FINAL

WIDE AREA ASSESSMENT FIELD DEMONSTRATION REPORT FOR THE CLOSED CASTNER RANGE FORT BLISS, TEXAS

PREPARED FOR:
U.S. ARMY CORPS OF ENGINEERS, OMAHA DISTRICT
U.S. ARMY ENVIRONMENTAL COMMAND

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URS

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U.S. Army Corps of Engineers, Omaha District

and

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EXECUTIVE SUMMARY

The U.S. Army manages millions of acres of closed ranges, areas formerly used for military training or testing purposes, that may be contaminated by munitions or munitions-related items. Before this land can be repurposed for military use or returned to the public, it must be investigated and cleared of munitions-related hazards to a standard consistent with the proposed land use. Conducting detailed investigations of very large sites (some exceeding 10,000 acres) using current geophysical technologies and practices is costly and time consuming. Large areas of land within the Army's Munitions Response Site (MRS) inventory may not contain munitions and explosives of concern (MEC), so the benefits associated with conducting detailed site characterization on all of this land are unlikely to justify the costs.

The U.S. Army Environmental Command (USAEC) has actively sought to identify, develop, and demonstrate technological approaches that would enable cost-effective and rapid classification of range lands into those with munitions-related impacts and those areas with no indication of munitions use. The Army requires methods to reliably:

- Identify areas of concentrated munitions use,
- Identify areas with no indication of munitions use, and
- Improve the understanding of relative MEC densities across the MRS.

Wide area assessment (WAA) is the specialized application of site characterization technologies to gather large amounts of data rapidly, thereby improving the understanding of a site and supporting site management decisions. WAA is not a single technology, but rather a set of methods for applying technologies that increases their coverage and data collection rates. WAA methods have been used extensively within the U.S. Air Force Military Munitions Response Program (MMRP) and the Formerly Used Defense Site program. These methods have been demonstrated to support decisions at various stages of the munitions response process, such as identifying MRSs during the Site Inspection phase, and characterizing the nature and extent of MEC contamination during the Remedial Investigation (RI) phase. In 2009, USAEC conducted a "desktop" study of the costs and benefits of applying WAA technologies under conditions common to MRSs within the Active Army MMRP (URS 2009).

Because of the uncertainties inherent in a desktop study, this current field demonstration was initiated to test and refine conclusions from the 2009 study. The Closed Castner Range MRS at Fort Bliss, Texas, was one of the four sites used as a reference location in the desktop study and was selected as the demonstration site because of its extensive prior use as a training range, large size (over 7,007 acres), and field conditions, including large areas of flat terrain and relatively sparse and low vegetation. The selected approach was to use WAA technologies—light detection and ranging (lidar), orthophotography, helicopter-borne magnetometry, man-portable electromagnetic induction (EMI) digital geophysical mapping (DGM), analog range reconnaissance, and intrusive investigation—in a layered approach. The objective was to demonstrate the ability to use multiple layers of data in identifying areas of concentrated munitions use, confirming areas with no munitions use, and improving the understanding of the density and distribution of MEC across the MRS. Although this project is not part of an MMRP

RI, data collection methods, stakeholder involvement, and application of quality control measures produced a data set that meets the stringent requirements of an RI.

Lidar and orthophotography data were collected at the same time from the same platform, with lidar data density at 22 points per m^2 and orthophotographs at a pixel size of 10 cm. Bare earth models were analyzed in conjunction with corresponding photos to identify features indicative of munitions-related activities. Lidar and orthophotography can delineate craters above 1 m diameter, as well as target features, berms/trenches, and demolition pits. They can be used to identify areas used for certain munitions-related activities (e.g., demolition); however, the absence of surface features cannot, by itself, be used to draw confident conclusions about the absence of munitions. Features discovered by lidar/orthophotography were used in conjunction with other data layers to refine maps of areas of interest, and topographical data were vital in planning helicopter-borne magnetometry and man-portable EMI DGM.

Helicopter-borne magnetometry data were collected over those parts of the Closed Castner Range MRS with an average slope of less than 5%, or about 1,742 acres, representing 25% of the total range area. Areas of greater slope make flying at the required 1–3 m altitude unsafe. The airborne platform covered a large area quickly but site conditions resulted in a less than optimum data set. Under optimal conditions, helicopter-borne magnetometry reliably detects metallic items as small as 60mm, but because of vegetation, a significant portion of the Closed Castner Range MRS data was collected above the optimum altitude, resulting in a weaker target signal. The Closed Castner Range MRS also contains large amounts of 37mm, 40mm, and 57mm projectiles and 2.36-in. rockets. Additionally, ferrous geology contributed significant background noise, and the resulting data were not used to identify areas of munitions use, identify areas without munitions use, or improve the understanding of MEC densities and distribution.

Man-portable EMI DGM was employed in a transect approach, where the transect spacing was calculated using Visual Sampling Plan software to achieve a 95% probability of traversal and detection of conservatively defined preliminary target areas. Two contractors each surveyed approximately half of the safely accessible acreage, areas with an average slope of less than 18%, which totaled approximately 3,521 acres, or 50% of the MRS. Man-portable DGM successfully located metallic anomalies representative of the types and sizes of munitions expected, which were later confirmed by intrusive investigation. The combination of digital geophysical data with precise locational data enabled the creation of anomaly density maps showing possible areas of concentrated munitions use (i.e., anomaly densities from 300 to 1700 per acre) and areas with little indication of concentrated munitions use (i.e., anomaly densities less than 300 per acre).

Stakeholders were engaged early and often through the Technical Project Planning process, and were briefed on the technologies, their limitations, and their accomplishments. Stakeholders at Fort Bliss included project and technical personnel from the Army, Fort Bliss personnel, Fort Bliss Restoration Advisory Board members, representatives from the state regulatory community, Native American tribal representatives, preservation and conservation organization personnel, and local citizens and community leaders. Stakeholder concurrence was obtained at every phase of the project. Because of their intimate local knowledge, stakeholders identified concerns about potential MEC along unofficial hiking trails and steep arroyos or eroded water channels, which were inaccessible to other methods of assessment. Consequently, an analog range reconnaissance approach was implemented, where unexploded ordnance (UXO) technicians wielding handheld metal detectors and global positioning system units investigated about 22 miles of these features of concern, mapping metallic anomalies and classifying surface debris. These data, while less formal than EMI DGM, nevertheless provided a key understanding of the types and quantities of munitions-related items in these areas.

The layers of data from these assessment technologies were compiled and compared to identify 18 preliminary target areas, or areas of possible concentrated munitions use. The remaining acreage was hypothesized to be non-target area based, in part, on a low probability of encountering MEC. A sample size calculation was performed to determine how many anomalies identified by man-portable DGM required investigation to estimate the proportion of anomalies within each preliminary target area that were munitions-related items. A separate sample size calculation, based on UXO Estimator, was performed to test a hypothesis about the relatively low MEC density (i.e., less than 0.5 per acre) in the non-target areas. UXO dig teams then returned to the field and excavated the randomly selected anomalies and classified each find as to type and source. Nearly 3,000 anomalies were reacquired and excavated. Using this approach, approximately half of the assessed acreage was confirmed as non-target area at the 90% confidence level.

This project successfully demonstrated the WAA technologies on an Active Army MMRP site and supported the conclusions of the cost-benefit analysis. Transect-based, man-portable EMI DGM proved to be highly effective to determine the relative density and distribution of anomalies in all but the steepest terrain. Lidar data effectively identified range and munitions-related surface features that were not visible at ground level or in orthophotographs. Lidar was also very useful for planning other site characterization methods. While helicopter-borne magnetometry proved less effective under these specific site conditions, it nevertheless remains an important tool for WAA, in general. Analog reconnaissance proved effective in investigating areas otherwise inaccessible to WAA technologies. Intrusive investigation was used for anomaly classification by confirming the source of individual anomalies; however, it remains the most labor intensive (i.e., costly) phase of the investigation process.

All the WAA methodologies require careful planning, with rigorous adherence to accepted statistical approaches, in order to obtain the desired confidence in conclusions about the relative densities and distribution of munitions-related items. Because no change from current land use has been proposed for this MRS, this report does not draw conclusions about MEC hazards on the site, nor does it make recommendations for response actions. The methods and data within this report should be re-examined for applicability when land use is selected and during the formal MMRP RI. This project does not complete the investigation at the Closed Castner Range MRS, but the data reported here will be of significant benefit to the subsequent RI.

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ACRONYMS AND ABBREVIATIONS

agl	Above Ground Level
ARDEC	Armament Research Development and Engineering Center
ASCII	American Standard Code for Information Interchange
CADD	Computer-Aided Drafting and Design
COG	Course-Over-Ground
DDESB	Department of Defense Explosives Safety Board
DGM	Digital Geophysical Mapping
DMM	Discarded Military Munitions
DoD	Department of Defense
DPE	Deflection Probable Error
EMI	Electromagnetic Induction
ESTCP	Environmental Security Technology Certification Program
GIS	Geographical Information System
GPS	Global Positioning System
GSV	Geophysical System Verification
HE	High Explosive
HFD	Hazardous Fragmentation Distance
HMX	Cyclotetramethylenetetranitramine
IMU	Inertial Measurement Unit
ISO	Industry Standard Object
IVS	Instrument Validation Strip
Lidar	Light Detection and Ranging
MC	Munitions Constituents
MD	Munitions Debris
MEC	Munitions and Explosives of Concern
MMRP	Military Munitions Response Program
MRS	Munitions Response Site
MYBP	Million Years Before Present
NMD	Non-Military Debris
NRL	Naval Research Laboratory
nT	nanoTeslas
OB	Open Burn
OD	Open Detonation
PDA	Personal Digital Assistant
QA	Quality Assurance
QC	Quality Control
RCRA	Resource Conservation and Recovery Act
RDX	Cyclotrimethylenetrinitramine
RI	Remedial Investigation
RMS	Root Mean Squared
RPE	Range Probable Error
RRD	Range-Related Debris
RTK	Real-Time Kinematic
SI	Site Inspection

TP	Target Practice
TPP	Technical Project Planning
URS	URS Group, Inc.
USACE	U.S. Army Corps of Engineers
USAE	USA Environmental, Inc.
USAEC	U.S. Army Environmental Command
UXO	Unexploded Ordnance
VSP	Visual Sampling Plan
WAA	Wide Area Assessment

1. INTRODUCTION

1.1 Project Purpose

The purpose of the Wide Area Assessment (WAA) Field Demonstration for the Closed Castner Range, Fort Bliss, Texas, was to demonstrate the costs and benefits of applying various investigation methods at an Active Army Military Munitions Response Program (MMRP) site, specifically, the Closed Castner Range Munitions Response Site (MRS). The primary objectives were to test and refine the conclusions of a previous desktop cost-benefit analysis conducted by the U.S. Army Environmental Command (USAEC) (URS 2009) and to collect data about the relative densities and distribution of munitions and explosives of concern (MEC) and munitions debris (MD) at the MRS to support future remedial investigation/feasibility study efforts and land management decisions. Data were collected with the objectives of (1) supporting the identification of areas of concentrated munitions use, (2) confirming the identification of areas with no indication of munitions use, and (3) improving the understanding of relative densities of MEC/MD across the MRS.

The WAA methods demonstrated include (1) light detection and ranging (lidar) and orthophotography, (2) helicopter-borne magnetometer survey, (3) man-portable electromagnetic induction (EMI) survey, and (4) analog range reconnaissance using handheld EMI instruments and personal digital assistants (PDA). Intrusive investigation was used to identify and classify metallic anomalies identified by geophysical means. The project also demonstrated Visual Sampling Plan (VSP) and UXO Estimator as statistically defensible methods to validate site characterization conclusions with limited transect coverage, as well as geophysical system verification (GSV) in place of geophysical prove-out as a method of quality control (QC) for geophysical instruments and data collection.

1.2 Site Description

Fort Bliss is located in three counties, Dona Ana and Otero counties in New Mexico and El Paso County in Texas. The cantonment area is situated adjacent to the city of El Paso, Texas, just north of the city of Juarez, Chihuahua, Mexico. The installation encompasses approximately 1.1 million acres. Figure 1-1 is a location map of Fort Bliss.

The Closed Castner Range MRS (FTBLS-004-R-01) on Fort Bliss is located within El Paso, Texas, between U.S. Highway 54 and the Franklin Mountains State Park and is approximately 15 miles south of the border with New Mexico. The MRS is now 7,007 acres, after acreage east of U.S. Highway 54 was transferred to non-Department of Defense (DoD) entities. The site contains medium and large caliber projectiles [including high explosives (HE), fragmentation, target practice (TP)], mortars, pyrotechnics, illumination flares, grenades, and small arms. Figure 1-2 is a map of the Closed Castner Range MRS.

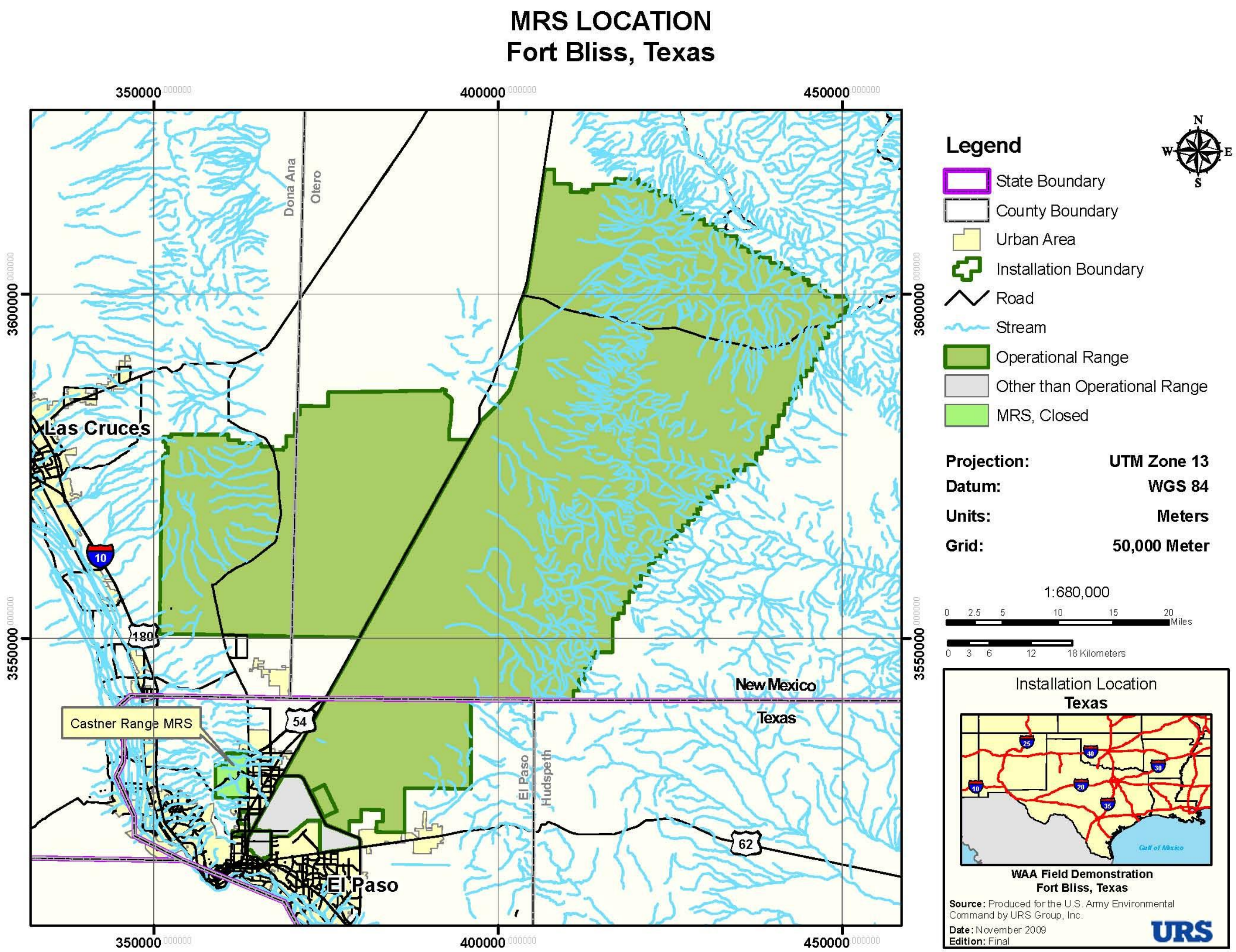

Figure 1-1. Fort Bliss Location Map

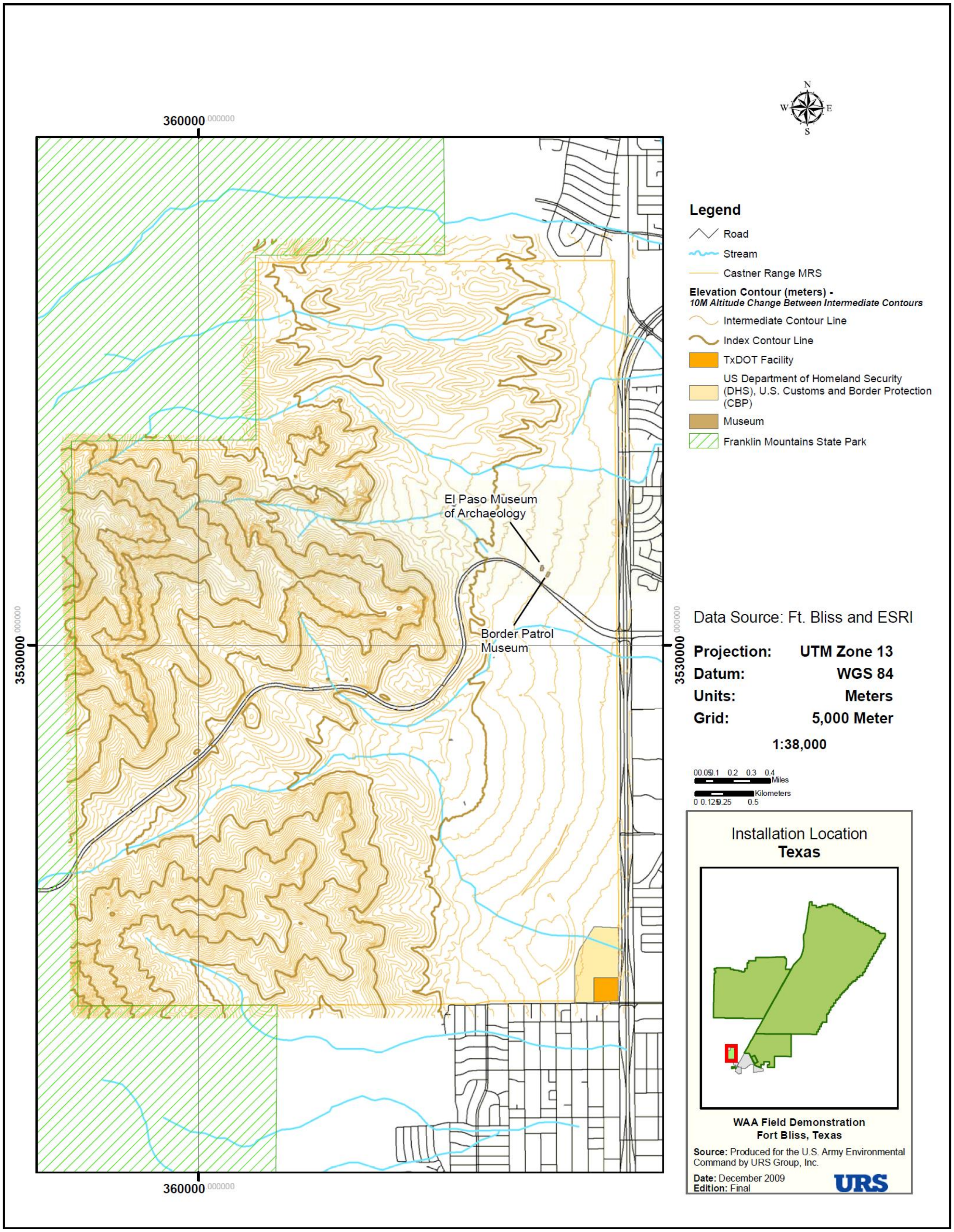

Figure 1-2. Closed Castner Range MRS Topography

1.2.1 Surface Topography

The Closed Castner Range MRS lies in the foothills of the Franklin Mountains. The dominant terrain types are gently rolling terrain (approximately 40%, or 2,800 acres), heavily rolling terrain (approximately 20%, or 1,400 acres), and mountainous terrain (approximately 40%, or 2,800 acres). The Franklin Mountains' northernmost reaches extend into Fort Bliss and are composed mostly of lower slopes and alluvial fans, which range in elevation from 4,265 ft to slightly over 5,000 ft above mean sea level. Topographic features of the Closed Castner Range MRS are shown in Figure 1-2.

1.2.2 Climate

The climate across Fort Bliss is typified by low relative humidity, hot summer months, and moderate spring and winter months. Higher elevations on the installation receive higher levels of precipitation and can, therefore, display semi- and sub-humid climatic zones.

The average annual precipitation at Fort Bliss ranges from 8 in. in the valley to 20 in. in the mountains. Warm, moist air from the Gulf of Mexico, and occasionally from the Pacific Ocean, precipitates thunderstorms in the region. Thunderstorm activity is prevalent between July and September, accounting for the majority of the annual rainfall. A dry season occurs from winter to early summer. Snowfalls average 4.6 in. annually, but rarely last for more than a day.

Fort Bliss experiences a highly variable range of temperatures throughout the year, between –8ºF and 114ºF. The daily average is 64ºF, with a daily maximum average of 76ºF and a minimum of 51ºF. Temperatures typically rise above 90°F on an average of 87 days per year, and fall below freezing on an average of 34 days per year. Evaporation rates are very high on the installation, averaging a 97-in. precipitation deficit each year (Fort Bliss 2001).

1.2.3 Vegetation

Vegetation types found on the site include barren or low grass (approximately 35%), low grass with brush (approximately 64%), and brush with some trees (approximately 1%). The topographic relief and associated heterogeneity of climate in the southwest result in rich vegetative biodiversity on Fort Bliss. The mountains of Fort Bliss are populated with juniper savanna, conifer and mixed woodlands, and montane conifer forests. The plant communities in the lowland areas include desert grasslands, Chihuahuan Desert scrub, and plains mesa sandscrub.

The Closed Castner Range MRS has three primary plant communities: Agave-Lechuguilla, alluvial fan-creosotebush, and draw yucca grassland. The Closed Castner Range MRS's mountainous areas are characterized by the Agave-Lechuguilla community, which forms dense clonal clumps on colluvial slopes of hills and mountains, extending downslope onto erosional piedmont surfaces. The Agave-Lechuguilla community's predominant species include viscid acacia (*Acacia neovernicosa*), lechuguilla (*Agave lechuguilla*), common sotol (*Dasylirion wheeleri*), ocotillo (*Foquieria splendens*), and catclaw mimosa (*Mimosa aculeaticarpa*).

The alluvial fans of the Franklin Mountains are home to the alluvial fan-creosotebush community, characterized by creosotebush (*Larrea tridentate*), whitethorn (*Acacia constricta*), American tarbush (*Flourensia cernua*), Spanish dagger (*Yucca torreyi*), broom snakeweed (*Gutierrezia sarothrae*), and lechuguilla. Grasses are rare, and, where present, basal coverage is low at less than 0.5%. Arroyos and drainage areas are more moist than other areas and support different vegetation types, including desert willow (*Chilopsis linearis*), Apache plume (*Fallugia paradoxa*), and little leaf sumac (*Rhus microphylla*) (Fort Bliss 2001).

Although there is no documentation of any threatened or endangered plants on the Closed Castner Range MRS, a high outcropping rock formation on the southwest corner of the range exemplifies preferred habitat and substrate for the Sneed Pincushion Cactus *(Coryphantha sneedii var. sneedii),* a federal and state endangered species. However, no specimens of the cactus have been found there (Corral 2011), and no project activities are planned in this area.

1.2.4 Wildlife

The borderlands region of New Mexico and Texas is a center of biodiversity in temperate North America for birds, mammals, amphibians, and reptiles, so the diversity of terrestrial vertebrates on Fort Bliss is high. However, a few warm-blooded vertebrates are centered in or limited in distribution to the Chihuahuan Desert. Many of the birds and mammals (and a good proportion of the herpetofauna) found on Fort Bliss are those generally found in the intermountain west, with a substantial great plains influence. Approximately 335 species of birds, 58 species of mammals, 39 species of reptiles, and 8 species of amphibians are known to occur on Fort Bliss lands. Although invertebrates play a crucial role in the trophic structure of desert ecosystems, no thorough inventories of invertebrates have been conducted on Fort Bliss. However, the highest known arthropod diversity in North America is found in the southwest, and several groups of arthropods have their centers of diversity for North America in the borderlands region (Fort Bliss 2001).

