A GUIDE TO SURVEY AND CLEARANCE OF UNDERWATER EXPLOSIVE ORDNANCE

GICHD

GENEVA INTERNATIONAL CENTRE FOR HUMANITARIAN DEMINING (GICHD)
The GICHD is an expert organisation working to reduce the impact of mines, cluster munitions and other explosive hazards, in close partnership with mine action organisations and other human security organisations. We support the ultimate goal of mine action: saving lives, returning land to productive use and promoting development. Based at the Maison de la paix in Geneva, the GICHD employs around 55 staff members from over 15 different countries. This makes the GICHD a unique and international centre of mine action expertise and knowledge. Our work is made possible by core contributions, project funding and in-kind support from more than 20 governments and organisations.

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LIST OF ACRONYMS AND ABBREVIATIONS

ADF
Australian Defence Force

AUV
Autonomous Underwater Vehicle

AXO
Abandoned Explosive Ordnance

CDT
Clearance Dive Team

CHA
Confirmed Hazard Area

COI
Contact of Interest

CONOPS
Concept of Operations

DGPS
Differential Global Positioning System

EO
Explosive Ordnance

EOD
Explosive Ordnance Disposal

EMI
Electro-magnetic Induction (also Pulse Induction)

GICHD
Geneva International Centre for Humanitarian Demining

GIS
Geographic Information System

GWHF
Golden West Humanitarian Foundation

HMA
Humanitarian Mine Action

IMAS
International Mine Action Standard

MCM
Mine Countermeasures

NTS
Non-technical Survey

R/I
Reacquire/Identify

RSIPF
Royal Solomon Islands Police Force

ROV
Remotely Operated Vehicle

SBAS
Satellite-based augmentation systems

SBP
Sub-bottom Profiler

SCUBA
Self-contained Underwater Breathing Apparatus

S/C/M
Survey/Classify/Map

SES
Ukraine Special Emergency Services

SHA
Suspect Hazard Area

SI
Solomon Islands

SSS
Side-scan Sonar

TS
Technical Survey

UAV
Unmanned Aerial Vehicle

UNCLOS
UN Convention on the Law of the Sea

UNESCO
UN Educational, Scientific and Cultural Organisation

UXO
Unexploded Ordnance

LIST OF FIGURES

SCOPE AND METHODOLOGY

The scope of this guide aligns with International Mine Action Standard (IMAS) 09.60 and is intended to augment the general information provided in the standard. Information in this guide applies to underwater explosive ordnance (EO) in the territorial waters of a nation (generally within 12 nautical miles of shore) and inland waters; this includes coastal waters, lakes, rivers, ports, harbours, ponds and canals below the Mean Lower Low Water (MLLW) mark to a water depth of 50 metres or less. Clearance of areas deeper than 50 metres of water fall outside humanitarian operations as defined in IMAS 09.60 due to the limited humanitarian and socio-economic impact of deeper water sites.

This guide focuses on providing a collection of current policy and best practices used in survey and clearance of underwater explosive ordnance. Specific cases are used; they provide examples and analysis. It is not intended to be a comprehensive database of policies and practices; it provides national authorities and mine action organisations with guidance to better understand the issues and complexities of underwater EO survey and clearance operations.

INTRODUCTION

In 2014, the GICHD conducted a survey of countries impacted by underwater explosive ordnance (EO). Through examining documentation and direct contact with national authorities, they found that EO affected a minimum of 64 countries. Of these, 33 are developing nations who have requested assistance in mitigating its impact. The mine action community will continue to encounter sites contaminated with underwater EO; the policies and practices discussed in this guide will assist in providing an understanding of the problems and potential solutions.

CURRENT UNDERWATER EXPLOSIVE ORDNANCE PROBLEMS

Underwater EO is located in inland waters, territorial waters and international waters throughout the world. Abandoned explosive ordnance (AXO) from sea dumping after the First and Second World Wars, along with unexploded ordnance (UXO) scattered in the littorals from dozens of other conflicts and wars, has resulted in millions of tons of ordnance in global waters. Military air and naval bombardments, naval mining operations, military firing ranges, sea-dumping of munitions, ship and aircraft wrecks have all contributed to the problem. EO is a direct hazard to coastal communities, maritime development, off-shore energy industry, the commercial fishing industry, tourism and more. National militaries have maintained, until recently, almost exclusive expertise in dealing with these hazards. This guide shares policies and practices in order to disseminate these largely unknown methods of underwater EOD operations.

Unexploded Ordnance (UXO)

UXO is ordnance that has been subjected to an arming sequence but has failed to explode. Typically, this occurs through a normal firing sequence. A conservative estimate is that modern ordnance has a misfire rate of ten percent but historically, a thirty percent misfire rate was more common during the world wars. Most UXO is from war. War and resultant UXO have affected most countries at one time or another. Germany, France, United Kingdom, Japan and other countries still routinely recover and dispose of thousands of tonnes of UXO each year from the Second World War era. Firing ranges are another source of UXO. Bombing and artillery ranges are common throughout the globe to prepare for war. As they become

Figure 1 Australian CDT preparing explosive charges to dispose of UXO.

de-commissioned or abandoned, the UXO left behind remains a deadly hazard. Progress has been achieved in clearing land-based UXO sites but underwater sites have received less attention.

Abandoned Explosive Ordnance (AXO)

AXO is also very common throughout the globe. AXO is ordnance that may or may not have been primed, fuzed, armed or otherwise prepared for use. Sea dumping of ordnance was a standard practice until the 1970s, with most occurring immediately after the Second World War. Dumping of millions of tonnes of ordnance into global waters took place during that period. Ship and aircraft wrecks also contain substantial amounts of AXO. Thousands of these wrecks remain along coasts, in lakes and rivers. Some AXO sites are in deep water with little hazard to coastal communities. Those in shallow coastal or inland waters result in considerable humanitarian and socio-economic impact.

Figure 2 Japanese depth charges in Koror Harbour, Republic of Palau.

THE IMPACT OF UNDERWATER EXPLOSIVE ORDNANCE

The impact of underwater EO should be the primary determinant of action required at contaminated sites. Unfortunately, it is not widely understood. This is primarily due to underwater ordnance being often out-of-sight. Accessibility is normally limited to those conducting activities on or under the water. Assessments should analyse those humanitarian, socio-economic and environmental factors which have an impact on EO sites. Assessments should be included in the planning phase to determine if impact warrants the time, risk and effort required to survey and clear the ordnance. For sites with no or limited impact, it may be prudent to monitor the area until

Figure 3 A GICHD advisor assisting Ukraine with an impact assessment of underwater areas along the Black Sea coast.

changes require action. There are three main impact criteria: humanitarian, socio-economic and environmental impact. Impact assessments should be conducted in coordination with local authorities who can access information, reporting and records.

TRAINING AND EQUIPMENT REQUIREMENTS

Organisations conducting underwater EO survey and clearance include NGOs, commercial organisations and military forces. Each of these organisations has knowledge and experience in certain aspects of underwater survey and clearance operations. Few, however, understand the overall complexities and the training and equipment requirements needed. The following paragraphs provide a basic structure for categorising underwater EO and determining needed resources.

Figure 4 A GICHD advisor conducting a capability assessment of Ukraine SES divers.

There are many methods of categorising underwater EO but the categories described below are useful when looking at training and equipment needed for survey and clearance operations. Categories are different based on the ordnance's location (buried or protruding) and the water depth. In many cases, more than one category will be relevant. For instance, underwater EO may be *buried (Cat 2)* in a water depth of *greater than 20 metres (Cat 3)*. In this case, training and equipment requirements for both Category 2 and 3 will be required.

Category 1 underwater EO

Definition: underwater EO not buried beneath the seabed and in less than 20 metres of water.

Generally, Category 1 underwater EO can be surveyed and cleared using manual search techniques with simple diving systems. Burial of underwater EO is dependent on seabed type and environmental conditions at each site. Some sites have very low burial rates,

Figure 5 Manual survey and clearance procedures being performed by Ukraine SES.

while at other sites the rate is very high. It is important for non-technical surveys to assess burial rates in order to determine training and equipment requirements for follow-on technical survey and clearance operations.

Main equipment requirements for Category 1 operations:

- Small boats suitable for scuba diving;
- Scuba or similar diving equipment
- Diver communication system
- Personal dive equipment (wet/dry suits, fins, masks, knives, etc.)
- Underwater search systems:
  - Lines, clumps and buoys
  - Underwater metal detector
- Maritime differential GPS
- Lift bags to recover EO
- Underwater demolition equipment
- Emergency medical equipment
- Geographic information system (GIS) to document survey and clearance

Basic training requirements:

- Basic dive training
- EOD level 1, 2 and 3 training
- Diving medicine and treatment
- Dive supervisor training
- Small boat coxswain training
- Marine navigation training
- Underwater search techniques
- Underwater demolition procedures
- Maintenance and certification of diving life support systems

Category 2 underwater EO

Definition: underwater EO buried below the seabed and in greater than one metre of water.

It generally requires a technical survey with advanced sensors such as electromagnetic induction (EMI) systems or magnetometers. Manual search techniques are not effective in areas where underwater EO burial is high. EMI systems or magnetometer survey systems map contamination in order to improve safety, efficiency and effectiveness of operations.

