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ENGINEERING AND DESIGN

ORDNANCE AND EXPLOSIVES RESPONSE

ENGINEER MANUAL

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7-11. Geophysical Investigation Plan. Prior to initiating field activities, a Geophysical Investigation Plan should be prepared. This Plan, which is a subsection of the Work Plan, is prepared to describe the project requirements for all geophysical activities that will take place during an OE project. The Geophysical Investigation Plan will include a justification for the proposal of the geophysical instrumentation, methodology, and prove-out. The proposed goals, methods, and procedures will be tailored to anticipated site conditions and technical requirements as well as applicable safety and security regulations. The Geophysical Investigation Plan must include procedures for a geophysical instrument prove-out, if not previously completed.

a. Contents. The project team member reviewing the Geophysical Investigation Plan should ensure that the following elements are addressed:

(1) Geophysical investigation methods:

(a) Equipment;

(b) Procedures;

(c) Personnel;

(d) Production rates;

(e) Data resolution, or line/grid width requirements;

(f) Data density; and

(g) Data processing.

(2) Location surveying, mapping and navigation:

(a) System description; and

(b) If GPS systems are used, correlate satellite availability with work/rest periods.

(3) Instrument standardization:

(a) Instrument drift (DC offset);

(b) Standardization procedures;

(c) Abbreviated standardization checks; and

(d) Instrument response to a known standard.

(4) Data processing, correction and analysis:

(a) Instrument drift correction;

(b) Diurnal drift correction;

(c) Digital filtering and enhancement; and

(d) Correlation with ground truth.

(5) Quantitative interpretation and dig sheet development.

(6) Anomaly reacquisition.

(7) Feed-back process (Comparison of dig-sheet predictions with ground-truth).

(8) Quality control.

(9) Corrective measures.

(10) Records management.

(11) Interim reporting.

(12) Final reports and maps.

b. Geophysical Investigation Plan Review and Approval. The Geophysical Investigation Plan, a component of the Work Plan, will be submitted to the PM and Design Center POC. The Design Center POC will route the plan to the appropriate USACE technical staff for review, comment and approval. Once approved by the Design Center and CO, the Geophysical Investigation Plan represents the standard to which all geophysical activities are compared to assure compliance during the project.

7-12. Geophysical Sampling.

a. Pre-Sampling Studies. When planning geophysical investigations for UXO at current and former military installations, it is necessary to determine the limits of the area to be investigated. Military installations are often extremely large and not all areas are likely to have buried UXO. The ASR, historical aerial photographs, range-control records, facility engineering and master planning documents, personnel interviews, and other pertinent documents should be carefully evaluated in order to locate evidence of how, when and where munitions might have been used at a site.

b. Sectorization.

(1) Once the review of historical documents has been accomplished, the site must be sectorized. Sectorization is the process by which large, non-homogenous areas of a military installation are subdivided into smaller, more homogenous areas. When defining sectors, the following factors should be considered:

(a) Former military use;

(b) Anticipated UXO type;

(c) Anticipated UXO distribution;

(d) Terrain and vegetation;

(e) Current land use; and

(f) Natural and cultural boundaries.

(2) Obviously, it is not possible to define a sector that is completely uniform and homogenous. However, the goal is to define sectors such that any necessary future OE response action can be applied to the entire sector. It should be noted that sectorization is an active process. As the project continues and more data is collected, it is likely that sector boundaries will need to be modified to reflect actual site conditions.

7-13. Sampling Within a Sector. When geophysically characterizing a sector, an initial decision must be made regarding where the geophysical investigations will occur. Basically, there are two choices: either investigate the entire sector, or sample a representative portion of the sector and infer the results across the whole. On relatively small sectors, it can be efficient in terms of cost, schedule, and environmental impact to geophysically map the entire area. However, large sites can present significant cost, schedule, access and environmental impact challenges that preclude geophysically mapping large areas as a method of site characterization. Various site sampling methodologies are discussed below.

a. 100% Sampling. Complete geophysical mapping is a good approach for small sites. At such sites the mobilization/demobilization and other fixed costs can be relatively high when compared to the actual mapping costs. In these cases, the most cost-effective approach might be to map the entire site. Such an approach is especially recommended for sites smaller than about 20 acres.

b. Authoritative Sampling. With authoritative sampling, an expert having knowledge of the site designates where and when samples are to be taken. This type of sampling should only be considered when the objectives of the investigation are not of a statistical nature. Generally,

conclusions drawn from authoritative sampling apply only to the individual samples and aggregation may result in severe bias and erroneous conclusions.

c. Probability Sampling.

