TECHNICAL ASSESSMENT
OF
THE PROMAC BRUSH-DEMINER 48

A cooperative effort by the
Canadian Centre for Mine Action Technologies
and the Thailand Mine Action Centre

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EXECUTIVE SUMMARY

This report presents the results of a technical assessment of the Brush-Deminer 48 (BDM48) conducted by the Canadian Center for Mine Action Technologies (CCMAT) and the Thailand Mine Action Centre (TMAC). The aim of the assessment was to determine if the BDM 48 is an appropriate tool for humanitarian demining.

Current demining practices rely on manual demining to locate and remove landmines. Mechanical systems offer a substantial increase in the rate of demining by removing underbrush therefore preparing the ground for locating mines, then detonating or neutralising antipersonnel land mines mechanically rather than destroying them by hand. To make available new and effective mechanical assistance equipment for demining CCMAT sponsored the design and testing of four proposed mechanical systems for demining. From that program it was determined that the BDM48, a proprietary equipment built by PROMAC, was operating well enough to progress to live trials. In November 2000 an agreement between the CCMAT and TMAC was signed to evaluate the BDM 48 in Thailand. The fieldwork was conducted in Sa Kaeo Province, Thailand from April to June 2001. Based on the Thailand fieldwork the BDM48 provides the following general capabilities:

- Safety and security for the operator by working from the cleared area and reaching into the mined area.
- Removes vegetation to make the ground available for using mine detectors or mine detecting dogs.
- Removes the tripwire threat.
- Removes or reduces the antipersonnel mine threat by neutralising mines by grinding or causing mines to detonate.

During the evaluation it was found that the BDM48 detonates or neutralises mines to a depth of 20 centimetres and can be operated in a manner that meets demining standards set out by the United Nations Mine Action Service. It was also found to be suitable for the environment and field conditions found in Thailand and is an appropriate equipment for humanitarian demining. It is therefore recommended that the Government of Canada contribute the BDM48 to TMAC to support the Thailand's Humanitarian Demining effort.

A secondary aim was to evaluate a new test and evaluation tool called the Mechanical Reproduction Mine (MRM). In these trials MRMs were found to act very closely to real mines and are considered appropriate tools for mechanical equipment testing and demining training.

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1.0 INTRODUCTION

In 1998 The Canadian Centre for Mine Action Technologies (CCMAT) established a program to test and evaluate (T&E) Mechanical Assistance Equipment (MAE) for Humanitarian Demining. This T&E program developed new test protocols and tools so that potential MAE systems could safely be evaluated in a controlled environment. The PROMAC BDM48 was one of the four equipments tested during that pilot phase.

In the MAE T&E program four standardized test environments were created in which inert but highly realistic MRMs were used to test candidate machines. The MRMs were designed to imitate an antipersonnel mine's physical characteristics and fuze action. Five different mines were selected to represent 5 of the most common types of anti-personnel mine fuze types, although only MRMs representing PMA 1, PMA2, PMA3 and PMN were used during tests in Canada. The ProMac BDM48 successfully neutralized (triggered the fuze or physically destroyed) 529 of 534 MRMs. At 99.1%, this was considered a superb result and preparations were made to expand testing of the BDM48 beyond the standardized test environments and MRMs and into real minefields with real mines. Before the BDM48 could be moved into a live environment the contractor, ProMac, selected the CASE 9040B as the prime mover and a protection package was built so that it could survive the blast environment. Blast trials were conducted to evaluate the effectiveness of the protection package. That trial series proved that the system performance was not affected after multiple 250 gram blasts to represent AP mine. Explosive testing against 81mm mortar, 105mm artillery shells and a 7.0 kilogram blasts demonstrated that the protection package provided very good protection to the operator and the machine.

In November 2000 the CCMAT visited the Thailand Mine Action Centre to determine if TMAC was able to support the T&E of the BDM 48. During that November 2000 liaison it was found that TMAC was already pursuing mechanical demining and had a progressive approach to combining mechanical tools with manual demining and mine detecting dogs. TMAC's operational focus as well as the available training and testing areas were ideal to conduct live trials of the BDM48. Moreover, the CCMAT assessment team understood Thailand's environment and felt that the level and type of threat present in that region was manageable for the trials. Finally, during the site visit it was found that while the test site was remote the necessary commercial services were present to support this class of equipment. Because of the positive environment that existed Thailand was selected as the preferred country in which to evaluate the BDM 48 and a letter of agreement between TMAC and CCMAT was signed.

