FINAL REPORT

Underwater UXO Standardized Demonstration Sites (Test Beds) Workshop Report

December 10, 2018

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Acknowledgements

The SERDP-ESTCP Program Office would like to thank the 50 participants of the test bed workshop for their interest, dedication, and perseverance during the nearly 8-hour workshop held during the 2018 SERDP-ESTCP Symposium at the Washington Hilton on 29th November 2018. A list of participants is provided in the appendices of the report. The workshop was preceded by numerous responses to a questionnaire by potential users and stakeholders of the test beds, PIs that have developed acoustic, magnetic, and electromagnetic systems that require demonstration, and by members of the SERDP and ESTCP Munitions Response Technical Committees (TC). The summary of these responses provided the background necessary to organize the workshop. Michael Book, Noblis Inc. was responsible for all the logistics associated with the workshop and provided excellent notes of the proceedings. Michael Richardson (IDA) and Kevin Williams (APL-UW) compiled this summary of the Test Bed workshop. Special thanks to the contributions of Mike Tuley (IDA), Shelley Cazares (IDA), Joe Calantoni (NRL), and David Bradley (UNH).

List of Acronyms

ADCP	Acoustic Doppler Current Profiler
APG	Aberdeen Proving Ground
APL-UW	Applied Physics Laboratory – University of Washington
AUV	Autonomous Underwater Vehicle
CAD	Computer-Aided Design
CTD	Conductivity-Temperature-Depth Profiler
DLS	Downward Looking Sonar
DMM	Discarded Military Munitions
EMI	Electromagnetic Induction
ESTCP	Environmental Security Technology Certification Program
FUDS	Formerly Used Defense Sites
IDA	Institute for Defense Analyses
LBL	Long Base Line
LF	Low Frequency (acoustics)
LIDAR	Light Detection and Ranging (remote sensing)
LSG	Laser Scalar Gradiometer
MBES	Multi Beam Echo Sounder
MCM	Mine Countermeasures
MR	Munitions Response
MTA	Marine Towed Array
NAVFAC	Naval Facilities Engineering Command
NRL	Naval Research Laboratory
NSWC-PCD	Naval Surface Warfare Center-Panama City Division
RTK GPS	Real-Time Kinematic Global Positioning System
ROV	Remotely Operated Vehicle
SAS	Synthetic Aperture Sonar
SERDP	Strategic Environmental Research and Development Program
TC	Technical Committee
TNO	The Netherlands Organisation for Applied Scientific Research
TOI	Target of Interest
USBL	Ultra Short Base Line
WHOI	Woods Hole Oceanographic Institution
UNH	University of New Hampshire
UXO	Unexploded Ordnance
YPG	Yuma Proving Ground

Executive Summary

This report provides a summary of a full day workshop on the development of standardized underwater UXO demonstration sites ("test beds") conducted during the Strategic Environmental Research and Development Program (SERDP) and Environmental Security Technology Certification Program (ESTCP) 2018 Symposium. The objectives of this workshop were to establish the requirements, framework, protocols, responsibilities, and time lines for development of a series of test beds used to test, evaluate, and demonstrate acoustic, magnetic, EMI, and optical systems designed to detect and classify underwater UXO. Potential systems include various combinations of commercially available sensors and platforms, systems developed for mine hunting (MCM) for the Navy, modifications of EMI and magnetic systems developed for terrestrial UXO remediation, and purpose-built systems developed with SERDP/ESTCP funding.

This report provides detailed information on the division of responsibilities among demonstration site managers, remediation system developers, and the ESTCP Program Office related to the design, construction, operation, maintenance, and use of underwater test beds. The program office is responsible for providing site requirements (this report), selecting and funding site contractors, selecting and providing targets of interest, and scoring demonstration results. The remediation system developers are responsible for demonstration plans; system preparation, testing, and shipping; and conducting and documenting demonstration results. The demonstration site manager is responsible for environmental permitting; planning and implementing demonstration site layout including target deployment, replacement, and removal; scheduling timelines for test bed demonstrations; providing basic logistic, facilities, and diver support; and providing all site environmental measurements.

Test bed site locations will be based on a combination of environments representative of sites and munitions slated for near-term remediation (surrogate environments) and test bed sites appropriate for systems and sensors that are ready for demonstration. Based on these criteria, a rather benign (easy) deeper area (5-20 m) free of native UXO or DMM with both sandy and muddy sediments should provide the best location for the development of the initial test bed. That area should contain large football-field-sized areas with little spatial and temporal variation in sediment properties. Targets of interest should be easily buried and exhibit little or no mobility. Based on lessons learned, a second location in shallow water (e.g. beach area) might provide a second test bed (there would be obvious efficiency advantages if both types of sites (deep and shallow) are available in close proximity). Test beds in vegetative areas, gravelly sites, and on coral habitats can follow as needed.

A list of environmental measurements (e.g., currents, waves, water column, bathymetry, meteorological, and sediment type, properties and layering) was developed with some suggested measurement approaches. It is the responsibility of the demonstration site managers to provide all long-term climatic characterization and near-term characterization during demonstrations. An extensive list of operational, logistical, and facilities requirements that should be available during demonstrations were developed as part of the workshop questionnaire.

The design of standardized underwater UXO demonstration sites will be informed by the layouts and lessons learned in developing terrestrial demonstration sites (APG and YPG). System training, testing, validation, and calibration will be conducted over a range of targets (approximately 30)

where types and positions are known to the demonstrators (e.g., calibration grids). Blind and/or open grids will be constructed where 100-200 targets and clutter are deployed at either at grids points where locations are known but the presence or absence of targets at those grid locations are unknown for blind grids or where unknown targets (100-200 targets) are deployed at random locations for open grids. It was decided that an independent team would develop scoring metrics and provide input to test bed design. Many compromises will be necessary to develop optimal test bed designs. One size fits all may not be possible and test beds may need to be relocated or re-seeded based on lessons learned.

It will be the responsibility of the ESTCP program office (in conjunction with system demonstrators) to select and procure the inert UXO and clutter used for these demonstrations (i.e., the standardized target repository). Test bed developers or managers will be responsible for storage, deployment, recovery, monitoring, and accurate positioning of all Targets of Interest (TOI) in grids provided by the Program Office. Navigation and positioning accuracy of the platforms and sensors is the responsibility of the system developers not the test bed managers. Test bed developers (managers) will be responsible for geo-positioning of UXO and clutter at the demonstration site. In order to exceed the performance objectives expected from demonstration plans, UXO and clutter should be geolocated to within a 1-m diameter circle.

1. Introduction

A workshop on the development of ***standardized underwater UXO demonstration sites ("test beds")*** was conducted during the Strategic Environmental Research and Development Program (SERDP) and Environmental Security Technology Certification Program (ESTCP) Symposium on 29 November 2018 between 8:00 AM to 4:00 PM in the Cardozo room of the Washington Hilton. This workshop was preceded by a questionnaire (Appendix A) to relevant PIs, TC members, and technical advisors with the objective of focusing the workshop objectives, limiting discussion to issues directly related test bed development, and providing a starting point for further discussion and debate. This approach proved mostly successful.

Michael Richardson summarized thirty-seven questionnaire responses (Appendix B). The interest in the development of underwater test beds was evident by a fully packed room with 50 participants (Appendix C). The discussions were both lively and instructive and most participants remained for the full 8-hour meeting. It is obvious that the requirements for and design of test beds differs based on the environments of interest, the types of sensors and platforms, the planned use of sensors, and the stage of sensor/platform development.