(1) When the study objectives involve estimation or decision making, some form of probability sampling is required. Probability sampling is sampling where every member of the target population has a known probability of being included in the sampling. This does not preclude use of an expert's knowledge of the site in designing a probability-based sampling plan; however, valid statistical inferences require that the plan incorporate some form of randomization in selecting the sampling locations. An efficient probability sampling design is one that uses all available existing information to stratify the region and set appropriate probabilities of selection. For example, probability sampling can take into consideration prior knowledge of areas with higher potential for UXO contamination (e.g., targets) by weighting such areas more heavily in the sample selection and data analysis.

(2) Probability sampling can be of various types, but all types use randomization, which allows valid probability statements to be made about the quality of estimates that are derived from the resultant data. USACE has developed a statistical process, known as UXO Calculator, to determine the amount of geophysical mapping necessary to characterize a homogenous sector of a UXO site. For a discussion of this methodology, refer to Chapter 10 of this manual. The statistical approach is designed to characterize "dispersed" UXO such as occurs at impact areas, bomb target areas, kick-out from open burn/open detonation operations, dispersal from munitions magazine explosions, and similar activities. It is not designed to statistically characterize activities that do not have random patterns, such as UXO intentionally buried, purposely hidden contraband munitions, and similar activities.

(3) The amount of necessary sampling within a sector is determined by USAESCH's UXO sampling protocols. The larger the sector, the smaller the percentage of sampling is required. UXO Calculator should be used on a site-specific basis to determine appropriate sampling percentages. However, Table 7.4 indicates the approximate amount of sampling (random plus directed) that should be anticipated.

(4) It should be remembered that mobilization/demobilization and other fixed costs can be relatively high when compared to total geophysical investigation costs at small sites. Therefore, at small sites it is often more cost-effective to geophysically investigate the entire site, rather than use statistical sampling.

Table 7.4
Typical Geophysical Sampling Requirements

Sector Size, Acres	Required Minimum Area Investigated	Recommended Minimum Area Investigated
< 50	5.0%	7.5%
51 -100	3.0%	4.5%
101 - 150	2.0%	3.0 %
151 - 1000	1.0%	1.5%
> 1000	0.5%	0.75%

(5) Probability sampling strategies include the following:

(a) Fixed Pattern Grid Sampling. Fixed-Pattern grid sampling is the process where grids are laid out in a pattern on a fixed percentage (often 10 percent) of a sector. Fixed pattern sampling is not normally used since other more random patterns can provide statistically valid results using fewer grids. An example of fixed pattern grid sampling is shown in Figure 7-3.

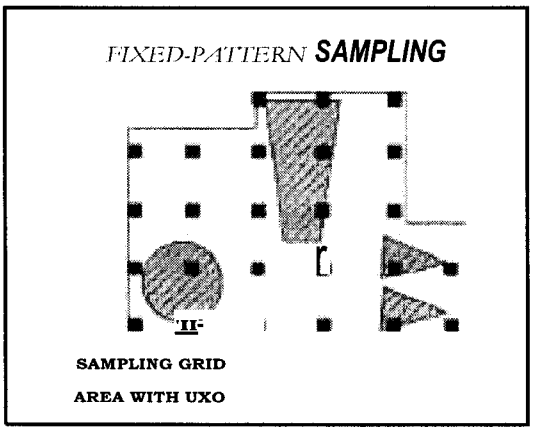

Figure 7-3
Fixed Pattern Grid Sampling

(b) Random Pattern Grid Sampling

(1) Random pattern grid sampling uses a statistical approach to place grids randomly throughout a sector. The total area to be sampled is first determined using a statistical process, such as UXO Calculator. Then, grid size and shape is determined based on site terrain, vegetation, and the geophysical instruments to be used. Grids can be any convenient shape, but square or rectangular grids are the most common. Grids may be as small as 2,500 square feet or

as large as one hectare in size. Grids need not all be the same size. An example of random pattern grid sampling is shown in Figure 7-4.

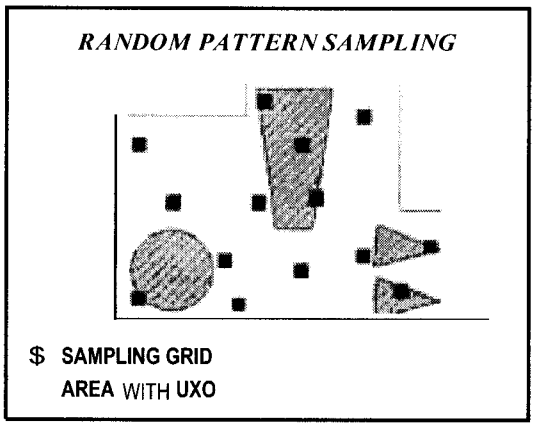

Figure 7-4
Random Pattern Grid Sampling

(2) Since in random pattern sampling grids are placed completely randomly, there can be large unsampled areas within a sector. Also, areas known to contain UXO might remain unsampled. For this reason, purely random pattern sampling is not recommended.

