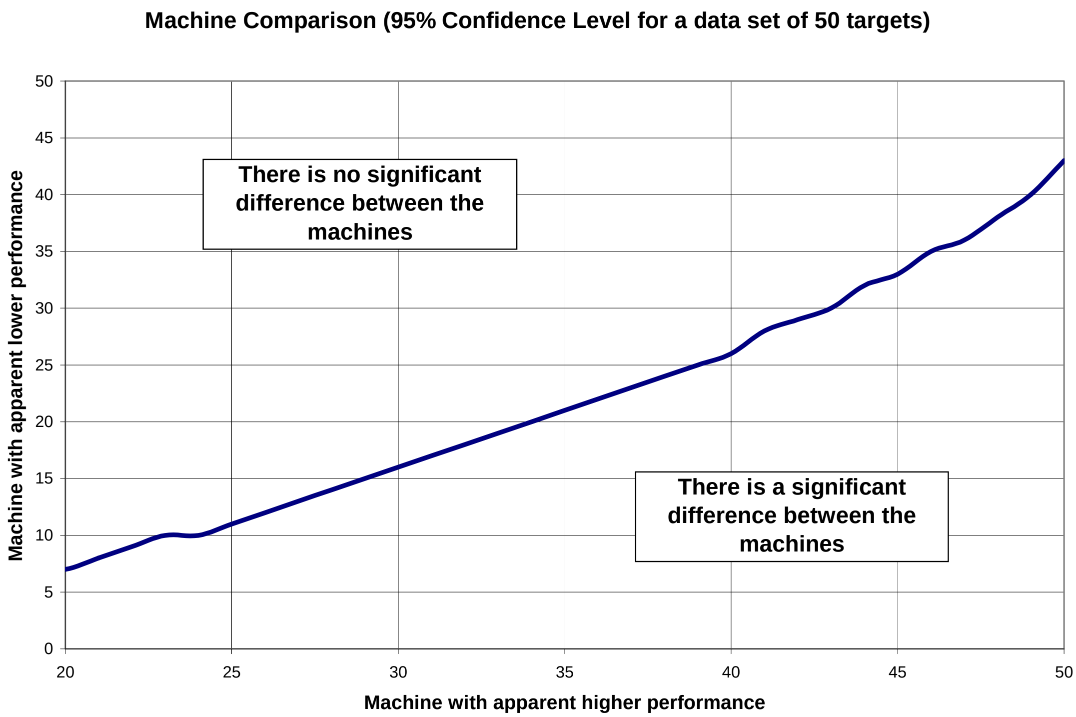

Figure 4. *Machine Comparison Based on Performance Data*

- If the two lines meet *above* the thick blue curve, there is a 95% probability that there is *no* significant difference between the performance of the two machines for that soil and depth condition. If the two lines meet *below* the thick blue curve, there is a 95% probability that there *is* a significant difference between the two machines. For example, a machine that neutralises 40/50 test targets in a particular test condition is not significantly different from a machine that neutralises 27/50 test targets in those same test conditions.

4.1.3 Debris and Scatter

When a machine such as the MineWolf engages a mine target it may leave the mine in a number of different conditions. As described in Annex A, the target may be left intact and fully functional or it may be intact but damaged. It may be lightly damaged or completely broken apart. Finally, it may be triggered, leaving only a 'smoking hole' with a scattering of inert debris.

After each test in the series, the test lanes were searched as described above, and the materials of interest were assembled and inspected. The study of debris was required in order to account for the status of mines that were not triggered. Materials of interest ranged from parts of WORM targets to nearly complete WORMs to completely intact and unaffected WORMs having their inert main charge intact.

The images in Figure 5 through Figure 13 show some of the debris collected following each trial. The test data sheets contained in Annex D describe the status of each WORM target. The reader is invited to draw his or her own conclusions about the type of the debris left in and around the area where the MineWolf has been used.

Mechanically neutralised

Mechanically neutralised

Figure 5. *Debris of Interest – Gravel, 0cm DOB*

Live damaged

Mechanically neutralised

Live damaged

Figure 6. *Debris of Interest – Gravel, 10cm DOB*

unknown serial thrown outside
of test lane

Live damaged

Figure 7. *Debris of Interest – Gravel, 15cm DOB*

Triggered (same target)

Triggered | Mechanically neutralised

Mechanically neutralised | Live damaged

Figure 8. *Debris of Interest –Sand, 0cm DOB*

Live damaged Live

Figure 9. *Debris of Interest – Sand, 10cm DOB*

Triggered

Mechanically neutralised

Triggered

Triggered

Triggered

Figure 10. *Debris of Interest – Sand, 15cm DOB*

Live damaged Triggered

Triggered General debris from trial

Figure 11. *Debris of Interest – Topsoil, 0cm DOB*

Live | Triggered

Triggered | Triggered

Figure 12. *Debris of Interest – Topsoil, 10cm DOB*

Triggered

Mechanically neutralised

Triggered

Figure 13. *Debris of Interest – Topsoil, 15cm DOB*

Many other targets and target fragments were recovered from the test lanes; the photos above only provide an indication of the type of debris remaining. The MineWolf did move some of the targets from their emplaced positions, generally pushing them forward of the machine. There was some scattering of test targets to the sides of the test lane but this was a minor problem compared to the debris scatter normally encountered from a flail.

Along with the items shown above, remains from the targets which were completely destroyed could be found in and around the test lanes. Although not as vigorous in throwing debris as a conventional chain flail, the MineWolf is prone to throwing soil, mine fragment debris, and potentially vegetation (see Figure 14) to a limited extent.

Figure 14. *Debris Thrown from Tiller After Processing*

4.2 Depth and Consistency of Penetration Across The Path

4.2.1 General

As described in Annex A, fibreboards were used to measure the depth and consistency of penetration across the path of the vehicle. Note that the grid on the paper behind the fiberboard in each of the photographs measures 2cm x 2cm. For situations where most of the fiberboard is missing, the photograph was taken from a shorter distance; the grid in the background is still 2cm x 2cm.

4.2.2 Depth and Consistency of Penetration in Sand

The fibreboards in Figure 15, Figure 16 and Figure 17 show an even depth penetration of 12cm or deeper. The fibreboards for the test lane at 10cm show the poorest performance; the remainder of the test lanes show digging to at least 30 cm and 26 cm where the test targets were at 0cm and 15cm respectively. There is no other apparent evidence of skip zones or lateral inconsistency in this test.

Only one out of three boards for both the 0cm and 15cm test lanes were intact. The other two boards in each test lane were only partially recovered as the machine dug deeper than the entire depth of the fibreboards.

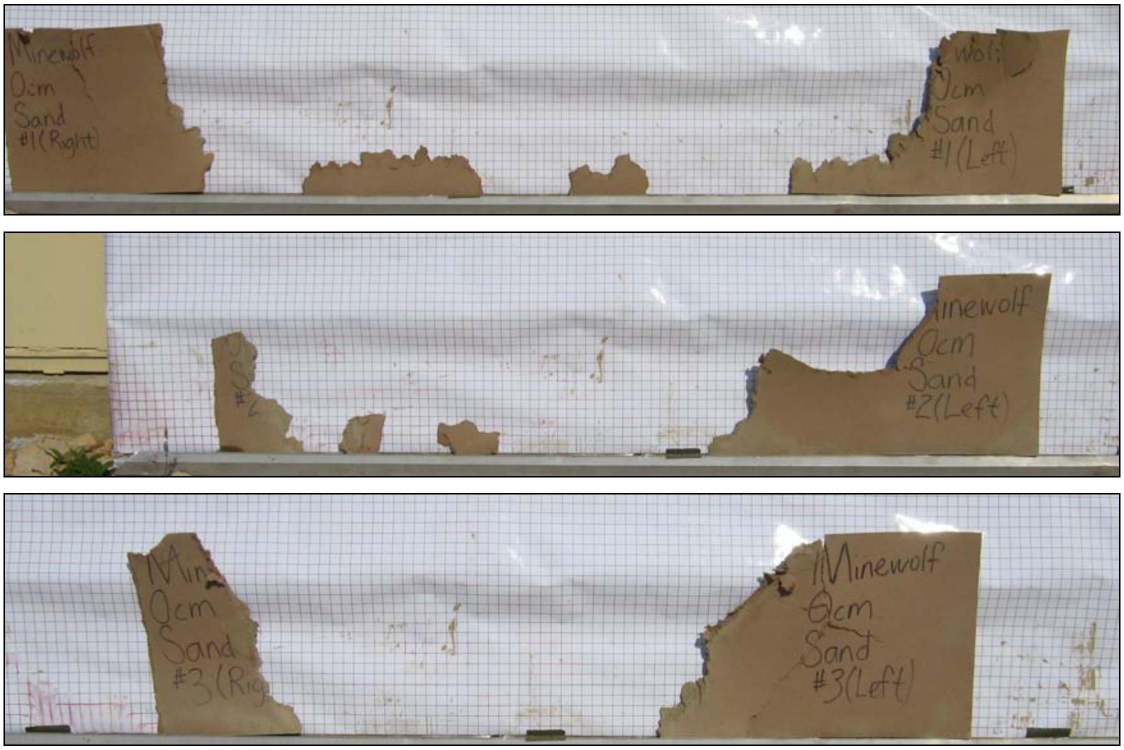

Figure 15. *Depth of Penetration in Sand with mines at 0 cm DOB*

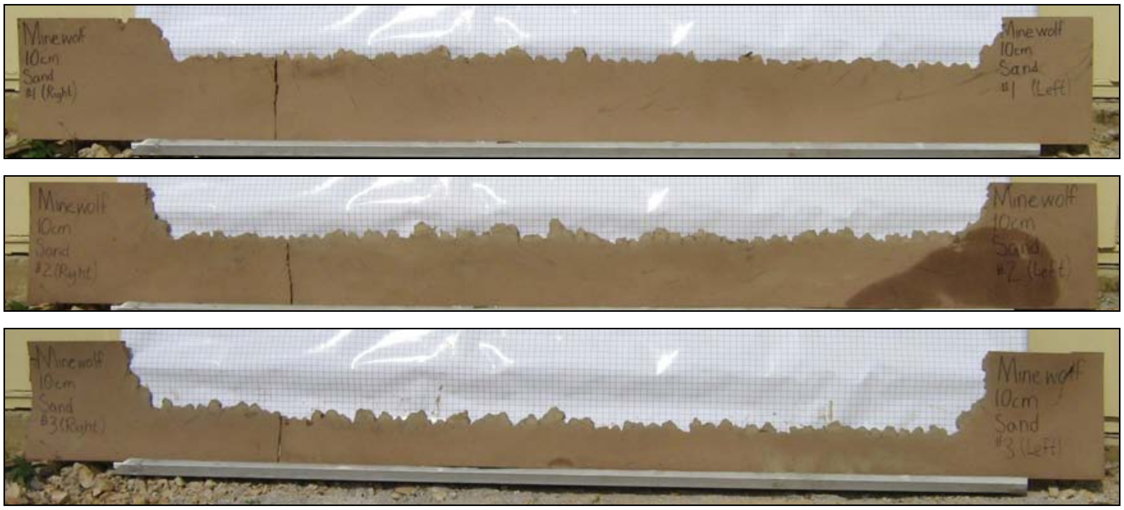

Figure 16. *Depth of Penetration in Sand with mines at 10 cm DOB*

Figure 17. *Depth of Penetration in Sand with mines at 15 cm DOB*

4.2.3 Depth and Consistency of Penetration in Gravel

The fibreboards in Figure 18, Figure 19 and Figure 20 show an even depth penetration of 14cm or deeper. As with the sand, the test lane with the targets buried at 10cm showed the least penetration, with the 0cm and 15cm test lanes recording 24cm and 30cm penetration respectively. There is no other apparent evidence of skip zones in this test.