Several species with various levels of protective status exist on Fort Bliss. Only two threatened fauna occur or potentially occur on the Closed Castner Range MRS, as shown in Table 1-1 (Locke 2011).

Table 1-1. Special Status Fauna Occurring or Potentially Occurring on the Closed Castner Range MRS

Species	Federal Status	Texas Status
Texas horned lizard (*Phrynosoma cornutum*)	—	T
Texas lyre snake (*Trimorphodon biscutatus vilkinsonii*)	—	T

T = threatened species
Source: e2M 2007.

1.2.5 Geology

The study area and vicinity were part of a relatively shallow marine shelf from the late Cambrian [600–500 million years before present (MYBP) through the early Pennsylvanian (310–280 MYBP) eras]. Dolomite beds are from the late Cambrian to the late Ordovician (500–425 MYBP) and are the oldest sedimentary deposits in the area. Deposition during Devonian time consisted mainly of marine shales and shaly limestones. A relatively thin sequence of upper Mississippian age limestone and shale overlies the Devonian rocks. Unconformably overlying the Mississippian deposits are approximately 3,000 ft of Pennsylvanian age sediments. These strata consist of limestone, sandstone, dolomite, and shale, which were deposited in a shallow marine environment. Tectonic disturbances in Virgilian time (late Pennsylvanian) altered the sedimentation origin from marine to terrestrial. The tectonic movement resulted in the subject area becoming a large depression with landmasses developed to the east, west, and southwest. In later Pennsylvanian and early Permian time, the Tularosa Basin received a thick sequence of land-derived sediments. Most sedimentary rocks in the area consist of limestone strata of the San Andres formation. These sediments mark the return of marine shelf deposition in the area. Broad regional uplift that occurred between 80 and 40 MYBP (Cenozoic Era) and differential drift within the North American Plate, which occurred 30 MYBP (Miocene), created fault patterns in the region. The result was a physiographic province characterized by down-dropped basins (grabens) bounded by tilted fault block mountains. These grabens have been filled with heterogeneous, unconsolidated to poorly consolidated sediments, which cover underlying sediments. By middle Cenozoic time (present to 65 MYBP), the Hueco and the Mesilla bolsons on the east and west of the Franklin Mountains, respectively, were the prominent basins of deposition. There is evidence that the Tularosa Basin has had a history of continuous, closed basin deposition, with Kansas playa complexes possibly united with Lake Cabeza de Vaca and/or Lake Lucero to the north. Eroded petrocalcic horizons, braided stream deposits alternating with poorly sorted mudflows, relic and Paleozoic horizons, topographic expressions of old sediment surfaces and terrace strand lines, and multiple superimposed petrocalcic (caliche) horizons demonstrate several periods of alternatively wetter and drier climatic trends during and since the Pleistocene (0.01–2 MYBP).

The southern portion of the Tularosa Basin contains more than 6,000 ft of valley fill, stream sand, and gravel; rock slides; alluvial fans from mountains on either side; and lake deposits rich in salt and gypsum derived from sedimentary rocks of the adjacent ranges. Any rainfall or melted snowfall that occurs in the valley either seeps into the porous valley deposits or evaporates from small pools, leaving deposits of gypsum, salt, or other minerals. Fault lines along the edge of the Tularosa Basin may still be active, although no movement has been recorded in recent time. The mountain ranges adjacent to Fort Bliss developed during separate geologic periods and comprise a variety of minerals and soils. These geologically different mountain ranges generally contain site-specific substrates, creating areas of unique communities. The Fort Bliss region lies in an area considered to be of moderate seismic activity. The Franklin Mountains block has been rising and the Hueco Bolson block has been sinking for tens of millions of years. Earthquake data estimate that the strongest earthquake in the area in a 100-year period lies between a magnitude of 4.8 and 6.0 on the Richter scale (e2M 2007).

Relatively small deposits of Castner Limestone containing diabase (or dolerite) dikes and sills are located in the central portion of the site, west of the Fusselman Dam area (see Figure 1-3). This area of potentially magnetic geology is in relatively higher elevations and steeper terrain. Magnetometer-based geophysical mapping was not performed in that area; however, magnetometer-based geophysical mapping was conducted in the lower elevations and generally flatter eastern part of the site, which is downslope from these potentially magnetic flows. These deposits, although localized, could be a source of the magnetic interference experienced in this

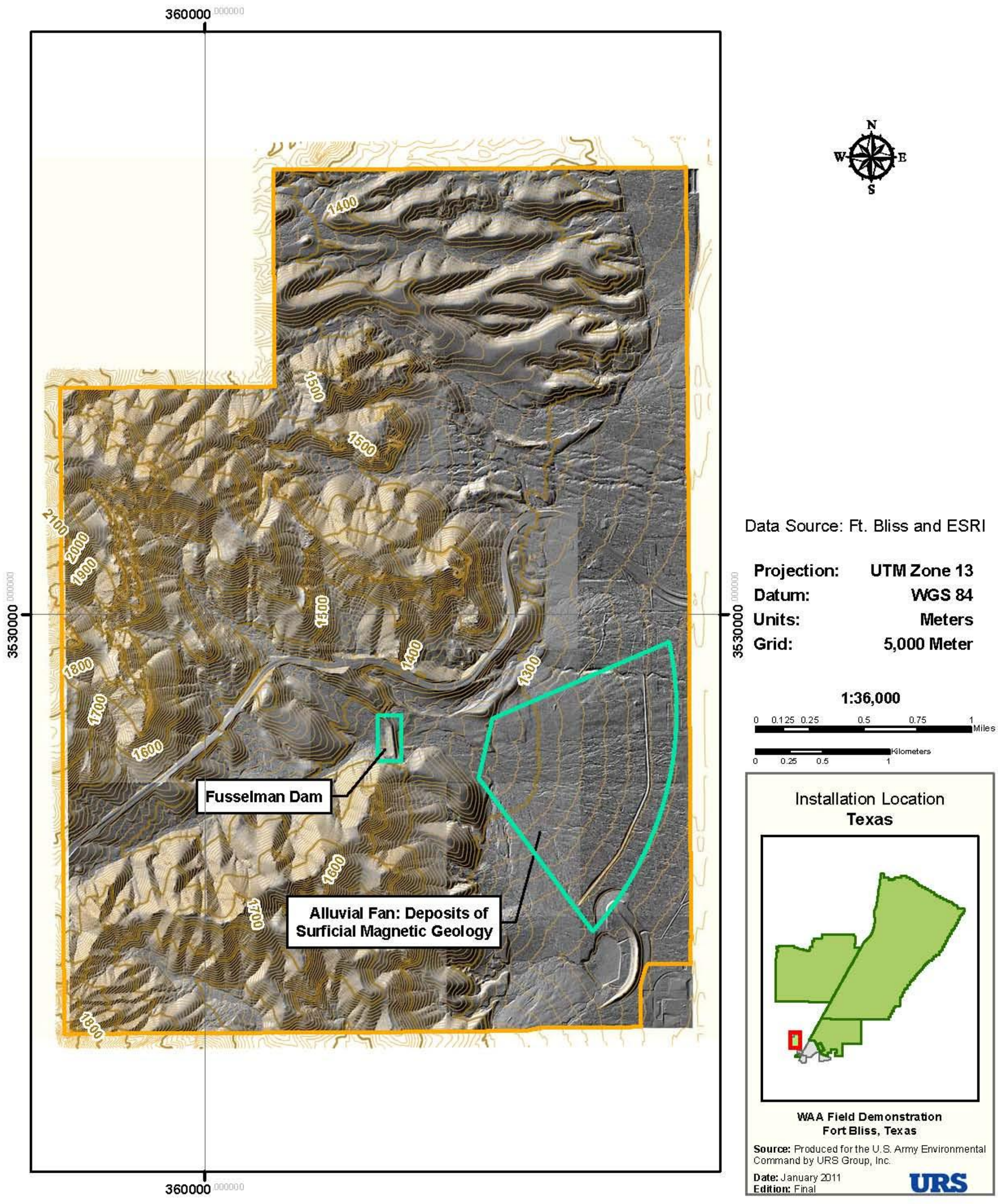

Figure 1-3. Areas Affected by Magnetic Deposits

downslope area. It is possible that, before the installation of the dam, the potentially magnetic geology to the north of the dam eroded and was deposited in the alluvial fan on the flat eastern part of the site at the base of the Franklin Mountains. This is depicted in Figure 1-3.

1.3 Historical Information

1.3.1 Overview of Historical Uses

During the war with Mexico in 1846, Colonel Alexander W. Doniphan and the 1st Missouri Mounted Volunteers became the first U.S. Army troops to enter the El Paso area. On November 7, 1848, the War Department directed the establishment of a post in El Paso to protect railways, stage routes, and settlers. The post was named Fort Bliss in honor of Lieutenant Colonel William Wallace Smith Bliss on March 8, 1854. El Paso established a permanent site for the post in 1890 and troops began to occupy the current location in 1893. The greatest period of growth for Fort Bliss occurred in response to a raid across the border by Pancho Villa, instigating a border control mission. World War II saw the cavalry dominance replaced by anti-aircraft artillery and the establishment of the installation as the largest overland air defense missile range and training center in the world. The U.S. Air Force closed neighboring Biggs Air Force Base in 1966 and turned it over to Fort Bliss (Fort Bliss 2001).

The acquisition of Castner Range began in 1926, initially encompassing approximately 3,500 acres. Additional land was acquired by 1939, bringing the range to 8,328 acres. Castner Range was heavily used for small arms firing courses and artillery firing and impact areas from 1926 until 1966 when ordnance use at Castner Range was discontinued (see Figure 1-4). In 1972, the Department of the Army declared Castner Range surplus to its needs and began to transfer parcels to non-DoD entities. Many isolated clearance operations have been conducted on Castner Range. Approximately 1,244–1,321 acres [discrepancies exist in the record (e2M 2007)] east of U.S. Highway 54 have been cleared of unexploded ordnance (UXO) and have been transferred; however, the remaining 7,007 acres of the Closed Castner Range MRS have not been transferred and remain in the Army's control.

1.3.2 Munitions Fired Onsite

Based on records reviewed in the Site Inspection (SI) Report (e2M 2007), the Closed Castner Range MRS potentially contains munitions items related to flares; signaling items; training simulator devices; screening smoke; grenades (hand, rifle, smoke); small, medium, and large projectiles (20mm–155mm); mortars; rockets; and small arms.

Reports from investigation and clearance activities on the Closed Castner Range MRS over the past 40 years have documented actual finds of munitions, including grenades (hand, rifle, and smoke); small, medium, and large projectiles (20mm–120mm); mortars (3 in. Stokes, 4.2 in., and 81mm); rockets (2.36 in. and 3.5 in.); and small arms items. The SI Report indicates that approximately 80% of the site was used for small arms training.

The Historical Records Review and SI indicate that mechanisms by which the munitions may have been released into the environment include intentional activities, such as firing into a target

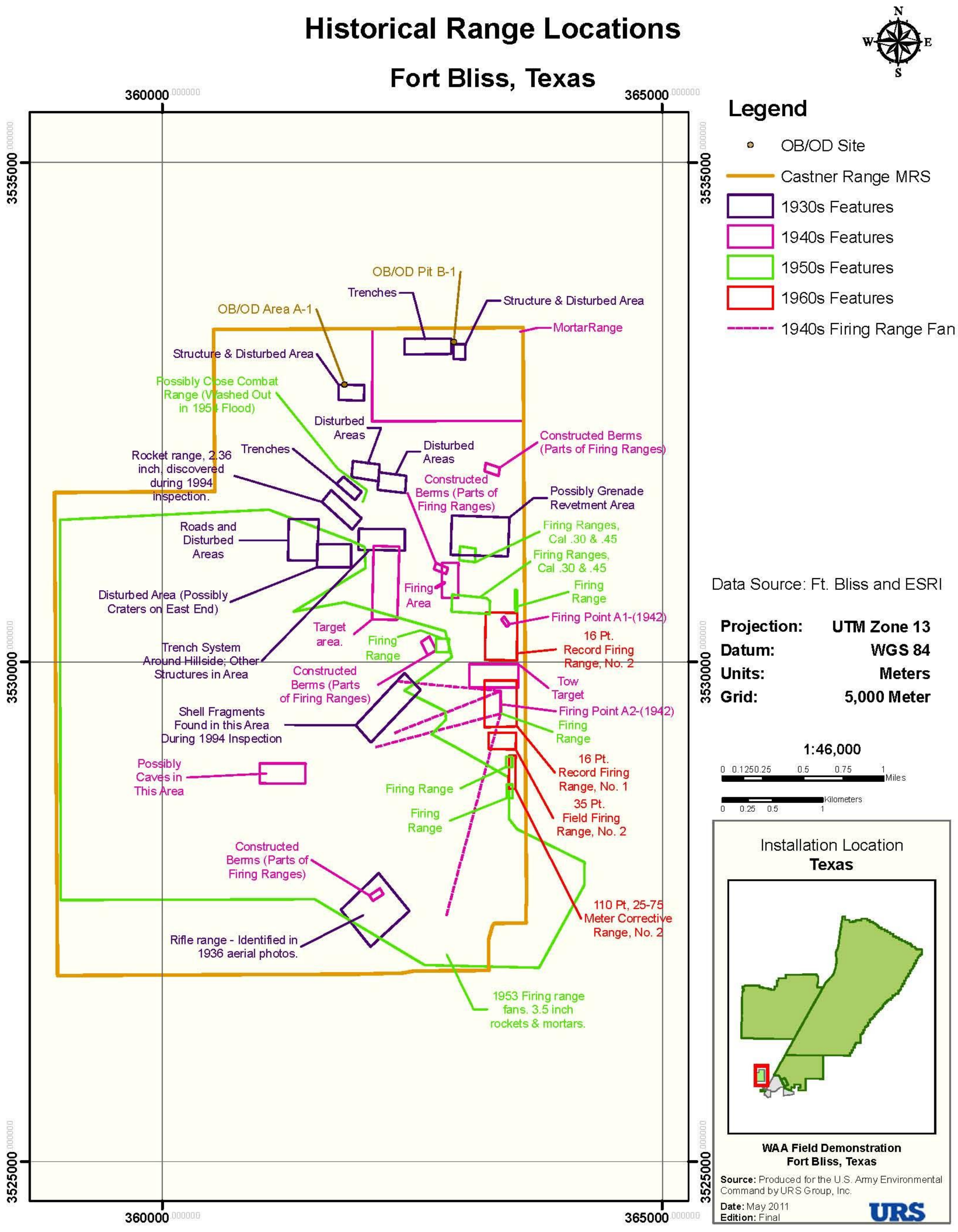

Figure 1-4. Historical Uses of the Closed Castner Range MRS Study Area

area, and disposal operations by open burn (OB)/open detonation (OD). The OB/OD area (FTBL-073) was found to contain cyclotetramethylenetetranitramine (HMX), cyclotrimethylenetrinitramine (RDX), and Resource Conservation and Recovery Act (RCRA) metals (e2M 2007).

1.4 Previous Studies

Historic site investigations between 1971 and 1999 included 12 surface clearance investigations, 1 subsurface clearance, and 4 soil sample studies (e2M 2007). These investigations discovered MEC as well as soil contamination on the Closed Castner Range MRS. MEC were either removed, blown-in-place or, in some cases left on the range, and included various projectiles, complete rounds, grenades, and other UXO and discarded military munitions (DMM). Analysis of soil samples documented metals, including lead, and various explosives in concentrations above minimum protective concentration levels.

In January and June–July 2001, at the Trans Mountain Buried Drum Site, a surface clearance resulted in the removal of one 105mm projectile and two 2.36-in. rocket motors prior to excavation of tar, asphalt, and metal debris. Analytical results from soil samples showed that this remedial action fulfilled clean closure requirements.

The OB/OD pit (FTBL-072) was cleared to a depth of 1 ft in June 2001, and no ordnance was found on the site. During site investigation of the OB/OD area in 2002, soil samples were tested for suspected munitions constituents (MC), including HMX, RDX, and RCRA metals. Results indicated that no regulated materials were released on the site above Environmental Protection Agency Region VI screening levels.

An additional MEC removal action was conducted on the Closed Castner Range MRS from July 1, 2003 to March 11, 2004; a surface clearance was conducted on 975 acres, and a subsurface clearance of 167 acres resulted in excavation of approximately 41,000 subsurface anomalies. During this action, 180 MEC and 241 assorted small arms ammunition items were located, identified, and disposed of. Surface soils sampled in the former OB/OD area (FTBL-073) in September 2003 did not show explosives or propellants. A test boring drilled on January 28, 2004 at the OB/OD site to a depth of 48.5 ft below ground surface did not reach groundwater.

1.5 Current and Projected Land Use

Although in 1972, the Army attempted to declare Castner Range surplus to its needs, the declaration was not accepted because of the presence of UXO. Several parcels have since been cleared of UXO and transferred either outright or via lease. These transfers have permitted public uses in connection with Trans Mountain Road and adjacent overlook picnic areas, the Border Patrol Museum, Archaeology Museum, Operation Head Start, and the Girls Scouts of America. Governmental sites on Castner Range include the Department of Homeland Security Border Patrol Station and Texas Department of Transportation maintenance yard. Despite signs, notices, fines, and potential jail time, illegal hiking, biking, digging, and harvesting of plants continues to occur on the Castner Range MRS.

Future land use for the Closed Castner Range MRS is undetermined at this time.

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2. PROJECT OBJECTIVES

2.1 Problem Statement

The U.S. Army manages millions of acres of closed ranges, areas formerly used for military training or testing purposes that may be contaminated by munitions or munitions-related items. Before this land can be repurposed for military use or returned to the public, it must be investigated and cleared to a standard consistent with the proposed land use. Conducting detailed investigations of very large sites (some exceeding 10,000 acres) using current detection and characterization practices is costly and time consuming. Large areas of land within the Army's MRS inventory may not contain MEC, so the benefits associated with conducting detailed site characterization on all of this land are unlikely to justify the costs.

WAA is the specialized application of site characterization technologies to gather large amounts of data rapidly, improving the understanding of a site and supporting site management decisions. WAA is not a specific technology, but rather a set of methods for applying technologies that increase coverage and data collection rates so that large tracts of land can be characterized quickly and relatively inexpensively. WAA methods have been used extensively within the U.S. Air Force MMRP and the Formerly Used Defense Site program. These methods have been demonstrated to support decisions at various stages of the munitions response process, such as identifying MRSs during the SI phase and characterizing the nature and extent of MEC during the remedial investigation (RI) phase.

In support of the Active Army MMRP, USAEC developed a desktop cost-benefit analysis of the relative cost effectiveness of various WAA methods, and applied it to four representative sites in the Active Army portfolio that met predetermined criteria (URS 2009). Because of the inherent uncertainties in a desktop analysis, a field demonstration was planned to confirm and refine conclusions.

The Closed Castner Range MRS at Fort Bliss, Texas, was one of four sites studied in the desktop analysis, and was selected as the demonstration site because of its extensive prior use as a training range, large size (over 7,007 acres), and field conditions, including large areas of flat terrain and relatively sparse and low vegetation. Historical activities on the Closed Castner Range MRS have resulted in the nonhomogeneous presence of MEC. Previous investigations discovered MEC on the Closed Castner Range MRS, including various projectiles, rounds, grenades, and other UXO and DMM (e2M 2007). A MEC investigation (including geophysical characterization and intrusive investigation) was needed to determine the density and distribution of MEC present and to define areas of concentrated munitions use and areas with no evidence of munitions use.

2.2 Purpose of Study

The purpose of this project was to demonstrate the costs and benefits of applying various WAA investigation methods at an Active Army MMRP site, Closed Castner Range MRS, Fort Bliss. The primary objectives were to:

- Test and refine the conclusions of the previous desktop cost-benefit analysis and
- Collect data about the relative densities and distributions of MEC to support the future remedial investigation/feasibility study within the MMRP.

The desktop study identified the following expected benefits of the proposed survey technologies:

- Lidar/orthophotography
  - Can quickly characterize munitions-related features (craters, target rings, earthen berms, and firing positions) across the entire site
  - May provide insight into areas of concentrated munitions use and may identify items not anticipated by a review of the historic record, such as large bombs
  - Will not allow conclusions about areas with no indications of munitions use
  - Provides highly detailed topographic maps to support other technologies

- Helicopter-borne Magnetometer Digital Geophysical Mapping (DGM)
  - Can conduct rapid survey of 100% of the accessible terrain (about 25% of the Castner Range MRS)
  - Can detect items 60mm or larger but unlikely to reliably detect items smaller than 60mm
  - At a site with historical usage of small munitions items, will not allow conclusions about areas with no indications of munitions use

- Towed-array EMI DGM
  - Can conduct transect-based survey of accessible terrain (about 40%) of the Closed Castner Range MRS
  - Multiple parallel sensors may reduce survey costs
  - Likely to detect all relevant munitions types

- Man-portable EMI DGM
  - Can conduct transect-based survey of the entire MRS
  - Likely to detect all relevant munitions types
  - Hypothesized to be the most cost-effective method to understand density and distribution of munitions on the Closed Castner Range MRS

- The combination of man-portable and helicopter-borne may be the best approach to defining areas with no concentration of munitions

Desktop cost estimates were prepared for each of these technologies and are compared with actual costs in Section 4 of this report.

2.3 Study Objectives

The objective of the lidar and orthophotography survey was to detect and locate surface features indicative of munitions-related activities. High-density lidar and orthophotography can identify surface features that are generally undetectable through observation at ground level. Lidar and orthophotography data can be collected in a single mobilization, and can survey large and topographically diverse areas quickly. This capability provides the potential to identify previously unrecognized firing points, target areas, debris burial sites, or other locations of munitions-related activities. Lidar and orthophotography data also provide highly detailed, bare-earth topographic models and vegetation elevation models, which support the delineation of areas suitable for helicopter-borne magnetometry, the placement of transects for ground-based geophysics, and planning for vegetation removal, if any is required. Lidar/orthophotography data were collected to answer the following study questions:

- To what degree does lidar/orthophotography detect surface features indicative of munitions-related activities?
  - Craters/crater fields
  - Target features
  - Berms
  - Demolition pits
  - Burial pits
- Do lidar/orthophotography images provide sufficient evidence to
  - Reliably identify areas of concentrated munitions use?
  - Reliably identify areas with no indication of munitions use?
  - Improve the understanding of relative densities and distributions of MEC across the MRS?
- How confident are stakeholders in these conclusions?
- To what degree do lidar/orthophotography data make subsequent characterization steps (e.g., helicopter-borne magnetometry) more efficient and cost effective?
- What are the total cost, cost per surveyed acre, and cost per characterized acre associated with lidar/orthophotography?

The objective of the geophysical characterization (both helicopter-borne and ground-based) was to detect subsurface MEC-related anomalies for intrusive investigation during the MEC investigation phase of the WAA field demonstration. DGM data were also intended to be used to validate the data collected in the historical records analysis and the data collected through lidar and orthophotography. The data were used to identify areas of high MEC density and areas of little or no evidence of munitions-related activity and provided insight into the distribution and density of potential MEC throughout the MRS.

The actual deployment of geophysical characterization methods at the Closed Castner Range MRS was generally based on:

- Areas of the site with terrain and vegetation consistent with safe deployment of the geophysical systems, whether helicopter-borne or ground-based;
- Estimated target area sizes [a function of weapon system firing error and hazard fragmentation distances (HFD)] for the munitions anticipated on the site;
- Outputs of VSP for transect spacing for the ground-based method; and
- The location of the arroyos (eroded gullies) and unofficial hiking trails throughout the mountainous areas for the analog range reconnaissance.

The WAA field demonstration collected helicopter-borne magnetometry data to answer the following study questions:

- Can helicopter-borne magnetometry reliably detect the munitions types expected on the MRS?
- Can helicopter-borne magnetometry:
  - Reliably identify areas of concentrated munitions use?
  - Reliably identify areas with no indication of munitions use?
  - Improve the understanding of relative densities and distributions of MEC across the MRS?
- How confident are stakeholders in these conclusions?
- To what degree does helicopter-borne magnetometry data make subsequent characterization steps (e.g., ground-based geophysics) more efficient and cost-effective?
- Over what percentage of the MRS can helicopter-borne magnetometry data be collected?
- For what percentage of the MRS can statistically valid conclusions be drawn based on helicopter-borne magnetometry data?
- What are the total cost, cost per characterized acre, and cost per surveyed acre associated with helicopter-borne magnetometry?

