FENIX INSIGHT

A STUDY ON ORDNANCE DEPTH DISTRIBUTION IN LAO PDR

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Contents

1 Executive Summary 1
2 Introduction 2
2.1 Maintaining confidence in released land 2
2.2 Learning and improving 3
2.3 Land release in three dimensions 4
2.4 Clearance depth requirements in international and national mine action standards 5
3 An ordnance depth analysis for Lao PDR 6
3.1 General management of the study 6
3.2 RQ 1: what is an appropriate default clearance depth to be specified in national standards? 7
3.2.1 Factors influencing the default clearance depth 7
3.2.2 A default clearance depth in Lao PDR 8
3.3 RQ2: can further analysis enable authorities/operators to amend site-specific clearance depth based on evidence-based decision making? 10
3.3.1 Variation of depth by munition group 10
3.3.2 Depth implication of different land profile types 11
4 Conclusions and recommendations 12
4.1 Default detection depth 12
4.2 Variations in depth by UXO category 12
4.3 Variations in depth by land type 13
Annex A – Methodology 14
Measuring depth 14
Depth by UXO category 15
Depth by land type 15
Annex B: Expanded Charts 17
Annex C: Study team 21

Abbreviations and acronyms

CHA	Confirmed Hazardous Area
EO	Explosive Ordnance
HI	Humanity & Inclusion
IMAS	International Mine Action Standards
IMSMA	Information Management System for Mine Action
MAG	Mines Advisory Group
NMAA	National Mine Action Authority
NMAS	National Mine Action Standards
NPA	Norwegian People's Aid
NRA	National Regulatory Authority
NTS	Non-Technical Survey
RQ	Research Question
SHA	Suspected Hazardous Area
SOP	Standard Operating Procedure
TS	Technical Survey
UNDP	United Nations Development Programme
UXO	Unexploded Ordnance

1 Executive Summary

Operating organisations working in Lao PDR provided this study with data on 107,739 individual UXO finds, covering up to 13 years of field operations. The study used that data to investigate the distribution of UXO by depth in order to inform discussions about an appropriate default clearance depth for the national programme. The study also investigated whether there are correlations between the depths at which UXO are discovered and the type of munition, and with the type of land.

The study found that more than 50% of all UXO are found on the surface or at a depth of less than 4cm. Around 90% of UXO are found within the top 17cm. The remaining 10% are found at greater depths, with around 3% at depths greater than the current default depth of 25cm.

A default clearance depth is never set with the intent of capturing every possible UXO find. Instead, it is used in combination with other policies and procedures that direct and guide operators in how they respond to deep signals and other site-specific factors, such as intended land use. In practice, every site exhibits different characteristics, and the extent of clearance (horizontal and vertical) varies in response to those characteristics.

The clearance depth implemented on any site reflects a balance of the increasing effort required to go deeper, the likelihood of any remaining risk at depth, and the expected follow-on land use. It is accepted that clearance need not release land that is safe for every possible follow-on land use. If, in the future, the land use changes to one that involves deep digging into the ground for construction purposes, then a further deeper search may be necessary.

The study concluded that there is no compelling case for an increase in the default depth used in Lao PDR. The study also concluded that there is reasonable scope to consider a reduction in the default depth, if it is defined and implemented in combination with policies and procedures on how to respond to detection signals that appear to be deeper than the default depth. Modifications to the default death, within the overall land release policy and procedural framework, need not imply any reduction in confidence in the quality and safety of released land.

Lao PDR benefits from an extensive data set relating to the depth at which UXO are discovered. Not every country is so well placed in this respect. The national programme's foresight and professionalism, reflected in the collection and recording of so much depth data, puts Lao PDR in an unusually favourable position to conduct an evidence-based review of its policy on default depth.

Demanding a deeper default clearance increases the cost of clearance and reduces the rate at which land is released. In any programme there are limited human, financial and other resources available. Releasing land more slowly, and at greater cost, means that other land that could be released is not, compromising the programme's ability to satisfy national land release targets, and diminishing the overall benefits delivered to the people of Lao PDR. The study was not presented with evidence to suggest that the risks associated with deeper UXO were so significant as to justify action that would have the consequence of reducing the overall area of land released to the people of Lao PDR.

The study found evidence of significant differences in the depth profile of UXO of different categories (submunition, cannon projectile, etc.). Any such differences are only likely to be helpful in informing decisions about clearance depth at specific sites if there is a high level of confidence in the mix of UXO categories present at that site. Further analysis would be necessary to understand the extent to which UXO categories are mixed on different sites.

The study also found evidence to suggest that there may be differences in the UXO depth profile associated with different land types. In particular, plantations appeared to exhibit a different depth profile from gardens and paddy fields. The available data set was smaller, and there were questions about the quality of some data, so no clear conclusions could be reached. Further research would be justified.

2 Introduction

The process of releasing land from the threat of landmines, submunitions and other explosive ordnance, is one of risk management. Information is collected through Non-Technical Survey (NTS), Technical Survey (TS) and clearance to reduce uncertainty, identify where physical action is necessary to find and remove or destroy hazardous objects, and to gain confidence in the safety of land that can be released. This may either be because it can be shown that no contamination was in fact present, or because appropriate action has been taken to remove contamination that was present.

The principle that survey and clearance action should be sufficient to satisfy the needs of any expected follow-on land use is well established. It is common in many parts of the world to conduct clearance to a relatively shallow level, while accepting that large air dropped bombs may remain deep beneath the ground. While they lie undisturbed, the evidence is that they pose little risk to people. The near weekly discoveries of bombs beneath German cities illustrate the way in which 'all reasonable effort' includes disposal action as a *reactive* response to the discovery of such bombs but does not demand a comprehensive *pro-active* national search to find every such bomb that may be lying beneath the ground.

The situation in Laos exhibits many of the same characteristics. Different types of contamination are found at different depths and interact in different ways with the various human activities that will, or may, subsequently take place in suspected or confirm hazardous areas (SHAs and CHAs). As with all risk management, a range of possible responses or mitigation measures are available. The task of national authorities and operating agencies is to identify and implement the right balance of policies and procedures that ensure safety while using available funds to best effect.

This study considers the role of the 'default clearance depth' within the wider range of risk mitigation policies and procedures available to national authorities, mine action agencies and operating organisations.

2.1 Maintaining confidence in released land

Establishing and maintaining confidence in the quality and safety of released land is of fundamental importance in any mine action programme. That confidence must be present in national authorities, mine action centres, operating organisations, monitors, and amongst those who will make use of the land once it is released.

Confidence is typically maintained through:

- Establishing national standards as the basis for land release operations;
- Implementing effective accreditation processes to ensure that operating organisations employ competent people, appropriate equipment and effective standard operating procedures (SOPs);
- Establishing and implementing decision-making processes, through NTS and TS operations to determine the geographical scope of hazardous areas;
- Defining the geographical scope of clearance operations in task orders and other similar documented agreements;
- Defining the depth of clearance operations, reflecting contextual and site-specific factors, in task orders and other documentation;
- Providing guidance on decision-making during land release operations, in response to new information encountered during those operations;
- Monitoring operations to confirm that accredited organisations are indeed using competent people and appropriate equipment within the application of effective SOPs within the defined scope of any land release work;
- Requiring operating organisations to record details of any UXO or other EO that they find;
- Maintaining information management systems (IMS) to record what was actually found, and where it was found;
- Reviewing the results of analysis of IMS data to refine and improve future land release decision-making processes; and
- Communicating descriptions of the overall approach to land release to interested parties, including donors, international institutions and the general public, especially those living in affected areas.

Determining the depth to which clearance should be carried out is only one part (a very important part) of the overall combination of risk and quality management actions implemented in mine action programmes.

The list of elements detailed above, exhibit an important principle of quality management – that of improvement. Any system of mine action management must include feedback loops, where experience and information is used to inform reviews and decisions about how to make the system better.

2.2 Learning and improving

Improvement loops, such as that shown in Figure 1 can only be implemented in circumstances where operating organisations gather and record operational data and then make it available. Laos is fortunate in that it has had the foresight to require the collection and reporting of relevant information over a period of many years. Having done so, the national programme is in a strong position to benefit from the improvement feedback loops that are characteristic of the best management systems.

