QUALITY ASSURANCE AND QUALITY CONTROL IN UXO REMEDIATION – A CASE STUDY FROM MONTANA

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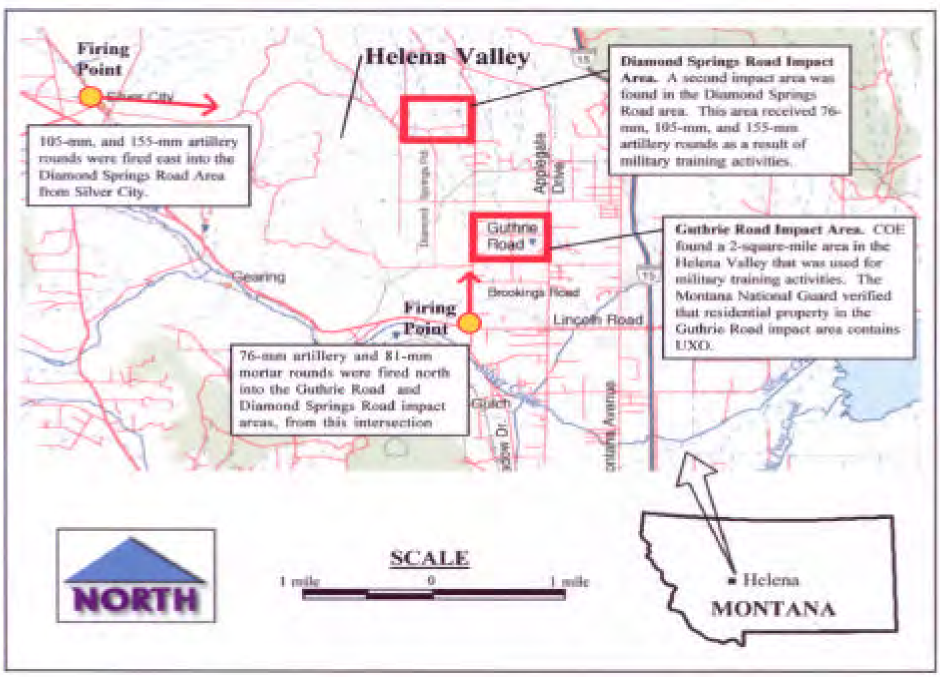
Clearance

Introduction

Since 1997, the Montana National Guard (the Guard) has implemented systematic UXO survey and removal actions on 420 acres of residential property in two separate impact areas (the Diamond Springs Road and Guthrie Road areas) in the north Helena Valley, Montana. The survey work resulted in the removal of a total of 136 mortar and artillery rounds (of which 28 were UXO or OEW).



Quality assurance methods in UXO clearance operations are fundamental to obtaining a reliable estimate of residual risk and hence "success." The theme of this paper is the role quality assurance and quality control (QA/QC) played in our UXO remediation efforts in the Helena Valley. As will be shown, we went to considerable effort to incorporate quality controls and quality assurance methods early on in this project. We did this because we were confronted with much uncertainty. These measures allowed us to match the site with the best subsurface UXO detection technology, assess the performance of this technology, and quantify performance results.

When we began, we were uncertain about the site-specific capability of the subsurface UXO detection technology and about the types and level of contamination on the site. Results from Phase II and III of the Advanced Technology Demonstration program at Jefferson Proving Ground (JPG) showed that there is often a considerable disparity between expected and actual detection efficiency. We recognized early that we needed a way to evaluate how well our methods were working. We were also uncertain as to how to best collect, manage, and present the data obtained during survey work. We felt strongly that the public should have unrestricted access to our results and that our results should incorporate a simple means for the layperson to evaluate the effectiveness of our efforts. We felt that such openness would advance public confidence, even if we fell short of 100 percent detection. In many ways, it was uncertainty that drove us to find better ways to collect, interpret, and manage data.

This paper will discuss how QA/QC measures were incorporated early on and at each step throughout the project. Specifically, we will discuss how QA/QC was applied to project planning activities, GIS mapping, surface sweep, emplacement, geophysical survey, and validation activities.

Project Planning Activities

Our initial project planning activities consisted of an extensive archival research that incorporated interviews of former guardsmen, an on-site surface assessment by EOD technicians, site selection and delineation and geophysical characterization.