Similar to the sand test lanes, only one out of the three boards in each of the 0cm and 15cm test lanes were recovered intact. Again the machine dug deeper than the boards.

Figure 18. *Depth of Penetration in Gravel with mines at 0 cm DOB*

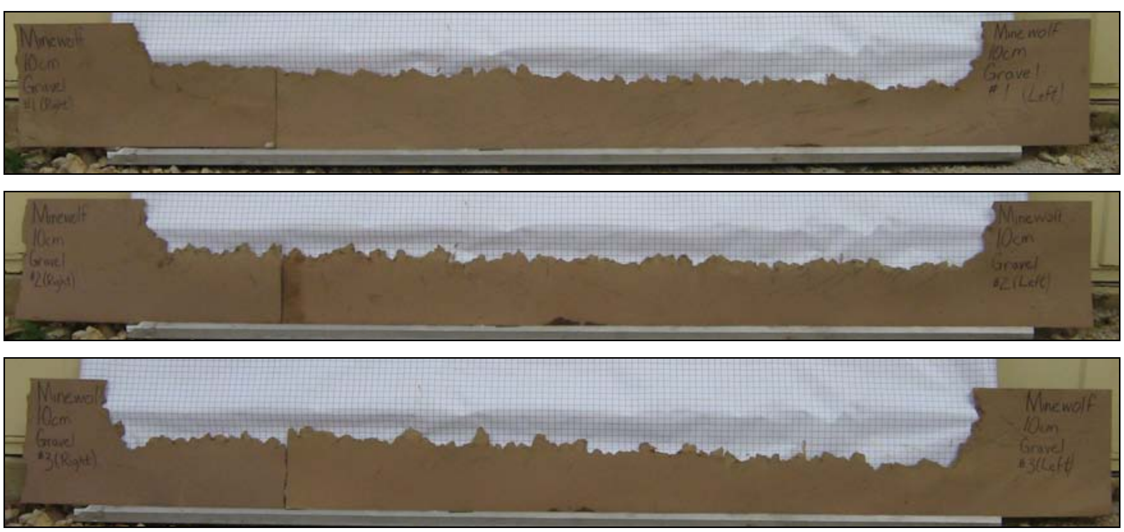

Figure 19. *Depth of Penetration in Gravel with mines at 10 cm DOB*

Figure 20. *Depth of Penetration in Gravel with mines at 15 cm DOB*

4.2.4 Depth and Consistency of Penetration in Topsoil

The fibreboards in Figure 21, Figure 22 and Figure 23 show an even depth penetration of 16cm or deeper. As with the sand and gravel, the test lane with the targets buried at 10cm showed the least penetration, with the 0cm and 15cm test lanes recording 30cm and 28cm penetration respectively. There is no other apparent evidence of skip zones in this test.

Unlike the sand and gravel test lanes, all of the fiberboards were recovered intact and the depth of penetration could be seen on all of the fiberboards.

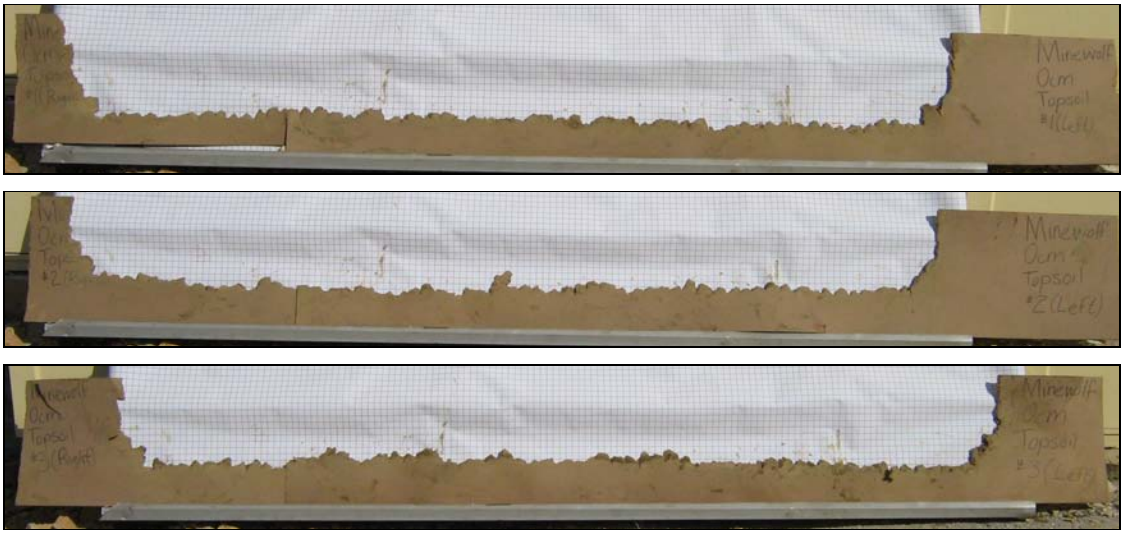

Figure 21. *Depth of Penetration in Topsoil with mines at 0 cm DOB*

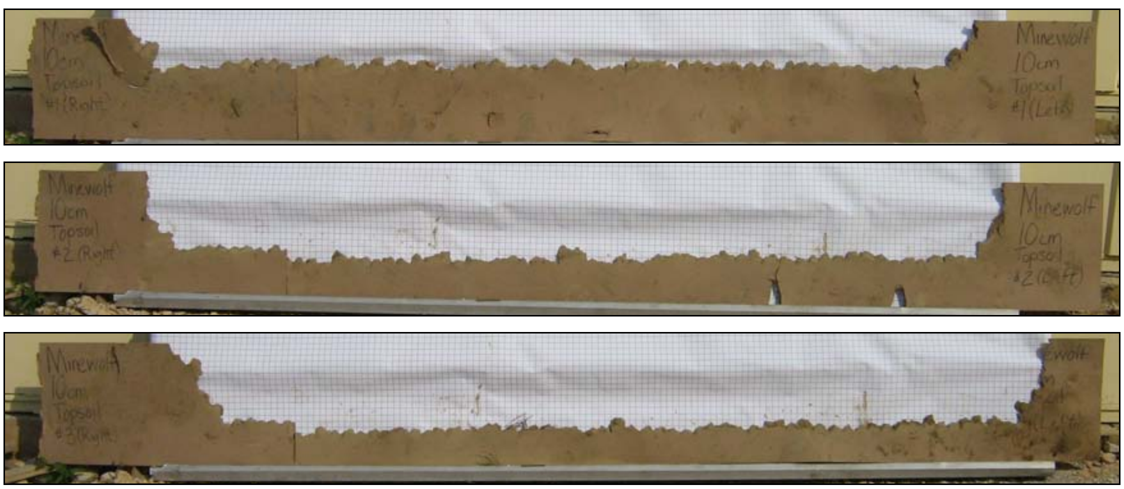

Figure 22. *Depth of Penetration in Topsoil with mines at 10 cm DOB*

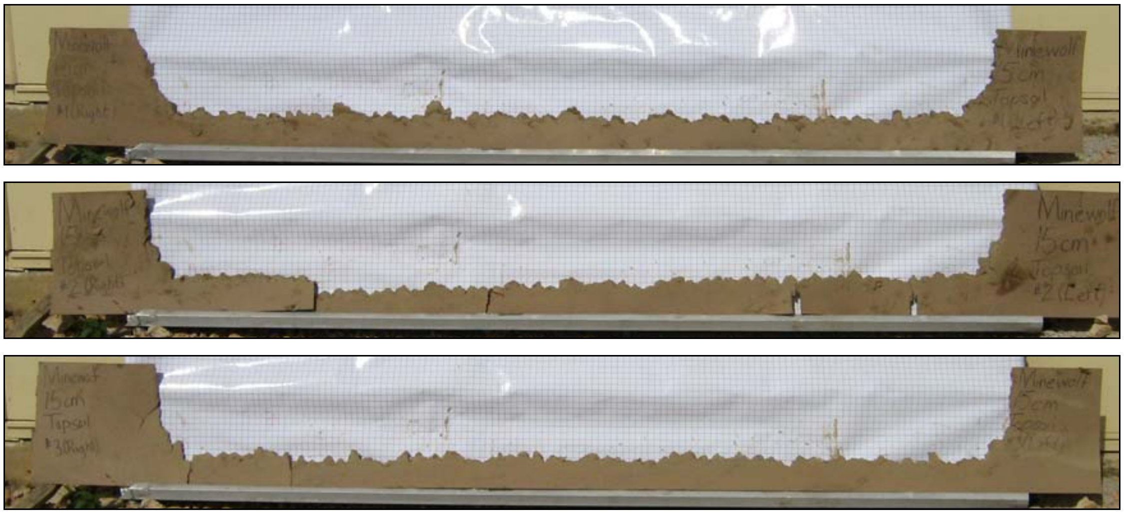

Figure 23. *Depth of Penetration in Topsoil with mines at 15 cm DOB*

4.2.5 Depth and Consistency of Penetration – Discussion

Based on the photographic evidence in the previous sections, the following points may be made.

4.2.5.1 Sand

The machine was able to penetrate consistently and uniformly to a depth of 12cm or greater in the sand conditions used in these tests. There was no evidence of skip zones in the sand.

4.2.5.2 Gravel

The machine also was able to penetrate consistently and uniformly to a depth of 14cm or greater in the gravel conditions used in these tests. Again, there was no evidence of skip zones.

4.2.5.3 Topsoil

The machine also was able to penetrate consistently and uniformly to a depth of 16cm or greater in the topsoil conditions used in these tests. Again, there was no evidence of skip zones.

4.2.5.4 General

Clearly the digging depths achieved were less than what has been observed from machines of this weight class and power. The results for the test lanes with the targets at 10cm were the worst; if these results are excluded, the machine successfully penetrated to a minimum depth of 24cm in the remaining test lanes. The relatively poor penetration for the 10 cm targets could be attributed to one of the following factors:

- The test lanes with targets at 10cm were the first lanes completed; the operator may have been adjusting to the soil conditions in the test lanes for the first lane in each soil condition.

- The machine operator's technique for dealing with targets at 10cm may have been to dig the machine to 10cm rather than a depth appropriate for targets of unknown depth. It is peculiar that the digging depth for the test lanes with targets at 10cm all experienced the least penetration in each soil condition.

- The machine may have been operated with a forward speed too high for the soil conditions. The forward speeds for all of the test lanes were significantly higher than what would normally be effective for a flail of a similar size.

4.3 Depth Consistency Along the Path

Although an automatic depth control system is available for the MineWolf, it was not installed until the final test lane for the topsoil with test targets at 0cm. MKA does not use the automatic depth control as they find that the perceived 'efficiency' of the machine is higher with the operator manually controlling the depth and anticipating the required machine control. In addition, MKA stated that the depth control sensing skids were prone to damage in environments with vegetation.