The WAA field demonstration collected man-portable geophysical data to answer the following study questions:

- Can man-portable EMI reliably detect the munitions types expected on the MRS?
- Can man-portable EMI:
  - Reliably identify areas of concentrated munitions use?
  - Reliably identify areas with no indication of munitions use?
  - Improve the understanding of relative densities and distributions of MEC across the MRS?
- How confident are stakeholders in these conclusions, particularly based on the transect survey approach?
- Over what percentage of the MRS can man-portable EMI data be collected?
- For what percentage of the MRS can statistically valid conclusions be drawn based on man-portable EMI data?
- What are the total cost, cost per characterized acre, and cost per surveyed acre associated with man-portable EMI?

As noted in the project work plan (URS 2010b), the steep and arroyo-riddled terrain made the deployment of towed-array geophysics impossible, and only man-portable approaches were used for ground-based DGM. In addition, some areas of the MRS were not accessible to litter-borne DGM, and analog range reconnaissance methods were used to survey arroyos and unofficial trails. The WAA field demonstration collected analog reconnaissance data to answer the following study questions:

- Can analog range reconnaissance reliably detect the munitions types expected on the MRS?
- Can analog range reconnaissance:
  - Reliably identify areas of concentrated munitions use?

  - Reliably identify areas with no indication of munitions use?
  - Improve the understanding of the types and quantities of MEC across the arroyos and unofficial hiking trails?
- How confident are stakeholders in these conclusions?
- Over what percentage of the MRS can analog range reconnaissance data be collected?
- For what percentage of the MRS can statistically valid conclusions be drawn based on analog range reconnaissance data?
- What are the total cost, cost per characterized area, and cost per surveyed area associated with analog range reconnaissance?

The objectives of the intrusive investigation were different for the preliminary target areas and non-target areas. For the preliminary target areas, the objective of the intrusive investigation was to determine the proportion of the detected anomalies attributable to MEC or MD. This was accomplished by performing statistically valid sampling (i.e., excavation and classification of selected anomalies) to confirm that target areas had been correctly identified. The objective of the intrusive investigation for non-target areas was to test the hypothesis that MEC densities were less than or equal to 0.5 MEC item per acre.

2.4 Study Boundaries

The study area was the Closed Castner Range MRS (FTBL-004-R-01), as defined during the SI (e2M 2007). The MRS is a generally open area, although the Franklin Mountains on the western portion of the parcel presented a constraint on the extent of the investigation. Helicopter-borne magnetometry was effective on those areas of the site consistent with safe low-altitude (1–3 m) helicopter flight. Man-portable DGM was effective on those areas safely traversed by two-person, litter mode geophysical teams. No vegetation removal was required to allow traversal of the area with man-portable geophysical equipment along predefined transects. The analog range reconnaissance process was used to characterize a subset of the areas inaccessible to man-portable geophysics, including the arroyos along the eastern portion of the site and unofficial hiking trails in the steep western mountains.

Anthropogenic constraints on the extent of the investigation included the presence of the Trans Mountain Road, the National Border Patrol Museum, the El Paso Museum of Archaeology, an Immigration and Naturalization Service Border Patrol Office, and a Texas Department of Transportation Regional Office within the MRS. Geophysical characterization was limited to areas where these constraints were not present.

2.5 Technologies Used

As described in the work plan (URS 2010b), the WAA technologies deployed to achieve the stated objectives included:

- Lidar and orthophotography over 100% of the MRS;
- Helicopter-borne magnetometer arrays over 100% of accessible area (average slope less than 5%);

- Man-portable EMI DGM over transects covering 100% of the accessible area (average slope less than 18%); and
- Analog reconnaissance with handheld EMI devices and handheld global positioning system (GPS) equipment.

The lidar/orthophotography data collection encompassed the entire MRS, or 7,007 acres; the helicopter-borne magnetometer arrays were flown in overlapping transects over the flattest portions of the MRS, with mean slopes of about 5% or less, which was 1,742 acres, or about 25% of the MRS. Man-portable EMI-based DGM was conducted along transects representing 3,521 acres. Teams from two subcontractors were deployed, each team surveying over 1,900 acres, with a 374-acre overlap for data comparison purposes. Analog reconnaissance was conducted along otherwise inaccessible drainages and trails, using handheld instruments, and covered approximately 22 miles of topographically determined transects.

For the intrusive investigation, the anomalies were reacquired using handheld GPS (Trimble GeoXH) and confirmed with handheld EMI-based metal detectors (Minelab Explorer II). Excavation and inspection were conducted by qualified UXO technicians using hand tools. The project also demonstrated the use of VSP as a method to support valid site characterization conclusions with limited transect coverage and UXO Estimator as a method to statistically confirm MEC density hypotheses about non-target areas.

3. SITE CHARACTERIZATION

3.1 Planning and Preliminary Activities

3.1.1 Site Survey

Because a suitable third order (1:5,000) accuracy survey monument was not available for correlation of sensor data with navigational data, a local professional land surveyor, Brock & Bustillos, was contracted to conduct a survey and establish appropriate and convenient survey monuments. Survey points were selected, marked, and reported to allow the URS team to collect geophysical characterization data using geophysical equipment within the spatial accuracy requirements of the project. Brock & Bustillos identified the property boundary of the entire site (approximately 7,007 acres), and established or confirmed monuments at 32 surveyed control points with a minimum of third order (1:5,000) accuracy. These surveyed control points allowed line-of-sight correlation between grid corner markers and were used to reference the placement of Trimble Real-Time Kinematic (RTK) GPS Base Stations, which supported geo-reference of all DGM data. The survey report is attached in Appendix A.

3.1.2 Determination of Transect Spacing through Visual Sampling Plan

Visual Sampling Plan (VSP) is a statistical sampling software tool designed to provide site investigators a defensible and reproducible method of planning a campaign to gather and analyze geophysical survey data at an MRS. VSP assumes non-uniform MEC distribution across the MRS, where MEC is distributed in higher densities in areas known as target areas and in lower densities in non-target, or “background,” areas. VSP calculates the maximum spacing allowed between transects to achieve the necessary confidence that target areas of specified size, shape, and density of anomalies will be traversed by one or more transects and detected by the geophysical survey equipment employed along the transects. In this way, only a portion of the site needs to be surveyed in order to characterize a much larger site, enabling ground-based DGM transect approaches to be used for WAA.

URS utilized VSP to calculate the planned distance between the man-portable DGM transects on the Closed Castner Range MRS. VSP requires the user to estimate and enter the size, shape, and orientation of the target areas of interest. In the case of the Closed Castner Range MRS, URS based the estimation of target area size on the munitions item historically used on the site that would generate the smallest target area. After reviewing the existing Fort Bliss SI Report (e2M 2007), 37mm projectiles, 60mm mortars, 75mm projectiles, and 2.36-in. rockets were determined to be the most representative munitions types on the Closed Castner Range MRS.

URS estimated the size of target areas based on both the distribution of rounds around an aiming point (dispersion) and the areal distribution of detectable fragments from each round that is fired into the target area (fragmentation). The dispersion of rounds landing around an aiming point is a function of the range probable error (RPE) and the deflection probable error (DPE), as taken from doctrinal firing tables for a particular weapon system or munitions type. RPE is the measure of overshot or undershot that will contain 50% of the rounds fired at an aiming point. DPE is the measure of lateral (left to right) aiming variation that will contain 50% of the rounds fired at an aiming point. The Armament Research Development and Engineering Center (ARDEC) firing tables were used to obtain this information for the selected representative munitions (ARDEC unpub, ARDEC 1944, ARDEC 1945, ARDEC 1951).

Since the actual charge and elevation angles of firing used with these munitions on the Closed Castner Range MRS are unknown, the smallest RPE and DPE values were chosen to produce the smallest probable target area (most conservative approach). These values assumed direct-fire munitions for the 2.36-in. rocket. They also assumed that the munitions items were fired into the middle of the range area, and the maximum range that these munitions items were fired did not exceed 2,700 yards, or approximately half of the horizontal width of the Closed Castner Range MRS. However, for some of the munitions items, maximum ranges were significantly less than 2,700 yards, so RPE and DPE data were chosen for the longest firing range available in the firing table. To ensure that the dimensions of the target area of interest were sufficiently conservative (i.e., small) and that the density of impacts (and potential anomalies) within the target area was sufficiently high, the study used a single RPE and DPE in the calculations of target area size (see Table 3-1).

Table 3-1. RPE, DPE, and HFD Values

Munitions Items	RPE (m)	DPE (m)	HFD (m)	Semi-Major Axis (m)	Semi-Minor Axis (m)	Target Area (VSP) (m^2)	Transect Spacing for 95% Probability of Traversal (VSP) (m)
37mm Projectile	61.3	8.2	27.4	88.7	35.7	9,337	99.1
2.36-in. Rocket	6.4	2.0	38.1	44.5	40.1	5,600	89.1
60mm Mortar	20.1	7.3	50.6	70.7	57.9	12,865	134
75mm Projectile	16.5	1.8	71.3	87.8	73.2	20,173	168

Source: ARDEC unpub, ARDEC 1944, ARDEC 1945, ARDEC 1951, DDESB 2007

Because the identification of a target area is dependent not only on detecting individual MEC items but also detecting munitions fragments, a fragmentation distance was added to the RPE and DPE to derive the expected target area dimensions. Ideally, the fragmentation distance should be equivalent to the radius around a HE detonation within which a significant amount of detectable (large and/or numerous) fragments are distributed. For purposes of this analysis, the HFD as contained in DoD Explosive Safety Board (DDESB) Technical Paper No. 16 (2007) was used.

Table 3-1 shows the munitions analyzed and the RPE, DPE, and HFD selected to determine the dimensions of the semi-major and semi-minor axes of an elliptical target area, the resulting target area and the VSP calculation of the minimum transect spacing required to ensure a 95% probability of traversal of the target area with a 95% confidence level. Historical evidence is insufficient to establish with certainty the firing and aiming points at the Closed Castner Range MRS. The orientation of the target areas with respect to the azimuth of the transects was, therefore, assumed to be random.

As shown in Table 3-1, the 60mm mortar, the 75mm projectile, and the 37mm projectile were all found to have larger and therefore less conservative estimated target areas and transect spacings than the 2.36-in. rocket, even though the 37mm projectile was the smallest munitions item determined to be representative of historic use on the site. As a result, the 2.36-in. rocket was chosen as the most conservative of the representative munitions items from which transect spacing would be estimated for the ground-based DGM survey of the Closed Castner Range MRS.

Transect width was chosen based on the width of the area detected by the sensors on the man-portable equipment. The detection width of the actual instrumentation (Geonics EM61-MK2) was 1 m, and the sensors were assumed to have limited detection ability beyond the edges of the array instrumentation. A transect spacing of 89 m was calculated for the 2.36-in. rocket target area based on a 95% probability of traversal only. To determine the final transect spacing required to ensure traversal and detection, the default background density of 10 anomalies per acre was used, an instrument false positive rate of 20% was assumed, and the expected anomaly density for target areas was selected as 541 anomalies per acre above background, based on an analysis of data from a surface and subsurface clearance at the Closed Castner Range MRS in 2003–2004 (USAE 2004). The resultant transect spacing was then calculated to be 57 m.

3.1.3 Geophysical System Verification

In accordance with the work plan (URS 2010b), URS implemented a Geophysical System Verification (GSV) approach to demonstrate that the geophysical data collected met project objectives for dynamic detection repeatability, positional accuracy, and detection capability (relative to site background noise levels). URS used the GSV process for the demonstration of the ground-based, man-portable (litter) EMI instruments and the helicopter-borne magnetometers. The URS team installed two instrument verification strips (IVS) at the Closed Castner Range MRS using equipment, techniques, and methodologies consistent with Environmental Security Technology Certification Program (ESTCP) and Naval Research Laboratory (NRL) standards and specifications (ESTCP 2009, NRL 2009). An IVS was prepared for the ground-based EMI systems, and an IVS was prepared for the airborne magnetometry. The GSV process verified that the geophysical data collection system performed consistently throughout the geophysical data collection process.

Each IVS consisted of a line of well-characterized objects placed in an area representative of local site conditions. For the ground-based IVS, rather than using inert munitions items, URS used industry standard objects (ISOs). The ISOs are three sizes of inexpensive, commonly available Schedule 40 pipe nipples, threaded on both ends and made from black welded steel. While munitions items may vary by make and model number, ISOs have the advantage of standard specifications regardless of vendor. The three sizes of pipe possess physical and electromagnetic characteristics that are well documented and sufficiently similar to the munitions of interest.

For the airborne IVS, inert munitions consisting of 2.75-in. rockets, 155mm projectiles, and 100-lb bombs were emplaced, in addition to three ISOs. Field teams measured the sensor responses of the items and confirmed that the responses and locations were within expected parameters. Teams also measured the background geophysical response to determine whether targets of interest could be detected reliably to relevant depths under the site conditions. The preparation and characterization of the ground-based IVS are described in detail in Appendix B. The preparation and characterization of the airborne IVS are described in Appendix C. Summaries are provided in the following sections.

3.1.3.1 Ground-Based Systems Instrument Validation Strip

URS subcontractors (NAEVA Geophysics and SKY Research) conducted DGM along safely accessible transects on the MRS using a Geonics EM61-MK2 instrument carried by two operators in a litter configuration (see Figure 3-1).

Figure 3-1. Man-portable DGM Data Collected Using EM61-MK2 in Litter Configuration

DGM teams collected data over the IVS prior to and following each day of data collection. These twice-daily data quality tests confirmed that the data collected by each DGM team fell within acceptable error ranges based on the theoretical response values for the seed items. The IVS was also used to evaluate dynamic response repeatability and geospatial positioning accuracy of the DGM teams. Data quality objectives for the ground-based systems were established as indicated in Table 3-2. The IVS was established in an easily accessible area near the project trailer (see Figure 3-2).

Table 3-2. Data Quality Objectives for Ground-based Systems

Data Quality Objective	Test Method	Performance Standard	Frequency	Consequence of Failure
Static Repeatability (instrument functionality)	Static background and spike test	Response within ±10% after subtraction of background	Beginning and end of day	Day's data fail unless seed item is mapped with repeatable anomaly characteristics
Along Line Measurement Spacing	Evaluation of DGM survey data to ensure compliance	98% less than or equal to 25 cm along line	By data set	Data set submittal fails
Speed	Evaluation of DGM survey data to ensure compliance	95% of data less than 3.5 mph	By data set	Data set submittal fails
Dynamic Detection Repeatability	Repeat survey data	• Number of anomalies within ±5% or ±4 of original, whichever is greater • Repeatability of response amplitude within 20% • Repeatability of position ±8 in.	100-ft section of transect per mile of transect	Lot submittal fails
	Repeat IVS data	Response ±10% of original value	Beginning and end of day	Day's data fail unless seed item is mapped with repeatable anomaly characteristics
Appropriate latency corrections applied	Evaluation of results of time calibration and point position tests to ensure compliance	No visible chevron effects in the data or pseudo-color plots.	By data set	Data set will be reprocessed

Figure 3-2. Collecting Data Along the Ground-based IVS

Geophysical personnel surveyed the plot for anomalies and background conditions. Based on the expectation that MEC items on the Closed Castner Range MRS would include small-sized munitions, represented by the 37mm items, the small ISO was selected as the IVS seed. Four ISOs were emplaced at 7.6 cm and 17.8 cm deep, in a horizontal attitude, both along and across the line of the track (see Table 3-3).

Table 3-3. Sizes, Depths, and Orientations of Seed Items in the Ground-Based System IVS

Seed Number	ISO Size	Position (m)	Depth (cm) [a]	Orientation (Relative to Instrument Path)	Theoretical (Expected) Response (Gate 2) [b]
1	Small	2.5	7.6	Horizontal along path	16 mV
2	Small	7.5	17.8	Horizontal along path	7.8 mV
3	Small	12.5	7.6	Horizontal across path	16 mV
4	Small	17.5	17.8	Horizontal across path	7.8 mV

[a]Indicates depth to middle of seed item.
[b] Assuming 39.9 cm coil height agl.

As described in Appendix B, the shape of the response curve for Gate 2 was essentially as expected, with double-humped peaks for ISOs oriented in line, and single hump peaks for the ISOs oriented cross-path, but the response magnitudes were different than expected. As directed by the ESTCP guidance document (ESTCP 2009), potential sources of error were examined and used to establish the range of acceptable responses.

Careful observation of the teams' data acquisition over the IVS revealed variations in coil height between the teams and within each team based on gait and harness adjustment. Slight variations in the coil height while collecting data in litter mode resulted in ISO response variations greater than 20% from test to test. Other sources of error included the orientation of the seed items, the lateral alignment of the sensor and the seed item, and noise. Table 3-4 is a summary of error sources and an estimation of their impacts on the response.

Table 3-4. Sources and Estimates of Error in Peak Response

Source of Error	Estimated Degree of Error	Estimated Response Variation by Seed Item			
		ISO 1	ISO 2	ISO 3	ISO 4
Variation in instrument height (dip)	Up to -3 cm	+3.9 mV	+1.8 mV	+3.9 mV	+1.8 mV
Variation in instrument height (grip and harness)	±5 cm	+7 mV -4.6 mV	+3.2 mV -2.2 mV	+7 mV -4.6 mV	+3.2 mV -2.2 mV
Seed orientation not horizontal	-2 degrees	+10 mV	+7 mV	N/A	N/A
Side-to-side sensor placement	±5 cm	+0 mV -0.5 mV	+0 mV -0.5 mV	+0.5 mV -0 mV	+0.5 mV -0 mV
Noise	2x RMS noise	±1.5 mV	±1.5 mV	±1.5 mV	±1.5 mV

As shown in Table 3-4, the primary and most variable source of error was the variation in instrument height above the ground surface. The sources of this variation of sensor height were the instrument dip caused by the walking motion of the carriers and the variation in grip and harness settings of each carrier. Instrument dip was estimated up to ±5 cm when traversing the IVS. Variation due to changing grips and slipping harnesses was estimated at ±5 cm. The acceptable range of responses specific to each seed item are shown in Table 3-5, and all IVS tests were accepted using these values.

Table 3-5. Ranges of Acceptable Responses for Daily IVS Collection

Seed Number	Theoretical (Expected) Response (Gate 2)	Acceptable Range of Peak Response (Gate 2)
1	16 mV	38.4 mV – 9.4 mV
2	7.8 mV	21.3 mV – 3.6 mV
3	16 mV	28.9 mV – 9.9 mV
4	7.8 mV	14.8 mV – 4.1 mV

Noise was measured on the IVS at 3 mV, peak-to-peak, and at 0.77 mV root mean squared (RMS). While these are higher values than typically encountered, the signal-to-noise ratio for IVS remained above 5:1, ensuring that the seeds were reliably detectable. Positional accuracy of the DGM instrumentation was also measured on the IVS and found to be within the required 25 cm. Appendix B contains further details of the IVS establishment and characterization for ground-based DGM.

3.1.3.2 Helicopter-borne System Instrument Validation Strip

The helicopter-borne magnetometer IVS lane was established in a location deemed representative of the Closed Castner Range MRS (Appendix C). It was composed of inert ordnance items ranging from 2.75-in. rockets to 100-lb bombs emplaced both parallel to and perpendicular to the line of travel to provide a test of the system detection performance under these two scenarios. In addition to the inert ordnance IVS seed items, three ISOs were placed in the helicopter-borne IVS. Table 3-6 lists the inert ordnance items and the ISOs placed in the IVS. All targets were placed on an approximately 5 m spacing, laid horizontally on the surface; positioning measurements were taken from the center of each object.

Table 3-6. Helicopter-borne System IVS Seed Items

ID	Description	Orientation
1	2.75-in. rocket	E-W (perpendicular)
2	155mm projectile	E-W (perpendicular)
3	155mm projectile	N-S (parallel)
4	100-lb bomb	N-S (parallel)
5	ISO Large	E-W (perpendicular)
6	ISO Medium	E-W (perpendicular)
7	ISO Small	E-W (perpendicular)
8	2.75-in. rocket	N-S (parallel)
9	100-lb bomb	N-S (parallel)
10	155mm projectile	N-S (parallel)
11	2.75-in. rocket	E-W (perpendicular)

Figure 3-3 shows the airborne magnetometer response over the IVS targets. The emplaced target locations are marked with small black circles and labeled using their ID number. The red trace represents a time-series profile of the measured magnetic field along a single sensor position line. This profile is plotted using the single line positions (black trace) as the zero base line. Approximate spatial extents for each target response are indicated by dark grey polygons, and approximate extents for two preexisting features identified as point A and point B are indicated by light grey polygons. The color represents the interpolated total magnetic field response (measured in nanoTeslas, nT) as indicated by the scale bar on the right. The variations in amplitude of the magnetic field are represented by changes in the false color image. Adjacent local “highs” (red) and “lows” (blue) are indicative of a point source dipolar target. For example, the combined high and low above and below (respectively) target 3 is the dipolar response for this single target. Depending on the orientation of the dipole, only a high or low may be visible (e.g., target 4).

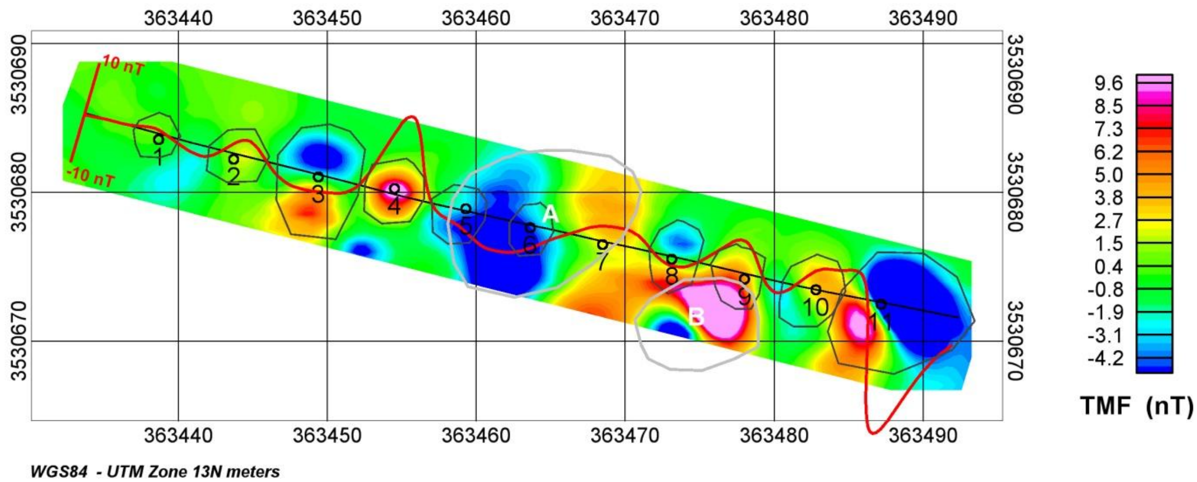


Figure 3-3. Airborne IVS Layout and Gridded Total Magnetic Field Image

The responses for many of the targets are distorted by local geologic interference and/or adjacent targets. For example, the target 5 (large ISO) response is almost lost due to a large magnetic "low" that is presumed to be of geologic origin. In the time series magnetic profile (plotted in red) the response due to this target is visible as a slight upward bulge on the side of the "low." In other examples, the target 9 and, to a lesser extent, target 8 responses are severely distorted by another preexisting feature (labeled as feature B). The time series also shows how the responses for targets 10 and 11 merge. In general, the distance between seeded items was a little too small, and the vegetation limitation to low survey altitude exacerbated the signal overlap problem. The response of the ISOs is mostly masked by adjacent geological interference and/or lost due to survey altitude, with the exception of the response of the "large" ISO (target 5).

The IVS target responses for the larger targets were sufficient to allow daily monitoring of data quality with respect to accuracy of target locations and repeatability of derived target parameters. The airborne IVS was flown prior to and following each survey day for testing and verification of system performance. In addition, the IVS was flown after any sensor replacement during a day's survey activities. Precise location measurements, made with RTK surveying techniques, were used to assess the performance of the system with respect to accuracy of detected target positions. The Project Geophysicist performed QC checks and procedures to document the proper operation of the sensors and data processing. These tests documented the functionality of the airborne survey equipment and monitored the instruments for noise, stability, and repeatability. Appendix C contains the daily QC data.

