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Systematic Test & Evaluation of Metal Detectors (STEMD)
Interim Report Field Trial Lao
27th September – 5th November 2004

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List of abbreviations

AIDCO	EuropeAid cooperation office
BLU	Bomb Live Unit, bomb submunition existing in different types
CWA	CEN Workshop Agreement
FAR	False alarm rate
GICHD	Geneva International Centre for Humanitarian Demining
GRH	Ground reference height
IPPTC	International Pilot Project for Technology Co-operation
ITEP	International Test and Evaluation Program
JRC	Joint Research Centre
MD	Metal detector
POD	Probability of detection
ROC	Receiver operating characteristics
STEMD	Systematic Test & Evaluation of Metal Detectors
UXO	Unexploded ordnance

Systematic Test & Evaluation of Metal Detectors (STEMD)

AIDCO-JRC Administrative Arrangement No. MAP/2004/078-257

Interim Report Field Trials Laos

27th September – 5th November 2004.

1 Introduction

In March 2004, the Lao National UXO Programme (UXO Lao) requested the United Nations Mine Action Service (UNMAS) to provide assistance in the testing of metal detectors best suited to the Lao context. UNMAS supported it and forwarded it to the Joint Research Centre of the European Commission (JRC Ispra, Italy). JRC in turn proposed incorporating a trial in Laos as a part of a larger European Commission (EC) project entitled Systematic Test & Evaluation of Metal Detectors (STEMD) which was being planned to be undertaken for the EuropeAid cooperation office (AIDCO). After AIDCO confirmed the funding of STEMD, it was decided to conduct the trial in Laos on an urgent basis, together with other participants in the International Test and Evaluation Program (ITEP). The UK participated with a specialist from QinetiQ, Belgium provided two personnel through the Ministry of Defence (MoD), the Geneva International Centre for Humanitarian Demining (GICHD) sent their Technology Officer for assistance in planning and during the trial itself.

2 Background

2.1 Systematic Test and Evaluation of Metal Detectors

The project consists of laboratory tests, field trials and training of interested parties in testing methods. Field tests are planned on three continents under different environmental conditions, the Lao trial being first. Lab tests are being carried out in the laboratories of the JRC Ispra.

A key milestone in metal detector evaluation was the International Pilot Project for Technology Co-operation (IPPTC) which was conducted from 1998 to 2000, producing a "consumer report" of the detectors available at the time.
The experiences of IPPTC and of those of other trials with international importance were subsequently integrated into CEN Workshop Agreement 14747:2003, henceforth referred to as CWA. This Agreement standardises test methods for both laboratory and field use, and summarises the practical experience and theoretical knowledge of a large number of deminers, engineers, managers, and manufacturers.

Between May and December 2003 an exercise to validate the CWA field trial methodology was conducted by the German Federal Materials Agency (BAM) with the collaboration of the JRC, the German Bundeswehr and the Croatian Mine Action Centre (CROMAC) (Mueller *et al* 2004). In addition to confirming the basic validity of the CWA methods, this project introduced improved techniques for test matrix design, statistical analysis and human-factor analysis which we adopted in the present trial.

STEMD can be regarded as a trial making use of the experience distilled into the CWA and giving an overview of the state of art of the current metal detector fleet. It provides scientifically sound data for the mine action centres and demining organisations and training in the use of CWA. It also provides the donors with information that allows a better understanding of detector performance under different field conditions. The collected data will be added to the catalogue on metal detectors published by GICHD.

Further field trials as well as training to the CWA are planned in the Southern African region, in the Republic of South Africa (RSA) and Mozambique, involving the mine contaminated countries with their MAC and demining organisations. Training in testing according to the workshop agreement is planned, in collaboration with the Council of Scientific and Industrial Research (CSIR) of the RSA. The last metal detector field trial, for the European region, is planned to be held in Croatia.

2.2 The UXO problem in Laos

Laos saw armed conflict almost continuously from 1960 to l975. Although there are some minefields in Laos, the primary threat is from unexploded ordnance (UXO). More than 2 million tonnes of explosive ordnance were dropped, it is estimated that between 10% and 30% failed to initiate at the time (UXO Lao Work Plan 2004) and many items remain in a dangerous state. UXO encountered in Laos includes artillery, mortar, rocket, cannon, and air-dropped munitions. The most problematic are cluster bomb submunitions that did not explode on impact , of which there are an estimated 8-25 million (UXO Lao Work Plan 2004). These UXO represent significant hazards in many areas of the country and have had a serious impact on economic development, tourism, food production, and other infrastructure development.

Clearance of these items requires locating the UXO and disposing of it. The primary equipment used to locate the UXO is the metal detector due to the presence of a relatively large amount of metal found in most UXO. The problem is made worse by the fact that many items of ordnance did function and left large amounts of metal fragments or debris, which are also detected by metal detectors. The problem of detecting UXO is two-fold; first the item must be located and it must be located in an environment contaminated with high concentrations of metallic fragments or “clutter”. Secondly, many areas in South East Asia have a laterite soil which is known to have an adverse effect on metal detectors. These factors and others make the selection of a suitable detector a difficult task. It is for these reasons that UXO Lao have requested assistance in providing the necessary data and test results in order to select a detector or detectors best suited for their environment and operational requirements.

UXO LAO is planned to make a major procurement for new mine detectors before the end of 2004. At the start of the trial described here, UXO Lao sent requests for quotations to the manufacturers of the participating detectors, for response by 5th November.

3 Purpose and Objectives

The **purpose** of the trials in Laos was to:

- Assess metal detectors (MD) which had been previously identified as possibly suitable on the basis of lab tests and on the advice of manufacturers.
- Provide UXO Lao with performance data, which will assist in the selection of future equipment.
- To extend the application of the CWA to small items of UXO

This exercise constitutes an Acceptance Trial in the terminology of the CWA 14747
Objectives of the trials:

- Carrying out a MD acceptance trial to the following requirements of UXO Lao:
    - ability to detect BLU-26B and 20mm cannon shell targets (Plate 3-1 and 3-2) up to 300mm depth, and
    - ability to reject small pieces of metal scrap.

Plate 3-1 BLU-26

Plate 3-2 Projectile of 20mm cannon shell (from website of Colin Stevens, Burnaby Village Museum, Canada)

- Training and preparation of UXO Lao personnel in the use of detectors, trial execution, and simple soil measurements, as well as determining the sensitivity area of the different detector under field conditions.
- Carrying out a statistically valid detection reliability trial (blind trials) on two different sites with different ground conditions.
- Establishment of the maximum detection depth in different soil conditions.
- Informing the international demining community about the advantages/disadvantages of UXO-version detector versus mine-version metal detectors. (UXO-version detectors have larger diameter heads more suited to searching for larger objects buried deeper.)

4 Preparation

4.1 Long-term preparation

The JRC contacted the manufacturers of metal detectors that are mainly used by UN programmes, NGOs, and commercial organisations to recommend their latest models of metal detectors for the foreseen STEMD project in the last quarter of 2003. The JRC financed the purchase of two examples of each recommended type. These detectors were tested in the Laboratories of the JRC in accordance with the CWA. Most of the tests listed in the CWA were carried out and the field trials could then be prepared.

For this purpose an in-country survey was carried out with the participation of the Technology Officer of the GICHD. In June 2004, 13 sites were surveyed. Soil samples collected from those sites, and measurements of the magnetic properties of the soils were made. Three test sites were selected because of their particular ground properties and the reduction of efforts for logistical support. (See map - red marked test area in the southern region Pakxé).

Figure 4-1 Laos

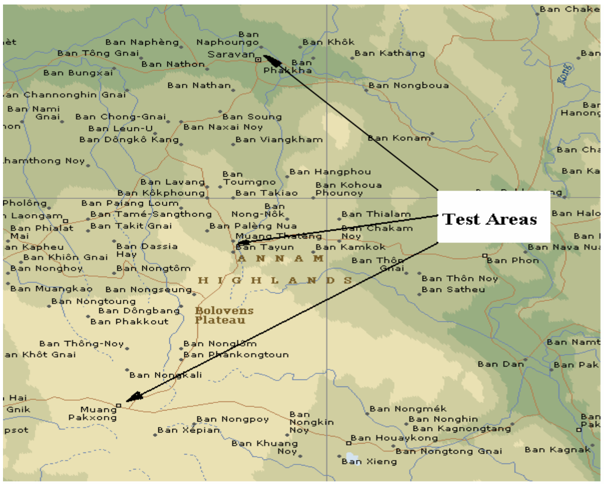

Figure 4-2 Location of test areas

4.2 Preparation and Planning of the Trial Parameters

In preparation of the trial, the trial matrix was designed according to the known number of available personnel and detectors, and the desired statistical confidence. With this basic data, the position and depth of the targets were randomly placed in each lane. Each operator was also attributed two detectors randomly. The layout of a lane and the approach is given in Figure 4-3.

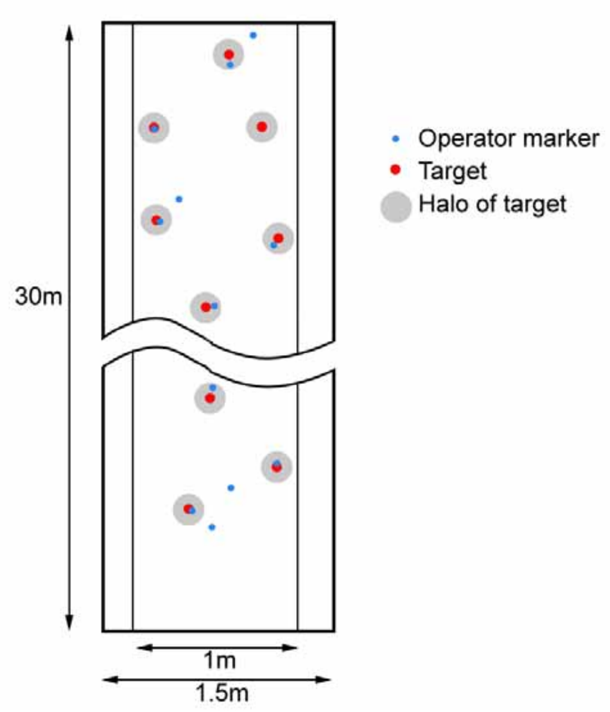

Figure 4-3 Sketch of lane layout (not to scale)

A typical lane was 30m long and 1.5m wide.

Targets were planted at least 250mm from the sides of the lane.

The minimum distance between the targets was 900mm to avoid target signal overlap.

Every target had a virtual halo with a 100mm radius. This halo determines if a marker placed by the operator is either a hit (“True Positive”) or a miss (“False Positive”).

The test included:

16 operators
8 detector types, 2 copies of each type
2 detector types were used by each operator
4 operators used each detector

4 lanes per site
2 types of target
17 of each target type per lane
4 depths

On each site, each deminer made 6 passes with each of his 2 detector types, 3 with each copy.

The number of opportunities to detect a particular target type, at each depth, with each detector model was

$$4 \text{ operators} \times 6 \text{ runs} \times 17 \text{ targets} \div 4 \text{ depths} = 102$$

The total number of runs on each site was

$$16 \text{ operators} \times 6 \text{ runs per detector model} \times 2 \text{ models} = 192$$

The number of starts per day was planned to be

$$192 \text{ runs} \div 4 \text{ lanes} \div 4 \text{ days} = 12$$

In practice, the starts were not equally distributed between the days, fewer taking place during the first two days, due to unfamiliarity with the detectors, rain and other delays.

4.3 Direct field trial preparation

UXO Lao prepared test lanes in for the blind trials (Plates 4-4, 4-5) in Sites 1 & 2, and test pits on all sites. Using available detectors, the teams tried to make the lanes and pits as free from metal as possible. On every site, two pits 2m × 2m for establishing maximum detection dept were prepared.
Two weeks before the trial, the targets were planted on Site 1. In every lane, seventeen BLU26B's and seventeen surrogate 20mm projectiles were buried. Four of each were buried at each of the four chosen depths (0.1m, 0.2m, 0.25m, and 0.3m) and the one remaining target of each type, was buried at a different depth in each of the four lanes. The cannon projectiles were placed horizontally, because this is the more difficult orientation to detect.
Unfortunately, insufficient targets were available to place the targets on Site 2 at the same time so the targets were placed only three days before the tests. The two chosen targets are easily detectable for all the metal detectors under test at a distance of 300mm, considerably more for some of the detectors. The detector operators did not participate in, or view the target burial so that they did not know the random pattern of the target placement.

PLate 4-4 Site 1 Pasture next to a rice paddy, near Saravan town

Plate 4-5 Site 2. Grounds of the Thateng Tai hospital

4.4 Detector selection before the trial and after the training in the field

A written invitation was sent to the following reputable companies on 28th July 2004 (ANNEX A):

- Adams Electronics International Ltd,
- CEIA S.p.A.
- Guartel Ltd.
- Ebinger GmbH
- Inst. Dr. Foerster GmbH and Co. KG
- Minelab Pty. Ltd.
- Schiebel Elektronische Geräte GmbH
- Vallon GmbH.

Key conditions were that only production models, not R & D prototypes, would be considered in this trial and that only electromagnetic induction devices would be considered. Manufacturers were asked to give an initial response within two weeks of receipt to allow delivery of any additional detectors or modifications to JRC by the last week in August 2004. This relatively quick delivery schedule was intended to allow laboratory tests to be completed before going to Laos for field trials in early October 2004. It was, at this time, stated to the manufacturers that any equipment received after that date would not be included in the evaluation. After that, Vallon and Minelab sent UXO versions of their devices. Ebinger and CEIA later asked to bring also UXO versions of their detectors to Laos. By this time, the trial matrix had been constructed and the maximum number of detectors in blind trials had been fixed at 8.
It was decided by the trial director to relax the conditions and allow these devices to be included but only if the non-UXO version was withdrawn.

As a result of the laboratory in-soil tests at Ispra it was determined that the Guartel MD8+, Ebinger 420HS solar and Adam AX777 detectors were essentially unusable on lateritic soil from Toscana, Italy, due to soil noise. Since it was known from magnetometer survey data that this soil is not as bad as that encountered in Laos, these detectors were not retained in the trial.

In Table 4.1 the shipped and lab tested detectors as well as the detectors added by the manufacturers are shown. The final choice of detectors was made after the last day of official training and after the manufacturers had decided, which type they wished to be tested.

Table 4-1 Preselected and added detectors

Ser. No	Manufacturer	Model (lab tested)	Added Model	Training Y/N	Recommended to be tested by Manufacturers
1	Ceia	MIL-D1		N	
2			MIL-D1/DS	Y	MIL-D1/DS
3	Ebinger	Ebex 421 GC		N	
4			Ebex 421 GC/LS	Y	Ebex 421 GC/LS
5	Foerster	Minex 2FD 4.500		Y	Minex 2FD 4.500
6	Minelab	F3		Y	F3
7		F1A4		N	
8			F1A4 UXO	Y	F1A4 UXO
9	Schiebel	ATMID		Y	ATMID
10	Vallon	VMH3		Y	VMH3
11			VMH3 CS UXO	Y	VMH3 CS UXO

The final list of tested equipment included 4 mine-version detectors (Schiebel ATMID, Foerster Minex, Minelab F3, Vallon VMH3) and 4 UXO-version detectors (Ebex 421 GC/LS, VMH3 CS UXO, Minelab F1A4 UXO, and Ceia MIL-D1/DS).

4.5 Personnel and Resources

In the phase of the urgent request to the JRC from UNOPS for supporting UXO Lao two ITEP participants, Belgium and UK, decided to provide personnel support to the trial for this purpose.

The international team responsible preparing and supervising the practical field trials, consisted of 8 persons:

- Adam M Lewis – Project Director – JRC
- Data Gathering Team, D. Guelle (also trial team leader), M. Pike – both JRC; A. Carruthers – GICHD. The data gathering team was responsible primarily for the collection and recording of the data related to the blind trial, measurement of soil magnetic susceptibility, GRH, and collection of soil samples.
- Lane Officer, S. Bowen – QinetiQ UK. The lane officer was responsible for coordinating activities in the lanes, making sure that the operators were in the right lane with the right equipment, recording start and end time of each run, and noting any problems, errors and environmental conditions.
- Pit Team, – J-L. Trullemans, P. Vergucht both Ministry of Defence Belgium. The pit team was primarily responsible for the conduct of the maximum detection depth to the used targets and a 10mm 100Cr6 steel ball for comparison.

All of the international team assisted in the preparation of the trial sites, positioning and recovery of the targets, and recording the ground truth locations of the targets.

UXO Lao made available a team leader, Mr. S. Kouavong, with 16 operators and two further deminers for additional support, needed during the establishment of the maximum detection depth. In addition the necessary logistic support for transport of the personnel and the equipment, storage, and accommodation was also provided. On site liaison and assistance was provided by NGO technical advisors on as required basis.

4.6 Detector Operator Training

The week before the commencement of the blind trials the manufacturers had two days (for every detector) to train four deminers in the use of their detectors. They were asked to propose the detectors that they had found during the training to be most suited to the requirements of UXO Lao. The detector training of the deminers took place in Pakxé (Champassak Province). All but one manufacturer sent their representatives to carry out the training. Every deminer was trained in the use of two detectors. The one manufacturer that could not provide training requested that the international trial team gave the training for both his models. The Belgium officers belonging to the international team carried out this training.
On Thursday 14 Nov 2004 the eight detectors shown in Table 4-1 were finally selected as the detectors to be included into the final trials.
The last day of the training was spent briefing personnel on the purpose of the trial, its methodology, and what was expected of the individuals during the trial. In addition, the operators were given instruction on some of the characteristics of detectors and how their sensitivity can vary.
A practical exercise was conducted demonstrating the sensitivity area of the detector to the trial targets and the 10mm 100Cr6 steel ball. This showed the operators that the sensitive area depends on metal content and shape of the target, the distance and orientation to the search head, ground conditions, and sensitivity of the detector. The operators actually plotted the sensitivity cones for the above mentioned targets using the general procedures as described for tests in air (CWA Test 6.7.2). A detailed description how to carry out this test in ground can be found in the Metal Detector Handbook for Humanitarian Demining[1] (see references).

Plate 4-6 Determination of the cone’s “width”

Plate 4-7 Measurements of the cone’s “depth”

This gave a three-dimensional understanding about the detection ability to the targets. For the 20mm bullet, two positions vertical and horizontal to the search head were used.

[1] Metal Detector Handbook for Humanitarian Demining ISBN 92-894-6236-1 (p. 108)

5 Principles and Procedures of the Blind and Test Pits Trials

5.1 Detection Reliability Tests Procedures (Blind Trials)

The objective of a detection reliability test is to evaluate the detection ability of a detector when used by an operator who does not know the location of the targets (CWA 8.5.1). To avoid introducing bias in the assessment of the detectors it is necessary that each is subjected to equivalent test conditions. In particular, it is important that several operators use each model of detector, CWA requires at least 3. Ideally, every operator would use every detector. For practical reasons: the total time available, and difficulty of learning many detectors without getting confused, this is impossible. We adopted the "graeco-latin square" method of experimental design (Mueller *et al.*, 2004 – see References) which produces as unbiased as possible test condition without having to test every possible combination of detector and operator. We did ensure that every detector in total was tested the same number of time in every lane. The Test Matrix is in ANNEX B. The total number of runs was designed so that the number of opportunities to detect a given target at given depth was over 100, which implies that a probability of detection of 80% could be determined to within ± 0.08 with 95% confidence. The matrix was used in both sites.

Before the trials, operators were "randomly" assigned to two detector models. To facilitate data collection, each detector model was attributed a number (the copy was primed) and each operator received a letter code.
In accordance with the matrix, the lane officer assigned operators to lanes with their assigned detectors. The deminer had to work as he would in a real mined area. However, he was not allowed to investigate the reason of the signal, as he would have done in reality.
When receiving an alarm signal, the operator would pinpoint the centre of the signal and place a non-metallic rubber marker. Once an operator finished the lane, the data-gathering team recorded the position of these markers using the total station and the unique operator/detector code. These records are used to determine the number of True Positives (i.e. a marker within the halo radius (0.1m) of a target), False Positives (i.e. markers outside halo of target) and the analysis.

In order to minimise the possibility of operators remembering the position of the targets, the direction of the search was changed once operators completed all 4 lanes.

The deminer was not restricted or directed in the establishment of the detector's sensitivity. He used it as he was trained and as he felt safe to use it, but he had to confirm the detection ability in the established calibration pit. Both targets were buried there in the required 300mm depth and in the same orientation as in the test lanes.

Measuring the position of the targets and the markers placed by the operators was done in a semiautomatic way by using a Leica remote controlled Total Station (an automatic theodolite with integrated laser range finder, Plate 5-1 & 5-2). The operator places the prism pole on the marker or target, the Total Station automatically rotates to locate the prism's direction and then determines its range. When the Total Station has acquired the prism, the operator remotely instructs it to record the coordinates. This allowed the daily storage of data on a standard memory chip and easy downloads to a computer.

Plate 5-1 Operating the Station remotely

Plate 5-2 Total Sation

5.2 In-soil Maximum Detection Depth Procedures

Operators who were not working in the lanes participated in determining maximum detection depth in the test pits (CWA Test 8.3A).
Four of the same targets were buried in each pit at 4 different depths. Each detector was called in turn to the pit to determine which of the 4 targets (of the same type and orientation) the detector could detect. Subsequently the targets were reburied at different depths so that the maximum depth could be found. In one pit, this was done starting from the maximum depth (before established in air) and in the other pit starting with a depth that could easily be achieved by all detectors. No special efforts were done to compact the ground. The ground was just level with the surrounding ground.

On Site 1 and 2, the same procedure was followed with the two copies of each model. For establishing the maximum detection depth, a depth increment of 50mm was used. If the detector could not detect a target at a particular depth, the previous recorded detection depth was used and increased by 25mm in order to establish a more precise detection depth. For the steel ball, lower increments of 30 and 10mm were used respectively. One of the two detector copies was used for one depth and the other for the next depth. A deminer, trained in use of the detector under test, was selected at random, and handled the detector for both set-up and establishment of maximum detection depth.

The same approach was used on Site 3 but both copies of each detector model were systematically tested in both pits due to their different ground measurement values. An additional test of the compensation capability was carried out on Site 3 as some detectors failed to compensate in the test pits. Furthermore, the site was used at some spots with extreme high values in magnetic properties of the ground and ground reference height[2] (GRH - see ANNEX C).

[2] GRH – Height measured where a calibrated Schiebel AN-19/2 metal detector Mode 7 starts to signal above the ground. The calibration is done by the help of the standard test piece of the detector at a 100mm distance to the centre of the search head. The sensitivity should be so adjusted that the detector just give a signal to the test piece.

The principles of this test are described in paragraph 8.1.5 , “General testing procedures”, of the CWA. The detector was set-up and ground compensated in accordance with the user manual.

The ground compensation was carried out in the way as the operator was trained to. In most cases there is a clear signal if the procedure of the ground compensation is finished. Other detectors just stop to signal when close to the ground if they have adjusted themselves to the ground. If this was the case, the detector had to be used like for searching targets in the ground. If during this procedure no ground interference was registered the detector was moved over a metal target and with a clear signal the compensation capability was confirmed. No efforts were undertaken to establish maximum detection depth.

The co-ordinates of the site were measured with a hand-held GPS with the respective accuracy in WGS-84 map datum, in latitude and longitude (dd.mm.ss).
Any measurements with a ruler (depth, sensitivity area) are to be considered with an error ± 1cm whilst the measurements of the markers in the lanes with the total station are <1cm.

