

APPENDIX C*

ORDNANCE AND EXPLOSIVES (OE) SITES

UNEXPLODED ORDNANCE (UXO) STATISTICAL ESTIMATION

STANDING OPERATING PROCEDURE (SOP)

*This appendix provides the USAESCH SOP for statistical estimation of UXO at OE sites.



**US Army Corps
of Engineers**
Engineering and Support
Center, Huntsville

**ORDNANCE AND EXPLOSIVES (OE) SITES
UNEXPLODED ORDNANCE (UXO)
STATISTICAL ESTIMATION
STANDING OPERATING PROCEDURE (SOP)**

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FOREWORD

This document presents the standing operating procedure (SOP) for statistical estimation of unexploded ordnance (UXO) at ordnance and explosives (OE) sites. It is intended to serve as guidance for OE professionals who may wish to use statistical estimation in the performance of OE investigations and OE removal response actions. The text proper discusses statistical estimation in general and sets forth specific responsibilities and requirements/procedures relative to its use. Appendixes to the text present supplemental materials, including an indication of the format and typical contents for a formerly used defense site (FUDS) UXO statistical report.

Please address any comments concerning this document to Commander, U.S. Army Engineering and Support Center, Huntsville, ATTN: CEHNC-OE-MCX, P.O. Box 1600, Huntsville, AL 35807-4301

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ORDNANCE AND EXPLOSIVES (OE) SITES
UNEXPLODED ORDNANCE (UXO) STATISTICAL ESTIMATION
STANDING OPERATING PROCEDURE (SOP)

1. PURPOSE. The purpose of this document is to provide the SOP for statistical estimation of UXO at OE sites for use by OE professionals engaged in the performance of OE investigations and OE removal response actions.

2. APPLICABILITY. This document applies to all U.S. Army Corps of Engineers and contractor personnel working with the U.S. Army Engineering and Support Center, Huntsville (USAESCH) OE Mandatory Center of Expertise (MCX) in the performance of OE investigations and OE removal response actions in support of the OE response process.

3. EXPLANATION OF ABBREVIATIONS. Abbreviations used in this document are explained below.

- a. FUDS Formerly Used Defense Site
- b. GridStats Grid Statistical Sampling Based Methodology
- c. HEI High Explosive Incendiary
- d. MCX Mandatory Center of Expertise
- e. OE Ordnance and Explosives
- f. SiteStats Site Statistical Sampling Based Methodology
- g. SOP Standing Operating Procedure
- h. USAESCH U.S. Army Engineering and Support Center,
Huntsville
- i. UXO Unexploded Ordnance

4. INTRODUCTION.

a. Philosophy. There are as yet no statistical standards that have been promulgated for UXO investigations. The philosophy underlying this document is that a UXO investigation must provide enough information to support a reliable estimate of the UXO density (overall and by type) at a site. This does not mean proving that there is no UXO at a site. To obtain a 90-percent confidence that there is no UXO at a site requires that 90 percent of the site be investigated. This is an expensive proposition. A higher amount of uncertainty will have to be accepted at low-density sites. This should not cause great concern, since low-density sites are much less dangerous than high-density sites. The procedure outlined herein is a sequential procedure that assumes a uniform distribution of UXO across the sector. The negative binomial distribution is the tool used for calculating the various associated probabilities. Use of this procedure is intended to develop a reasonable estimate of UXO in a sector at a reasonable cost. Different sites will have different data needs, and the OE team should make every effort to anticipate the unique data needs of the site in question.

b. Background.

- (1) There are three distinct statistical questions that must be answered at an OE site. The first is, what is

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the boundary of each of the sectors at this site. The second is, what is the UXO density (by type of UXO) for each sector. The third is, what is the overall UXO density for each sector. A sector is also called an Ordnance Operable Unit. It provides a uniform area for the application of response actions. A sector is defined as follows:

- (a) Being contiguous.
- (b) Having the same future land use.
- (c) Having an equal likelihood of UXO (except for the buffer zone).
- (d) Possibly having a buffer zone where the UXO density is much less than in the sector proper.

UXO density is defined as being the amount of UXO per acre to a specified depth of interest.

(2) Different definitions may be required for different sites. The OE team should provide the sector and UXO definitions that will be used in the statistical analysis if they differ from the definitions provided here.

5. RESPONSIBILITIES.

a. OE Team. The OE team is responsible for ensuring that this SOP is used to determine UXO density at FUDS properties or for obtaining USAESCH OE MCX approval if some other procedure is used.

b. OE Investigation Contractor.

(1) The OE investigation contractor is responsible for operating all statistical estimation tools (Site Statistical Sampling Based Methodology (SiteStats), Grid Statistical Sampling Based Methodology (GridStats), UXO Calculator, etc.) required.