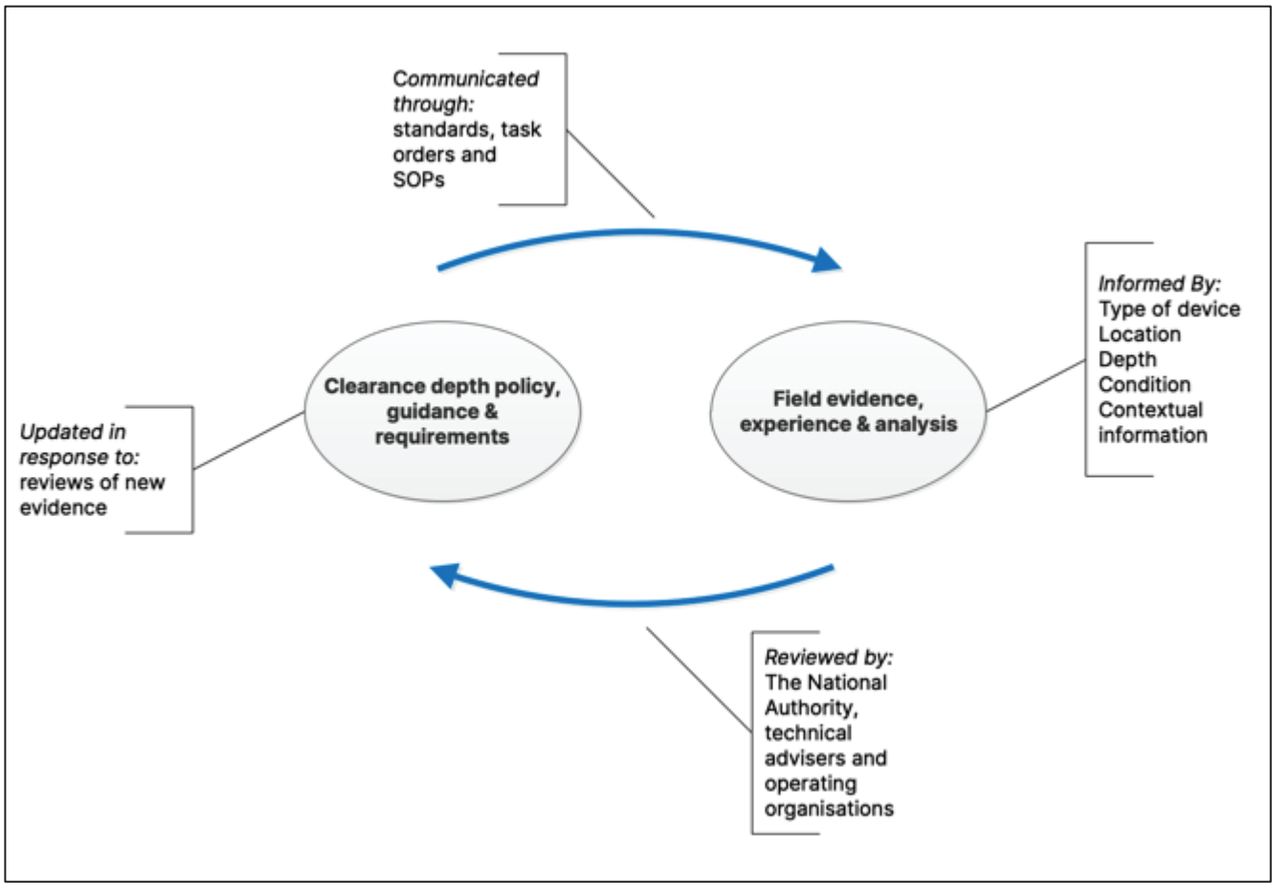


Figure 1 Learning and improving in relation to detection depth policy and guidance.

The land release process is itself an improvement process, based on an informed hypothesis as to where mines, submunitions and other UXO might be. That hypothesis is confirmed or disproved through the application of NTS, TS and eventually clearance. The data associated with each, and every find is of the utmost importance as it helps inform future hypothesis building. Important data points include the type of object, where it was found, the surrounding circumstances, the depth at which it was found and its physical condition. In the whole of that process, the only point at which 'estimation and assumption' stops, and 'hard information' becomes available, is when a mine or UXO is found. At that point the situation changes from one of asking '*where do we think a UXO item might be*' to being able to answer, '*we definitely know a UXO item is here*'.

This information, if collected and used, reinforces the ability of authorities and operators to develop informed and increasingly accurate definitions and policies. Unfortunately, that data has not always been collected consistently in the mine action sector. Once again, it is greatly to the credit of the Lao PDR that so much data specific to individual UXO finds is available for this study. It puts the national programme in an unusually well-informed position to benefit from analysis of the data.

2.3 Land release in three dimensions

Land release is typically viewed as something that happens primarily in the horizontal plane. It is all about decisions about where to start operations and where to stop. Different programmes adopt different approaches to taking decisions about the extent of land release operations, through NTS, TS, clearance and the establishment, refinement and eventual removal of SHAs and CHAs.

At the same time land release is also always a three-dimensional decision-making process. The same questions of where to start operations (normally, but by no means always, on the surface) and at what depth to stop them are relevant in the vertical direction.[1] No programme anywhere in the world demands that all clearance carries on down to the greatest depth at which UXO are ever found. Instead, a mix of policies, standards, and guidance are used to ensure that operating organisations apply an appropriate level of effort (defined in mine action as all reasonable effort) to ensure that land is safe for intended follow-on activities.

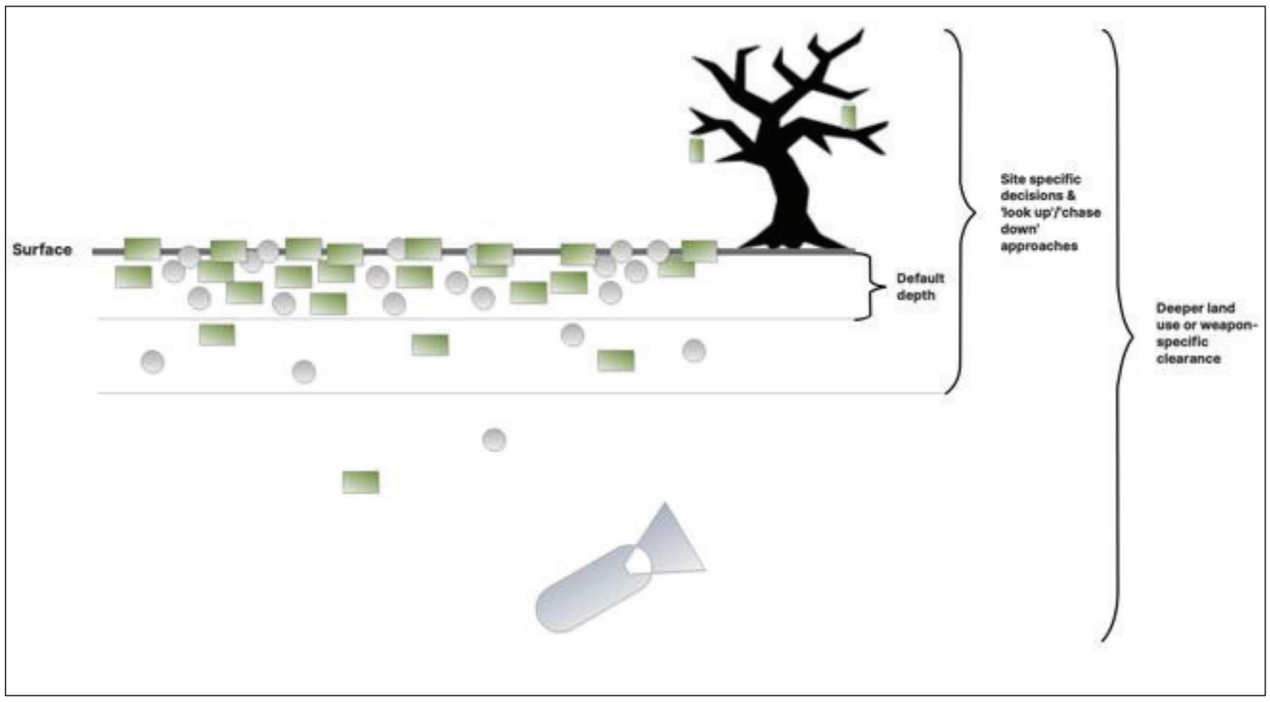


Figure 2 Interacting functions of direction, guidance and on-site responses in determining clearance depth.

A number of factors influence decisions on site about how deep to conduct search and clearance operations. They include:

- recommendations arising from NTS and TS;
- analysis of data held in IMSs relevant to the region or locality where clearance will take place;
- the intended use of the land following release;
- a default depth to be used in the absence of other information;
- new information discovered on site during survey and clearance operations; and
- observations and recommendations of on-site monitors, often in coordination with higher authorities.

Figure 2 above illustrates some of the ways in which different inputs to land release depth decisions are reflected in operational activity. Most, but far from all, objects in any programme are found between the surface and any specified clearance depth (which may be site-specific or some default value). A significant number of other objects, as in Laos, are found deeper than the specified clearance depth. They are usually encountered based on either 'chasing' detection signals that go deeper, or as a result of observing downward trends in the depths of target objects found during clearance operations. Other objects are found either as a result of site-specific threat

[1] Clearance in beach areas often requires the removal of several vertical metres of 'clean' sand before getting down to the 'threat layer'. Similarly, submunitions may be on roofs, or hung up in trees and bushes above the local ground level.

assessments (such as those involving submunitions hung up in vegetation) or in response to land use expectations that demand a deeper search response (usually when activity is likely to involve digging foundations, laying pipelines, etc.).