The IVS for the helicopter-borne magnetometers was placed in a relatively geologically quiet area of the site. The height flown over the IVS was intended to simulate the flying altitude over the wider area of the range, which was near 3 m above ground level (agl) because of vegetation. At this altitude, however, the signal of the smaller items was frequently lost. In this regard, the IVS was representative of the site; at the higher altitudes the smaller items of interest were not well discriminated. Also, at the higher altitude, closely spaced items do not resolve into individual signals. Although it might have been useful to reposition the IVS for the helicopter-borne magnetometers, extending the distance between seeds, and placing seeds farther away from background anomalies, it would not have changed the basic characteristics of the MRS.

The IVS was successful in providing a day-to-day verification of instrument repeatability and accuracy. The SKY Research QC Geophysicist used the IVS data collected at the start and end of each day to monitor the performance of the system with respect to accuracy of target positioning and repeatability of dipole analysis-derived target features. For each of the items with sufficient signal-to-noise to support accurate dipole fit analyses, a model dipole was fit to the observed data. The parameters describing this model were used as estimates of the position, size, and orientation of the dipole response of each of these targets. These derived feature estimates were monitored for validity and consistency, and the results are provided in Appendix C. The average position error was 0.41 m—well under the 0.5-m pass/fail threshold, although higher than typically achieved due to the local geologic response. The average target size variation was 14%, and the average dipole angle variation was 4 degrees. These values were well under their respective pass/fail thresholds of 20% and 20 degrees, although they were higher than typically achieved due to the local geologic noise.

3.1.3.3 Geophysical System Verification Blind Seeds

A key part of the GSV process in a production program is the use of blind seeds placed in the production area. According to ESTCP guidance, however, blind seeding may not have application to WAA, especially those that involve spaced transects. To determine what role blind seeding might play in a WAA assessment, 93 ISOs were placed in the area mapped by the helicopter-borne magnetometers, since the helicopter-borne DGM would survey 100% of the accessible ground surface. Seeds were obtained as follows: 31 small ISOs, 31 medium ISOs, and 31 large ISOs. The locations were scattered randomly, with each ISO buried in random orientations at a depth equaling three times the diameter of the ISO. Two ISOs of each size were collocated in the same location, with one ISO buried to three times its diameter, and one ISO buried to five times its diameter.

As the IVS showed, the helicopter-borne magnetometer did not reliably detect the small and medium ISOs due to local geological conditions and the vegetation limitations to low flight altitudes. Following the helicopter-borne survey and data analysis, SKY Research returned 52,751 anomalies noting that, “separation of geologic anomalies from discrete ferrous objects was not reliably achieved.”

The seeding program outlined in the ESTCP guidance is aimed at 100% production survey work to support the removal of munitions. As noted in the ESTCP document (2009), “seeds may be difficult to apply to transects and meandering path surveys, where 100% survey coverage is not required and the exact locations of survey lines is not known in advance.” From this guidance and these results, it was determined that the blind seed element of the GSV was not relevant to this transect-based WAA study, because seeds could not be reliably placed in transects for discovery.

One of the objectives of this project was to develop information about the density and distribution of MEC on the range and to help delineate the areas requiring additional investigation in an RI to determine nature and extent of contamination. The IVS portion of the GSV approach was an important tool to validate DGM instruments and processes to that end.

3.2 Characterization Methods

3.2.1 Lidar and Orthophotography

Lidar is a broadly used airborne technology for modeling ground surfaces. Lidar uses the time of return for a laser pulse to reflect back to the sensor from a surface to measure the elevation and horizontal location of the point of reflection. The equipment typically operates from 50 to 200 thousand pulses per second (kHz), creating a grid of points from which a model of the ground surface is created (ESTCP 2007). The degree of detail of the surface model increases with the density of lidar points. Since lidar data contain horizontal and vertical positional information, they can be analyzed and manipulated to display range-related ground features such as structures or firing points or roads, and can then subsequently be used to calculate the depths of craters or the height of covering vegetation.

An orthophotograph is a digital aerial photograph that has been geometrically corrected for topographic relief, lens distortion, and camera tilt. Individual images are combined to create a seamless mosaic image, which is then corrected using mathematical models and terrain data, such as lidar data. This orthorectification process results in an accurate positional location of each photo pixel, allowing the images to be used in a Geographical Information System (GIS) or Computer-Aided Drafting and Design (CADD) system with other spatial data (e.g., contour lines or survey data). Orthophotographs are typically collected concurrently with lidar data. In theory, lidar and orthophotography could be deployed in transects, but in practice these technologies are almost always deployed to achieve 100% site coverage for two reasons. First, the resulting surface models and site photographs are used for all phases of subsequent site investigation and management and are much less useful when they contain data gaps from areas between transects. Second, the overall cost of these technologies, and the incremental cost of adding additional coverage area once the system has been deployed, is generally low enough to justify 100% coverage.

As optical technologies, lidar and orthophotography do not directly detect MEC, either on or below the ground surface. Rather, they detect surface features indicative of anthropogenic activities. In support of munitions response, lidar and orthophotographs have successfully located evidence of munitions-related activities, including bombing targets, crater fields, OB/OD areas, range berms, bunkers, burial pits, and firing points. These technologies are most appropriately deployed early in the investigation of munitions response areas, where they can provide an overview of site conditions and identify areas of interest. Used alone, these technologies do not provide sufficient evidence to draw definitive conclusions about the presence or absence of MEC at an MRS. Consequently, further investigation with magnetometers or EMI sensors is required.

3.2.1.1 Equipment and Methods

This project simultaneously deployed lidar and orthophotography using a sensor array combining a digital camera, laser and sensor, GPS, and inertial measurement unit (IMU) affixed to a helicopter flown at approximately 400 m agl. Operational methods included:

- Lidar collection altitude: 400 m agl
- Photo collection altitude: 400 m agl
- Helicopter platform: Bell Jet Ranger 206b
- Ground speed: 50 knots
- Lidar shot rate: 200 kHz at 60 degree scan angle
- Lidar scan rate: 87 Hz
- Resultant raw point density: 22 points per m^2
- Photo pixel size: 10 cm
- Base station distance: less than 30 km

The sensor array met industry standard specifications for accuracy and produced orthophotographs at a pixel size of 10 cm and lidar data density of 22 points per m^2. Orthophotographs were spatially accurate to within 3 pixel widths compared to surveyed control points. The lidar point classification was sufficient to create bare surface models free of trees and large vegetation. Lidar and orthophotography data were collected across the entire 7,007-acre Closed Castner Range MRS.

3.2.1.2 Data Analysis

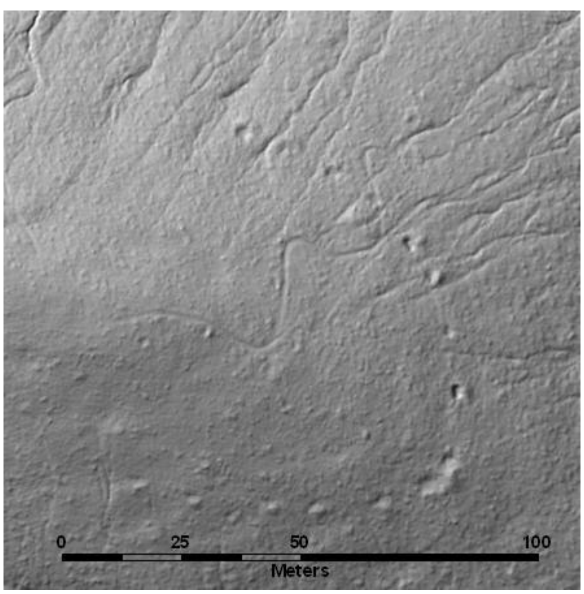
The lidar point density specifications were designed to detect craters and other objects of approximately 1 m in diameter or large. Lidar data were collected at approximately 22 points per m^2, and two data sets were created for analysis: one at 20 points per m^2 and another at 5 point per m^2, which is a density more typical of MMRP lidar applications. Comparison of detection abilities at various point densities may be useful in determining the data requirements for future projects. The lidar data had a vertical accuracy of ±15 cm and a horizontal accuracy of ±60 cm RMS error compared to the established survey control points. Accuracy testing was performed on two cross-sections of lidar data running east-west, 60 m wide, spanning the entire project width. An automated bare earth extraction algorithm was run on the individual flight lines to create individual flight line ground planes. The vertical offset between overlapping flight line ground planes (via triangulated irregular networks) was calculated within the Terrascan software. Flight line to flight line calibration error for lidar points did not exceed 12 cm RMS error.

3.2.1.3 Characterization Results

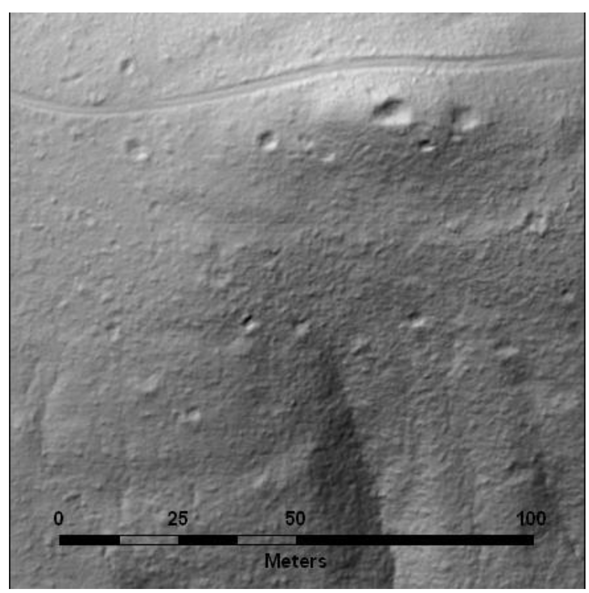
Lidar and orthophotography data collected on the Closed Castner Range MRS during the WAA technology demonstration made it possible to detect surface features potentially indicative of munitions-related activities. Lidar-based bare surface models of the Closed Castner Range MRS showed numerous depressions in the ground surface (see Figure 3-4). These depressions were typically roughly circular and had diameters ranging from 1.5 m up to 5 m. Field work subsequent to lidar data acquisition identified some depressions as demolition pits and others as fighting positions.

Figure 3-4. Features Visible in the Lidar Data Inspected on the Ground

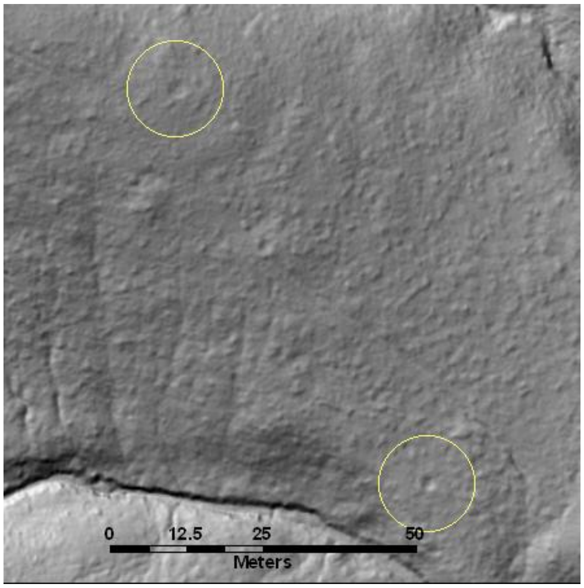
Clusters of surface depressions were seen along steep hillsides that would be difficult or impossible to survey with helicopter-borne, towed-array, or litter-carried geophysical mapping systems. While these clusters of features were highly suggestive of human activity, lidar and orthophotographs were not sufficient, by themselves, to determine the origin of these depressions or the presence or absence of MEC. Some typical examples are shown in Figures 3-5, 3-6, and 3-7. At other range sites, lidar and orthophotography have been used to detect aerial target objects such as bull's-eye rings and ship targets. Targets of this type were not seen in the lidar data or orthophotographs for the Closed Castner Range MRS.



Depressions identified as demolition pits



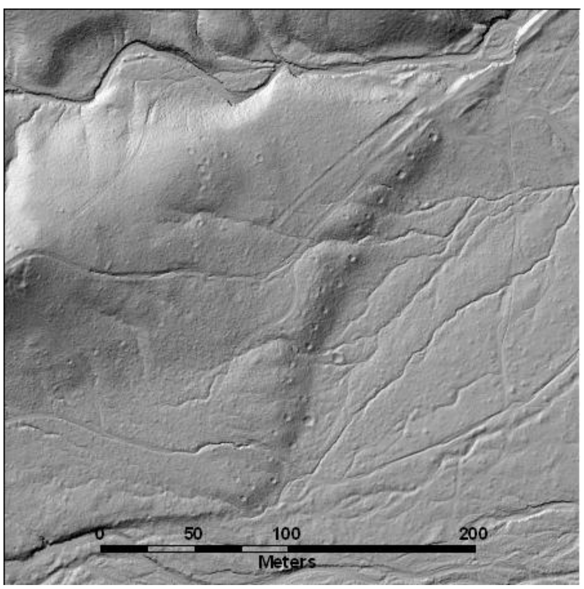
Depressions tentatively identified as demolition pits



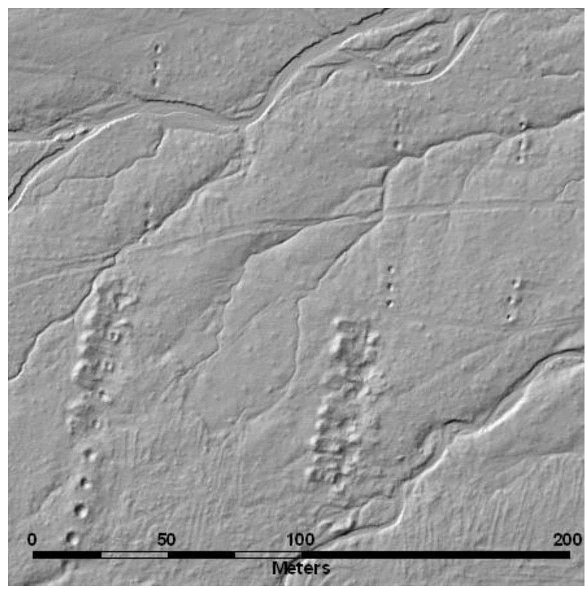
Faint depressions identified as demolition pits (lidar image)

Faint depressions identified as demolition pits (orthophotograph)

Figure 3-5. Closed Castner Range MRS Surface Depressions Identified as Disposal Pits (shown at 20–22 points per m^2)

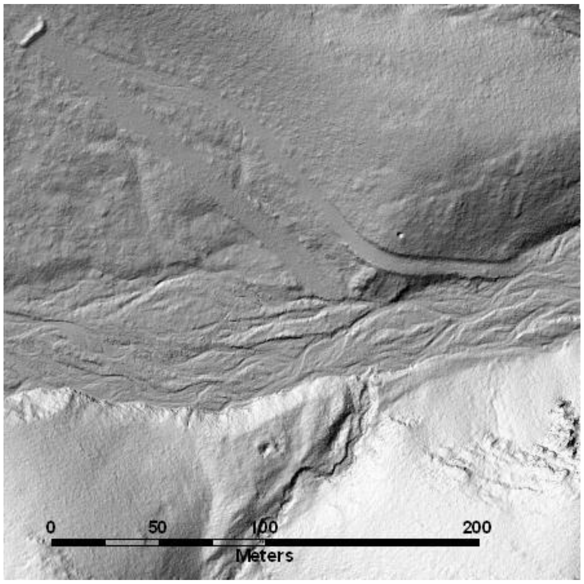


Depressions along hillside identified as fighting positions, with additional scattered depressions to the left (west)

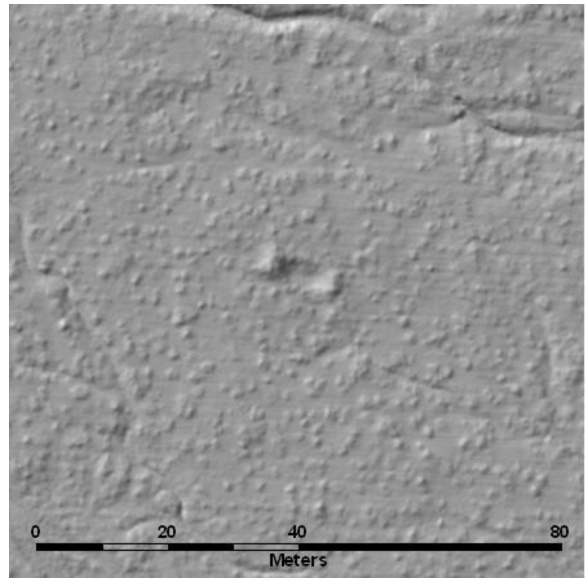


Depressions in flat area identified as fighting positions

Figure 3-6. Closed Castner Range MRS Surface Depressions Identified as Fighting Positions (shown at 20–22 points per m^2)



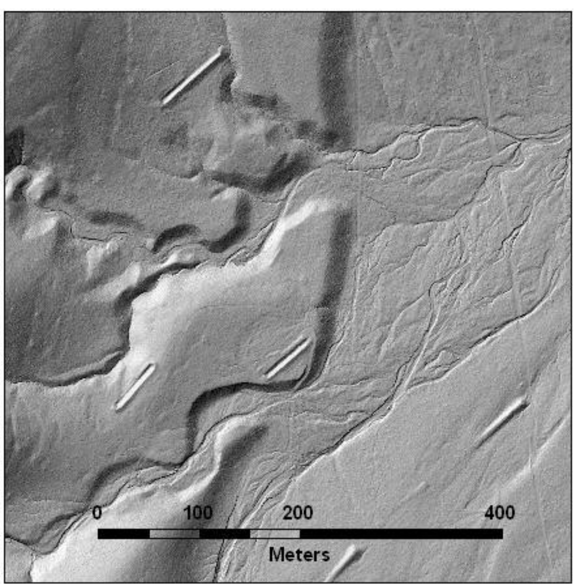
Isolated depressions with remnant road and berm



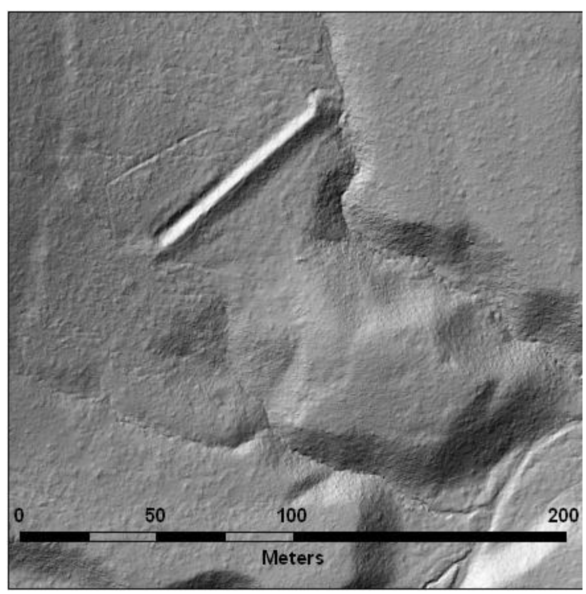
Isolated depression with piled soil

Figure 3-7. Closed Castner Range MRS Isolated Surface Depressions (shown at 20–22 points per m^2)

At the Closed Castner Range MRS, lidar images showed the presence of numerous berms in a wide variety of sizes. Typical examples are shown in Figures 3-8, 3-9, and 3-10. Berms ranged widely in length, from 30 m to over 1,800 m and from around 2 m to 4 m in width. Some berms appeared to have culverts, but in other cases the berms appear to have been breached by erosion channels, offering some potential clues to their ages. Orthophotographs showed vehicle tracks on some of the largest berms. These images also show the complex arrangements of berms, trenches, remnant roads, and other features at this site.

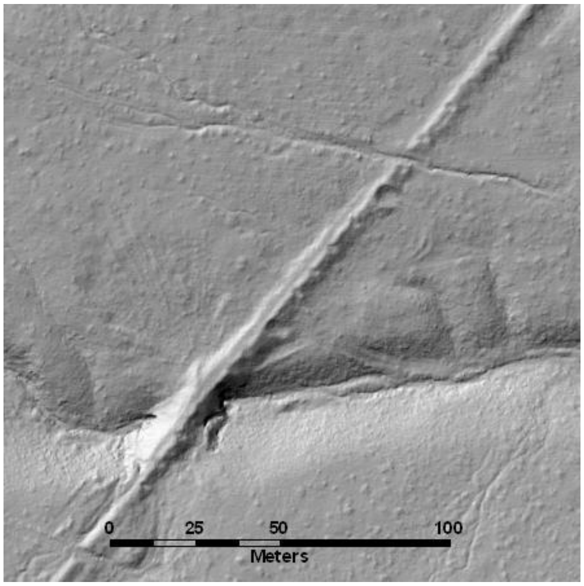


Berms in south portion of study site

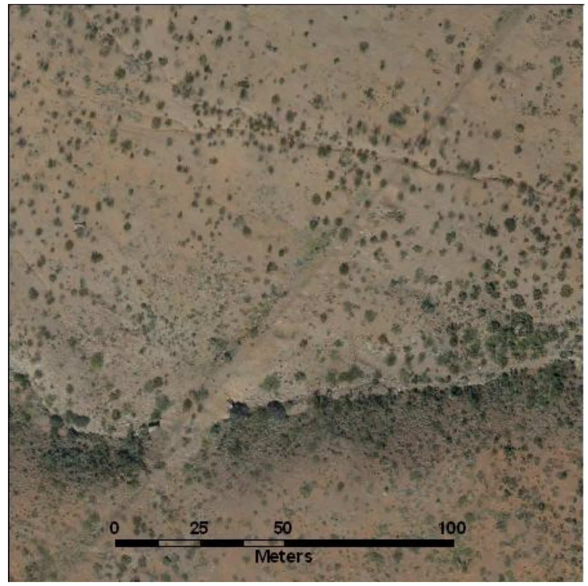


Detail of upper berm

Figure 3-8. Closed Castner Range MRS Berms (shown at 20–22 points per m^2)

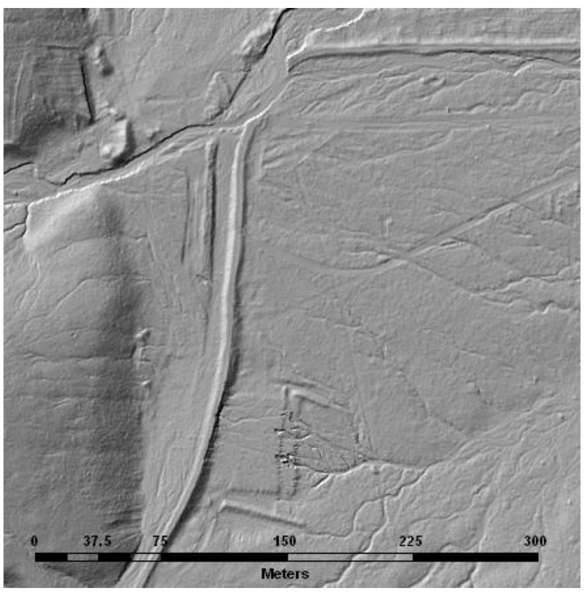


Berm with culvert and erosion breach (lidar image)

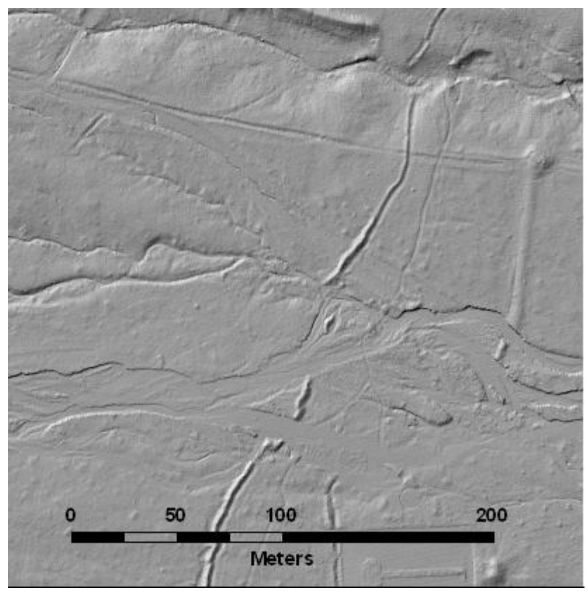


Berm with culvert and erosion breach (orthophotograph)

Figure 3-9. Closed Castner Range MRS Berms with Culvert and Erosion Breach (shown at 20–22 points per m^2)



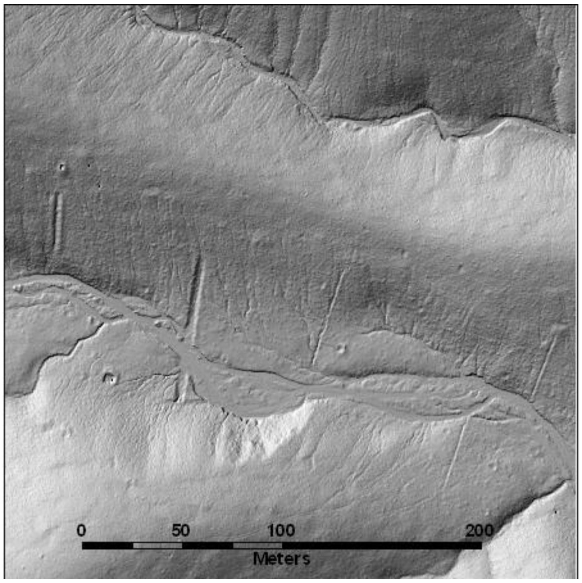
Linear berms with erosion breaches



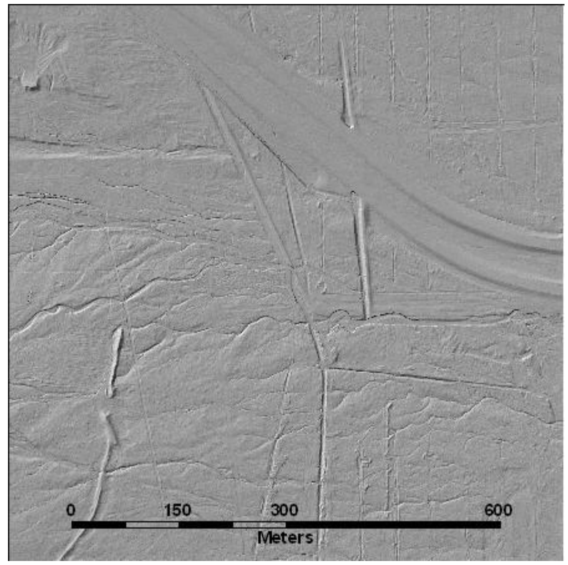
Linear berms with erosion breaches

Figure 3-10. Closed Castner Range MRS Linear Berms with Erosion Breaches (shown at 20–22 points per m^2)

Lidar images also showed the presence of numerous trenches in a variety of sizes. Typical examples are shown in Figure 3-11. Trenches varied widely in length from a few meters to over 1,000 m. Most trenches were around 2 m in width, with one trench over 7 m wide. In several cases, trenches appeared to cross narrow draws and to have been filled in by eroded material at the bottom of the draw. Trenches were found with and without accompanying berms. In the flat areas in the eastern portions of the site, the mixture of trenches and berms was very complex.