The size of the area we selected for remediation at each site was constrained by limited funding and personnel. Therefore, we had to prioritize what areas to include in the initial remediation effort. Areas where exposure was highest due to the presence of homes and residential activity were selected as our top clearance priority. At the Diamond Springs site, we delineated a 220-acre area of private property where 11 homes had been built and from which UXO had been recovered. This area was several hundred meters south of where we determined the actual center of the artillery impact area was located. We could not have adequately supported a remediation of a significantly larger scale.

We conducted ballistic modeling to estimate the depth at which we could expect to find UXO. Ballistic modeling, along with subsequent validation data, allowed us to deviate from the clearance depth default standard of 10 feet (Chapter 12, DoD STD 6055.9) and narrow our search depth. Records indicated that 105-, 155-, and 76-mm rounds had been fired into the Diamond Springs Road area. Ballistic modeling results predicted that a 155 mm round could penetrate the hard shales on the site to a depth of 8 feet. Data gathering for Guthrie Road indicated that 76- and 81-mm rounds were present in that area and ballistic modeling indicated that the M43 series 81-mm mortar penetration would not exceed 3 feet at this site.

GIS Mapping/Grid Survey

We established a system of 100 meter X 100 meter grids across the Diamond Springs and Guthrie Road areas. Positional reference at Diamond Springs required the establishment of a grid system. Navigation of the geophysical survey equipment was ground-referenced to the grid system at Diamond Springs. The presence of a grid system facilitated navigation across the site during all subsequent phases. Each grid stake was marked with the NAD 83 easting and northing coordinates, allowing quick positional reference and the ability to navigate to within one 1 meter of an anomaly with nothing more sophisticated than a set of survey tapes. This grid system allowed the total station EDM survey team to set up at many locations to quickly and more accurately survey in anomaly positions. At Guthrie Road, the grid system allowed us to quickly check the initial dGPS positioning results from the geophysical survey.

The grid system facilitated differential rectification of pre-existing aerial photographs. These differentially rectified photographs served as base maps using Arc View GIS for both Diamond Springs and Guthrie Road. This technology proved extremely useful at Guthrie Road. The GIS technology allowed a variety of maps to be produced rapidly, each tailored to depict a specific QA question. For example, we could extract from an Excel™ spreadsheet all "high confidence" anomalies that met certain QA criteria. Using GIS, we could quickly plot extracted anomalies onto the base aerial photograph and print a GIS map for use in the field.

Surface Sweep

The Diamond Springs surface sweep was contracted to a commercial firm. The detection rate of surface UXO was under 50 percent. There are several reasons for this low detection rate. We were unfamiliar with the detection capabilities of surface sweeps in general and in particular what to expect from a commercial UXO contractor. Consequently, there were no provisions in the contract specifying a performance standard. Limited funding precluded such language. We had no QA measures in place prior to the surface sweep. We had too little experience with detector aided surface sweeps to feel confident enough to insist that UXO technicians "slow down" or rely less on Schonstedt flux-gate magnetometers and more on visual acquisition of UXO. Had we emplaced inert ordnance on the surface as a QA measure, we may have seen a better result.

The high cost and low detection of surface UXO at Diamond Springs led us to seek the support of Montana Air National Guard 120th FW EOD team. This team had performed well during the validation work of Diamond Springs and volunteered to perform the surface sweep at Guthrie Road. Several intact mortar rounds were recovered during the surface sweep; however, numerous intact rounds and large pieces of surface shrapnel were missed. No QA measures were used during the surface sweep, as we believed that having our own EOD team would solve the problems encountered at Diamond Springs. Again, had the EOD team been challenged with QA measures, we could have demonstrated that ordnance and scrap metal was too often being missed.

What are the consequences of a poor surface sweep and how do they relate to QA? The first consequence is the failure to substantially reduce the exposure to surface UXO. This means the geophysical and land survey teams are exposed to more danger. The second consequence is that large pieces of shrapnel and ordnance-related scrap are missed along with UXO. As ordnance-related metallic debris and large segments of rounds - such as we often encountered in the form of 81-mm white phosphorus (WP) and 76-mm WP rounds - are very difficult to discriminate from the geophysical signal produced by actual UXO. The presence on the surface of such items at the time of the geophysical survey results in an increase in the number of geophysical anomalies that cannot be discriminated from UXO. False positive rate profoundly influence overall clearance costs because they require multiple subsequent actions, each costing time and money.