The blind trials were carried out without any major problems. The temperature on the different sites varied from about 20 degrees Celsius in the morning to up to 40ºC at 14:00 before dropping back to 20ºC again in the evening depending also on the working site. The only environmental interruption was caused by a 30 minute rain shower on Site 1. A further 30 minutes interruption occurred on Site 1 as a nearby UXO had to be blown up. We had temporarily to evacuate the site.
Running the blind trial and the maximum detection depth test in parallel allowed the operators to repeatedly perform detector setup procedure to maximum sensitivity. Nevertheless on Site 2, some Vallon VMH3 UXO and CEIA operators experienced difficulties in the use and with the ground compensation procedures. Short refresher instructions of the procedures were given to the deminers and they were supervised for the rest of the day. This eliminated the difficulties.

The CEIA MIL-D1/DS demonstrates a new approach and the sweep method is quite different to that of normal metal detectors. The sending and receiving coils are physically at least a meter apart (see Chapter 8). This requires a change in the operators’ sweeping habits, although the training officer allowed the operators to use the detector in the traditional way. They had a hard time making the transition from the method of operating a typical detector to using a detector that operates in a different mode.

Due to the limited size of the lanes, the frequent targets, metal contamination outside of the lanes, and the rather large dimensions of the detector, some operators got puzzled. We believe strongly that the detector easily picked up metal contamination when either end was swept partially outside of the test lane. The deminers were collected and received a practical instruction how they can detect and pinpoint keeping the detector within the border of the test lane. This was combined with the explanation of the sensitivity area and the restriction as far as possible not to leave the test lane during searching targets and pinpointing. With this understanding no further questions came up.

6 Short Introduction to the influence of ground on metal detectors’ detection capability

Above was mentioned that there were two main reasons for choosing the used sites. One was for logistics and the more significant for us due to the different ground conditions. This is important to understand when later during the assessment of the general and the individual detector results

the terms easy or more complicated ground conditions are mentioned. There are different factors influencing detector performance. These include human factors, the technical solutions of the manufacturer, the metal object, shape and position, and distance of the “target”, and at the end the ground properties, in particular magnetic susceptibility[3].
We will only cover magnetic susceptibility and ground reference height (GRH). These give an indication of how the ground material reacts to a magnetic field. Both are related to each other and allow a certain assessment of the detector performance. In very general terms, the level of magnetic susceptibility in a particular ground and its frequency dependency are the main factors influencing the detector performance. The frequency dependency is included in the column “Low Frequency Susceptibility minus High Frequency Susceptibility”. Both the frequency dependency and the ground reference height are correlated if one only looks at the absolute figures in the Tables 6-1 and 6-2.

The chosen sites for the blind trials had only one essential difference beside the geographical one, the magnetic susceptibility and in accordance the GRH. On all sites the Bartington Susceptibility Meter (see **ANNEX D**) was used to measure the magnetic susceptibility with 3 frequencies (465, 958, 4650hz).

Table 6-1 Susceptibility measurements in the lanes of sites 1 and 2

	Magnetic Susceptibility measured with the Bartington MS2 meter (SI)			Low Frequency Susceptibility minus High Frequency Susceptibility	GRH (mm)
Site 1	MS2B (465Hz)	MS2D Loop (968Hz)	MS2B (4650Hz)	MS2B (465Hz) minus MS2B (4650Hz)	Schiebel AN19 Mod 7
Lane1	20	19,23,13,12,13,15,20	21	-1	0
Lane2	105	21,22,13,14,18,15,16,	106	-1	0
Lane3	94	36,38,70,49,55,67,15,6,21	94	0	10
Lane4	209	19,29,40,17,11,9,15	208	1	0
Site 2					
Lane1	904	505,356,470,476	849	55	280,310,290
Lane2	764	471,437,359,512	716	48	270,290,280
Lane3	964	391,397,433,400	906	58	290,300,270
Lane4	868	450,499,571,520	828	40	270,270,300

On Site 1 the results were between 15 and 70 SI (GRH 10mm) on Site 1 on Site 2 with 359 to 789 SI (GRH 270 – 310mm). Site 3 magnetic susceptibility was measured in the test pits with 1684 to 1760 SI (GRH 350 – 480mm accordingly). It has to be added that on that site spots were found that went over 11000 SI in the low frequency (465 Hz) measurement and the high frequency (4650Hz) above 10100SI. The GRH was at the same spot 930mm, that means around

[3] Magnetic susceptibility is the degree to which a material can be magnetized in an external magnetic field. If the ratio of the magnetization is expressed per unit volume, volume susceptibility is defined as $\kappa = M / H$, where M is the volume magnetization induced in a material of susceptibility κ by the applied external field H.

a meter above the ground the calibrated Schiebel detector AN-19 started to signal due to the soil. The extreme changes between 2000 SI units happened within a distance of 3 to 10m.

Plate 6-1 Site 3

Plate 6-2 Susceptibility 9304 SI

If we look at the test pits and random spots the following data were measured (Table 6-2):

Table 6-2 Susceptibility measurements in the pits on the three sites

	Magnetic Susceptibility measured with the Bartington MS2 meter (SI)			Low Frequency Susceptibility minus High Frequency Susceptibility	GRH (mm)
Site 1	MS2B (465Hz)	MS2D Loop (968Hz)	MS2B (4650Hz)	MS2B (465Hz) minus MS2B (4650Hz)	Schiebel AN19 Mod. 7
Pit 1	14	22,24,23,19	14	0	20
Pit2	29	18,17,16,16	27	2	0
Site 2					
Pit 1	936	681,782,678,744	900	36	260, 280
Pit 2	977	679,654,668,720	918	59	250,250
Site 3					
Pit 1	1903	2238,2100,2009,2089	1697	206	480
	1827		1638	189	
Pit 2	1767	1760,1728,1684,1706	1647	120	350
	1654		1576	78	
Spot 1	6574	6071	6016	558	650
	6330		5772	558	
Spot 2	7101	6600,6441,6514,8499,8534	6472	629	820
	7718		7020	698	
Spot 3	10544	8776,9403,9209,9676	9688	856	930
	11056		10185	871	

Both tables are clearly showing a frequency dependency of the magnetic susceptibility on the ground. The lower frequency measured with the laboratory instrument MS2D mainly show a higher susceptibility as the higher frequency. Exceptions are the generally low susceptibility measurements in lanes 1 and 2 on Site 1. Measurements with the MS2D loop do not in every case give figures that lie between the measurements from the lab-version. The measurement conditions are too different if one takes into account the site vegetation and the surface of the lane. The loop can not have the same contact with sample and therefore does not have the analogue accuracy of the lab instrument. Even with the MS2B lab instrument, large differences occur between values from samples taken at random points within a few centimetres of each other (see Site 3 in Table 6-2). However, changes from point to point in the susceptibility measured with the MS2D field loop measurements do correlate with the MS2B lab measurements and with the GRH[4] . Both the frequency dependency and the GRH are related with the influence of the ground on the detector performance. An increasing magnetic susceptibility, especially a growing frequency dependency, creates increasing problems for the detectors, as also indicated by the GRH.

[4] In general, it is the frequency dependence of susceptibility, rather the susceptibility itself, which is most closely corrrelated with GRH and with the "noisiness" of the soil. See "Soil Characterization for Evaluation of Metal Detector Performance" F. Borry et al. , www.itep.ws, EUDEM2 Sept 2003. It is possible to have soils with high susceptibility but low frequency dependence and low GRH. However, we did not encounter such soils in this trial.

7 General Test Sites Results and Individual Detector/Operator Results

7.1 Probability of Detection (POD) as a function of target depth

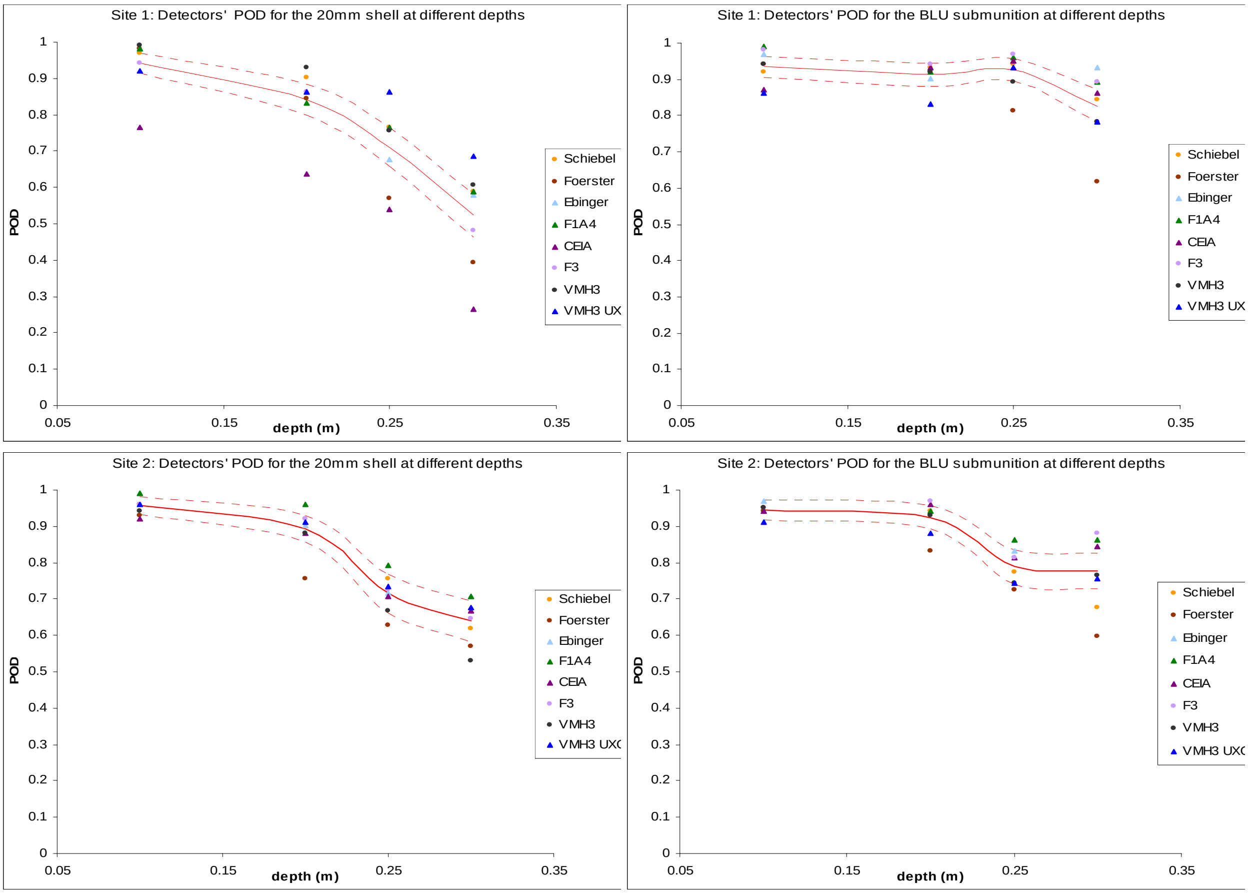

Figure 7-1 and Figure 7-2 (top), Figure 7-3 and Figure 7-4 (bottom): POD of targets at different depths (0.1m, 0.2m, 0.25m, 0.3m) per detector at the two sites.

Figure 7-1 to 7-4 show the estimated Probability of Detection (POD) for the 2 targets at 4 different depths on both sites. For all detectors, POD generally falls with increasing depth as expected, and the 20mm cannon shell is more difficult to detect than the BLU-26B submunition. Differences in POD mainly become apparent at the two larger depths. The red solid line represents the average performance of all detectors. The dashed lines represent the interval of statistical confidence. Differences in POD between detectors smaller than the spacing between the two dashed lines are not statistically significant[5].

There is no obvious degradation of performance in more difficult soil (Site 2, Fig. 7-3 & 7-4). This surprising observation may possibly be attributed to increased operator capability with the detector compensating for the more difficult soil conditions.

[5] The dashed lines are calculated using a *t*-distribution to represent 95% confidence that a detector with an estimated POD on the upper line has a true POD which is greater than that of a detector with an estimated POD on the lower line. This confidence interval is about ± 0.03 at shallowest depth rising to ± 0.06 at greatest depth.

7.2 Receiver Operating Characteristics (ROC)

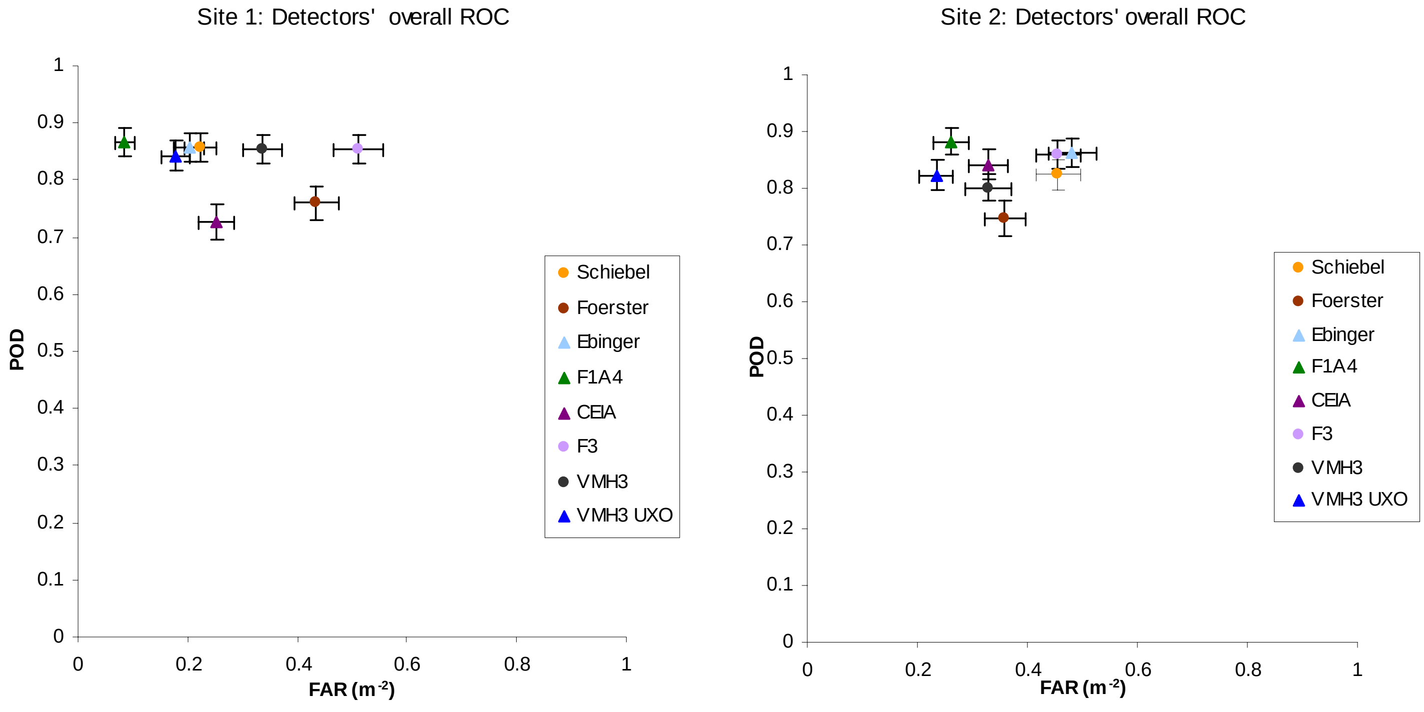

Figure 7-5 and Figure 7-6 Overall OC graphs for the two sites[6]

The ROC diagrams (Fig. 7-5 & 7-6) display Probability of Detection against False Alarm Rate (FAR). An ideal detector would have a POD of 1 and 0 FAR (i.e. detect all targets and give no false alarms), and be displayed in the top left corner of the diagram. Increasing sensitivity should, in theory, results in an increase of both POD and FAR.

In the results shown, the detectors with higher FAR did not generally display higher POD, which implies that the differences between detectors are not only due to differences in sensitivity. There is a ceiling of POD of the order of 85% and detectors for which a number of markers larger than this were placed just gave more false alarms.

The UXO-version detectors (triangles in diagram) mainly gave lower FAR without reducing the POD of targets considered here. In site 2 (Fig. 7-6), there is a slight tendency for the FAR to be higher but it is not very marked considering the ground is more difficult.

The FAR in practice maybe due to a combination of ground effects, ground metal contamination, electronic noise and human factors. For a trial such as conducted here, according to CWA, the lanes are first cleaned of metal debris.

[6] The error bars correspond to ±2 standard errors on either side of the mean. One may be 95% confident that the individual detector's POD and FAR lie within the range of the bars. Differences between two detectors may be regarded as statistically significant at this level when their means differ by about 2.3 standard errors.

The results are ranked according to the average number of markers placed per lane.

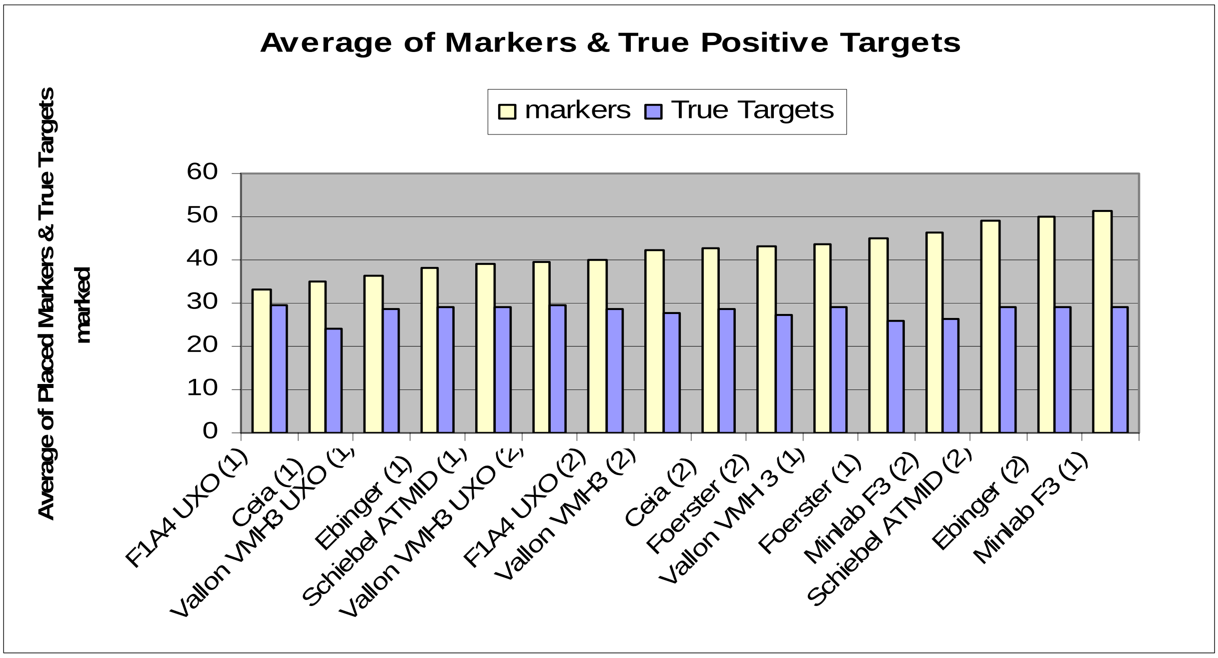

Figure 7-7 Average number of true positives and markers placed by lane per site.

Figure 7-7 displays the average number of markers (i.e. alarm indications) placed using the different detectors on each test site (1 & 2 - shown in brackets behind the detectors), which is increasing to the right. The second column represents the average number of positive detections per lane. The difference between the “markers” column and the “True Positives” column for a particular detector is the number of False Positives. If the only difference between the detectors was their position on some common ROC curve, then the number of True Positives would increase with the number of markers placed, but it does not seem to do so.

As before described the two sites have different soil properties. On Site 1 it is much easier to work with metal detectors than on site 2. Another obvious tendency is that the UXO detectors have a better ratio between hits and false calls. The ranking demonstrates that the UXO-versions keep the lead, excluding the Schiebel ATMID on Site 1. The small search head detectors are designed to find minimum metal mines and therefore will pick up a bigger amount of smaller metal fragment than the UXO search heads. In real clearance areas this would become more obvious because the metal contamination is usually higher than in the test lanes.

7.3 Overall Time needed on Sites & "clearance" time for 50m² ("clearance speed")

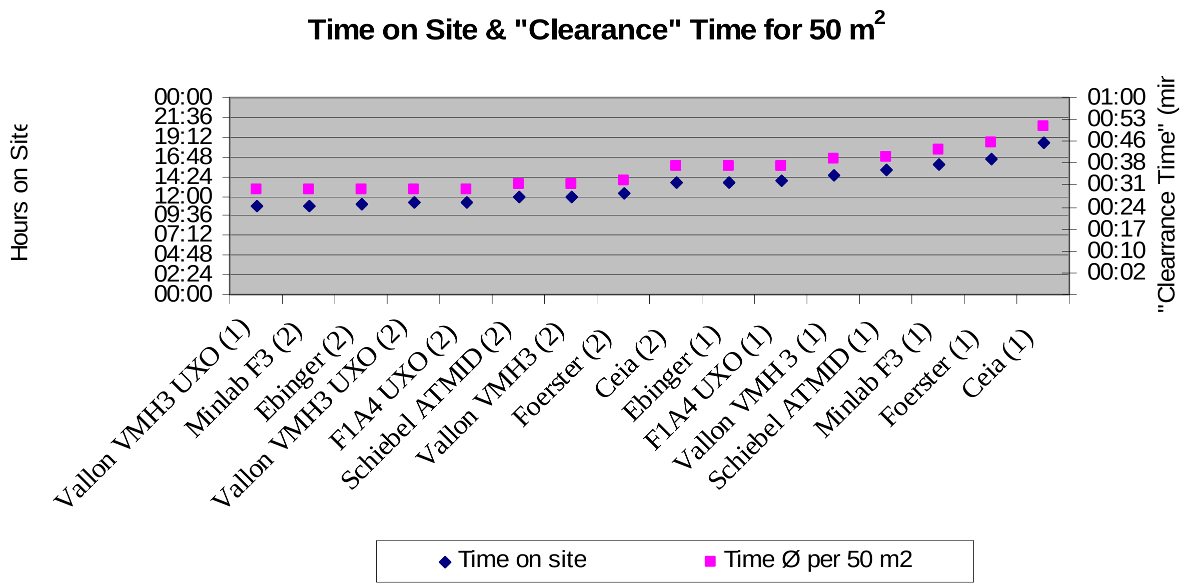

Figure 7-8 Total time needed per site and average for "clearance" of 50 m² per minutes

Figure 7-8 displays the total operating time per site and average searching ("clearance") time per 50m², one being proportional to the other. For our purpose the ranking of the detectors is more important than the absolute time. Operation time on Site 2 was generally shorter than on Site 1, although the Vallon VMH3 UXO achieved on Site 1 the overall best time from both sites. Whereas one would expect operating times would be longer in a more difficult/contaminated soil (as the Vallon VMH3 UXO seems to display), we observe the opposite, which may be due to operators gaining confidence in use of the detectors.
Each detector model covered 1080 m² per site. The time taken to cover this on Site 1 varied from 10h49m to 18h26m. This time difference of more than 7h was reduced to about 2.5h on Site 2. This means the average time on Site 2 was reduced to a more realistic level, comparable with what would be normal for detection in a real operation. This shows also that the deminer needed time to get habit and confidence in the use of the new tools.

To relate these figures to typical field conditions, the right hand axis displays average time needed to clear 50m². For the fastest example, 30 minutes were needed to clear $50m^2$ and the slowest 51 minutes, which means that 70% more time used. Alternatively, in 30 minutes, the fastest rate corresponds to clearing 50m² and the slowest to clearing only 35m² .

Ease of use of the detectors also played a role: there are significant differences between the detectors on each site.