We hope this document provides those proposing to develop and manage the underwater UXO Standardized Demonstration Sites a better understanding of the requirements of UXO remediation system developers and end users in order to provide a well-integrated way forward for successful underwater test bed design, development, and management. *A call for test bed proposals will be included in the ESTCP Munitions Response Program FY2020 funding.*

2. Background

SERDP/ESTCP MR conducted three sidebar symposium meetings (2011, 2017, and 2018) to discuss the development of, and requirements for, standardized demonstration sites for SERDP and ESTCP underwater Munitions Response (MR) projects. This report summarizes the results of those meetings and provides a guide for those proposing to design, develop, operate, and maintain underwater UXO Standardized Demonstration Sites (test beds). These test beds will be designed to test and demonstrate sensor platforms used for detection and classification of UXO for underwater remediation. These test beds are focused on both wide area and detailed survey system demonstrations but do not include test beds designed for demonstration of predictive models for UXO burial and migration.

Several ESTCP demonstrations have been conducted using test beds developed by the system developers. ESTCP now seeks to develop test beds that can be used by multiple investigators and multiple sensors systems and allow quantitative comparisons (scoring) by independent contractors. This approach should also decrease the cost of demonstration of multiple systems.

3. Objectives of the 2018 Workshop

ESTCP Munitions Response Program has a requirement to develop a series of demonstration sites to test and evaluate the sensors and platforms that are designed to detect and classify UXO in the underwater environment. The approach should follow the framework for UXO standardized sites

developed for demonstration of magnetic and electromagnetic systems designed for detection and classification of UXO on land. The terrestrial standardized sites were developed at the Aberdeen Proving Ground (APG) and the Yuma Proving Ground (YPG). Michael Tuley (IDA) described the development and use of these sites during the workshop.

The objectives of this workshop were to establish the requirements, framework, protocols, responsibilities, and time lines for test beds used to test, evaluate, and demonstrate acoustic, magnetic, EMI, and optical systems designed to detect and classify underwater UXO. Discussion and comparisons of the merits of specific test bed sites was not encouraged.

The results of this workshop should provide developers and managers of underwater test beds basic information needed to generate proposals for designing, developing, operating, and managing these test beds. This report should also provide detailed information on division of responsibilities for the development of demonstration plans. It is important that remediation system developers provide demonstration requirements during test bed development and have early interaction with test bed managers during the development of demonstration plans.

4. Responsibilities

Table 1 is provided to give overall guidance as to the responsibilities of the three main contributors (the program office, the remediation system developers, the demonstration site managers) to the overall success of ESTCP Underwater UXO Demonstration activities. Many of the entries in the table are discussed in detail within the various sections of the document. Within those sections, if assignment of responsibilities is not given, the table is assumed to give guidance to those that seek to establish, operate, and maintain test beds.

5. Platforms and Sensors

A number of sensors and platforms are or should be ready for testing and demonstration in the next few years (See Appendix D). Potential systems include various combinations of commercially available sensors and platforms, systems developed for mine hunting (MCM) for the Navy, modifications of EMI and magnetic systems developed for terrestrial UXO remediation, and purpose-built systems developed with SERDP/ESTCP funding.

Sensor modalities include high and low frequency acoustic sensors, various magnetic sensors, optical systems including LIDAR and traditional video and photographic systems, and cued and single pass electromagnetic sensor combinations. Platforms include AUVs, ROVs, towed systems, surface systems, crawlers, and airborne platforms. Based on the requirements of various sensors and platforms a single test bed will probably not be adequate for demonstration of all systems. For the purposes of test bed requirements, the most important division is between shallow water (< 5 m) and deeper water (> 5 m) applications. Additional test beds may be required for coral, gravelly, and shallow grass bed environments.

Table 1: Responsibilities of the program office and contractors involved in ESTCP Underwater UXO Standardized Demonstration Site (test bed) activities. More details relative to these responsibilities are given within this document.

RESPONSIBILITIES		
Program Office	**Remediation System Developer**	**Demonstration Site Manager**
Definition of site(s) requirements	System preparation and shipping	Obtain and maintain all environmental assessments required
Selection of sites and site contractors. Determine needed environmental measurements	Demonstration Plan	Provide both historical and real time environmental measurements/characterization
Define demonstration site design (framework)	Define needs and timeline in collaboration with Demonstration Site Contractor	Plan and Implement demonstration site layout
Emplacement Plan - Determination of targets of interest (TOI) - types, numbers, sizes, grids, accuracy of placement	Conduct Demonstration	Carry out TOI placement that fulfills program office specifications
Supply TOI	Provide program office preliminary results suitable for scoring	Develop plans and timelines for accommodating multiple System Demonstrations
Determine scoring methodology	Document Demonstration Results	Provide logistics, facilities, ship, diver support
Implement Scoring procedures		Provide TOI replacement fields as required by program office

6. Timeline

Demonstration sites for wide area and cued survey systems that are designed for shallow water or deeper water will certainly have different environmental requirements but the timelines associated with demonstrating a variety of systems in a cost-efficient manner will be similar.

Developing timelines that fulfill program office requirements and remediation system developer needs is the responsibility of the demonstration site manager. One can envision timelines associated with extensive use of a demonstration site by several systems within specified testing periods. Alternatively, a more open-ended site philosophy is possible where system demonstrations can be carried out anytime weather/regulations permit provided the appropriate planning has been carried out in advance.

Proposals need to explicitly address demonstration timelines and associated costs. This should include a description of both the yearly activity that will be supported as well as a general summary of a possible five-year evolution of the site. The following sections serve to inform the proposer relative to the site contractor responsibilities summarized in Table I.

7. Logistics and Safety

One of the biggest issues is associated with the permitting process. This is especially relevant for active, higher-powered acoustic systems or for platforms that crawl on the bottom. Burial or placement of UXO-like targets may also present permitting issues in vegetative areas. Permits should be obtained as early as possible, for the longest time, and include the widest range of sensors and platforms as possible. It may take up to a year to obtain all the required permits. Remediation system developers should provide timely well thought out demonstration plans that include extensive early interaction with test bed managers. Past experience suggests some PIs have excellent theoretical expertize but little experience in operating in dynamic (harsh) marine and estuarine environments.

Another topic that should be considered is diver and explosives safety. Methods need to be developed to either avoid areas where explosives (UXO or DMM) are suspected, or to detect and then clear the test beds of any potential targets (UXO or clutter). The needs and methods of clearance or avoidance may differ with sensor types. Avoidance of areas with explosives is the preferred option for the initial test beds.

8. Types of Test Bed Environments

Most workshop participants suggested beginning with a limited number of test bed environments. Test beds will evolve based on successes and failures and the lessons learned can be applied to future test beds design and management. The location of test bed sites should be based on a combination of environments representative of sites and ordnance slated for near-term remediation (surrogate environments) and test bed sites appropriate for systems and sensors that are ready for demonstration (Appendix D). These environments can be defined by sediment types, water depths, and hydrodynamic conditions, sub-bottom structure, and biologics.

The most basic description of environments includes lakes, rivers, bays, estuaries, harbors (especially near piers and docks), near-coastal shallow (< 5 m), and deeper coastal (5-40 m) sites. Sediment types are generally divided into mud, sand, gravel, coral, cobbles, and vegetative (e.g., sea grass meadows). Most previous ESTCP demonstration sites were sandy followed by muddy sites. This order of sediment dominance is in general agreement with the distribution of sediment types in US coastal waters and an evaluation of sediments of sites in the FUDS database (Appendix E).

