Geophysical Classification for Munitions Response

Regulatory Fact Sheet | October 2014

This fact sheet was developed by the Interstate Technology & Regulatory Council (ITRC) Geophysical Classification for Munitions Response (GCMR) Team. It is the last of three fact sheets designed to provide basic information about geophysical classification for munitions response. For more information about this ITRC team, please visit the ITRC website at http://www.itrcweb.org/Team/Public?teamID=9.

Introduction

For decades, the Department of Defense (DOD) has produced and used military munitions for live-fire testing and training to prepare the U.S. military for combat operations. As a result, unexploded ordnance (UXO) and discarded military munitions (DMM) may be present on former ranges and former munitions operating facilities (such as production and disposal areas). Over 4,900 sites in the United States require a munitions response, with an estimated cost to complete of $13 billion and completion date of 2100.

To identify munitions for removal at these sites, DOD and its contractors have historically used various types of detection instruments to simply detect buried metal items. Consequently, on munitions response sites, most detected items must be uncovered and examined to determine whether they are military munitions. Typically, highly-trained, UXO-qualified personnel excavate hundreds of metal items for each munition recovered. Given the costs associated with this inefficiency, only limited acreage can be addressed with existing resources and budgets.

Geophysical Classification Process Overview

DOD's Environmental Security Technology Certification Program (ESTCP) and its research partners in academia and industry have developed and demonstrated a new approach, using a process called *geophysical classification,* to improve the efficiency of munitions response. As before, geophysicists use electromagnetic induction (EMI) sensors during an initial survey to detect metal items beneath the ground surface. Then, advanced EMI sensors specifically designed to support geophysical classification are used to collect additional data, which geophysical analysts can use to estimate the depth, size, wall thickness, and shape of each buried item. Geophysical classification is the process of using these data to make a principled decision as to whether a buried metal item is a potentially hazardous munition, called a target of interest (TOI), or metal clutter, debris, or geology (non-TOI) that can be left in the ground. Use of the geophysical classification process can focus a munitions response on excavating only those geophysical anomalies identified as potential munitions. The use of this process, in combination with quality assurance (QA) investigations of other anomalies, results in a more efficient, more rigorous, better understood, and better documented munitions response.

This fact sheet provides regulators responsible for munitions response sites with a source of information about geophysical classification that clearly explains what geophysical classification is, its benefits and limitations, and, most importantly, the information and data that regulators need to monitor and evaluate its use. This fact sheet also emphasizes using a systematic planning process to develop upfront data acquisition and decision strategies. Systematic approaches include the U.S. Environmental Protection Agency's (USEPA's) Data Quality Objectives (DQO) process and the Uniform Federal Policy for Quality Assurance Project Plans (UFP-QAPP).

Benefits of Geophysical Classification

Geophysical classification can focus a munitions response on excavating only those geophysical anomalies identified as potential TOI and those anomalies for which a classification determination cannot be made. By minimizing unnecessary excavations, the limited resources available for cleanup can be applied to address more land quickly, thus freeing up land sooner for appropriate use. The time required for unnecessary excavations not only prolongs munitions response, but also can be disruptive to communities or recreational areas because the public is prohibited from entering sites while excavations are taking place. This practice can result in extended area closures and evacuations. Additionally, digging unnecessary holes can disturb the landscape, vegetation, and cultural resources at these sites, whether they are recreational areas, habitat, farmland, or private backyards.

Using a simple but realistic cost model, if 75% of the detected anomalies can be confidently classified as non-TOI and left in the ground, then the area that can be remediated for a fixed budget roughly doubles. For example, at the former Camp Beale, California demonstration site, properly performed geophysical classification would have reduced the number of non-TOI items excavated by 78%, from 1,310 to 285.

Geophysical Classification Process

The geophysical classification process generally consists of three steps:

1. Measure the response of a buried metal item to an electromagnetic field using an advanced EMI sensor.
2. Analyze the measured response to determine parameters such as depth, size, wall thickness, and shape.
3. Use these parameters as inputs to a classifier, which is a computer program that sorts detected items as either likely TOI that must be excavated or as non-TOI.