(2) The OE investigation contractor is responsible (1) for ensuring that the personnel who operate the required statistical estimation tools and who perform the statistical analyses are thoroughly familiar with the statistical estimation tools used and (2) for obtaining the manuals, training, and assistance needed to ensure personnel competency in the use of the required statistical estimation tools and in the writing of the statistical report.

(3) The OE investigation contractor is responsible for providing (in-house or via subcontract) a technical manager to oversee the development of the statistical report. The technical manager will assure the Government that the statistical analyses were performed in accordance with this SOP, that he or she has audited some of the mathematics in the report as a quality control check and has found no errors, that the primary purpose of the report was met, and that the personnel who used the required statistical estimation tools and developed the statistical report were adequately trained either by education or experience to perform the work. Minimum qualifications for a technical manager are as follows:

- (a) Bachelor's degree in engineering (industrial engineering or systems engineering preferred).
- (b) Engineering or statistics courses covering general, parametric, and nonparametric statistics and design of experiments.

(c) Graduate engineering, operations research, or management science courses in linear, nonlinear, dynamic, and stochastic programming.

(d) At least 1 year's experience in developing ordnance (or related fields) statistical assessments or at least 2 years' experience in developing other types of statistical assessments.

c. OE MCX. The USAESCH OE MCX is responsible for overall quality assurance at OE sites.

d. Statistical Report Developer. The statistical report developer is responsible for the following:

(1) Reviewing the Archives Search Report prior to start of the OE investigation in order to become familiar with the site.

(2) Meeting with the OE team and the OE investigation contractor to develop logical sectors needed to run the statistical estimation tool used.

(3) Working with the OE team and the OE investigation contractor to determine expected ordnance density if SiteStats, GridStats, or UXO Calculator is not used.

(4) Working with the OE team and the OE investigation contractor to develop removal alternatives for the site.

(5) Loading gathered data into the statistical estimation tool used, running computer program, and interpreting results.

(6) Writing statistical report.

(7) Coordinating with appropriate personnel to ensure inclusion of statistical report in OE investigation report.

6. REQUIREMENTS/PROCEDURES. The purpose of the statistical estimation process is to obtain a statistical characterization of the UXO at formerly used defense site (FUDS) properties. This methodology prescribes the recommended amount of sampling that should occur. The final sampling requirements will be highly dependent upon site conditions and requirements. It is the responsibility of the OE team to determine the required sampling for each site and to document the sampling procedure that will be used (particularly if the sampling procedure is different than the sampling procedure expressed herein).

a. Selection of Areas to be Investigated. Only suspect target areas of ranges and detonation or burial pits at open burning/open detonation sites should be investigated. The purpose of the statistical report is to provide a UXO density estimate for the risk report. Areas without evidence of UXO contamination are assumed to be noncontaminated and, therefore, do not require a density estimate. The preliminary estimate is zero. Upon

finding evidence of UXO, it then becomes appropriate to provide a statistical estimate prior to determining the public risk present at the site.

b. Sector Development.

(1) The OE team should develop a sector profile based upon past land use, expected UXO density, and future land use. A sector should include the area with the suspected UXO contamination and possibly a buffer zone about that area. The size of the buffer zone will depend on sector characteristics. A buffer zone should be included only

if there is a safety reason for doing so.

(2) The USAESCH-developed statistical tool, SiteStats, can be used to assist in determining whether a suspected area is one or more than one sector. However, there is no substitute for human logic. The mathematical methodology in SiteStats is based upon variability of UXO among grids investigated. A freak distribution might not be caught by the program. To assist the decision makers in ensuring that they have an appropriate sector, the OE team should develop a site map which indicates all sectors to be investigated. As each sector is investigated, the team should update the map, indicating the area investigated and the results of the investigation. If there is sufficient variability among subareas in the sector (say 300 percent, but, again, this will be highly site dependent), then the OE team should break the sector under development into two or more sectors, as required, regardless of what SiteStats or any other mathematical methodology indicates.

(3) Investigative areas should be placed in the buffer zones about the sector when buffer zones are used. Usually, these buffer zones should contain no UXO. However, the decision as to whether or not buffer zones should contain UXO is site specific. For instance, very high density sites may require buffer zones that do contain UXO. Regardless, the OE team should investigate enough area about the suspected UXO area to ensure that a proper buffer zone has been specified when buffer zones are required.

(4) The sector area should be based (at a minimum) on the Archives Search Report, aerial maps, and expert opinion. Different types of UXO sectors will require different areas. The OE team should document all of the decision-making criteria used to determine the sector area.

c. Investigative Area Selection.

(1) The OE team should determine the total area in a sector that needs to be investigated to develop a realistic estimate of UXO in the sector. The degree of

confidence required is highly site dependent and is determined by the following two considerations:

- (a) How certain do we want to be that we have properly identified the sector.
- (b) How certain do we want to be concerning our UXO density estimate for the sector.