Many sensors and platforms are designed (optimized) for specific environments where burial or proud positioning of targets is important. Buried targets are required for evaluation of LF sonar, EMI, and magnetic systems: whereas, proud targets are required for demonstration of high-frequency acoustic and optical systems. Previous wide area surveys with magnetic sensors suggest that up to 70% of UXO are found buried in sandy and muddy environments. UXO mobility is most common in areas of where strong hydrodynamic forcing is prevalent: e.g., surf zones and rivers. Burial state and mobility are also important considerations for the stability and longevity of target grids used for demonstrations. Shallow water areas with potential human exposure are of higher priority as surrogate test bed environments.

Participants expressed no clear preference for mobile, semi-permanent, or permanent test beds. This, in part, results from a lack of definition for these concepts and from the variety of environments and sensors and platforms selected for demonstration. Shallow-water sites in energetic (e.g. surf zone) areas may require mobile or at least semi-permanent target deployment. Permanent sites with occasional rearrangement of UXO are appropriate for deeper sites.

Based on the discussion above, a rather benign (easy) deeper area (5-20 m) free of native UXO or DMM with both sandy and muddy sediments might provide the best site for the development of the initial test bed. A 1-km^2 area is need so as to allow adequate turning space for AUV and towed systems and should contain large football-field-sized regions for target grids with little spatial and temporal variation in sediment properties. Targets of interest should be easily buried and exhibit little or no mobility. Naturally occurring clutter items need to be located and eventually characterized. This is especially important if clutter is close to seeded UXO creating trouble resolving UXO and clutter thus limiting detection and classification. Detection and classification of clutter might be done with detection systems (acoustic or EMI) of opportunity prior to seeding the test bed or during and after test bed demonstrations. A second location in shallow water (e.g. beach area) might provide a second test bed. Test beds in vegetative areas, gravelly sites, or on coral habitats can follow.

9. Environmental Measurements and Characterization

Environmental measurements are important inputs for choosing the appropriate demonstration sites. Platform operational constraints, UXO deployment and recovery, prediction of UXO subsequent burial or mobility, and sensor performance are important drivers. The first three require more general (think climate) and temporal (long-term) information on currents, waves, tides, bathymetry, meteorological conditions, and sediment type and layering.

For sensor performance, real-time measurements of sediment and water characteristics and weather and hydrodynamic conditions should be made. At a minimum, water surface and water column measurements should include a CTD (salinity, temperature, conductivity, and depth), turbidity, sound speed, current speed, tides, and wave height statistics (bottom mounted ADCP or wave rider buoy). Basic meteorological conditions (air temperature, humidity, wind speed and direction, and barometric pressure) should be continuously monitored before, during and after demonstrations. Appropriate hydrographic, meteorological, and sediment properties should be measured to allow prediction of subsequent burial and mobility of UXO and clutter.

Sediment type and layering needs to be quantified over the entire test bed. Acoustic characterization coupled with direct sediment sampling is suggested. Bathymetry, sediment texture, finer scale seafloor topography (bottom roughness), backscatter strength, and surface clutter should be characterized using high-frequency side-scan sonar or appropriate optical techniques. Lower-frequency subbottom profiling should be used to characterize near surface layering and to detect target like contacts. Anomaly avoidance should be considered. Cores, grabs, and in situ probes should be used to determine sediment strength, sediment grain size distribution, porosity, bulk density, sediment and water conductivity, sediment permeability, magnetic susceptibility, and sediment geoacoustic (sound speed and attenuation) properties. Bottom-mounted video characterization of biological activity (fish and larger benthos), bottom turbidity, and sediment transport events should be considered. Near-surface sediment (upper 50 cm) measurements should be emphasized.

A list of sediment, weather, and water column properties should be developed by the test bed managers and include appropriate collection and measuring techniques. Common sampling and analysis approaches need to be developed and approved. Temporal and spatial scales of sediment characterization need to be determined based on site characteristics and sensor requirements. Sediment, water surface, water column, and meteorological characterization are very mature fields with well-established sampling and analysis techniques.

Discussions among the ESTCP program office, system demonstrators, and test site managers should insure that all relevant environmental measurements are conducted before and during demonstrations. However, care should be exercised to avoid oversampling in both space and time. Highly specialized remediation-system-specific environmental measurements may be the responsibility of the system demonstrators.

10. Operational Requirements and Test Bed Design

Most systems and platforms require shore-based wet and dry (electronics, office, meeting rooms, and internet access) laboratory space for sensor and platform preparation before deployment. Other potential requirements include a) basic machine shops for system and platform repair or modifications, b) cranes for platform deployment, c) access for large vans or containers (up to 40 ft.), d) medium-sized boats (20-50 ft.) for platform deployment, movement, and recovery as well as supporting diver operations, e) small boat launches, and f) diving support facilities for filling tanks and a nearby recompression chamber. Shipment of systems and support to the test bed site is an important consideration as are travel and nearby accommodations for all personnel.

Many participants suggest a 1-km^2 area is required for the test bed grids for deeper water and perhaps a quarter of that for shallow water sites. The area defined for deeper water needs to allow adequate turning space for towed and AUV systems. Test beds that allow demonstration of multiple sensor modalities, platform types, and environments are preferred. Setup, maintenance, and scoring of test bed demonstrations will be carried out by entities independent of the remediation system developers. This is a similar approach used in terrestrial UXO demonstrations. System developers agreed multiple projects could use a single test bed but most prefer non-overlapping time schedules for logistic reasons or acoustic contamination. Test bed managers are responsible for scheduling demonstrations on a not-to-interfere basis. Vessel support will be required to deploy targets, support divers, recover malfunctioning platforms, and maintain the test bed.

It was decided that demonstrations should be scored by an independent team. System calibration, training, validation, and testing should be done over a range of targets and clutter where types and positions are known to system developers and demonstrators (calibration grid). Blind and open grid demonstrations should be conducted where the location and positioning of targets of interest (TOI) are unknown to the demonstrator. The standard terrestrial UXO test site at APG used for demonstrating Magnetic and EMI systems included a calibration area (known locations, known targets), blind grid area (blind grids where locations are known but the presence or absence of targets at those locations are unknown), and open areas (unknown locations). This graduated approach seems both reasonable and achievable for the underwater test beds. However, evolution of the test bed areas (e.g., starting with just a calibration area and designing the next areas based on lessons learned) may be most cost effective.

Many compromises will be necessary to develop optimal test bed designs. One size fits all may not be possible and test beds may need to be relocated or re-seeded based on the issues listed above. The performance metrics (scoring) used for underwater demonstrations should be based on how many TOI can be correctly identified and how many non-TOI are incorrectly identified as TOI (false alarms). Eventually, the overall value of different remediation technologies must be related back to the cost.

Questions to be addressed by further discussions/working groups/program office: How should objects (both TOI and clutter) be emplaced? How long do blind targets need to remain in place (e.g., multiple demonstrations or related to mobility)? How often should the position of embedded targets be checked? What is the optimal spacing of targets related to both radius of detection scoring and to sensor capability. Demonstration scoring requirements? Should the scoring be based on a) two small steps (detection and classification) or b) a single detection and classification step? What determines adequate classification? How is the deployment strategy affected by the number and types of TOI required for statistical analyses, the separation distance between TOI, the size of the potential test bed, the location and positioning requirements, potential mobility of TOI, the time and costs of deploying and recovering TOI, the types and characteristics of sensors and platforms, and the need for detailed calibrations of the sensor systems as configured during the demonstrations?

11. Navigational Requirements

Navigation and positioning accuracy of the platforms and sensors is the responsibility of the system developers not the test bed managers. Test bed developers (managers) will be responsible for geo-positioning of UXO and clutter at the demonstration site. In order to exceed the performance objectives expected from demonstration plans, UXO and clutter should be geolocated to within a 1-m diameter circle. Knowing where the UXO is placed is more important than accurately placing UXO or clutter at predetermined locations. Positioning should include all six axes (location, depth, and orientation).