Main equipment requirements for Category 2 operations:

- Small boats suitable for technical survey operations
- Maritime differential GPS
- Sonar (boat-towed or AUV)
- EMI system or Magnetometer (boat-towed or AUV)
- Underwater remotely operated vehicle (ROV) – optional
- Geographic information system (GIS) to document technical survey
- Software for conducting post-mission analysis

Basic training requirements:

- Technical survey system training (towed/AUV, sonar/magnetometer)
- Small boat coxswain training
- Marine navigation training
- Technical survey mission planning
- Post-mission analysis training (sonar, magnetic anomaly interpretation)
- Software training

Category 3 underwater EO

Definition: underwater EO located in greater than twenty metres of water depth or in situations where ordnance is located inside the compartment of a shipwreck.

Category 3 underwater EO generally requires the use of advanced dive training and equipment. A professional surface-supplied diving system and support equipment is required when conducting search and clearance work at a greater depth than 20 metres of water or within a shipwreck.

Main equipment requirements for Category 3 operations:

- Diving support vessel (typically 40 metres or more in length)
- Surface-supplied diving equipment
- Dive communications system
- Personal dive equipment (wet/dry suits, fins, masks, knives, etc.)
- Transportable diver recompression chamber
- Underwater search systems:
  - Lines, clumps and buoys
  - Underwater metal detector
- Underwater remotely operated vehicle (ROV) – optional
- Maritime differential GPS
- Lift bags or davits to recover EO
- Excavation equipment (pumps to dredge mud, sand and debris)
- Underwater demolition equipment
- Emergency medical equipment
- Geographic information system (GIS) to document survey and clearance

Basic training requirements:

- (all Category 1 training)
- Surface-supplied dive training
- Diving supervisor training – surface supplied diving
- Dive recompression chamber operations and maintenance
- Treatment of dive casualties

UNDERWATER SURVEY AND CLEARANCE OPERATIONS

The approach described in this section derives from the principles and standards developed in the mine action community. Tactics, techniques and procedures from military underwater mine countermeasures (MCM) operations, and the currently available technology, have been included in this guide.

RISK MANAGEMENT FRAMEWORK

The framework outlined in **Figure 6** displays the integration of risk management into the overall mine action process for underwater EO survey and clearance operations. The following paragraphs discuss each step of the risk management process.

Identifying risks

Part of the General Mine Action Assessment includes a desk study of the history of an underwater EO site. It should identify the underwater EO by providing a general description of the location, type of EO and reason for its presence. Collected information may come from national archives, military databases, war records, range maps, records of disposal, vessel logs documenting activities, nautical charts, sailing publications, records of previous incidents of recovered munitions, public documents, databases developed by private researchers, the recreational diving community and other relevant sources. This information will feed into a more detailed study during a Non-Technical Survey (NTS).

Before progressing to a NTS, an impact assessment should be conducted to determine if the risks identified justify further effort. An impact assessment analyses humanitarian, social, economic and environmental risks of an underwater EO site. For example, determining the likelihood of both encountering underwater EO at a site and detonation of the EO with its consequences would provide authorities with the information needed to decide whether resources, effort and operational risk should be employed to survey and clear an underwater EO site. The threshold for taking action is different based on the risk tolerance of the authorities involved. An NTS should only proceed when authorities decide that they should expend additional effort to reduce the impact of an underwater EO site. The 'Non-Technical Survey' section of this guide describes it further.

NTS refers to on-site collection and analysis of data on the presence, type, distribution and surrounding environment of EO contamination. This is used to define better where EO is present, and where it is not. It should follow a desk study by building on data and information to provide a more detailed view of the problem. It will confirm whether there is evidence of a hazard, identify the type

FIGURE 6 RISK MANAGEMENT FRAMEWORK

Risk management process	Underwater EO survey/clearance process	Mine action phases
1. Identify risks • Type of EO • Condition of EO • Quantity and density of EO • General EO location	**A. General mine action assessment** • Desk study • Review of policy, regulations and laws • Underwater EO impact assessment • Capability assessment • Select and prioritise areas for survey/clearance • Specify survey and clearance requirements and responsibilities	Planning
2. Risk assessment • Probability of encountering underwater EO • Severity of impact of underwater EO **3. Develop risk response** • Avoid, Transfer, Mitigate or Accept	**B. Non-Technical Survey (NTS)** • Collect and analyse survey information **C. Technical Survey (TS)** • Survey site to defined requirements **D. Enabling activities** • Develop capabilities and establish funding	Preparation
4. Control risks • Direct and manage work • Monitor and control work • Reassess risk	**E. Operations** • Remove and dispose of underwater EO • Monitor and inspect (quality assurance)	Clearance
5. Monitor risks • Monitor residual risks	**F. Closeout** • Inspect cleared sites (quality control) • Clearance documentation • Post-project review	Post-clearance

and extent of hazards and defines, as far as possible, the perimeter of the actual hazardous areas without physical intervention. Sources of information include police, military, hospitals, local authorities, fishermen, dive shops, etc. Information from the desk study and the NTS feeds into the risk assessment process.

Risk assessment

The purpose of a risk assessment is to assess risks posed by underwater EO based on the probability of a threat occurring and its potential severity. It should be applied to both the underwater EO site and the secondary risks that arise as a direct result of implementing a risk response (see next section). Hazards at a site directly related to underwater EO may be beach-going, scuba diving, dredging, port development, bridge construction, etc. Secondary hazards related to mitigation operations may be small boat operations, towed magnetometer survey, diving operations, ROV operations, *in situ* EO disposal, recovery and transport of EO, etc. An example of a four-step risk assessment process is shown below. It can be used to assess and mitigate underwater EO and the secondary risks from implementing a risk response.

Example hazard activity: *in situ* EO disposal operations of scattered underwater EO near a port facility.

Step 1: identify hazard (see matrix developed in *step 4* below).

- Hazards are physical activities conducted on site.

Step 2: identify associated threats (see matrix developed in *step 4* below).

- Threats are defined by historic evidence and likelihood of occurrence.

Step 3: develop a risk assessment matrix

Risk assessment matrix

				Probability			
				Frequency of occurrence over time			
				A	B	C	D
				Likely	Probable	May	Unlikely
Severity	Effect of hazard	I	Damage to critical infrastructure, equipment or environment; death of personnel	1	1	2	3
		II	Significantly degraded infrastructure, equipment or environment; severe injury of personnel	1	2	3	4
		III	Degraded infrastructure, equipment or environment; minor injury of personnel	2	3	4	5
		IV	Little or no impact to infrastructure, equipment or environment; minimal injury of personnel	3	4	5	5

Risk assessment codes: 1 Critical 2 Serious 3 Moderate 4 Minor 5 Negligible

Step 4: institute a risk mitigation strategy, then reassess (example below)

Hazard	Threat	Initial RAC	Mitigations	Reassess RAC
In situ EO disposal	Damage to port facility infrastructure by underwater explosive shock wave.	2(IIB)	Move ships and other critical infrastructure out of hazard area; ensure pipelines are not within hazard area.	4(IID)
In situ EO disposal	Swimmers or divers killed or injured by underwater explosive shock wave.	2(IC)	Warn local community of operations; coordinate with local authorities; establish cordon around hazard area.	4(IID)
In situ EO disposal	Damage to marine environment (coral, fauna, sea life, etc.)	3(IIIB)	Assess potential damage area around each site to determine if damage is acceptable.	4(IIIC)
In situ EO disposal	Marine mammals killed or injured by underwater explosive shock wave.	2(IC)	Establish cordon around hazard area and designate personnel to watch for marine mammals.	4(IID)

After assessing all hazards in the four-step process, authorities should have a clear understanding of the risk associated with both the underwater EO and the secondary risk response options. With both the risk assessment and the impact assessment complete, authorities are ready to develop a risk response.

Developing risk responses

An organisation's risk tolerance, operational capability and available funding will be the primary influence on risk response options. There are four basic options to consider when developing a risk response:

1. **Avoid** risk by limiting activities at the underwater EO site. Avoidance is a good option in areas that have little activity and no plans for development or activities that would produce an intolerable risk.
2. **Transfer** risk by shifting responsibility to another organisation. For instance, in an area planned for commercial development, underwater EO clearance operations could be included in the commercial development project.
3. **Mitigate** risk by conducting underwater EO clearance operations. Ideally, clearance is the best outcome because it removes the source of underwater EO risk but clearance capability or available funding may limit an organisation's ability to conduct clearance.
4. **Accept** risk by putting reactive procedures in place to respond when finding underwater EO. Risk acceptance is typical with residual contamination. Even in areas where underwater EO has been cleared a residual risk of encountering EO will remain. It is common for marine dredging operations to accept underwater EO risk when ordnance is smaller than a specified diameter. Magnetometers or other detection technologies are usually applied to detect EO during dredging, followed by pre-planned response procedures to remove and dispose of the detected EO.

Authorities should analyse the following criteria when considering risk response options:

a. humanitarian, environmental, social and economic impact data provided in the impact assessment;
b. primary risk of the EO at the site;
c. secondary risks that arise as a direct result of implementing a risk response;
d. residual risk remaining after risk response;
e. available underwater EO survey and clearance capabilities;
f. funding available for clearance.