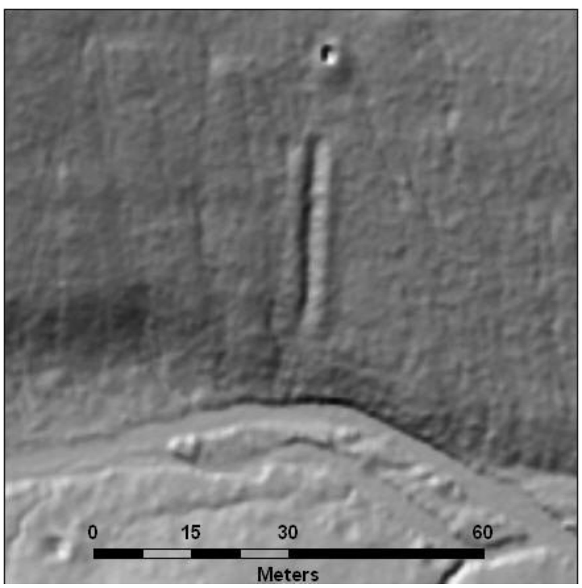
Trenches crossing draw



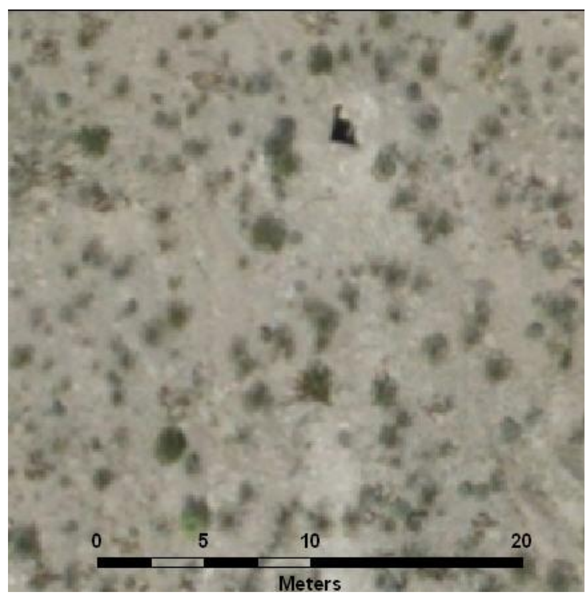
Complex trenches and berms

Figure 3-11. Closed Castner Range MRS Trenches (shown at 20–22 points per m^2)

While lidar images showed more features than the orthophotographs, the orthophotographs nevertheless showed a variety of objects on the ground surface that were indicative of human activity that were not visible in the lidar data. These included old building foundations and unidentified objects on the ground surface. Typical examples are shown in Figure 3-12.

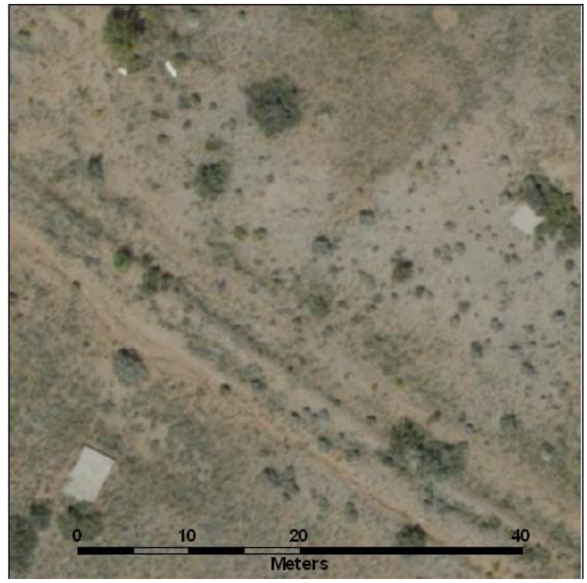


Trench and depression (lidar image)

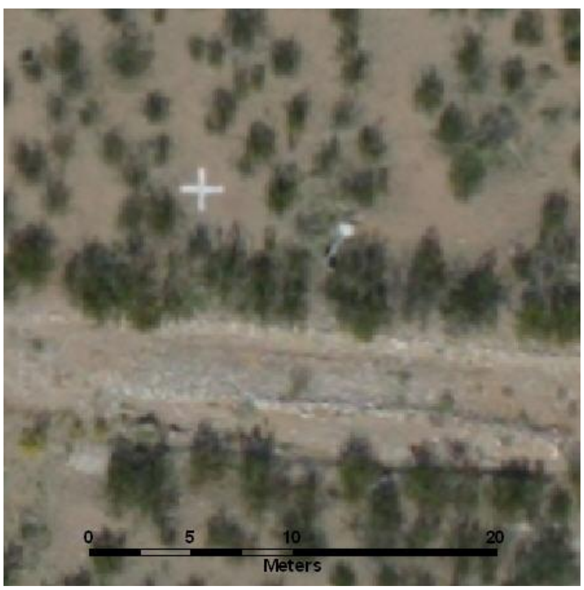


Close up shows an object in the depression (orthophotograph)

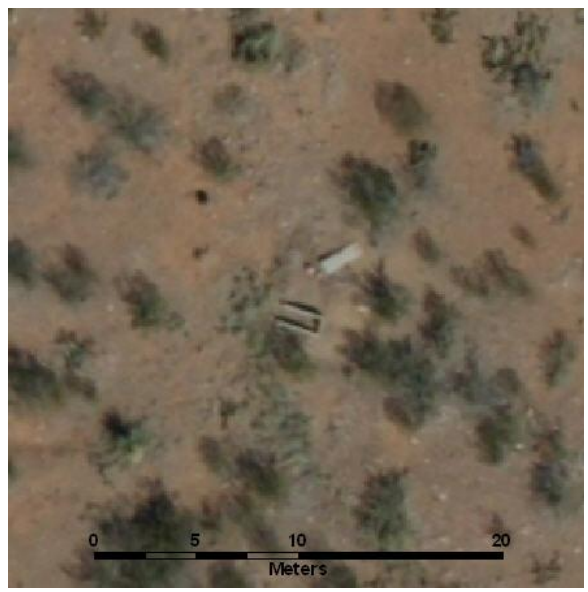
Objects (boulders) on the ground surface



Potential building foundations and scattered unidentified man-made objects



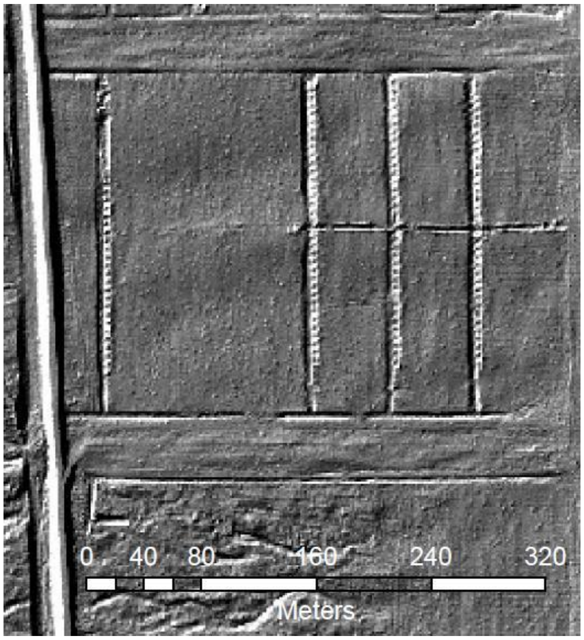
Objects on the ground surface

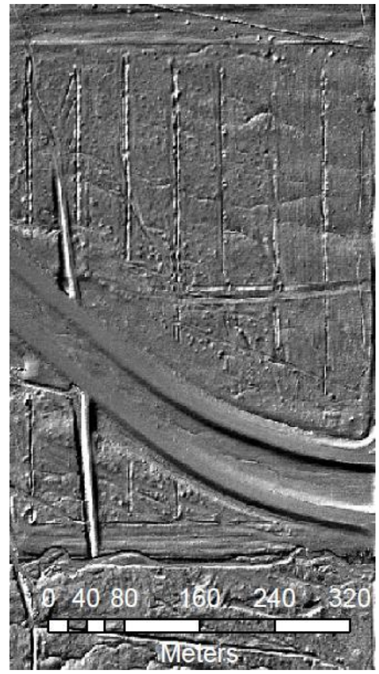


Objects on the ground surface

Figure 3-12. Features Visible in Orthophotographs

Additionally, lidar and orthophotography were able to delineate features that were not highly visible at ground level, but represented human activity in general, and military range activity specifically. Figure 3-13 depicts two groupings of linear features that represent purposeful disturbance of the ground, possibly in support of training range development or use. At the Castner Closed Range MRS, many of these features relate to small arms ranges, where MC contamination is a more significant issue than MEC; in these cases, lidar may be used to help delineate areas of interest for further investigation of MC.





Linear scoring likely depicts small arms ranges

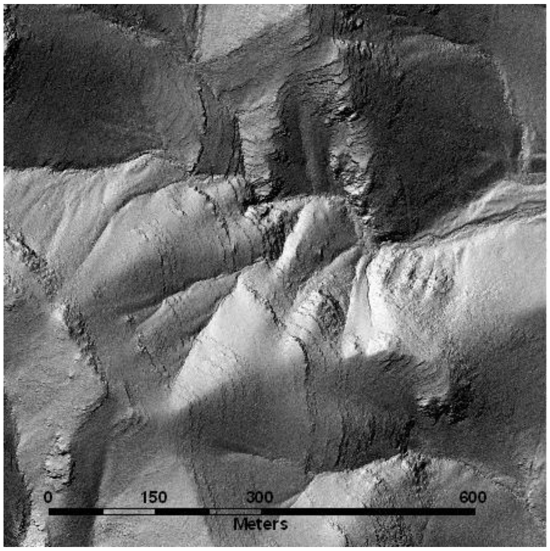
Figure 3-13. Range-related Features at Closed Castner Range MRS

These data demonstrate that lidar and orthophotography were able to identify areas of concentrated anthropogenic activity, as indicated by depressions, craters, berms, trenches, remnant roads, building foundations, and occasional objects on the ground surface. Although the images are clear, the two technologies contain insufficient information to reliably confirm that the identified features are necessarily indicative of concentrated munitions use. At the Closed Castner Range MRS, lidar and orthophotography identified anthropogenic features on much of the relatively flat area on the eastern portion of the site and in scattered areas in the lower, rounded hills just to the west of this flat area. Given the historical uses of these areas, the presence of anthropogenic features supports the recommendation to conduct further investigation.

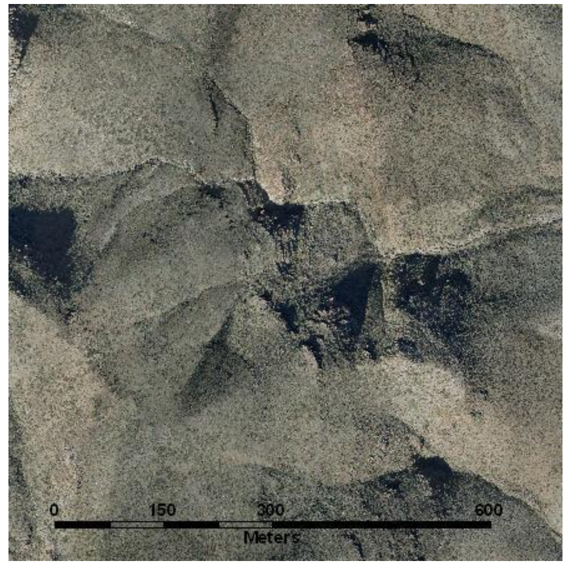
Areas in the western portions of the site in the Franklin Mountains show fewer visible indications of human activity, such as roads, berms, trenches, target features, or patterns of surface depressions (see Figure 3-14). Even in these areas, however, isolated depressions can sometimes be found, and it cannot be definitively determined from the lidar and orthophotographs whether these are the result of human activity.

A Historical Records Review for Fort Bliss, conducted in 2006, stated,

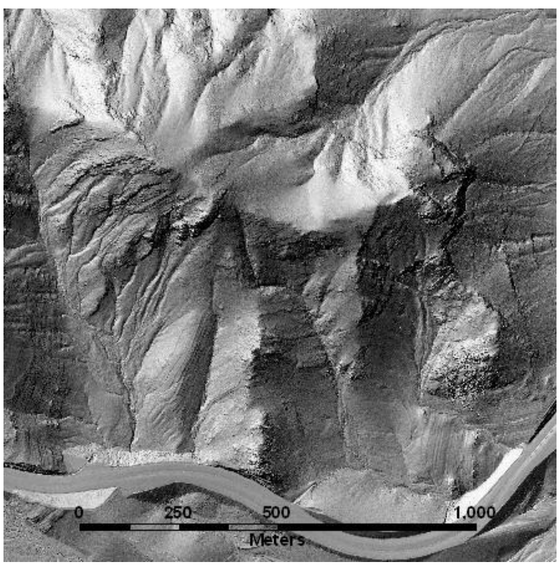
> "Three field artillery firing points were identified in addition to the ranges. These firing points were located in the eastern portion of the range, and firing was to the west or southwest. A report from the Commander of Fort Bliss, dated 11 May 1971, states the western mountainous portions of the range had been used for large artillery impact areas during the 1930's and 1940's." (e2M 2007)



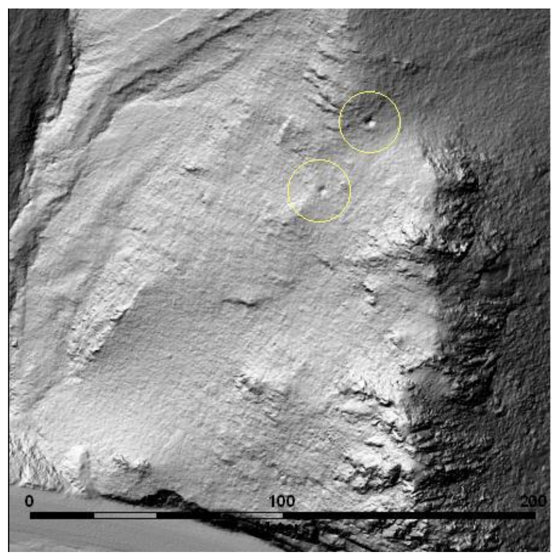
Areas with no evidence of human use (lidar)



Areas with no evidence of human use (orthophotograph)



Area north of the road with little evidence of human activity such as roads, berms, or patterns of depressions

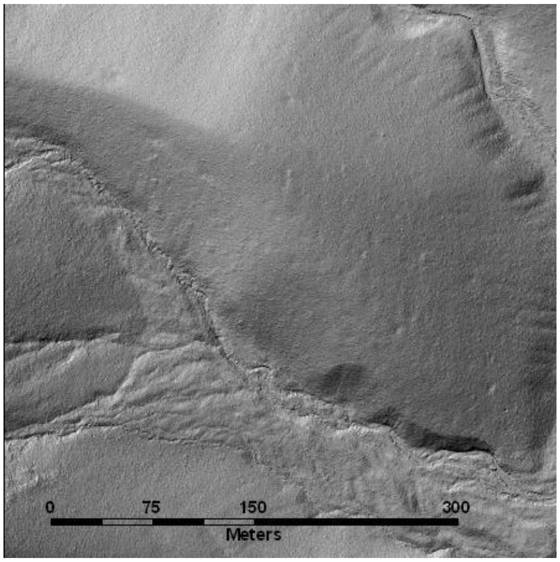


Isolated depressions of unknown origin

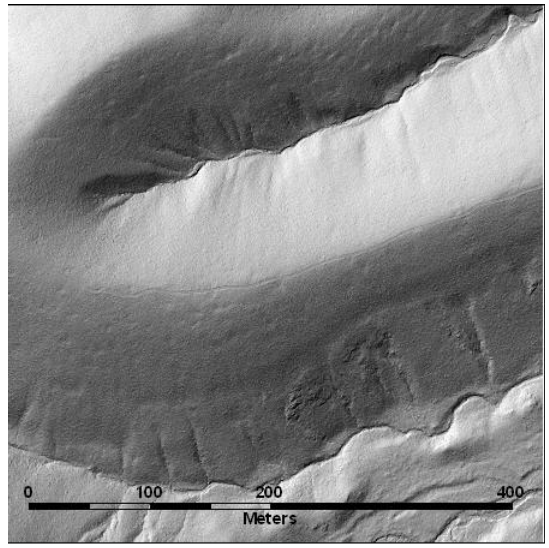
Figure 3-14. Areas with No Evidence of Munitions Use (shown at 20–22 points per m^2)

The report also states, "The entire Caster Range area west of US Highway 54 [the eastern border of the study site] was a potential impact area for 3.5-inch rockets and grenades."

Based on this information, the mountainous portions of the site that do not contain roads and would be difficult to traverse on foot could nevertheless have had at least some level of MEC exposure from artillery or rockets or other military activity. It is not known whether artillery or rocket fire in the 1930s or 1940s would produce craters sufficiently large to be visible in lidar surface models using data collected 70 years later. Portions of the site show faint, diffuse dimpling that could potentially reflect old munitions use (see Figure 3-15). However, these features do not appear to be clear indications of human use, and could easily be the result of natural ground variation.



Faint, diffuse, potential depressions



Faint, diffuse, potential depressions

Figure 3-15. Diffuse Ground Depressions

It is possible to delineate areas where lidar and orthophotographs show no evidence of human use, but the conclusion cannot be definitive, since MEC may be present, but resulting surface features may have eroded or not be discriminated at this level of resolution.

During Technical Project Planning (TPP) meetings, URS presented lidar and orthophotograph imagery. Stakeholders agreed that in some cases the features detected using these technologies are highly suggestive of human use. The Closed Castner Range MRS was used for live-fire training between 1926 and 1966, and the studied portion of the range has remained in DoD ownership since live fire training came to an end. In this context, “human use” most likely indicates DoD use and thus potential ordnance-related activities.

Lidar images and orthophotographs were able to improve the understanding of relative densities and distributions of MEC across the MRS by offering evidence as to the intensity of human use of the site. Follow-up field visits to the features seen in the lidar surfaces located munitions-related activities, including demolition pits.

From the lidar and orthophotography data, 221 individual surface features believed to be associated with munitions activities were identified. These are displayed on Figure 3-16. By correlating these features with the areas of interest on a historical use map (Figure 1-4), it was possible to refine and augment the historically mapped range areas with the actual lidar/orthophotograph data. It is estimated that using lidar-identified features to augment potential areas of interest resulted in a 10% increase in surface area when compared with just historic use maps. Figures 3-17, 3-18, and 3-19 show how the lidar/orthophotograph data were used to redefine the boundaries of areas of interest. The use of lidar and orthophotography resulted in approximately a 10% increase of the acreage in areas of interest. Figure 3-20 shows the resulting map.