In many cases direct RTK GPS navigation and positioning are not possible. Even in shallow water areas where RTK GPS provides cm-level positioning, UXO and clutter may be mobile and repeated surveys may be required. It is the responsibility of the test bed manager to procure or develop, operate, and maintain a navigation and positioning system providing the level of accuracy needed. Site managers should also provide a surveyed monument where system developers may install an RTK base station.

SERDP and ESTCP PIs have previously used a variety of navigation and positioning methodologies including RTK GPS masts or poles for shallow water and USBL and LBL systems for deeper water. Targets with embedded acoustic sensors (active and passive), temporary reflectors over targets coupled with MBES surveys, accurate marking of survey grid corners, and static lines of targets were all suggested. High tidal ranges might be exploited in shallow water allowing target burial and positioning similar to what is used in terrestrial environments (RTK-GPS).

12. Munitions and Clutter

It will be the responsibility of the ESTCP program office (in conjunction with system demonstrators) to select and procure the **inert** UXO and clutter used for these demonstrations (i.e., the standardized target repository). Test bed developers or managers will be responsible for storage, deployment, recovery, monitoring, and accurate positioning of all Targets of Interest (TOI) in grids provided by the Program Office. As discussed in section 11.0, geolocation accuracy to within a 1-m diameter circle is required for all TOI. Depth of burial and orientation of UXO must be accurately recorded during the demonstrations.

Three types of grids are being considered: a) calibration grids where specific targets and their locations are known, b) blind grids where potential locations are known but the presence or absence of targets at those locations are unknown, and c) open grids where locations are unknown. In all cases, a list of all potential targets (the standardized target repository) will be provided to the demonstrators. This approach will allow demonstrators to generate EMI dipole or acoustic response characteristics of potential targets for use in library or signal processing matching. The initial calibration grid will consist of approximately 30 UXO with equal numbers of small (20-40 mm), medium (41-81 mm), large (82-127 mm), and very-large (128-155 mm and up) UXO (ESTCP program office responsibility). The rationale for having size bins was motivated by the Explosives Safety Quantity Distance (ESQD) arcs (i.e., standoff distances) that are required when dealing with munitions (note that all munitions deployed in the test beds will be inert and contain no explosive material). A mixture of proud, partly buried, and fully buried targets will be

considered. UXO degraded by corrosion or biofouling will not be included in the initial demonstrations. A limited number of science targets (e.g., spheres or solid cylinders) may be included in the calibration grid. System demonstrators will provide science targets well in advance of their respective demonstrations.

The blind and open grids will consist of roughly 100-200 TOI, to be determined by the ESTCP program office (same mix of targets). It is expected that the calibration grid will also be used to verify that sensor systems are properly working before and after covering the blind and open grids. This is the equivalent to the validation strip commonly used at land test beds to validate detection and classification sensors performance before and after each day of operation.

Varieties of UXO targets and clutter have been used for sensor and platform development and testing and during past underwater demonstrations. These range from 20 mm up to 155 mm projectiles (Figure 1 and Appendix F). The emphasis has been on the larger-size (> 60 mm) targets. In most cases, targets were either dropped from the surface or placed by divers. For some studies, targets and clutter of opportunity were used, often in areas selected for future remediation. However, test bed design and site selection should lead to an avoidance of naturally occurring UXO and only a limited number of clutter items. ESTCP welcomes proposals for mechanized deployment and recovery of UXO and clutter but the ultimate selection and/or development of methods of deployment, monitoring, and recovery of TOI are the responsibility of test bed managers.

The following comments pertain to the selection of targets and clutter. Manufactured targets (if used) should match the acoustic and magnetic characteristics of targets found at remediation sites. Physical (shape, density, and CAD drawings), acoustic, magnetic, EMI characteristics should be measured for model and library matching. The effects of various fillers (air, water, and energetics) should be considered. The distance between various targets needs to be determined (e.g., APL-UW suggests 5-m separation for independent acoustic measurements. The same 5-m separation may be appropriate for initial scoring of demonstration results. Clutter should be fully characterized. A limited number of larger smart (instrumented) munitions (targets that have sensors embedded to allow tracking of motion due to environmental forcing) may be seeded in the demonstration grids in order to assure that changes in burial state or migration do not affect the demonstrations, especially related to scoring. Simple versions of smart munitions and smart clutter would at least provide information on movement (moved or not). This is especially important in shallow water (e.g., surf zones) where mobility and burial are to be expected. Embedded acoustic pingers will be considered for larger UXO to facilitate location and recovery of targets and clutter.

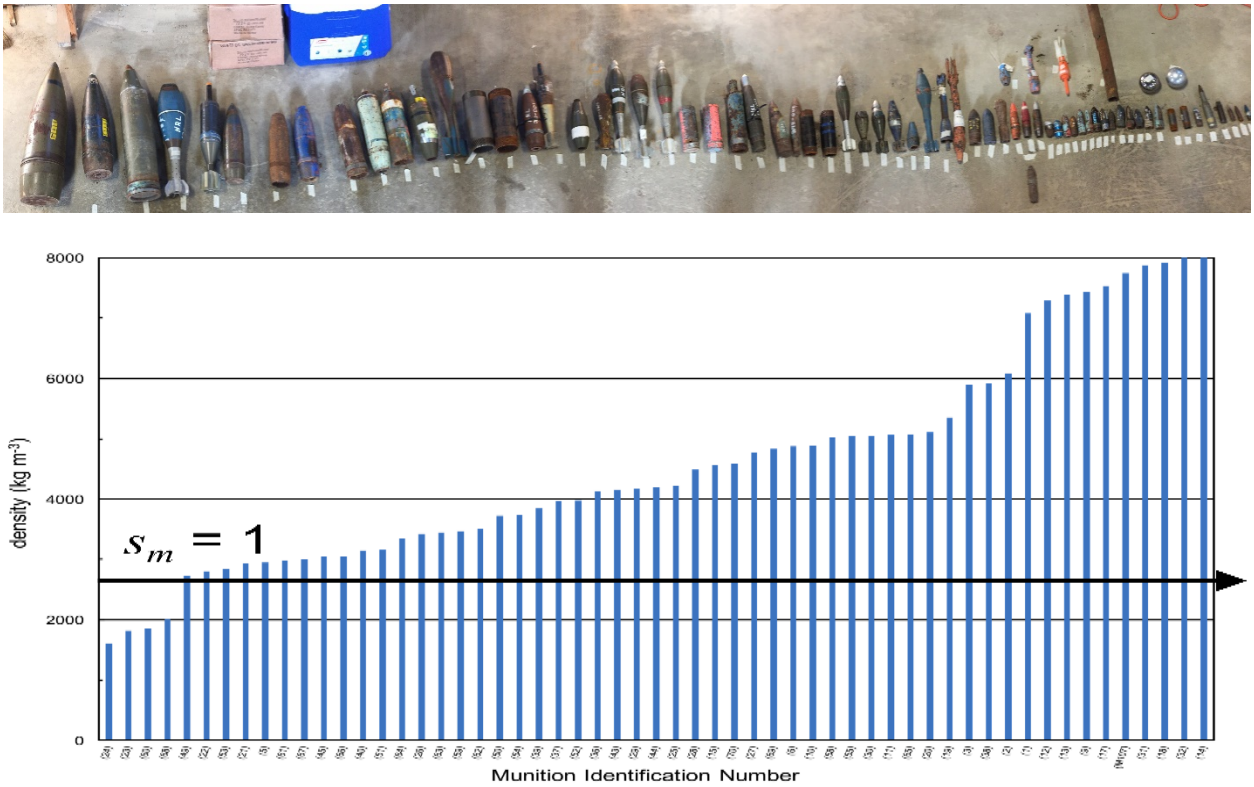

Figure 1. Photograph of UXO that are part of the NRL Blossom Point UXO repository. Sizes range from 20-25 mm projectiles on the right to 155 mm projectiles on the left. Bulk density ranges between 1800-8000 kg/m^3 with most densities greater than quartz sand (2650 kg/m^3). Photograph courtesy of Blake Landry, Marine Sciences Division, U.S. Naval Research Laboratory at Stennis Space Center.