Emplacement for Quality Assurance

For the Diamond Springs Road emplacement effort, we determined the types of ordnance that could be present from three sources: archival search activities, preliminary site characterization, and surface sweep results. We selected inert ordnance that was of the same age, condition and type as recovered from the site. Whenever possible, we used inert ordnance that was recovered from the site. Inert ordnance from the site ensured a close signal match with the magnetic properties of actual UXO. This method reduced bias in estimating detection efficiency.

We emplaced inert rounds at depths and orientations that were representative of actual penetration depths. We determined depths for each type from ballistic modeling (CONWEP). We emplaced many of the rounds in the least favorable orientation for detection (azimuth was horizontal and long axis of round oriented along perpendicular to the earth's magnetic field). The rounds were concealed and ground disturbance concealed when possible. When a backhoe was needed to bury rounds at depth, ground disturbance could not be concealed. Instead, we made two additional "empty" digs.

Rounds were emplaced in specific orientations and depths and this information was recorded on pre-printed emplacement worksheets. These sheets could then be shared with geophysical contractor for comparison of results once the anomaly was declared.

We used the same process for Guthrie Road in the selection of representative inert ordnance. The relative position of emplaced ordnance was surveyed to allow estimates of positional accuracy. Note that it was the knowledge of the position of emplaced rounds that led to identification of a systematic position error by GTL. This knowledge allowed GTL to fix this error in the field in less than 24 hours. Had this error not be caught, the entire project could have been jeopardized.

Geophysical Technology Selection

JPG II and III demonstrated that site conditions can have significant influence on performance. Preliminary site investigation of the geology of Diamond Springs indicated that the site should have little noise from mineralized soils as the site was primarily of Pleistocene shale. Ballistic modeling along with data on the types of UXO to be expected led to the conclusion that total field (cesium vapor) magnetometers would be the best choice. This is because we would be looking for rounds as deep as 8 feet in a geologically quiet substrate.

In the selection of a geophysical contractor, we looked to firms with a demonstrated ability to find UXO at high detection efficiency. We used JPG II demonstration results to select potential bidders. We looked at each firm's JPG record or equivalent experience, cost, and overall credentials. Geophysical Technology, Ltd. (GTL) of Armidale, Australia was awarded the contract to conduct the geophysical survey in the Diamond Springs area. GTL used a man-portable, dual-sensor cesium vapor magnetometer. Relative position information was tracked using a cotton thread odometer.

Man-portable, dual-sensor cesium vapor magnetometer

In contrast to the Diamond Springs area, the Guthrie Road area was littered with shrapnel. We learned from experience at Diamond Springs that large shrapnel and pin flags are hard to discriminate from UXO. High levels of shrapnel create a serious problem with "noise." Geophysical tests were conducted with a variety of instruments that confirmed the presence of large amounts of noise from shrapnel. In-field equipment tests by GTL demonstrated that their cart system could filter shrapnel and still detect UXO. We concluded that the best way to handle the problem was through a multiple sensor towed array with sensors close to the ground and highly accurate positioning capability.

Multiple sensor towed array system

Physical Location of Geophysical Anomalies

After completing geophysical surveys of the Diamond Springs and Guthrie Road areas, GTL provided us with the locations of all detected geophysical anomalies within the two areas. They prioritized the anomalies as high, medium, or low confidence. They also provided a list of “junk” anomalies. Junk anomalies are those in which a metallic item is present, but in which the item does not model like UXO. Each geophysical anomaly that was validated was first located in the field by conducting an EDM (electronic distance measuring) survey. The anomaly location was marked in the field with both a survey flag and an aluminum tag attached to a six-inch steel nail. Each aluminum tag was inscribed with the anomaly number. This aluminum tag became the "validation tag."

Anomaly Validation

The results of each anomaly validation were recorded on a validation sheet. The sheet was completed at the time of validation and consists of a series of data blocks, each with specific questions that relate to the size, shape, orientation, depth and position of the item found. We required that detailed information be collected for ordnance and non-ordnance alike. A photograph of all intact ordnance was taken. Our method requires that the aluminum tag with the anomaly number be handled in one of two ways: (1) attached to the validation sheet if the anomaly was non-ordnance or (2) attached directly to the ordnance if the item was an intact round. This system ensured a means of accounting for the status of each reported anomaly.

Field validation of anomaly by Air Guard EOD

We recognized that there would be some irreducible uncertainty about validation results. Uncertainty stems from the fact that each geophysical anomaly identified in the initial survey must be re-located during validation. Because detection equipment used by EOD during validation (Vallon 1620B and Ferex®) does not have the same signal discrimination capability as a cesium vapor magnetometer, it is possible that the actual source of the anomaly will not be located. This possibility increases as the density of shrapnel and metallic debris increases. In our experience, it was difficult to discriminate near surface items from deeper anomalies. If positional accuracy is suspect, validation can be tedious and time-consuming. Uncertainty is lowest when positional accuracy is high (< 50 cm), discrimination capability is known to be high, and the match between the item found and the reported anomaly is good.