Before developing a risk response, authorities should understand their organisation's underwater EO survey and clearance capabilities or the costs associated with contracting a commercial company to complete the work. In many instances, an organisation's capacity or the available funding may limit risk response options. Authorities should use information from the impact and risk assessments to develop an appropriate risk response. In some cases, the risks of conducting clearance operations will outweigh the potential humanitarian, environmental, social or economic benefits. However, it is possible to reduce operational risk to an acceptable level when sufficient resources are available. Conversely, if authorities decide to forego clearance, measures should be put in place to avoid or manage the underwater EO site. Additional information about site management is included later in this guide in 'Underwater EO Clearance and Site Management'.

Control risks

Controlling risk involves directing and managing work by implementing risk response plans, tracking identified risks and identifying new risks. The information collected from work performance data enables routine risk reassessments to improve the effectiveness of risk response plans continually. In some cases, corrective action may dictate an alternative risk response.

Monitor risks

Residual risk is probable at most underwater EO sites; therefore, post-clearance inspection of EO sites may be necessary. Residual risk is the risk remaining following the application of 'all reasonable effort' to identify, define, and remove underwater EO through non-technical survey, technical survey and/or clearance. It is minimised when competent organisations follow approved procedures and processes. It is possible to quantify residual risk by monitoring areas to identify any incidents, accidents or evidence of missed items. Confidence in the clearance process can be maintained through the results of such monitoring and areas requiring improvement can be identified.

In the case of response plans that include avoiding or accepting the EO risk, monitoring and active management will also be necessary. Authorities should establish a safety perimeter around known underwater EO sites and prohibit activities in the area that would adversely risk disturbing the EO.

LIABILITY CONSIDERATIONS

The mine action community have developed well-established policies, practices and guidelines to address liability over the last two decades. Liability considerations apply as equally to underwater EO survey and clearance operations as for traditional land-based clearance operations. Policies, standards and principles of liability within mine action are outlined below.

Liability in the mine action community

Liability refers to any legal responsibility, duty or obligation that a country, organisation or individual may have. A well-documented, transparent, evidence-based approach to underwater EO survey and clearance operations, which demonstrates the application of 'all reasonable effort', provides the primary mechanism for addressing questions of liability; authorities at all levels then can have the confidence to make appropriate decisions. It is important that national authorities develop policies that detail liability aspects, including transfer of liability from the underwater survey and/or clearance organisations to government or local communities when certain criteria have been fulfilled. The following principles should apply:

a. Underwater EO contamination is firstly and ultimately a national responsibility. National authorities should accept accountability and liability for victims and areas impacted by underwater EO. This includes known, as well as unknown, areas and areas that have been cleared and handed over to the national authority or local population. An underwater EO survey and/or clearance organisation is considered to be liable for injuries only when it is directly and currently responsible for an affected area. Proof of the validity of this claim will still be required on a case-by-case basis.

b. An agreement that details the underwater EO survey and clearance plan implies that all stakeholders agree on the definition of 'all reasonable effort'. Identifying and quantifying these efforts will help to prevent disputes related to liability issues.

c. If an underwater EO survey and clearance plan has been approved by a government, then appropriate application of the principles by operators and acceptance of handover by the national authority implies that the level of risk of underwater EO contamination in the area after survey or clearance is deemed tolerable by the government.

d. If an investigation shows that the agreed underwater EO survey and clearance plan had been implemented appropriately and thus the organisation had made all reasonable effort to ensure that the area was safe before handover, the organisation will, in principle, not be liable for missed underwater EO contamination or accidents. Additional guidance on the conduct of investigations is provided in IMAS 10.60.

e. National policy or contractual agreements should clarify liability for dealing with items found after underwater EO survey and clearance.

Types of liability insurance

Evidence of appropriate levels of liability insurance during operations should be obtained by organisations performing underwater EO survey and clearance operations. A brief description of the types of insurance is provided below:

a. **Professional liability insurance**: provides indemnity for the insured against loss arising from claims made for error, omission or negligent act committed in the conduct of consultancy or contracted service.

b. **Employer's liability insurance**: provides coverage to a business or organisation for liability for employees in the case of work-related bodily injury or disease. Underwater EO survey and clearance operations require many types of work that involves risk. Employers should adequately insure employees for risks involved in diving, explosive handling and disposal, small boat operations and many other risks identified during the risk management process.

c. **Public liability insurance**: provides protection against claims of personal injury or property damage that a third party may have suffered. Policies to address third party liability should detail:

    1. personal injury of a third party;

    2. damage to third party property and infrastructure.

Underwater liability considerations

Organisations must also understand liability consideration with respect to the marine environment. Some issues include:

a. **Marine mammals and protected marine species**: marine mammals are particularly susceptible to pressure resulting from an underwater explosion. In many parts of the world, there is designated protection for marine mammals and other species. Organisations must understand regulatory requirements to comply with national and local policies to protect these species.

b. **Marine pollution and damage to the marine environment**: the United Nations Convention on the Law of the Sea (UNCLOS) delineates rights and responsibilities of nations in their use of global waters. It institutes guidelines for business and the management of the marine environment and resources. Article 192 generally obliges signatories to 'protect and preserve the marine environment'.

c. **Underwater cultural heritage sites and human remains in ships and aircraft**: the United Nations Educational, Scientific and Cultural Organisation (UNESCO) Convention for the Protection of Underwater Cultural Heritage has established that 'States Parties shall ensure that proper respect is given to all human remains located in maritime waters'. It also states, 'Activities directed at underwater cultural heritage shall avoid the unnecessary disturbance of human remains or venerated sites'. As the wrecks of ships and aircrafts often still contain human remains they must be approached with respect. This includes proper treatment of discovered human remains and notification of local authorities for preservation and recovery. Preservation of historic sites must also occur, to the greatest extent possible, when balanced with the primary and secondary hazards of the underwater EO.

Detailed discussions and agreements on risk and liability should take place between underwater EO survey and/or clearance organisations, and national authorities before commencing operations.

NON-TECHNICAL SURVEYS

General policies and procedures

The application of NTS methods to underwater EO survey and clearance may be more difficult than land-based operations due to the dynamic nature of the marine environment. IMAS 08.10 presents the basic NTS methodology that should be applied but procedures have to be adapted to the underwater environment.

Figure 7 A GICHD advisor discussing underwater EO in Palau.

An NTS will confirm whether there is evidence of a hazard or not, identify the type and extent of hazards and define the perimeter of the actual hazardous areas, without physical intervention. In addition to these general criteria, the humanitarian, environmental, social and economic impact of the underwater EO should be analysed to determine if additional effort is necessary for clearance. In many cases, underwater sites do not pose a significant hazard and management of them may not require clearance. For example, an isolated underwater dump site with abandoned explosive ordnance (AXO) may not pose a significant hazard or impact local communities or development; therefore, the site should be monitored or managed instead of expending clearance effort.

Another aspect of underwater NTS is the need to conduct a site survey. Information collected will be critical for follow-on underwater technical survey and clearance operations. Underwater operations are more complex and dynamic that land-based operations. In addition to the standard information gathered during a land-based NTS (see IMAS 08.10), information about annual weather conditions, water depth, tidal fluctuations, sediment type, currents, underwater obstructions, shipwrecks, bottom clutter, seasonal maritime activities, dangerous marine life, endangered wildlife or marine life, historical sites, cultural sites, oil/gas pipelines, ports, boat ramps and other infrastructure information should be collected. An individual country or site will always need to develop more detailed requirements.

A non-technical survey:

a. assesses whether areas are contaminated by ERW, or to refine the limits of previously reported hazardous areas;
b. cancels incorrect reports of EO;
c. identifies socio-economic and threat factors that may influence future priority-setting;
d. collects information about accidents, the type and pattern of hazards, water depth, bottom composition, marine life, ecological environment, local infrastructure, the security situation and other factors that may influence priority setting and method of following up with additional support.

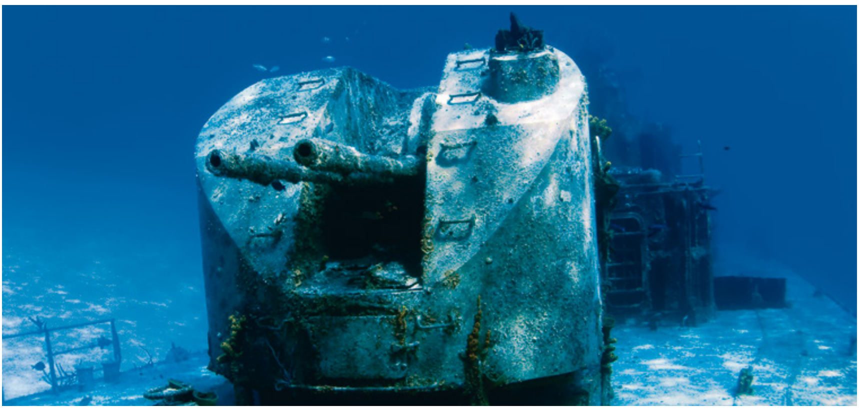
A non-technical survey may further serve as a planning tool for future efforts (i.e. technical survey and/or clearance).