2.4 Clearance depth requirements in international and national mine action standards

IMAS says that organisations should 'record the type of device [...], the depth of the device, the location of the device [...], and the condition of the device.'[2] The depth of clearance 'shall be determined by a technical survey, or from other reliable information, which establishes the anticipated depth of the mine and ERW hazards, and an assessment of the intended land use.'[3] The depth may be adjusted as clearance work progresses[4] and further information is gathered. A default depth should only be considered when there is no reliable information on the ERW hazard[5].

The Lebanon National Mine Action Authority (NMAA) encourages operators to take an evidence-based approach. Although the default clearance depth is fifteen centimetres[6], the clearance[7] depth of cluster munitions and other EO 'may vary on a task-by-task basis'[8] based on the information gathered during the Technical Survey[9]. The Lebanon NMAA require that 'depth of all EO found shall be recorded so that future depth requirements can be based on a growing body of evidence'.[10]

[2] Section 9.2, IMAS 07.11, *Land release*, Edition 1, 1st of February 2019.
[3] Section 4, IMAS 09.10, *Clearance requirements*, Edition 2, 1st of January 2020.
[4] Section 4, IMAS 09.10, *Clearance requirements*, Edition 2, 1st of January 2020.
[5] Section 4, IMAS 09.10, *Clearance requirements*, Edition 2, 1st of January 2020.
[6] Section 6.5, Lebanon NMAS 07.12, *Quality Management in Mine Action*, Edition 2.1, March 2020.
[7] Sometimes referred to in Lebanon NMAS as search depth.
[8] Section 4.4, Lebanon NMAS 09.10, *Clearance requirements*, Edition 2.1, March 2020.
[9] Section 7, Lebanon NMAS 08.20, *Technical Survey*, Edition 2.1, March 2020.
[10] Section 5.2, Lebanon NMAS 09.11, *Battle Area Clearance*, Edition 2.1, March 2020.

3 An ordnance depth analysis for Lao PDR

Fenix Insight Ltd was contracted by UNDP to conduct an analysis of the depth at which ordnance is found in Lao PDR in order to take advantage of the availability of data and to inform ongoing discussions about the efficient and effective management of land release. The study revolves around two research questions reflecting the discussion in the earlier part of this paper:

Research Question (RQ) 1: What is an appropriate default depth to be specified in national standards?

Research Question (RQ) 2: Can further analysis enable authorities/operators to amend site-specific clearance depth based on evidence-based decision making?

3.1 General management of the study

The study team collected data from four operators: the HALO Trust, Humanity & Inclusion (HI), Mines Advisory Group (MAG) and Norwegian People's Aid (NPA). The data included:

- depth at which ordnance was discovered;
- ordnance type (specific designation or general category);
- land profile data (using the categories in relevant IMSMA forms);
- location data (by province); and
- date (when UXO was discovered).

In addition, each organisation completed a questionnaire describing:

- how each organisation measures and records depth;
- if this is a standardised procedure; and
- for how long they have been measuring depth in this way.

Inclusion criteria were established for all types of data and all submitted datasets were reviewed for completeness and consistency. Any anomalies were identified and resolved.

The final dataset contains data on 107,739 UXO found during survey and clearance operations[11]. Table 1 provides a breakdown of the number of data points per indicator.

Indicator	Number of data points
Depth	107,739
Type of UXO	107,469
Land profile type	10,871
Location where UXO was found	94,061
Date UXO was found	94,061

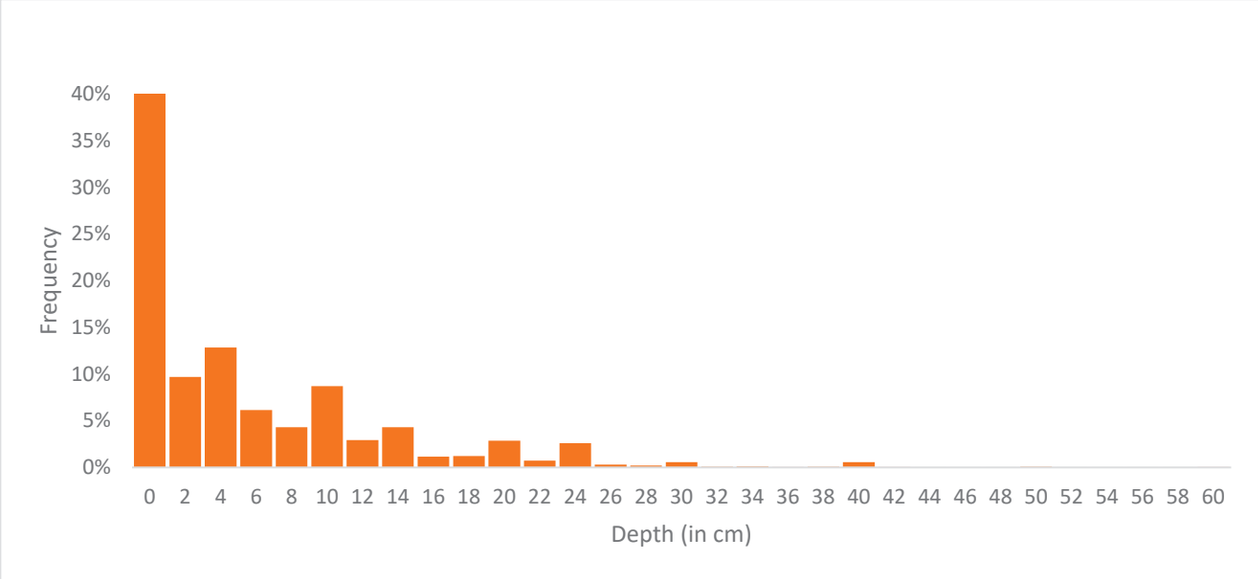
Table 1 Summary of number of data points satisfying inclusion criteria

Data available from the publicly available IMSMA dashboard was used to obtain the number of UXOs reported per operator since the date declared to this study when they first began recording depth. The proportion of data provided by the different operating organisations ranged from as much as 90% of their reported finds to as little as 10%. Overall, the study had access to data relating to around 34% of publicly reported finds across all operators included in the study.

[11] Clearance types included Technical Survey, BAC, EOD and Clearance.

3.2 RQ 1: what is an appropriate default clearance depth to be specified in national standards?

Figure 3 Distribution of depth at which UXO were found (in %)



Analysis of the data provided to the study yields a profile of the proportion of UXO found at different depths in Lao PDR (figure 3). The largest single result is found on the surface or within 2cm depth (40%). More than 50% of UXO objects are found within the first 5cm and 90% in the top 17cm. Only 10% are found at greater depths, continuing down to the deepest reported depth of 200cm (an air dropped bomb not shown on the chart).

3.2.1 Factors influencing the default clearance depth

The default clearance depth is never a depth that would ensure that every UXO item will always be found. If it were, it would need to be measured in metres not centimetres. Judgement and evidence are always involved in setting a default depth that ensures that the majority of UXO, under most circumstances, will be found, but it is always applied in combination with other policies and requirements. The two most significant being those associated with any requirement to 'chase down' detection signals at greater depths than the specified default, and those relating to land use and threat type.

The shallower the defined default depth, the greater the reliance on other policies; the deeper the defined default depth, the less the reliance on other policies. But decisions about where to set the default depth have huge implications for the time and cost associated with land release. Although firm data is not readily available, it is likely that the relationship between clearance depth and effort is not a linear one. That is, doubling clearance depth may well demand more than twice the technical effort, extending the time and cost of the task and reducing the capacity of precious clearance resources to deliver benefit to more people each year. If the land use changes at a later date, demanding the digging of deep foundations, or excavations for other civil engineering purposes, then it is accepted that further technical action at the site may be justified.

Setting a default depth does not mean that no UXO below that depth will be identified and dealt with (around 3% of UXO are found deeper than the current 25cm default clearance depth specified in Laos). It means that, *in the absence of other evidence*, the default clearance depth provides a high degree of confidence that land will be safe to release. But even then, it does not generally mean that clearance must stop at that depth. If other evidence is available, then it may be appropriate to clear to a different depth, which could be shallower under some circumstances, or deeper if the evidence demands it.

Exactly the same process is applied horizontally when determining the extent of SHAs and CHAs and the point at which clearance can be declared complete. We do not set some general horizontal minimum extent of clearance. Instead, each task site is assessed on the basis of what is known about it. The extent of the task is refined as the

land release process progresses. An initial SHA, determined through NTS, is reduced, following TS or the collection of further NTS evidence, and finally clearance takes place, with the option to further adjust the extent of the clearance area in response to new evidence that becomes available during practical operations.