7.4 Loss of sensitivity

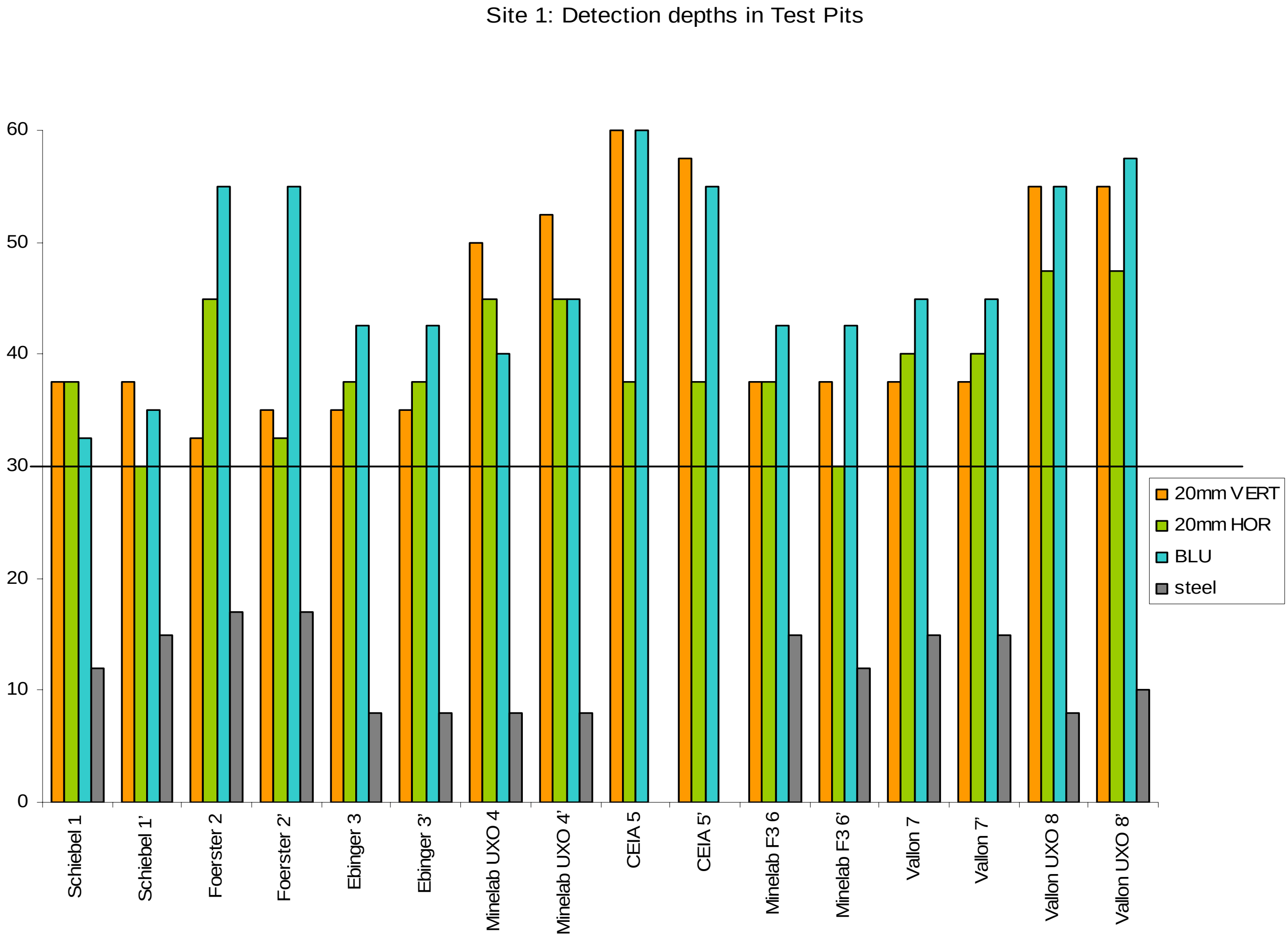

Figure 7-9 Detection depths for different targets in site 1.

Figure 7-9 displays the maximum detection depth as measured in the test pits on Site 1. Results are given for the 20mm shell in both vertical and horizontal orientation, the BLU26B submunition, and for a 10mm diameter 100Cr6 chrome steel ball. The latter is commonly used as a target in lab tests and is introduced for comparison.

All the detectors are able to detect the trial targets at 300mm (black line) on Site 1. In general the detection of the 20mm shell in a vertical position is easier than in the horizontal position. An exception was the Vallon VMH3 and one of the Foerster 4.500. Some indication of the advantage of UXO-versions of detectors in rejecting small pieces of scrap may be gathered from the detection depths of the chrome steel ball. It seems that UXO models have lower or no sensitivity, in the case of the CEIA, to this particular target.

The magnetic susceptibility was measured about 29 up to 200 in the different frequencies of the Bartington meter and the GRH to a max of 20mm in one test pit when in the lanes the maximum was 10mm.

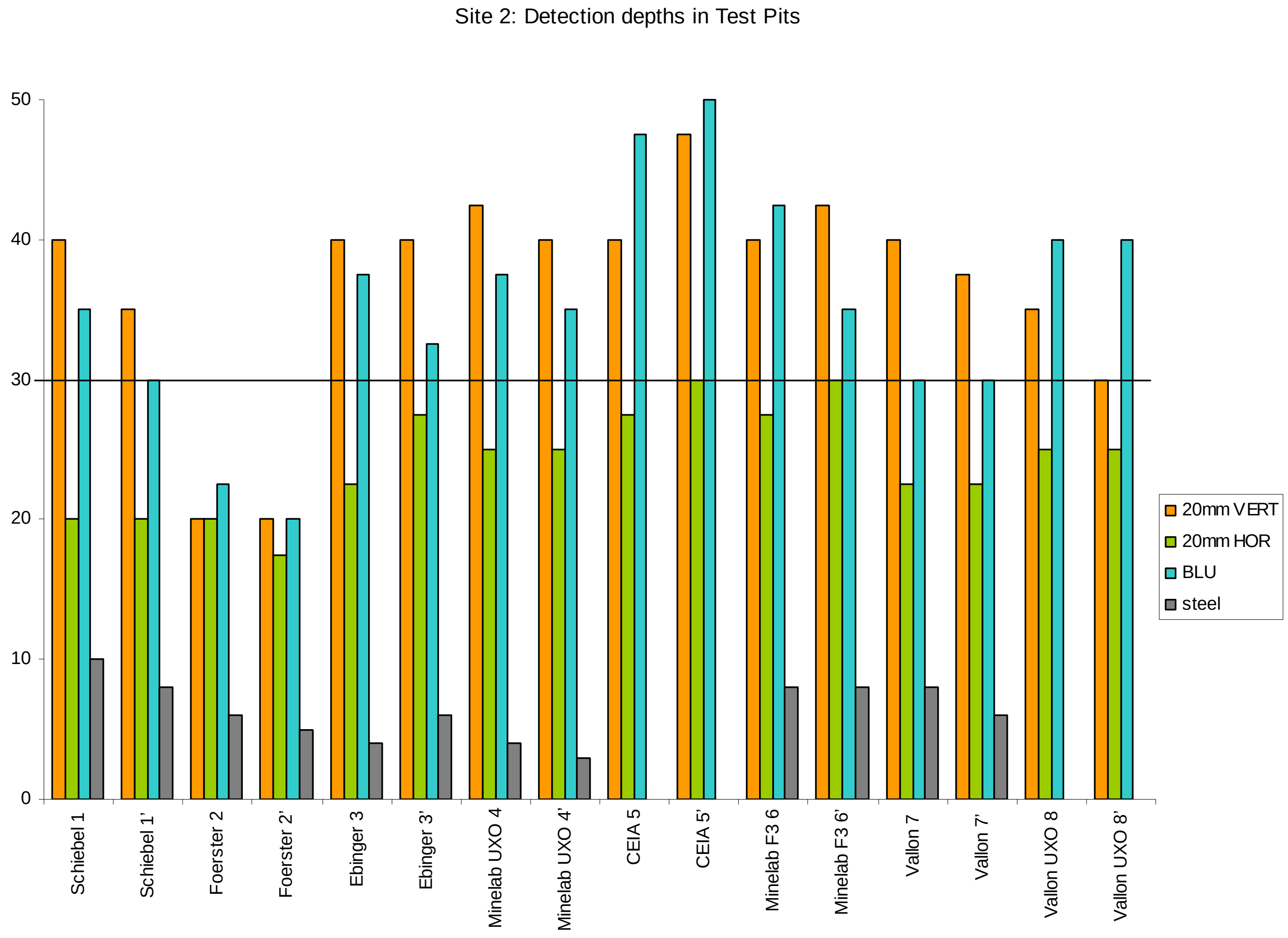

Figure 7-10 Detection depths of different targets on site 2.

Site 2 (Fig.7-10), which had higher magnetic susceptibility values (400-900 SI) and GRH of 270-300mm, display lower overall detection depths for all targets. One CEIA and one F3 are able to detect all targets in all orientations to the required depth.

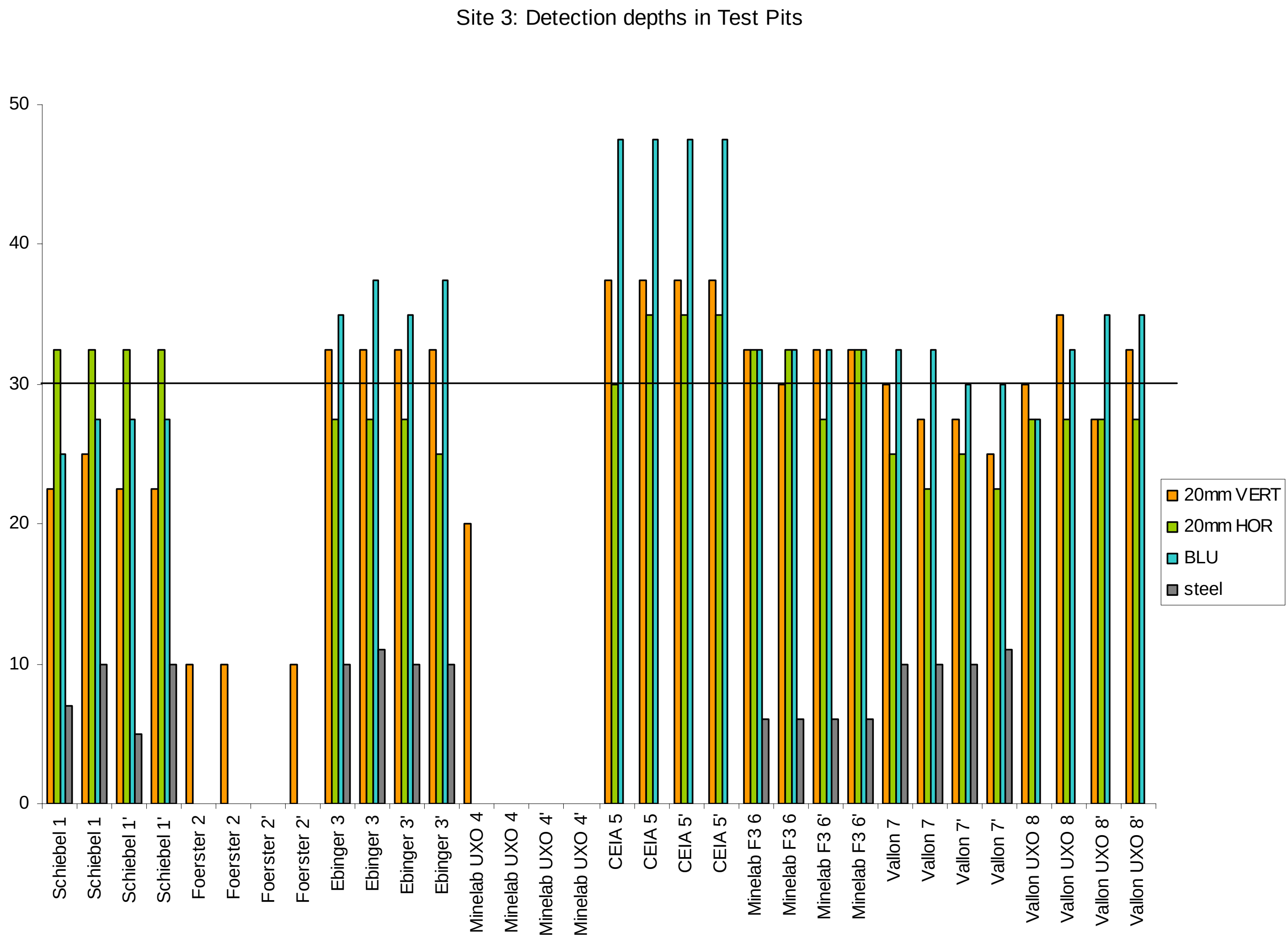

Figure 7-11 Detection depths of different targets in pits 1 and 2 (in brackets) on Site 3.

Due to failure in soil compensation on Site 3, no meaningful data could be collected for the Foerster and the F1A4 (Fig. 7-11). This site displayed high susceptibility values (Pit 1: 1700 to 2000, Pit 2: 1500 to 1700 SI). Both CEIAs and one F3 were able to detect all targets in all orientations to the required depth.
Table 7-1 (below) lists the detectors which compensated soils with increasing magnetic susceptibility and detected a metal pen on the surface.

7.5 Compensation capability with increasing magnetic susceptibility and Ground Reference Height[7]

The compensation capability was additionally tested as first problems in ground compensation were established during the tests in the pits on Site 3. An additional advantage was that the test team found spots with extremely high magnetic susceptibility and GRH (see Table 7-1). These figures are measured by the Bartington meter and similar extreme GRH distances could be established.

Table 7-1 Ground compensation capability

Manufacturers & Detector	Detector Copy	Susceptibility (SI – to nearest 1000)				
		2000	4000	5000	7000	9000
Schiebel ATMID	1	Y	Y	Y	N	N
	1'	Y	Y	Y	Y	N
Foerster 2FD 4.500	2	N	N	N	N	N
	2'	N	N	N	N	N
Ebinger 421 GC/LS	3	Y	Y	Y	Y	Y
	3'	Y	Y	Y	Y	Y
Minelab F1A4UXO	4	N	N	N	N	N
	4'	N	N	N	N	N
Ceia MIL-D1/DS	5	Y	Y	Y	Y	Y
	5'	Y	Y	Y	Y	Y
Minelab F3	6	Y	Y	N	N	N
	6'	Y	Y	N	N	N
Vallon VMH3	7	Y	Y	Y	N	N
	7'	Y	Y	Y	N	N
Vallon VMH3 UXO	8	Y	Y	Y	Y	N
	8'	Y	Y	Y	Y	N
Ground Reference Height (mm)		480	650	770	820	930

The green colour in Table 7-1 displays successful compensation with followed confirmation by signals to metal at the same spot. The results confirmed the pit data to the both unusable detectors, which stayed further unable for ground compensation. Two detectors went through all spots without problems. Some detectors finished the procedure of ground compensation with a clear signal but if they should be used they gave signals to the ground as from targets. As in Table 7-1 above and the figures of maximum detection depth a certain individuality of detectors from the same type could here be registered too.

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[7] The authors allowed comments of the manufacturers, here the comment of Minelab in Italic:
"An alternate interpretation of the measured data is that Site 3 consists of a base of mineralised ground, laced with pockets of fast conducting metal targets. For example, pieces of shrapnel, coupled with a tropical climate that accelerates decomposition of metallic hardware, lead to high concentrations of small rusted particles that blend into the soil structure.
In the case of the "hot spots" at Site 3, the detectors did not ground balance because they sensed that there was significant metal content in the ground and, under normal circumstances, ground balancing to it could compromise the safety of the operator. The "decision" by Minelab detectors not to compensate at the "hot spots" in question is not related directly to the ground susceptibility as Table 7-1 suggests (nor to the frequency dependence of the susceptibility) as this is easily overcome using core technology, but instead to a metal/no-metal decision derived in Minelab proprietary signal processing."

8 Individual results of the detectors

8.1 Individual detector description and results

This section gives the individual technical description of each participating metal detector, its results and human factor: the deminers ROC plots and an assessment of the questionnaire responses. How diverse the results may be, when four different deminers use the same tool, will be apparent.

First, we include some technical background, so that it may be better understood what we are assessing. The principle of electromagnetic induction[8] is common to all metal-detectors but there are many variations in the way it is used. The participating detectors represent a broad spectrum of different practical technical solutions (Table 8-1).

Table 8-1 Tested metal detectors their working principles and design

Detectors	Manufacturer	Technical Principles & Design											
		Induction		Pulse		Domain		Mode		Send/receive Coil		Coil	
		Pulse	Continuous wave	Bipolar	Unipolar	Time	Frequency	Static	Dynamic	Single	Separate	Single "O"	Double D
MIL-D1/DS	CEIA	-	X	X	-	-	X	X	-	-	X	X	-
EBEX® 421 GC /LS	Ebinger	X	-	X	-	X	-	-	X	X	-	X	-
Minex 2FD 4.500	Foerster	-	X	X	-	-	X	X	-	-	X	-	X
F1A4 UXO	Minelab	X	-		X	X	-	-	X	X	-	X	-
F3	Minelab	X	-	X	-	X	-	X	-	X	-	X	-
ATMID™	Schiebel	-	X	X	-	-	X	-	X	-	X	X	-
VMH3	Vallon	X	-	X	-	X	-	-	X	X	-	X	-
VMH3 CS UXO	Vallon	X	-	X	-	X	-	-	X	X	-	X	-

The practical merits of a particular detector will not depend solely on its working principles, but the design with certain types of circuit or coil can be very relevant, as can the availability of good components or the ease of manufacture and use. There are considerable differences in the details of how metal-detectors are designed. From the user's point of view, some of these differences matter a lot more than others. Whether a detector is frequency-domain or time-domain has a single-coil or separate receive-transmit coils do not change the practicalities very much, unless the approach is as unusual as with the MIL-D1/DS, where sending and receiving coils can be separated 1.6m from each other. On the other hand, a detector with a double-D coil behaves very differently from one with a simple circular coil and it is dangerous to confuse the two. Similarly, a detector that operates in the static mode behaves very differently from one that operates in the dynamic mode. The ability for pinpointing and detection depends on these factors

[8] An explanation of the technical working and design principles are described in "METAL DETECTOR HANDBOOK FOR HUMANITARIAN DEMINING" (see References).

and the operator should be aware of these things. During training, those factors that really matter should be emphasised to the deminer.

A very short description about special technical solutions, features, differences that have influence on the performance, and ease of use will be laid out for every tested detector.

The POD as a function of target depth and the ROC curves for every operator using the detector are also given. The interpretation is the same as mentioned in the general part. For direct comparison of the detectors the curves are collected in **ANNEX E**

The maximum detection depth achieved by every detector is shown in tables for the two copies of each type and on Site 3 for both pits. If there were individual differences the best result was taken. The full set of data is in ANNEX F**.** The BLU 26B targets were old, rusted examples and may not all have given exactly the same electromagnetic response. The 20mm cannon projectiles were fabricated just before the test and may be regarded as identical.

All tested detectors have a ground compensation function that can, to a certain degree, reduce the influence of magnetic ground on the detector performance. At the time of writing, there are still limits to the effectiveness of this technology, so that some loss of sensitivity does occur. The degree of sensitivity loss, when using ground compensation, can be assessed by comparing the results of the test pits. The capability of the detectors to compensate is given in Table 7-1. In this case the magnetic susceptibility and the GRH had been measured for comparison.

The deminers' answers to the questionnaire (**ANNEX G**), regarding the detectors they used, will be summarised and should be seen as the collective opinion of four deminers, who have different education and demining experience including the use of detectors, personal constitution, habits, and attitude. One general remark can be made here: most deminers were confident that they would use both of the detectors they were trained in, in a real minefield. The exception was the CEIA, whose operators' were not as confident, after first using it on Site 1.

8.2 CEIA SpA, Detector MIL-D1/DS


Plate 8-1 The MIL-D1/DS detector during the trial Site 1

The detector **MIL-D1/DS** (Plate 8-1) demonstrates a new approach for detecting UXO. The detector has separated sending and receiving coils that are at an adjustable distance apart, 1.60m maximum to about 1m minimum. The coil which is set vertically is the sending coil, and the one which is set horizontally the receiving coil. A target signal is indicated by sound and on a screen. The latter is a good tool for pinpointing. The highest signal level on the display demonstrates that the telescopic pole keeping the coils is in the center of the target. The operator may regulate the sensitivity on a continuous scale by turning a control knob. Because of the distance between the coils, the detector covers a bigger area than the other tested detectors. The device mainly uses components from the standard MIL-D1 mine detector (coils, poles, electronics housing), adapted as necessary. Due to the weight of the detector (5.8kg), it is recommended to use it with the harness supplied.

Ordinarily, the operator holds the detector as shown in Plate 8-1 and walks in a serpentine pattern, so as to cover a swath several meters wide, advancing slowly in a direction perpendicular to the direction in which he walks. In accordance with the target and depth for search, different extensions of the pole, and different pitches of serpentine, may be used. When an indication is encountered, a change of the search direction is used to locate the centre of the target.

This standard method of operation is not compatible with the 1.5m wide lanes used in the test, so instead the detector was swept sideways, i.e. moved parallel to the yellow cord marking the edge of the lane shown in Plate 8-1. Depending on the target, the detector can easily cover 1.20m wide strips, when used in this mode, which is a common maximum width for clearance lanes. In our case, the sensitive area for the BLU 26B was about 1.80m wide and that for the 20mm projectile about 1.40m. This advantage was, during the tests, a disadvantage because of metal contamination outside the lanes and the high target density in the lanes, making it difficult to pinpoint targets without going outside the lane with the receiving head. It was also sometimes difficult to find a good metal-free background.

The width of the sensitive area, in the direction perpendicular to the pole, for targets such as the BLU26B and 20mm projectile, is about 0.4m.

The point of maximum sensitivity is not under the heads but about one third of the way back from the receiving head, under the electronic unit (Plate 8-1). We made additional efforts to explain to the deminers the unusual location of the point of maximum sensitivity, but we believe that some of them may not have fully understood this point.

With this detector, it is particularly important that the deminers' footwear should be free of metal, which we were careful to ensure.

The test protocol is therefore not really ideal for assessing this type of detector. However, the decision to submit the MIL-D1/DS was taken in response to a late request from CEIA SpA, which we received after the trial had been planned.