Testing the BDM 48 in Thailand required administrative support to ensure timely customs clearances, access to Royal Thai Army controlled border areas in Sa Kaeo province, trained personnel to operate and supervise the equipment and run ranges. TMAC also provided and accounted for the live mines used during this evaluation. To provide an appropriate level of support for all tasks TMAC formed an assessment committee that was chaired by MGen Thamasak. The committee members were assigned from TMAC Headquarters, Burapha Field Force Headquarters, Humanitarian Demining Unit 1, and CCMAT. A final task of the committee was to hear the results of the evaluation and then based upon the test results decide if the BDM48 should remain in Thailand to be used by TMAC for day-to-day demining operations.

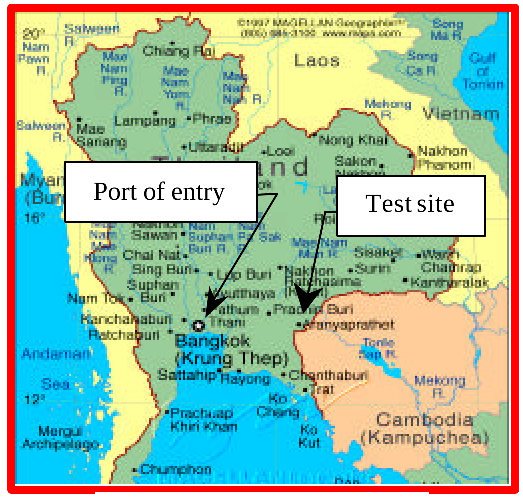

Figure 1: Test Site Location

The test site was co-located with TMAC’s Humanitarian Mine Action Unit 1 (HMAU1) in Sa Kaeo province. The evaluation would occur in two separate areas at Ban Nong Ya Kaeo: one area for training with MRM and testing with unfuzed M14 mines, and a second area located in a cleared area of a minefield where live M14 tests could be conducted. The live test were done in a minefield because HMAU1 already had control points set up with radio communications to prevent people from entering the area, and the area was far enough away from the nearest village to allow for safety when a mine blast occurred.

The CCMAT assessment team was organised to provide operational and technical control over the evaluation. The PROMAC assessment team was organised to provide administrative, training and mechanical support to the evaluation. PROMAC provided personnel with the skill sets to train, maintain, or modify the BDM 48 system in the field. PROMAC's approach greatly added to the success of the evaluation. TMAC provided area control through the HMAU1 plans officer.

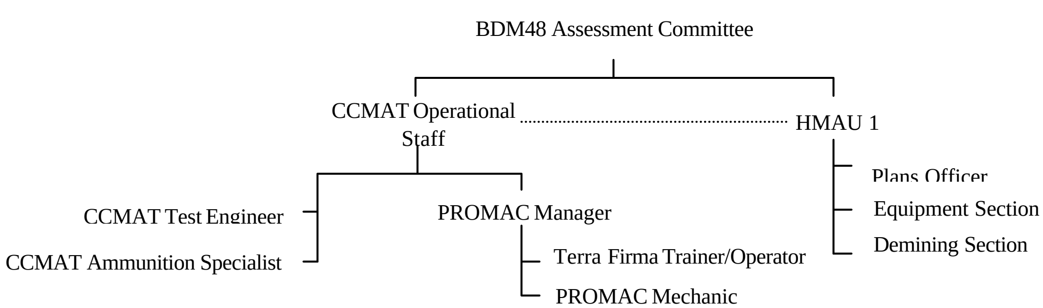

Figure 2: Organization of BDM48 Assessment team

2.0 AIM

The aim of this evaluation was to determine if the PROMAC Brush-Deminer is an appropriate tool for humanitarian demining.

Secondary goals were:

- To confirm the performance of the CCMAT Mechanical Reproduction Mine.

- To provide positive feed back to PROMAC so that they could improve the BDM 48 system performance.

- To determine if the PROMAC BDM 48 should be used by the Thailand Mine Action Centre for demining operations.