The difference in surface soil profile following the passage of the machine with and without automatic depth control is interesting to note (Figure 24). The differences are quite significant as terrain which was originally flat and level shows a sinusoidal pattern following the passage of the machine without automatic depth control. The photograph shown in Figure 24 has terrain undulations in excess of 15cm after the passage of the MineWolf without depth control over almost completely flat terrain. This is corroborated by the videos taken of the trials that clearly show the tiller head moving up and down by what appears to be 15cm. Conversely, the soil surface following the passage of the MineWolf with automatic depth control is quite flat with no significant undulations.

The following sequence of events, repeated as the machine progresses along the track, may explain this phenomenon:

1. A small increase in ground height is experienced by the tiller head.

2. As the tiller head digs into the slightly higher ground, more soil is pushed behind the tiller head.

3. The tracks of the MineWolf climb up onto the slightly higher pile of soil, causing the front of the machine and thus the tiller head to lift.

4. As the MineWolf descends the rise created from the higher pile of soil, the tiller head digs in more, resulting in a larger pile of soil behind the tiller head as in (1) above.

The cycle listed above in Steps 1 to 4 repeats itself along the length of the test lane. Since there is no sudden increase or decrease in the height of the ground or tiller head, the operator has no indication that this sequence is occurring. A long, gentle, sinusoidal pattern is created in the surface of the ground following the passage of the tiller, presumably resulting in a similar trend in the maximum digging depth of the machine. Even if the operator is able to recognize that the undulation is occurring, any correction will likely exacerbate the problem as the machine will be on a different part of the undulating pattern than the working head.

Figure 24. *Terrain After Passage Of MineWolf Without (Left) and With (Right) Automatic Depth Control*

Consider now a real-world situation in which the ground is not virtually flat but where terrain irregularities are present. In this case the vehicle will be pitching and rolling enough that it will be impossible to notice small depth changes occurring. Add vegetation, dust or other obstacles to the operator's view of the tiller head, and the situation becomes even more difficult. After the machine has passed, the natural terrain irregularities will make it impossible to detect the depth variations caused by this phenomenon. Of course, it is in this real world situation with natural terrain irregularities that the ability to follow those irregularities is critical.

Figure 25. *Automatic Depth Control Hardware*

With the automatic depth control system, the tiller head is kept at a relatively constant height with respect to the original ground surface. The small skis outboard and on each side of the tiller head shown in Figure 25 provide a ground height signal to control depth of cut. The control system proved effective at eliminating the sinusoidal pattern of the ground resulting from manually controlling tiller depth. This system was not tested in undulating terrain but is presumed to be effective for the reasons discussed above.

Clearly the depth control skis are quite open and may be exposed to damage from vegetation and blast in their current configuration. As a result, MKA reported that they do not routinely employ them. The incorporation of some sort of protection, particularly from vegetation from the front and side would probably help to alleviate this problem.

Although a thorough study was not conducted, this trial indicated that the use of the depth control system was desirable to increase the consistency of tiller head penetration.

4.4 Mobility

The mobility of the MineWolf was not directly tested during this trial series. The MineWolf did not have any problems moving around the test site.

4.5 Survivability Test

The CEN Workshop Agreement methodology calls for survivability testing using antipersonnel and/or antitank mines. Antipersonnel mines are required to test all machines for susceptibility to damage from normal operational conditions created by triggering of antipersonnel mines. Machines which are advertised for use against antitank mines are also required to be tested against antitank mine charges to ensure that they are able to absorb antitank mine blasts without undue levels of damage. Finally, any machine with a human operator onboard is required to be tested against antitank mines to ensure the safety of the operator.

According to the manufacturer, the MineWolf has been proven in over 8 million square metres of mechanical demining in Croatia, Bosnia, Jordan, and Sudan and has been certified for use against anti-personnel mines and anti-tank mines by the CROMAC and by the German Army. It was therefore agreed that the survivability of the machine had already been demonstrated and that there was no requirement to repeat this type of test.

4.6 Other Observations

4.6.1 Cab

The cab appeared to provide a good level of comfort for the operator, enabling him or her to operate the machine without experiencing significant fatigue. Visibility from the cab was sufficient to allow the machine to be operated effectively. However, a complete examination of human factors performance was not examined as a part of this study.

4.6.2 Logistics

The MineWolf is designed to be somewhat modular; the working tool (flail or tiller) is removable from the machine. In addition, the cab is removed from the prime mover to allow easier transportation.

A brief overview of the maintenance required on the MineWolf was provided by MKA and the manufacturer. The maintenance appears to be fairly straightforward and ease of maintenance was obviously considered during the design of the MineWolf.

4.6.3 Speed

The operator selected the speed based on what was felt to be the most appropriate for the conditions in the test lanes based on his experience in commercial operations. Average speeds were calculated by measuring the time to complete the 25m pass through the test area, and are shown below in Table 4. The speeds used during these trials were higher than typically expected for a ground-engaging machine of this size such as a flail by a factor of two or three. Although this machine is not a flail, the soil is processed in a similar way. The effectiveness and depth of penetration may have been somewhat improved with a lower forward speed. The high forward speed may cause the soil to be mixed by the tiller rather than pulverized, resulting in fewer mines being triggered or neutralised.

Table 4. *Speeds Achieved*

	0 CM DOB	10 CM DOB	15 CM DOB
	metres/hour	***metres/hour***	***metres/hour***
Sand	865	1364	1071
Gravel	811	769	1011
Topsoil	887	1071	756

4.6.4 Tiller Shroud Design

The tiller shroud design ensures that the most of the soil and other debris generated by the flail is thrown forward rather than up in the air. The more predictable nature of the tiller when compared to a chain flail means that there is less scattering of debris.

4.6.5 Debris Traps

The track of the MineWolf causes concern with respect to trapping potentially hazardous debris. Figure 26 shows the area under the track where one of the targets was found after a trial. Although this target had been neutralised, it is not difficult to imagine a situation where this could have been a hazardous piece of UXO or a live mine as not all of the targets were neutralised or triggered by the tiller. Modifying the profile of the structural members within the track system may help to eliminate this problem.

Figure 26. *Debris Collects Around Tracks*

4.6.6 Tiller Wear

Tiller tooth wear did not appear to be excessive following use on the test lanes, although total machine usage was less than one hour.

4.7 Manufacturer Comments

MineWolf has provided feedback to a draft version of this report. This response is contained in Annex E. Changes to the text of this report have been incorporated where appropriate.

Some of the recommended changes were not incorporated as this report deals only with the results of the effectiveness trials of the MineWolf Tiller as it was operated by MKA Demining. Observations about performance and operational techniques in other parts of the world or by other operators are not included in this report as they were not witnessed as part of this trial.

A certain amount of subjective assessment based on the experience of the trial personnel is necessary to provide the reader with a clear understanding of the performance and limitations of this equipment and those portions of the report were retained.

5. Conclusions and Recommendations

5.1 Positive Observations

The MineWolf tiller has many good characteristics and has a good history of usage. MKA reports that the MineWolf was used for approximately 2 million square meters in 2006 and between 0.8 and 1 million square meters in 2005. The machine is ruggedly built and has been designed for ease of use for the operator and ease of maintenance.

The machine had sufficient power for the task of ground penetration. In addition, the tiller configuration removes the possibility of the type of skip zones experienced by a chain flail where the hammers are free to move laterally. While a flail may experience skip zones around harder pieces of ground or rocks, the tiller cannot. The entire tiller head must move up if the ground cannot be penetrated, and this can be monitored and corrected by the operator.

5.2 Areas Requiring Attention

The depth control on the MineWolf appears to be effective ***when used***. Additional effort should be placed on making the depth control system sufficiently rugged that the user (MKA Demining in this case) does not remove it due to frequent damage.

The experience of the trial team suggests that the overall effectiveness of the MineWolf would likely have been higher with a lower forward speed. The average speed for all nine runs was 956 m/hr, which is quite high for a ground engaging machine with this size of engine and clearance width. The high forward speed may have caused the soil to be mixed rather than pulverized, reducing the overall mine triggering and neutralisation performance. This forward speed may be adequate to prepare the soil for follow-on operations, but a speed reduction for 'clearance' operations may require examination.

5.3 Recommendations

The MineWolf is a capable machine that displayed good but not exceptional performance in this trial, likely due to some relatively minor and easily fixed problems. Correcting the problems with the mechanical vulnerability of the depth control system will allow this feature to be employed by the user. Changing operator training and understanding of the importance of maintaining a lower forward speed should also improve performance.

6. References

1. Wagner, M. (2004). Final Report – MineWolf – Clearing of Live Mines. (WTD 91 – 300 – 143/04). German Federal Armed Forces Technical Center for Weapons and Ammunition WTD 91.

Annex A – Trial Description

The following material provides an overall description of the test facilities, the test targets and the test methods. This information is relevant to almost any machine tested at this site. It is summarized briefly in the main body of this report along with information that is specific to this particular machine evaluation.

Test Facilities and Tools

The CTRO test facilities outside of Karlovac, Croatia, have been used to test several pieces of equipment in recent years. This site includes three soil environments specifically for performance tests. Parallel test lanes 4m wide and 75m long provide compacted sand, compacted gravel and compacted topsoil. The sand and gravel lanes are easily replicated almost anywhere. As the characteristics of topsoil may vary from one location to the next, data from the topsoil lane may not be quite as repeatable.

The soil in each test lane was prepared as follows. Prior to a test the soil was loosened with a piece of ground engaging equipment, such as the flail or tiller under test. The soil was then levelled using a grader and compacted using the vibratory compacter as shown in Figure A-1. The soil compaction and moisture content were monitored to ensure consistent test conditions.

Figure A-1. *Soil Preparation – Grading and Compacting The Soil*

Figure A-2. *Soil Cone Penetrometer*

Soil Conditions

The maintenance of consistent soil conditions for each passage of the machine was critical to ensure that useful test data was collected. During the soil preparation operations, a cone pentrometer was used to determine the consistency of the soil. An example of a cone penetrometer is shown in Figure A-2. Cone index readings in excess of approximately 100 psi were considered acceptable to proceed with the trial as soil conditions with lower cone index readings would not be trafficable by a significant number of vehicles. Excessively low cone index readings generally occurred when the moisture content of the soil was very high; these test areas were left to dry until higher cone index readings were obtained.

Compaction and moisture content were measured using manual methods described in Annex C. Photographs of the soil drying are shown in Figure A-3. For each test lane, three samples were taken.

Figure A-3. *Soil Drying Using a Microwave*

Test Targets

The test targets used in this trial were developed by CCMAT to be a low cost, inert target suitable for use anywhere in the world. The Wirelessly Operated Reproduction Mine (WORM) system uses a small, low power radio frequency electronic transmitter board. The plastic body and trigger force (10-15 kg) have been designed to meet the specification in the CEN Workshop Agreement CWA 15044. A cut-away view of a WORM target is shown in Figure A-4.

When the trigger force is reached, the WORM sends out a 0.5 second signal consisting of a target-specific serial number repeated 200 times. This signal is received by a specialised receiver through a high-gain antenna, and recorded to a computer running Windows-based software. The target-specific serial number is permanently marked on the transmitter board as well as at several locations on the exterior of the plastic body.

Prior to burying the test targets, it was necessary to manually trigger each target in order of lane placement. This baseline test ensured that each target was functional and recorded the original order in which the targets are buried.

During the machine trial, signals from the triggered WORMs were recorded on the computer. Following the completion of that test lane by the machine, it was then necessary to recover the test targets. The key recovery priority was test targets from which no radio frequency signal was received. These targets were examined for further categorization.