Appendix A: SERDP/ESTCP Test Beds Questionnaire

SERDP/ESTCP MR conducted two sidebar symposium meetings (2011 and 2017) to discuss the development of and requirements for test beds and demonstration sites for SERDP and ESTCP underwater Munitions Response (MR) projects. The second sidebar meeting wandered off track and did not result in actionable results and no summary was produced. Attached is a summary of the 2011 sidebar meeting and a power point pdf of the 2017 meeting objectives. The test bed under consideration will be designed to test and demonstrate sensors and platforms used for detection and classification of UXO for underwater remediation. These include both wide area and detailed surveys but do not include test beds designed for demonstration of predictive models for UXO burial and migration. Several ESTCP demonstrations have been conducted using test beds developed by the system developers. It is past time to develop test bed concepts that can be used by multiple investigators and multiple sensors.

This questionnaire will be used to establish an agenda for the third meeting on requirements for test bed development. No date has been established for that meeting but it is hoped a full-day meeting can be scheduled for some time in 2018. The short 2-hour meeting held at last year's symposium provided insufficient time to develop a test bed plan or requirement for requests for proposals in the MR Statement of Need (SON).

What are the requirements for test beds for upcoming MR demonstrations, including types of environments, sensor and systems, munitions types and emplacement methods, logistics support, operational concepts, navigation issues, development of smart munitions, and environmental characterization required? SERDP/ESTCP has provided a list of questions to provide direction and scope for this meeting. Respondents can either provide answers to these questions or provide a response in their own format. The questions apply to the responder's system requirements but general requirements are also welcome.

Schedule and Length of 3rd Test Bed Meeting
Suggestions are welcome for a date, length, and location of the test bed meeting:
Would you or a member of your team attend this meeting?

Platforms and Sensors
List of sensors and platforms (acoustic, magnetic, electromagnetic, optical, and other types of sensors) and platforms (towed, ROV, AUV, UUV, surface vehicles. bottom crawlers):
Navigational Requirements:
Estimate of time (days, weeks) required for your demonstration:
Number of times your system has a test bed requirement:
Suggested and previously used test beds (include justification for these specific sites):
Munitions and Clutter
Types, numbers, and condition of UXO and clutter (be as specific as possible):
Burial state, location (positioning), mobility, and orientation:
Methods of emplacement and recovery:
Use of smart munitions:

Environmental Considerations and Characterization
Environmental types (near-shore coastal, off-shore oceanic, estuarine, swamps, rivers, and lakes):
Sediment types (sand, mud, coral, rocky, vegetation):
Water depths including bathymetry:
Hydrodynamic conditions:
Water clarity:
Environmental measurements needed (sediment or water column characterization):

Logistics
Permitting requirements, if known:
Vessel/platform support required:
Diver support:
Laboratory and electronics support:
Deployment support required (cranes, piers, etc.):
Travel or mobilization requirements:

Operational Requirements and Test Bed Design
When would your project require the test bed?
How large a test bed is required?
Limitations of temporal co-use of the test bed.
Mobile, permanent, or single use test beds?
Who scores and sets up test bed?

Appendix B: Summary of Test Bed Questionnaire Returns

Compiled by Mike Richardson, IDA

We had 29 out of 38 questionnaire returns from the PIs and 8 out of 15 from TC members and advisors. Every group that responded plans on sending at least one representative. Base on this response, I would expect about 30 attendees. This document provides a summary of the questionnaire responses. My biases are evident in this summary; therefore, this document should only be considered a starting point for further discussion and debate. I tried to include all comments and ideas from the questionnaires but we welcome any corrections, additions, or later thoughts to this summary document. In fact, a few minor changes to this document were based on suggested changes and additions to the first draft. I had to compile and organize many different responses. It is obvious that the requirements for and design of test beds differs based on the environment of interest, the type of sensor and platform, the planned use of sensor, and the stage of sensor/platform development. The more we can accomplish before the meeting the greater the chance for a document with insightful requirements and a way forward for a successful underwater test bed design.

Schedule and length

The meeting is scheduled during the SERDP Symposium on 29 November 2018 (Thursday) between 8:00 AM to 4:00 PM in the Cardozo room with a 90-minute break for lunch. The agenda and objectives for this meeting will be sent out at later date.

Platforms and Sensors

A number of sensors and platforms will be ready for testing and demonstration in the next few years (See Appendix A for an incomplete list). Potential systems include various combinations of commercially available sensors and platforms, systems developed for mine hunting (MCM) for the Navy, modifications of EMI and magnetic systems developed for terrestrial UXO remediation, and purpose-built systems developed with SERDP/ESTCP funding. The sensor modalities include high and low frequency acoustic sensors, various magnetic sensors, and cued and single pass electromagnetic sensor combinations. Platforms include AUVs, ROVs, towed systems, surface systems, crawlers, and airborne platforms. SERDP expects optical sensors (LIDAR or traditional photography) to be included in the demonstrations but no optical system is currently scheduled for demonstration. Based on the requirements of various sensors and platforms a single test bed will probably not be adequate for demonstration of all systems. For the purposes of test bed requirements, the most important division may be between shallow water (< 5 m) and deeper water (> 5 m) applications.

Conclusions: There is an immediate need for test beds to demonstrate current and emerging sensors and platforms. A list of sensor types and platforms ready for demonstration in the next 5 years should be compiled. Please add your sensors and systems to Appendix A.

Navigational requirements
Most of the navigational responses concerned the navigation and positioning accuracy of the platforms and sensors rather than the intent of the question, which was defining requirements and methods for positioning of UXO in the test bed and providing accurate positioning for ground truth. These are of course related but the accurate location of UXO and clutter are the responsibility of the test bed developers (managers) and the sensor/platform navigation is the responsibility of the PIs and should be part of their demonstration objectives. UXO and clutter positioning needs to be at least as accurate demonstration objectives. In many cases direct RTK GPS navigation and positioning is not possible. Even in shallow water areas where RTK GPS provides cm-level positioning, UXO and clutter may be mobile and repeated surveys may be required. The PIs listed a variety of navigation and positioning methodology including RTK GPS masts or poles for shallow water and USBL and LBL systems for deeper water. Targets with embedded acoustic sensors (active and passive), temporary reflectors over targets coupled with MBES surveys, accurate marking of survey grid corners, and static lines of targets were all suggested. High tidal ranges might be exploited in shallow water where target burial and positioning is similar to terrestrial environments (RTK-GPS).

Conclusions: Navigation and positioning requirements for UXO deployment needs to be established (sub meter?). These should be based on the stakeholders needs and an evaluation of what is reasonably possible at acceptable costs. Do commercial systems capable of that accuracy exist at affordable costs? If not, do they need to be developed? Environment ground truth also requires accurate navigation. Would fiducial marks or reference strips provide useful reference to calibrate platform navigation during demonstrations? These reference strips can also be used to calibrate detection and classification sensors and to insure platforms and sensors are functioning as designed prior to deployment.