The detailed information on the validation sheet allowed us to evaluate the quality of the match between the object found by EOD and the anomaly identified by the geophysical team. When there was asymmetry in this match (i.e. small object found large dipole reported), we took additional QA measures.

Additional QA Measures

During the Guthrie Road validation, Air Guard EOD technicians defined about 100 points as "nothing found" points. Nothing found could mean one of two things: (1) the EOD technicians detected a magnetic deviation but could not find an obvious source of the anomaly, or (2) the EOD technicians could not detect an anomaly with their equipment because the anomaly was moved, their equipment was used improperly, or the anomaly was outside of the range of the equipment. In about 9 percent of the points, no geophysical anomaly could be detected. These sites had to be checked for positional accuracy, and if positional accuracy was correct, then the original source of the anomaly remained unknown. We did not want any unresolved anomalies in a residential area. We sought to resolve the anomalies by using a similar technology to attempt to replicate the result. As a result, we brought another geophysical surveying contractor (SC&A) to the site to look at about 75 of these locations using a quad sensor cesium vapor magnetometer. After reviewing SC&A's data, a UXO technician from Tetra Tech NUS reinvestigated all 100 "nothing found" points. The points were revalidated with a fluxgate magnetometer (Ferex®). No additional discoveries were made; however, fragmentation and metallic debris were found at some of these sites.

This quality assurance check led to the discovery of 15 anomaly points that were missed by the land surveyor. We located all of these points in the field for validation by a UXO technician. QA validation results were incorporated into the GIS database. Once all of the validated anomalies were plotted, a clear pattern emerged that allowed us to delineate where the actual targets for the 81-mm mortars were located. This, in turn, allowed us to prioritize anomalies where some uncertainty remained as to the source. We then focused our efforts on validating selected anomalies that were identified by GTL as "junk" points within these anomaly clusters. These additional validation efforts will be completed in the spring of 2000.

Conclusions

By building quality assurance meaures into each stage of the project, we were able to quantify detection efficiency, quantify positional accuracy, and reduce false positives. Results from the Diamond Springs and Guthrie Road investigation are summarized in Table 1 below:

Table 1: Summary of Findings

Site	Percent of Emplaced Rounds Detected	Mean Positional Accuracy	True:False Positives
Diamond Springs Area	94.7 %	72 cm	1:10 (n=370)
Guthrie Area	100%	20 cm	1:10 (n = 840)

Quantifying Detection Efficiency:

Emplaced ordnance allows a simple, direct, and inexpensive means to estimate detection efficiency. We emplaced 19 and 31 rounds for Diamond Springs and Guthrie Road sites, respectively. The number emplaced was based the availability of representative ordnance and a desire to have a sample size that would constitute ten percent or more of the total number of intact rounds recovered from each site. GTL correctly classified 18 of the 19 emplaced rounds at Diamond Springs as ordnance and all 31 emplaced rounds at Guthrie Road.

Quantifying Positional Accuracy:

We determined positional accuracy by measuring the distance between the item and the survey flag position. There will always be a small, random error associated with the position of the survey flag due to survey error. Results indicate that this error is negligible. Positional accuracy on Diamond Springs was generally within one meter of the survey flag. We found that one meter positional accuracy was sufficient to resolve nearly all geophysical anomalies at Diamond Springs. Uncertainty increased sharply when positional accuracy exceeded one meter. At Guthrie Road, the dGPS positioning allowed for a mean positional accuracy of fewer than 25 cm. Positional accuracy >50 cm would have greatly increased validation time and uncertainty due to shrapnel levels.

Reducing False Positives:

We were able to reduce false positives to under 10:1 without a concomitant decline in detection efficiency. We believe that several factors influenced this result. We took care to match the technology to site conditions and target parameters and selected a proven geophysical technology operated by an experienced geophysical contractor. We reduced the surface clutter through surface sweeps. We established calibration grids using representative ordnance and emplaced inert ordnance on the site providing an immediate and obvious incentive to the geophysical contractor to carefully evaluate each anomaly. Finally, we collected detailed performance metrics data and shared this data with the geophysical contractor.