Successful geophysical classification currently depends upon the quality of the initial geophysical survey. This initial survey is designed to detect all buried items to a specific depth using a time-domain EMI sensor or a magnetometer, and 100% site coverage should be achieved. Previous ITRC documents provide more information on technologies and quality considerations associated with geophysical surveys on munitions response projects (see *Survey of Munitions Response Technologies* (UXO-4) and *Quality Considerations for Munitions Response Projects* (UXO-5) at www.itrcweb.org). High-quality detection data with tight survey line spacing, precise geolocation, and low noise result in accurate anomaly locations and fewer false detections. These data characteristics lead to efficient classification.

> ***Cued Interrogation (Data Collection)—****Static data collection over an anomaly detected in a separate survey for improved classification*

The location of each item detected during the initial geophysical survey is recorded, to be revisited with an advanced EMI sensor to collect data needed to classify the anomaly. These data are acquired in a cued mode, which requires the advanced EMI sensor to remain stationary over each anomaly for approximately 30 to 90 seconds. During this time, thousands of spatial and temporal measurements are recorded from a variety of angles and locations. Field-level quality control (QC) checks should be performed at this stage to confirm that adequate signal-to-noise ratios are achieved, the sensor was properly located over the anomaly location, and all geophysical hardware was functioning as designed. All data are recorded and thus may be revisited as needed to verify their quality.

Data that meet the QC criteria are then entered into computer software that derives the EMI response for each anomaly interrogated. These EMI responses are used as inputs to a classifier. Subsequently, each anomaly classified as a TOI and those anomalies that cannot be classified are passed along to an excavation crew for recovery and disposal. See *Technical Fact Sheet: Geophysical Classification for Munitions Response* (GCMR-1) for more information regarding the science and analysis of EMI responses.

> ***Blind QC Seed—****Inert munition or munitions surrogate (such as an Industry Standard Object) buried on the site to serve as a process QC check. Surrogates are selected to correspond with munitions of interest on the site. The location and identities of these surrogates should be unknown to the data collectors, analysts, and excavation crew.*

As innovative applications of geophysical classification are developed and brought to market, the detection survey and cued survey may eventually be combined. In this scheme, detection and some level of classification will be accomplished using survey data collected with an advanced EMI sensor.

Building and validating the performance of a sensor/classifier are integral components of the geophysical classification process. At some sites, a small pilot study to demonstrate the applicability of geophysical classification to the site conditions is performed as a component of the Feasibility Study (FS) or prior to beginning a munitions response (removal or remedial) action. At other sites, data collected from equivalent sites with similar site conditions can fulfill this purpose. This pilot study is generally conducted on a small portion of a munitions response site with a significant number of blind QC seeds emplaced to ensure confidence in the results. Detection and classification are performed within the study area and all buried items are subsequently excavated. The geophysical classification process is judged by its success in detecting and correctly classifying the QC seed items and TOI, as well as by the reduction in the number of buried items selected for excavation that are non-TOI. Once validated, the classification process can be confidently applied to the remainder of the site.

Geophysical Classification Challenges

The geophysical classification process can generally be used at terrestrial sites where high-quality geophysical EMI data sensors can be towed or pushed across the site, or handheld equipment can be walked in a grid. This process has been used successfully at a variety of sites with different types of terrain and varying vegetation.

The geophysical classification process is not applicable in every situation. Site-specific characteristics can impose limitations on its use, such as areas of dense vegetation; extremely rough, unstable or steep terrain; or areas subject to electromagnetic interference. In addition, advanced EMI sensors are not currently used on airborne or underwater platforms. Correctly classifying TOI and non-TOI is easier if the items being classified are consistent, possess unique signatures, are present in lower densities, and are not located in geophysically-noisy environments. To the extent that these conditions are not met, geophysical classification performance suffers.