Test targets that were mechanically damaged to the point of being non-functional were recorded as mechanically neutralised. Test targets that were damaged but still functional were recorded as live damaged. Occasionally, examination of the recovered target indicated that the target should have initiated based on damage to the switch or plunger, but no signal was received. These targets were recorded as neutralised. Test targets that were recovered intact, with no damage and from which no signal was received, were considered live.

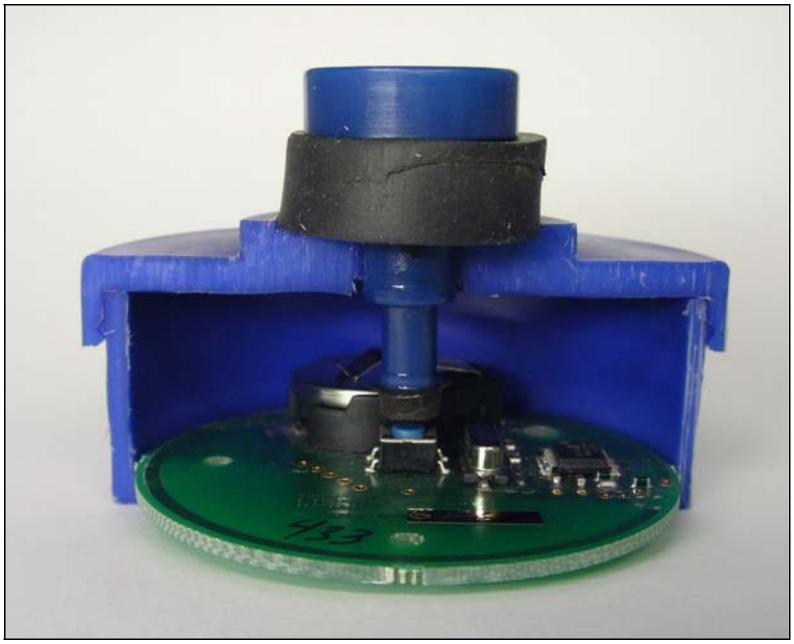

Figure A-4 *Cut-away View of WORM Test Target*

For the trial, 50 targets were buried at each depth, in each soil. Based on three depths in each soil type, this translated to 450 individual mine targets for a complete trial. To simplify the test procedures and data collection, each test comprised 50 targets, all at a single depth. Once that test was completed, another 50 targets were placed at a different depth or in a different soil.

The targets were located approximately 0.5m apart to minimize the possibility of more than one target triggering at once. They were laid in a path whose width was approximately 50% of the width of the machine working tool. In other words, a machine with a 2 metre wide tool would have targets spread approximately 0.5m on either side of the machine centreline, for a total path width of 1 metre. The layout of the test targets is shown in Figure A-6.

***Figure A-5**. WORM Antipersonnel Mine Surrogate*

***Figure A-6**. WORM Test Lane Layout*

Mine Target Burial

In all cases, the mines were buried as shown in Figure A-7. The depth of burial (DOB) was measured from the top surface of the mine (*not* the top surface of the fuze), to the ground surface. Hence, a burial depth of 0 cm is illustrated in Figure A-6. To minimize soil disturbance, a small hole was drilled with the tool shown in Figure A-8. The final hole was adjusted by hand and the target placed in the ground. Soil was then placed over top of the target to fill the hole and lightly packed to provide more realistic soil conditions.

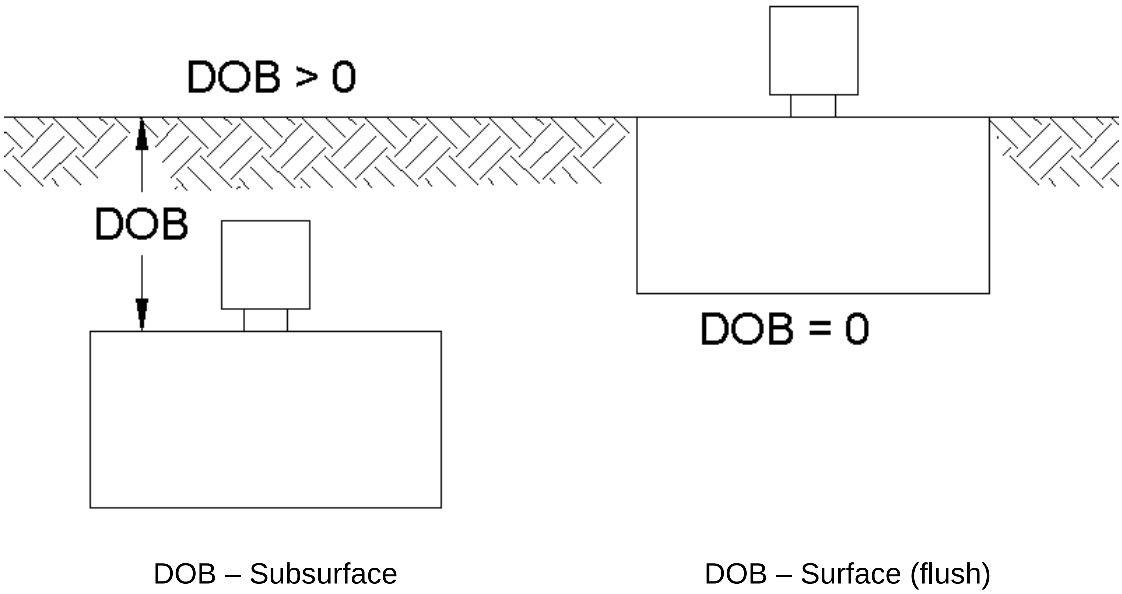

Figure A-7. *Depth of Burial For All Mine Targets*

Figure A-8. *Mine Target Burial Tool To Minimize Soil Disturbance*

Mine Target Level of Damage

In accordance with the CEN workshop agreement, the results of the tests against mine targets were evaluated as follows.

- Live, undamaged: Targets in this condition have not been damaged in any way, and remain fully functional.

- Damaged, functional: Targets in this condition have been damaged by the machine but remain functional. This could include mines which have had part of the main explosive charge broken away, but where the fuze/initiation train remain attached to remaining explosive material.

- Mechanically neutralised: Targets in this condition have not been triggered, but have been broken apart to the point where they can no longer function. This may be as simple as having removed an intact, functional fuze from an intact mine body, or it may be a complete mechanical shredding of all components of the mine and fuze.

- Triggered: Mines in this category are known to have been triggered by the machine. The electronic record captured by the computer and those recovered WORMs from which no signal was received that have an obvious indication of the plunger impacting the switch are in this category.

The flow-chart in Figure A-9 illustrates the criteria used to evaluate the status of each WORM following a trial.

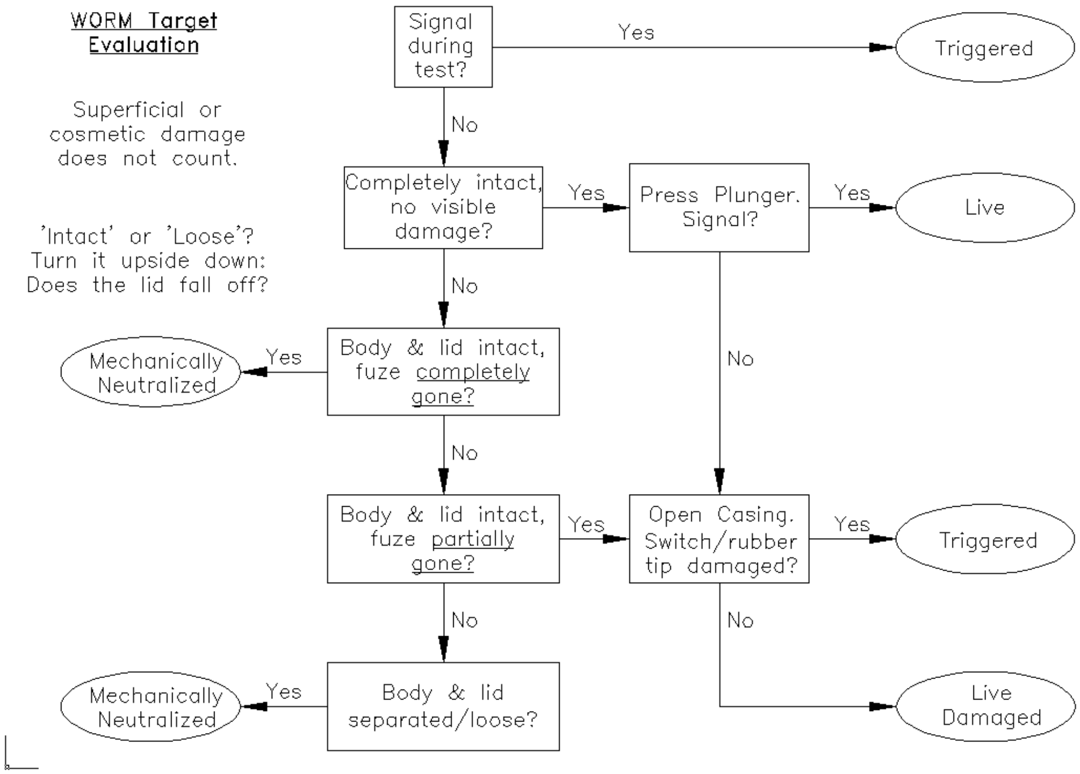

Figure A-9. *WORM Status Evaluation*

Witness Boards

Along with the mine targets, witness boards were installed at three locations across each lane. At the 0, 12.5m and 25 m point of each test lane, 0.3cm thick, 40cm tall fibreboards were installed across the full width of the tiller head. The witness panels were buried flush with the surface of the ground as shown in Figure A-10, in order to record the consistency of penetration of the tiller across the width of the machine.

A narrow trench was dug by hand across the width of the test area to accommodate the witness boards. The width of the trench was kept to a minimum to reduce the effects of the softer replacement soil on tiller penetration. The fiberboard was placed against the side of the trench nearest the start line of the machine. This technique reduces the chances of the witness board being removed by the tool rather than simply cutting into it. Figure A-10 illustrates a trench being dug.

Figure A-10. *Witness Board Installation*

The witness board was buried flush with the surface, acting as a witness panel to record the depth of penetration of the tool. A photograph of a partially excavated witness board is shown in Figure A-11. No direct indication of the force or neutralisation effectiveness of the tool at any depth is provided, however a clear indication of the consistency of soil cutting is provided. This indicator is obviously only useful for soil penetrating machines such as flails and tillers and cannot be used for low-disturbance tools such as rollers.

Figure A-11. *Witness Board Partially Excavated*

Test Methods

Following preparation of the soil in the test lanes, and installation of the mine targets and witness boards as described above, the machine was prepared for a test run. The machine was positioned about 2-3 metres before the start of the test lane to allow the operator to get the machine operating in a consistent, stable manner prior to the start of the lane. The computer recording the WORM trigger signals was started, cameras operators positioned, and personnel moved from the debris – throwing path of the machine.

The machine operator began the test lane once all personnel were ready. The machine was operated through the test area containing 3 witness boards and 50 mine targets and the time of passage was recorded.

After the passage of the machine through the test area, the computer recording of WORM trigger signals was stopped. The test lane was examined and visible test targets removed. The computer operator began developing a table of data, such as those shown at Annex D. Recovered test targets were examined to establish status. Other personnel continued to recover test targets using a metal detector to locate them. Once the target recovery team had been through the test lane once, the computer operator noted the targets from which no signal had been received and no status determined. Special attention was given to recovering these targets.