(2) As in all statistical sampling, the higher the amount of sampling, the more accurate the results. However, sampling is expensive, so there has to be a tradeoff between statistical accuracy and sampling costs. The OE team will have the best information upon which to formulate the requirements relative to the site in question. If the OE team does not develop an independent estimate (USAESCH approved) of the area required to be investigated, then the following rules should be applied:

(a) For safety buffers, investigate an area that provides 90-percent confidence based on either a target value of 0.5 or 0.2 (as calculated by UXO Calculator) given that no UXO is found. If there is no evidence of UXO (i.e., no scrap), then the target value should be 0.5 per acre. If there is evidence of UXO, then the target value should be 0.2 per acre.

(b) For type A sectors (sectors expected to have less than 0.5 UXO per acre), investigate an area that provides 90-percent confidence that the density is 0.5 UXO per acre or less (as calculated by UXO Calculator).

(c) For type B sectors (sectors expected to have less than 2.0 UXO per acre but more than 0.5 UXO per acre), investigate an area that provides 90-percent confidence that the density is less than 2.0 UXO per acre.

(d) For type C sectors (sectors expected to have less than 4.0 UXO per acre but more than 2.0 UXO per acre), investigate an area that provides 90-percent confidence that the density is less than 4.0 UXO per acre.

(e) For type D sectors (sectors having greater than 4.0 UXO per acre), investigate an area that provides 90-percent confidence that the density is greater than 4.0 UXO per acre.

(3) The sampling will be sequential. Daily results should be fed into UXO Calculator to determine how much more sampling, if any, should be performed. A worst case scenario can be developed prior to site sampling by using module 5 (minimum discrimination module) to determine the amount of sampling it suggests. The OE investigation contract should be structured such that there is a minimum area of sampling required regardless of the outcome of the sampling (2 percent is recommended), and such that adjustments to the contract can be made based on the sequential sampling. As always, these are recommendations. If the budget will not support this level of certainty, then it may be necessary that less area be sampled and, therefore, that a level of certainty of perhaps only 80 percent can be attained.

(a) When grids are used, grid sizes of 100 feet by 100 feet or 50 feet by 50 feet are recommended, with the total amount of the sector area investigated remaining the same. (The size and dimensions of a grid are site determined. A grid may take any shape required to obtain the necessary data; however, the total amount of area sampled for the sector should remain the same.)

(b) Eighty percent of the grids should be selected at random. Twenty percent of the grids should be selected by visual inspection. A map showing where the grids are should be generated. The OE team should closely evaluate the map to identify any additional sectors requiring investigation.

(c) If grids are not used, then an equivalent area per sector should be investigated regardless of the method employed.

d. Sampling. A dig sheet will be developed by the geophysicist. This dig sheet will show those anomalies that are most likely to be UXO. The dig sheet will be prioritized. The following rules will apply to sampling, unless the OE team decides otherwise, when grids are used:

(1) If there are 50 anomalies or less in the grid, then dig all anomalies.

(2) If there are more than 50 anomalies in the grid, then a decision must be made prior to digging. In order to prevent added uncertainty in the analysis, an area must be cleared of all anomalies. The team must decide if they wish to increase the number of digs or decrease the size of the grid.

(3) The results of each dig must be recorded in full detail. If there is no computer tool that will assist the OE team in detailing the exact information required, then the OE team should contact USAESCH (Kiss) to obtain a data sheet that will assist them in developing a format for recording the information. (See appendix A for a listing, per subject matter area, of points on contact cited in this SOP.) GridStats may be used to assist the investigation, and if used, the results should be recorded in the GridStats

computer program. The OE team should not use GridStats as a stopping procedure unless approval from the USAESCH OE MCX (Manthey) has been obtained.

(4) SiteStats may be used to assist in determining the extent of a sector. SiteStats should not, however, be used in a vacuum. A detailed map showing the location and density of UXO found in all grids should be developed and updated daily. If the map suggests that the area should be broken into more than one sector, then the OE team

should do so. As an example, if the map shows five UXO items in one side of a sector and only one in the other side of the sector, then the OE team should evaluate the desirability of developing two sectors. Assistance in making this decision can be obtained from USAESCH (Fanning).

e. Developing the Statistical Results.

(1) If UXO is found, the OE team should develop a standard statistical confidence interval about the UXO mean. UXO Calculator will provide this information. If the contractor wishes to verify the information, he should develop a confidence interval using a binomial distribution (the assumption of UXO Calculator). Most college level statistics textbooks provide examples of confidence interval development and contain binomial charts (the charts may not present enough information, but the intervals can be developed on a spreadsheet).

(2) The UXO Calculator software should also be used to investigate the amount of UXO at a site. There are several modules in UXO Calculator that can be used to assist the OE team in understanding the statistical parameters of the site.