Setting the default clearance depth requires the setting of associated policies as well, usually in national standards, but also reflected in standard operating procedures (SOPs). The default depth sits within a hierarchy of obligations upon different programme stakeholders. Key obligations are to:

- take into account the expected follow-on land use, while not trying to satisfy the demands of every possible future follow-on land use;
- ensure that data from previous operations is readily available to task planners;
- apply all reasonable effort to the collection and analysis of data relevant to the site (including a review of what was previously found at similar sites);
- review site-specific data to determine a clearance depth for the task;
- implement the policy on how to handle detection signals deeper than the task clearance depth;
- monitor new evidence as it becomes available during operations at the site and be ready to adjust the task clearance depth if necessary; and
- apply a standard default clearance depth if no other evidence is available to allow satisfaction of higher-level obligations in the hierarchy; but
- again, respond to evidence, discovered during clearance operations, of contamination below the default depth, appropriately and effectively.

In any mature mine action programme, there should always be data and resources available to implement all levels of the hierarchy of obligations listed above. It should almost never be the case that there is no evidence available to allow informed assessment and decision-making. As such, it should be a rare occasion when there is no choice but to rely wholly upon the stated default clearance depth. Indeed, any mine action manager presented with a task where the intent is simply to apply the default clearance depth should probably suggest that further attempts to collect relevant NTS or TS evidence should be carried out.

3.2.2 A default clearance depth in Lao PDR

Analysis of the data made available to this study yield a depth frequency distribution as illustrated in figure 4 below. Each dot on the diagram represents 1% of reported finds, with a total of 100% of finds associated with the different depth bands in which they were discovered.

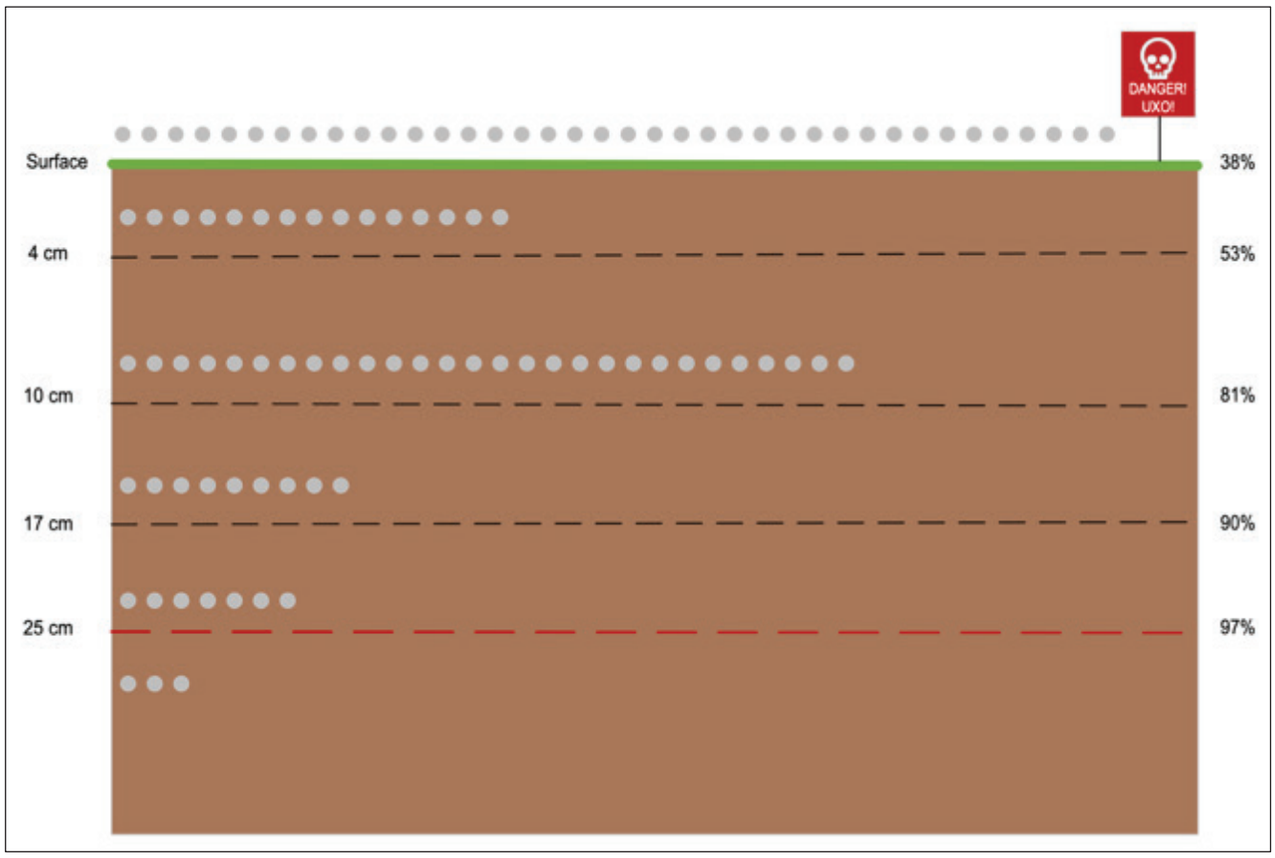
IMAS suggests that, in the absence of any other evidence, a clearance depth of 13cm should be adopted (although this is related primarily to the presence of minimum metal mines). The data for Lao PDR indicates that applying such a default depth would capture 84.6% of all UXO. A default depth of 17cm would capture 90% of UXO. The current default depth of 25cm captures 97% of finds.

It has been suggested that detection capabilities with some detectors, against typical threat objects, can be achieved down to 35cm below surface level and that this should therefore become the default depth. Care should be exercised in adopting such a position. Firstly, not every operating organisation may have access to the most capable detectors. Imposing such a requirement on them would result in significant cost and time consequences; consequences that mean that less land is released in a given time period and for a given cost, and fewer affected people benefit from access to land.

Secondly, there should be consideration of the ‘diminishing returns’ associated with each increase of the default depth. The level of effort goes up significantly as each extra centimetre of default depth is added. Such effort only be justified if there was evidence that the risk associated with the relatively rarely found UXO at greater depths was ‘intolerable’. That would reflect evidence such as frequent occurrences of accidents causing death or injury associated with encounters with deeper buried UXO. It is not clear that such evidence is available.

All humanitarian mine action stakeholders have a moral obligation to achieve as much as they can with the available resources. Any action that may adversely affect their ability to maximise the benefit they deliver should be considered with the utmost care. Decisions about default depth are not taken in isolation to other land release decision-making processes. A deeper default depth is likely to be justified on the basis that it reduces the risk of accidents involving deeper buried UXO. Yet, this needs to be balanced against the associated risks of a reduction in the overall rate of land release. These may include reduced human safety at other sites, increased costs, reduced economic development, social dislocation and political perceptions. The risks associated with deeper buried UXO are limited, occasional and hypothetical, whereas the risks associated with failing to deliver land in accordance with annual targets are significant and predictable.

Figure 4 Cumulative distribution of UXO findings according to depth



Any decision to impose additional costs and time demands on mine action work needs to be justified by clear evidence of significant risk if such action is not taken. In the absence of any compelling evidence to suggest that deeper buried UXO presents a significant risk, it does not appear necessary or appropriate to increase the default depth beyond its current value of 25cm.

The next question is whether there is justification for a reduction in the default depth. The IMAS approach to setting a default depth (remembering that it is only recommended in situations where no other evidence is available) revolves around detection capability, particularly in relation to minimum metal mines. The situation in Lao PDR is different. The main threats are UXO, generally of a relatively detectable type. The question of whether 'because I can detect to a given depth I should always clear to that depth' is an important one. We can detect large air dropped bombs at considerable depths, but we don't always do so, normally only actively looking for such objects if the intended follow-on land use will involve digging deep into the ground. It must be emphasised again that a default depth should never be implemented in isolation of the hierarchy of obligations detailed earlier.

The question of the default depth remains one of balancing benefit and risk. The greater the default depth, if it is applied in isolation of other site-specific factors, the greater the effort needed to satisfy the requirement. The greater that effort, the longer it takes to complete the task and the more it costs to do so. The more time and money devoted to one site, the less that is available to address needs at other sites. The analysis in this study indicates that a persuasive and credible case could be presented to reduce the default depth to 20cm, or even 17cm (which would encompass 90% of all UXO finds). In the Falkland Islands the UK Government decided to set a default clearance depth for mines and UXO (including submunitions) of 20cm in order to 'exceed the demands of IMAS'. The use of associated policies relating to the need to reflect conditions at each site ensured that many mines were found at over 40cm below the local surface. Confidence was maintained throughout, but at no point was it suggested that there was a need to increase the default depth. Lao PDR has the option of adopting a similar approach.

It is important to be clear that adopting a default depth that covers 90% of finds does not imply any reduction in the general confidence level associated with clearance. The use of a default depth, in combination with effective survey and planning stages, as well as other policies such as 'chase down' approaches, aims to ensure that

released land is entirely safe for its subsequent use.[12] Once again, the fundamental principle is that a default depth is used as part of the overall land release system.

The advantage of adopting a clearer mix of default depth and site-specific responses is that it can allow operations to progress more quickly, without compromising quality. There is no single hard-and-fast answer to the question of 'what should the default depth be?', but the analysis in this study indicates that there is considerable scope for an update to the nationally defined default clearance depth.