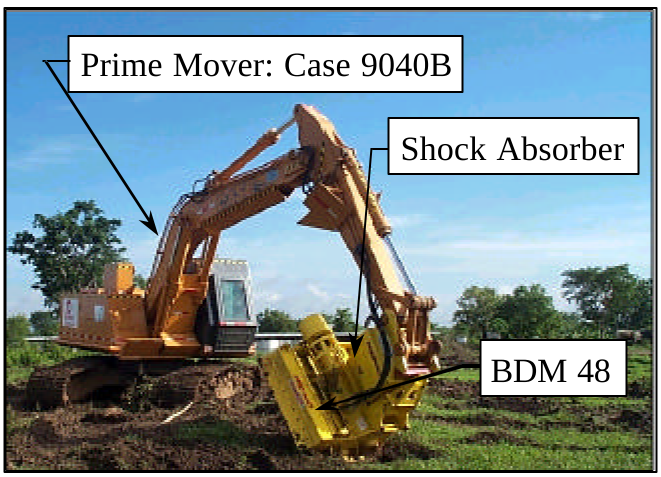

Figure 3: BDM 48 System

3.0 TESTING METHODOLOGY

In keeping with the intent of the CCMAT MAE program, testing of the BDM48 was conducted in the following logical step-by-step process.

- **Operator training**. Before testing could begin TMAC operators had to be trained to use the prime mover and apply the BDM48 attachment. The CCMAT assessment team included an operator/trainer provided by Terra Firma from Edmonton Alberta,Mr. S. Schmidt. Mr Schmidt was the same operator who used the BDM48 system in the DRES trials, which provided excellent continuity between the Canadian tests and Thailand. TMAC provided two excavator operators as per the TMAC/CCMAT letter of agreement. Both operators were trained combat engineers who understood humanitarian demining. One operator had formal heavy equipment training, while the second operator had only practical experience. Both operators were well versed with the prime mover and the controls before arriving on site. This greatly sped up the training process allowing the assessment team to focus on training the operators to use the BDM48 rather than training the operators to use the entire machine. A total of 29.5 hours of theory and practical training was done. See Annex A for more detail.

- **MRM testing.** Using MRMs permitted the assessment team and operators to safely develop drills that would be applied to all test scenarios. It also enabled the operators to use the machine against mine like targets while working in a benign environment. MRM testing also allowed the assessment team to compare the performance of the MRM with the test results in Canada and directly with the M14 mine.

- **Unfuzed M14 testing.** Testing with unfuzed mines allowed the assessment team to predict what would happen should the M14 mine not detonate during the tests. Using unfuzed mines practised the assessment team's test procedure in advance of live testing. Finally the M14 mines were built in1956, unfuzed testing allowed the team to test the M14's ability to function as designed.

- **Live M14 testing**. Fuzed M14 mines were placed in specifically prepared areas of a minefield. Placing the mines just beyond the edge of the prepared "safe" areas, provided the realism needed for this technical evaluation. In earlier testing at Defence Research Establishment Suffield it was found that the pressure required to function M14 mines is substantially lower than the advertised 20 to thirty five pounds. This presented a safety hazard to the assessment team while burying mines during the live trials that was mitigated by not covering deeply buried mines with soil during testing.

- **Vegetation Clearance.** To provide a general debrushing rates, and to demonstrate the machines ability to work in the challenging jungle foliage and root structure.

4.0 MECHANICAL REPRODUCTION MINE TEST SUMMARY

While the result that captures everyone's interest is the performance of the system against live mines, it is useful to examine the results of the mechanical reproduction mines and the unfuzed M14 mines. A total of 36 trials were conducted using Mechanical Reproduction Mines. The trials, described in detail in Annex B-1 and B-2, took place in low grass, heavy grass, brush, wet and somewhat drier soil, along the sides of termite hills, and in the slope transition zones along the edge of the termite hills. MRMs were placed at depths ranging from 5-20cm.