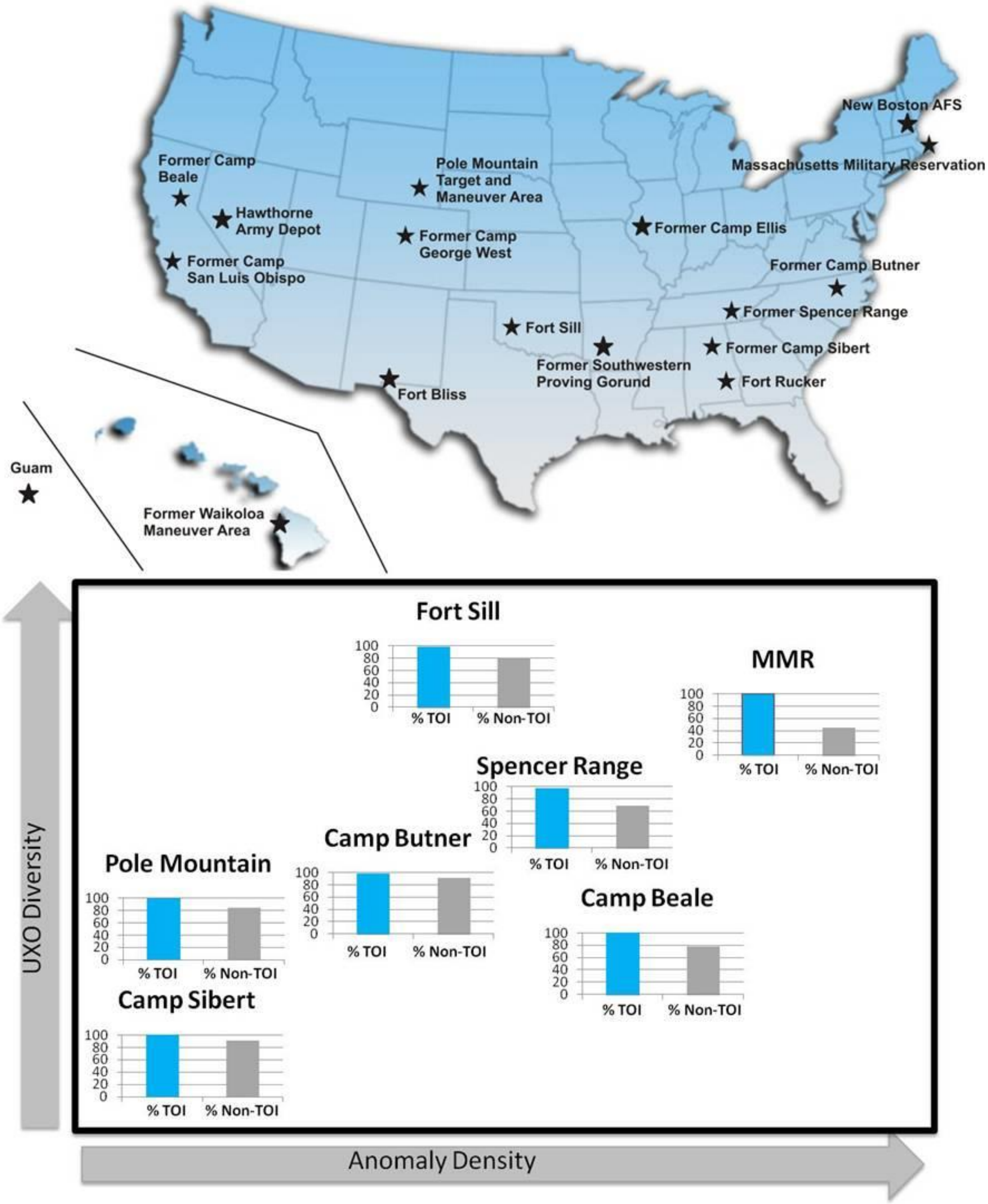
What does this mean in practice? Some common challenges and situations include:

- Anomaly density: If non-TOI is present to the extent that each excavation recovers multiple distinct pieces of metal of similar size to a TOI, then classification performance declines. Additionally, high anomaly densities can limit the opportunity to measure the local soil response and sensor drift, which also degrades classification performance.
- TOI diversity: Classification performance improves when the diversity of TOI is limited and the munitions known or suspected to be present are of different size and character than the non-TOI at the site. Sites with a limited number of munitions types are generally more conducive to correctly identifying TOI than sites with a greater diversity of munitions types.
- TOI density: If the ratio of TOI to non-TOI across the site is much higher than typical, the number of excavations avoided by using geophysical classification may not justify the additional cost of employing the process. This situation was observed on an air-to-ground gunnery range at New Boston Air Force Station, New Hampshire, but is not commonly encountered at most munitions response sites.
- Magnetic geology: Magnetic geology can also affect success of the geophysical classification process, especially at sites where the near-surface geology changes rapidly over short distances. At sites exhibiting extreme magnetic geology, the EMI contribution from the ground response can approach the magnitude of small- to mid-size munitions.
- Terrain: Variable and rough terrain impedes the geophysical classification process when it hinders the survey team's ability to get the sensor close to the buried item during data collection.
- Environmental interference: At some sites, environmental noise and EMI signatures resulting from structures such as power lines or other utilities can saturate the sensor and thereby prevent the use of geophysical classification.