Munitions and Clutter
A variety of UXO targets and clutter has been used for sensor and platform development and testing and during past underwater demonstrations. These range from 20 mm up to 155 mm projectiles (Appendix B). The emphasis has been on the larger-size (> 60 mm) targets. In most cases, targets were either dropped from the surface or placed by divers. For some studies, targets and clutter of opportunity were used, often in areas selected for future remediation. The following comments pertain to the selection of targets and clutter. Manufactured targets should match the acoustic and magnetic characteristics of targets found at remediation sites. Physical (shape, density, and CAD drawings), acoustic, magnetic, and dipole characteristics should be measured for model and library matching. The effects of various fillers (air, water, and energetics) should be considered. The distance between various targets needs to be determined (e.g., APL suggests 5-m separation for independent acoustic measurements). Clutter should be fully characterized. UXO mobility should be considered in most shallow water environments. One comment related to the over emphasis on Army UXO and suggests additional Navy and Air Force UXO should be considered.

There was very little interest expressed in the development or use of smart munitions. I think the point was to choose sites where subsequent burial and/or migration of UXO and clutter was not expected. UXO burial and migration modelers could provide predictions to assure that changes in burial state or migration do not affect the demonstrations, especially the scoring part. Simple

versions of smart munitions and smart clutter would at least provide information on movement (moved or not). This is especially important in shallow water (e.g., surf zones) where mobility and burial are to be expected. There may be some interest in measuring the source level of incident wave field at the targets. Embedded acoustic pingers were suggested to facilitate location and recovery of targets and clutter. In general, smart munitions were considered a luxury not a necessity. This may not be true for the surf zone.

Questions: Given that logistics (costs, diver or robotics time, size of area, and distance between targets) controls the number of UXO targets and clutter deployed, what is the best mixture of UXO types, numbers of each type, fillers, condition (biofouling, corrosion, other degradation), burial state, orientation, and number and diversity of clutter that can be deployed. Will these restrictions require multiple test beds or frequent reseeding of a permeant site? Is a classification system for the state of UXO necessary needed (new, barely degraded, or extensively degraded)? Most UXO have been either dropped to the bottom or deployed by divers (buried). Is there a better, faster, safer, and less costly way for UXO and clutter deployment? Robotics? The importance and potential use of smart munitions should be debated.

Additional Questions: What size targets can be reasonably detected with underwater technology? What level of classification is needed? Is the separation of large targets (> 40 mm) from clutter sufficient or is the classification between 105 and 155 mm projectile important? How about separation into classes of small, medium, and large UXO? Is the separation of inert verses live rounds important? Water or air filled UXO may not be worth recovery or in situ remediation. Is the recovery of small bullets (20 or 25 mm) important or even possible? The intersection (Venn diagram) of 1) what is required, (2) is technically possible, and (3) what is cost effective needs to be decided. Should UXO degraded by corrosion or biofouling be included in initial demonstrations? How will the degradation of these targets be defined? How do we clear the test bed of potential targets of interest? Should sensor specific calibration of targets and clutter be considered and included as part of calibration strips?

Conclusions: A short list of targets and clutter needs to be developed. Deployment methods, positioning accuracy, and burial states and orientation, and condition need to be determined. One of the more difficult issues relate to the number and types of targets needed for statistical evaluation and comparison of various detection and classification systems.

Types of Environments

Most responders suggest beginning with a limited number of test bed environments. These environments can be defined by sediment types, water depths, and hydrodynamic conditions. The most basic description of environments includes lakes, rivers, bays, estuaries, harbors (especially near piers and docks), near-coastal shallow (< 5 m), and deeper coastal (5-40 m) sites. Sediment types were divided into mud, sand, gravel, coral, cobbles, and vegetative (e.g., sea grass meadows). To date most sites were sandy. Many sensors and platforms were designed (optimized) for specific environments where burial or proud positioning of targets is important. Burial state and mobility are also important considerations for the stability and longevity of the demonstrations. It was suggested that test beds include multiple sediments types and that test beds be established on both east and west coast of the US (not sure how the GOM or coral

environments fits into this separation). Shallow water areas with potential human exposure are of higher priority as surrogate test bed environments.

Conclusions: Define the types of test bed environments representative of sites that are slated for remediation within the next 5 years. Select environments that can be used for demonstration of multiple sensor modalities and platforms supported by SERDP and DOD and that best represent near term underwater remediation requirements. It would seem the requirements for shallow-water and deep–water test beds might be different. This especially relates to potential for mobility and burial from high-energy hydrodynamic processes. Another division might be sensor related. Buried targets are preferred for evaluation of LF sonar, EMI, and magnetic systems: whereas, proud targets are preferred for high-frequency acoustic and optical systems. There was no clear preference for mobile, semi-permanent, or permanent test beds. This, in part, results from a lack of definition for these concepts and from the variety of sensors and platforms selected for demonstration. Shallow-water sites in energetic (e.g. surf zone) areas may be mobile or at least semi-permanent with a need for constant target redeployment. Permanent sites with occasional rearrangement of UXO are appropriate for deeper sites.

Potential Test Bed Sites

A number of sites have been used or proposed for SERDP development and ESTCP demonstrations. In no particularity order, these include ACOE Duck facility, various sites near Panama City (NSWC-PCD), Sequim Bay (APL), approaches to Boston Harbor (NRL), Martha's Vineyard Coastal Observatory (WHOI), Tampa Bay (SRI), Delaware Bay (U of Delaware), APG pond, Pat Mayes Lake, San Jacinto Lake, and Culebra Island. A variety of other sites have been used for system testing and live-site demonstrations. Most have been inadequately characterized with respect to environmental characteristics and target location and positioning. Proposals should be solicited for development of test beds from the next statement of Need (SON) that is based on the requirements established during the symposium workshop.

Environmental Measurements and Characterization

Environmental measurements are important inputs for choosing the appropriate demonstration sites. Platform operational constraints, UXO deployment and recovery, prediction of UXO subsequent burial or mobility, and sensor performance are important drivers. The first three require more general and temporal information on currents, waves, tides, bathymetry, sediment types and layering.

For sensor performance, real-time measurements of sediment and water characteristics and hydrodynamic conditions should be made. At a minimum water surface and column measurements should include a CTD (salinity, temperature, conductivity, and depth), sound speed, current speed, tides, and wave height statistics (bottom mounted ADCP). Appropriate hydrographic and sediment properties should be measured to allow prediction of subsequent burial and mobility of UXO and clutter.

Water clarity is limiting for optical systems and for deployment and recovery of targets. Acoustic, EMI and Magnetic systems are not adversely affected by poor visibility. Hence, water clarity does not seem to be of much interest as a parameter to determine sensor performance but reasonable visibility (3-5 m), slow currents, and low sea states are more requirements for diver deployment and recovery of targets.

Sediment type and layering needs to be quantified over the entire test bed. Acoustic characterization coupled with direct sediment sampling is suggested. Bathymetry, sediment texture, finer scale seafloor topography, backscatter strength, and surface clutter should be characterized using high-frequency side-scan sonar. Lower-frequency sub bottom profiling should be used to characterize near surface layering and to detect target like contacts. Anomaly avoidance should be considered. Cores, grabs, and in situ probes should be used to determine sediment strength, sediment grain size distribution, porosity, bulk density, sediment and water conductivity, sediment permeability, and sediment geoacoustic (sound speed and attenuation) properties.