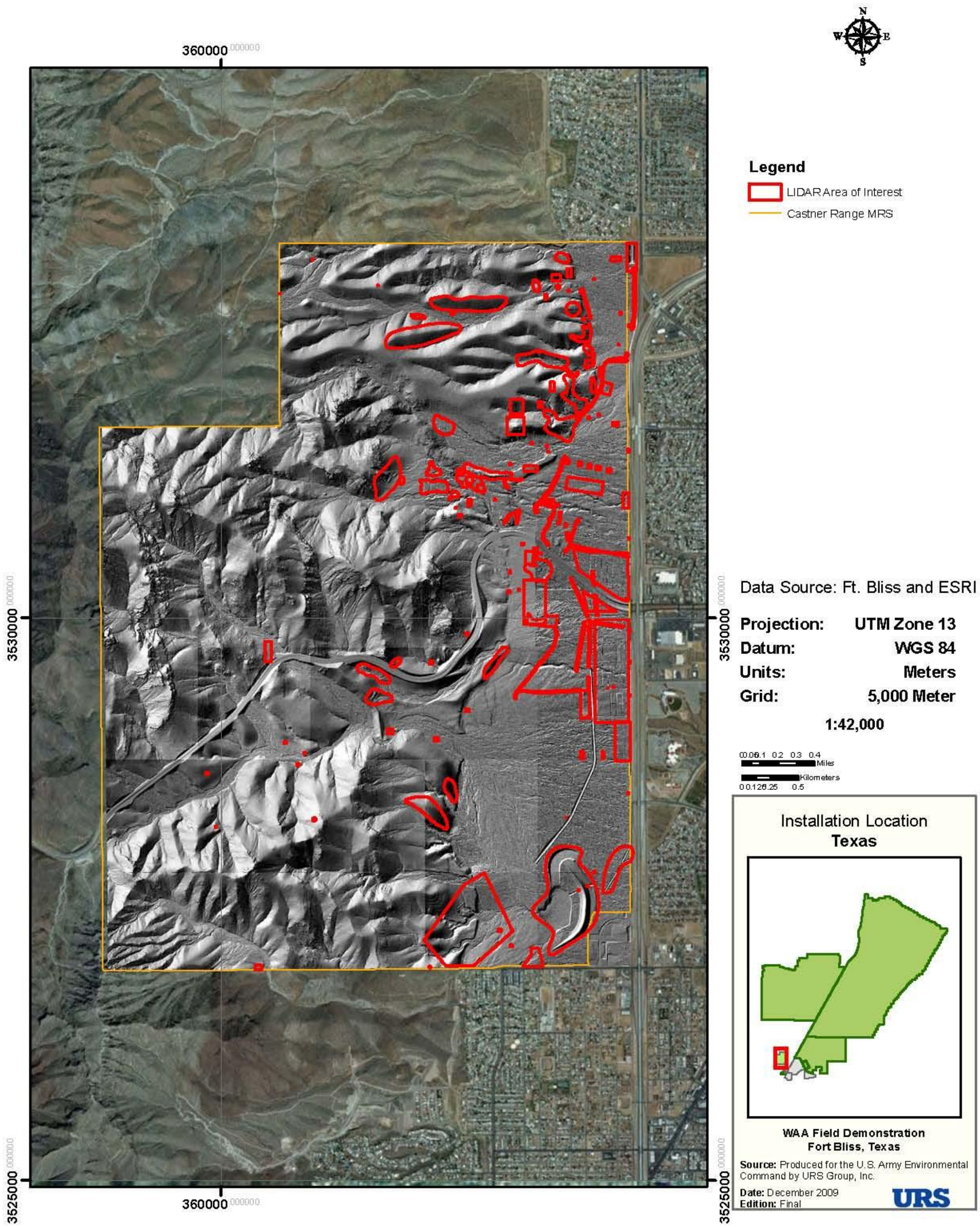


Figure 3-16. Features of Interest Identified from Lidar Data

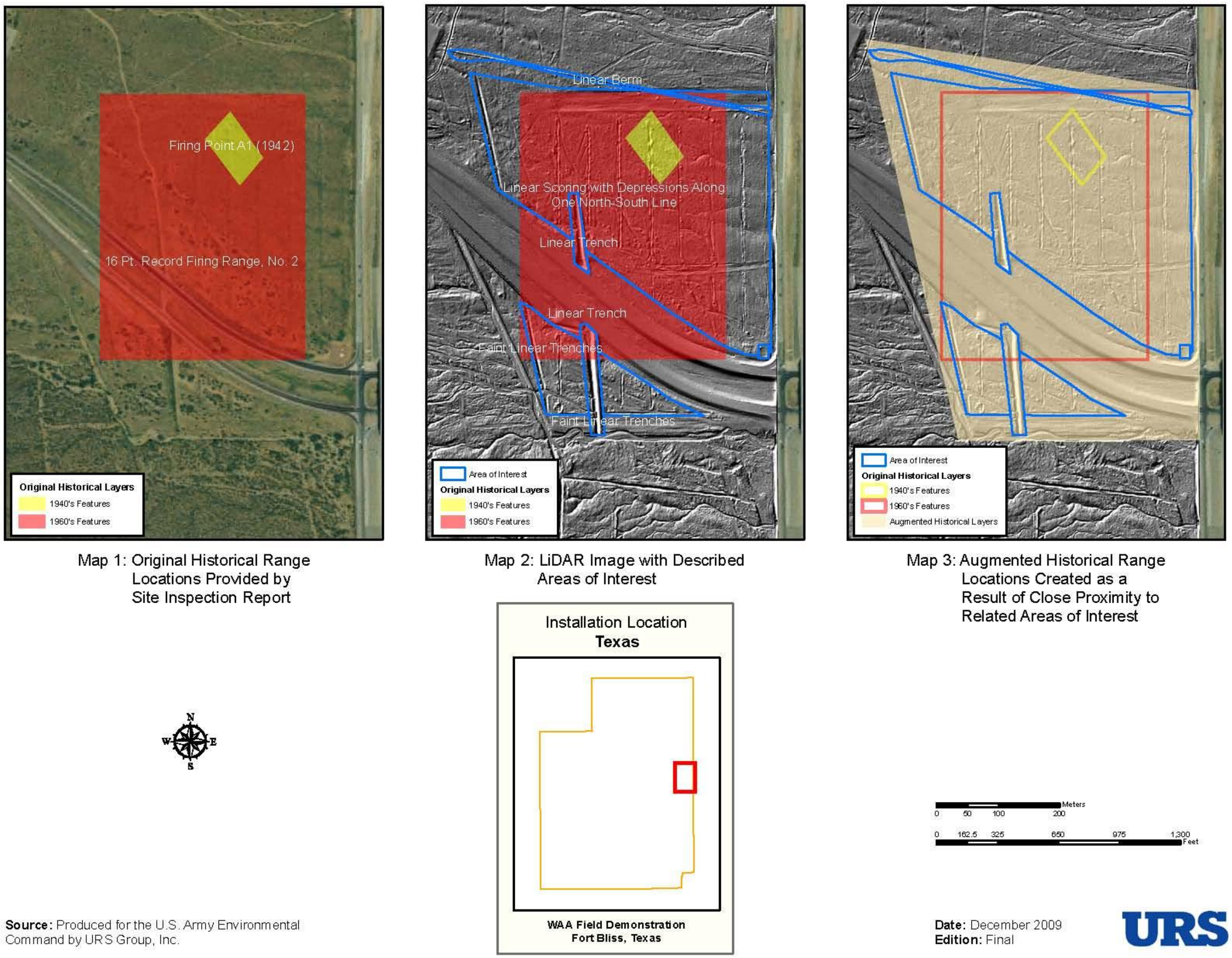


Figure 3-17. Using Lidar Features to Augment Historical Range Maps—16 point Record Firing Range No. 2

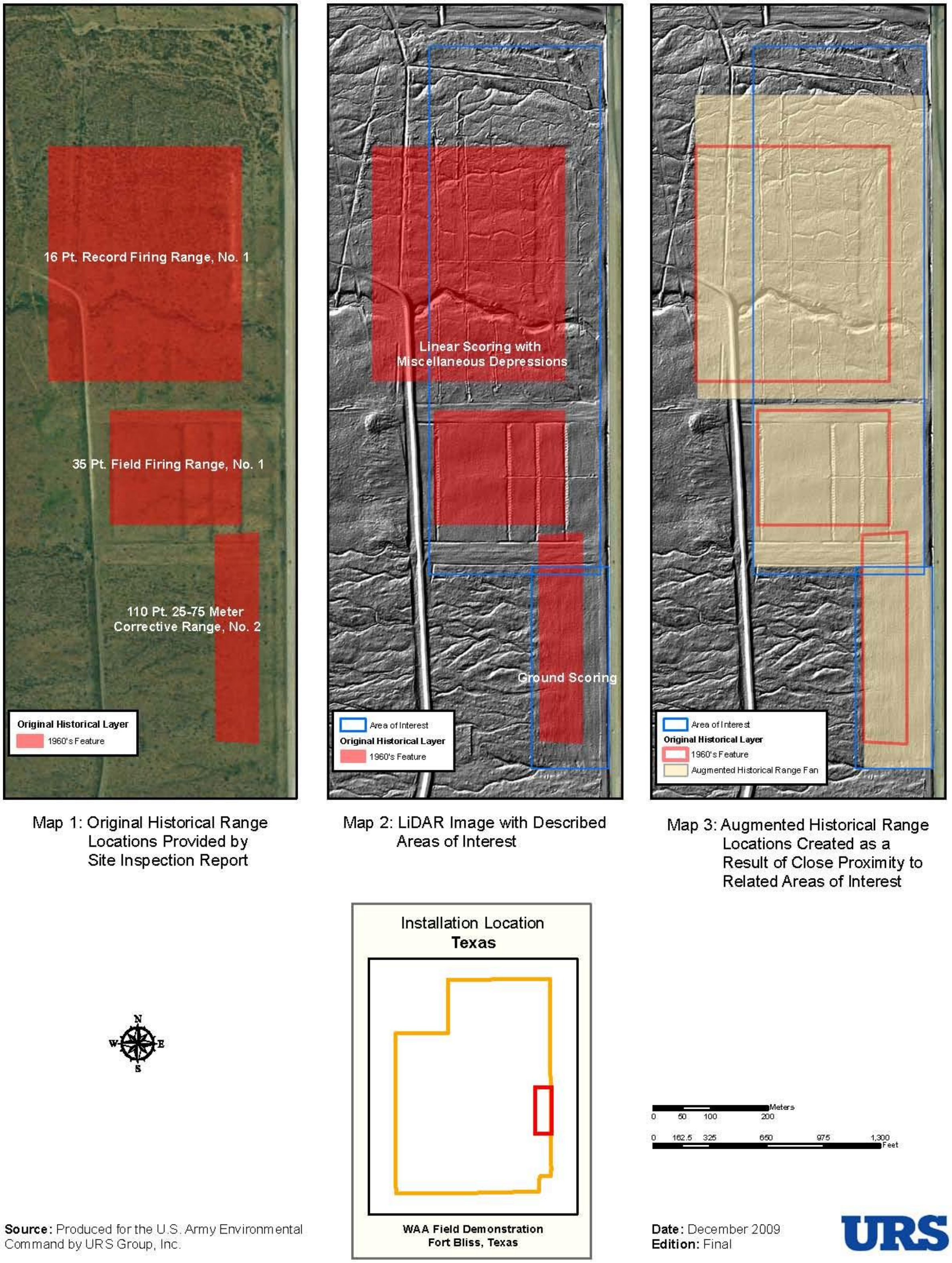


Figure 3-18. Using Lidar Features to Augment Historical Range Maps—Small Arms Ranges

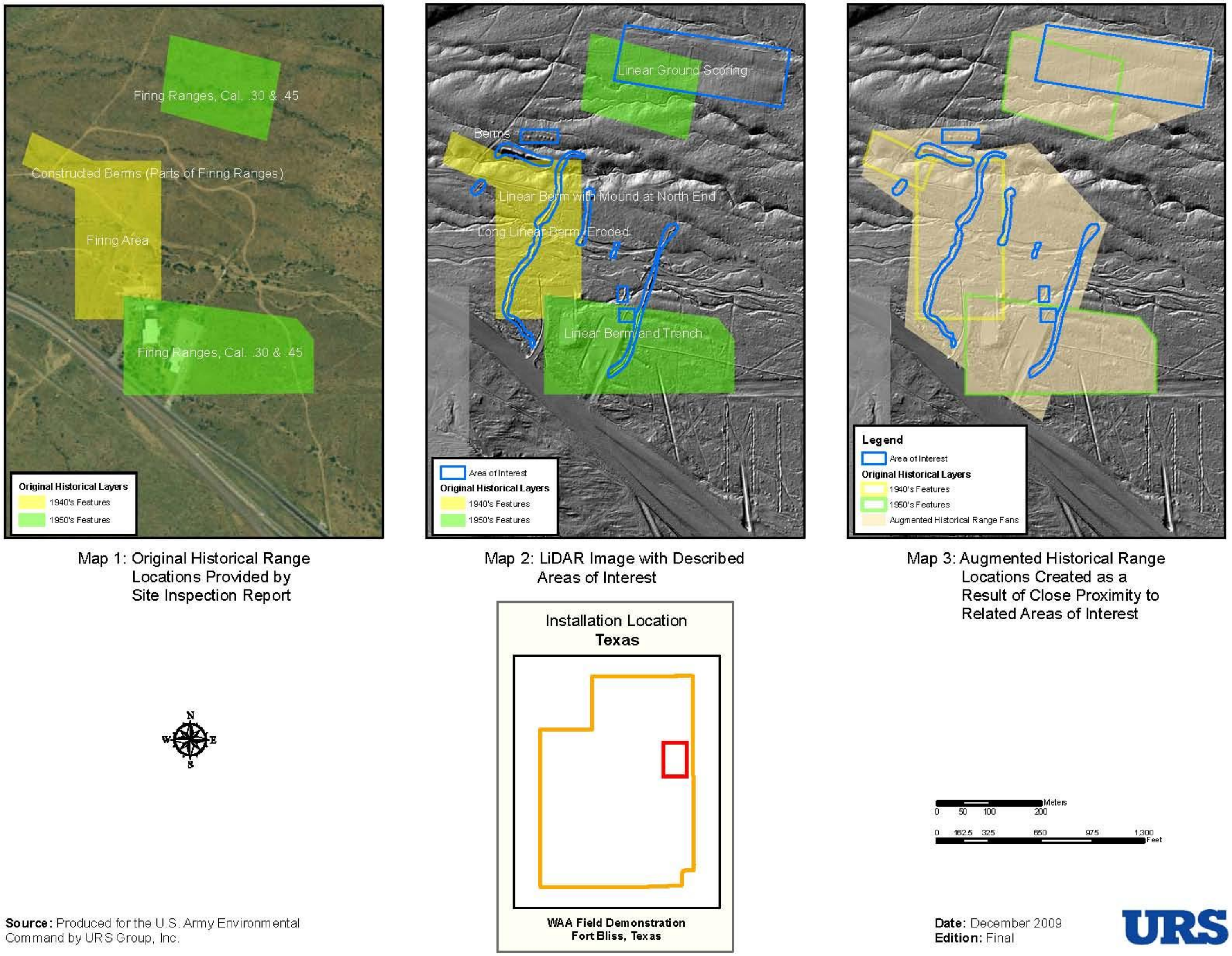


Figure 3-19. Using Lidar Features to Augment Historical Range Maps—.30 and .45 Caliber Ranges

One other question raised during project planning was the minimum lidar data (point) density required to detect munitions-related features. Data were collected at approximately 20 points per m^2, but a second data set was prepared with the data density parsed to 5 points per m^2. One reason to look at lowered data density is that some sites may not have as favorable conditions as the Closed Castner Range MRS (e.g., vegetation cover may be heavier). In these cases, a lower data density may be all that can be achieved. Figure 3-21 compares images of representative crater features from each data set. Although the incremental cost to obtain higher data density when possible is small, it is evident that for all but the most subtle features 5 points per m^2 is an adequate density to enable feature identification.

In summary, a number of key benefits of lidar and orthophotographic data were demonstrated in the WAA project. In general, lidar/orthophotography technologies can be used to inexpensively collect data over large tracts and in areas inaccessible to other characterization technologies. Lidar and orthophotographic data may also be used to:

- Support planning for subsequent characterization steps (e.g., helicopter-borne magnetometry) by determining slope, vegetation height, location of roads, wash-outs, structures, and other land features.
- Support refinement and delineation of areas of interest previously known or suspected through historical records, conventional aerial photography, and map research.
- Support identification of unanticipated areas of interest through clusters of features that indicate human use. Of particular interest are features associated with or near roads or trails.

As lidar and orthophotographic data acquisition and processing technologies continue to evolve, they may have additional application at specific sites, in the role of confirming or even expanding areas of interest. With regard to the objectives of this project, however, because of munitions effects too small to be visible, it is concluded that lidar/orthophotography data alone do not provide sufficient information about either the presence or the absence of human/ordnance activity. At the Closed Castner Range MRS, the entire western mountainous portion of the range could have been an impact range of munitions that would not likely leave lidar-visible indications.

3.2.2 Helicopter-Borne Magnetometry

Helicopter-borne magnetometry employs an array of magnetometers mounted on booms attached directly to a helicopter (see Figure 3-22). When flown 1–3 m agl, helicopter-borne magnetometry can detect large MEC and clusters of small MEC items. Magnetic anomalies are recorded continuously, and are spatially located with GPS and IMU equipment.

A desired advantage of using helicopter-borne magnetometry is that it can characterize a suitable MRS more rapidly than ground-based methods. Suitability refers to the size of the MEC to be mapped, the steepness of the MRS terrain, the height of vegetation, and the existence of potentially interfering conditions, such as ferrous geology and/or man-made features like fences, power lines, buildings, etc. Conditions at the Closed Castner Range MRS included:

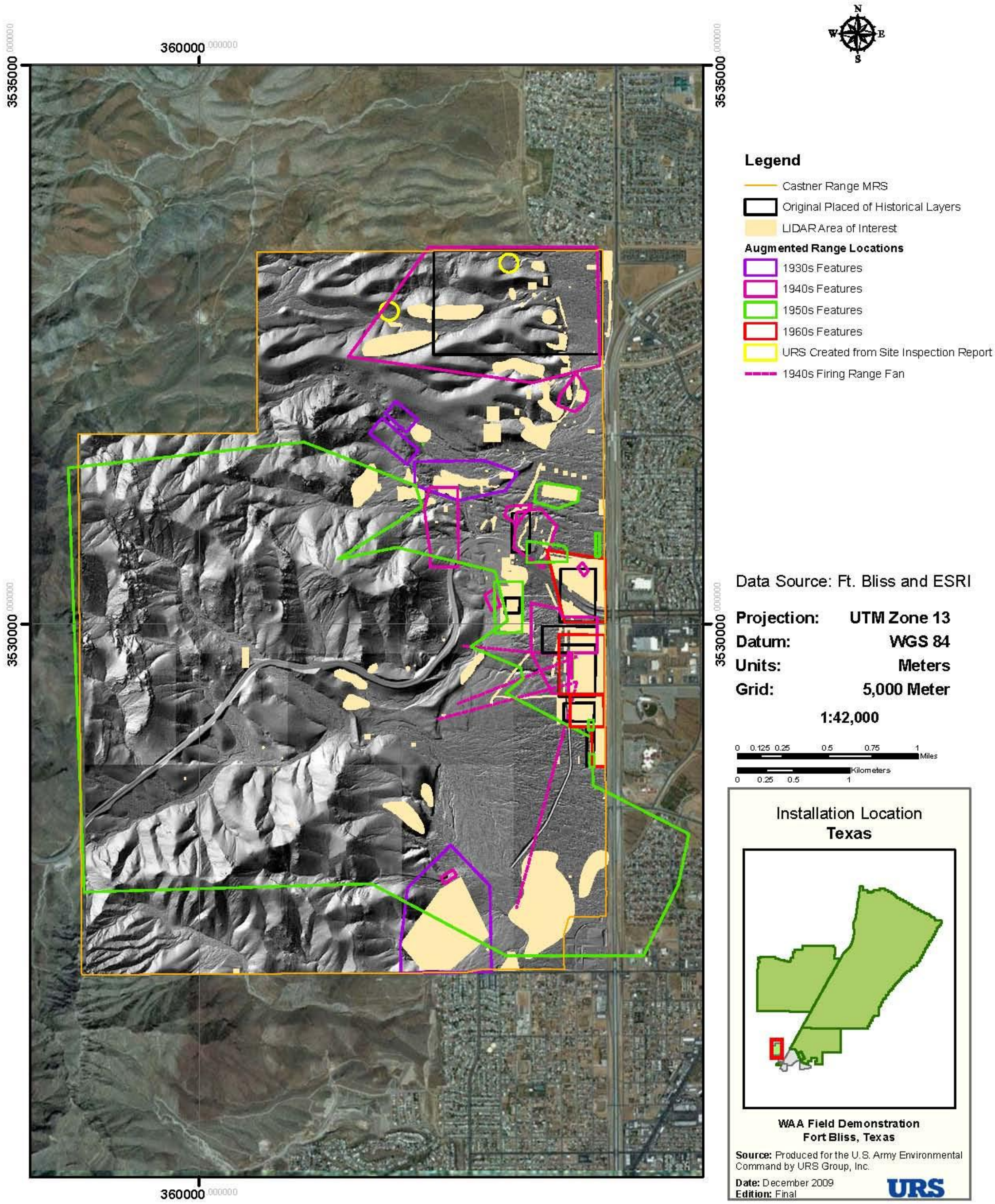
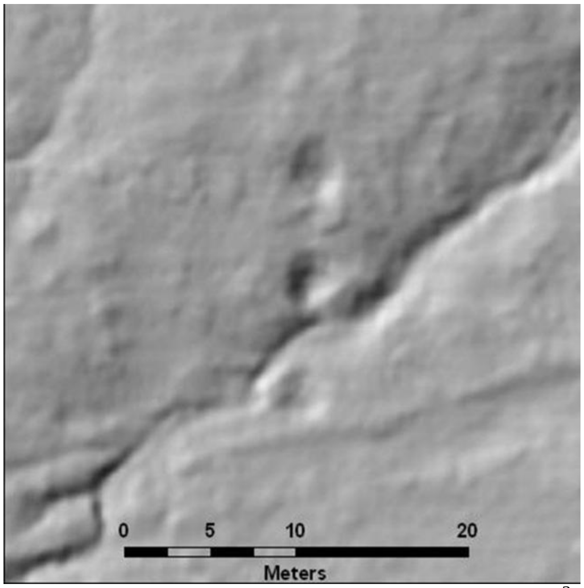
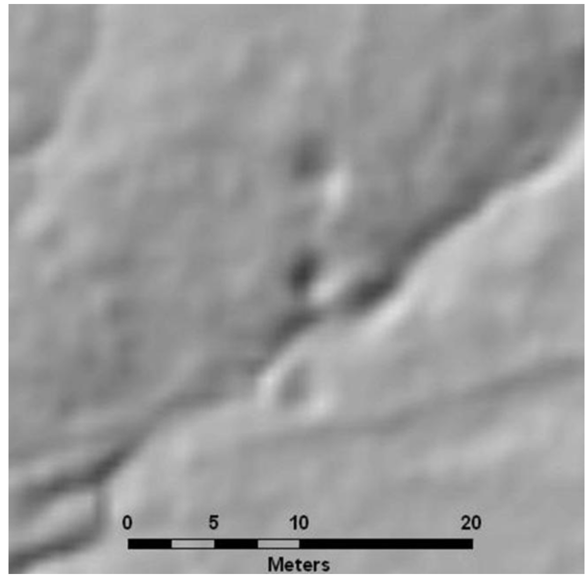


Figure 3-20. Expanded Areas of Interest as a Result of Lidar Data Analysis



Representative crater features (20 points per m^2)



Representative crater features (5 points per m^2)

Figure 3-21. Comparison of Images of Representative Crater Features From Each Data Set

Figure 3-22. SKY HeliMag System in Flight

- MEC size: Helicopter-borne magnetometry is best suited to detect relatively large MEC items. The sensors on a helicopter-borne magnetometry platform are 4–20 times farther away from the ground surface than ground-based geophysical platforms such as man-portable or towed arrays, resulting in poor detection of MEC items 60mm or smaller. Consequently, while data relating to anomalies over the size threshold are more reliable, findings of “no anomalies” are not conclusive at sites where smaller munitions may have been used. At the Closed Castner Range MRS, smaller munitions were used extensively, including 20mm, 37mm, 40mm, 2.36-in. rockets, 57mm, and a variety of flares, grenades, and other items. Small arms were extensively used, and the debris from OB/OD operations is frequently smaller than 60mm.

- MRS terrain: Because of the low altitude flight (1–3 m agl) required for helicopter-borne magnetometry, it is only safely deployed in areas where the slope is less than 5%. At the Closed Castner Range MRS, this includes the eastern flatter area of the MRS (approximately 1,742 acres). This acreage possesses a mean slope (considering 50 m^2 tiles) of less than 5% and was generally deemed within the safe and effective coverage range of the helicopter-borne system.

- Vegetation: Helicopter-borne magnetometry is effective on sites consistent with safe, low-altitude helicopter flight. The vegetation at the Closed Castner Range MRS, although sparse, could range up to 3 m high (in particular, the stalks of the agave plant). As with other geophysical technologies, magnetometry depends on sensor proximity to the anomaly for the signal-to-noise ratio to allow reliable identification. Three meters is at the upper end of the effectiveness range for detection.

- Potentially interfering conditions: The Closed Castner Range MRS does not have a large amount of man-made structures, fences, utility lines, etc. The geologic magnetic signature, however, was not as benign as initially anticipated. Benign noise levels are typically about 1–5 nT, standard deviation. The geologic noise levels in the Closed Castner Range MRS ranged from 35 to 100 nT, standard deviation. This interference had a significant effect on data quality, as noted in Section 3.2.2.3.

3.2.2.1 Equipment and Methods

The helicopter-borne magnetometry equipment consisted of seven Geometrics 822A cesium vapor magnetometer sensors horizontally spaced 1.5 m apart on a Kevlar boom, providing a swath width of approximately 9 m. The flight lines were spaced 7 m apart, providing for a 2 m overlap. A Hughes MD530F helicopter was used as the deployment platform. Appendix C contains the full report. Spatial positioning was monitored by laser altimeter (one Optech laser altimeter and four acoustic altimeters, 1 cm resolution), RTK GPS (two Trimble MS750 GPS receivers, 2–3 cm horizontal precision), and an IMU. The Data Acquisition System consisted of a Linux CerfCube/Field Programmable Gate Array and a clean power supply for the sensors.

Data processing involved a series of standardized procedures to transform raw data into a geo-referenced, total magnetic field data file suitable for UXO target selection and analysis. SKY Research utilized the custom software SkyNet for initial data processing of helicopter survey data. This software transcribed, filtered, aligned, and merged the raw geophysical data into a geo-referenced, leveled, airborne magnetic data set using the same input and providing the same outputs as Geosoft Oasis Montaj. Data analysis was conducted using Geosoft Oasis Montaj software for visualization, manual/automatic target selection, and QC. Advanced analysis was completed using proprietary UXOLab software to produce parameters describing each selected target, including the x and y location, depth, orientation (inclination and declination of the dipole), and dipole size. Target density derivation and mapping were completed using ArcGIS. Density distribution maps provide the ability to identify and delineate regions recommended for further investigation as well as to estimate the level of effort required for remediation of these sites.