Geophysical Classification Demonstration Results

In 2007, ESTCP initiated a Geophysical Classification Pilot Program to validate the application of a number of recently-developed technologies in a comprehensive approach during a munitions response. The program goals are to (1) demonstrate that classification decisions can be made using an explicit approach, based on physics-based analysis that is transparent and reproducible; (2) gain acceptance of the geophysical classification process by federal and state regulators, the munitions response industry, and the public; and (3) transition the analytical tools and techniques to production use.

During the course of the Geophysical Classification Pilot Program, ESTCP successfully demonstrated use of the geophysical classification process and its benefits at multiple military sites that possessed a variety of geophysical classification challenges (Figure 1). The sites were ordered based on their perceived difficulty, starting with the easiest. The initial site, Camp Sibert, Alabama, was selected because it had favorable terrain, a single munition of concern, and a single dominant non-TOI type. Subsequent sites had between 3 and 21 different munitions types and variable survey conditions, terrain, and anomaly densities. All buried items were excavated and identified to confirm technology performance in these demonstrations. Regardless of the specific objectives, analysts were able to demonstrate successful geophysical classification. In some cases, near-perfect classification results were realized. In others, analysts correctly classified 100% of the TOI and 50-70% of the non-TOI. In the bar charts presented in Figure 1 below, classification performance is plotted as a function of site anomaly density and munition diversity including the percent of correctly classified TOI (blue) and correctly classified non-TOI (gray). TOI classification at these sites was highly successful. At sites with increased munition diversity and anomaly densities, non-TOI was more difficult to confidently identify, and additional non-TOI excavations were required to achieve 100% correct classification of TOI. Non-TOI classification is more successful at sites with lower munition diversity and anomaly densities, resulting in a substantial reduction of non-TOI excavations. The ESTCP Classification Pilot Program website provides further information about the program at http://www.serdp-estcp.org/Featured-Initiatives/Munitions-Response-Initiatives/Classification-Applied-to-Munitions-Response.



ESTCP classification demonstration site locations (top). Classification performance plotted as a function of site anomaly density and munition diversity (bottom) , percent correctly classified TOI (blue), and percent correctly classified non-TOI (gray). TOI classification is highly successful. At sites with increased munition diversity and anomaly densities, non-TOI is more difficult to confidently identify and additional non-TOI excavations are required to achieve 100% correct classification of TOI. Non-TOI classification is more successful at sites with lower munition diversity and anomaly densities, resulting in a substantial reduction of non-TOI excavations.

Munitions Response Regulatory Framework

Munitions response projects can be performed under the regulatory framework of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) or the Resource Conservation and Recovery Act (RCRA). Most commonly, however, munitions response projects are performed under CERCLA. During the CERCLA process, geophysical classification may be evaluated as part of a remedial option in the FS analysis. A treatability study may be required either in the FS or remedial design phase, if suitable examples similar to the site are not readily available.

Regulators face a unique challenge in providing oversight of the geophysical classification process. Additional regulatory approvals are not required for use of the geophysical classification process. However, early and continuous communication among project teams, which include regulators and stakeholders, is recommended to develop project objectives that may help avoid costly re-work. Project teams must be informed about the geophysical classification process and how it will be implemented at the site. The first in this series of ITRC fact sheets, *Overview Fact Sheet: Geophysical Classification for Munitions Response,* explains the geophysical classification process to stakeholders who may not wish to examine all of the technical details associated with the process (GCMR-1). The second in this series, *Technical Fact Sheet: Geophysical Classification for Munitions Response*, provides an overview of the geophysical classification technology and process, types of applicable terrestrial sites, and data quality considerations for those familiar with executing or managing munitions responses (GCMR-1).