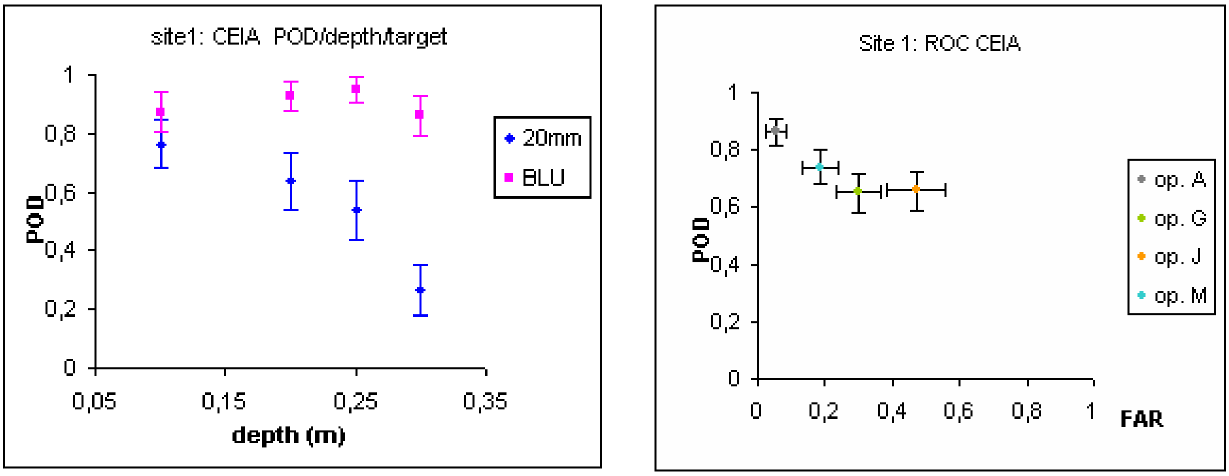


Figure 8-2 , 8-3 : Site 1 MIL-D1/DS POD vs target depth & operator

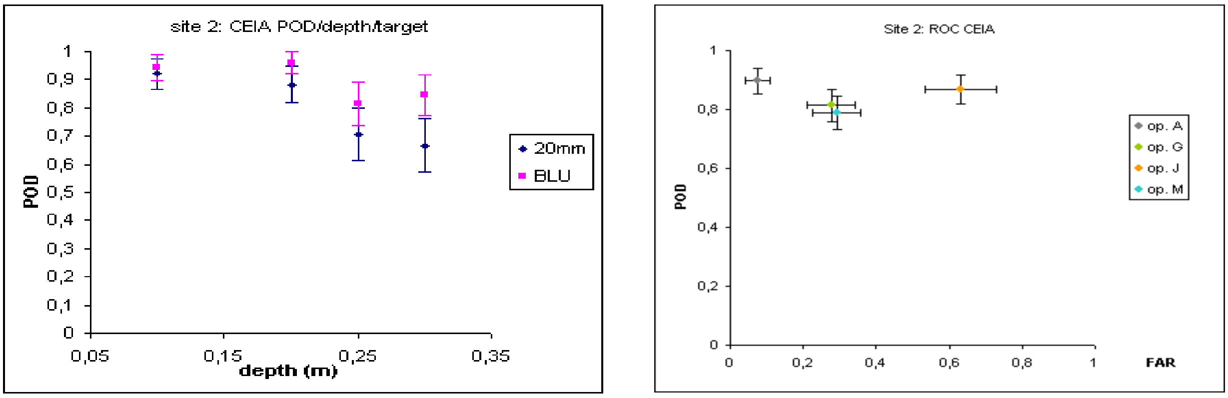


Figure 8-4 , 8-5 : Site 2 MIL-D1/DS POD vs target depth & operator

Looking at the POD results in Figures 8-2 to 8-5 one may see some apparent anomalies which we believe to be due to the human factor. The results of Site 2 are better than on Site 1, although Site 2 had more difficult ground conditions. We believe that this is because the operators were more familiar with the detectors in the second week and had had additional training, which we gave in response to their request. In particular, it appeared from their behaviour that the operators had not, at first, fully understood the unusual location of the most sensitive point.

Operator A demonstrated on both sites a high probability of detection, and very good false alarm rate with no statistically significant changes between the sites.

Operators G and J improved their POD in the second week. Operator M did not do as well as Operator A but performed comparably to Operator G, apart from showing no significant improvement in the second week. Operator J gave a high FAR in both weeks.

Table 8-2 MIL-D1/DS maximum detection depth

MIL-D1/DS	Site 1		Site 2		Site 3			
	Copy 1	Copy 2	Copy 1	Copy 2	Pit 1/C1	Pit 1/C2	Pit 2/C1	Pit 2/C2
20mm Vertical	600	575	400	475	375	375	375	375
20mm Horizontal	375	375	275	300	300	350	350	350
BLU 26B	600	550	475	500	475	475	475	475
Steel ball	no detect	no detect	no detect	no detect	no detect	no detect	no detect	no detect

The tests for establishing maximum detection depth on the three sites did confirm a loss of sensitivity with growing magnetic properties of the ground. The maximum loss was 225mm. The data for comparison are taken only from the test pits. One anomalous result with the CEIA, which we are unable to explain, was that the 20mm projectile appeared to be as easy to detect in the very highly magnetic soil on Site 3 as it was on Site 1. The individual copy difference was, at most, three depth increments (75mm).
The results of the ground compensation test clearly show that the detector could cope with the known complicated ground conditions in Lao. At all points, on all three sites, it was able to achieve compensation.

It should also be mentioned that this detector ignored small targets: it could not detect the 10mm 100Cr6 steel ball or a bottle cap. There was a slight individual difference between the two copies.

The results of the questionnaire showed that the deminer had difficulties with the dimensions, the use and weight. The individual statements were not all in agreement: some deminers liked the detector more than others.

The test pit results indicate that the detector satisfies the requirements of UXO Lao to detect both targets to the required 300mm.

Table 8-3 MIL-D1/DS Technical Data

Parameters	Value	Unit	Comments
Metal detector	**MIL-D1/DS**	-	
Working technology	Three harmonics of a triangular wave	-	Static, frequency domain, separate sending and receiving coil
Ground compensation	Yes	-	
Price	Not stated	€	
Package			
Operator manual	Yes	-	
Instruction card	Yes	-	
List of content	Yes	-	
Test piece	Yes	-	
Batteries	No	-	
Size parameters			
Operational	L: 1020 to 1430 H: 290 to 610	mm	Extensible in both length and height
Search head / shape	280	mm	Circular, 2 coils aft & fore effectively forming one large search head (approx the length of detector)
Transport case	975 x 450 x 80	mm	Hard case plastic
Backpack	None	mm	
Mass Parameters	Value	Unit	Comments
Operational	6.25	kg	
In transport case	14.2	kg	
In backpack	None	kg	
Set up			
Mechanical set-up	34	s	
Handbag storage	n/a	s	
Standing/kneeling	n/a	s	
Right/left	0	s	
Electrical set-up	13	s	
Battery			
Inversion polarity	Not tried	-	
Type - Number	D Cell (LR20) x 4	-	or high capacity (>7000mA/h) rechargeable

8.2.1 Pictures details

8.3 Ebinger GmbH, EBEX® 421 GC/LS UXO

Plate 8-6 EBEX® 421 GC/LS during the tests on Site 1

The detector **421 GC/LS** is based on the EBEX® 421 GC. It has a bigger search head (LS – large search head) than the original. Due to the modular approach of Ebinger, the larger search head is exchangeable with the normal one. The operator regulates the detector manually using two continuously adjustable control knobs, one for sensitivity and one for ground compensation.
During the trial no questions concerning use or detection arose from the deminers and the trial team.

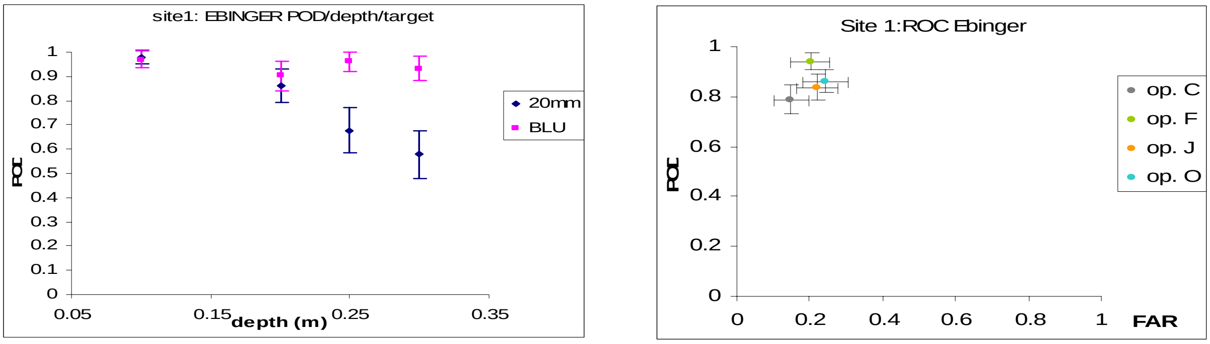


Figure 8-7 , 8-8 : Site 1 EBEX® 421 GC/LS POD vs target depth & operator

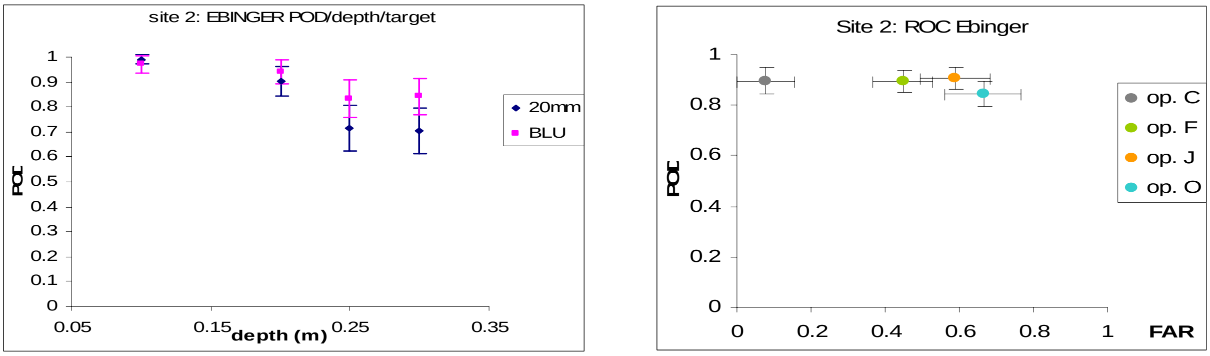


Figure 8-9 , 8-10 : Site 2 EBEX® 421 GC/LS POD vs target depth & operator

The results in Figure 8-7 to 8-10 demonstrate the dependency of POD on the target metal content and the depth at which it is laid. There is no significant change in POD versus depth between the two sites.
All operators returned a relatively high POD with this detector on Site 1, operator F, in particular, achieved an outstanding result. It is also clearly visible that Site 2 created significant problems for the operators concerning false alarm rate. On Site 2 only operator C

could keep the level he achieved on site 1. Three operators (F,J,O) had a significant increase in FAR and operator F a significant decrease in POD.

Table 8-4 EBEX® 421 GC maximum detection depth

EBEX® 421 GC	Site 1		Site 2		Site 3			
	Copy 1	Copy 2	Copy 1	Copy 2	Pit 1/C1	Pit 1/C2	Pit 2/C1	Pit 2/C2
20mm Vertical	350	350	400!	400!	325	325	325	325
20mm Horizontal	375	375	225	275	275	275	275	250
BLU 26B	425	425	375	325	350	375	350	375
Steel ball	80	80	40	60	100	110	100	100

The maximum detection depth established on all three sites mainly demonstrates a loss of detection ability (sensitivity) going from Site 1 to Site 2 and then to Site 3, for the 20mm projectile, in both orientations, and the BLU 26B. The maximum loss was 100mm. However, the data points are relatively close to each other and there are some exceptions, where sensitivity increases, which we are not able to explain. A unique phenomenon was that this detector is the only one that had a lower detection depth for the vertical position than for the horizontal position of the 20mm projectile, but only on Site 1. On the other sites it was the other way round, as normal. Site 1 was the first site for testing and the ability of the operators to achieve an optimum sensitivity set up may have been responsible. It cannot, however, explain the increase of detection depth for the steel ball, which occurred between sites 2 and 3.
There was a difference in sensitivity of two depth increments between the two copies.

It should be mentioned that this detector was one of only two which easily achieved ground compensation on all the lanes, test pits and test points, even those with extreme magnetic susceptibility and GRH.

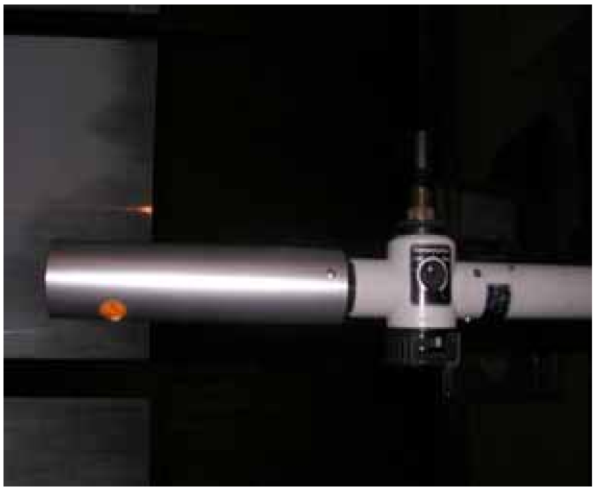
Responses to the questionnaire were positive. The individual statements mainly indicated easy and accurate use.

In general, this detector can detect the two targets in accordance with the UXO Lao requirements but with one exception: the 20mm projectile in the horizontal position could be detected only to 275mm on the increased magnetic susceptibility soils of Sites 2 and 3.

Table 8-5 EBEX® 421 GC/LS Technical Data

Parameters	**Value**	**Unit**	**Comments**
Metal detector	EBEX® 421 GC/LS UXO	-	
Working technology	Pulse induction	-	Bipolar pulse, dynamic & static mode, single sending and receiving coil
Ground compensation	Yes	-	
Price	2360	€	Without VAT – Unit price in. discount
Package			
Operator manual	Yes	-	
Instruction card	Yes	-	
List of content		-	
Test piece	Yes	-	
Batteries	Yes	-	
Size parameters			
Operational	1460	mm	Short version including battery pack
Search head / shape	420 x 280	mm	Truncated oval
Transport case	760 x 375 x 175	mm	Hard case metal
Backpack	630 x 335 x 105	mm	Fabric
Mass parameters	Value	Unit	Comments
Operational	3.1	kg	With battery pack
In transport case	6.7	kg	
In backpack	4.7	kg	
Set up			
Mechanical set-up	110	s	Tools: No – Continuous length set up (control box fixed on the handle)
Handbag storage	72	s	Tools: No
Standing/kneeling	50	s	Tools: No
Right/left	0	s	Tools: No
Electrical set-up	~5	s	
Battery			
Inversion polarity	Not tried	-	
Type - Number	C cells (LR14) × 8	-	Nominal voltage: 12V or special rechargeable pack

8.3.1 Pictures detail

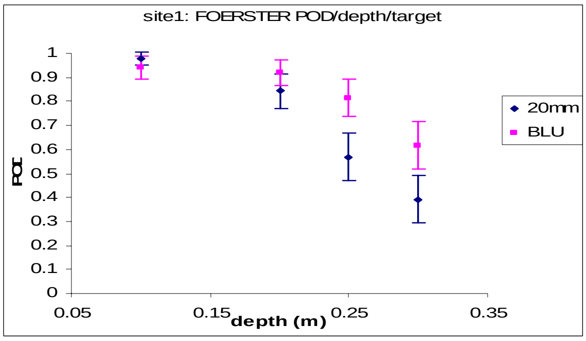


8.4 Inst. Dr. Foerster GmbH and Co. KG, Minex 2FD 4.500.01

Plate 8-11 Minex 2FD 4.500.01 during the trial Site 1

The detector Minex 2FD 4.500.01 is a compact detector with fixed sensitivity to three levels HIGH, MEDIUM, and LOW. It was the only tested detector with a double D search head. When the target is under one side a high pitched sound is produced, when it is under the other a low pitched sound. In the centre is a zero line, where no signal is produced. This feature allows easy and accurate pinpointing. A sweep from another direction, ideally 90 degrees, will establish a cross of the zero lines, where the centre of the metal/target is.

Between the two coils in front and at the end of the search head the sensitivity is reduced. This has the advantage that it may be used closer to large linear metal targets as railways, fences, and similar large metal objects but it is very important that the detector is used with a sideward sweep only, otherwise the detector can come very close to targets before signalling.



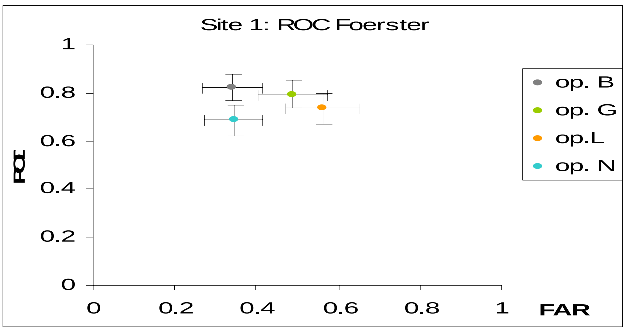
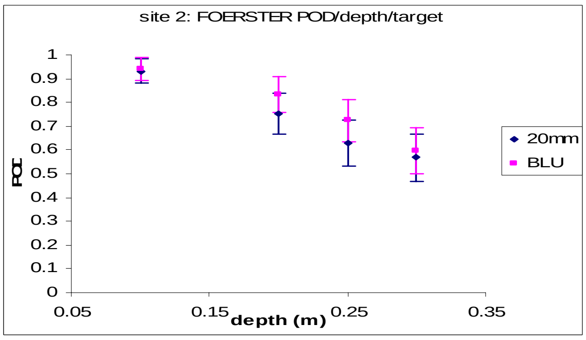


Figure 8-12 , 8-13 : Site 1 Minex 2FD 4.500.01 POD vs target depth & operator



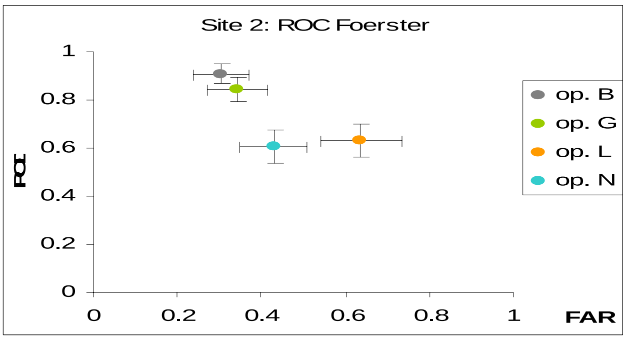


Figure 8-14 , 8-15 Site 2 Minex 2FD 4.500.01 POD vs target depth & operator

The POD as a function of target and depth demonstrate the dependency of POD on the target metal content and the depth at which it is laid. There are no significant changes in the POD versus depth results between Site1 and Site 2. Operators B and G show no significant change in POD between the sites, operator L showed a significant decrease and operator N a marginal decrease. There are no significant changes in FAR between the sites, with the exception of marginal decrease in FAR by operator G.

Table 8-6 Minex 2FD 4.500.01 maximum detection depth

Minex 2FD	Site 1		Site 2		Site 3			
	Copy 1	Copy 2	Copy 1	Copy 2	Pit 1/C1	Pit 1/C2	Pit 2/C1	Pit 2/C2
20mm Vertical	325	350	200	200	100	100	no detect	100
20mm Horizontal	450	325	200	175	compensation failure			
BLU 26B	550	550	225	200				
Steel ball	170	170	60	50				

The achieved maximum detection depth on all three sites demonstrates a significant loss of detection ability (sensitivity) going from Site 1 to Site 2 and then to Site 3, for the 20mm projectile, in both orientations, and the BLU 26B. The detector showed the highest sensitivity of all detectors for the steel ball. There was a significant difference between the two copies in the detection ability.
On Site 1, an unexpected phenomenon was observed in which the detector could not detect the horizontally laid 20mm projectile at depths between 375mm and 425mm but was able to detect it at 450mm. This effect occurred for only one copy but was reproducible (Annex F).
The loss of sensitivity from Site 1 to 2 was considerable. After numerous failures in ground compensation on Site 3, it was decided not to continue with the detector there (the three data points in the table were obtained by lifting the detector head high above the soil until it did not sound). The detector was also tried on some other spots with higher magnetic susceptibility and GRH but was not able to compensate there either.

The answers in the questionnaire suggested that this detector is easy and accurate to use but also mentioned weak volume of sound and soil compensation difficulties.

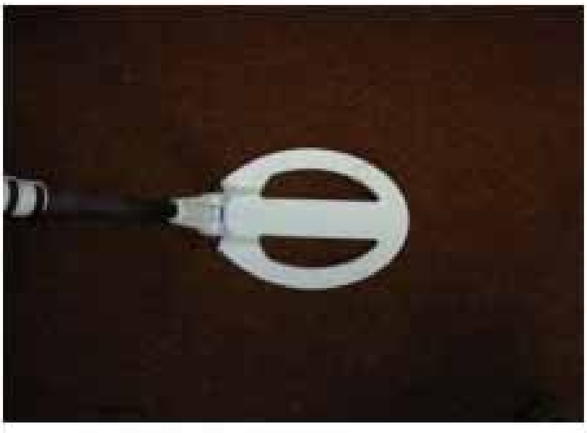
In general the detector can only fulfill the requirements of UXO Lao under ground conditions similar to Site 1.

Minex 2FD 4.500.01 Inst. Dr. Foerster GmbH and Co. KG

Table 8-7 Minex 2FD 4.500.01 Technical Data

Parameters	Value	Unit	Comments
Metal detector	Foerster Minex 2FD 4.500.01	-	
Working technology	Sine wave	-	Static mode, two frequency used, double-D coil
Ground compensation	Yes	-	
Price	2990	€	Without VAT – Unit price
Package			
Operator manual	Yes	-	Format A4 – English - Not plastified
Instruction card	No	-	
List of content	No	-	
Test piece	Yes	-	
Batteries	Yes	-	
Size parameters			
Operational	L: 850 to 1800	mm	Adjustable length
Search head / shape	210 x 285	mm	Oval
Transport case	980 x 270 x 330	mm	Hard case – Plastic
Backpack	910 x 245 x 70	mm	Fabric
Mass parameters	Value	Unit	Comments
Operational	2.75	kg	With headphones
In transport case	9.40	kg	
In backpack	3.75	kg	
Set up			
Mechanical set-up	< 60	s	Tools: No – Continuous length set up
Handbag storage	< 120	s	Tools: No
Standing/kneeling	< 15	s	Tools: No
Right/left	0	s	Tools: No
Electrical set-up	< 15	s	
Battery			
Inversion polarity	No effect	-	Battery voltage: 4.73 V (take picture of symbol of polarity)
Type - Number	LR20 x 3	-	Nominal voltage: 4.5 V

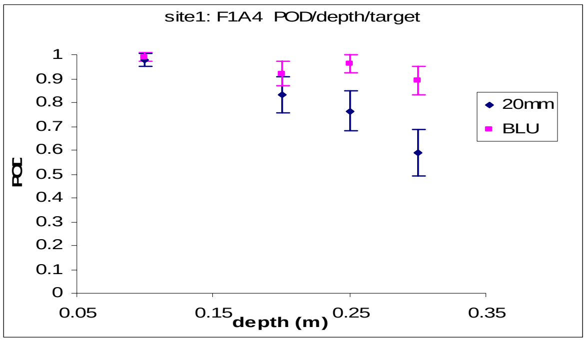
8.4.1 Picture details Minex 2FD 4.500.01



8.5 Minelab Pty. Ltd, Detector F1A4 UXO

Plate 8-16 F1A4 UXO during the trial Site 1

The Minelab F1A4 UXO is based on the standard metal detector F1A4 and equipped with a round search head, about 450mm diameter. Due to the size of the search head the balance and ergonomics are different to the original detector.