3.3 RQ2: can further analysis enable authorities/operators to amend site-specific clearance depth based on evidence-based decision making?

The second part of the study looked at two types of potential site-specific data to establish whether correlations can be identified between:

RQ 2.1: the depth at which UXO are found and the types of UXO involved; and
RQ 2.2: the depth at which UXO are found and the types of land within which the UXO was found.

The size of the data sets that met the inclusion criteria were smaller than for RQ1. For RQ 2.1 only a small number of data points were excluded leaving a total of 107,469 entries. For RQ2.2 10,871 data points met the inclusion criteria. In both cases the volume of data was adequate to allow at least exploratory analysis, although it may be inappropriate to extrapolate further until more data is available.

3.3.1 Variation of depth by munition group

Figure 5 shows the percentage of UXO found by munition group. A full breakdown can be found in Annex A.

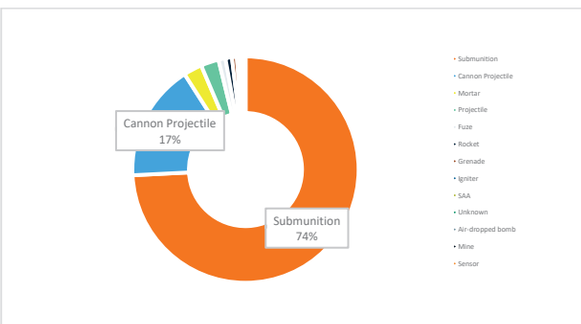


Figure 5 Frequency of munition group within the data.

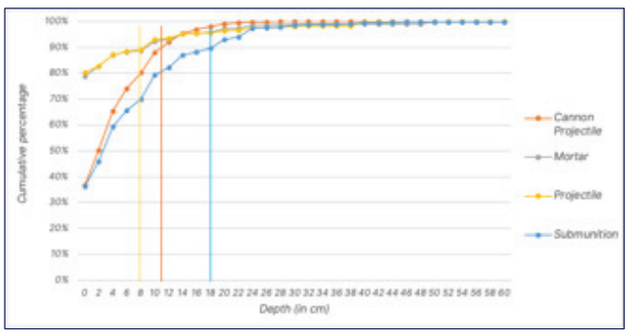


Figure 6 Cumulative distribution of depth at which the four most common UXO were found (in %) with 90% depth lines for each category.

The overwhelming majority of the UXO found consists of submunitions, accounting for 74.3% of the dataset. Cannon projectiles make up the second-largest share, comprising 16.8% of the findings. Mortars and projectiles each represent just under 3% of the dataset, with a small number of other objects accounting for the remaining finds. The different categories of weapon exhibit somewhat different depth discovery profiles, as shown in Figure 6.

Projectiles and mortars show the shallowest depth profiles, with 90% of finds at less than 8cm from the surface. Cannon projectiles come next, with 90% found at less than 11cm, and then submunitions showing a relatively deeper distribution, with 90% being found at less than 18cm.

The results suggest that there may be potential to apply different clearance depth requirements depending on the munition category present on site, but such a policy could only be applied if there was a high level of confidence that categories showing deeper profiles were not present. In practice that would mean working on a site where there was high confidence that submunitions would not be present, but where other categories of UXO could be expected. With the huge dominance of submunitions as a category, it must be unlikely that there will be many tasks that do not include submunitions in the mix. It is certainly appropriate to collect data and conduct further

[12] 'Chase down' policies and procedures are those that dictate how to respond to detection signals that appear to be from objects deeper than the default depth.

analysis on this aspect of operations. In particular a better understanding of the proportion of sites that do not contain all of the major groups (especially submunitions) would help identify whether task planners and managers could adopt different clearance depths under some circumstances. Full size charts are available in Annex B.

3.3.2 Depth implication of different land profile types

The study also looked at whether there are any significant differences in the depth discovery profiles in different land profile types. Only one of the operating organisations was able to provide data that met the inclusion criteria for this part of the study. 92.5% of the results related to submunitions (compared with the 74% proportion in the main data set). On that basis, it was decided to limit the analysis to only those results that related to submunitions. Doing so meant that the analysis was only considering one variable (land type) rather than two (land type and munition category).

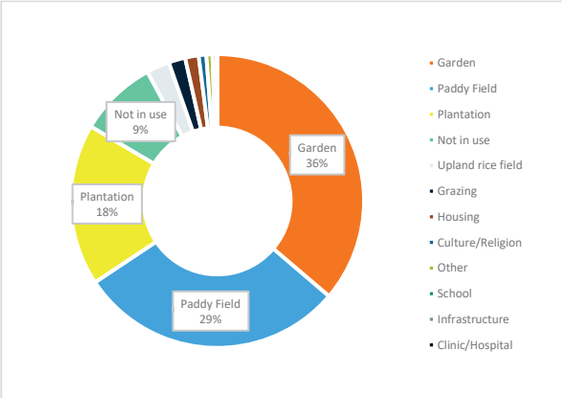


Figure 4 Land profile type as a proportion of included data

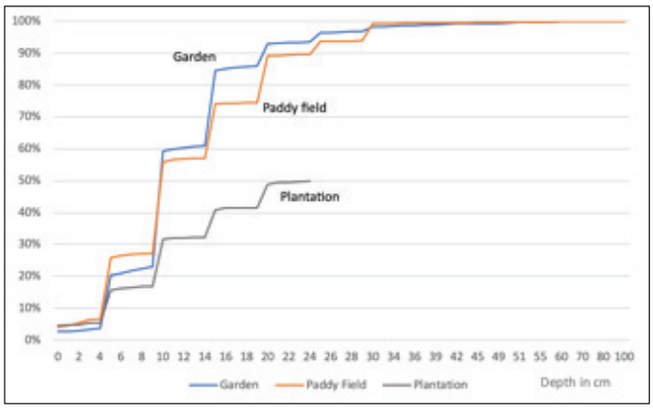


Figure 5 Cumulative distribution of depth at which submunitions were found by the top three most common land profile types

The depth data showed a series of spikes at 5cm intervals, strongly suggesting that the organisation in question is in the habit of rounding reported depth to the nearest 5cm interval. There appears to be enough consistency in this approach to allow meaningful analysis to take place, although it may have some limited impact on the averaging of depths reflected in subsequent charts. Further details are provided in the methodology section in Annex A.

The main land profile types are garden (36%), paddy field (29%) and plantation (18%). The analysis focuses on these three main land profile types. Further analysis is available in annex A.

Sites recorded as 'garden' and 'paddy field' exhibit a similar profile, broadly reflecting the proportion of finds shown in the analysis of RQ 1 above. Sites recorded as 'plantation' show a distinctly different profile, with a greater proportion of UXO items being recorded at deeper depths. However, the plantation data profile has a large number of items recorded at 25cm. It appears that items deeper than 25cm have all been lumped under the heading of 25cm (perhaps meaning 'more than 25cm'). A similar approach to objects deeper than 40cm was seen in one of the other submitted data sets. Data that appears to have been recorded simply as 'more than a given depth' were excluded from the study as failing to meet the 'consistent and accurate depth measurement' inclusion criterion. Full size charts are available in Annex B.

The data set for this part of the study is relatively much smaller than for the other analysis. Nevertheless, there is enough of a difference in depth profile between 'plantation' sites and other types of land category to suggest that further research would be justified.

4 Conclusions and recommendations

4.1 Default detection depth

Conclusions	Recommendations
The default depth definition is only one of several depth-related policies and practices associated with the clearance of UXO.	Avoid taking decisions about default depth in isolation of other relevant policies including those relating to chasing down detection signals that are deeper than the default depth and those relating to later changes in land end use.
Policies and procedures should be subject to review taking into account evidence and experience, especially evidence related to the discovery of UXO objects, gained during operations.	Make use of the excellent and extensive UXO discovery data set available in Lao PDR to update the integrated body of policies and procedures relating to specifying depth requirements at clearance sites.
Analysis of the data showed that more than 50% of UXO items are discovered either on or within 4 cm of the surface. 90% are found within the top 17cm.	Recognise that the default depth is not, and has never been, set to capture 100% of UXO objects. Instead, it provides a reliable basis upon which associated policies, such as for 'chasing down' deeper signals, are applied on a site-specific basis.
The default depth guidance in IMAS focuses on detection capability against minimum-metal landmines. It is not clear that the guidance is transferable to the question of a default depth for clearance in Lao PDR, where the threat is primarily that of high metal content submunitions. The ability to detect items of UXO at a given depth is not an obvious reason to make that depth the default depth. Doing so brings potential issues of increased false positive rates and the imposition of procurement burdens on agencies with less capable detection equipment.	Decisions about the default depth definition in Lao PDR should be based on: • statistical analysis of field data (as in this study); • integration of the default depth with other policies such as those relating to 'chase down' or 'change of land use'; and • recognition of the need to balance the moral imperative to deliver as much benefit to as many people as possible, against the diminishing returns of demanding greater effort to look for deeper buried objects, unless there is compelling evidence that they present an 'intolerable' risk.
There is no clear or compelling case to increase the default clearance depth. Around 97% of all UXO discoveries already fall within the current default depth definition of 25cm.	Do not increase the specified default depth in Lao PDR.
The analysis indicates that there is a reasonable case to be made to reduce the specified default depth, if integrated with other procedural guidance on how to respond to deep signals and other site-specific factors.	Consider a reduction in the default depth to 18 or 20cm, while clarifying the importance of other planning and procedural requirements relating to clearance depth at individual sites.