QC measures, as described in the report (Appendix C), were implemented to ensure quality of the data collection methods, instrument function, and data processing steps. These QC measures included:

- IVS to validate system response prior to the commencement of data acquisition. Also used daily at the start and end of surveying, as well as after any adjustments to the system.
- High altitude sensor noise tests, twice daily.
- Equipment drift check.
- Lag test, checking the timing match of positional and EMI data.
- Sensor position check.
- Initial review of geophysical data for magnetic field strength, position dropout/spike, and GPS fix quality.
- Final review of processed data.

SKY Research collected 1,742 acres of survey data, at an average of 435.5 acres per day.

3.2.2.2 Data Analysis

Although the magnetometry system performed within established specifications for the hardware and met the survey data quality objectives, the local geology and vegetation degraded the utility of the final data set. Vegetation forced the survey to be flown at the upper end of the system’s effective survey altitude envelope (3 m) in some areas and outside its effective altitude (4+ m) in others (see Figure 3-23).

As shown in Figure 3-23, the distance of the sensor above the ground has a strong effect on the amplitude of the magnetic response of the munitions of interest at the Closed Castner Range MRS. Further, as shown in Figure 3-24, the background geologic noise levels were high in many areas, especially south of Trans Mountain Road. The localized magnetic geologic response was significantly higher (35–100 nT) than optimal (less than 5 nT), effectively resulting in increased noise levels. The lower signal level due to the increased flying altitude, combined with the increased geologic noise levels, effectively lowered the signal-to-noise ratio and rendered discrimination of anomalies more difficult.

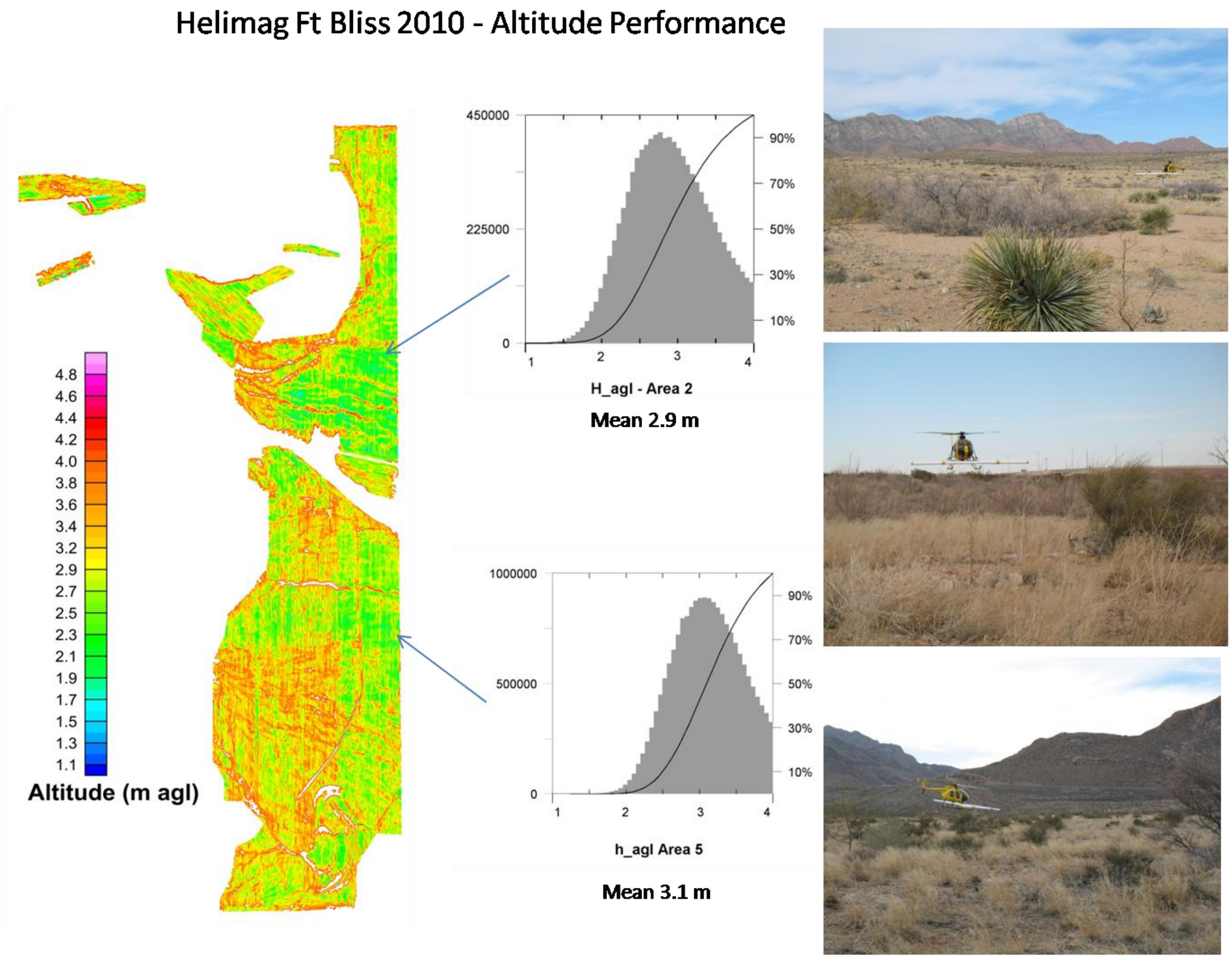


Figure 3-23. Vegetation Interference Impact on Flight Altitude

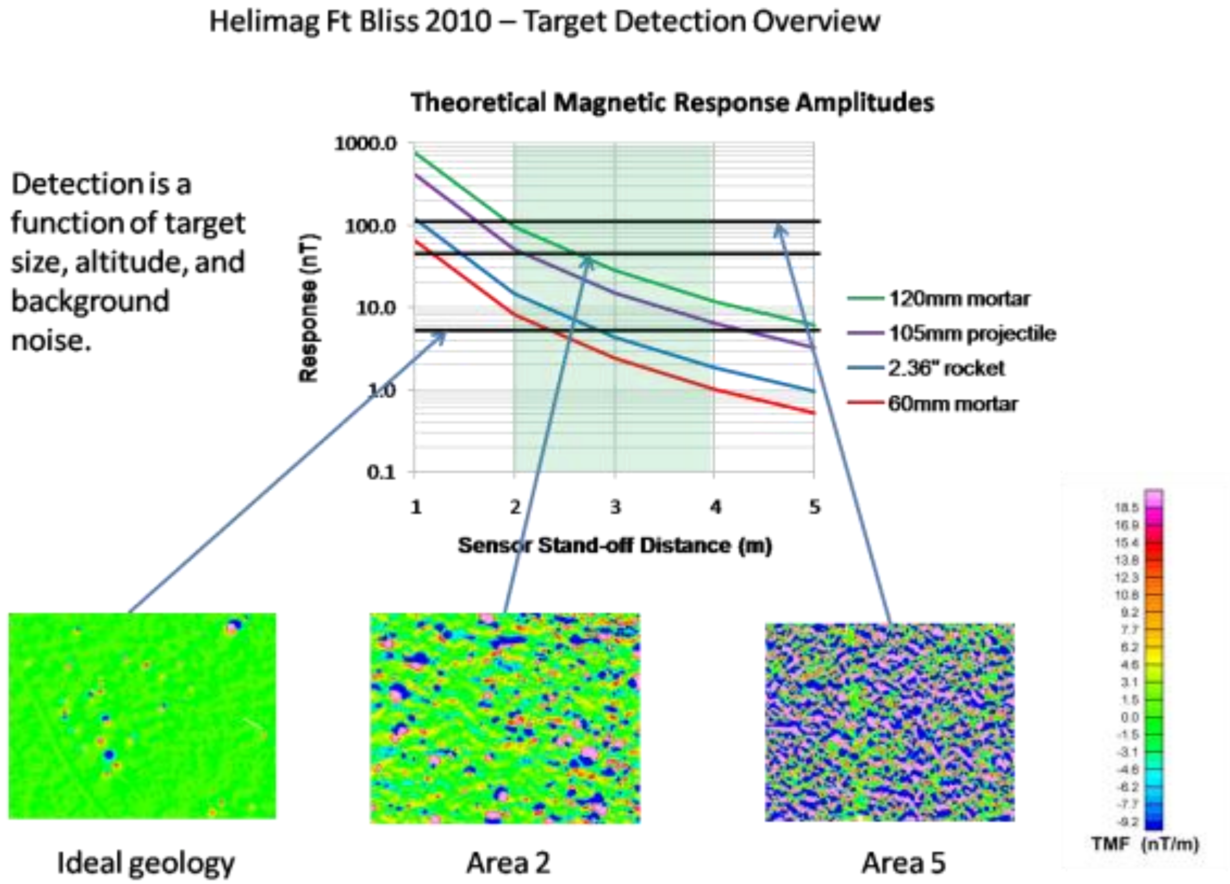


Figure 3-24. Signal-to-Noise Ratio Degraded by Sensor Standoff Distance and High Background Noise

Due to the interfering nature of the geologic response across most of the site, the anomalies were selected manually by an experienced analyst based upon the anomaly amplitude and spatial extent. After data processing, 52,751 anomalies were identified within the survey boundary (see Figure 3-25). Although these anomalies were classified with respect to their apparent size and dipole orientation, separation of geologic anomalies from discrete ferrous objects was not reliably achieved.

Anomaly density maps were produced to provide an image of the spatial anomaly distribution over the site. Figure 3-26 shows the spatial distribution of anomalies presented as a density image. This figure is derived from a density raster computed using a 100-m radius neighborhood kernel that assigns anomaly densities in anomalies per hectare to each cell in the raster.

The initial set of anomalies consisted of those anomalies potentially due to targets of interest as well as anomalies caused by other metallic debris and localized geology. Conventionally, density images using all selected targets are useful for differentiating between areas of high use and areas that have only background levels of ferrous material distributions. The pervasive nature of the ferromagnetic geology at the Closed Castner Range MRS limits the utility of the density image because anomaly density changes due to the geologic effects cannot be easily separated from changes in the distribution density of anthropogenic ferrous material.

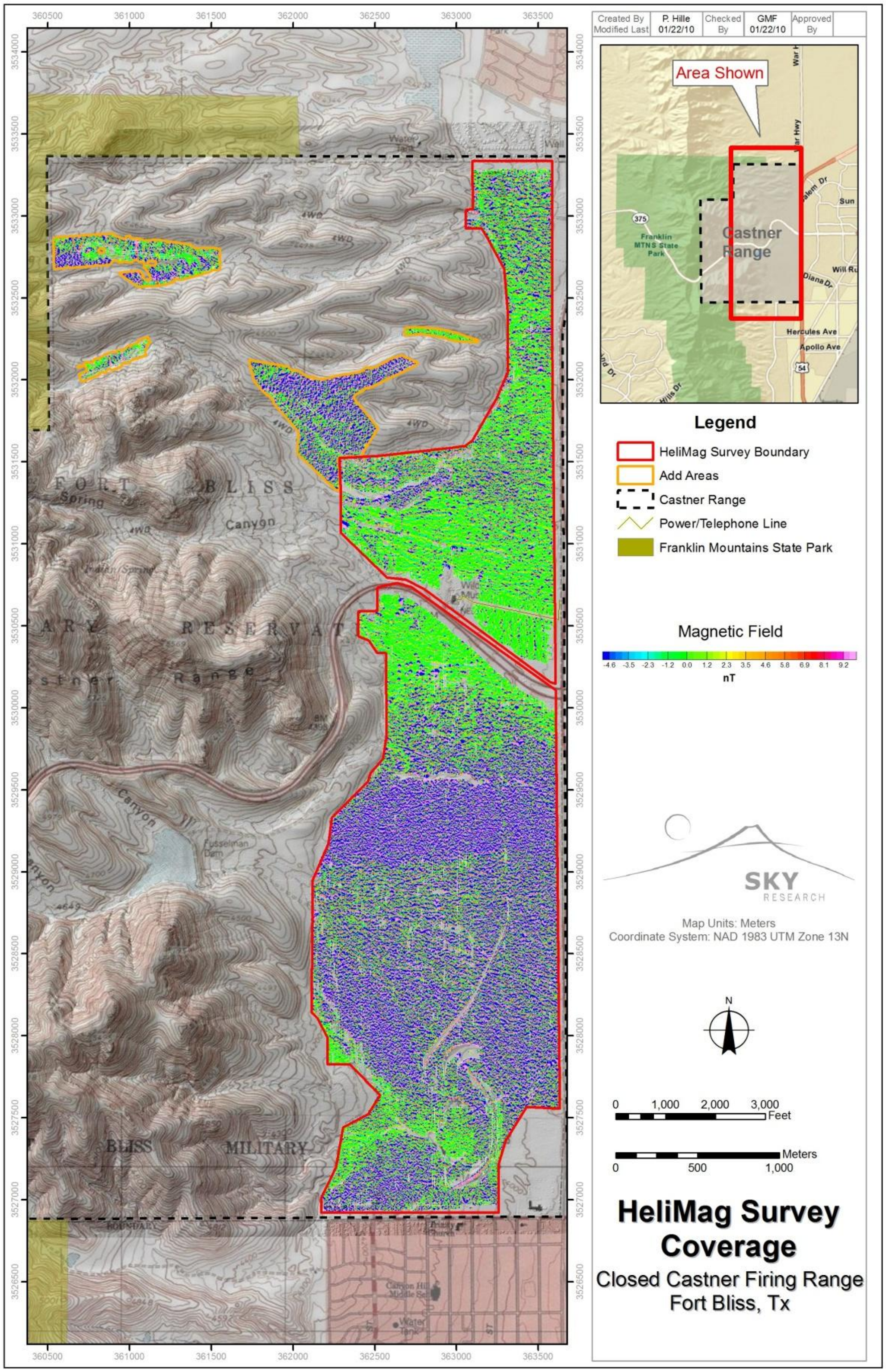


Figure 3-25. Helicopter-borne Magnetometry Generated a Total Magnetic Field (Filtered), From Which 52,751 Anomalies Were Identified

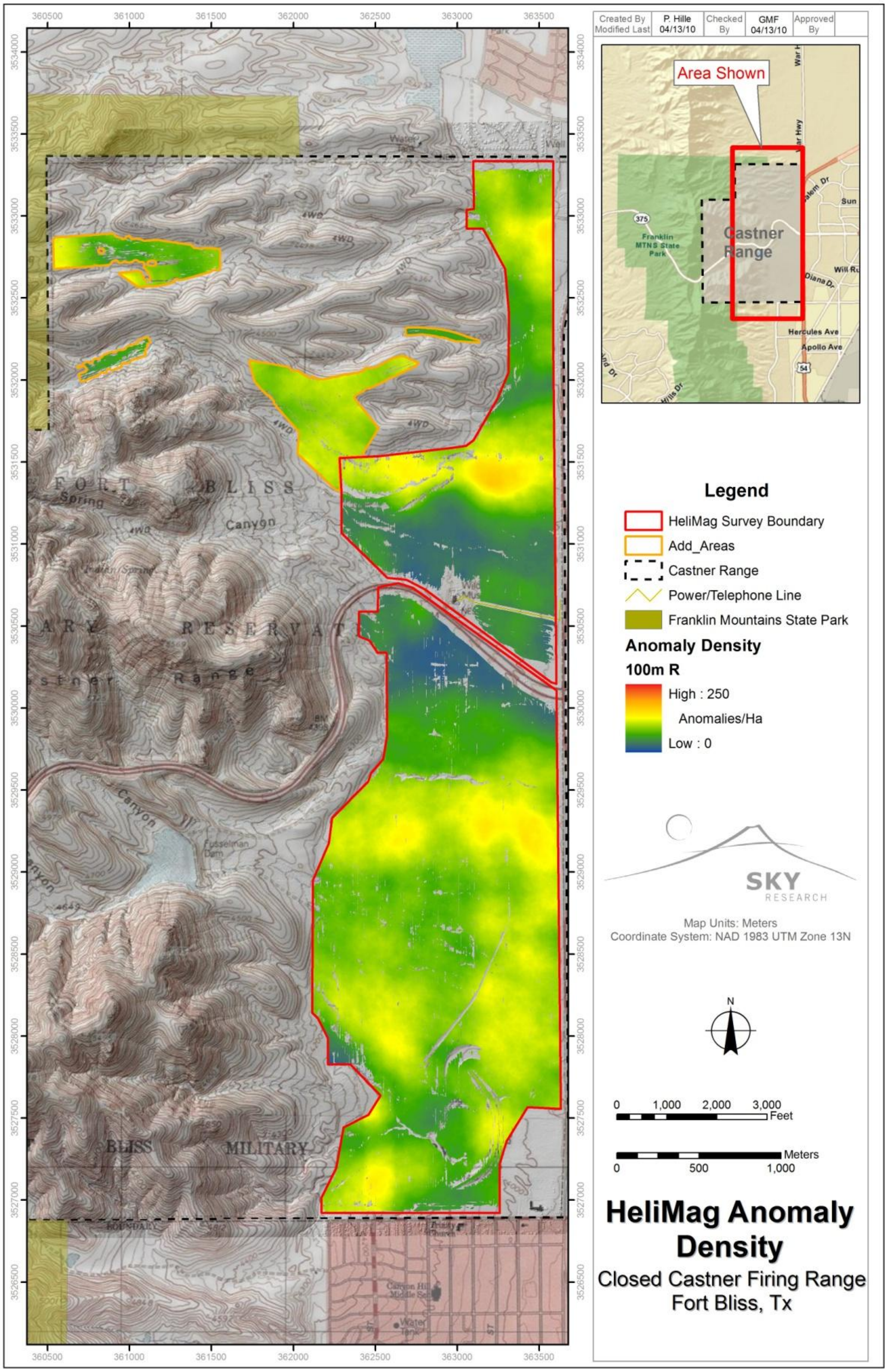


Figure 3-26. Helicopter-borne Magnetometry Anomaly Density

In an effort to extract as much information as possible from the data set, additional data processing algorithms were applied. Often the density distribution maps can be refined by rejecting a subset of anomalies based on the classification results. At this site, the spatial density distribution of the various classes did not differ significantly from that of the entire set. Efforts to identify spatial correlations based on specific anomaly features such as dipole size, orientation, and depth were met with limited success. Typical munitions-related targets of interest are small in size (less than 5 A-m^2), shallow (less than 1 m depth), and/or exhibit low magnetic remanence (dipole angle less than 60 degrees). When elevated percentages of these features are presented in a spatial context, they may more clearly indicate areas of interest. Figures 3-27, 3-28, and 3-29 show the results of these site characterization analyses, respectively.

Figure 3-27 shows the anomaly distribution displayed as the percentage of anomalies with depth less than 1 m (all angles and sizes). Although these results are distorted by the presence of active geology, relative “highs” may be indicative of anthropogenic activity, anthropogenic targets will, on average, have a shallow bias relative to geologic targets. Figure 3-28 shows the anomaly distribution displayed as the percent of moment less than 5 A-m^2 (all angles and depths). Under the assumption that anthropogenic targets will in general provide smaller responses than geologic targets, a higher percentage of small targets might be indicative of anthropogenic activity. However, regions with extreme geologic activity may mask smaller targets, thus artificially lowering the percentage of small targets—this is likely the case for the southern half of the site. Figure 3-29 shows anomaly distribution displayed as a percentage of anomalies with a dipole angle less than 60 degrees (all sizes and depths). A high percentage of dipole angles less than 60 degrees indicate that many of the targets in the sample have little or no remanent magnetization. A lack of remanent magnetization is often consistent with MEC activity due to the phenomena of shock demagnetization.

3.2.2.3 Characterization Results

Based on these results, seven areas of interest were identified by virtue of being indicative of some kind of anthropogenic activity, such as clusters of large discrete dipoles that do not appear natural, linear features, or elevated anomaly density that is incongruent with the apparent local geologic response (see Figure 3-30). Much of the survey area was masked by the geologic response and/or contained vegetation that necessitated survey altitudes at greater than the effective altitude of the system. In these areas, the data do not support any conclusions with respect to the density and distribution of ferrous material at the site.

3.2.3 Man-Portable Geophysics

The man-portable DGM method employed at the Closed Castner Range MRS used Geonics EM61-MK2 EMI (EM61) sensors, coupled with RTK GPS, and data collection computers, mounted on stretcher-like litters, carried between two operators. The EM61-MK2 is a high-resolution, time-domain EMI sensor capable of detecting both ferrous and non-ferrous metallic objects. The EM61-MK2 system consists of an air-cored coil, a digital data recorder, batteries, and processing electronics. The EM61’s transmitter generates a pulsed primary magnetic field, which then induces eddy currents in nearby metallic objects. These eddy currents are measured by the same coil acting as a receiver. Secondary voltages are measured in millivolts (mV) at four

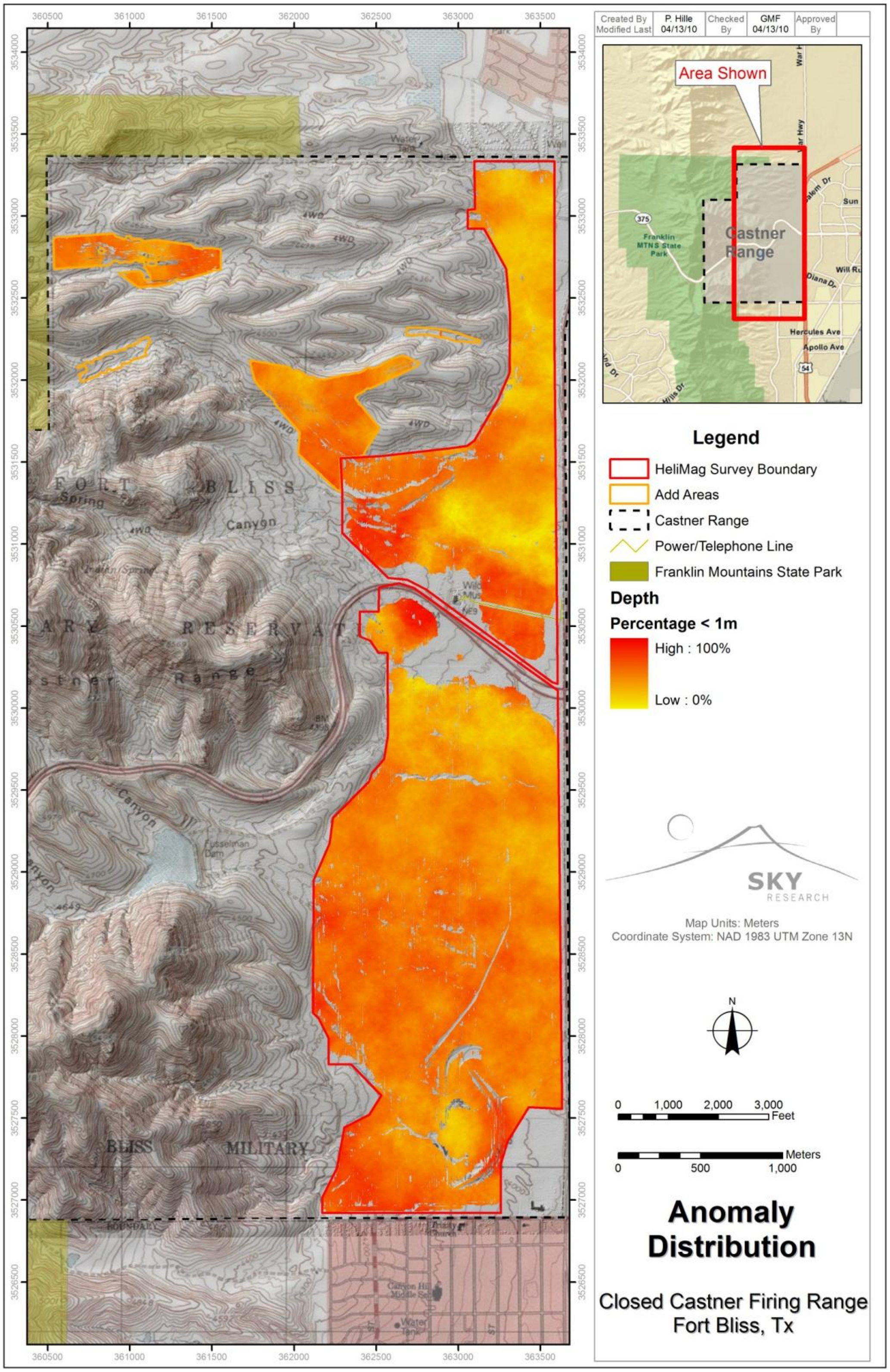


Figure 3-27. Anomaly Distribution Displayed as a Percentage of Anomalies With Depth Less Than 1 m