(c) Hybrid Sampling. In order to assure that a sector receives thorough sampling grid coverage, and that areas known or suspected to contain UXO are geophysically investigated, a modified version of random pattern sampling is recommended. In this hybrid approach, grids are placed randomly across the sector as described above. Afterwards however, approximately 20 percent more grids are placed in biased locations to fill any apparent data gaps. This approach is recommended when sampling grids are used. An example of hybrid sampling is shown in Figure 7-5.

(d) Transects. Geophysical investigation transects are another approach used to characterize sectors. Transects are also a good approach to determine boundaries of contaminated areas. When used for sector sampling, transects may simply be considered as very narrow, fixed pattern-grids. Transects are best utilized at sites with easy terrain and vegetation. An example of transect sampling is shown in Figure 7-6.

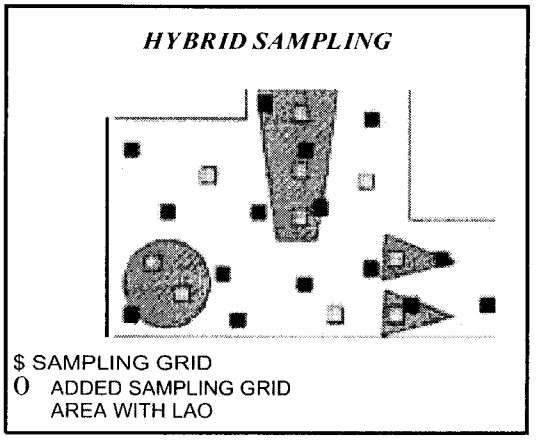

Figure 7-5
Hybrid Sampling

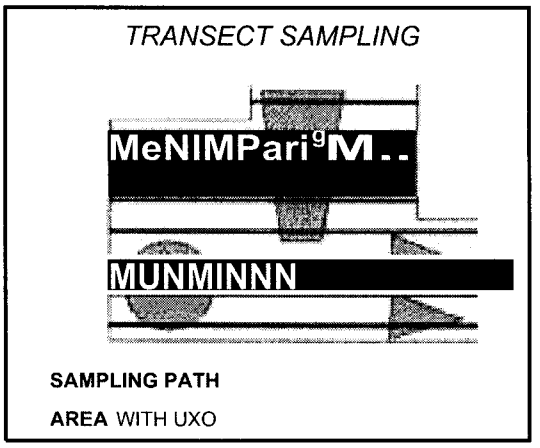

Figure 7-6
Transect Sampling

(e) Meandering Path Sampling. Meandering path sampling is a process where a geophysical investigation instrument is integrated with a navigation instrument, usually differential Global Positioning System (GPS), that links extremely accurate positional data with the geophysical readings. Then, a geophysical team "meanders" randomly throughout a site, until the total area geophysically mapped equals the area that would have been required if sampling grids were used. Afterwards, the geophysical data is analyzed, anomalies are located, then excavated and evaluated. Meandering path sampling offers large cost savings at sites with difficult vegetation and terrain since vegetation removal costs are virtually eliminated and surveying costs are greatly reduced. An example of meandering path sampling is shown in Figure 7-7.

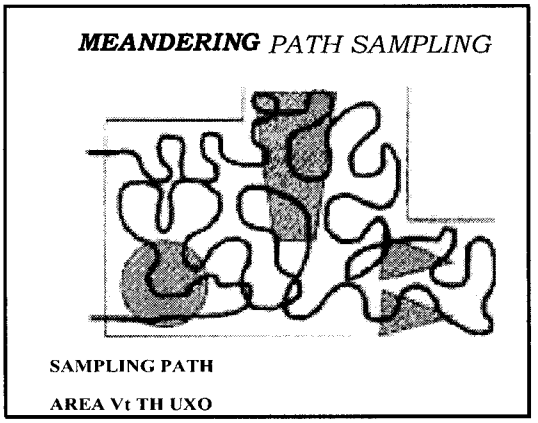

Figure 7-7
Meandering Path Sampling

7-14. Sampling Anomalies Within a Grid. After a grid or other area has been geophysically mapped, multiple "anomalies" are likely to have been located. For mag & flag projects, these anomalies will be marked as flags at the location of each subsurface anomaly. For projects where digital geophysical methods are used, the geophysicist will pick and evaluate anomalies with the help of analytical software. In either case, the anomalies must be excavated by qualified UXO personnel in order to determine if the anomaly represents a UXO or some other feature. On many grids, the number of anomalies will be manageable and all should be excavated in order to characterize the grid. However, on some sites, particularly those within impact areas, the number of anomalies may range from several dozen to several thousand anomalies per acre, most of which will be small metallic frag. When this occurs, statistical sampling of the grid may be necessary.

a. 100% Sampling. When there are, on average, fewer than approximately 20 anomalies per grid, all anomalies should be excavated and evaluated.

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