4.2 Variations in depth by UXO category

Conclusions	Recommendations
There is evidence of differences in the depth profiles for different category of munition, but it is not clear to what extent any such variations can be reflected in operational decision-making. Category variations can have value when planning task operations, but only if there is a high level of confidence in the assessment of which categories will be present and, equally important, which will not be present.	Investigate the mix of UXO categories at individual task sites to establish how often submunitions are not present.

4.3 Variations in depth by land type

Conclusions	Recommendations
The study suggests that there may be significant differences in the depth profile at which UXO are discovered, but the sample size was not enough to form any firm conclusions about the nature of those differences.	Encourage operators to report land use digitally to allow further investigation of this aspect of UXO depth distribution.

Annex A – Methodology

Measuring depth

The primary data inclusion criterion for RQ1 was that depth should have been recorded in a consistent, specified way. A questionnaire sent as part of the data collection phase revealed that all operators record

depth from the top of the soil surface to the top of the item (as seen in the diagram and photo below). To ensure accurate depth recordings, operators implement quality management strategies such as annual refresher training and monitoring. These measures help maintain consistency and reliability in the depth data collection process. Individual operators began to measure and record depth in a consistent way at different points in time, with the first operator commencing in 2009 and the most recent operator starting in 2017.

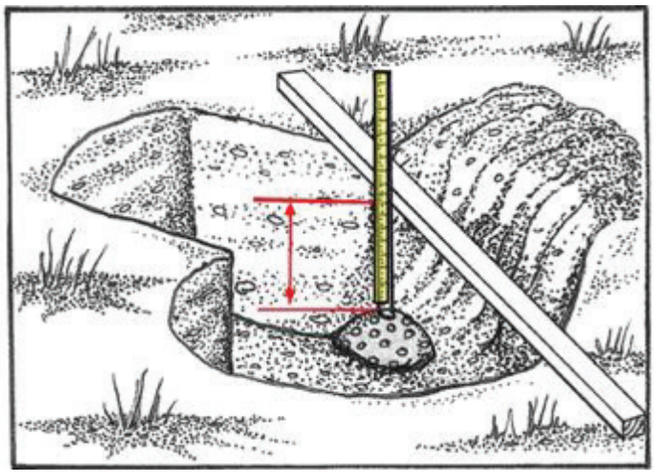


Diagram 1 - measuring depth (courtesy of MAG)

Image 1 - measuring depth (courtesy of NPA)

One operator recorded any depth measurement over forty centimetres as 'Over 40 cm'. These data points were excluded from the analysis as they were not exact measurements of the depth at which UXO were found. This affected a very small part (0.2%) of the overall dataset.

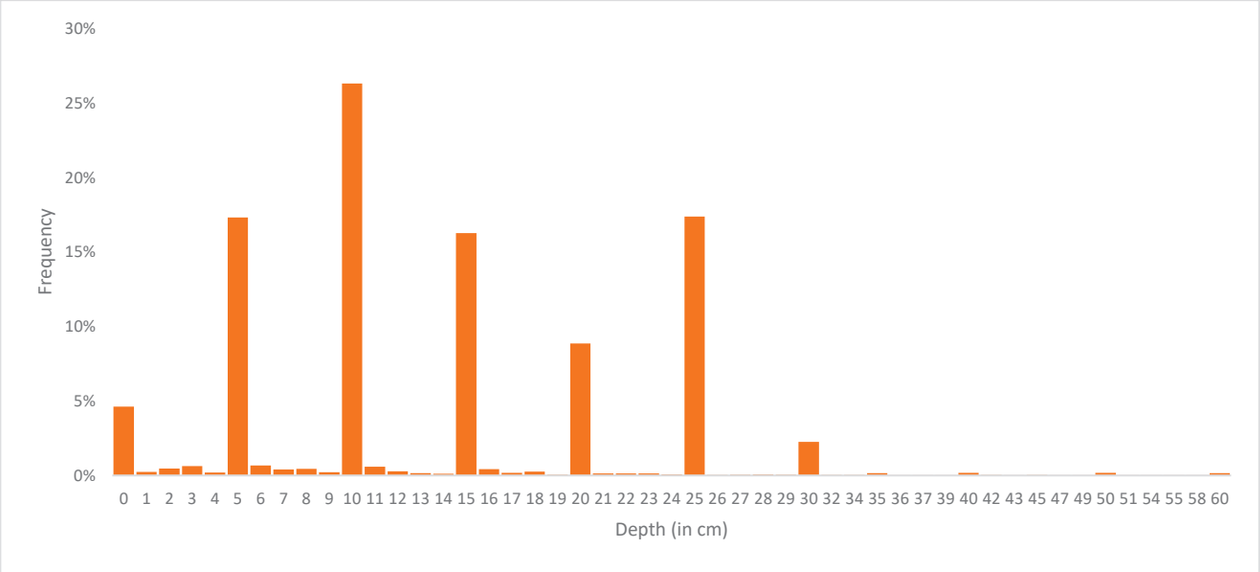


Figure 6 Distribution of depth at which UXOs were found for one operator

Another operator shared a dataset which displayed spikes of data every 5 cm as displayed in Figure 9. This suggests a habit of rounding to the closest 5 cm interval. Although this raises some questions as to the accuracy of the measured depths, it was decided to include it in the analysis as the pattern of depths recorded are still accurate. This dataset accounts for 10% of the total dataset.

Depth by UXO category

Data on UXO designation was shared by all operators involved. However, only one operator provided information on the munition group. For the remaining operators, the information regarding the munition group was manually added.

In cases where the munition group was ambiguous or not clearly identifiable, it was labelled as 'unknown'. A total of 270 UXOs, representing 0.3% of the total dataset, fell into this category. Nevertheless, a substantial majority of the UXOs, totalling 107,469, were successfully associated with a specific munition group.

Table 2 presents the percentage of UXO found above specific depths categorized by munition groups.

Table 2 Percentage of UXO found above a specific depth by munition group

Munition Group	Number of data points	% of total (excluding unknowns)	<25%	<50%	<75%	<90%	<95%	<99%
Submunition	79,894	74.2%	0 cm	5 cm	10 cm	20 cm	25 cm	38 cm
Cannon Projectile	18,085	16.8%	0 cm	3 cm	8 cm	12 cm	15 cm	20 cm
Mortar	2,851	2.6%	0 cm	0 cm	0 cm	10 cm	15 cm	32 cm
Projectile	2,773	2.6%	0 cm	0 cm	0 cm	10 cm	15 cm	40 cm
Fuze	1,071	1%	0 cm	0 cm	1 cm	10 cm	12 cm	25 cm
Rocket	999	0.9%	0 cm	0 cm	0 cm	6 cm	20 cm	50 cm
Grenade	759	0.7%	0 cm	0 cm	5 cm	30 cm	40 cm	40 cm
Igniter	407	0.4%	0 cm	0 cm	0 cm	0 cm	5 cm	16 cm
SAA	321	0.3%	0 cm	0 cm	0 cm	0 cm	0 cm	0 cm
Air-dropped bombs	254	0.2%	0 cm	3 cm	30 cm	40 cm	50 cm	70 cm
Mine	47	0.04%	0 cm	0 cm	1 cm	9 cm	16 cm	25 cm
Sensor	8	0.01%	0 cm	5 cm	32 cm	46 cm	50 cm	50 cm

Depth by land type

Data on the type of land where UXO were discovered was shared by a single operator, representing a relatively small portion of the overall dataset (10%). This is the same dataset which exhibited sharp spikes every five centimetres as discussed in '3.1 measuring depth'. The land profile types used in the analysis are the ones dictated by the NRA and are therefore used by all operators. Table 3 provides a breakdown of the analysis. Only submunitions are included in the analysis.