Finally, the witness boards were recovered, labelled, and photographed.

Figure A-12. *Locating Test Targets After Passage of the Machine*

Annex B – MineWolf Manufacturer Brochure

The following material is included by permission of MineWolf Systems, the machine manufacturer. While not all of the details included herein were independently verified by the test team, the brochure is believed to be representative of the machine tested.

The contact information for the manufacturer is:

International Sales & Operations Office
MineWolf Systems AG
Seedammstr. 3
8808 Pfäffikon SZ
Switzerland

Phone: +41 (0) 55 417 46 85
Fax: +41 (0) 55 417 46 86

E-Mail: info@minewolf.com
Internet: www.minewolf.com

MineWolf SYSTEMS






MineWolf

Product Profile

The MineWolf is the ultimate response to the challenges encountered in day-to-day demining operations. It has set new standards in terms of reliability and efficiency and has shown unprecedented results in various demining projects worldwide.

Key Features

- Choice of Tiller or flail operations depending on conditions
- Effective clearance of AP- and AT-mines up to 10 kg TNT
- Continuous ground penetration up to a depth of 35 cm and efficient removal of vegetation
- Tiller application excels in terms of reliability and survivability
- Manned or remote controlled handling
- Operator assistance through automatic depth control and optional GPS
- Engine and cooling modules withstanding extreme conditions of heat and dust
- Average clearance performance 15,000 m^2 – 25,000 m^2 per day

MineWolf Systems provides skilled personnel to effectively integrate the machine into its customers' infrastructure.

Technical Data

Length (with tiller)	7420 mm
Height, overall	3795 mm
Width (with tiller)	3480 mm
Clearance/working width	2800 mm
Mass, overall	25500 kg
Max. clearance depth	350 mm
DEUTZ diesel engine	270 kw / 367 hp
Fuel capacity	440 l
Max. clearance capacity	3800 m^2/h
Vegetation cutting	150 mm diameter
Winch power	20000 kg
Remote control (max)	1000 m

Company Profile
MineWolf
Mini MineWolf
MineWolf Bagger
Technology
Services
Training
Tailor Made Solutions
Manu-facturing
References

www.minewolf.com

MineWolf Systems AG ■ Seedammstraße 3 ■ 8808 Pfäffikon SZ ■ Switzerland

04/2006

Annex C – Soil Test Procedures

Soil Density

Apparatus:

Digging tools – Shovel or trowel, screwdriver or heavy knife.

Containers for storing samples

Non-porous material, e.g.: poly bag

Graduated container or container of known volume

Container of water

Scale

Marking implement – felt marker, grease pencil etc.

Method:

1. Weigh the sample container
2. Mark the weight of the container weight on the sample container
3. Mark the container with the sample number and location
4. Place non-porous material on ground next to location of hole
5. Place sample container on non-porous material
6. Using shovel or trowel, excavate hole ensuring that ALL material from the excavation is placed in the sample container
7. Seal the sample container and weigh the container immediately
8. Mark the container with the gross weight
9. Smooth the sides and bottom of the excavation with the trowel or knife, without removing any additional material
10. Place non-porous material in the excavation ensuring that it is in contact with the sides and bottom
11. Fill the graduated container from the water container
12. Note the amount of water in the graduated container

13. Pour water from the graduated container into the lined excavation. Fill the excavation with water as close as possible to ground level without overflowing

14. Note the amount of water left in the graduated container. (NOTE: Alternately, the non-porous material can be removed from the hole, being careful not to spill any water. This water is than poured into a container and weighed. This mass can be converted into volume.)

15. Subtract the amount remaining from the starting amount. The difference is the amount in the excavation and represents the volume of the excavation

16. Mark this on the sample container

Calculations

Soil density refers to the mass per unit volume. For our purposes, density, ρ, is given in kilograms per cubic metre.

$$\rho = m/V = kg/m^3$$

Example: A soil sample has a wet mass of 1174.75 grams; the excavation the soil was removed from has a volume of 500ml or 500cm3.

$$\rho = m/V$$

$$= 1174.75g/500ml$$

$$= 1.17475kg/0.0005m^3$$

$$= 2349.5kg/m^3$$

In this example, the object is to convert the mass of the sample from grams to kilograms and the volume of the excavation from millilitres to cubic metres .

Moisture Content

Apparatus:

Shallow containers with lids

Scale

Heat source (hot plate, heat lamp or oven etc) or microwave

Spatula

Fan (optional)

Standard Method:

1. Weigh a shallow container and record the weight

2. Place the soil from one of the sample containers in a shallow container

3. Place the shallow container on the heating element of the hot plate or in the oven. DO NOT OVER HEAT. Small pieces of paper mixed with the soil will act as an indicator and turn brown if overheated.

4. If heated on a hot plate, frequently turn the soil with a spatula during heating

5. Drying time will vary. (Check weighing should be done to determine the minimum drying time necessary.)

6. Remove the shallow container from the heat, cover and allow to cool

7. The container can be weighed as soon as it is cool enough to handle

8. Record this weight

9. Reheat cool and weigh the sample until the weight no longer changes.

Microwave method:

Method remains similar to standard method above. Heat the sample five minutes each time on medium heat. Weigh the sample once. Ensure that the sample is cool enough not to affect electronic scale. Reheat and reweigh until no change in mass is recorded. Soil is then dry.

Calculations

The moisture content of a soil is expressed as a percentage of the dry mass:

moisture content, w = loss of moisture/dry mass x 100%

In the above example of soil density calculations, the wet mass was 1174.75g. Suppose that, after drying the soil, the mass was 1147.65gr. Moisture content can then be calculated by:

w = (wet mass – dry mass)/dry mass x 100%

w = (1174.75g – 1147.65g)/1147.65g x 100%

w = 27.1g/1147.65g x 100%

w = 0.0236 x 100%

w = 2.36%

This page intentionally left blank.

Annex D – Test Data Sheets

The tables that follow show the data collected from the WORM test targets. This data is the source for the tables and analyses in the main body of this report. Note that 'fuze removed' is considered a subset of 'mechanically neutralised' and thus these two categories were added together for the final result.

Gravel 0 cm

pretest	posttest	count	1st occurence	last occurence	time diff.		Triggered	Fuze removed	Live damaged	Mech neut	Comment
0	-	-	-	-	-		x				
1	-	-	-	-	-					x	
2	-	-	-	-	-				x		
3	-	-	-	-	-					x	
4	-	-	-	-	-		x				
5	5	235	67312	67984	672		t				
6	-	-	-	-	-		x				
7	7	3	71703	71703	0		t				
80	-	-	-	-	-						
9	-	-	-	-	-		x				
0A	0A	56	77781	77984	203		t				
0C	-	-	-	-	-						
0D	-	-	-	-	-					x	
10	-	-	-	-	-		x				
11	-	-	-	-	-		x				
13	-	-	-	-	-		x				
15	-	-	-	-	-		x				
16	-	-	-	-	-				x		
17	17	1	94031	-1.15805E+12	-1.16E+12		t				
1A	-	-	-	-	-		x				
1B	-	-	-	-	-				x		
1C	-	-	-	-	-					x	
1D	-	-	-	-	-					x	
1F	1F	111	104265	104703	438		t				
22	22	317	106546	107468	922		t				
23	-	-	-	-	-		x				
25	25	215	110734	111359	625		t				
28	-	-	-	-	-					x	
29	-	-	-	-	-					x	
2A	-	-	-	-	-		x				
2B	-	-	-	-	-						
2C	-	-	-	-	-					x	
2D	-	-	-	-	-						
2F	-	-	-	-	-					x	
32	-	-	-	-	-		x				
33	-	-	-	-	-		x				
38	-	-	-	-	-					x	
39	-	-	-	-	-						
3A	-	-	-	-	-				x		
3B	-	-	-	-	-		x				
3C	3C	16	140171	140187	16		t				
3D	-	-	-	-	-		x				
3E	3E	199	144515	145000	485		t				
3F	-	-	-	-	-		x				
40	-	-	-	-	-		x				
41	-	-	-	-	-					x	
42	42	10	152765	152781	16		t				
43	43	788	154812	157125	2313		t				
44	-	-	-	-	-					x	
45	45	101	159203	159562	359		t				
-	52	68	79828	80062	234		t				
-	5F	327	107468	108437	969		t				
-	64	56	114203	114375	172		t				
						TOTAL	32	0	4	12	

Figure D-1. *Test Data Sheet, Gravel, 0 cm*

Gravel 10 cm

pretest	posttest	count	1st occurence	last occurenc	time diff.		Triggered	Fuze removed	Live damaged	Mech neut	Comment
7D	7D	194	91438	92078	640						
7E	7E	122	92078	92610	532						
7F	7F	296	93156	94047	891						
80	80	225	94375	94969	594						
81	81	172	95625	96281	656						
82	-	-	-	-						x	
83	-	-	-	-							
84	-	-	-	-						x	
85	-	-	-	-							
86	86	242	101969	102641	672						
87	87	9	103078	103094	16						
89	-	-	-	-					x		
8A	-	-	-	-						x	
8B	8B	64	107094	107219	125						
94	-	-	-	-			x				
95	95	58	110360	110516	156						
96	-	-	-	-							
97	-	-	-	-						x	
98	-	-	-	-							intact/active
9A	9A	61	115422	115656	234						
9B	9B	296	116688	117625	937						
9C	9C	194	118391	118938	547						
9D	9D	196	119594	120125	531						
9E	-	-	-	-					x		
9F	9F	249	121766	122453	687						
A0	A0	256	123547	124344	797						
A1	-	-	-	-							
A2	A2	202	126094	126672	578						
A3	A3	223	127328	127953	625						
C0	C0	10	128828	128844	16						
7C	-	-	-	-			x				
C1	C1	244	131547	132235	688						
C2	C2	8	132891	132985	94						
C3	-	-	-	-						x	
C5	C5	243	135578	136203	625						
C6	C6	247	137188	137860	672						
C8	C8	25	138625	138703	78						
CA	-	-	-	-						x	
CB	-	-	-	-			x				
D0	D0	23	142813	142875	62						
D1	D1	244	144156	144813	657						
D2	D2	303	145688	146500	812						
D3	-	-	-	-			x				
D4	D4	248	148031	148641	610						
D5	D5	321	149078	149922	844						
D6	-	-	-	-						x	
D7	D7	199	151453	152078	625						
D8	D8	337	153063	153985	922						
D9	-	-	-	-						x	
DA	DA	251	155625	156344	719						
						TOTAL	35	0	2	8	