The starting point of a NTS typically involves a desk study. Similar to a land-based NTS, information is analysed from sources such as historical records, police, military, hospitals and provincial authorities. However, an underwater NTS must also include information from local fishermen, dive shops, marine businesses, coastal communities and others with knowledge of the area. Historical research may also provide unique challenges; information is often located in nautical charts, ships logs and other naval records.

The environmental conditions at the site, type of EO, method of delivery and available information directly relate to the ease of defining and refining limits of a suspect hazard area (SHA) or a confirmed hazard area (CHA). An example of a relatively simple underwater NTS would involve an intact shipwreck in which historical records document the EO cargo, nautical charts document the wreck, and local authorities or marine businesses have evidence of the EO through photographs or other documentation. Precise boundaries of a CHA can be defined around the shipwreck or within specific compartments of the wreck using this information. Aircraft wrecks, underwater EO dump sites and other AXO sites can often be defined in a similar manner. There are problems, however, when environmental conditions move or bury EO. Some environments, for example, lakes, are static, while others, such as swift rivers, are very changeable. Understanding the impact of environmental conditions on the EO is an essential factor in some underwater NTS.

At battle or bombing sites, the NTS process may be less precise, thereby requiring definition of a larger SHA or CHA. The typical NTS process of research and surveying local communities, businesses and authorities will refine the hazard area. However, organisations cannot expect the precision of land-based surveys in some cases. The hazard area requiring technical survey and clearance can be further refined by reducing underwater areas that would not be impacted by activities planned for the site. For example, an underwater CHA at a river site may only require technical survey and clearance around the area of a bridge construction project. The portion of the CHA not cleared should be properly managed to ensure hazardous activities are prohibited within the remaining CHA.

The case study presented below will illustrate the complexity of the underwater NTS process and the need to adapt to the area impacted by underwater EO.



CASE STUDY: CAMBODIA[1]

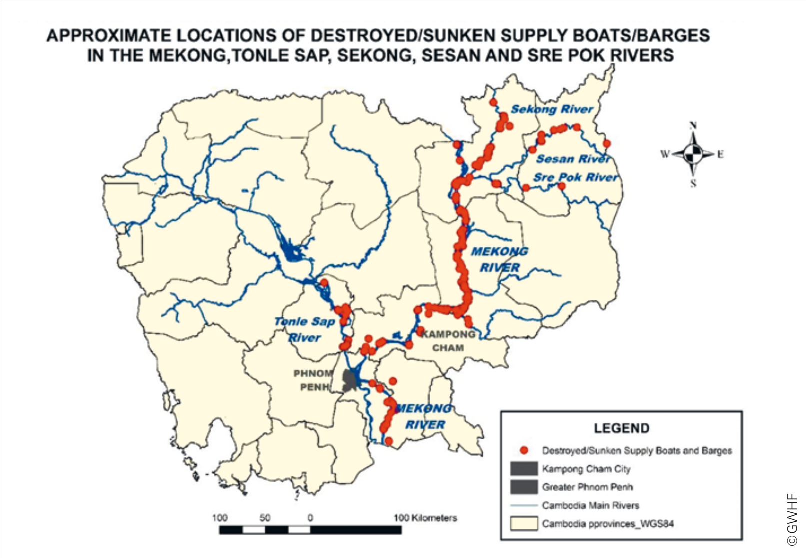


Figure 8 Approximate locations of sunken supply vessels in the Mekong, Tonle Sap, Sekong, Sesan and Sre Pok rivers.

Background

During the Vietnam War, ordnance supplies moved between northern and southern Vietnam by rivers in eastern Cambodia. Between 1970 and 1975, barges and boats carrying ordnance were often targeted and sunk.

In 2011, information provided by local authorities and a scrap metal hunter led Golden West Humanitarian Foundation (GWHF) to the location of two sunken boats on the Tonle Sap River near Kampong Chhang. GWHF was able to pinpoint the location of the wrecks and in May–June 2011, salvage of eleven metric tons of U.S. ordnance occurred. Following further research, they found evidence of nearly two hundred such sites in the rivers of Cambodia.

1 Case study information is based on discussions with GWHF personnel and the report: Non-Technical Surveys to Investigate the Level of UXO and Ordnance Contamination in the Mekong, Tonle Sap, Sekong, Sesan and Sre Pok Rivers in Cambodia by Golden West Humanitarian Foundation, Marcel Durocher and Heang Sambo, April 2015.

The estimated suspect hazard area totalled approximately one billion square metres. Based on available technology and operational limitations, a technical survey of the entire area would have taken more than a decade to complete. As a result, GWHF developed a NTS methodology to reduce the area required for technical survey operations.

Successes

GWHF used NTS methodology between 2011–2015 along the Mekong, Tonle Sap, Sekong, Sesan and Sre Pok rivers in eastern Cambodia. The first stage of the process involved historical research to detail the problem and understand the operations. Declassified U.S. military reports provided bombing data and information on military operations. Research of news articles and documentaries by correspondents was also undertaken. The desk study provided valuable insight into when and where attacks took place and how each of the belligerents sunk the vessels. The research identified 197 vessels sunk during the period with approximate locations but the information was not yet accurate enough to reduce the size of the survey area for the technical survey process.

GWHF then developed an interview process to obtain additional information from villages along the shores of the rivers and from people earning their living on the rivers. The most valuable information came from fishermen, itinerant traders and scrap metal hunters. Individuals, who would have had direct knowledge of the attacks during 1970–1975, were preferred for interview. Through early interviewing experience, GWHF learned that a sampling density of one interview per five-kilometre stretch of river was sufficient. Additional interviews were conducted at approximately each kilometre to better define the area of the sunken vessel after a positive response about a sunken vessel was obtained. They found, after follow-on technical surveys, that information from two or more interviews about a sunken vessel site produced very accurate locations.

Based on the inability of vessels transporting equipment and supplies to navigate in shallow waters some of the areas were reduced in size. In other areas, interview-sampling density was lower because of the precise information provided by scrap metal hunters. Many of the sunken vessels and cargo were salvaged by Vietnamese scrap metal companies between 1982–1987 and again in 1997–2003 from the Tonle Sap, Mekong, Sekong and Sre Pok rivers: approximately sixty to seventy vessels were recovered.

Cambodian scrap metal hunters also salvaged some sites. In one instance, Cambodian authorities apprehended local scrap metal hunters for illegally salvaging ordnance from a barge on the Mekong River. Remaining ordnance at the site (approximately 70 metric tons), along with two other sites, were salvaged by government authorities and a private contractor. Salvage operations by scrap metal hunters have reduced the amount of EO in the rivers but the quality of clearance was unknown and the information management process was non-existent.

NTS of the Cambodian rivers has resulted in the identification of 14 sites where performance of technical survey operations is required. Technical surveys and salvage operations are complete at some sites, while other sites await the required technical equipment and expertise. Although the NTS process has been effective at identifying wreck sites, there is a gap between the 197 vessels identified in the desk study and the approximately 74–84 discovered during the interview process.

Challenges

The dynamic nature of the rivers and the quality of data available about the location of the wrecks limited the accuracy and completeness of the NTS data. The sinking of the smaller wooden transport vessels has contributed to the discrepancy. These vessels were often destroyed much more easily than metal boats, resulting in the remnants of the vessels and cargo vanishing quickly. River sediment or flow either buried the scattered remains or washed them down river. The evolution of the Mekong River also explains some of the challenges. Several metres of sediment now bury munitions barges, which have been sunk for forty years. In other areas, the path of the river has moved up to 200 metres. As a result, some vessels are no longer located near the rivers. This changing environment adds complexity and inaccuracy not seen in land-based surveys. Although challenging, management of the process can create the required results.

Analysis

An underwater NTS is different from land-based NTS in a very significant way: not all underwater sites contaminated with EO require clearance. For example, munitions buried below ten metres of sediment along an isolated section of the Mekong River would not be likely to make much of an impact on the local communities. In such a case, the survey and clearance process would expose personnel to unnecessary risk and waste time and resources. Before GWHF moved to the technical survey phase, they would assess the impact of the underwater EO at the sites identified.

Impact assessments are an important element in determining whether underwater EO clearance is worth the risk. Diving and clearance of EO are highrisk operations. There must be value in clearing the underwater EO, otherwise it would be more prudent to leave it in place and manage the sites.

TECHNICAL SURVEYS

General policies and procedures

The underwater technical survey process and available technology has rapidly evolved over the last decade. Commercial industry has made progress with EO survey projects supporting marine industry such as wind farms and oil/gas infrastructure. The military continues to make progress with naval mine countermeasures technology. Programmes, projects and technology developed to support military and commercial industry have enabled safe, efficient and effective technical survey operations for the mine action community. However, the scale and scope of military and commercial operations is often different from operations conducted by the mine action community.

This guide will therefore use the GICHD underwater equipment trials completed in 2015 to analyse best practices for the underwater technical survey process. Equipment trials evaluated a select set of commercial equipment suitable for underwater technical survey operations. In the following section, we will look at the various sensors and platforms available then discuss a process to analyse equipment needed for specific sites.