Table 3 - Percentage of UXO found above a certain depth by land profile type

Land profile type	Number of data points	% of total	<25%	<50%	<75%	<90%	<95%	<99%
Garden	3643	36,23%	9 cm	9 cm	14 cm	19 cm	24 cm	39 cm
Paddy Field	2960	29,44%	4 cm	9 cm	19 cm	24 cm	29 cm	29 cm
Plantation	1792	17,82%	10 cm	24 cm	24 cm	24 cm	24 cm	24 cm
Not in use	867	8,62%	10 cm	24 cm	24 cm	24 cm	24 cm	24 cm
Upland rice field	256	2,55%	4 cm	9 cm	19 cm	24 cm	24 cm	29 cm
Grazing	184	1,83%	5 cm	9 cm	14 cm	24 cm	24 cm	24 cm
Housing	150	1,49%	0 cm	4 cm	14 cm	19 cm	24 cm	29 cm
Culture/Religion	84	0,84%	9 cm	14 cm	14 cm	14 cm	19 cm	19 cm
Other	68	0,68%	4 cm	4 cm	9 cm	29 cm	29 cm	29 cm
School	45	0,45%	4 cm	9 cm	9 cm	14 cm	24 cm	24 cm
Infrastructure	6	0,06%	24 cm	24 cm	24 cm	24 cm	24 cm	24 cm
Clinic/ Hospital	1	0,01%	9 cm	9 cm	9 cm	9 cm	9 cm	9 cm

Annex B: Expanded Charts

Figure 5 Frequency of munition group within the data.

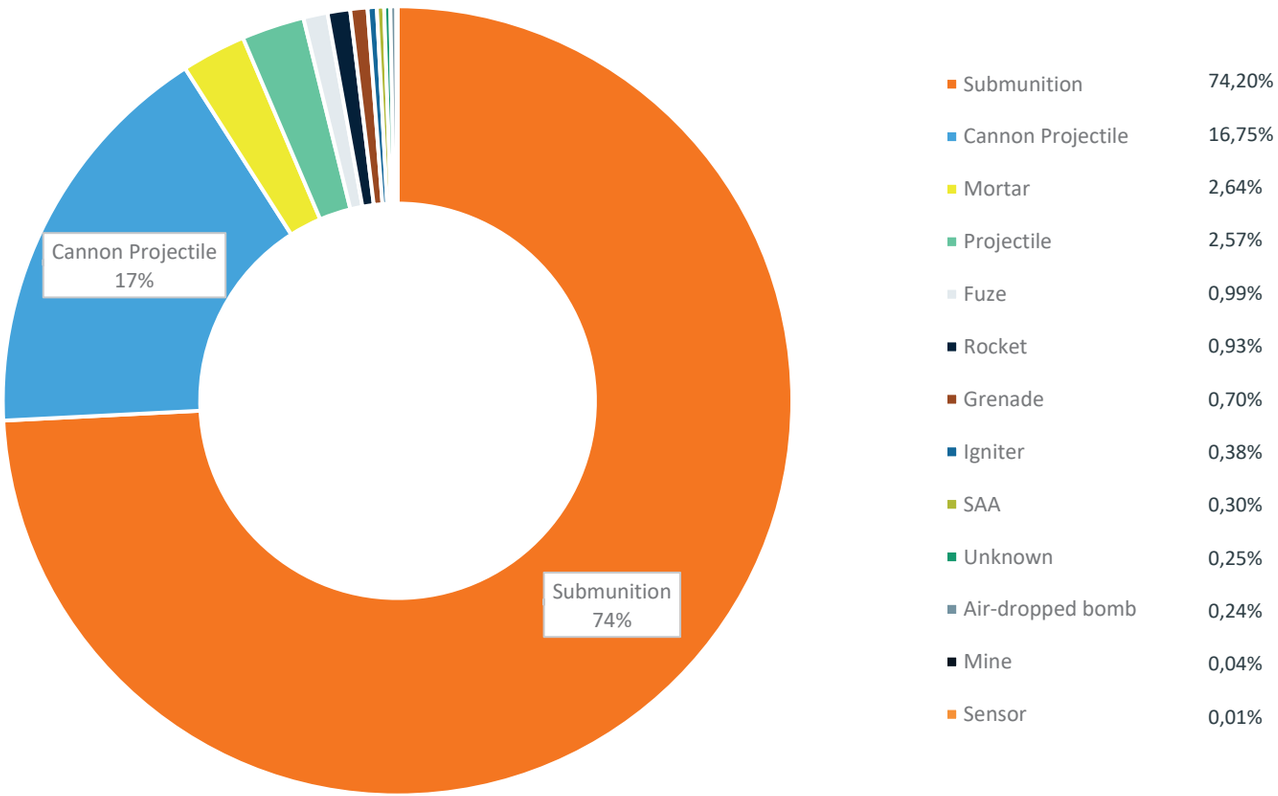


Figure 6 Cumulative distribution of depth at which the four most common UXO were found (in %) with 90% depth lines for each category.