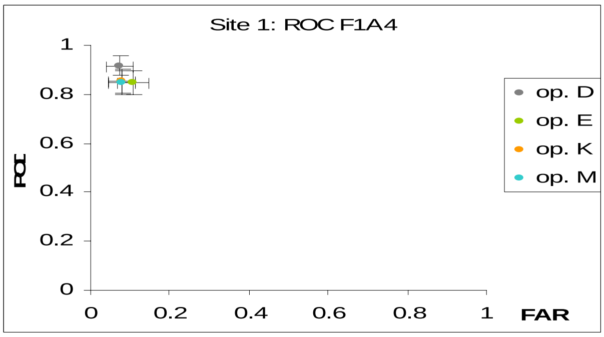
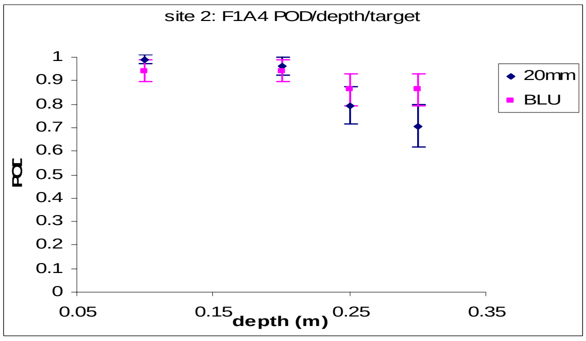


Figure 8-17 , 8-18 Site 1 P F1A4 UXO OD vs target depth & operator



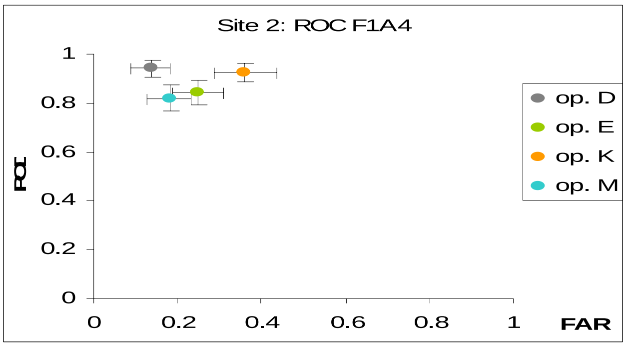


Figure 8-19 , 8-20 Site 2 F1A4 UXO POD vs target depth & operator

The results in Figure 8-17 to 8-20 demonstrate the dependency of POD on the target metal content and the depth at which it is laid. All operators had high and relatively similar POD's. The low false alarm rate changed significantly on site 2 for three operators (E, K, M). Operator D had only a slight increase in FAR, without reducing his POD.

Table 8-8 F1A4 UXO maximum detection depth

F1A4	Site 1		Site 2		Site 3			
	Copy 1	Copy 2	Copy 1	Copy 2	Pit 1/C1	Pit 1/C2	Pit 2/C1	Pit 2/C2
20mm Vertical	500	525	425	400	200	no detect	no detect	no detect
20mm Horizontal	450	450	250	250				
BLU 26B	400	450	375	350	compensation failure			
Steel ball	80	80	40	30				

The achieved maximum detection depth on all three sites demonstrates a loss of detection ability (sensitivity) going from Site 1 to Site 2 and then to Site 3, for the 20mm projectile, in both orientations, and the BLU 26B. The loss of sensitivity from Site 1 to 2 was considerable. After numerous failures in ground compensation on Site 3, it was decided not to continue with the detector there (the single data point in the table was obtained by lifting the detector head high above the soil until it did not sound). The detector was also tried on some other spots with higher magnetic susceptibility and GRH but was not able to compensate there either.

The operators assessed an easy and functional use but some times the weight was mentioned as a part for improving.

In general this detector could keep up with the requirements of UXO Lao to detect both targets at a depth of 300mm on Site 1, on Site 2 the 20mm projectile horizontal position created problems. Under ground conditions such as on Site 3, we do not recommend using it.

F1A4 UXO Minelab Pty. Ltd.

Table 8-9 F1A4 UXO Technical Data

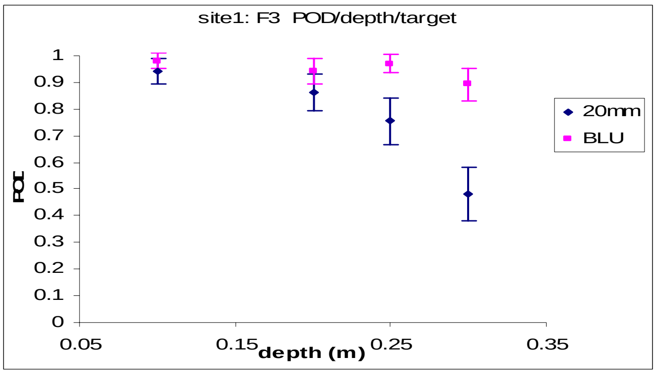
Parameters	Value	Unit	Comments
Metal detector	Minelab F1A4 UXO	-	
Working technology	Pulse induction	-	-polar pulse, time domain, dynamic mode (multi period sensing system)
Ground compensation	Yes	-	
Price	2100	€	Without VAT – Unit price (quoted as USD 2500)
Package			
Operator manual	Yes	-	Format A5 – English - Not plastified . Same as for standard F1A4
Instruction card	Yes	-	Format single page A5 – English – Plastified. Same as for standard F1A4
List of content	Yes	-	On the instruction card
Test piece	Yes	-	
Batteries	Yes	-	
Size parameters	Not provided		
Operational	L: 1100 to 1320	mm	Adjustable length
Search head / shape	450	mm	circular
Transport case	750 x 480 x 110	mm	Fabric soft case
Backpack	none	mm	
Mass parameters	Value	Unit	Comments
Operational	3.9	kg	
In transport case	5.6	kg	
In backpack		kg	
Set up			(Same as standard F1A4)
Mechanical set-up	180	s	Tools: No – Continuous length set up (control box fixed on the handle)
Handbag storage	150	s	Tools: No (time needed to pack the MD into the handbag, withdraw the batteries)
Standing/kneeling	30	s	Tools: No (it is requested to withdraw the surplus cable from the inside of the handle to unblock the sliding movement)
Right/left	0	s	Tools: No
Electrical set-up	15	s	(Same as standard F1A4)
Battery			
Inversion polarity	No effect	-	Battery voltage: 6.4 V
Type - Number	LR20 x 4	-	Nominal voltage: 6 V

8.5.1 Picture details F1A4 UXO

8.6 Minelab Pty. Ltd, Detector F3

Plate 8-21 Detector F3 during the trial Site1

The Minelab F3 is a compact one-piece detector, currently available only with a standard small head. There is no switch or knob to adjust the sensitivity. It can only be changed using special coloured caps which are fitted to the electronic unit. Available as standard are black for highest sensitivity and red for reduced sensitivity. Other sensitivity settings may be requested.



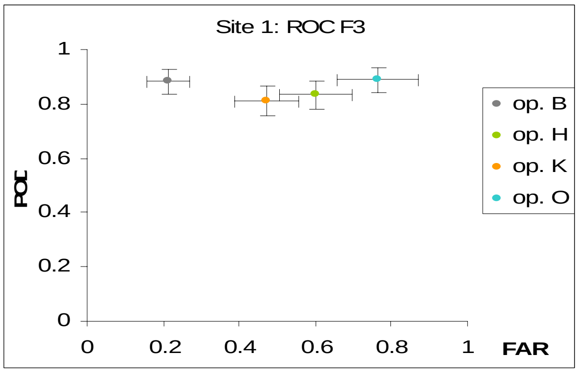
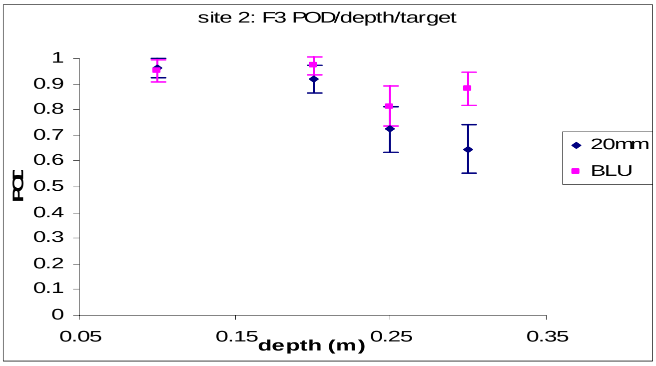


Figure 8-22 , 8-23 Site 1 F3 POD vs target depth & operator



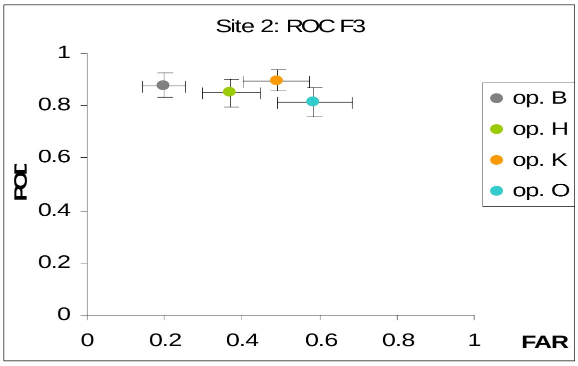


Figure 8-24 , 8-25 Site 1 F3 POD vs target depth & operator

The results in Figure 8-22 to 8-25 demonstrate the dependency of POD on the target metal content and the depth at which it is laid. There is not very much evidence for decrease in POD on Site 2, with the exception of the BLU26B at 25cm depth. If anything, there is a slight increase in POD on Site 2, which we believe is related to the increasing confidence in the use of the detector. The operators had high and relatively similar PODs, apart from operator B who gave outstanding results on both sites. There is an significant improvement from operator H in the FAR on Site 2.

Table 8-10 F3 maximum detection depth

F3	Site 1		Site 2		Site 3			
	Copy 1	Copy 2	Copy 1	Copy 2	Pit 1/C1	Pit 2/C1	Pit 1/C2	Pit 2/C2
20mm Vertical	375	375	400	425	325	325	300	325
20mm Horizontal	375	300	275	300	325	325	275	325
BLU 26B	425	425	425	350	325	325	325	325
Steel ball	150	120	80	80	60	60	60	60

The maximum detection depth established on all three sites demonstrates a general loss of detection ability (sensitivity) to the horizontal/vertical position of the 20mm projectile from Site to the Site 3 for all targets. In general this data are relatively close to each other. The maximum loss was from Site 1 to Site 3 for the BLU 26B with 100mm. The individual differences measured of the copies are from 75mm maximum distance to the same target.
The ground compensation is done automatically by pressing compensation button and moving the detector from and to the soil up to the moment where the ground stops to create a signal to the detector. It should be mentioned that the ground compensation in the Pit 1 of Site 3 was close to the limits of the detector. At the spots used for ground compensation with the extreme magnetic ground properties the detector was not able to cope with.

The results of the questionnaire confirmed a very easy use and good capabilities for field use. The battery consumption was mentioned as high.

In general this detector can detect the two targets in accordance with the UXO Lao requirements but not in all positions of the 20mm projectile. There are some difficulties with one or the other copy for achieving the 300mm detection depth for the horizontal position of projectile due to individual differences.

Detector F3 Minelab Pty. Ltd.

Table 8-11 F3 Technical Data Detector

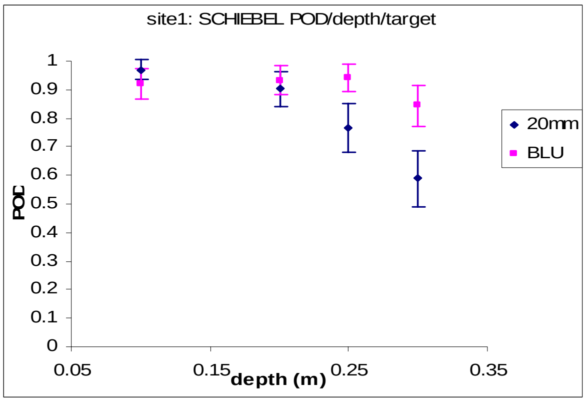
Parameters	Value	Unit	Comments
Metal detector	Minelab F3	-	Static, pulse induction technology
Serial number		-	
Serial number		-	
Price	2450	€	Without VAT – Unit price
Package			
Operator manual	Yes	-	Format A5 – English - Not plastified
Instruction card	Yes	-	Format single page A5 – English – Plastified
List of content	Yes	-	On the instruction card
Test piece	Yes	-	
Batteries	Yes	-	
Size parameters			
Operational	L: 750 to1510	mm	Adjustable length
Search head / shape	210	mm	Circular
Transport case	860 x 460 x 190	mm	Plastic hard case
Backpack	750 x 300 x 100	mm	Fabric
Mass parameters	Value	Unit	Comments
Operational	3.2	kg	
In transport case	11.9	kg	
In backpack	4.25	kg	
Set up			
Mechanical set-up	30	s	Tools: No – Continuous length set up + search head rotation limit
Handbag storage	120	s	Tools: No (time needed to pack the MD into the handbag, withdraw the batteries)
Standing/kneeling	15	s	Tools: No
Right/left	0	s	Tools: No
Electrical set-up	15	s	
Battery			
Inversion polarity	No effect	-	Battery voltage: 6.46 V
Type - Number	LR20 x 4	-	Nominal voltage: 6 V

8.6.1 Picture details Detector F3

8.7 Schiebel Elektronische Geräte GmbH, Detector ATMID

Plate 8-26 ATMID during the trial Site 1

The Schiebel ATMID is built in the traditional way with a telescopic pole, the cable connected to the search head outside the pole, and a separate electronic box. The search head and the earphone are to be connected with the electronic box. The sensitivity is changeable by the operator.



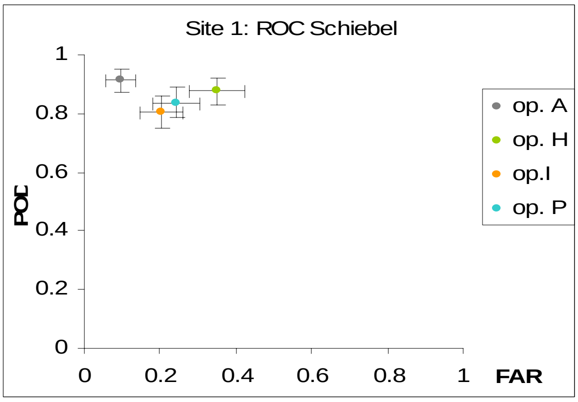
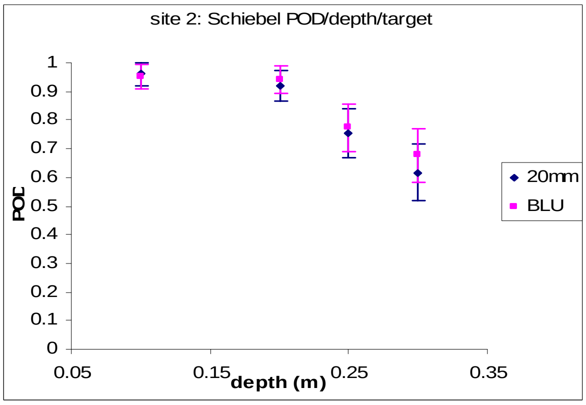


Figure 8-27 , 8-28 Site 1 ATMID POD vs target depth & operator



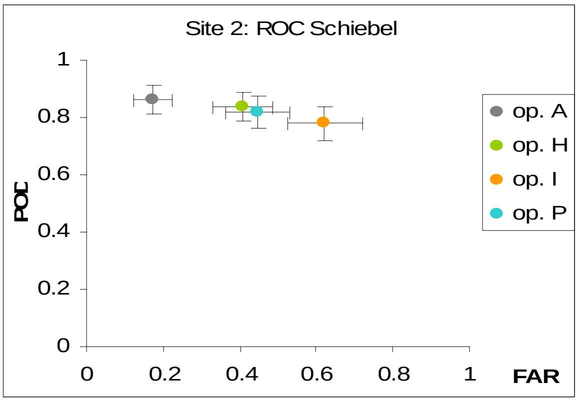


Figure 8-29 , 8-30 Site 2 ATMID POD vs target depth & operator

The results in Figure 8-27 to 8-30 demonstrate the dependency of POD on the target metal content and the depth at which it is laid. There is no improvement from Site 1 to Site 2. On the contrary, a significant drop in POD at the 25cm depth occurred, as was expected on the more difficult site. All other changes in POD are not statistically significant. Operators I,P had a significant increase in the FAR.

Table 8-12 ATMID maximum detection depth

ATMID	Site 1		Site 2		Site 3			
	Copy 1	Copy 2	Copy 1	Copy 2	Pit 1/C1	Pit 2/C1	Pit 1/C2	Pit 2/C2
20mm Vertical	375	375	400	350	225	250	225	225
20mm Horizontal	375	300	200	200	325	325	325	325
BLU 26B	325	350	350	300	250	275	275	275
Steel ball	120	150	100	80	70	100	50	100

The maximum detection depth established on all three sites demonstrates a general loss of detection ability (sensitivity) to the horizontal/vertical position of the 20mm projectile from Site 1 to the Site 3 and to the BLU 26B too. The maximum loss was from Site 1 to Site 3 for the 20mm projectile with 150mm. The individual differences of the copies are up to three-depth increment and may have different reasons that could not be investigated in more detail. For the maximum detection depth it has to be mentioned that there was on Site 3 a gap from 200mm depth to 325mm depth where both copies did not detect the 20mm projectile in the horizontal position and could detect it again at 325mm.
The ground compensation is done automatically by pressing compensation button and keeping the detector in a fixed position up to the moment to a special signal. It should be mentioned that the ground compensation came to its limits at the spots for testing ground compensation with the extreme magnetic ground properties there the detector was not able to cope with.

The results of the questionnaire confirmed an easy use with good capabilities for field use. The necessity of assembling the detector before use was mentioned as a disadvantage.

This detector can detect the two targets in accordance with the UXO Lao requirements and the conditions on Site 1, on Site 2 excluding the horizontal 20mm projectile and has problems where the magnetic soil properties achieve figures like on Site 3 Pit 1with the 20mm projectile.

ATMID Schiebel Elektronische Geräte GmbH

Table 8-13 ATMID Technical Data

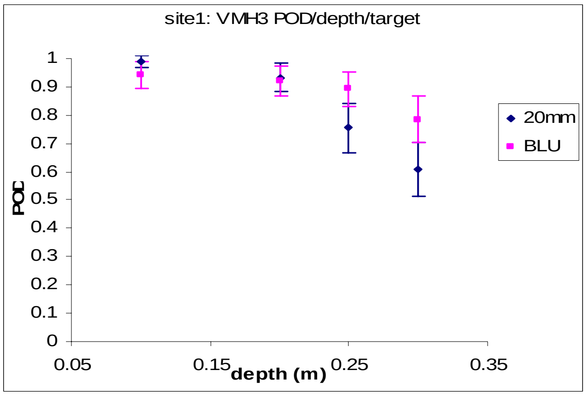
Parameters	Value	Unit	Comments
Metal detector	Schiebel ATMID	-	MT5001/10/001
Working technology	Sine wave	-	Dynamic mode, frequency domain, separate sending and receiving coil
Ground compensation	Yes	-	
Price	3050	€	Without VAT – Unit price
Package			
Operator manual	Yes	-	Format A5 – English - Not plastified
Instruction card	Yes	-	Format single page A5 – English – Plastified
List of content	Yes	-	
Test piece	Yes	-	
Batteries	No	-	
Size parameters			
Operational	1260, 1360, 1460	mm	Fixed increments
Search head / shape	265	mm	circular
Transport case	800 x 310 x 120	mm	Hard case – Metal
Backpack	695 x 280 x 95	mm	Fabric
Mass parameters	Value	Unit	Comments
Operational	3.2	kg	Incl. control box, without C-box 1.4 kg
In transport case	7	kg	
In backpack	4.5	kg	
Set up			
Mechanical set-up	120	S	Tools: No – Discontinuous length set up (3 positions-old fashion system) – not possible to fix control box on the handle unless request of optional clips.
Handbag storage	120	S	Tools: No
Standing/kneeling	15	S	Tools: No
Right/left	0	S	Tools: No
Electrical set-up	15	S	
Battery			
Inversion polarity	No effect	-	Battery voltage: 6.37 V
Type - Number	LR20 x 4	-	Nominal voltage: 6 V

8.7.1 Picture details ATMID

8.8 Vallon GmbH, Detctor VMH3

Plate 8-31 VMH3 during the trial Site 1

The Vallon VMH3 is a compact detector with changeable sensitivity. There are three ways of target indication sound, optical, and via vibration of the handle that may be used independently. That means depending on the environmental situation the operator has the choice to use one or the other or all possible indication ways together. No trainer was available from the manufacturer, so two officers of the Belgium Army carried out the training, under the supervision of the Team Leader.



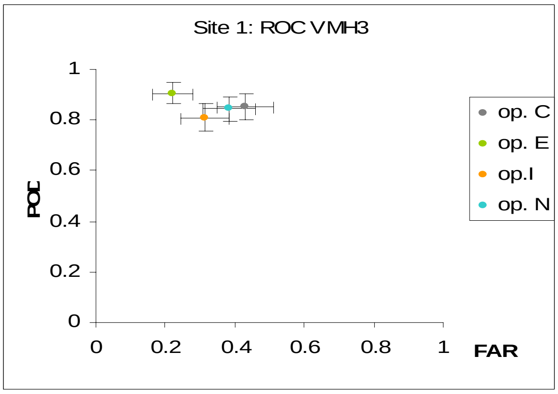
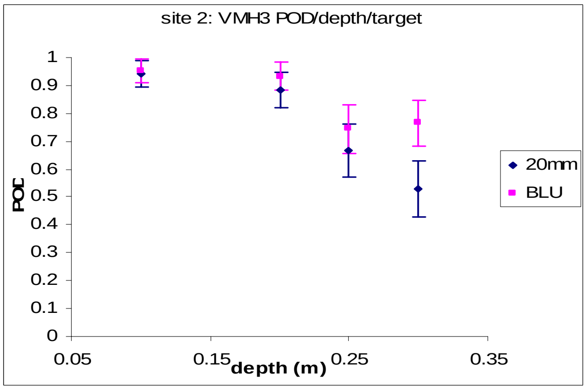


Figure 8-32 , 8-33 Site 1 VMH3 POD vs target depth & operator



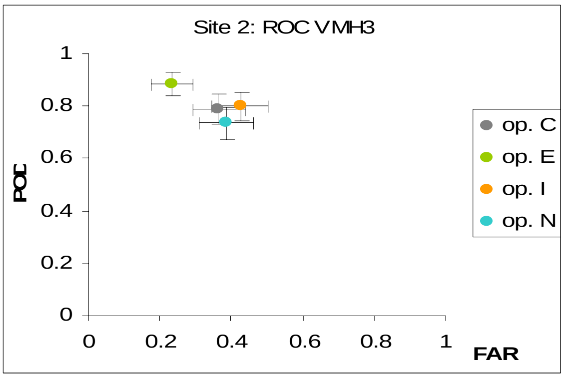


Figure 8-34 , 8-35 Site 2 VMH3 POD vs target depth & operator

The results in Figure 8-32 to 8-35 demonstrate the dependency of POD on the target metal content and the depth at which it is laid. There is no improvement from Site 1 to Site 2. At 25cm depth, there was a decrease in POD, as expected on the more difficult site. All other changes in the POD versus depth results are not statistically significant. Operator C kept his high level on the second site, with a very slight drop of both POD and FAR. Operator N showed a significant loss of POD on Site 2.

Table 8-14 VMH3 maximum detection depth

VMH3	Site 1		Site 2		Site 3			
	Copy 1	Copy 2	Copy 1	Copy 2	Pit 1/C1	Pit 2/C1	Pit 1/C2	Pit 2/C2
20mm Vertical	375	375	400	375	300	275	275	250
20mm Horizontal	400	400	225	225	250	225	250	225
BLU 26B	450	450	300	300	325	325	300	300
Steel ball	150	150	80	60	100	100	100	110

The maximum detection depth established on all three sites demonstrates a general loss of detection ability (sensitivity) to the horizontal/vertical position of the 20mm projectile and the BLU 26B from Site to the Site 3. The maximum loss was from Site 1 to Site 3 for the 20mm projectile with 175mm. The individual differences of the copies are from one depth increment. They may have different reasons and are not essentially.
The ground compensation is done automatically by pressing compensation button and moving the detector from and to the soil up to the moment to a special signal. It should be mentioned that the ground compensation came to its limits at the spots for testing ground compensation with the extreme magnetic ground properties there the detector was not able to cope with.

The results of the questionnaire confirmed a very easy use and good capabilities for field use.

This detector can detect the two targets in accordance with the UXO Lao requirements and the conditions on Site 1, on Site 2 excluding the horizontal 20mm projectile and has problems where the magnetic soil properties achieve figures like on Site 3 with the 20mm projectile.