Figure D-2. *Test Data Sheet, Gravel, 10 cm*

Gravel 15 cm

pretest	posttest	count	1st occurence	last occurence	time diff.		Triggered	Fuze removed	Live damaged	Mech neut	Comment
42	42	6	66312	66312	0						
44	44	392	67469	206625	139156						
46	46	208	69094	69641	547						
47	47	243	70844	71531	687						
48	48	233	72734	73609	875						
49	49	180	74484	74953	469						
4A	4A	249	76156	76797	641						
4B	4B	11	77562	77578	16						
4C	4C	267	79281	80016	735						
4D	4D	271	80672	81406	734						
4E	-	-	-	-							
4F	4F	201	83922	84531	609						
50	-	-	-	-						x	
51	51	57	87375	87453	78						
52	52	250	88844	89531	687						
53	53	95	90406	90609	203						
54	54	5234	92125	143281	51156						
55	55	200	93953	94437	484						
56	56	52	95203	95359	156						
58	-	-	-	-					x		
59	-	-	-	-					x		
5A	-	-	-	-							
5B	5B	444	101984	117641	15657						
5C	-	-	-	-							
5D	5D	64	105281	105469	188						
5E	5E	150	107125	107516	391						
5F	5F	283	108812	109578	766						
60	60	200	110500	111484	984						
61	61	114	112422	112953	531						
62	-	-	-	-						x	
63	-	-	-	-							
64	64	209	117359	118125	766						
65	65	276	118891	119719	828						
66	66	138	120922	121250	328						
67	-	-	-	-							
68	68	250	124109	124797	688						
69	69	9	125781	125812	31						
6A	-	-	-	-							
6B	-	-	-	-					x		
6C	6C	15	130766	130797	31						
6D	6D	281	132391	133172	781						
6E	6E	386	134062	135156	1094						
71	71	7	135609	135641	32						
73	-	-	-	-			x				
74	74	6	139187	139234	47						
77	77	229	140594	141141	547						
78	-	-	-	-						x	
79	79	25	143828	143922	94						
7A	7A	332	145641	146625	984						
7B	7B	253	146953	147719	766						
						TOTAL	38	0	3	3	

Figure D-3. *Test Data Sheet, Gravel, 15 cm*

Sand 0 cm

pretest	posttest	count	1st occurence	last occurence	time diff.		Triggered	Fuze removed	Live damage	Mech neut	Comment
0	-	-	-	-			x				
1	1	3	135360	135360	0						
2	-	-	-	-					x		
3	-	-	-	-						x	
4	-	-	-	-						x	
5	-	-	-	-			x				
6	-	-	-	-						x	
7	7	5	146141	146141	0						
8	8	269	147735	148485	750						
47	-	-	-	-						x	
9	-	-	-	-						x	
0A	-	-	-	-			x				
0C	-	-	-	-			x				
0D	0D	43	157032	157047	15						
0E	0E	1	158860	-1.15805E+12	-1.16E+12						
0F	-	-	-	-			x				
20	-	-	-	-						x	
21	-	-	-	-						x	
22	-	-	-	-						x	
23	-	-	-	-						x	
24	-	-	-	-						x	
25	-	-	-	-			x				
26	-	-	-	-					x		
27	-	-	-	-						x	
28	-	-	-	-			x				
29	29	5	180907	180922	15						
2A	-	-	-	-						x	
2B	2B	13	185797	185813	16						
2D	-	-	-	-					x		
2E	2E	13	190578	190594	16						
2F	-	-	-	-						x	
30	-	-	-	-			x				carried on tracks
31	-	-	-	-						x	
32	32	35	200282	200297	15						
33	-	-	-	-			x				
35	35	20	205719	205735	16						
34	34	11	207719	207719	0						
36	-	-	-	-					x		
37	-	-	-	-						x	
38	-	-	-	-			x				
3A	-	-	-	-						x	
3C	-	-	-	-							
3D	3D	1	222547	-1.15805E+12	-1.16E+12						
3E	-	-	-	-						x	
41	-	-	-	-			x				
4D	-	-	-	-			x				
FA	-	-	-	-			x				
FC	-	-	-	-							
FE	-	-	-	-						x	
FF	-	-	-	-			x				
						TOTAL	26	0	4	18	

Figure D-4. *Test Data Sheet, Sand, 0 cm*

Sand 10 cm

pretest	posttest	count	1st occurence	last occurence	time diff.		Triggered	Fuze removed	Live damage	Mech neut	Comment
1	1	55	125250	125453	203						
2	2	10	126312	126312	0						
0B	-	-	-	-					x		
8	8	157	128890	129421	531						
2C	2C	26	129531	129546	15						
28	-	-	-	-					x		
2A	-	-	-	-			x				
2B	-	-	-	-						x	
2E	-	-	-	-						x	
2F	-	-	-	-						x	
32	-	-	-	-						x	
36	-	-	-	-						x	
3A	3A	47	138359	138765	406						
4A	4A	62	139640	140921	1281						
4B	-	-	-	-						x	
4C	4C	49	141796	142125	329						
4D	-	-	-	-					x		
51	-	-	-	-							intact/live
CB	CB	94	144843	145359	516						
CC	CC	24	145703	148031	2328						
DB	DB	27	147078	147921	843						
DC	DC	15	148031	148437	406						
DD	-	-	-	-			x				fuze damaged
DE	DE	33	150281	150578	297						
DF	DF	24	151328	151843	515						
E0	E0	36	152390	152906	516						
E1	E1	13	152703	154937	2234						
E2	E2	26	154625	154843	218						
E3	-	-	-	-					x		
E4	E4	18	157656	166468	8812						
E5	E5	43	158718	159125	407						
E6	E6	47	159781	159984	203						
E7	-	-	-	-						x	
E9	E9	88	162156	162593	437						
EA	-	-	-	-			x				
EB	EB	71	164546	164875	329						
EC	EC	28	165953	166468	515						
ED	ED	122	167343	168203	860						
EE	EE	29	168531	168843	312						
EF	EF	74	169812	170343	531						
F1	F1	101	170781	171546	765						
F2	F2	48	172093	172843	750						
F3	F3	158	173171	174218	1047						
F4	F4	107	174437	174875	438						
F5	F5	51	175750	176281	531						
F6	-	-	-	-						x	
F8	-	-	-	-			x				
F9	F9	89	178796	180312	1516						
FA	-	-	-	-			x				
FB	FB	23	180656	180765	109						
						TOTAL	37	0	4	8	

Figure D-5. *Test Data Sheet, Sand, 10 cm*

Sand 15 cm

pretest	posttest	count	1st occurenc	last occurence	time diff.		Triggered	Fuze remove	Live damaged	Mech neu	Comment
4A	4A	184	78657	79203	546						
4B	4B	68	79422	79657	235						
4C	4C	736	80828	83391	2563						
4D	-	-	-	-			x				
4E	4E	57	84157	84328	171						
4F	4F	76	85719	85969	250						
50	-	-	-	-			x				
51	51	29	88469	88578	109						
58	-	-	-	-			x				
5C	5C	9	91828	91844	16						
5D	5D	447	93219	94594	1375						
5E	-	-	-	-			x				
5F	5F	322	96235	97235	1000						
60	60	27	97563	97688	125						
61	61	90	99188	99485	297						
62	62	57	100782	100860	78						
63	63	319	102578	112157	9579						
65	65	191	104094	104782	688						
68	68	26	105766	105922	156						
69	69	13	107313	107328	15						
6A	-	-	-	-						x	
6C	6C	509	110453	111953	1500						
6D	-	-	-	-			x				
6E	-	-	-	-			x				
6F	6F	1035	115547	118594	3047						
78	78	7	117313	117422	109						
7A	7A	60	118594	118813	219						
7C	7C	263	120641	121453	812						
7D	-	-	-	-						x	
7E	7E	73	124516	124750	234						
7F	-	-	-	-			x				
80	-	-	-	-						x	
81	81	5	129860	129875	15						
82	-	-	-	-			x				
83	83	7	133750	133782	32						
85	-	-	-	-						x	
86	86	266	137235	138235	1000						
87	-	-	-	-			x				
B3	B3	307	141078	141813	735						
E5	E5	128	142578	142875	297						
EE	EE	61	144282	144500	218						
F1	F1	34	146344	146438	94						
FB	FB	208	148157	148782	625						
F9	-	-	-	-			x				
FA	-	-	-	-			x				
FC	FC	27	154250	154328	78						
FD	-	-	-	-						x	
FE	FE	883	158344	160828	2484						
FF	FF	53	161047	161282	235						
8	8	27	163110	163250	140						
						TOTAL	45	0	0	5	

Figure D-6. *Test Data Sheet, Sand, 15 cm*

Topsoil 0 cm

pretest	posttest	count	1st occurenc	last occurence	time diff.		Triggered	Fuze removed	Live damaged	Mech neut	Comment
0	-	-	-	-			x				
1	1	7	289969	289984	15						
2	-	-	-	-			x				
3	3	9	294312	294312	0						
4	-	-	-	-				x			
5	-	-	-	-			x				
6	6	10	300500	300516	16						
7	-	-	-	-					x		
8	-	-	-	-						x	
9	-	-	-	-			x				
0A	0A	45	308891	309000	109						
0B	0B	6	311156	311156	0						
0C	0C	34	313078	313172	94						
0D	-	-	-	-						x	
0E	-	-	-	-					x		
0F	0F	125	319484	319812	328						
10	-	-	-	-						x	
11	-	-	-	-						x	
12	12	54	325703	325906	203						
13	-	-	-	-						x	
14	14	50	329719	329922	203						
15	15	52	331656	331859	203						
16	16	54	333484	333687	203						
17	-	-	-	-			x				
18	18	4	337500	337500	0						
19	19	54	339750	339875	125						
40	-	-	-	-			x				
41	-	-	-	-						x	
42	-	-	-	-						x	
43	-	-	-	-			x				
44	-	-	-	-					x		machine pulled the fuze
45	-	-	-	-			x				
46	-	-	-	-						x	
47	47	4	355703	355797	94						
48	48	34	357734	357750	16						
49	-	-	-	-			x				
50	-	-	-	-						x	
51	-	-	-	-			x				
52	52	46	365906	366016	110						
53	-	-	-	-			x				
54	-	-	-	-			x				
55	-	-	-	-						x	
56	56	23	373969	374078	109						
57	57	50	376000	376203	203						
58	-	-	-	-						x	
59	-	-	-	-			x				
5A	5A	41	381984	382203	219						
5B	-	-	-	-			x				
5C	5C	19	386125	386141	16						
5D	-	-	-	-						x	
						TOTAL	34	1	3	12	

Figure D-7. *Test Data Sheet, Topsoil, 0 cm*

Topsoil 10 cm

pretest	posttest	count	1st occurence	last occurence	time diff.		Triggered	Fuze removed	Live damaged	Mech neut	Comment
9F	9F	112	70281	70609	328						
92	-	-	-	-							
93	93	43	73000	73203	203						
94	-	-	-	-							intact/active
95	95	241	76250	76953	703						
96	96	369	77828	79328	1500						
97	97	248	79343	80109	766						
98	-	-	-	-			x				
99	99	218	82843	83468	625						
A0	A0	174	84343	84828	485						
A1	A1	4544	86578	108750	22172						
A2	-	-	-	-						x	
A3	A3	52	90047	90187	140						
A4	A4	72	91703	92390	687						
A5	-	-	-	-			x				
A6	-	-	-	-			x				
A7	-	-	-	-			x				
A9	A9	190	98984	99515	531						
9E	9E	95	100515	101250	735						
AC	-	-	-	-						x	
AE	-	-	-	-			x				
AD	AD	248	105640	106265	625						
AF	-	-	-	-							
9D	9D	268	109406	110172	766						
B0	B0	193	111922	112406	484						
B1	B1	221	114484	115031	547						
B2	B2	76	115593	115734	141						
B4	B4	286	117453	118265	812						
B5	B5	57	119484	119609	125						
B6	B6	250	121000	121609	609						
B7	B7	59	122593	122828	235						
B8	-	-	-	-			x				
B9	B9	226	125984	126625	641						
BA	BA	58	127625	127859	234						
BB	BB	1079	128922	138078	9156						
BC	BC	204	130718	131203	485						
BD	-	-	-	-						x	
BE	-	-	-	-						x	
BF	BF	62	134812	134953	141						
C0	C0	83	136609	136890	281						
C1	-	-	-	-			x				
C2	C2	261	139390	139984	594						
C3	C3	259	140750	141515	765						
C4	C4	58	142078	142218	140						
C5	C5	61	143843	144000	157						
C6	C6	125	145312	145672	360						
C7	-	-	-	-			x				
C8	C8	61	148281	148453	172						
C9	C9	74	149953	150125	172						
9C	9C	438	151515	152859	1344						
						TOTAL	43	0	0	4	