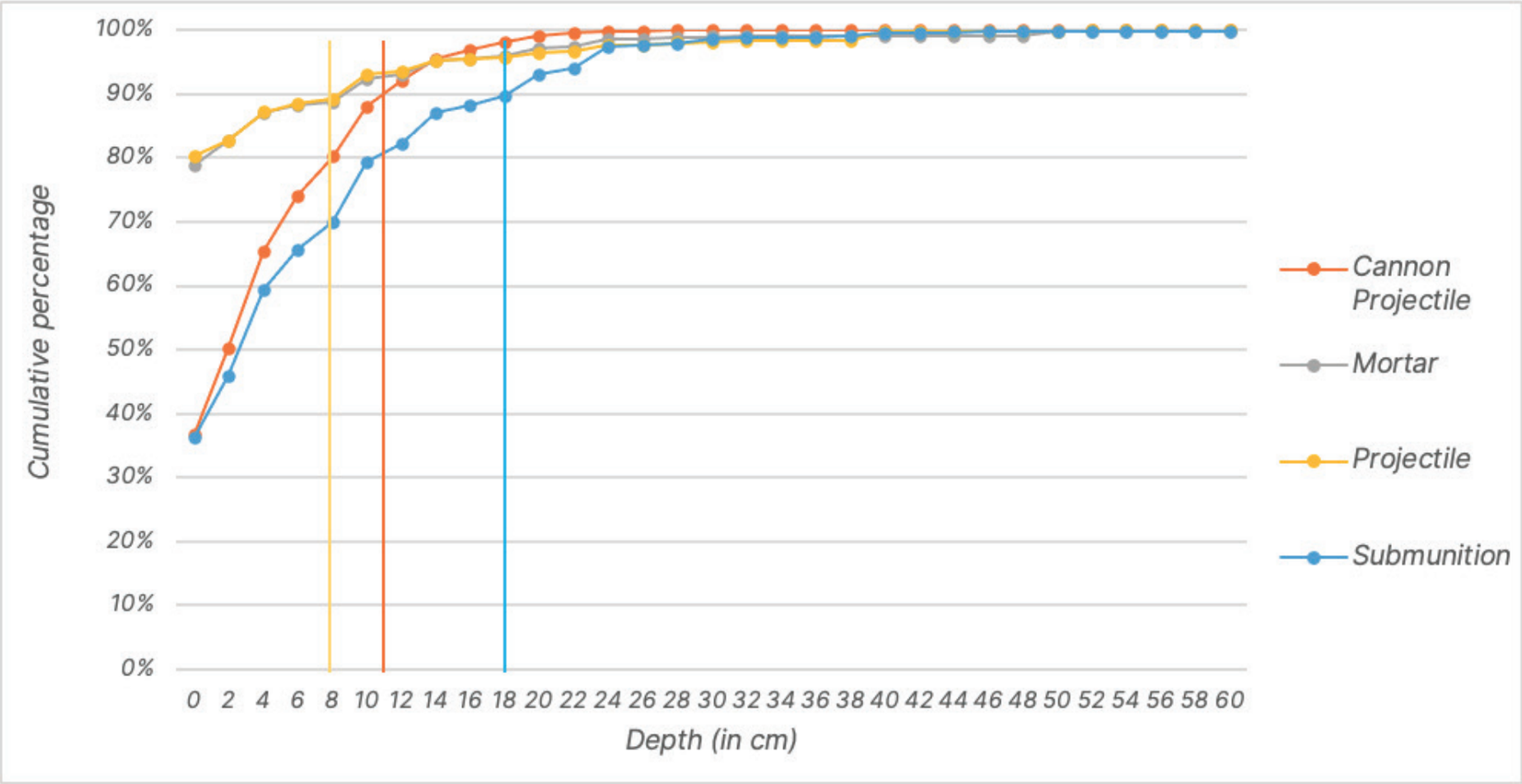


Figure 7 Land profile type as a proportion of included data

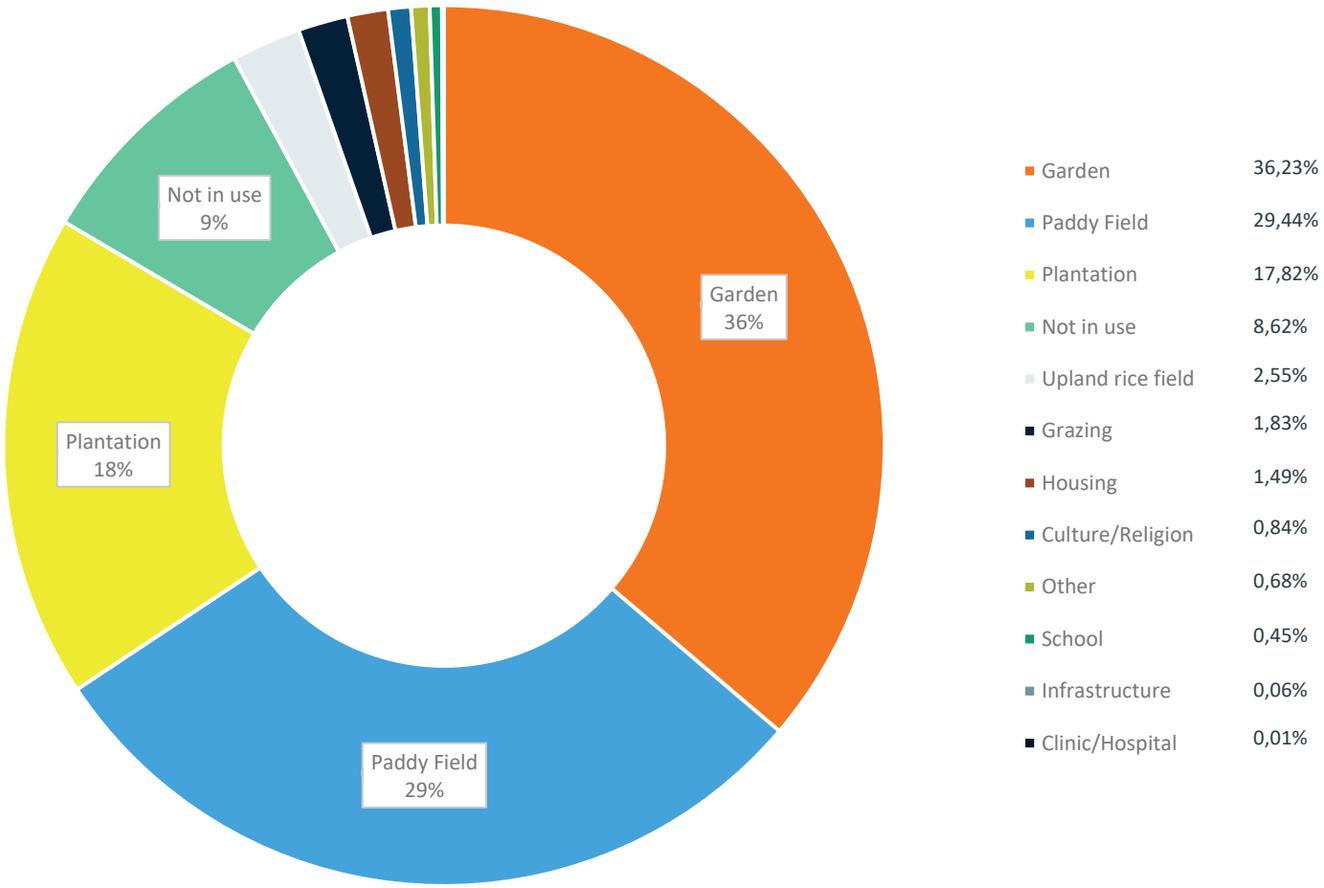
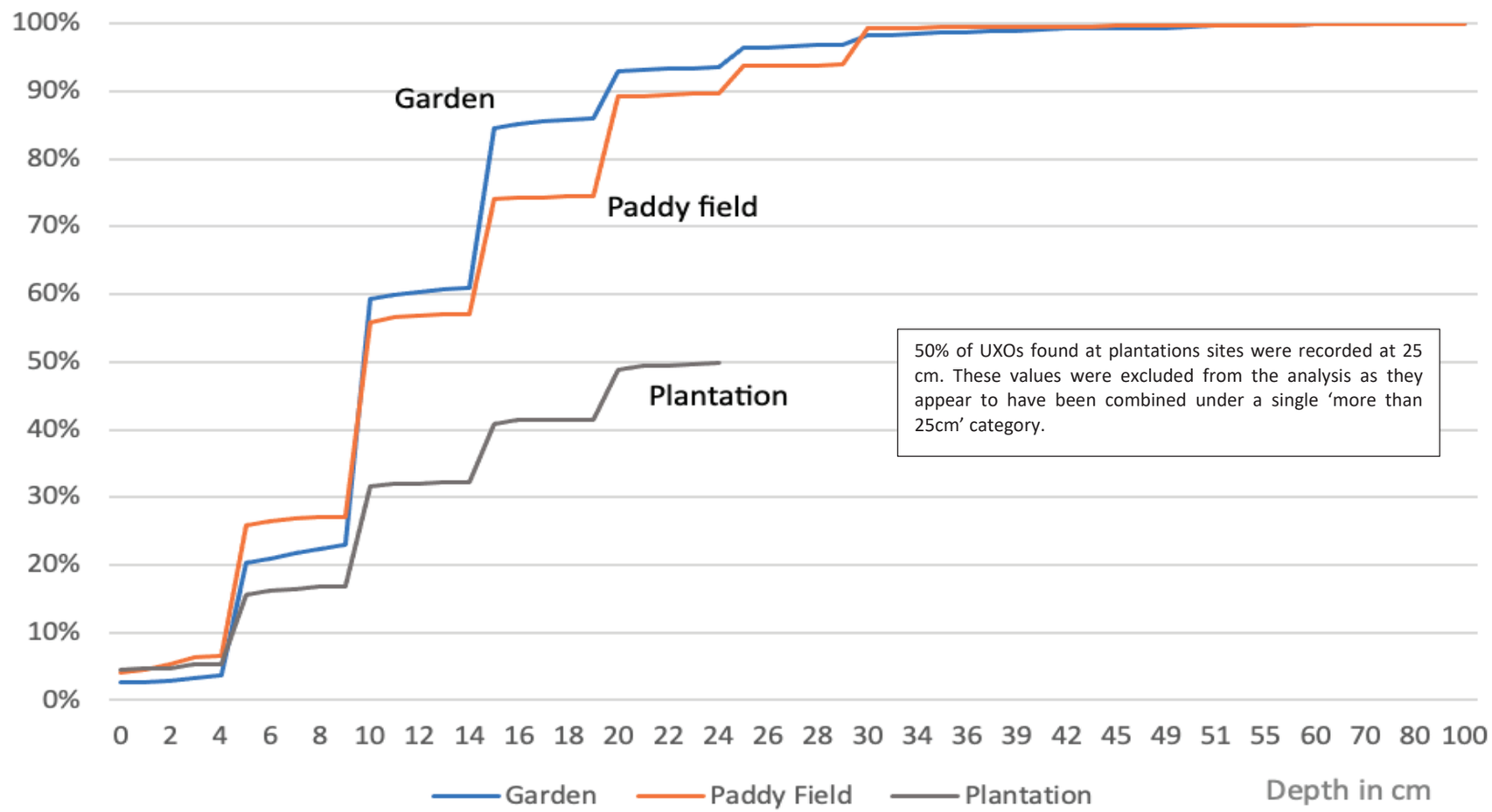


Figure 8 Cumulative distribution of depth at which submunitions were found by the top three most common land profile types



Annex C: Study team

Throughout the last 12 years Fenix Insight Ltd has been at the forefront of the development of policy, practice and tools for the humanitarian mine action sector. The company has worked with international institutions, donors, national governments, mine action centres (MACs) and mine action operating organisations (MAOs) to improve understanding of every aspect of mine action work, from the most detailed technical aspects, through operating procedures, standards, policies and strategic planning to the creation of digital tools. Fenix Insight has more than eleven years of experience working in the South East Asia region. The study was conducted by David Hewitson, CEO of Fenix Insight Ltd, and the overseeing Director for this project, as well as Raphaela Lark, Project Officer.

David Hewitson has a degree in Aeronautical and Astronautical Engineering. He spent several years in hands-on field operational work in Afghanistan, Cambodia, Mozambique and Angola before IMAS and EOD qualifications had been established. He was a significant contributor on the UN-chaired IMAS Review Board when IMAS were first being developed over 20 years ago, and has personally drafted many of the most significant chapters in the last decade and more, including those relating to Land release (07.11), Non-technical Survey (08.10), Technical Survey (08.20), Quality Management (07.12), Monitoring (07.40) and Risk Management (07.14). He has also supported drafting of others including for Accident Investigation and Reporting (10.60) and Environmental Management (10.70). He remains closely associated with the IMAS development process. He also drafted the entirety of the NMAS for Azerbaijan. He has extensive experience working in the region, notably in Lao PDR, Vietnam and Cambodia.

Raphaela Lark is EOD 3 qualified. She holds a Research master's in Urban Studies from the University of Amsterdam. This master's degree prepares students to undertake a PhD and is therefore heavily focused on research methodology and ethics. She has engaged in field mine action operations in Somalia, Cambodia, Abkhazia and Nagorno-Karabakh, as well as research work in Cambodia and Lebanon. She led the research work on the study into Gender and Operational Efficiency conducted by Fenix Insight Ltd for the GICHD and was a leading member of the team involved in research into Operational Efficiency in Land Release also for GICHD. She deployed to Peru as part of Fenix's demilitarisation advisory team.