State Regulator Role in the Munitions Response Process

The regulator's responsibility on a munitions response project is to ensure that the project complies with federal and state laws and regulations and meets the requirements for characterization, cleanup, and site closure. Environmental regulators should participate in defining the overall objective of the munitions response project, concur with key processes necessary to realize the objectives, approve process and final product performance requirements, and agree with the QA/QC activities necessary to demonstrate that requirements have been achieved (UXO-5).

Properly implemented, the team-based process approach should generate a QAPP. This document identifies the necessary QA and QC activities to be performed and data requirements that must be met during the munitions response. Standard geophysical classification QC requirements should include repeatability of instrumentation verification strip measurements and sensor function tests; detection and classification of all blind QC seed items; and adequate spatial sampling during data collection. Typical QC steps include problem identification, problem analysis, problem correction, and feedback. In the geophysical classification process, QC tasks would generally be carried out by the project geophysicist. A QA evaluator may be a manager, a client, or even a third-party auditor. QA activities may include verifying the data coverage, noise levels, classifier used, and classification logic, as well as failure analyses, if necessary.

Data quality and integrity are critical to the geophysical classification process. Compliance with QA and QC activities helps to ensure that reliable, high-quality data are generated. Effective QA and QC also provides confidence that the tasks or processes were completed properly, the data meets quality requirements, and the decision making is scientifically defensible. Currently, the Intergovernmental Data Quality Task Force (IDQTF) is developing a geophysical classification QAPP template. This document is expected to be completed in 2015.

Geophysical Classification Participants and their Respective Roles and Experience

Munitions response project planning may include a wide variety of individuals and organizations, including project managers and technical personnel, contractors, customers, suppliers, scientific experts, and stakeholders, who together determine if the project is successful (Uniform Federal Policy for Implementing Environmental Quality Systems).

Geophysical analysts, whether contractors or government staff, are responsible for analyzing the data and making classification decisions. These analysts should have documented experience in every aspect of the geophysical classification process. Performance and supervision of geophysical classification data acquisition and analysis should be carried out by geophysicists with documented experience in successfully applying geophysical classification methods. Organizations should have a process in place to educate and train personnel to implement the quality system and quality requirements of individual projects. Third party technical reviewers can also provide valuable insight regarding the reasonableness and defensibility of the classification decisions offered by the geophysical analysts.

Regulators can enhance their knowledge about geophysical classification and the munitions response process through training sessions offered by the ITRC and by using the ITRC GCMR guidance document, which is expected to be published in 2015. Additional resources will be cited in the guidance document.

The public should be viewed as partners in munitions response projects. To create a constructive partnership, responsible parties and regulators must establish trust with engaged members of affected communities and inform them as to how the geophysical classification process works and how munitions response projects are carried out.

Summary

Geophysical classification technologies and processes have been successfully demonstrated and are transitioning to accepted use on munitions response projects. These demonstrations have shown that using geophysical classification technologies and processes improves the efficiency and effectiveness of munitions response projects on a variety of sites. As with all technologies, the use of geophysical classification has some limitations and should be considered on a site-by-site basis. The successful use of geophysical classification requires that the initial detection survey provides quality data. Additional quality measures must also be implemented, which are specific to the geophysical classification process (such as those related to cued data collection, feature extraction, and classification). In addition, experienced geophysicists must participate in designing the project, operating the equipment, and processing and interpreting the data in order for geophysical classification to be successful.

For More Information

ESTCP has completed a number of geophysical classification demonstrations at munitions response sites across the country and is currently conducting additional demonstrations. For further information, please see the ESTCP website at http://www.serdp-estcp.org/Featured-Initiatives/Munitions-Response-Initiatives/Classification-Applied-to-Munitions-Response.

The ITRC GCMR Team is reviewing the results of the ESTCP demonstrations as part of the process for developing the guidance document and training for geophysical classification. The guidance will describe when and where use of the geophysical classification process is appropriate, the geophysical expertise and experience necessary for the successful use of geophysical classification, and recommendations for appropriate QA/QC procedures.

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