Of the 36 MRMs used in the trials, 2 were found to be intact and functional ("live"). The first missed MRM was the first ever attempt by one of the operators and so should be discounted due to operator inexperience. In the second case the MRM showed no signs of contact by the machine, but the MRM had been moved from its original location into the berm of loose, processed soil. While it cannot be stated with certainty, it is suspected that the reason for this type of result is slow drum speed. If the operator allows the BDM48 drum to stall or rotate too slowly, the teeth may simply push the MRM (or mine) from one place to another. To help the operators avoid slowing the drum rotation by pushing the BDM48 into the ground too fast, PROMAC installed a gauge in the cab that helped the operators monitor the hydraulic pressure in the BDM48. By observing the gauge the operators could maintain a high drum speed thus ensuring the BDM 48 teeth could contact the mine with sufficient energy to break it. In many MRM tests is was not possible to tell whether the MRM fuze had functioned, and if so, whether it had functioned before or after the MRM had been broken apart. For the purposes of these tests either a broken (neutralised) MRM or a detonated MRM is considered a good result.

5.0 UNFUZED M14 TEST RESULTS SUMMARY

The details of the unfuzed M14 mine testing are included in Annex C. M14 mines have a Belleville spring that drives a firing pin into a detonator. To allow the Belleville spring to function normally without detonation the dust plug was removed and trimmed to the length of the live detonator. The dust plug was then reinserted into the mine to act as a surrogate fuze. By burying the unfuzed M14 mine in varying scenarios and applying the BDM 48 the assessment team could monitor the location and status of the spring, explosive filler, and surrogate detonator after each test. This proved to be an excellent method to evaluate how the BDM48 interacts with a mine that may not have fired, and to prepare the evaluation team for live trials. For the purposes of this evaluation the results of each test were classified as follows:

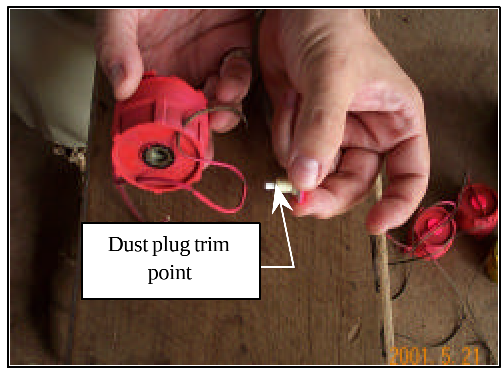

Figure 4: M14 Shipping Plug Modification

Detonated	The fuze functions as designed causing the mine to detonate (high order)
Neutralized	The mine cannot detonate because - the fuze, detonator, and filler have been separated - the firing system has been disrupted
Live	The Belleville spring, detonator, and explosive filler are intact, and the mine can function as designed.

Table 1: Evaluation Terminology

Initial plans called for the unfuzed M14 trials to be conducted in a cleared area of an adjacent minefield. During MRM trials it was noted that searching the berms for mine pieces following soil processing by the BDM48 could be very time consuming. The assessment team also observed that TMAC had buried unfuzed mine bodies in the area for training purposes. Discussions with TMAC personnel concluded that the unfuzed M14 trials could be conducted in the same low risk training area used for the MRM trials. The benefits of this decision were threefold. First, being a low risk area rather than a minefield, searching for pieces could be conducted by several people at a time thus hastening the test process. Second, trials could be conducted with much greater speed without the need for removing people to a distant safe area between trials. Finally the limited number of "brush" sites available in the minefield could be reserved for the live trials exclusively.

A total of 25 unfuzed M14 mines were placed at depths of burial from 0 to 200mm, with three of the trials being conducted at depths beyond 200mm. These trials were done intentionally at depths beyond the machine's stated depth capability of 20 centimetres to test the limits of the machine. One mine deeply buried mines was neutralised with evidence that suggests no detonation would have occurred while the other two remined intact.

Of the remaining 22 unfuzed M14 mines, 3 were found intact but with their fuzes functioned, thus indicating detonations. One other mine was found neutralized (broken up and with the fuze and detonator removed from the main charge), but with the spring in the unfired position. It is impossible to make definitive conclusions about whether the mine would have been broken apart before the fuze functioned, or whether it would have detonated first but either result is acceptable. The unfuzed trials did confirm the BDM 48's operating depth of 20 centimetres as required by UN Standards.

In addition to varying depths of burial and soil/environment, several mines were intentionally buried rolled onto their sides. Some were buried with the pressure plates facing the machine teeth, and some with the pressure plates facing the operator. The purpose of this test was to see if soil deformation alone would function the mine. Test results did not vary from normally employed mines in that mines buried within the operating depth of the machine were neutralised/detonated, mines buried deeper than 20 centimetres were left intact.