(3) If no UXO is found, the OE team should use the minimum discrimination module of UXO Calculator to assist them in determining the likelihood of UXO being present at the site. When no UXO is found, the confidence of the density (0) is the amount of sector investigated. If we have investigated only 5 percent of the site, then we are only 5-percent certain of the density number. It is not always clear whether we have found nothing because there is nothing to find or because insufficient data were investigated to draw a conclusion. The minimum discrimination module shows the probability that we would have found something given that there was something to find. A target density must be provided (use 0.2 per acre or 0.5 per acre for the engineering evaluation/cost analysis unless the OE team decides on a different value) for this module to work. What results is a confidence number that shows that even with only 2 percent of the site having been investigated, we are often highly confident that there is little UXO present because, otherwise, we would have found at least one UXO item for some target density.

(4) A confidence interval must be developed for each UXO type found. For instance, if there are both 3-pound practice bombs and 20-millimeter high explosive incendiary (HEI) rounds at a site, then two confidence intervals would be developed, one for each type of UXO. A third confidence interval must be developed for all UXO taken together. This means that the 3-pound practice bombs and the 20-millimeter HEI rounds would be added together and a confidence interval developed about this value. If a surface characterization is required, then a surface confidence interval should also be developed. Target densities and area investigation results are to be developed for all UXO found.

f. Developing the Statistical Report.

(1) A statistical report detailing the results of all of the statistical investigations of the site should be developed. The report should stand alone and not need data from any other source to support the statistical conclusions. The format and typical contents of the report are indicated in appendix B.

(2) The analyst who develops the report should be a statistician or an engineer with at least 12 hours of college level statistics courses. The report must show all uncertainties that are related to the statistical results. The report must also show the confidence interval developed (if UXO is found), the minimum discrimination confidence (if no UXO is found), the GridStats results, the SiteStats results, and the results for each module of UXO Calculator.

(3) The report must specify all assumptions made in developing the sectors and all factors considered in excluding some of the area from statistical evaluation (e.g., there was no proof of UXO shown in the Archives Search Report and no ground scars shown by aerial maps). Any deviations from the detailed statistical process set forth in this SOP must be fully documented. The quality control procedure used by the OE team to ensure accuracy of results must be fully documented. The report must provide a confidence interval for each type of UXO found at the site, as well as a confidence interval for all UXO added together. If a surface characterization is required, then a surface confidence interval should also be developed and detailed in the statistical report.

7. USAESCH HOTLINE. USAESCH has a telephone hotline for questions relating to UXO risk and for statistical and software problems. The number is 800-632-7306.

APPENDIX A
POINTS OF CONTACT

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<u>Point of Contact</u>	<u>Subject Matter Area</u>	<u>Office/Telephone</u>
Arkie Fanning (Principal)	risk analysis/statistical analysis	CEHNC-ED-SY-O (205) 895-1762
Preston Kiss (Alternate)	advanced technology	CEHNC-ED-SY-T (205) 895-1889
James Manthey (Principal)	OE MCX requirements	CEHNC-OE-MCX (205) 895-1588

APPENDIX B
FORMAT AND TYPICAL CONTENTS
FOR THE
FUDS UXO STATISTICAL REPORT

FORMAT AND TYPICAL CONTENTS
FOR THE
FUDS UXO STATISTICAL REPORT

1. Executive Summary. The Executive Summary should summarize the significant facts and conclusions of the statistical report in nontechnical language suitable for the general reader.
2. Purpose. The purpose of the statistical report should be stated.
3. Background. Any background information that was used in developing the statistics (aerial maps, Archives Search Reports, Inventory Project Reports, etc.) should be listed. Also, present any specific information that would help the general reader in understanding the statistical report or indicate where such information is available for review.
4. Sector Development. The rationale behind the selection of sector areas should be presented. Also, the rationale behind the excluding of areas from statistical analysis should be presented.
5. Area Investigated. The rationale behind the choosing of the areas investigated should be discussed at length. A map showing the areas investigated and the results of the investigations should be provided for each sector.
6. Sector Conclusions. The statistical conclusions that can be drawn from the analyses performed should be provided. All tools used in the analyses (visual inspection, SiteStats, etc.) should be indicated. All investigation results for each sector should be provided. Any other information deemed important should be provided.
7. Uncertainties. The uncertainty associated with the values developed should be indicated. For instance, if we investigated 20 percent of a site and found no UXO, there is still some uncertainty that there is no UXO at the site. Each sector should be addressed, and the qualitative uncertainties should be indicated for each sector.
8. Appendixes. Appendixes must present all calculations used to determine the confidence intervals, all SiteStats and GridStats results, all dig sheets, all UXO Calculator results, and any other information deemed important from a technical perspective.