Vallon VMH3 Vallon GmbH

Table 8-15 VMH3 Technical Data

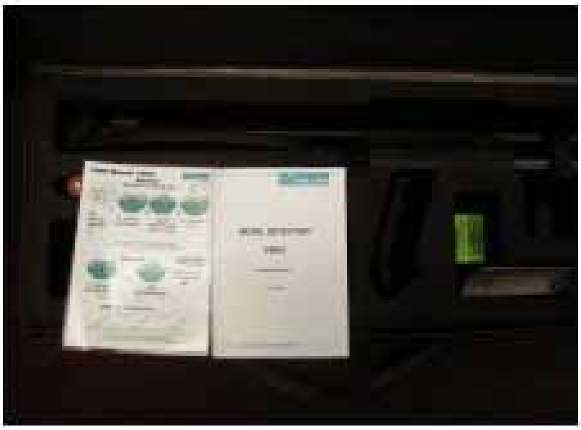
Parameters	Value	Unit	Comments
Metal detector	Vallon VMH3	-	
Working technology	Pulse induction	-	Bipolar pulse, time domain, dynamic mode, single sending and receiving coil
Ground compensation	Yes	-	
Price	2420	€	Without VAT – Unit price – including optional earphone
Package			
Operator manual	Yes	-	Format A5 – English - Not plastified
Instruction card	Yes	-	Format single page A5 – English – Plastified
List of content	No	-	
Test piece	Yes	-	
Batteries	Yes	-	Optional battery charger with Ni-Mh
Size parameters			
Operational	900 to 1500	mm	
Search head / shape	310 x 170	mm	Truncated ellipse
Transport case	840 x 300 x 250	mm	Soft case – Plastic
Backpack	none	mm	Transport case has back straps, can be used as backpack
Mass parameters	Value	Unit	Comments
Operational	2.6	kg	
In transport case	5.45	kg	
In backpack	-	kg	
Set up			
Mechanical set-up	30	s	Tools: No – Continuous length set up
Handbag storage	30	s	Tools: No
Standing/kneeling	10	s	Tools: No
Right/left	0	s	Tools: No
Electrical set-up	10	s	
Battery			
Inversion polarity	No effect	-	Battery voltage: 4.85 V
Type - Number	LR20 x 3	-	Nominal voltage: 4.5 V

8.8.1 Picture details VMH3





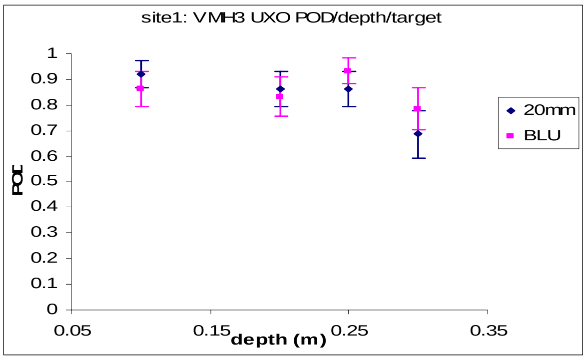





8.9 Vallon GmbH, VMH3 UXO

Plate 8-36 VMH3 UXO Test Pit on Site 1

The Vallon VMH3 UXO is a compact detector with changeable sensitivity. There are three ways of target indication sound, optical, and via vibration of the handle that may be used independently. That means depending on the environmental situation the operator has the choice to use one or the other, or all possible indication ways together.



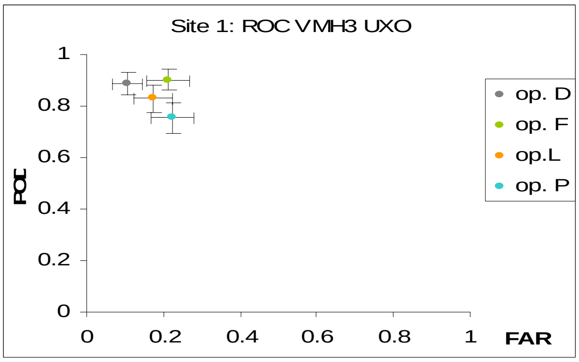
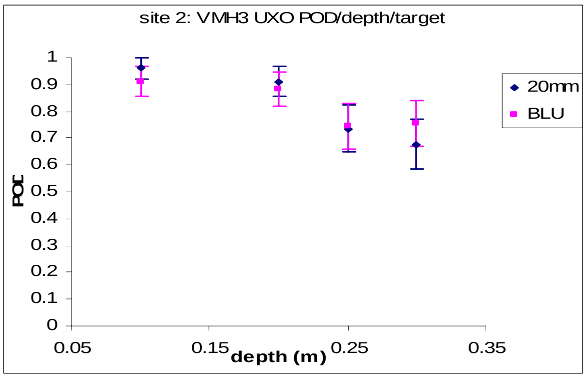


Figure 8-37 , 8-38 Site 1 VMH3 UXO POD vs target depth & operator



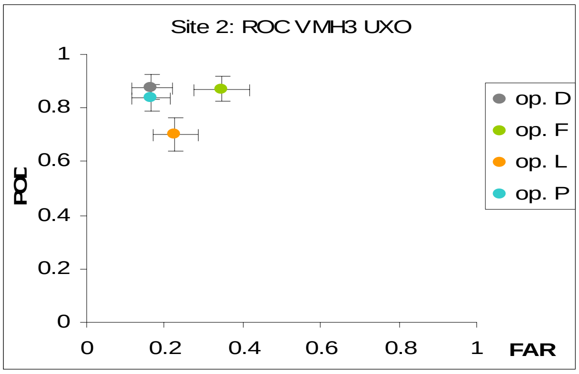


Figure 8-39 , 8-40 Site 2 VMH3 UXO POD vs target depth & operator

The results in Figure 8-37 to 8-40 demonstrate the dependency of POD on the target metal content and the depth at which it is laid. There is no improvement from Site 1 to Site 2. There was significant drop in POD at 25cm depth, as expected on the more difficult site. This reaction is the same as with the VMH3 basic type. The operators achieved a compact result concerning the POD on Site 1 i.e. they all gave similar results. On Site 2, there was a significant drop of the POD by operator L and significant increase of the FAR by operator F.

Table 8-16 VMH3 UXO maximum detection depth

VMH3 UXO	Site 1		Site 2		Site 3			
	Copy 1	Copy 2	Copy 1	Copy 2	Pit 1/C1	Pit 2/C1	Pit 1/C2	Pit 2/C2
20mm Vertical	550	550	350	300	300	350	275	325
20mm Horizontal	475	450	250	250	275	275	275	275
BLU 26B	550	575	400	400	275	325	350	350
Steel ball	80	100	no detect	no detect	no detect	no detect	no detect	no detect

The maximum detection depth established on all three sites demonstrates a general loss of detection ability (sensitivity) to both the horizontal and vertical position of the 20mm projectile and to the BLU 26B from Site 1 to Site 3. The maximum sensitivity loss was from Site 1 to Site 3 for the 20mm projectile with 250mm. The individual differences of the copies are up to two-depth increments and may have different reasons that could not be investigated in more detail. As visible, with the need to compensate the detector started to ignore the 10mm steel ball.
The ground compensation is done automatically by pressing compensation button and moving the detector from and to the soil up to the moment to a special signal. It should be mentioned that the ground compensation came to its limits at the spots for testing ground compensation with the extreme magnetic ground properties there the detector was not able to cope with.

The results of the questionnaire indicated a very easy use and good field capabilities. The new features of signalling a target visually and by vibration via the handle were mentioned as advantages.

This detector can detect the two targets in accordance with the UXO Lao requirements and the conditions on Site 1, on Site 2 excluding the horizontal 20mm projectile and has problems where the magnetic soil properties achieve figures like on Site 3 Pit 1 with the 20mm projectile.

Detector VMH3 UXO Vallon GmbH

Table 8-17 VMH3 UXO Technical Data

Parameters	Value	Unit	Comments
Metal detector	VMH3 UXO	-	
Working technology	Pulse induction	-	Bipolar pulse, time domain, dynamic mode, single sending and receiving coil
Ground compensation	Yes	-	
Price	2420	€	Without VAT – Unit price – including optional earphone
Package			
Operator manual	Yes	-	Format A5 – English - Not plastified
Instruction card	Yes	-	Format single page A5 – English – Plastified
List of content	No	-	
Test piece	Yes	-	
Batteries	Yes	-	Optional battery charger with Ni-Mh
Size parameters			
Operational	L: 960 to 1300	mm	Adjustable length
Search head / shape	615	mm	circular
Transport case	515 x 410 x 205	mm	Hard plastic case. NOTE: search head has separate soft case fabric bag (approx 660 x 720mm)
Backpack	470 x 280 x 120	mm	Fabric
Mass parameters	Value	Unit	Comments
Operational	3.3	kg	
In transport case	9.2	kg	NOTE: UXO search head has separate bag (3.1kg inc. head)
In backpack	4.4	kg	
Set up			
Mechanical set-up	30	s	Tools: No – Continuous length set up
Handbag storage	30	s	Tools: No
Standing/kneeling	10	s	Tools: No
Right/left	0	s	Tools: No
Electrical set-up	10	s	
Battery			
Inversion polarity			
Type - Number	LR20 x 3	-	Nominal voltage: 4.5 V

8.9.1 Picture details VMH3 UXO

9 Lessons learned

- When finalising the test plan, it is important to stay flexible but not to change the principles. For example, last minute requests from manufacturers for different models to be used, gave us the dilemma of either having to use models we had not tested in the lab or to exclude models which were potentially the most suitable. We did not make the final decision until three days before the blind trial, but the total number of detectors was fixed several weeks beforehand.
- It is preferable to inform manufacturers of trial details as soon as possible and to check that the organisations have really understood what is planned. We feel that some of the information we sent had not got down to the sales engineers.
- Battery life is best measured in the lab, under controlled conditions. It is important to check the battery policy of the demining organisation in advance (e.g. whether or not they use rechargeable batteries) and to conduct the lab tests accordingly.
- It is valuable if supervisors oversee operators and QC the procedures during runs.
- Allowance should be made for possible operator absence during training and trial sessions e.g. due to sickness. Attendance during the Laos trial was excellent but we believe this to be exceptional.
- The number of targets per square meter should not be too high or else there is a risk that the deminer will be able to guess when he will reach the next target. It is desirable to have some gaps of more than a metre. With hindsight, we consider the density we chose was a little too high but not so high as to compromise the test.
- As much information as possible should be obtained in advance regarding country logistics, habits in providing transport and available hotel support. At minimum, accommodations for the first (two) nights should be arranged *before* arrival in the country.
- The value of using Total Station technology was confirmed from the experience with the Leica 1205. It is quite fast, eliminates manual transcribing and recording of data and interfaces well with software such as Excel. Automatic tracking and remote control are valuable features. Cost can be reduced by specifying moderate precision (e.g. 5mm); more is unnecessary. Total stations can be hired for a short period. A simplified instruction set specific to the trial should be written because the manufacturer’s manuals cover a wide range of applications and include much information that is not relevant. The prism needs to be mounted on its pole closer to the ground to speed up the alignment on each marker. With the current system it was possible to keep up with the operators on three lanes, but not four. It is essential to have some form of backup option in the event of a station failure, either with a substitute instrument from the manufacturer or tape measures.
- Shipment of equipment and customs clearance tends to take up a disproportionate effort and the time required to organise it should not be underestimated.
- Translators who are familiar with mine action are an asset.
- Language knowledge is an asset and allows parallel work on different sites.
- Exact details of the set-up method and set-up results for each detector at the calibration should be recorded.
- Settling of the targets can give rise to visual clues. It is preferable to avoid this by burying the targets well in advance and the lanes should also be checked by the supervisors during the trial.

10 Conclusions

- *Meeting the requirements of detecting a BLU26B and 20mm projectile at 300mm depth:*
    - Based on the Blind Trial POD with depth, all detectors find the 300mm deep targets albeit at a lower POD than shallower targets. From 200mm onwards, the decrease in POD is visible. In general, and on both Sites 1 and 2, the differences between the detectors' PODs are small.
    - Based on the Pit Tests, all detectors on Site 1 meet requirements. On Site 2, several detector fail to find the 20mm projectile at 300mm. On Site 3, which can be considered difficult, only one detector was able to detect all targets at the required depth.
    - There are some anomalies in the pit data. These may be due to lack of experience of the operators in setting up the detector, especially on Site 1.
- *False Alarm Rates:*
    - Detectors seem to operate with higher FAR on Site 2 without any apparent change of POD. Whereas the distribution of detectors is fairly homogeneous on Site 1, it seems to have narrowed. Despite this shift, the relative differences did not change much.
- *Operating Time:*
    - All timings presented here exclude vegetation removal, signal investigation, etc.
    - Operating time decreases over the period of the test and the average time on Site 1 was generally longer than on Site 2. This can be attributed to operators' increasing knowledge and confidence in their instruments. Operators nevertheless operated their respective detectors for only about 12h excluding time in the test pits.
    - Most UXO-type detectors (excluding the CEIA) appear to have a slight time advantage over conventional detectors in both sites. We believe this could be connected to the lower FAR of UXO-type detectors but further analysis is required to be sure.
    - Despite the fact that that overall times decreased at the second site, there seems to be little difference in the relative time ranking between the detectors. For example, the CEIA and Foerster seem to need more time than other detectors in both sites.
- *Human Factors:*
    - Some ROC & FAR data suggests that the performance of the detector is dependent on human factors. Conversely, the ease of use of certain models influenced both positively and negatively the results. Further analysis is needed to get a more complete understanding.
- *Detectors' compensation capabilities:*
    - All detectors lost detection capability when the ground compensation had to be used. The loss is specific to each detector model.
    - In general all detectors successfully compensated for the ground conditions in Sites 1 & 2. On Site 3, whilst evaluating maximum detection depths, two detectors could not compensate.
    - On spots of extreme magnetic properties, only two detectors were able to compensate and successfully detect a piece of metal.
- *POD and FAR: possible explanations*
    - The differences between Sites 1 and 2 are essentially that Site 2 showed significantly higher FAR, with little, if any, change in POD. This is not consistent with a single ROC curve applying to both sites.
    - It may have been due to greater metal contamination in Site 2

- It may have been due to stronger magnetic properties of ground in Site 2
- In a few cases, where the detector was able to compensate for the soil, there is some evidence that the operators improved their performance in Site 2, as they gained experience with the detector.
- The test was designed to measure the performance of the detector models. There are differences between the different copies but further analysis is required to know if this is a property of the detector copies themselves or due to human factors.

11 Recommendations regarding detector use

- *Ground magnetic properties (magnetic susceptibility, GRH)*
  - These should be measured and recorded as a survey task because it has to be known for planning and proper use of the detector fleet (see decrease in detection capability with growing magnetic response in the test pit results).
  - Existing geological and soil maps should also be consulted.
  - It is also desirable for GRH data to be collated internationally.

- *Training*
  - Deminers should be trained to understand that the detector can detect only to a limited depth. The concept of the sensitivity cone, the idea that the footprint is narrower at greater depths, should be explained to them.
  - They should also understand that the orientation, size and shape of the target affect the signal strength.

12 Annexes

12.1 List of Annexes:

A: Invitation to Manufacturers
B: Matrix
C: GRH
D: Magnetic Susceptibility Meter
E: POD & ROC
F: Pit observations
G : Questionnaire

12.2 ANNEX A: Letter to Manufacturers

EUROPEAN COMMISSION
DIRECTORATE GENERAL JRC
JOINT RESEARCH CENTRE
Institute for the Protection and the Security of the Citizen
Humanitarian Security Unit

Ispra, 28th July 2004

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European Commission Joint Research Centre
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Fax +39 0332 785469
Adam.Lewis@jrc.it

Subject: Detectors for Tests in Laos

Dear Sir or Madam,

I am writing to invite you to indicate suitable detectors manufactured by your company and to provide training for a metal-detector trial in Laos, which is being conducted on behalf of the national mine action authority for Laos, UXO Lao, which intends to use the results to enable them to select a detector or detectors for a new fleet which is to be purchased in the near future.

The trial also forms part of ITEP Project 2.1.2.3 STEMD – Systematic Test and Evaluation of Metal Detectors, a recent International Test and Evaluation Program initiative whose scope is to evaluate all existing, commercial-off-the-shelf metal detectors that are used for landmine detection and the detection of Unexploded Ordnance (UXO) and are suitable for humanitarian demining operations in specific regions. The intent of this test and evaluation (T&E) is to identify which detectors are best suited for a geographical scenario or operational environment.

The test team consists of representatives from the ITEP participating countries including the European Commission Joint Research Centre, UK, and Belgium. The Geneva International Centre for Humanitarian Demining and representatives from mine action agencies from mine affected countries will all be involved in laboratory and field tests. The laboratory testing will be done at the Joint Research Centre at Ispra, Italy and the field tests will be conducted at sites within Croatia, Laos and Mozambique. The Joint Research Centre has overall responsibility for directing the trial.

Joint Research Centre · I-21020 Ispra (VA), Italy · TP 723
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WWW: http://www.jrc.org/

The requirements of UXO Lao are as follows:

- **BLU 26B bomblet** and **20mm cannon projectile** to be detected.
- Targets to be detected at 30cm depth (to top of object from surface of soil).
- Ground compensation capability to compensate for the effects of "mineralized" soils
- Some capability to reject signals from small metal fragments on the ground.

In short, the detection of large metal objects buried deeply in difficult soils is required, with some rejection of small metallic clutter. The two munitions mentioned above will be used as the primary targets for the field tests in Laos.

The detectors will be subjected to the T&E standard CWA 14747 and is available on the ITEP web site at
http://humanitarian-security.jrc.it/demining/cw07/pdf/CWA14747.pdf .
This T&E standard takes into account factors such as performance of detectors in conditions of difficult magnetic soils, high temperature and humidity conditions. Human factors such as ease of use, training requirements, clear indication of detections, etc. Life cycle considerations such as reliability ease of maintenance and after-sale service and maintenance, battery life, sturdiness and reliability of hard shell case, and durability of the detectors are also going to be assessed. The T&E will provide humanitarian demining agencies with the data necessary to select the detector(s) which are suitable for use in their particular scenario and geographic region. The final report will not attempt to provide an overall ranking or, in any way, certify the detectors tested. Certification of a detector for use in a mine affected country is the responsibility of the national mine action authority. The evaluation will, however, tabulate each detector's performance against the criteria specified in the T&E Standard (CWA 14747) under a range of defined conditions. A final evaluation report will be released to all interested parties upon the completion of the trials.

Threat munitions used for T&E in Croatia and Mozambique will be more along the lines of conventional landmines and include minimum metal versions of anti-tank and anti-personnel mines. In all three of the regions we intend to measure the maximum detection depths for local targets in local soil conditions.

A number of metal detectors have already been obtained for this project, including the following, manufactured by your company

Company Name	**Detector model**	**Serial No.**

We would like to invite you to

a. Propose detectors that you currently manufacture that are available for retail sale and are best suited for the above requirements for Laos.
b. Identify the appropriate sales representative that should be contacted to obtain two copies of each unit for test and evaluation.
c. Propose any suitable updates or specific software versions that would be needed to optimize the detector for the Lao requirements.
d. Provide training of operators for the Lao trial or, if this is not possible, to "train a trainer" at JRC Ispra.

We stress that only production models will be considered in this trial. We regret that we must decline any research and development prototypes.

We would be grateful if you give us an initial response within two weeks of receipt of this communication. Please be aware that we need to have delivery of the detectors to JRC by the last week in August 2004. This relatively quick delivery schedule must be adhered to if the laboratory tests are to be completed before going to Laos for field trials in early October 2004. Any equipment received after that date will not be included in the evaluation. Your sales representative will be contacted at a later date to arrange for appropriate equipment training after the receipt of the detectors at JRC.

Please provide the above information to Dr. Adam Lewis at the above address.

In case of Dr Lewis' absence, please contact Dr Tom Bloodworth (x 9131) or Dieter Gülle (x 5576)

Yours sincerely,

Adam Lewis

12.3 ANNEX B: Test matrix

DAY 1

Lane 1	A 1	E 7	I 1'	M 5	B 2	F 3	J 3'	N 2'	C 3'	G 2	K 4'	O 6
Lane 2	B 6	F 8	J 5	N 7'	C 7	G 5'	K 6'	O 3'	D 4'	H 6	L 2'	P 1
Lane 3	C 3	G 2'	K 4	O 6'	D 8	H 1	L 8'	P 8	A 1'	E 7'	I 1	M 5'
Lane 4	D 4	H 6'	L 2	P 1'	A 5	E 4'	I 7'	M 4	B 6	F 8'	J 5'	N 7'

DAY 2

Lane 1	D 8'	H 1'	L 8	P 8'	A 5	E 4'	I 7'	M 4	B 6'	F 8'	J 5'	N 7
Lane 2	A 5'	E 4	I 7	M 4'	B 2	F 3	J 3	N 2'	C 3'	G 2'	K 4	O 6
Lane 3	B 2'	F 3'	J 3'	N 2	C 7'	G 5	K 6	O 3'	D 4'	H 6	L 2	P 1'
Lane 4	C 7	G 5	K 6	O 3	D 8	H 1	L 8'	P 8'	A 1'	E 7	I 1'	M 5'

DAY 3

Lane 1	C 7'	G 5	K 6	O 3'	D 4	H 6'	L 2'	P 1	A 1'	E 4	I 7	M 4'
Lane 2	D 8'	H 1'	L 8	P 8	A 1	E 7'	I 1'	M 5	B 6'	F 3'	J 3	N 2
Lane 3	A 5'	E 4'	I 7	M 4'	B 6	F 8'	J 5	N 7	C 3	G 5'	K 6'	O 3
Lane 4	B 2'	F 3	J 3	N 2	C 7	G 2'	K 4	O 6'	D 4'	H 1	L 8	P 8

DAY 4

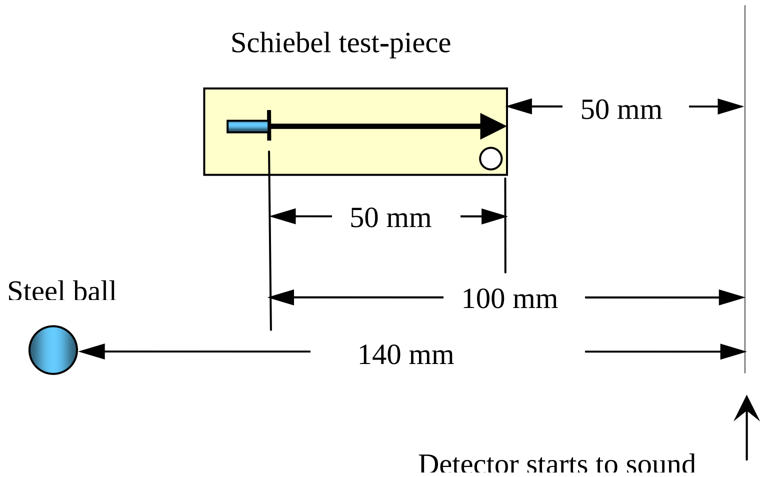
Lane 1	B 2'	F 8	J 5'	N 7'	C 3	G 5'	K 6'	O 3	D 8	H 6	L 2	P 1
Lane 2	C 7'	G 2	K 4'	O 6'	D 4	H 1'	L 8'	P 8'	A 5	E 7	I 1	M 5'
Lane 3	D 8'	H 6'	L 2'	P 1'	A 1	E 4	I 7'	M 4	B 2	F 8	J 5	N 7
Lane 4	A 5'	E 7'	I 1	M 5	B 6'	F 3'	J 3'	N 2'	C 3'	G 2	K 4'	O 6

The test matrix above shows which operator (A-P) uses which detector (1-8; 1’-8’ for the second copy) in which lane (on the left). The matrix is designed in such a way that an operator uses one model of detector 6 times in total (3 for each copy). Each detector type is used the same number of times on each lane. As far as possible, use of an individual detector is spread evenly across the available days.