6.0 LIVE M14 TEST RESULTS SUMMARY

The details of the live M14 testing are presented in Annex D, the full test procedure is explained in Annex E. In all 35 live M14 mine trials were conducted, of which 33 mines detonated.

Figure 5: Live Test Area

In preparation for live M14 mine testing, TMAC prepared a section of road until it was deemed to be a low risk area. Off each side of this road 3-meter stub lanes spaced four to 5-metres apart were prepared, first by debrushing with the Tempest flail, and then by either manual demining teams or demining dog teams, or both. Some lanes were in clear ground with little vegetation, or low grassy cover, while others were in brush conditions ranging from waist high weeds to small trees 2-3 metres tall or more.

For safety, one M14 was buried at a time. Following the BDM48's processing the area was checked to ensure there were no partial detonations or pieces of other mines. At this point the location for the next mine was prepared. For safety reasons, the live M14 mines were not covered with soil after being placed. They were, securely seated at the bottom of their holes, and soil was packed around the sides of the mine body. While this approach was taken to avoid the risk of setting of a mine while packing soil on top of it, a side effect was that it made it more difficult for the machine to detonate the mines since there was no “plug” of soil which could be pressed down onto the fuze.

Live M14 mines were buried in clear or low-grass conditions and in brush conditions at depths of burial ranging from 0 centimetres (flush buried) to 20 centimetres. Generally soil conditions were dry although a few tests were conducted in soil that was saturated with water. In addition to the variations in soil/terrain/environment and depth of burial, two mines were rolled onto their sides, one with the pressure plate facing the machine teeth, and one facing the operator.

All but two of the live M14 mines resulted in detonations. One mine that did not detonate was thoroughly neutralised with the belleville spring removed and destroyed, and the explosive filler removed and demolished. The detonator was retrieved and showed no signs of contact from the firing pin even though the spring was triggered. Examining the fragments suggests that one of the BDM48 teeth likely caught the side of the mine body and peeled the top (fuze) section from the bottom section. This or subsequent impacts broke the mine apart separating the fuze mechanism and shattering the explosive filler.

The second undetonated M14 was found unfired, and intact in the berm. This mine had been laid at 100mm depth, and rolled on its side, presenting the pressure plate toward the machine operator. In this position the BDM48 teeth are aimed at the side of the mine rather than at the pressure plate. The mine may have rolled through the BDM48 because of low drum speed or may have been caught between teeth. In any case the subsequent scraping action was responsible for moving the mine from its initial location and into the berm. TMAC deminers demined the berm and removed the intact mine. This result illustrates the need to follow the proper machine SOP and to include clearing the berm after the BDM48 is used.

7.0 CORRELATION OF RESULTS

Normally users focus on the machine’s performance against live mines. But it is useful to determine if the MRM and unfuzed mine trials were of any value. If it can be shown that using safer unfuzed mines or even inert MRM test pieces provide the same or even similar results to the live trials, then machine performance might be estimated or predicted based on these types of trials before committing to live trials.

Working from the live trials backward, it is interesting to note that almost all of the live mines detonated, and of the two that did not, one was thoroughly neutralized. This corresponds closely with the results of the unfuzed mines. Ignoring those mines buried beyond the machine's operating depth of 20 centimetres, all but one of the unfuzed mines were neutralized or detonated, while one mine was neutralized rather than being detonated. Considering that detonated mines and neutralized mines are both satisfactory results, the unfuzed trials seem to provide a valuable evaluation tool.

Did the MRM trials provide any useful data that correlates with the mine trials, either live or unfuzed? If the results of the trials are simply normalized by calculating the percentage which were detonated, neutralized or live, we find a very good correlation between the MRMs and the M14 mines.