Conclusions: A list of sediment and water column properties should be developed including appropriate collection and measuring techniques. Common sampling and analysis approaches need to be developed. Temporal and spatial scales of sediment characterization need to be determined based on-site characteristics and sensor requirements. This is a very mature field with well-established sampling and analysis techniques. Characterization is best left to the experts that may include a combination of test bed mangers and demonstrators.

Logistics and Safety

One of the biggest issues is associated with the permitting process. This is especially relevant for active, higher-powered acoustic systems or for platforms that crawl on the bottom. Burial or placement of UXO-like targets may also present permitting issues in vegetative areas. Permits should be obtained as early as possible, for the longest time, and include the widest range of sensors and platforms as possible. It may take up to a year to obtain all the required permits. Emphasis should be placed on timely well thought out demonstration plans and extensive early interaction with test bed directors and organizers. Past experience suggest some PIs have excellent theoretical expertize but little experience in operating in dynamic (harsh) marine and estuarine environments. Another topic that should be considered is diver and explosives safety. Methods need to be developed to either avoid areas where explosives (UXO or DMM) are suspected to be present or to detect and then clear the test beds of any potential targets (UXO or clutter). The needs and methods of clearance may differ with sensor types.

Operational Requirements and Test Bed Design

Most systems and platforms require shore-based wet and dry (electronics, office, meeting rooms, and internet access) laboratory space for sensor and platform preparation before deployment. Other potential requirements include a) basic machine shops for system and platform repair or modifications, b) cranes for platform deployment, c) access for large vans or containers (up to 40 ft.), d) medium-sized boats (20-50 ft.) for platform deployment, movement, and recovery as well as supporting diver operations, e) small boat launches, and f) diving support facilities for filling tanks, nearby recompression chamber. Shipment of systems and support to the test bed site is an important consideration. A point of contact for shipping is necessary. The shipment of lithium batteries was listed as a potential issue. Travel to and mobilization at the test bed site should be factored in the site location.

Many participants suggest a km^2 area is required for the test bed. This will allow adequate space for turning for towed and AUV systems. Can test beds be optimize for demonstration of multiple

sensor modalities, platform types, and environments? If multiple test beds are developed, should this be based on regions (east or west coast), based on logistics, compatible sensor modalities, similar platforms, or environments (shallow vs deep, sediment types, munitions types, or hydrodynamic conditions).

Most PIs suggest that the setup, maintenance, and scoring of test bed demonstrations be done by entities independent of the system developers (PIs). This is a similar approach used in terrestrial UXO demonstrations. A long-term commitment for test bed support and environmental data collection is required. There was a mixture of responses to the types of test beds. Mobile, permanent, single use or semi-permanent with exchangeable targets are a few of the scenarios suggested. Most PIs suggested multiple projects could use a single test bed but most prefer non-overlapping time schedules for logistic reasons or acoustic contamination.

Vessel support may be required to deploy targets, support divers, recover malfunctioning platforms, and maintain the test bed. Will test bed specific platforms be required to deploy sensor systems that do not provide their own platforms?

Scoring: It was generally decided that demonstrations should be scored by an independent team. System training and testing should be done over a range targets and clutter where types and positions are known to system developers and demonstrators. Blind demonstrations should be conducted where the location and positioning of targets of interest (TOI) are unknown to the demonstrator. Standard UXO test site at APG for demonstrating systems included a calibration area (known locations, known targets), blind grid area (known locations, unknown targets), and open areas (unknown targets and unknown locations). Is this graduated approach reasonable and achievable for the underwater test beds?

Questions: How long do blind targets need to remain in place (e.g., multiple demonstrations or related to mobility)? How often should the position of embedded seeds be checked? What is the optimal spacing of targets related to both radius of detection scoring and to sensor capability. Should the scoring be based on a) two small steps (detection and classification) or b) a single detection and classification step? What determines adequate classification?

Conclusions: Those involved in previous test bed designed for EMI demonstrations should describe the process of development and use of those test beds (APG and YPG) and described methods of scoring. How do the requirements for underwater test beds differ? Is a gridded or random deployment of TOI best for underwater test beds? How is the deployment strategy affected by the number and types of TOI required for statistical analyses, the separation distance between TOI, the size of the potential test bed, the location and positioning requirements, potential mobility of TOI, the time and costs of deploying and recovering TOI, and the types and characteristics of sensors and platforms? Many compromises will be necessary to develop optimal test bed designs. One size fits all may not be possible and test beds may need to be relocated or re-seeded based on the issues listed above.

List of sensors and platforms

Underwater multi-axis EM sensors: cued EMI (Jacobs)
Acoustic Boss-like systems either towed or as part of AUVs

Low-frequency SAS (APL-UW, NRL, TNO)
High-Frequency SAS (ARL-Penn State)
High-Frequency phase-measuring sidescan sonar using shallow-draft surface vessel (WHOI)
High-frequency side scan sonar (WHOI, NSWC-PCD, TNO)
Sea Ox bottom crawler (Margolds, White River)
Crawler, ROVs, AUVs, drones EM and Mag (White River)
MCM systems: combined acoustic (SAS, DLS) and magnetic systems (MAGNUM. LSG) such as SSAM3 (NSWC-PCD)

List of potential UXO and clutter

UXO: 155 mm projectiles, 5” rockets, 120 mm and 81 mm mortars, corroded and pristine targets (NRL) 40 mm projectiles, 60mm mortars, 81 mm mortars, 3” naval rounds, 105 mm projectiles, 155 mm projectiles (Schultz)
Near shore: BDU33 practice bomb, MK 23 practice bomb, M38A2 practice bomb, M30A1 100-pound HE bomb; MK81 bomb, MK82 bomb, 2.25” SCAR rocket; 2.75” rocket motor with warhead, 3.5” rocket motor with warhead; 5” artillery, 6” artillery, 8” artillery, 12” artillery, 3 pounder cannon ball, 4 pounder cannon ball, 6 pounder cannon ball, 9 pounder cannon ball (Schwartz).
Deep water: M38A2 practice bomb, M30A1 100-pound HE bomb; MK81 bomb, MK82 bomb, 2.75” rocket motor with warhead, 3.5” rocket motor with warhead; 5” artillery, 6” artillery, 8” artillery, 12” artillery, 3 pounder cannon ball, 4 pounder cannon ball, 6 pounder cannon ball, 9 pounder cannon ball (Schwartz).
Clutter: anchors, paint cans, scuba tanks, crab and lobster traps, concrete blocks, cinder blocks, tires, rocks, munitions fragments, and cobbles or boulders. Clutter should be fully characterized.

Appendix C: List of Attendees

Name	Organization	Email
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Appendix D: List of Sensors and Platforms

AUVS

Combined acoustic (SAS, DLS) and magnetic systems (MAGNUM. LSG) such as SSAM3 (NSWC-PCD) **Ongoing MCM testing, ready for UXO demonstration**

Buried Object ID System (BIDS) (NSWC-PCD) **Testing in 2020**

Skyfish winged Down-look (NRL) **Demonstration in 2019**

Low Frequency Side-look (NRL) **Demonstration in 2019**

LIDAR (SCRIPPS) – **not currently being developed for SERDP**

CRAWLERS

Sea Ox bottom crawler (Margolds, White River)

EM and Mag systems (White River)

SENSORS DIRECTLY ATTACHED TO SHIP

SAS (ARL-Penn State) **testing in 2019, demonstration in 2020**

High-Frequency phase-measuring sidescan sonar (WHOI) **testing in 2019, demonstration in 2020**

TOWED SYSTEMS

eBOSS (Edge Tech, APL-UW) **testing in 2019, demonstration in 2020**

High-frequency side scan sonar (Edge Tech, APL-UW) **testing in 2019, demonstration in 2020**