12.4 ANNEX C: GRH - Calibration of the Schiebel AN19/2 M7

This Annex describes how to calibrate the Schiebel Metal Detector AN19/2 M7 before measuring the Ground Reference Height (GRH). This process should be done before measuring the GRH at each site.
The calibration is used to set the detectors to a repeatable sensitivity for measuring the GRH. This is necessary for two reasons. First, the detector must always be set up in the same way if the GRH readings are to be meaningful. Second, the electronic units of these detectors are "individual" and must be set to a common benchmark for their results to be interchangeable when different detectors are used.
The targets to be used for this process are the Schiebel test piece (delivered with each detector) or a 10mm diameter chrome steel ball (10mm Ø 100Cr6).
There are two ways to achieve the same sensitivity settings:

a) The Schiebel test piece is held 100mm away of the centre from the search-head in air. The sensitivity knob is then moved clockwise to a point where a reading starts. This should be repeated several times for confirmation. The distance to the Schiebel test piece should not be measured from the real position of the metal piece but from the bottom of the arrow on the plastic cover (base of the arrow).
b) A 10mm diameter chrome steel ball is placed 140mm away from the centre of the search-head in air. The sensitivity knob is then moved clockwise to a point where a reading starts. This should be repeated several times for confirmation.



Use the marking and add another 50mm for the Schiebel Test Piece, or use a 10 mm Ø 100Cr6 ball at 140 mm distance to the centre of the search head.

Note 1: Using the instructions above, whether the Schiebel test-piece or the steel ball is used, the results in terms of setting a benchmark sensitivity will be similar enough to give interchangeable results.

After calibration, the measurement of the Ground Reference Height (GRH - height at which the detector signals to the ground) is to be made when the detector makes the same sound as it did during the calibration procedure. At least five GRH measurements should be made at each place where a reading is taken and the results should normally be within ± 5 mm of each other. This level of accuracy is both achievable in field conditions and useful. The final GRH result is then calculated as an average of the five readings.

Note 2: The search-head of early versions of the Schiebel AN19 may be particularly sensitive to ground and atmospheric moisture. When it was the most widely used metal-detector in HD, deminers in some countries were advised to wrap the search-head in a plastic bag before using the detector on wet grass or in damp conditions.

12.5 ANNEX D: Magnetic Susceptibility Meter

The magnetic susceptibility measurements presented in this report were carried out using a Bartington MS2 system. The system used consists of a meter (MS2) and two different sensors (MS2B & MS2D). Using both sensors gives a good indication of a soil's potential difficulty for metal detectors.

The MS2B is used to obtain mass or volume susceptibility measurements of soil samples (Plate 12-1). It operates at 2 frequencies (0.465kHz and 4.65kHz) enabling the calculation the "frequency dependency". It is accepted that the greater the frequency dependency is, the more uncooperative a soil is for metal detectors.

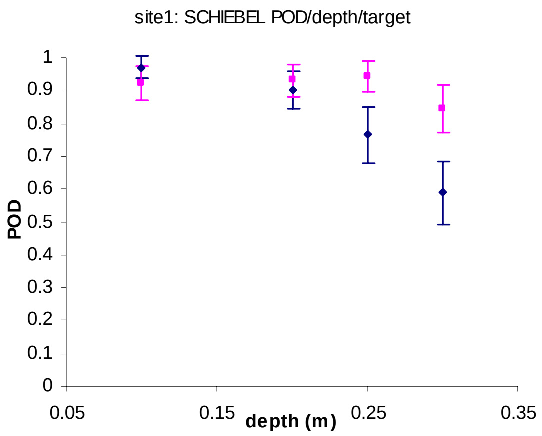
Plate 12-1 Bartington MS2B configuration

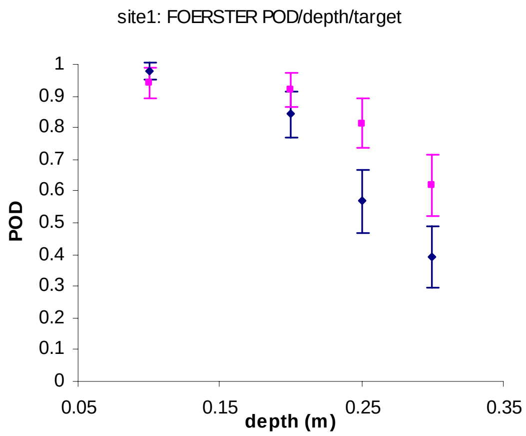
The MS2D is a handheld probe to evaluate the concentration of ferromagnetic materials in the upper parts of the soil surface (Plate 12-2).

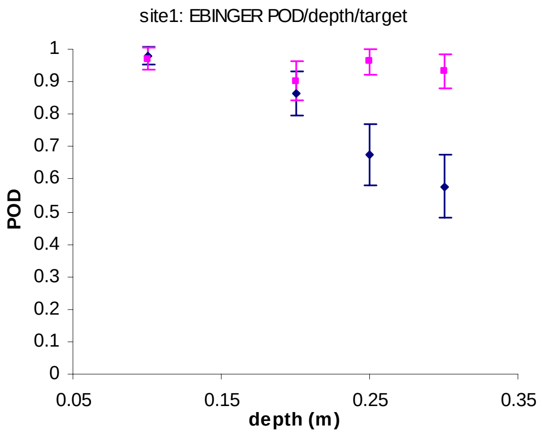
Plate 12-2 Bartington MS2D configuration

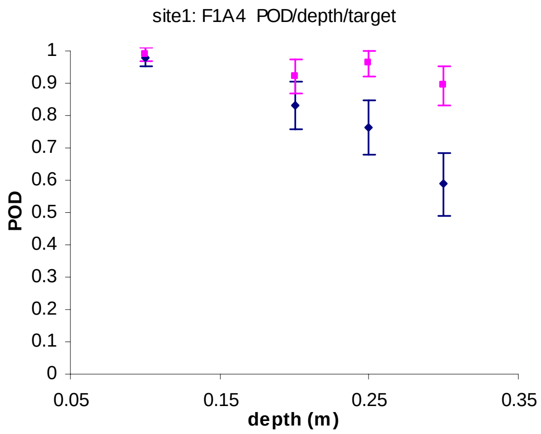
12.6 ANNEX E: POD on Site 1 (Saravane)

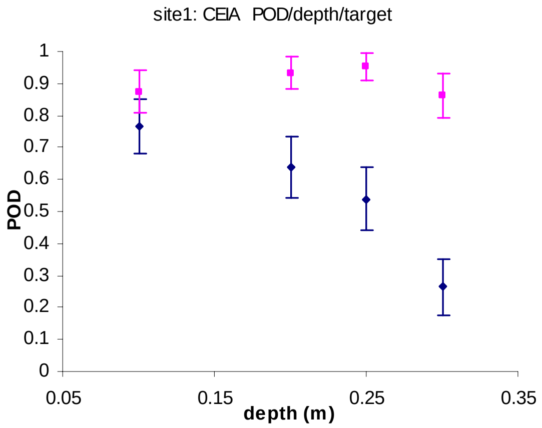
Legend ■BLU ◆20 mm :

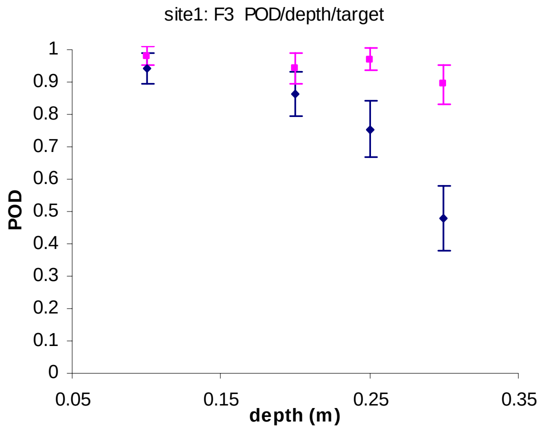


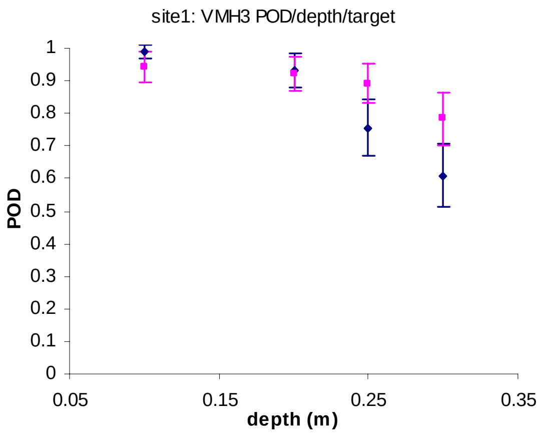


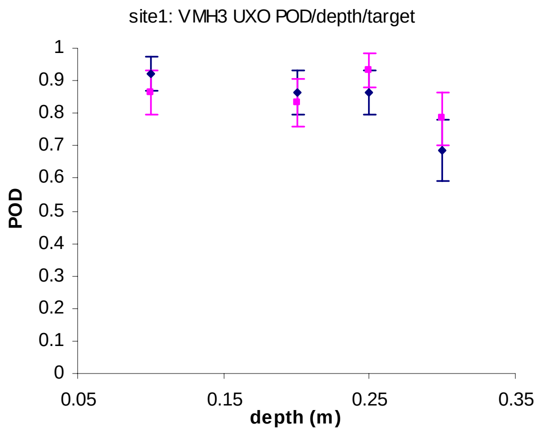






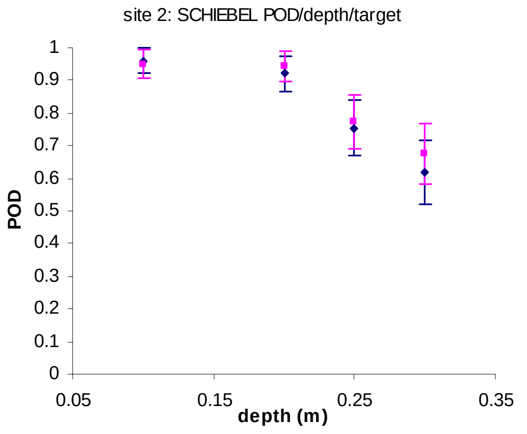


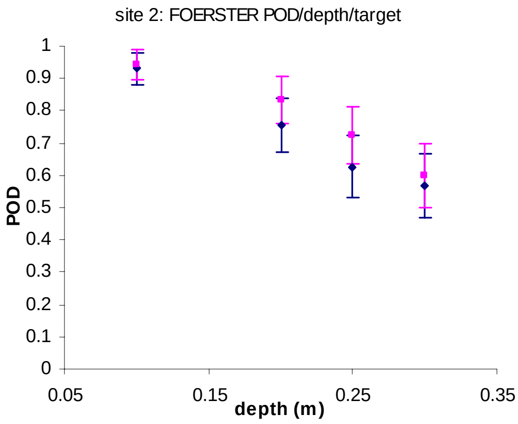


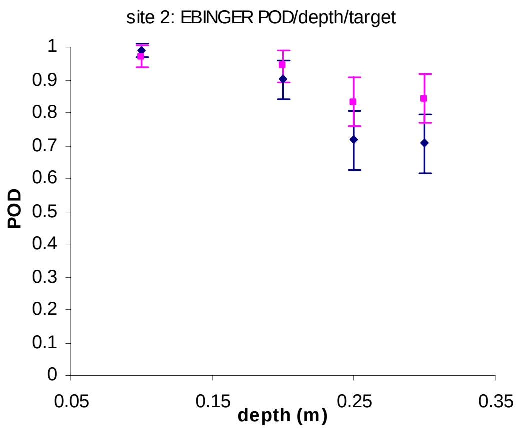


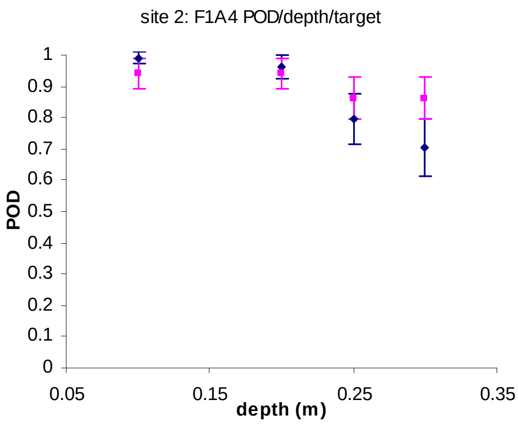
12.7 <u>ANNEX E: POD on Site 2 (Thateng)</u>

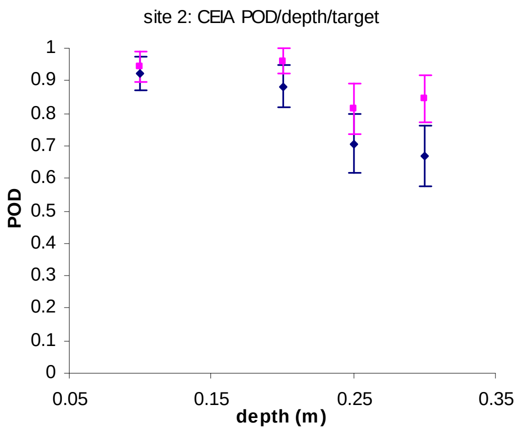
Legend: ■ BLU ◆ 20 mm

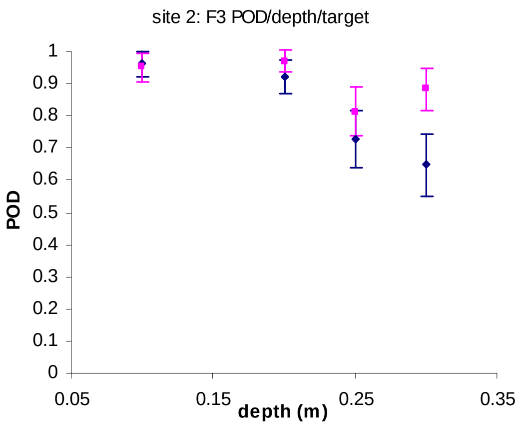


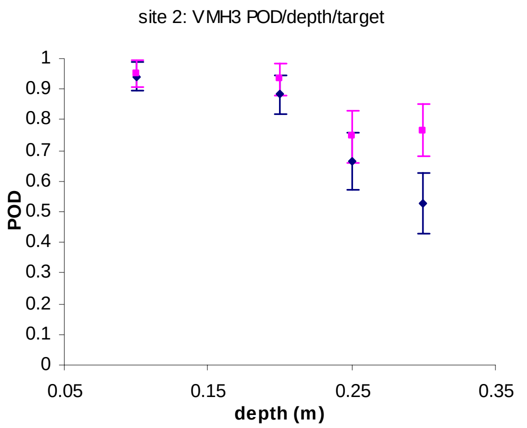


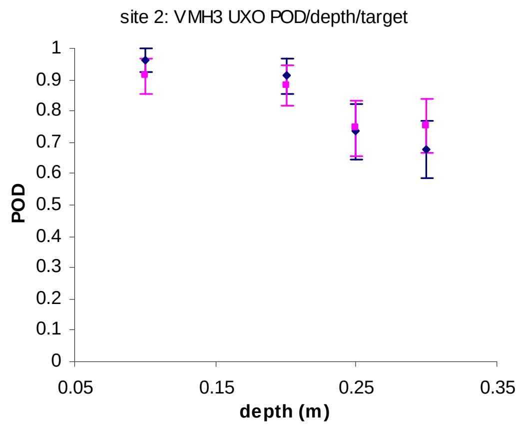




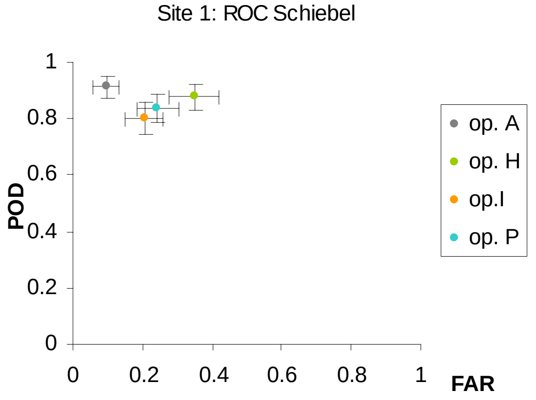


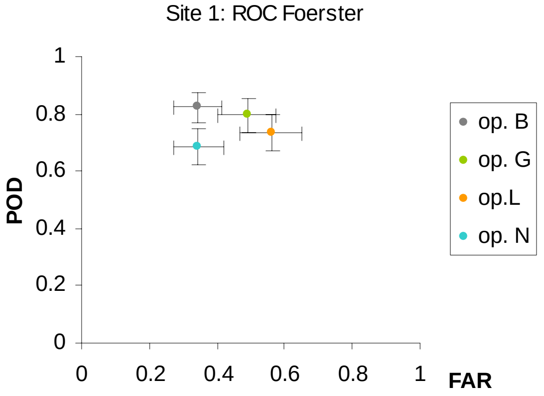


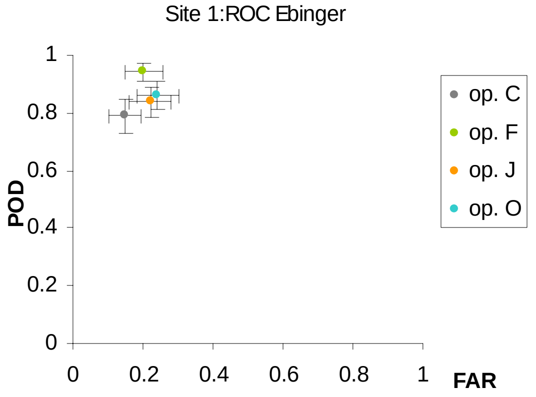


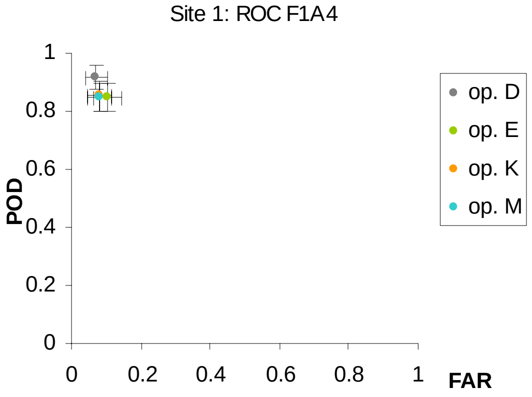


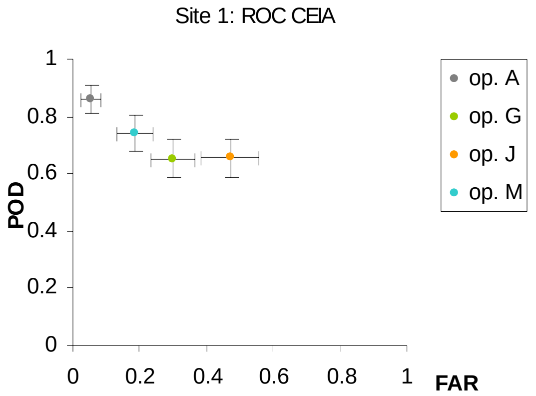
12.8 ANNEX E: ROC on Site 1 (Saravane)

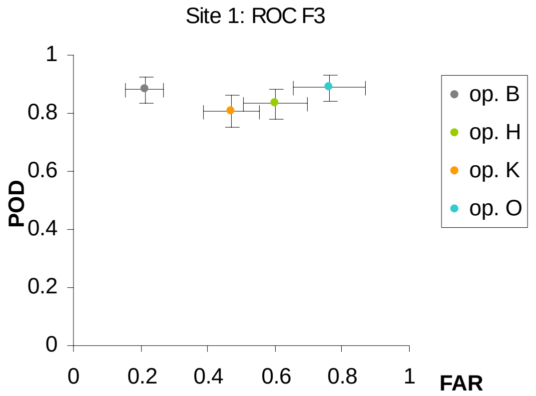


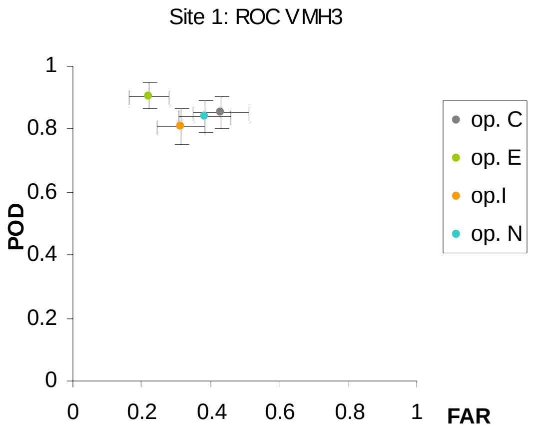


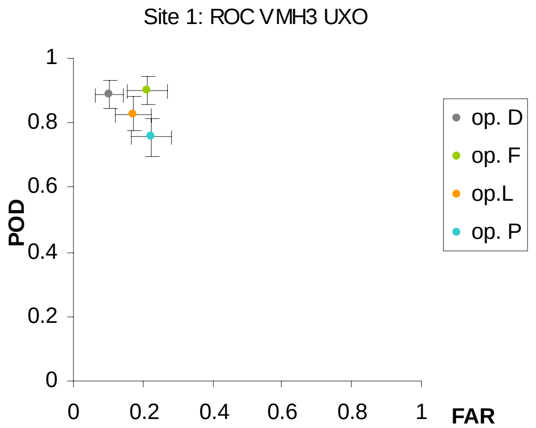




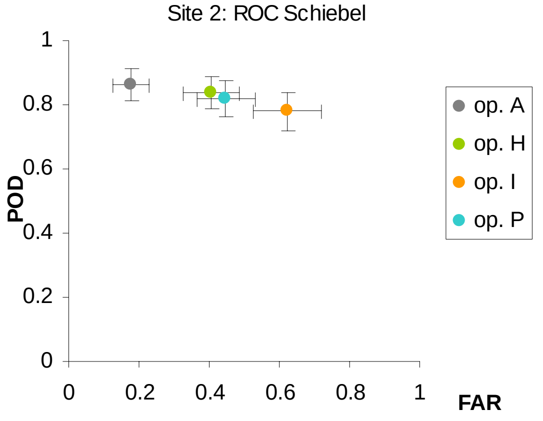


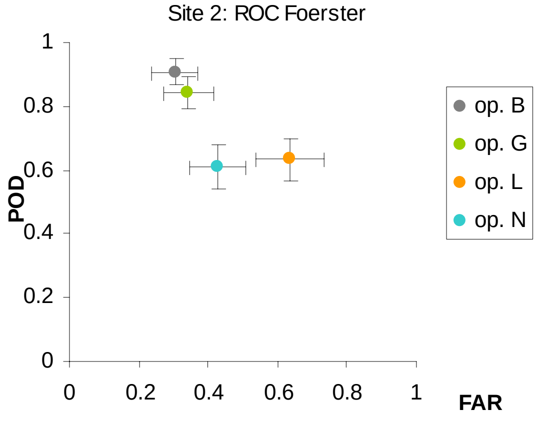


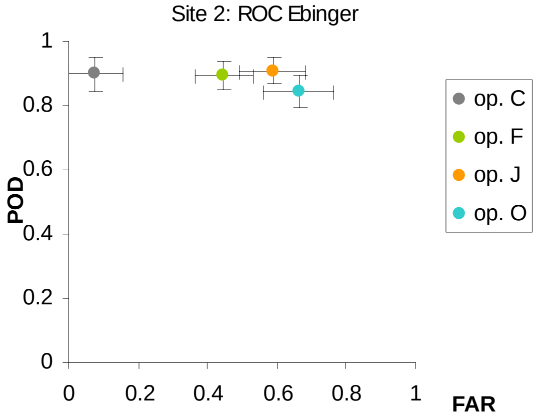


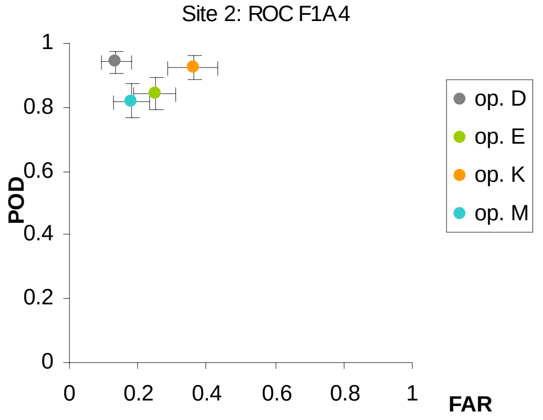


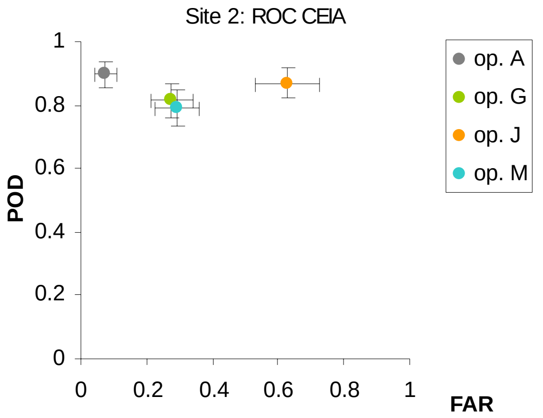
12.9 ANNEX E: ROC on Site 2 (Thateng)