Target Type	Live	Neutralized	Detonated	"Dead" (Neutralized or Detonated)
Type 72A MRM	6	86	8	94
Unfuzed M14	0	86	14	100
Live M14	3	3	94	97

Table 2: Percentage Comparisons

Table 2 illustrates that the BDM48's performance against Type 72A MRMs is analogous to its performance against M14 mines. The reasons for this is that the machine breaks up virtually all of the mines and those that are not broken normally detonate. For a machine like the BDM48 it is constructive to examine "how" the mines and MRMs are normally broken up. Are the MRM fragments similar to the M14 fragments? For this we relied heavily on the unfuzed M14 data. Annex F shows a sampling of MRM fragments and M14 fragments. By comparing the broken unfuzed M14 mines with the broken MRM mines it can be seen that there is a very good correlation between the two even considering that the MRM is not an M14 model. While there are structural and materials differences between the MRMs and their real counterparts, the MRMs appear to be a good substitute target for the real mines, at least in the case of the Type 72A MRM and the M14 mine. Therefore we conclude that for machines like the BDM48, MRMs perform close enough to real mines and are a useful tool for T&E as well as for training.

Figure 6: M14/MRM Correlation

8.0 DEBRUSHING

The purpose of debrushing is to expose the ground in preparation for locating mines using hand held metal detectors or mine detecting dogs. Debrushing can take up to seventy percent of the deminers time. Consequently the debrushing capability alone offered by the BDM48 provides a significant increase in the overall rate of demining that deminers can achieve. In Thailand the minefields have been overgrown by underbrush and bamboo. Bamboo, especially, slows or prevents demining to the point where debrushing equipment is an operational necessity. The rate of debrushing can vary widely and depends on many variables. However, in the five trails held in Thailand, debrushing rates in thick underbrush and bamboo from 4 to 8 square metres per minute were achieved. Annex G describes the five timed debrushing trials that were undertaken.


Figure 7: Debrushing Bamboo

When using mechanical equipment for demining the machine must not only deal with vegetation above the ground, but it has to work through the root mass in the ground. In dry hard-baked ground root mass acts like reinforcing bar in concrete that obstructs manual demining. Bamboo has a large interwoven root mass that, in wet conditions, is elastic and is very difficult to work through. During these trials the BDM48 was used in both dry and wet conditions. Tests confirmed that the constant pressure of the BDM48 is enough to work through root mass up to 8 centimetres in diameter and still detonate or neutralise the mine.

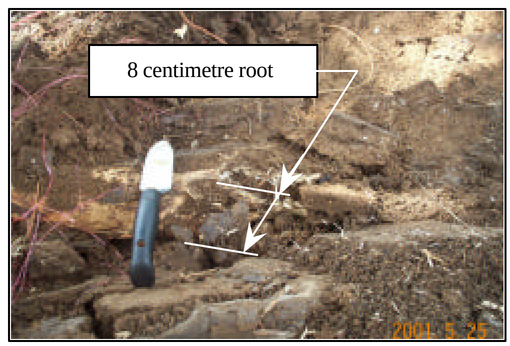

Figure 8: Root Structure Successfully Removed

9.0 SYSTEM LIMITATIONS

Despite its impressive performance in the original MAE T&E trials and the subsequent results in Thailand, the BDM48 does have limitations. The assessment team observed the following limitations of the system:

- The successful application of the ProMac BDM48 is highly dependent on operator skill. Careless use or inattention to the SOP may cause the machine to miss mines.

- It is critical that the rotational speed of the BDM48 drum be maintained when grinding a suspected mine location so that the BDM 48 contacts the mine with sufficient energy to break the mine into pieces. Failing to maintain rotational speed could result in mines being pushed rather than being detonated or neutralized.

- The live trials in Thailand indicated that a very high percentage of M14 mines detonated or were neutralized. Using the BDM 48 in other environments or against other mine types may offer different results. Initially, as the machine experience grows, MACs should test the machine against their threat mines and in their environment to ensure the BDM 48 suits their needs.

- Even with a skilled operator there is the possibility that mines buried at the limit of the machine (20 centimetres) may be missed or incompletely destroyed. The operation of the machine must be followed up by other means to check that the target area is clear of suspected mine targets.

- Any operation, but especially operation in saturated soil, can result in soil being packed under the head of the machine. This results in mud and soil being packed around the bearings that supports the BDM48 drum. The operators should remove all soil from around the bearings to prevent the mud from slowing the drum rotational speed. This is also a preventive maintenance measure. The trials demonstrated that mine fragments may become embedded in soil packed in the BDM48 itself. The operators should remove packed soil at the end of the day and watch for mine fragments that may need to be destroyed.