Low-frequency SAS (TNO)

High-frequency side scan sonar (TNO)

Underwater multi-axis EM sensors: cued EMI (Jacobs) **demonstration in 2019**

Marine Towed Array (MTA (NRL)) **Ready for demonstration**

DRONES

EM and Mag (White River)

Astralite (LIDAR) Jeff Thayer **ready for 2019**

Appendix E: FUDS Database Summary

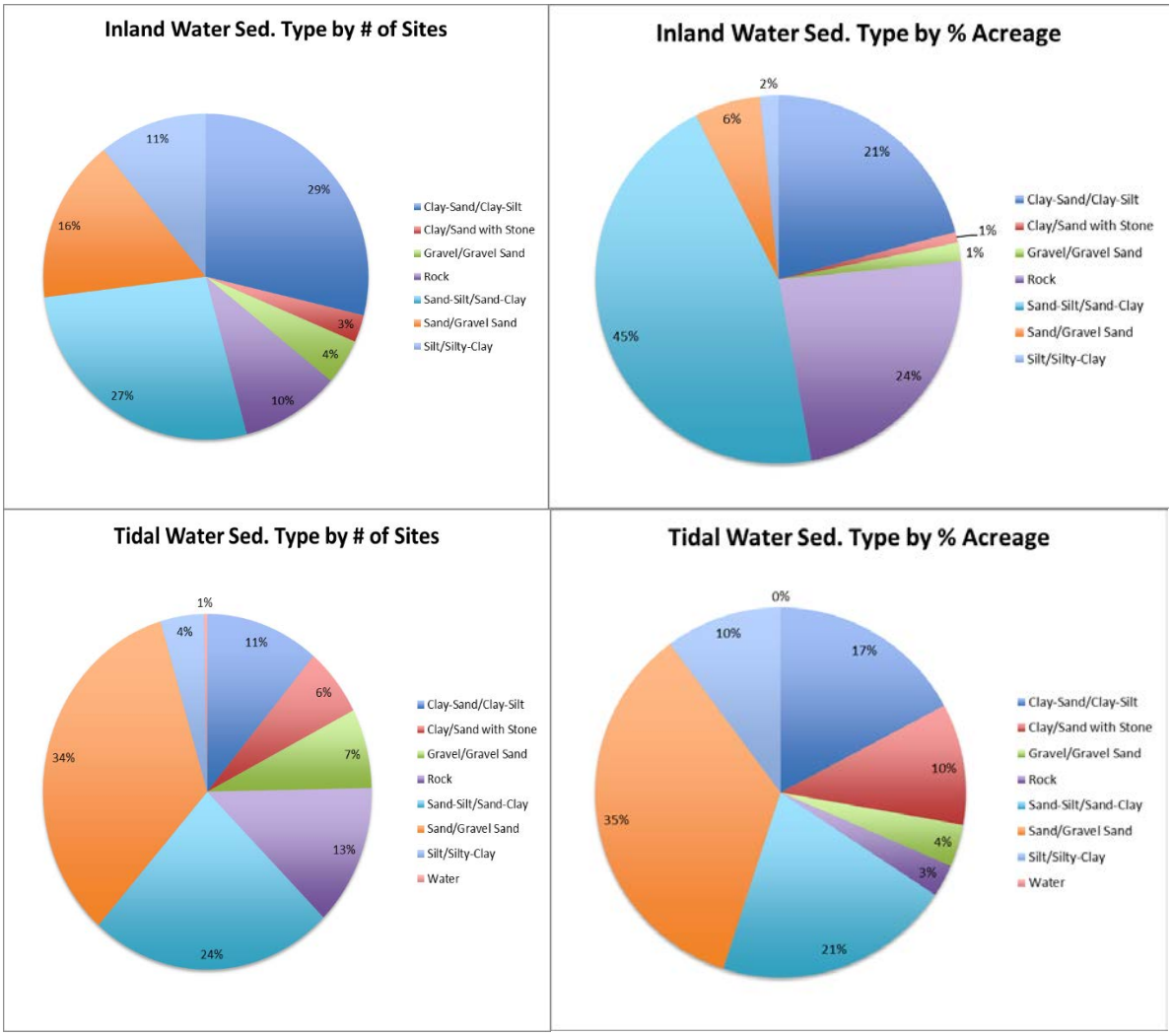

Figure E-1. Pie charts for sediment types found at inland waters and tidal waters site summarized from the Formerly Used Defense Sites (FUDS) database.

Appendix F: List of Potential UXO and Clutter

The ESTCP Program Office will develop a list of potential targets and clutter based in-part on the questionnaire responses. As a starting point, a list of suggested UXO and clutter items based on the questionnaire is provided in Appendix B. The list of UXO used at terrestrial demonstration sites (APG and YPG) is also included at the end of this appendix.

A short list of targets and clutter will be developed. Deployment methods, positioning accuracy, and burial states and orientation, and condition will be determined. One of the more difficult issues relate to the number and types of targets needed for statistical evaluation and comparison of various detection and classification systems.

Questions to be addressed by further discussions/working groups/program office:

Given that logistics (costs, diver or robotics time, size of area, distance between targets, and scoring requirements) controls the number of UXO targets and clutter deployed, what is the best mixture of UXO types, numbers of each type, fillers, condition (biofouling, corrosion, other degradation), burial state, orientation, and number and diversity of clutter that can be deployed?

Will these restrictions require multiple test beds or frequent reseeding of a permeant site?

Is a classification system for the state of UXO necessary needed (new, barely degraded, or extensively degraded)?

Most UXO have been either dropped to the bottom or deployed by divers (buried). Is there a better, faster, safer, and less costly way for UXO and clutter deployment? Robotics?

What size targets can be reasonably detected with underwater technology?

What level of classification is needed? Is the separation of large targets (> 40 mm) from clutter sufficient or is the classification between 105 and 155 mm projectiles important?

How about separation into classes of small, medium, large, and very large UXO? Is the separation of inert verses live rounds important?

Water or air filled UXO may not be worth recovery or in situ remediation. Is the recovery of small bullets (20 or 25 mm) important or even possible?

How is the intersection (Venn diagram) of 1) what is required, (2) is technically possible, and (3) what is cost effective decided?

Should UXO degraded by corrosion or biofouling be included in initial demonstrations?

How will the degradation of these targets be defined?

How do we clear the test bed of potential targets of interest?

Should sensor-specific calibration of targets and clutter be considered and included as part of calibration strips?

List of Ordnance targets at APG & YPG

Type	Description	Length (mm)	Width (mm)	Aspect Ratio	Weight (lbs)	Size
20 mm	20 mm M55	75	20	3.75	0.25	Small
40 mm	40 mm MK II	179	40	4.48	1.55	Small
40 mm	40 mm M385	80	40	2.00	0.55	Small
M42	Submunition	62	40	1.55	0.35	Small
M75*	Submunition	69	64	0.93	1.19	Small
BLU-26	Submunition	66	66	1.00	0.95	Small
BDU-28	Submunition	97	67	1.45	1.70	Small
57 mm	57 mm M86	170	57	2.98	6.00	Medium
MK118	MK118 ROCKEYE	344	50	6.88	1.35	Medium
60 mm	60 mm M49A3	243	60	4.05	2.90	Medium
81 mm	81 mm M374	480	81	5.93	8.75	Medium
M230	2.75-inch Rocket	328	70	4.69	9.41	Medium
105 mm	M456 HEAT RD	640	105	6.10	19.65	Large
105 mm	105 mm M60	426	105	4.06	28.35	Large
155 mm	155 mm M483A1	803	155	5.18	56.45	Large