Technical survey equipment

The technical survey phase of underwater survey and clearance operations is often the least understood due to the technical nature of the work. Although there are limited instances when technical surveys can be accomplished using manual procedures (divers), it is more common that advanced sensors will be required. This guide concentrates on technology appropriate for use in water depths of 50 metres or shallower. Typical sensors used in underwater technical surveys include the following:

- **Magnetometers**: these, in varying configurations, are widely considered the most effective sensor for detecting underwater EO. Its proximity to the ferrous metal in the ordnance is the basis of its ability. Magnetometers can be configured as a single sensor, a sensor array or in a gradiometer configuration. For sites that contain non-ferrous EO or sites in which the magnetometer cannot be deployed close enough to the seabed (due to obstructions or seabed profile), then a different sensor may be more effective.
- **Side-scan sonar (SSS)**: these are a common tool used during the technical survey process but are rarely used alone to detect underwater EO. An SSS alone may be effective for sites which contain only large EO (such as sea mines) or EO contained within shipwrecks.
- **Multi-beam sonar**: the multi-beam sonar (or echo sounder) is mainly used to obtain bathymetry. Sonars do not need to be employed as close to the seabed as other sensors; this allows mapping of the depth profile and large underwater obstructions at the site before employing other sensors that must be close to the seabed.
- **Sub-bottom profiler (SBP)**: an SBP provides a sonar image beneath the seabed. To date, the technology has limited applications in the underwater survey and clearance process. SBPs are only effective in very small survey areas and the data alone is rarely adequate to distinguish EO.

Figure 9 Technical survey team preparing SeaQuest gradiometer for operation.

Figure 10 Deployment of a Klein 3000 side-scan sonar for a technical survey.

- **Electromagnetic induction (EMI)**: these systems (also known as pulse induction) are common in land-based EO surveys but employing them underwater can be more difficult. They are typically reserved for underwater sites that contain ordnance encased in non-ferrous metal or in locations with shallow water where manual survey is possible.
- **Bore-hole magnetometers**: these can be used in areas that require detection of buried EO beyond the capability of other magnetometers. The sensor bores through the seabed to detect buried EO within the area around each borehole. The time and effort required in this process limits the applicability of borehole magnetometers to very small areas.
- **Optical/tactile**: although less efficient and effective than other sensors, the eyes and hands of divers have detected underwater EO for decades. The next section discusses this further. Underwater cameras are also readily available. The most common use of cameras or divers is to verify that anomalies previously detected by magnetometers or sonar contacts are, in fact, ordnance.
- **Other sensors**: explosive and heavy metal sampling sensors are currently available and being adapted for use in EO surveys. As technology evolves, more efficient and effective sensors will become available.

Selection of the proper platform to employ the sensor is as equally important as sensor selection. Typical platforms include:

- **Divers**. Divers are rarely selected as the preferred 'platform' for the technical survey phase. They can employ many of the sensors described above but their efficiency and the inherent risk involved in diving would normally limit extensive use during technical survey operations. Surveying small areas, shallow portions or a site would be the most appropriate use of divers.
- **Small boats or vessels**. Use of small boats and larger vessels to mount or tow sonars, magnetometers and other sensors through the survey area is the most common platform currently in use. Proper deployment and navigation of the selected sensor is the most challenging aspect with small boats or other vessels.

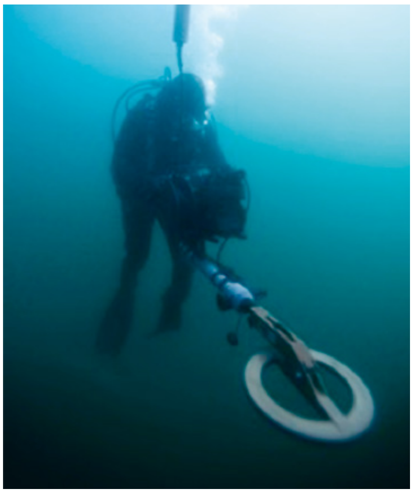


Figure 11 A scuba diver descending with a Shark Marine Navigator with integrated metal detector.

- **Autonomous underwater vehicle (AUV)**. Where cost is not a concern, AUVs would be a good option in a majority of situations. AUVs are outfitted with multiple sensors; SSS, multi-beam sonar, SBP, video cameras are all common and magnetometers have recently been added to selected AUVs. Reduced logistics requirements, improved navigational capabilities and efficiency are just some of the positive aspects of AUVs over other platforms. An AUV would not be effective in some environments, such as some rivers with swift currents.

Figure 12 Iver3 AUV by Ocean Server.

- **Remotely-operated vehicles (ROV)**. These provide a structure for cameras, sonars and, in some cases, magnetometers. They can limit the need for divers by verifying that anomalies detected by other survey systems are actually EO. The case study will discuss the verification process. ROVs are also a great tool for exploring hazards inside shipwrecks or other 'enclosed spaces' which pose a significant safety risk to divers. ROVs provide a great option for reducing risk and improving efficiency although they are not typically used as the sole platform in technical survey operations.

Figure 13 A Seabotix vLVB 300 ROV being deployed.

- **Other platforms**. Unmanned Aerial Vehicles (UAV) could be particularly useful in surveying the surf zone and areas less than one-metre water depth. Sensor packages are currently in development for this type of work. It is important to be aware of developing technology that can make operations more efficient and effective.

The sensors and platforms discussed in this section must be integrated into a system that includes accurate navigation and data collection capability. Maritime Differential Global Positioning Systems (DGPS) typically provide the required sub-meter accuracy for navigation. Satellite-based augmentation systems (SBAS) are also widely available. Another primary component of the technical survey system is the software required to collect and analyse data. It is common to use different software programmes for each type of sensor used. For example, magnetometer data is commonly processed and analysed by a different software programme than the one used for sonar data. Software companies are making strides in providing an all-in-one solution capable of processing, analysing and displaying the data collected from the technical survey systems. There is not, however, a programme that currently stands out which has that capability.

Figure 14 Marine Magnetics Explorer magnetometer towed behind an Iver3 AUV with SSS.

Selection of technical survey equipment is dependent on site characterisation. A particular sensor may be suitable at one site but not suitable at another; the same principle applies to platforms. For example, a relatively small area, such as a site for bridge construction, can be effectively surveyed using divers with handheld metal detectors (as long as the detector has the required detection capability). In an area that is much larger with deeper water, such as a coastal firing range with unexploded ordnance (UXO), boat-towed systems with sonars and magnetometers would be more appropriate. Assessing equipment requirements and selection of suitable equipment is crucial to a successful technical survey.

Training and support requirements for technical survey operations can be significant. Diving, small boat operations, analysis of sonar and magnetometer data, equipment maintenance, etc., often require months or years of training to become proficient. Operational safety, efficiency and effectiveness will be compromised without proper equipment, training and support.

CASE STUDY: GICHD UNDERWATER EQUIPMENT TRIALS[2]

Background

In March 2015, the GICHD sponsored an Underwater Equipment Demonstration Trial to evaluate available commercial technology suitable for use in underwater technical surveys. The trial assessed sonar, magnetometer and optical sensors mounted on AUV, ROV, boat-towed and diver systems in water depths of 0–50 metres. Selected systems were deployed in two 100 metre by 200 metre ranges with eleven simulated EO targets between 2 to 8 inches in diameter for each range. Although the demonstration was relatively limited, the technology and methodology used provided important information about available sensors and platforms for technical surveys.

Demonstrations and evaluations took place of the following systems:

- An AUV with a high frequency side scan sonar, combined with interferometric bathymetry and a total field magnetometer.
- Multi-sensor gradiometer magnetometer towed by a small boat.
- Diver underwater navigation system. This system reacquired and identified previously detected targets to verify that they were the simulated EO targets. It was not used for initial detection or 'area survey'.
- ROV with a high frequency scanning sonar and video camera. As with the diver navigation system, the ROV reacquired and identified the simulated EO targets.

The full report is available on www.gichd.org

Successes

As has been demonstrated in other studies and operations, magnetometers provided the best sensor for locating individual EO during an underwater technical survey. Demonstrations of a boat-towed gradiometer and an AUV-towed magnetometer took place during the trial; both systems produced

2 Case study information is based on author participation in the equipment trials and the report: Technology Demonstration Report for Underwater Survey Equipment in support of Explosive Remnants of War (ERW) Technical Survey Operations, Revision 1.0, 12 November 2015, Prepared by Orca Maritime Inc. The report is available on the GICHD website.

nearly identical results. During the ordnance identification phase, ROVs were more efficient and effective than the diver system in reacquiring and identifying the targets, particularly in water deeper than 20 metres. ROVs required significantly fewer logistics and less set-up time and maintenance than the dive systems, and the ROVs could remain at depth for significantly longer periods.

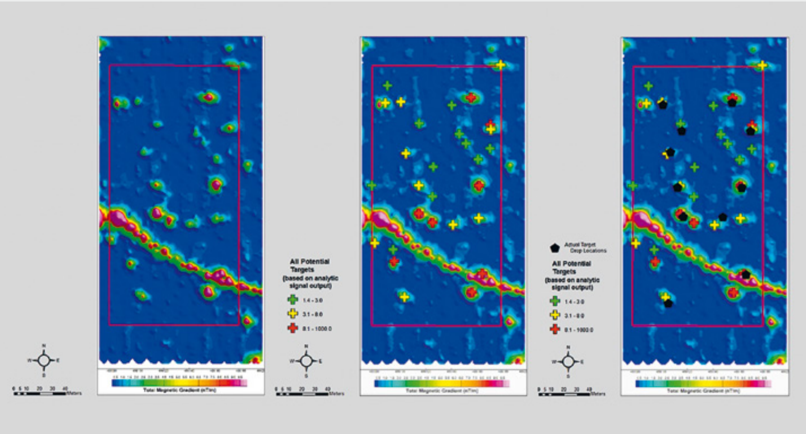


Figure 15 Results of an underwater magnetometer survey. The graphic on the left displays processed magnetometer data. The centre graphic displays the analyst marks of anomalies resembling EO. The right graphic overlays the marks of the actual location of the simulated EO planted in the test range for the equipment trials.