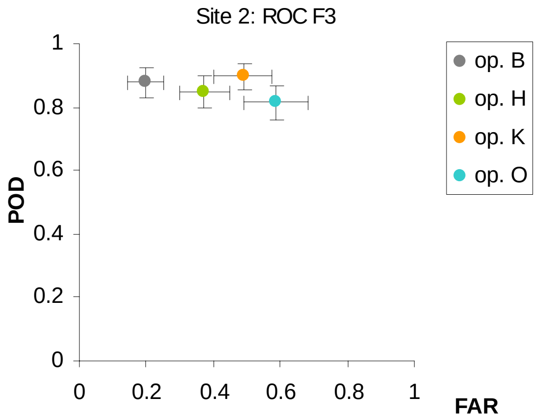


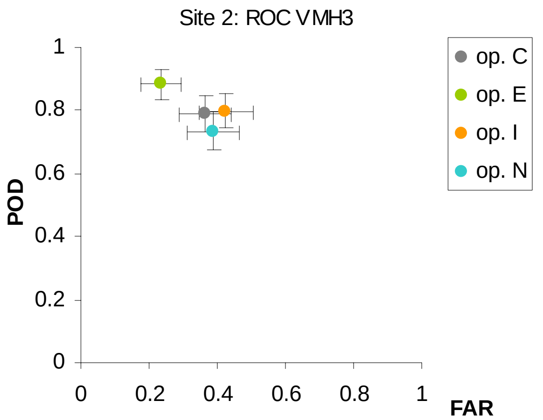


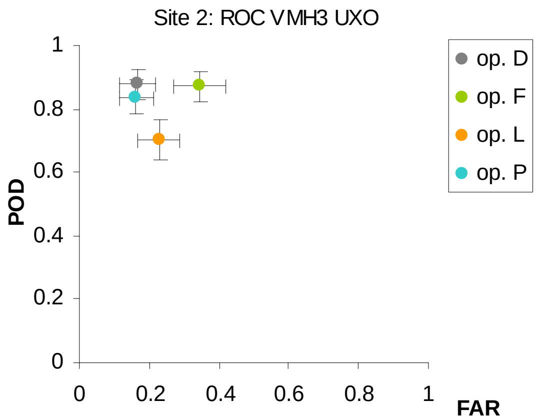












12.10 ANNEX F : Test Pit Measurements

Site 1: 20mm Vertical

Depth (cm)	30	32.5	35	37.5	40	42.5	45	50	52.5	55	57.5	60	65	70
Schiebel 1	Yes	Yes	Yes	Yes	No	No	No	No	No	No	No	No	No	No
Schiebel 1’	Yes	Yes	Yes	Yes	No	No	No	No	No	No	No	No	No	No
Foerster 2	Yes	Yes	No	No	No	No	No	No	No	No	No	No	No	No
Foerster 2’	Yes	Yes	Yes	No	No	No	No	No	No	No	No	No	No	No
Ebinger 3	Yes	Yes	Yes	No	No	No	No	No	No	No	No	No	No	No
Ebinger 3’	Yes	Yes	Yes	No	No	No	No	No	No	No	No	No	No	No
Minelab UXO 4	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	No	No	No
Minelab UXO 4’	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	No	No
CEIA 5	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	No	No	No	Yes	No	No
CEIA 5’	Yes	Yes	Yes	Yes	Yes	Yes	No	No	Yes	No	Yes	No	No	No
Minelab F3 6	Yes	Yes	Yes	Yes	No	No	No	No	No	No	No	No	No	No
Minelab F3 6’	Yes	Yes	Yes	Yes	No	No	No	No	No	No	No	No	No	No
Vallon 7	Yes	Yes	Yes	Yes	No	No	No	No	No	No	No	No	No	No
Vallon 7’	Yes	Yes	Yes	Yes	No	No	No	No	No	No	No	No	No	No
Vallon UXO 8	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	No
Vallon UXO 8’	Yes	Yes	Yes	Yes	No	Yes	Yes	No	Yes	Yes	No	No	No	No

Site 1: 20mm Horizontal

Depth (cm)	30	32.5	35	37.5	40	42.5	45	47.5	50	55
Schiebel 1	Yes	Yes	Yes	Yes	No	No	No	No	No	No
Schiebel 1'	Yes	No	No	No	No	No	No	No	No	No
Foerster 2	Yes	No	Yes	No	No	No	Yes	No	No	No
Foerster 2'	Yes	Yes	No	No	No	No	No	No	No	No
Ebinger 3	Yes	Yes	No	Yes	No	No	No	No	No	No
Ebinger 3'	Yes	Yes	No	Yes	No	No	No	No	No	No
Minelab UXO 4	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No
Minelab UXO 4'	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No
CEIA 5	Yes	No	No	Yes	No	No	No	No	No	No
CEIA 5'	Yes	No	No	Yes	No	No	No	No	No	No
Minelab F3 6	Yes	Yes	Yes	Yes	No	No	No	No	No	No
Minelab F3 6'	Yes	No	No	No	No	No	No	No	No	No
Vallon 7	Yes	No	No	No	Yes	No	No	No	No	No
Vallon 7'	Yes	Yes	Yes	No	Yes	No	No	No	No	No
Vallon UXO 8	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No
Vallon UXO 8'	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No

Site 1: BLU26B

Depth (cm)	30	32.5	35	37.5	40	42.5	45	47.5	50	55	57.5	60	62.5
Schiebel 1	Yes	Yes	No		No		No		No	No			
Schiebel 1'	Yes		Yes	No	No		No		No	No			
Foerster 2	Yes		Yes		Yes		Yes		Yes	Yes	No	No	
Foerster 2'	Yes		Yes		Yes		Yes		Yes	Yes	No	No	
Ebinger 3	Yes		Yes		Yes	Yes	No		No	No			
Ebinger 3'	Yes		Yes		Yes	Yes	No		No	No			
Minelab UXO 4	Yes		Yes		Yes	No	No		No	No			
Minelab UXO 4'	Yes		Yes		Yes	Yes	Yes		No	No			
CEIA 5	Yes		Yes		Yes		Yes		Yes	Yes		Yes	No
CEIA 5'	Yes		Yes		Yes		Yes		Yes	Yes	No	No	
Minelab F3 6	Yes		Yes		Yes	Yes	No		No	No			
Minelab F3 6'	Yes		Yes		Yes	Yes	No		No	No			
Vallon 7	Yes		Yes		Yes		Yes	No	No	No			
Vallon 7'	Yes		Yes		Yes		Yes	No	No	No			
Vallon UXO 8	Yes		Yes		Yes		Yes		Yes	Yes	No	No	
Vallon UXO 8'	Yes		Yes		Yes		Yes		Yes	Yes	Yes	No	

Site 1: 10mm steel ball

Depth (cm)	5	8	10	12	15	17	20
Schiebel 1	Yes	Yes	Yes	Yes	No	No	No
Schiebel 1'	Yes	Yes	Yes	Yes	Yes	No	No
Foerster 2	Yes	Yes	Yes	Yes	Yes	Yes	No
Foerster 2'	Yes	Yes	Yes	Yes	Yes	Yes	No
Ebinger 3	Yes	Yes	No	No	No	No	No
Ebinger 3'	Yes	Yes	No	No	No	No	No
Minelab UXO 4	Yes	Yes	No	No	No	No	No
Minelab UXO 4'	Yes	Yes	No	No	No	No	No
CEIA 5	No	No	No	No	No	No	No
CEIA 5'	No	No	No	No	No	No	No
Minelab F3 6	Yes	Yes	Yes	Yes	Yes	No	No
Minelab F3 6'	Yes	Yes	Yes	Yes	No	No	No
Vallon 7	Yes	Yes	Yes	Yes	Yes	No	No
Vallon 7'	Yes	Yes	Yes	Yes	Yes	No	No
Vallon UXO 8	Yes	Yes	No	No	No	No	No
Vallon UXO 8'	Yes	Yes	Yes	No	No	No	No

Site 2: 20mm Vertical

Depth (cm)	12.5	15	17.5	20	22.5	25	27.5	30	32.5	35	37.5	40	42.5	45	47.5	50
Schiebel 1					Yes	Yes	Yes	Yes	No	Yes	No	Yes	No	No	No	No
Schiebel 1'					Yes	Yes	Yes	Yes	No	Yes	No	No	No	No	No	No
Foerster 2	Yes	Yes	Yes	Yes	No	No	No	No	No	No	No	No	No	No	No	No
Foerster 2'	Yes	Yes	Yes	Yes	No	No	No	No	No	No	No	No	No	No	No	No
Ebinger 3					Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	No
Ebinger 3'					Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	No
Minelab UXO 4					Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No
Minelab UXO 4'					Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	No
CEIA 5					Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	No
CEIA 5'					Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
Minelab F3 6					Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	No
Minelab F3 6'					Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No
Vallon 7					Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	No
Vallon 7'					Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	No	No
Vallon UXO 8					Yes	Yes	Yes	Yes	No	Yes	No	No	No	No	No	No
Vallon UXO 8'					Yes	Yes	Yes	Yes	No	No	No	No	No	No	No	No

Site 2: 20mm Horizontal

Depth (cm)	10	15	17.5	20	22.5	25	27.5	30	32.5	35
Schiebel 1			Yes	Yes	No	No	No	No	No	No
Schiebel 1'			Yes	Yes	No	No	No	No	No	No
Foerster 2			Yes	Yes	No	No	No	No	No	No
Foerster 2'			Yes	No	No	No	No	No	No	No
Ebinger 3			Yes	Yes	Yes	No	No	No	No	No
Ebinger 3'			Yes	Yes	Yes	No	Yes	No	No	No
Minelab UXO 4			Yes	Yes	Yes	Yes	No	No	No	No
Minelab UXO 4'			Yes	Yes	Yes	Yes	No	No	No	No
CEIA 5			Yes	Yes	Yes	Yes	Yes	No	No	No
CEIA 5'			Yes	Yes	Yes	Yes	Yes	Yes	No	No
Minelab F3 6			Yes	Yes	Yes	Yes	Yes	No	No	No
Minelab F3 6'			Yes	Yes	Yes	Yes	Yes	Yes	No	No
Vallon 7			Yes	Yes	Yes	No	No	No	No	No
Vallon 7'			Yes	Yes	Yes	No	No	No	No	No
Vallon UXO 8			Yes	Yes	No	Yes	No	No	No	No
Vallon UXO 8'			Yes	Yes	Yes	Yes	No	No	No	No

Site 2: BLU26B

Depth (cm)	15	20	22,5	25	30	32,5	35	37,5	40	42,5	45	47,5	50	55
Schiebel 1	Yes	Yes		Yes	Yes		Yes	No	No	No	No		No	
Schiebel 1'	Yes	Yes		Yes	Yes	No	No		No					
Foerster 2	Yes	Yes	Yes	No	No		No		No					
Foerster 2'	Yes	Yes	No	No	No		No		No					
Ebinger 3	Yes	Yes		Yes	Yes		Yes	Yes	No		No		No	
Ebinger 3'	Yes	Yes		Yes	Yes	Yes	No		No					
Minelab UXO 4	Yes	Yes		Yes	Yes		Yes	Yes	No		No		No	
Minelab UXO 4'	Yes	Yes		Yes	Yes		Yes	No	No		No		No	
CEIA 5	Yes	Yes		Yes	Yes		Yes		Yes		Yes	Yes	No	No
CEIA 5'	Yes	Yes		Yes	Yes		Yes		Yes		Yes		Yes	No
Minelab F3 6	Yes	Yes		Yes	Yes		Yes		Yes	Yes	No		No	
Minelab F3 6'	Yes	Yes		Yes	Yes		Yes	No	No		No		No	
Vallon 7	Yes	Yes		Yes	Yes	No	No		No		No		No	
Vallon 7'	Yes	Yes		Yes	Yes	No	No		No		No		No	
Vallon UXO 8	Yes	Yes		Yes	Yes		Yes		Yes	No	No		No	
Vallon UXO 8'	Yes	Yes		Yes	Yes		Yes		Yes	No	No		No	

Site 2: 10mm steel ball

Depth (cm)	3	4	5	6	7	8	10	11	12	15
Schiebel 1	Yes		Yes		Yes		Yes	No	No	No
Schiebel 1'	Yes		Yes		Yes	Yes	No		No	No
Foerster 2	Yes		Yes	Yes	No		No		No	No
Foerster 2'	Yes		Yes	No	No		No		No	No
Ebinger 3	Yes	Yes	No		No		No		No	No
Ebinger 3'	Yes		Yes	Yes	No		No		No	No
Minelab UXO 4	Yes	Yes	No		No		No		No	No
Minelab UXO 4'	Yes	No	No		No		No		No	No
CEIA 5	No		No		No		No		No	No
CEIA 5'	No		No		No		No		No	No
Minelab F3 6	Yes		Yes		Yes	Yes	No		No	No
Minelab F3 6'	Yes		Yes		Yes	Yes	No		No	No
Vallon 7	Yes		Yes		Yes	Yes	No		No	No
Vallon 7'	Yes		Yes	Yes	No		No		No	No
Vallon UXO 8	No		No		No		No		No	No
Vallon UXO 8'	No		No		No		No		No	No

Site 3: 20mm Vertical

	DEPTH : 10	15	20	22,5	25	27,5	30	32,5	35	37,5	40
Schiebel 1	Yes	Yes	Yes	Yes	No	No	No	No	No	No	No
	Yes	Yes	Yes	Yes	Yes	No	No	No	No	No	No
Schiebel 1'	Yes	Yes	Yes	Yes	No	No	No	No	No	No	No
	Yes	Yes	Yes	Yes	No	No	No	No	No	No	No
Foerster 2	Yes	No	No		No	No	No		No		No
	Yes	No	No		No	No	No		No		No
Foerster 2'	No	No	No		No	No	No		No		No
	Yes	No	No		No	No	No		No		No
Ebinger 3	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No
	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No
Ebinger 3'	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No
	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No
Minelab UXO 4	Yes		Yes				No				No
	No		No				No				No
Minelab UXO 4'	No		No				No				No
	No		No				No				No
CEIA 5	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	No	Yes	No
	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	No
CEIA 5'	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
Minelab F3 6	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No
	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	No
Minelab F3 6'	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	No	No	No
	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No
Vallon 7	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	No
	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	No	No
Vallon 7'	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	No	No
	Yes	Yes	Yes	Yes	Yes	No	No	No	No	No	No
Vallon UXO 8	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	No
	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No
Vallon UXO 8'	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	No	No
	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No

Site 3: 20mm Horizontal

DEPTH :	17.5	17.5 repeat	20	22.5	22.5 repeat	25	27.5	27.5 repeat	30	32.5	32.5 repeat	35	37.5	40
Schiebel 1	Yes	Yes	Yes	No	No	No	No	No	No	Yes	No	No		No
	Yes	Yes	No	No	No	No	No	No	No	Yes	No	No		No
Schiebel 1'	Yes	Yes	No	No	No	No	No	No	No	Yes	No	No		No
	Yes	Yes	Yes	No	No	No	No	No	No	Yes	No	No		No
Foerster 2	This detector could not be tested in Paksong.													
	It was impossible to achieve a sufficient compensation in this type of soil.													
Foerster 2'	Permanent detection alarm.													
Ebinger 3	Yes		Yes	Yes		Yes	Yes		No	No		No		No
	Yes		Yes	Yes		Yes	Yes		No	No		No		No
Ebinger 3'	Yes		Yes	Yes		Yes	Yes		No	No		No		No
	Yes		Yes	Yes		Yes	No		No	No		No		No
Minelab UXO 4	This detector could not be tested in Paksong.													
	It was impossible to achieve a sufficient compensation in this type of soil.													
Minelab UXO 4'	Permanent detection alarm.													
CEIA 5	No	Yes	Yes	No	No	No	No	No	Yes	No	No	No	No	No
	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes	No	No	Yes	No	No
CEIA 5'	No	Yes	Yes	No	No	Yes	No	No	Yes	No	No	Yes	No	No
	No	Yes	Yes	No	No	Yes	No	No	Yes	No	No	Yes	No	No
Minelab F3 6	Yes		Yes	Yes		Yes	Yes		No	Yes		No		No
	Yes		Yes	Yes		Yes	Yes		No	Yes		No		No
Minelab F3 6'	Yes		Yes	Yes		Yes	Yes		No	No		No		No
	Yes		Yes	Yes		Yes	Yes		No	Yes		No		No
Vallon 7	Yes		Yes	Yes		Yes	No		No	No		No		No
	Yes		Yes	Yes		No	No		No	No		No		No
Vallon 7'	Yes		Yes	Yes		Yes	No		No	No		No		No
	Yes		Yes	Yes		No	No		No	No		No		No
Vallon UXO 8	Yes		Yes	Yes		Yes	Yes		No	No		No		No
	Yes		Yes	Yes		Yes	Yes		No	No		No		No
Vallon UXO 8'	Yes		Yes	Yes		Yes	Yes		No	No		No		No
	Yes		Yes	Yes		Yes	Yes		No	No		No		No

Site 3: BLU26B

	DEPTH : 10	15	20	25	27,5	30	32,5	35	37,5	40	45	47,5	50	55
Schiebel 1	Yes	Yes	Yes	Yes	No	No	No	No		No	No			
	Yes	Yes	Yes	Yes	Yes	No	No	No		No	No			
Schiebel 1'	Yes	Yes	Yes	Yes	Yes	No	No	No		No	No			
	Yes	Yes	Yes	Yes	Yes	No	No	No		No	No			
Foerster 2	No	No	This detector could not be tested in Paksong.											
	No	No	It was impossible to achieve a sufficient compensation in this type of soil.											
Foerster 2'	No	No	Permanent detection alarm.											
	No	No												
Ebinger 3	Yes	Yes	Yes	Yes		Yes	Yes	Yes	No	No	No			
	Yes	Yes	Yes	Yes		Yes	Yes	Yes	Yes	No	No			
Ebinger 3'	Yes	Yes	Yes	Yes		Yes	Yes	Yes	No	No	No			
	Yes	Yes	Yes	Yes		Yes	Yes	No	Yes	No	No			
Minelab UXO 4	No	No	This detector could not be tested in Paksong.											
	No	No	It was impossible to achieve a sufficient compensation in this type of soil.											
Minelab UXO 4'	No	No	Permanent detection alarm.											
	No	No												
CEIA 5	Yes	Yes	Yes	Yes		Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No
	Yes	Yes	Yes	Yes		Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No
CEIA 5'	Yes	Yes	Yes	Yes		Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No
	Yes	Yes	Yes	Yes		Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No
Minelab F3 6	Yes	Yes	Yes	Yes		Yes	Yes	No	No	No	No	No		
	Yes	Yes	Yes	Yes		Yes	Yes	No	No	No	No	No		
Minelab F3 6'	Yes	Yes	Yes	Yes		Yes	Yes	No	No	No	No	No		
	Yes	Yes	Yes	Yes		Yes	Yes	No	No	No	No	No		
Vallon 7	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No		No	No			
	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No		No	No			
Vallon 7'	Yes	Yes	Yes	Yes	Yes	Yes	No	No		No	No			
	Yes	Yes	Yes	Yes	Yes	Yes	No	No		No	No			
Vallon UXO 8	Yes	Yes	Yes	Yes	Yes	No	No	No		No	No			
	Yes	Yes	Yes	Yes	Yes	No	Yes	No		No	No			
Vallon UXO 8'	Yes	Yes	Yes	Yes		Yes	Yes	Yes	No	No	No			
	Yes	Yes	Yes	Yes		Yes	Yes	Yes	No	No	No			

Site 3: 10mm steel ball

	DEPTH: 0	3	4	5	6	7	10	11	12
Schiebel 1	Yes	Yes		Yes		Yes	No	No	No
	Yes	Yes		No		Yes	Yes	No	No
Schiebel 1'	Yes	Yes		Yes		No	No	No	No
	Yes	Yes		No		Yes	Yes	No	No
Foerster 2	No	No	This detector could not be tested in Paksong.						
	No	No	It was impossible to achieve a sufficient compensation						
Foerster 2'	No	No	in this type of soil.						
	No	No	Permanent detection alarm.						
Ebinger 3	Yes	Yes		Yes		Yes	Yes	No	No
	Yes	Yes		Yes		Yes	Yes	Yes	No
Ebinger 3'	Yes	Yes		Yes		Yes	Yes	No	No
	Yes	Yes		Yes		Yes	Yes	No	No
Minelab UXO 4	No	No	This detector could not be tested in Paksong.						
	No	No	It was impossible to achieve a sufficient compensation						
Minelab UXO 4'	No	No	in this type of soil.						
	No	No	Permanent detection alarm.						
CEIA 5	No	No		No		No	No		
	No	No		No		No	No		
CEIA 5'	No	No		No		No	No		
	No	No		No		No	No		
Minelab F3 6	Yes	Yes	Yes	No	Yes	No	No		
	Yes	Yes	Yes	No	Yes	No	No		
Minelab F3 6'	Yes	Yes	Yes	Yes	Yes	No	No		
	Yes	Yes	Yes	Yes	Yes	No	No		
Vallon 7	Yes	Yes		Yes		Yes	Yes	No	No
	Yes	Yes		Yes		Yes	Yes	No	No
Vallon 7'	Yes	Yes		Yes		Yes	Yes	No	No
	Yes	Yes		Yes		Yes	Yes	Yes	No
Vallon UXO 8	No	No		No		No	No		
	No	No		No		No	No		
Vallon UXO 8'	No	No		No		No	No		
	No	No		No		No	No		

12.11 ANNEX G: Questionnaire.

All questions allow free-form answers except 1 and 6 which had tick-boxes.

Questions:

1. Assembling the detector and getting started :
    a. easy,
    b. normal,
    c. difficult.
2. Handling during use (weight, size of the search head…)
3. Compensation procedure
4. Locating and pinpointing targets
5. Personal comments and short description
6. Would you be confident in using this detector on a real clearance site?
    a. very confident,
    b. confident,
    c. a little confident,
    d. not at all,

13 References

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