- In cases where the mine has been rolled over on its side and deeply buried, the machine may neutralize rather than detonate the mine. This was especially noted when the pressure plate of the mine was oriented toward the machine operator; in this position the BDM48 teeth are aimed at the side of the mine and the downward pressure of the machine is also aimed at the side of the mine. Therefore the ground soil forming the berm as well as the bottom of the ground spot will have to be cleared by deminers after the machine is used to check for and remove mine parts.

- As the machine is employed in a spot-digging operation rather than a continuous in-ground grind, there is the opportunity for ridges to be formed on the bottom of the processed area. The standard operating procedures adopted must ensure that these ridges are also ground off.

10.0 TMAC STANDARD OPERATING PROCEDURES SUMMARY

The Thailand Mine Action Centre (TMAC) considers mechanical assistance to demining as an essential element of its humanitarian demining program. The reason for using mechanical systems is to accelerate manual demining or demining with dogs. Therefore the BDM48 will not be used as a stand-alone system. Annex H provides draft SOPs for using the BDM 48 in support of humanitarian demining. These SOPs are specific to TMAC and will be amended as experience is gained with operating the BMD48. The BDM48 provides the following general capabilities:

- Safety and security for the operator by working from the cleared area and reaching into the mined area.

- Removes vegetation to make the ground available for using mine detectors or mine detecting dogs.

- Removes the tripwire threat.

- Removes or reduces the mine threat by neutralizing mines by grinding or causing mines to detonate.

- Follows the contours of the ground.

- Works in and around obstacles to demining including termite hills, slope up to 45 degrees.

- Applies the BDM48 tool head above and below the level of the machine

- Works through root structure, and rough ground.

- Works in adverse weather conditions such as rain and saturated soil.

- Provides the demining unit with a finesse tool that can work around specific locations without destroying infrastructure and vegetation.

The BDM 48 system will fit into TMAC's current command and control structure and integrate into TMAC's process of mine clearing which includes all levels of survey, mined area marking, demining, and post demining action. The system will be employed as part of a mechanical demining platoon. The mechanical demining platoon will be controlled centrally by TMAC's Humanitarian Mine Action Units (HMAU) plans staff who selects and controls the locations and priorities of work where the platoon will work.

Role 1: Brush clearing and demining.

Role 2: Area reduction.

Role 3: Quality assurance.

11.0 CONCLUSIONS

The MRM is an appropriate tool that specialist teams or demining units can use in the field to safely test and evaluate mechanical tools for demining. It also offers a realistic tool for manual demining training.

As a result of testing, the BDM48 system was modified on site so that it better suited the operational task of demining. Modifications included a gauge that allows the operator to monitor the hydraulic pressure in the BDM 48 working head, and a scraping blade to allow the operator to remove the spoil from the ground location and see the bottom of the excavation. With those modifications, the BDM 48 system was ideally suited to the demining conditions found in Thailand. See annex I for a full description of the system modifications employed.

The existing shock damping device works well when loaded vertically during a mine blast. However during this evaluation it was found that the device is too flexible for the operators to control the BDM 48 during the scraping process. The scraping process also creates lateral loads that the damping system was not designed to withstand and could become a maintenance problem over time. It is recommended that the shock damping include lateral stiffening to that the shock absorbing qualities of the system are not degraded because of continual lateral loading of the system.

12.0 RECOMMENDATIONS

During the evaluation it was found that the BDM48 detonated or neutralized all mines to a depth of 20 centimetres and can be operated in a manner that meets demining standards set out by the United Nations Mine Action Service. It was also found to be suitable for the environment and field conditions found in Thailand. It is therefore recommended that the Government of Canada contribute the BDM48 to TMAC to support the Thailand's Humanitarian Demining effort. TMAC's observations are included in this report at annex J.

Should the Department of Foreign Affairs and International Trade fund a project to utilise the BDM48 in Thailand, it is recommended that operational statistics be collected and returned to CCMAT as experience with the system increases.

The CASE 9040B contains sophisticated computers and controls that the operators and supervisors are not familiar with. It is highly recommended that the operators and supervisors be given formal training on the use and maintenance of the prime mover by CASE representatives working in Thailand before demining with the BDM48 starts.