Standard methodology and mission planning details were also validated and established during the event. Technical surveys are normally conducted in two distinct phases. The first phase is to Survey, Classify and Map (S/C/M), followed by the Reacquire and Identify (R/I) phase. Usually The S/C/M phase is conducted using platforms that can cover a large area in a relatively short period. These broad-area surveys are best suited to boat-towed or AUV systems. Data is collected on the entire area by boats or AUVs methodically deploying sensors at a specified height-above-bottom and distance between search lanes (similar to the process of mowing a lawn). Once data from the sensors is processed and analysed by appropriate software systems, magnetic anomalies or sonar contacts are classified as either meeting the characteristics of the suspect ordnance or not.

The contacts of interest (COI) are then mapped and made available for the follow-on R/I phase. In this case, the latitude and longitude coordinates were passed to divers and ROVs. Divers used an underwater navigation system, sonar and their vision to reacquire and identify the COIs. The diver system also had the capability of photographing the ordnance for data collection purposes. ROVs use sonars and cameras for the same purpose but obviously do not require a diver.

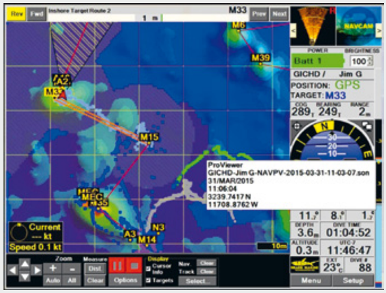


Figure 16 Shark Marine Navigator multi-function display.

The R/I phase is not always required during technical survey operations. If data collected during the S/C/M phase is of high enough quality, the R/I process can wait until clearance operations commence. This process is important to understand and the report contains a full explanation[3].

Challenges

The GICHD underwater equipment trials highlighted several challenges in the technical survey process. Primary among them were the limitations of sonars, the constraints of diver systems and the complications of conducting a technical survey in areas with a large amount of metallic debris. Understanding these challenges is important in both the selection of systems and application of the systems in the technical survey process.

Sonars are important sensors to most underwater technical survey operations but they are not normally effective in detecting individual EO. Sonars use sound waves to create images of the area. These images are then analysed to find objects that resemble the size and shape of EO or other relevant contacts. The equipment trials found that sonar, by itself, would be ineffective in detecting EO less than six inches in diameter. The inability of most sonars to locate buried EO (an SBP can detect EO but only in very limited scenarios) is another key limitation. Sonars are, however, very effective and efficient at finding larger EO, AXO sites, shipwrecks and obstructions. Sonars also provide important bathymetry and other data needed for planning the

3 See the GICHD Underwater Equipment Demonstration report.

collection of technical survey data for other sensors, such as magnetometers. Understanding the technical capability and limitations of sensors is critical to a successful underwater technical survey.

The employment of divers, whether in the technical survey process or during clearance, requires an understanding of the associated risk and limitations. Diving involves inherent risks; decompression sickness, arterial gas embolisms, and dangerous marine life are just a few of these. Their equipment and physiology limit divers. For example, a SCUBA diver may have enough breathing air in a cylinder to dive for ninety minutes at a water depth of twenty metres but the diver's physiology is limited to one hour due to the risk of decompression sickness. There are also limitations for exposure to cold or heat.

Figure 17 Scuba diver using a Shark Marine Navigator system.

During the GICHD underwater equipment trials, diving had to be significantly abbreviated because some divers could not Valsalva (or clear their ears) in order to descend to the seabed. Some divers were also seasick and supervisors were concerned about diving in the moderate weather conditions. To improve the safety, efficiency and effectiveness of underwater survey and clearance operations, it is often better to use systems that do not require divers, when practical. When divers are required, proper training and equipment is essential prior to commencing operations.

The overall purpose of an underwater technical survey is to detect and map all EO in a specified underwater area. This process can be particularly difficult in former conflict areas and firing ranges with metallic debris strewn throughout. Analysis of magnetometer data can filter some of the debris by eliminating magnetic anomalies that are outside the signature of expected EO at the underwater site. Other magnetic anomalies can be eliminated through analysis of sonar data. A problem arises, however, after filtering the technical survey data, when a significant number of non-EO COI remain. Understanding the cause of false alarms and the means to reduce false alarms is essential to a successful underwater technical survey.

The challenges highlighted in the GICHD underwater equipment trials are all manageable:

a. sonars are necessary sensors for technical surveys but they are rarely effective by themselves
b. diving operations involve risk but the risk is manageable with proper training and equipment, or by limiting risk by using ROVs
c. factors affecting the false alarm rate must be understood in order to produce a high quality technical survey. The technical survey process can be difficult but proper training, equipment and expertise will produce the required results.

Analysis

A standard concept of operations (CONOPS) for underwater technical surveys can be developed through analysis of the GICHD trials. Through a thorough understanding of the capabilities and limitations of each sensor and platform, a process can be developed to employ the systems in the most effective and efficient manner.

Results of a NTS will provide fundamental details to begin development of a standard CONOPS for the technical survey process. At a minimum, the NTS should provide details such as type of EO in the hazard area, size of area, water depth and other environmental details. From these details, it is generally possible to select the appropriate sensors and platforms for the technical survey. In the GICHD underwater equipment trial example, two separate areas were used to simulate firing ranges with scattered UXO between 2 inches to 8 inches in diameter. The first survey area was located in the inner waterways with a silt and sand seabed in 1 to 5 metres of water depth. The second survey area was located in coastal waters with a sand seabed in 5 to 50 metres of water depth. Based on this limited information, it is possible to develop a CONOPS for the technical survey, with the following phases:

Phase 1: Broad sonar survey to collect bathymetry and map obstructions.

- A ‘high-pass’ with a sonar is often a needed step prior to deploying sensors close to the seabed. Without this information, it is likely that survey equipment would foul during phase 2 operations.

Phase 2: Magnetometer and detailed sonar survey to detect and map EO.

- In this scenario, a sonar alone would not be effective in detecting the EO because of the small size of the EO and likelihood of burial. Combining magnetometer and sonar data provides a higher confidence in the COIs detected by both sensors.

Phase 3: Reacquire and identify COIs with ROV to verify that they are EO.

- This reduces the effort and risk required during follow-on clearance operations by reducing the number of false alarms.

At the end of the technical survey process, bathymetry, sonar, and magnetometer data should populate a GIS along with video/photographs of the hazard areas. The analysed data will provide a list of COIs with relevant data for clearance operations.

UNDERWATER EO CLEARANCE AND SITE MANAGEMENT

General policies and procedures

The process of underwater EO clearance involves much more than simply understanding procedures for ordnance disposal. Before deciding on the most appropriate action in an area contaminated with underwater EO, a detailed knowledge of local regulations and the underwater ecosystem is required. Local, regional and international policies, regulations and standards may limit options available for clearance. Underwater environments often contain rare or endangered marine life, historical sites, war graves, sensitive infrastructure or other concerns. Planning should take these into account. Options to mitigate the EO may then be reduced. There are two general choices available for sites with underwater EO: clear the EO, or leave the EO in place and manage the site.

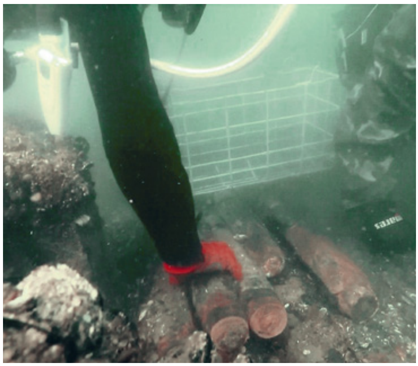


Figure 18 Ukraine Special Emergency Services scuba diver recovering AXO in the Black Sea.

Clearance options

Clearing underwater EO has two options available: dispose of EO *in situ*, or recover EO for disposal at an alternate location. *In situ* disposal tends to be the safest option to minimise risk to personnel but it also has the greatest impact to the surrounding environment. The process involves initiating an explosive counter-charge next to the EO on the seabed. The underwater pressure wave from the explosion can cause secondary damage to marine life (particularly marine mammals), infrastructure and other underwater objects in the immediate vicinity.

Figure 19 Vietnamese military team recovers EO at bridge construction site.

When the risk to the surrounding environment is too great, it may be acceptable to recover the EO from the seabed for disposal at an alternate location. The process of recovering EO is ordinarily conducted by divers using various recovery techniques, such as: attaching a line to the ordnance and pulling it to the surface, floating the EO with a lift bag, use of cranes and barges, and even the use of industrial magnets in limited situations. Once recovered, the EO is transported to an alternate location for disposal. The problem with this option is that more risk is assumed by EOD personnel handling the ordnance. EO that has been fired or otherwise subjected to an arming sequence (UXO), or EO with sensitive main charges may be too hazardous to be handled by personnel. Assessment of the threat and risk of underwater EO should be conducted by underwater EOD experts in consultation with local authorities. For situations in which clearance is not safe or practical, site management options should be considered.