Figure D-8. *Test Data Sheet, Topsoil, 10 cm*

Topsoil 15 cm

pretest	posttest	count	1st occurence	last occurenc	time diff.		Triggered	Fuze remove	Live damage	Mech neu	Comment
60	60	186	72563	73422	859						
61	61	335	75391	76297	906						
62	62	99	77391	77719	328						
63	-	-	-	-						x	
64	64	53	83610	83813	203						
65	65	56	86422	86532	110						
66	66	4	88469	88469	0						
67	67	159	91266	91719	453						
68	68	7	93578	93578	0						
69	69	19	96047	96063	16						
6A	6A	116	97766	98110	344						
6B	6B	114	100078	100422	344						
6C	6C	395	103032	104110	1078						
6D	6D	59	104657	104891	234						
6E	6E	9	106953	106969	16						
6F	6F	255	109438	110047	609						
70	70	53	111250	111422	172						
71	71	309	114250	115110	860						
72	72	10	115657	115750	93						
73	-	-	-	-			x				
74	74	6	120203	120219	16						
75	75	251	122360	123047	687						
76	76	3	125235	125235	0						
78	78	289	127813	128625	812						
79	-	-	-	-			x				
7A	-	-	-	-						x	
7B	7B	375	134969	135875	906						
7C	7C	86	137516	137735	219						
7D	7D	182	139782	140282	500						
7E	7E	110	142907	143235	328						
7F	7F	59	144860	145047	187						
81	81	47	147313	147500	187						
82	82	397	149438	150578	1140						
83	83	119	151672	152016	344						
84	84	244	154094	154719	625						
85	85	239	156360	157032	672						
86	-	-	-	-			x				
87	87	61	160860	161016	156						
88	88	314	162860	163750	890						
89	89	379	165172	166188	1016						
8A	8A	276	167610	168391	781						
8B	8B	241	170032	170688	656						
8C	-	-	-	-						x	
8D	8D	258	174313	175157	844						
8E	8E	375	176797	177844	1047						
8F	8F	58	178282	178500	218						
90	90	260	180016	199641	19625						
91	91	123	182391	182672	281						
9A	9A	122	184625	184938	313						
9B	9B	40	187110	187203	93						
						TOTAL	47	0	0	3	

Figure D-9. *Test Data Sheet, Topsoil, 15 cm*

Annex E – Manufacturer Comments

The following material was received from the machine manufacturer in response to a draft version of this report.

MineWolf Tiller Test and Evaluation Report

Manufacturer's comments

Introduction

MineWolf Systems have reviewed the draft MineWolf Test and Evaluation Report produced by the ITEP testing and evaluation team and have identified several shortfalls and inaccuracies in the current draft. MineWolf Systems find the factual results acceptable within the tests conducted but recommend that the suggested amendments are made to the current report or that the list of observations made are at least noted in the manufacturer's comments.

General comments on the report

In general the report leaves question as to the research carried out by the team as it seems very apparent that they have not fully understood the capabilities of the machine when used in various scenarios. The MineWolf operates both with tiller and flail depending on the given threat yet nowhere in the report does it consider or even mention the option of using an alternative tool in different ground conditions.

MineWolf Systems would also like to remind the author that when the request was placed to test the machine, it was intended that both tiller and flail would be tested. ITEP choose not to test the flail due to limitations on resources and time constraints. As it stands the MineWolf System has only been tested to 50% of its capability. This is not referenced in the report.

The report consistently refers to the machine being used in Croatia with a tiller, yet this is just one area of operations in the global context of the MineWolf machine use. The ITEP report is designed to test machines in various ground conditions to give an overview of its performance for deployment globally. When reading the report it appears very focused on how the machine operates and functions in Croatia, with no mention made of its deployment in other theatres such as Africa or the Middle East.

Several comments appear throughout the report that seem to be based on opinion rather than fact and remarks appear to be loosely written. For example, in one of the opening narratives it states that, "because the MineWolf is commonly used with tiller (and not flail attachment) in Croatia, only the tiller configuration was evaluated". If the report is for global use, then it should be mentioned that the flail is used in conjunction with the tiller in Southern Sudan to defeat M15 anti-tank mines with a Net Explosive Content (NEQ) of 10kg.

Other comments refer to some of the terms used. Accompanying figure x, the label, "debris collected around tracks" they show part of a "WORM" body on the track system, yet it does not state the condition of the WORM, leaving some doubt in the readers mind. If such a photograph is to be shown then it should clearly state the condition of the WORM as the photograph certainly leads to some miss-interpretation. In this particular instance the WORM had functioned and as the WORMs have no explosive content then the bodies will always remain in some shape

Manufacturer Feedback to DRAFT Report

or form. Again what is slightly misleading is the photo showing "Typical debris Throwing" clearly it shows the WORM being forward of the machine but fails to state the condition of the WORM. Are these WORMS really throw-outs as the author leads you to beleive or are they mechanically neutralised or triggered WORMs that have been processed through the tiller system.

The machine is deployed with several other major organisations both commercial and NGO. MKA Demining is just one user of the machine and its activities should not be solely used as a reference to the compiling of the report.

MKA Demining is a commercial mine clearance company and does not represent MineWolf Systems. The machine tested is **owned** by MKA Demining, MineWolf Systems do not have any control over how the machine is operated (**Speed**) and modifications made (**Depth control**). No reference was made in the report on the instructions given to the operator before and during the testing procedure. The test report should focus on the machine performance and not the operator's performance. Certainly in this instance would it not be reasonable to ask for a written brief to be produced for the operator, to prevent any misinterpretation as to what is required of him/her. Having read the report and followed up with the operator it seems very clear that he did not understand what was required of him in the first few test runs.

Considering this whole report has taken eight months to produce MineWolf Systems finds the final draft to be lacking in factual descriptive content, in certain instances the report refers to "flail" as opposed to "tiller" indicating that the author has not given the required level of diligence that a test of this magnitude requires. Also if the author had researched the product before conducting testing he would know that the machine cabin had been officially certified and tested by the German Army (See report attached) and would not be using opinions from a commercial operator as to its suitability.

MineWolf Systems recommend that the comments below are used to amend the draft report before the final draft is submitted.

Manufacturer Feedback to DRAFT Report

Specific comments and suggested amendments to the report

1. Abstract

It is not mentioned that MineWolf Systems requested that the whole "system" (i.e. Tiller and Flail) be tested by ITEP not just the tiller, and that ITEP did not test the flail due to limited resources and time limitation. As MineWolf Systems always deploy both tiller and flail and never just the single tool, it is suggested that the beginning of the first sentence of the abstract be reworded to say:

- "A test of the MineWolf tiller (which is part of the MineWolf machine's tiller and flail system) was performed ……………...

2. Executive Summary

The last sentence of the first paragraph is factually incorrect as both tiller and flail are used both in Croatia and on other global operations. It is suggested that this sentence be reworded to,

> "The MineWolf Machine is provided with both tiller and flail attachments to be used as part of a System, interchangeable dependent upon conditions. Only the machine with the tiller attachment was evaluated by ITEP for this report."

The summary reflects that the machine is used in "Croatia" and fails to mention its other global deployments, and makes general assumptions based on these facts. It is suggested that the following sentence be inserted to inform the reader of its global deployment, saying,

> "The MineWolf is deployed in Bosnia and Herzegovina, Croatia, Jordan and Sudan and has been tested on live mines in the United Arab Emirates."

Paragraph 2 refers to the operational test conditions and makes mention of the "WORMs". It is suggested that an additional explanatory sentence be added here stating that,

> "These WORMs have no explosive content and will always be visible on the test site after the test has been conducted."

If this is not highlighted in the report it will appear to the uneducated reader that the machine has "missed mines" and has failed to achieve its objective.

The first sentence of paragraph 4 states that "the depth control on the MineWolf **appears** to be effective when used.". It should actually mention that "the depth control **is** effective in other operations in Sudan and Jordan. Paragraph 4 also states that the depth control skids are removed due to frequent damage. It is strange that the test was conducted without the depth control system activated, as it was fully serviceable as shown by the later tests and in operational deployments the depth control skids are used by all users of the MineWolf machine. It is appreciated that the skids do get damaged occasionally but this is not a frequent occurrence as indicated in the report. Based on lack of evidence, it is suggested that the second sentence of paragraph 4 be removed.

Manufacturer Feedback to DRAFT Report

3 Introduction Page 1

The introduction purely reflects the machine is only being used in the Balkans and again does not mention its global activities. As the machine is deployed with several other major organisations in a variety of countries, MKA Demining should not be solely used as a reference to the compiling of the report.

Survivability tests have been conducted previously by CROMAC CTRO and the German Army.

Given the above the following amendments are suggested:

- Re-word the last sentence of the second paragraph of page 1 be re-worded to,
  "Only a performance test was conducted since this machine is already certified for use in Croatia and survivability tests have been carried out by CRMAC CTRO and the German Army."
- It is suggested that the third paragraph of page 1 be completely reworded to say,
  "The MineWolf Machine is provided with both tiller and flail attachments to be used as part of a System, interchangeable dependent upon conditions. Only the machine with the tiller attachment was evaluated by ITEP for this report."
- Remove "and survivability tests" from the last sentence of page 1 as they were not conducted.

4. 2.1. MineWolf Tiller **Pages 2 and 3**

The shaft rotates at 480 rpm, this has been left out of report. Please include it in paragraph 2.

The machine can be operated both manually and by remote control, when operating by remote control means the operator cabin is normally removed. Please include this in the text.

In paragraph 3 the report states that "MKA Demining considers the level of protection provided by the cab to be sufficient for the types of threats encountered during their commercial demining operations". MKA Demining are not experts on armoured cabins. MineWolf Systems have gone to get expense at having the cabin tested by the German Army, and an official test report is available upon request. It is suggested that this sentence be removed and a sentence saying that,
"The German Army survivability test shows that the level of protection provided by the armoured cab is ….*within the admissible and acceptable range.*"

Manufacturer Feedback to DRAFT Report

5. 4.1.1 Tabular data and explanations Page 6

The third paragraph states that , " The reasons for the poorer performance are unknown……….. This is not the case, the reasons are well known to the manufacturer and in Jordan and the UAE where the machine operates in sand conditions the tiller rotation speed (RPM) has been increased to address this problem. This would be unknown to the MKA Demining operator who would not have encountered sand conditions in Croatia. It is suggested that the sentence be replaced with ,

> "The reasons for poor performance in sand conditions are known to the manufacturer and in Jordan and the UAE where the machine operates in sand the tiller rotation speed (RPM) has been increased to address this problem."

6. 4.1.3 Debris and Scatter Pages 10 and 11

The last sentence of the second paragraph states that , " The reader is invited to draw his or her own conclusions about the type of debris left in and around the area where the MineWolf has been used." This sentence is not necessary as the whole report should be facts upon which the reader makes his/her own conclusions. It is suggested that the sentence be removed.