Site Management options

There are many instances when the relatively limited impact of underwater EO in an area does not justify the associated risk of clearing the ordnance. There are also times when funding is not available or regulations do not support underwater EO clearance. In these cases, site management would be the only remaining option. The process generally involves marking the area on nautical charts, restricting activities such as fishing, dredging and development and periodic monitoring of the site to reassess the threat and risk. The *SS Richard Montgomery*, sunk in the Thames Estuary, is a well-known example of an underwater EO site that is managed in this manner. Germany is also known to manage many underwater AXO dump sites. In Kiel, underwater AXO sites are routinely mapped with sonar to monitor the location and condition of the ordnance. Germany also moves underwater EO from shipping channels and ship anchorages to some of the designated underwater dump sites that originated after the Second World War.

Another option is to accept the risk of underwater EO. As discussed in the section on risk, marine dredging typically accepts the risk of ordnance smaller than a specified diameter during operations. Ordnance detection and response procedures are actioned, in this option, to remove and dispose of found EO.

CASE STUDY: OPERATION RENDER SAFE[4]

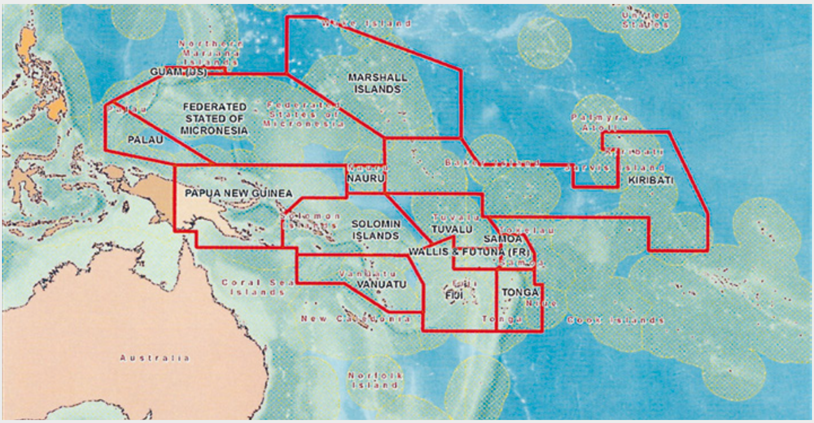


Figure 20 RENDER SAFE operation area.

Background

Advanced militaries have long maintained capability to survey and clear underwater EO. NGOs and commercial organisations have only recently begun underwater clearance operations. In many cases, advanced military forces still provide the most effective capability for clearance. Training and experience

4 Case study information is based on discussions with Royal Solomon Islands Police Force EOD teams and ADF personnel.

required of clearance divers can be extensive and require several years to develop a robust capability. Investment in such a capability is often reserved for military forces.

The Australian Defence Force (ADF) leads an ongoing multinational force operation every year in the Pacific islands to support EO clearance originating from the Second World War. The operation, entitled RENDER SAFE, includes military support from the United States, the United Kingdom, New Zealand, Canada and the Solomon Islands (SI). RENDER SAFE commenced in 2009 and has included deployments to Nauru in October 2010, Solomon Islands in November 2010 and 2013, Vanuatu during January to February 2011, and Papua New Guinea, first in Rabaul, from October to November 2011, then on the Kokoda Track in October 2011, and finally in the district of Torokina in 2014. The operation has cleared hundreds of sites and disposed of tens of thousands of ordnance items. This case study includes details and discussion of the operation conducted in the Solomon Islands in 2013.

From 28 October to 6 December 2013, Operation RENDER SAFE completed EO clearance activities on Guadalcanal, Tulagi Harbour and Russell Islands in areas identified by the SI government. Operations were partnered with the Royal Solomon Islands Police Force (RSIPF) EOD teams. This partnership assisted in overcoming language gaps and provided enhanced local knowledge on ordnance problems and disposal techniques. 12,164 explosive items with a net explosive weight of 6,851 kilograms were cleared during the period.

Figure 21 RSIPF using a mobile cutting system to cut ordnance before disposal in a burn pit.

Successes

Underwater EO clearance operations during RENDER SAFE in 2013 were successful in many aspects. The primary achievement was making SI communities safer through the removal of ERW. The operation also provided valuable capability development opportunities for RSIPF EOD teams. The RSIPF became aware of the training and equipment required to conduct underwater clearance and was able to obtain support from the U.S. to fill some of their needs. The U.S. Department of Defense Humanitarian Mine Action (HMA) programme provided RSIPF with scuba diving equipment and training. More recently, the HMA programme provided technical survey equipment and training. RSIPF EOD teams have proven their capability. As a result, they have been invited by ADF to support future RENDER SAFE operations throughout the region.

Figure 22 *In situ* disposal of underwater EO during Operation RENDER SAFE.

The ADF also demonstrated proficiency in coordinating multinational force participation in the operation. Although ADF encountered difficulties, it is unlikely that a non-military organisation could have coordinated the planning, operations and logistics required to support such an extensive clearance operation. In some cases, underwater clearance operations are more challenging in the Pacific region due to remoteness and limitations with logistics. However, even in more accessible areas, substantial coordination must take place in order to safely and effectively conduct operations. The ADF used their wide-ranging resources to provide medical support to diving and explosive operations, recompression chambers for diving casualties in case of an emergency and, most importantly, EOD experts to ensure EO disposal operations protected personnel, property and the environment. Throughout the operation, the ADF provided the required leadership to safely and effectively coordinate and manage activities.

Figure 23 Scuba divers preparing disposal charges during Operation RENDER SAFE.

Australian Clearance Dive Teams (CDT) primarily conducted the underwater EO clearance activities of RENDER SAFE. The CDT disposed of the EO *in situ*, recovered the EO for disposal at an alternate location, or, in rare circumstances, moved the underwater EO to deep-water dump sites. The CDT are highly experienced. Their knowledge and experience in diving, demolition and EOD operations allowed them to rapidly assess and select the proper disposal method based on a risk analysis framework. Training, experience and professionalism of advanced military forces and similar government organisations establishes a standard for underwater clearance tasks; anything less could result in unacceptable risk to operations and surrounding communities.

Figure 24 Transportation of bombs recovered during Operation RENDER SAFE to an alternate disposal location.

Challenges

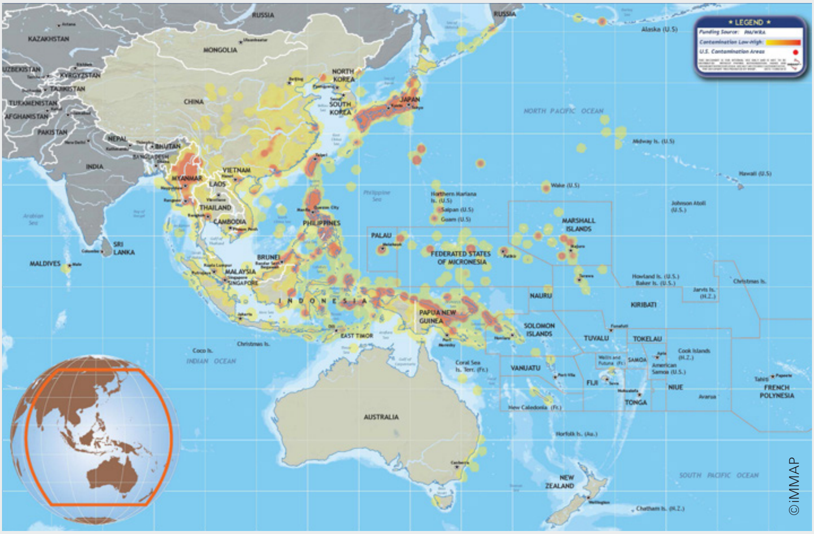


Figure 25 Heat map representing ERW in the Pacific from the Second World War.