In general it is felt that there are too many photos which do not tell the reader much. As the series of photographs in figures 5 to 13 are not proportionally representative of the results and are not taken in situ, it is suggested that only one example from each of the four categories (live, live damaged, Mechanically neutralised and triggered) be shown to better reflect the actual test results. Otherwise it is rather misleading.

In figure 7, the photo showing an 'unknown serial thrown outside of test lane' is not clear what this means. What does an unknown serial mean? Which of the four categories does it fall into? If the category is known please re-word accordingly. If it has been triggered or mechanically neutralised then it should not be considered a throw-out. It the category is unknown it should not be included in the report as it is misleading.

On page 17, the first paragraph implies that pushing targets forward of the machine may be a negative result, whereas this is to be expected from a tiller. It is suggested that some additional explanation for the reader be inserted. Please add the following to the end of the second sentence,

> "…forward of the machine……….. once they had been processed by the tiller. This is to be expected when using WORMS rather than live mines which explode upon impact."

The second paragraph of page 17 mentions vegetation but no vegetation was encountered during the test and therefore this is an invalid assumption and should be removed. The use of 'is prone to' implies repeatedly over a long time, not for the test duration. It is suggested that the second clause in the last sentence be re-worded to:

> "…, the MineWolf did throw soil and mine fragment debris (see figure 14) to a limited extent.

Manufacturer Feedback to DRAFT Report

The label for the photograph in figure 14, currently reads 'Typical debris throwing'. As it is usual to throw debris forward after processing with a tiller, it is recommended that the label be reworded to, "Debris thrown from the tiller after processing.

7. 4.2.5. Depth and consistency of penetration – Discussion Pages 24 & 25

The fourth paragraph on page 24 mentions, "Clearly the digging depths achieved were less than what has been observed from machines of this weight, class and power. The results for the test lanes with the targets at 10cm were the worst; if these results are excluded, the machine successfully penetrated to a minimum depth of 24cm in the remaining test lanes.

The only lane which achieved poor results was the sand 10 cm lane. This was one of the first lanes to be conducted and was due to a poor briefing of the required task given to the operator. The fact that the MineWolf tiller achieved 24cm and 30cm depth in the remaining test lanes means that the statement "Clearly the digging depths achieved were less than what has been observed from machines of this weight, class and power" is unjustified.

The three following bullet points in the fourth paragraph are all attributable to operator issues not the machine. Given the comment above that the performance in the 10cm lane is not a real issue, these bullet points focus too much of the reader's attention on the performance in the Sand 10cm lane and it is recommended that the entire paragraph 4.2.5.4 be replaced with a simple statement saying that,

"The results for the first test lanes conducted in the sand 10cm lanes achieved relatively poor penetration. As the machine successfully achieved a penetration of 24 cm in other lanes this could be attributed to operator error."

8. 4.3 Depth consistency along the path Pages 25, 26 & 27

This test report is supposed to evaluate the machine not the operator. The fact that MKA Demining chose not to operate the automatic depth control system, was an operator error, which was outside the control of the manufacturer in this instance. The automatic depth control system should have been used throughout the test and when it was used it clearly gave good results.

MKA's opinion on perceived efficiency of the use of the depth control system is just one operator's opinion and should not be reported. In fact, the depth control skids are used by MKA, as well as all the other users of the MineWolf machine. It is appreciated that the skids do get damaged occasionally but this is not a frequent occurrence as indicated in the report. Before quoting MKA's opinions on the use of the depth control skids, perhaps their use in other programmes should be looked at. Based on total lack of evidence, it is suggested that the whole of the last two sentences in the first paragraph be removed.

Whilst it is felt that too much emphasis was given to the machine operating without the automatic depth control system, given that this is unusual in actual 'real-world' situations and it was a factual record of the test and thus should be left in. The last paragraph on page 26, " Consider a real world situation…………..'' is however entirely opinion and should be removed. The text also in this paragraph is inaccurate as it refers to "flail" where it should read attachment of tiller.

The second paragraph on page 27, "Clearly the depth control skids……. Refers to MKA's use but not to other users. Also, as stated above MKA do actually use the skids in the field. In this instance it was an operator decision not to use the skids as he felt confident that he could perform the task without them.

9. 4.5 Survivability Test — Page 28

The second paragraph of page 28, The MineWolf has been proven…. Does not take into account other global operations and does not mention the survivability testing by the German Army. It is therefore suggested that the first sentence be re-worded to say:

> " The MineWolf has been proven in over 8 million square metres of mechanical demining in Croatia, Bosnia, Jordan, and Sudan and has been certified for use against anti-personnel mines and anti-tank mines by the Croatian Mine Action Centre and by the German Army."

10. 4.6.3 Speed — Page 28

The report states that, " the speeds used during these trials were higher than typically expected for a machine of this type by a factor of two or three." Since this machine is quite unique, please could you define what the expected speeds are here and why? If the comment cannot be justified by using similar machines of design and construction then it is suggested that the comment is removed.

11. 4.6.5 Debris traps — Page 29

This whole paragraph is entirely based on opinion. The WORM had been neutralised by the tiller. If it had been a live mine it would have exploded and not been trapped under the track. So speculation as to whether it had been a live mine is unjust as it would have detonated. With regard to this matter, the use of the WORM in the test does not reproduce realistic conditions and therefore this whole paragraph should be removed altogether or the last two sentences re-written to say that , "This target had been neutralised and on a live mine would have exploded".

12. 5.1 Positive observations — Page 32

Again the machine is being evaluated purely on its operational capacity in Croatia, it is recommended that the machine should be evaluated on its global capacity.

13. 5.2 Areas requiring attention — Page 32

Manufacturer Feedback to DRAFT Report

Given the above observations, please remove the first paragraph, as stated before, the depth control is effective when used.

14. Recommendations **Page 32**

In light of all the above comments it is suggested that this paragraph be re-written to reflect the rest of the report. MineWolf Systems would certainly recommend constructive criticism in this paragraph relating to machine modifications and improvement. For instance, tiller rpm speeds when operating in sand and protective measures for the depth control.

Paul J Collinson
Director Operations
MineWolf Systems

Manufacturer Feedback to DRAFT Report

List of symbols/abbreviations/acronyms

CCMAT	Canadian Centre for Mine Action Technologies
CROMAC	Croatian Mine Action Center
CTRO	Centre for Testing, Development, and Training
hp	Horsepower
km/h	Kilometres per hour
DOB	Depth of burial – see Figure A-7 in Annex A
Kg	Kilogram
cm	Centimetre
dm	Decimetre
N/A	Not Applicable
kW	Kilowatt(s)
m	Metres
R&D	Research and Development
CEN	Comité Européen De Normalisation (European Committee for Standardisation)
ITEP	International Test and Evaluation Program
mm	Millimetres
rpm	Revolutions per minute
TNT	Tri-nitrotoluene

DOCUMENT CONTROL DATA

(Security classification of title, body of abstract and indexing annotation must be entered when the overall document is classified)

1. ORIGINATOR (the name and address of the organization preparing the document. Organizations for who the document was prepared, e.g. Establishment sponsoring a contractor's report, or tasking agency, are entered in Section 8.)

   Defence R&D Canada – Suffield
   PO Box 4000, Station Main
   Medicine Hat, AB T1A 8K6

2. SECURITY CLASSIFICATION (overall security classification of the document, including special warning terms if applicable)

   Unclassified

3. TITLE (the complete document title as indicated on the title page. Its classification should be indicated by the appropriate abbreviation (S, C or U) in parentheses after the title).

   MineWolf Tiller Test and Evaluation

4. AUTHORS (Last name, first name, middle initial. If military, show rank, e.g. Doe, Maj. John E.)

   Roberts, William C. and Eagles, John Leslie

5. DATE OF PUBLICATION (month and year of publication of document)

   November 2007

6a. NO. OF PAGES (total containing information, include Annexes, Appendices, etc) 82

6b. NO. OF REFS (total cited in document) 1

7. DESCRIPTIVE NOTES (the category of the document, e.g. technical report, technical note or memorandum. If appropriate, enter the type of report, e.g. interim, progress, summary, annual or final. Give the inclusive dates when a specific reporting period is covered.)

   Technical Report

8. SPONSORING ACTIVITY (the name of the department project office or laboratory sponsoring the research and development. Include the address.)

   Canadian Centre for Mine Action Technologies

9a. PROJECT OR GRANT NO. (If appropriate, the applicable research and development project or grant number under which the document was written. Please specify whether project or grant.)

9b. CONTRACT NO. (If appropriate, the applicable number under which the document was written.)

10a. ORIGINATOR'S DOCUMENT NUMBER (the official document number by which the document is identified by the originating activity. This number must be unique to this document.)

   DRDC Suffield TR 2007-164

10b. OTHER DOCUMENT NOs. (Any other numbers which may be assigned this document either by the originator or by the sponsor.)

11. DOCUMENT AVAILABILITY (any limitations on further dissemination of the document, other than those imposed by security classification)

   (x) Unlimited distribution
   (   ) Distribution limited to defence departments and defence contractors; further distribution only as approved
   (   ) Distribution limited to defence departments and Canadian defence contractors; further distribution only as approved
   (   ) Distribution limited to government departments and agencies; further distribution only as approved
   (   ) Distribution limited to defence departments; further distribution only as approved
   (   ) Other (please specify):

12. DOCUMENT ANNOUNCEMENT (any limitation to the bibliographic announcement of this document. This will normally corresponded to the Document Availability (11). However, where further distribution (beyond the audience specified in 11) is possible, a wider announcement audience may be selected).

   Unlimited

13. ABSTRACT (a brief and factual summary of the document. It may also appear elsewhere in the body of the document itself. It is highly desirable that the abstract of classified documents be unclassified. Each paragraph of the abstract shall begin with an indication of the security classification of the information in the paragraph (unless the document itself is unclassified) represented as (S), (C) or (U). It is not necessary to include here abstracts in both official languages unless the text is bilingual).

A test of the MineWolf tiller (which is part of the MineWolf tiller and flail system) was performed in a cooperative International Test and Evaluation Program trial in September 2006 at the Croatian Mine Action Center (CROMAC) Centre for Testing, Development, and Training (CTRO). Canada and Croatia cooperated to conduct these trials. The project was conducted in accordance with the methodology specified in the European Committee for Standardisation (CEN) Workshop Agreement 'CEN Workshop Agreement 15044; Test and Evaluation of Demining Machines' available at the International Test and Evaluation Website (www.itep.ws).

14. KEYWORDS, DESCRIPTORS or IDENTIFIERS (technically meaningful terms or short phrases that characterize a document and could be helpful in cataloguing the document. They should be selected so that no security classification is required. Identifies, such as equipment model designation, trade name, military project code name, geographic location may also be included. If possible keywords should be selected from a published thesaurus, e.g. Thesaurus of Engineering and Scientific Terms (TEST) and that thesaurus-identified. If it is not possible to select indexing terms which are Unclassified, the classification of each should be indicated as with the title.)

MineWolf, flail, tiller, humanitarian demining, mechanical assistance equipment

Defence R&D Canada

Canada's Leader in Defence
and National Security
Science and Technology

R & D pour la défense Canada

Chef de file au Canada en matière
de science et de technologie pour
la défense et la sécurité nationale

DEFENCE R&D DÉFENSE

www.drdc-rddc.gc.ca