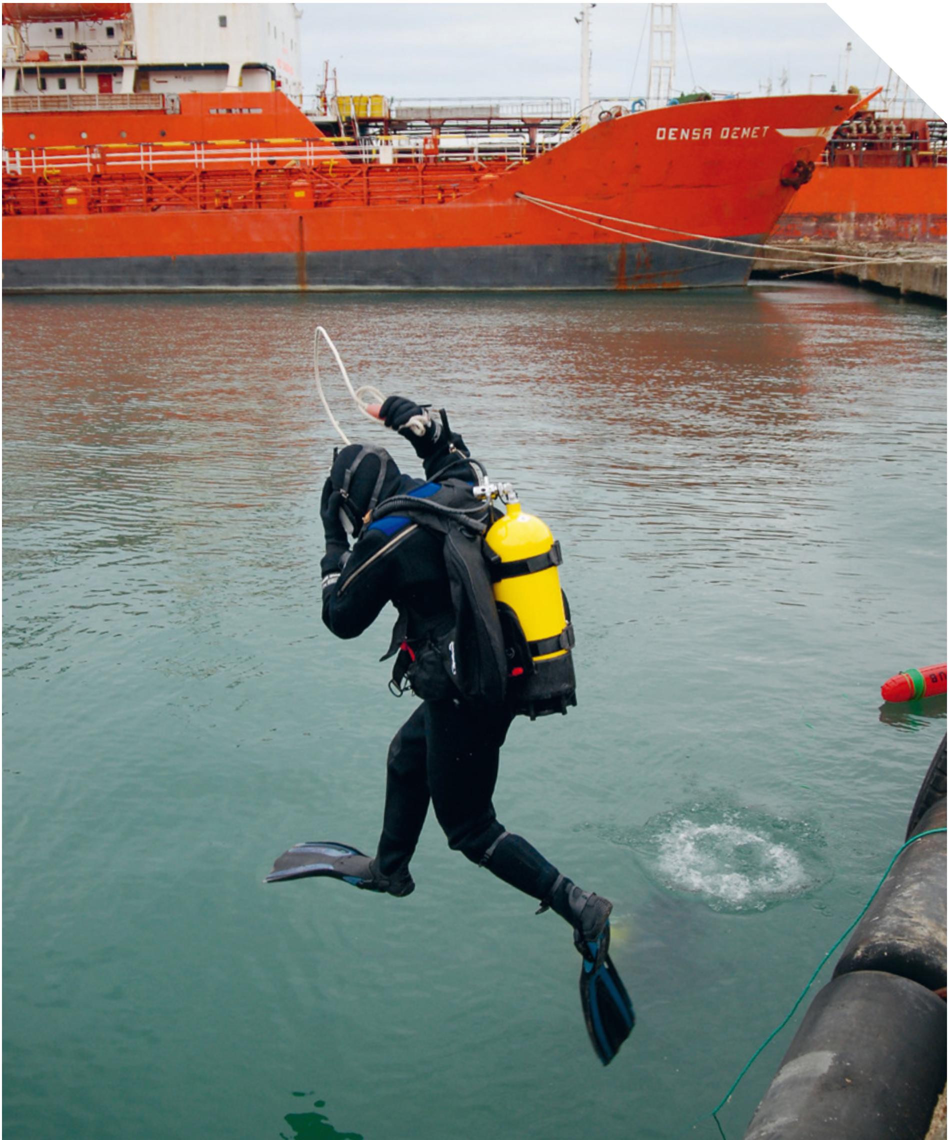
A common challenge to RENDER SAFE operations is the time and effort expended on the NTS process once forces have arrived on site. ADF relied heavily on the SI government to identify sites with EO contamination. It would be more efficient to complete the NTS process before deploying an entire RENDER SAFE contingent. Allocating personnel to complete a NTS during the scheduled reconnaissance phase or site survey, will provide more defined areas for clearance and enable a more efficient use of resources when clearance teams are available.

For decades, the Pacific has had a problem with information management for EO clearance. Clearance operations have taken place throughout the Pacific islands since the end of World War II yet documentation has seldom been undertaken. CDTs expended time and effort during RENDER SAFE searching for underwater EO at sites with known contamination, only to find out that other military clearance teams had previously cleared the areas. Clearance data collected during Operation RENDER SAFE is also only accessible to the ADF. A regional IM system at the Pacific Island Forum Secretariat was proposed on several occasions but has not yet been put in place or funded. Inefficient duplicated clearance operations will continue until a regional IM system is instituted.

Analysis

Risk to personnel, property and environment is greater in the clearance phase than in the previous survey phases. As a result, the requirement for adequate training and equipment is critically important. Diving operations are often a requirement for underwater EO clearance; even basic scuba dive training involves a substantial commitment of time and resources. Advanced dive training and support requirements are more onerous. Extensive investment in training and equipment is required for small boats or larger vessels. EOD procedures normally conducted on land become much more difficult underwater. Special training is needed for explosive demolition materials, equipment and procedures. These few examples highlight the commitment required to develop and maintain teams proficient in underwater EO clearance operations.

An analysis must be conducted to determine whether that country should develop their own underwater EOD capability or contract a commercial company for clearance, when there is extensive underwater contamination in their waters. Development of this capability is a significant process that could take up to a decade and a large amount of funding to mature to full capability (*See section on Training and Equipment Requirements*). A capability development programme is generally the best option when a country already has a capability for underwater EO clearance and only advanced training or equipment is required. Commercial underwater clearance can also be very expensive but clearance can be relatively quick and efficient if funding is available.

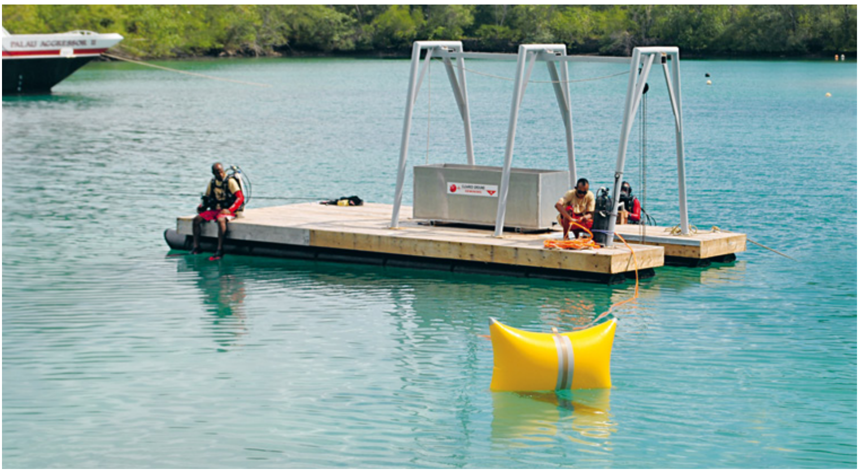


CONCLUSIONS AND RECOMMENDATIONS

Underwater survey and clearance of EO can be a difficult and expensive task. Solving underwater EO problems in vastly different areas cannot be achieved through a one-size-fits-all approach. Assessment of an area's problem, along with evaluation of the required capability for survey and clearance, will be useful in developing a plan to progress operations. As technology changes and capabilities mature, more options will become available although current choices are limited. A few mine action non-governmental organisations (NGO) have explored underwater EOD operations; commercial companies have made remarkable progress with technical surveys; and government organisations generally maintain the most capable clearance capacity. However, a single organisation with a full-range of capabilities is rare.

The mine action community has developed and mastered the NTS process through decades of clearing landmines and other explosive ordnance. Organisations with such detailed knowledge and experience, combined with underwater EOD experts, would be best suited to complete an NTS for areas with underwater EO. Commercial organisations are capable in undertaking desk studies and militaries often have access to databases with information required during the NTS process. However, mine action organisations are generally more proficient in on-the-ground NTS activities. Applying the NTS approach to underwater operations provides an opportunity to improve efficiencies.

In recent years, the offshore energy industry has significantly progressed technology suitable for use in underwater EO technical surveys. Companies have since used sonars and magnetometers to detect and map EO in coastal waters, rivers and lakes in support of commercial development activities. The technology



continues to mature and commercial organisations have often maintained an advantage in providing the most efficient and effective systems and processes for underwater TS operations.

Advanced military and government organisations continue to be best suited to clearance tasks. Extensive training, equipment and support requirements for underwater clearance require investment and commitment that is difficult to establish and maintain outside of government organisations. There are some commercial bodies with clearance capabilities but most fully capable underwater EOD teams are organised, trained and funded through government resources.

Understanding and applying experience from the mine action community, commercial industry and advanced militaries is key to the development and implementation of a successful underwater EO survey and clearance programme. Whether planning to develop a capability within a government organisation or simply contract a commercial business for the work, underwater operations will require a considerable investment. Before deciding on a solution, it is best to have an expert assess the underwater EO areas to provide advice and recommendations for future survey and clearance tasks.

ADDITIONAL RESOURCES

- Technology Demonstration Report for Underwater Survey Equipment in support of Explosive Remnants of War (ERW) Technical Survey Operations. (rev 1.0)

  Author: Orca Maritime Inc.

  Publisher: GICHD

  Date of publication: November 2015

- Assessment and Management of Unexploded Ordnance (UXO) Risk in the Marine Environment.

  Author: Cooper, N and Cooke, S

  Publisher: CIRIA

  Date of publication: September 2015

- Unexploded Explosive Ordnance (UXO) and Munitions Diving (Z275.6-11).

  Publisher: Canadian Standards Association

  Date of publication: August 2011

- A Guide to the Project Management Body of Knowledge – Fifth Edition.

  Publisher: Project Management Institute

  Date of publication: 2013

- IMAS 07.11 Land release
- IMAS 07.30 Accreditation of demining organisations and operations
- IMAS 08.10 Non-technical survey
- IMAS 08.30 Post-clearance documentation
- IMAS 09.11 Battle Area Clearance (BAC)
- IMAS 09.30 Explosive Ordnance Disposal
- IMAS 09.60 Underwater Survey and Clearance of Explosive Ordnance
- IMAS 10.20 S&OH – Demining worksite safety
- IMAS 10.70 S&OH – Protection of the environment

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Geneva International Centre
for Humanitarian Demining
Maison de la paix, Tower 3
Chemin Eugène-Rigot 2C
PO Box 1300
CH – 1211 Geneva 1, Switzerland
info@gichd.org