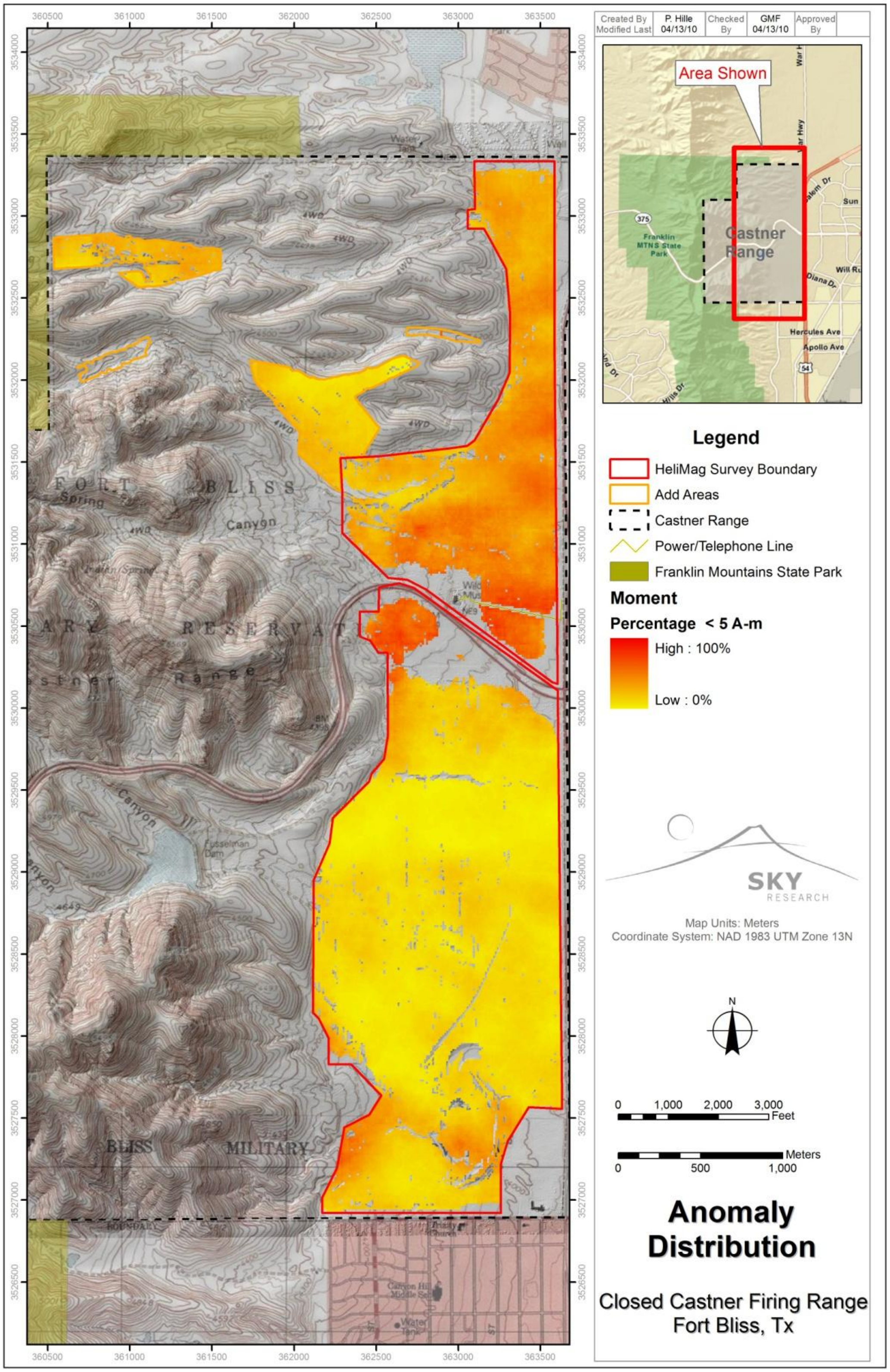


Figure 3-28. Anomaly Distribution Displayed as a Percent of Moment Less Than 5 A-m^2

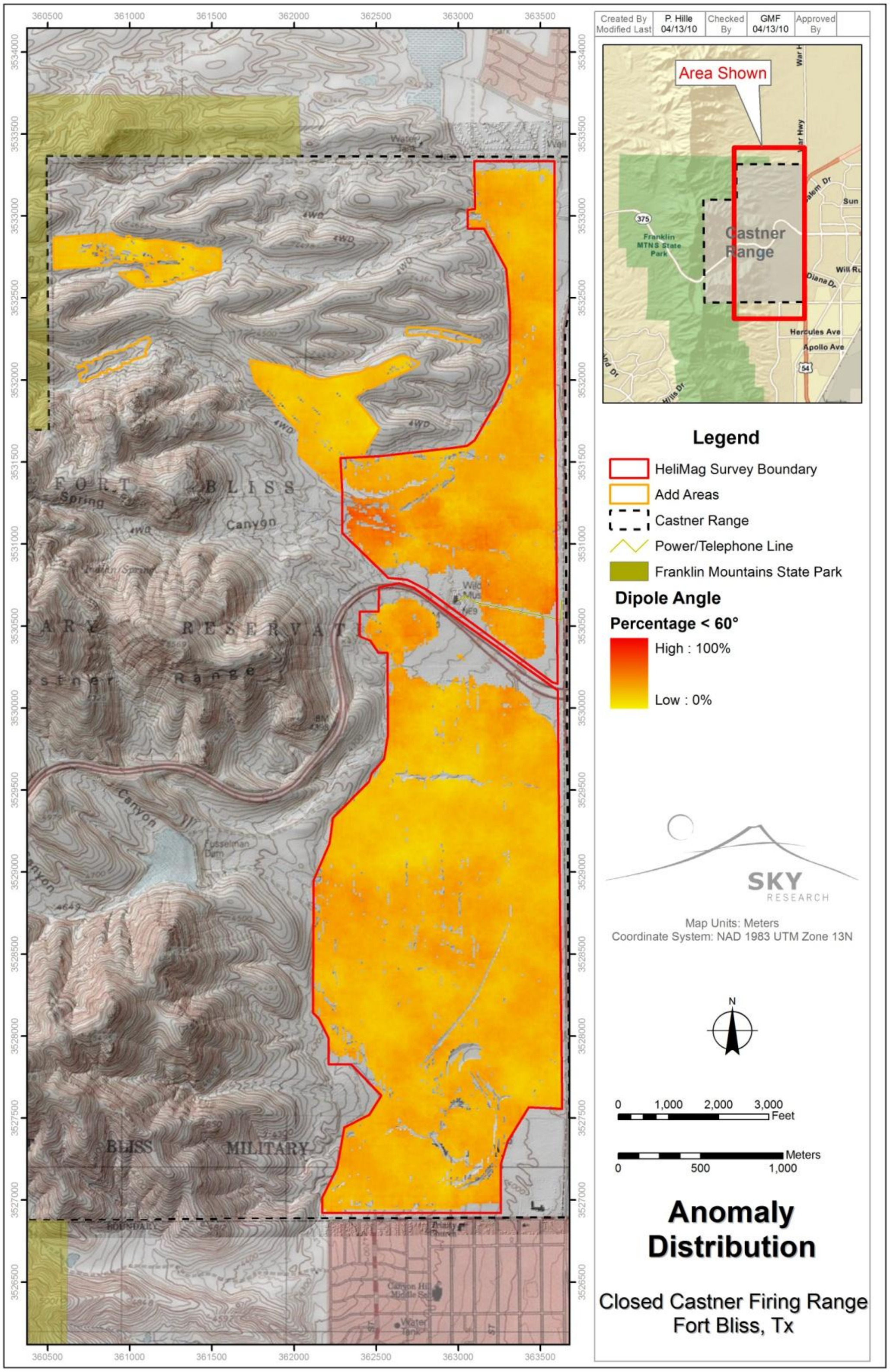


Figure 3-29. Anomaly Distribution Displayed as a Percentage of Anomalies With a Dipole Angle Less Than 60 Degrees

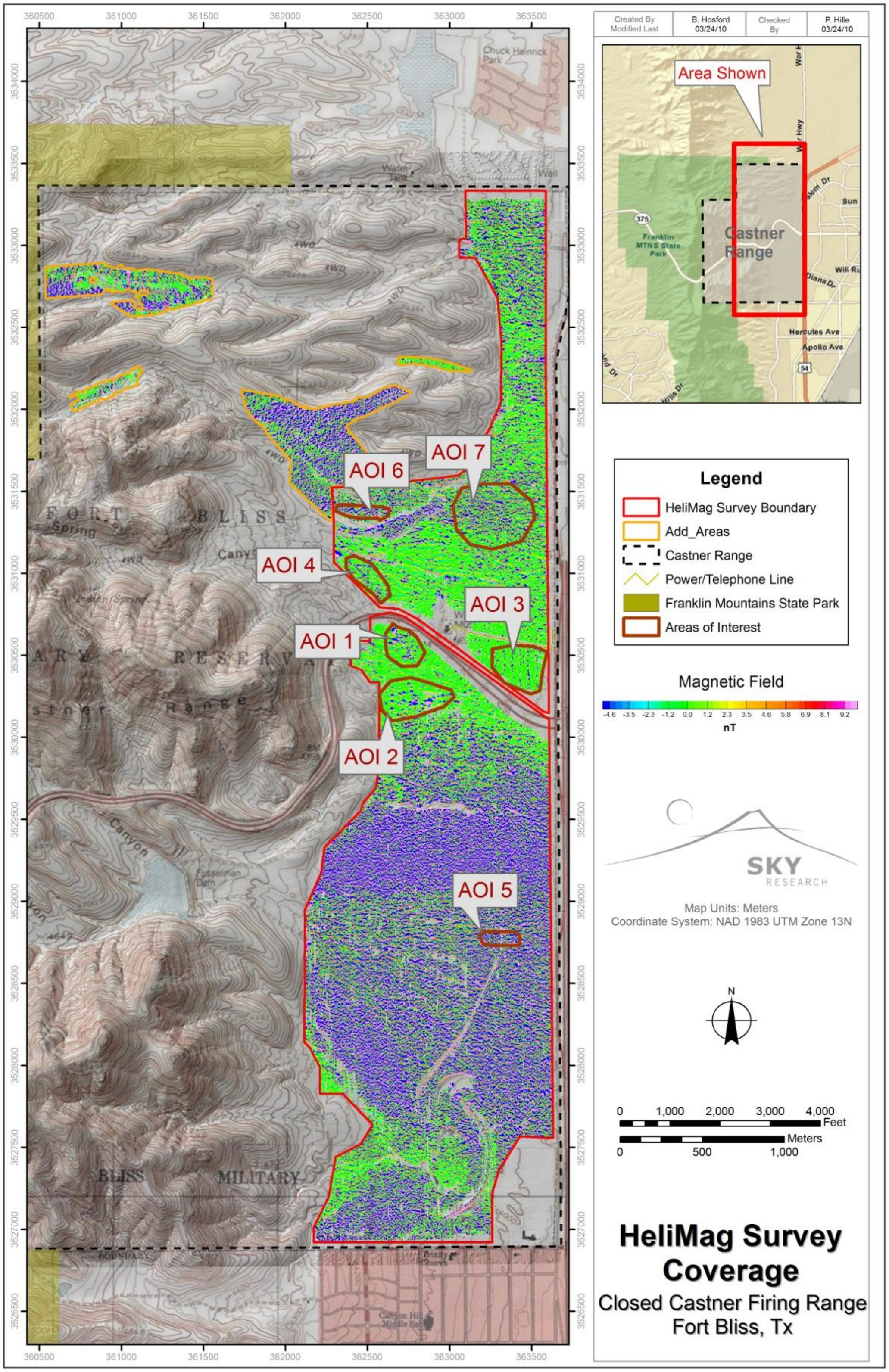


Figure 3-30. Areas Potentially Indicating Munitions Activity Identified by Helicopter-borne Magnetometry

separate time gates. The arrangement of coils is such that there is a vertical separation of 40 cm from the ground surface to the coil. The litter arrangement was selected over a towed-array approach—usually preferred for WAA because of the survey speed and width of the swath—because of the difficult terrain. A larger portion of the MRS was able to be surveyed with the man-portable equipment than would have been accessible to a towed array.

As previously noted, the objective of this WAA project was not to locate all MEC items on the Closed Castner Range MRS, but to implement and evaluate technologies that could enable quick, inexpensive, and reliable characterization of a site. The objective was to not only identify areas having a high density of anomalies that require more investigation, but also areas of very low anomaly density that might be confidently excluded from further investigation. Consequently, the approach selected for man-portable DGM was to cover the area of interest using transects spaced 57 m apart. Transect spacing was calculated at 57 m using the VSP function “Transect Spacing to Ensure High Confidence of Traversal and Detection of Target Areas,” as described in Section 3.1.2. Using the width calculated above, transects were planned for terrain where the average slope was 18% or less. The total area meeting this criterion was 4,020 acres.

The MRS was divided into two approximately evenly sized pieces, and employed two independent geophysical contractors, SKY Research and NAEVA Geophysics, to characterize the site with man-portable EMI equipment. SKY Research mapped the southern portion of the MRS, and NAEVA Geophysics Inc. mapped the northern half, each having a planned coverage of about 1,900 acres. Approximately 200 acres of the same terrain were mapped by both contractors. The use of two contractors allowed comparison of results from slightly different equipment configurations, data collection teams and methods, data processing methods, and presentations. The methods, transect spacing, instruments, data specifications, and quality assurance (QA)/QC methods were intended to be consistent between contractors. In addition to characterizing the MRS, the 374-acre overlap area provided an opportunity to compare the repeatability of end results.

3.2.3.1 Equipment and Methods

Both contractors utilized a Geonics EM61-MK2 electromagnetic coil in a litter configuration (see Figure 3-31), coupled to survey-grade RTK GPS, and a data collection computer. The litter consisted of a single EM61-MK2 inductor/detector mounted on a rigid fiberglass frame. Data were recorded at 10 Hz.

A survey-grade RTK GPS was used to position the data. The RTK Differential GPS consisted of a mobile GPS antenna and a base station also utilizing a Trimble 5700/R7/R8 receiver. The base receiver was established over a known “Class 1, Third Order” or equivalent control point or benchmark. The accuracy of the GPS rover typically depends partly on the accuracy of the base station location. Other factors such as nearby obstructions and time of day affect the number of satellites visible to the GPS and, thus, the accuracy. Under ideal circumstances, accuracies of 3 cm horizontal and 5 cm vertical are expected when five or more satellites are visible. Real-time corrections from the base GPS receiver are broadcast to the roving GPS unit via a radio link using a TRIMMARK 3 or HPB450 radio modem. This system provides positional updates at a rate of 1 Hz.

Figure 3-31. Data Collection Using a Litter Configuration

Prior to commencing DGM, the transects were walked by UXO technicians to check the surface for MEC, and marked with flagging tape to delineate the survey path. Georeferenced shape files, containing the idealized and surveyed transects as well as mapped roads within the area of concern, were provided to the contractors. Navigation and UXO avoidance were facilitated by a UXO technician who walked in front of the survey crew and navigated with a handheld GPS.

NAEVA Geophysics conducted DGM of the northern portion of the MRS from January 27 to February 16, 2010. NAEVA Geophysics surveyed 171.8 km (106.8 miles) of transects, including tactical trails/roads, which were added to the scope of work. This mileage was greater than originally scoped (91.2 miles) even though some transects were not surveyed because they were too steep or otherwise inaccessible. The increased coverage was due to the meandering paths walked along the idealized transects, which were necessary due to difficult terrain and thick vegetation. Some of the steeper hills necessitated walking in a switchback manner instead of straight up the slope. Appendix D contains a detailed report.

SKY Research conducted DGM of the southern portion of the MRS from January 27 to February 18, 2010. SKY Research surveyed 165.6 km (102.9 miles) under conditions similar to NAEVA Geophysics. Appendix E contains a detailed report.

3.2.3.2 Data Processing and Analysis

NAEVA Geophysics data processing tools and steps are described in detail in Appendix D; SKY Research data processing tools and steps are described in detail in Appendix E. In general, in both cases, data were captured, preprocessed, and assessed daily, with final processing following within several days. Preprocessing was completed within 24 hours to enable re-collection of missing or problematic data while collection teams were still in the field.

Preprocessing typically consisted of merging raw sensor and positional data and converting to the appropriate coordinates for xyz files. The data were reviewed and daily QC tests evaluated, followed by evaluation of data synchronicity, positional accuracy, and data density characteristics. Auto-leveling, instrument drift, and default lag corrections were preliminarily applied, and preliminary maps generated for assessment of coverage/gaps and content.

Final processing was conducted over the next several days, and typically consisted of additional filtering, review and finalization of data completeness checks, QC data detailed review, review and adjustment of correctional factors, analysis of signal-to-noise ratios, and preparation for anomaly selection.

Anomalies were selected using a threshold of 4 mV on Channel or Gate 2. This threshold was useful for showing the distribution of metallic items across the site, corresponding to six times the RMS noise level, which is an industry standard threshold determination method (Nelson et al. 2010). The threshold of 4 mV on Channel 2 would enable the identification of a hand grenade in the least favorable orientation at a maximum depth of 9.5 in. (as calculated by ESTCP's EM61 Response Calculator software). All the ISO items from the IVS had responses higher than 4 mV on Channel 2, even in the least favorable orientation at a depth of 7 in. For each anomaly the peak response on all four channels was recorded, along with field crew or processor comments; signal-to-noise ratio, anomaly size, and decay ratios were calculated.

Each contractor used a software module to make the initial anomaly selections from the master anomaly list. Data profiles corresponding to the anomalies were then analyzed by geophysicists, with the targets evaluated as to their validity and position. Targets found to be invalid or incorrectly located were removed or adjusted. Additionally, anomalies that were not selected by the software, yet deemed to represent a potential MEC target, were manually selected.

3.2.3.3 Quality Control

In accordance with the work plan, extensive QC measures were applied to the acquisition, processing, and presentation of the man-portable DGM data, including the following. Appendices D and E contain complete details.

- An IVS was constructed to enable the establishment of instrument response to known anomalies, as discussed in Section 3.1.3. As noted, the transect method of WAA is not well-suited for the use of blind seeds in the production area. Each team walked the IVS at the beginning and end of each day, and whenever other significant changes were made to the equipment.
- Dynamic noise test (including cable shake) daily to check consistency of equipment.
- Static noise test daily to check consistency of equipment.
- Spike test to ensure equipment returned to zero.
- Personnel repeatability.
- Positional test daily to confirm ongoing accuracy of equipment.

- Drift check, lag test to check the timing match of positional and EMI data.
- Production repeatability, where a 100-ft length out of each mile of transect was mapped a second time so that the data could be compared to determine repeatability in number and position of detected anomalies.
- Initial review of geophysical data.
- Final review of processed data.

Additionally, approximately 200 acres of the same terrain were mapped by both contractors (see Figure 3-32). In this subset of the MRS, each contractor was given the same transect navigation map, although minor deviations were common due to terrain and vegetation avoidance decisions. SKY Research identified 1,297 anomalies in this overlap area; and NAEVA Geophysics identified 1,249 anomalies in this area, with a resulting difference of 3.7%. This difference was expected to be very small since, even if the transects were slightly different, each team would characterize the same areas with the same relative densities of anomalies. Using the density interpolation approach described below, density maps for each contractor were prepared, confirming that each contractor identified the same preliminary target and non-target areas (see Figure 3-33). This analysis confirmed the repeatability and reliability of both contractors' results.

3.2.3.4 Characterization Results

SKY Research identified 14,474 anomalies in the southern area. NAEVA Geophysics identified 6,435 anomalies in the northern area.

Final processed XYZ (ASCII) files were created for each data set, and individual geophysical maps and target lists were created for each transect. A final composite anomaly target list was created as the starting point for planning the intrusive activities.

Data were not collected along a few of the planned transects due to difficulty of traversal or access, particularly in the western canyons (see Figure 3-34). Data collection in many of these areas was supplemented with analog reconnaissance data (described in Section 3.2.4).

The DGM and anomaly data were combined, and an anomaly density model was created using the GIS software ArcInfo by Environmental Sciences Research Institute. Survey transects collected by both SKY Research and NAEVA Geophysics were loaded into the GIS as polyline features. Polygon features were created from those polylines by applying a 1-m buffer to each survey transect (half meter on either side of the polyline) to create a file that encompassed the total coverage of the EM61-MK2 [course-over-ground (COG) coverage area]. Polygon features were also created for both the northern and southern survey areas. These polygons were created by manually digitizing the extents of all the survey transects in order to define a general survey area. The area of each polygon was then calculated for both the northern and southern survey areas and the COG coverage areas. The ratio of the total survey area to COG coverage area was determined for both the northern and southern survey areas.

Density calculations were performed using the spatial analyst extension in ArcInfo. Three groups of targets were identified. The targets consisted of locations that met or exceeded the predefined electromagnetic response thresholds (4 mV). Density calculations were performed independently

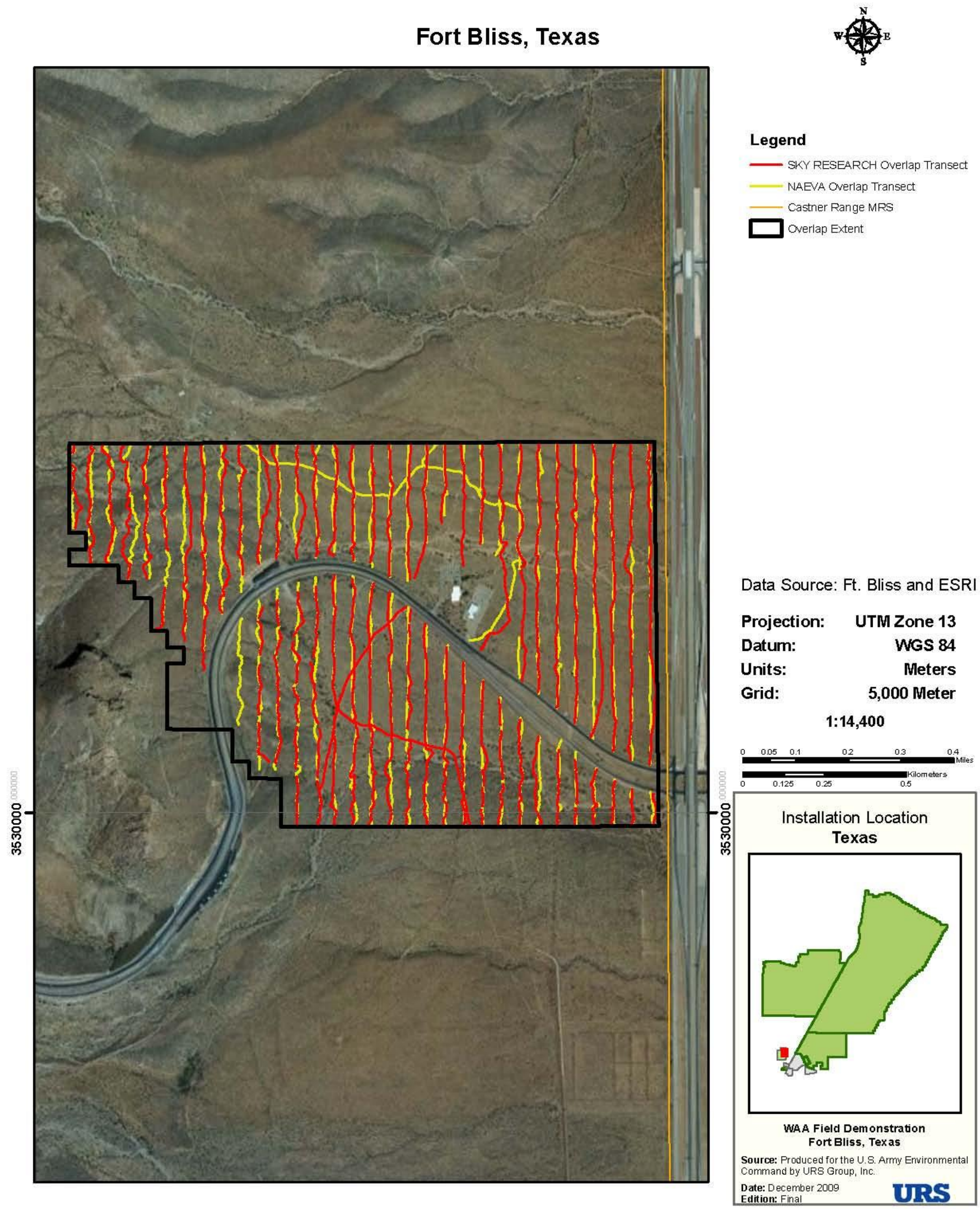


Figure 3-32. 374-acre Overlap Parcel

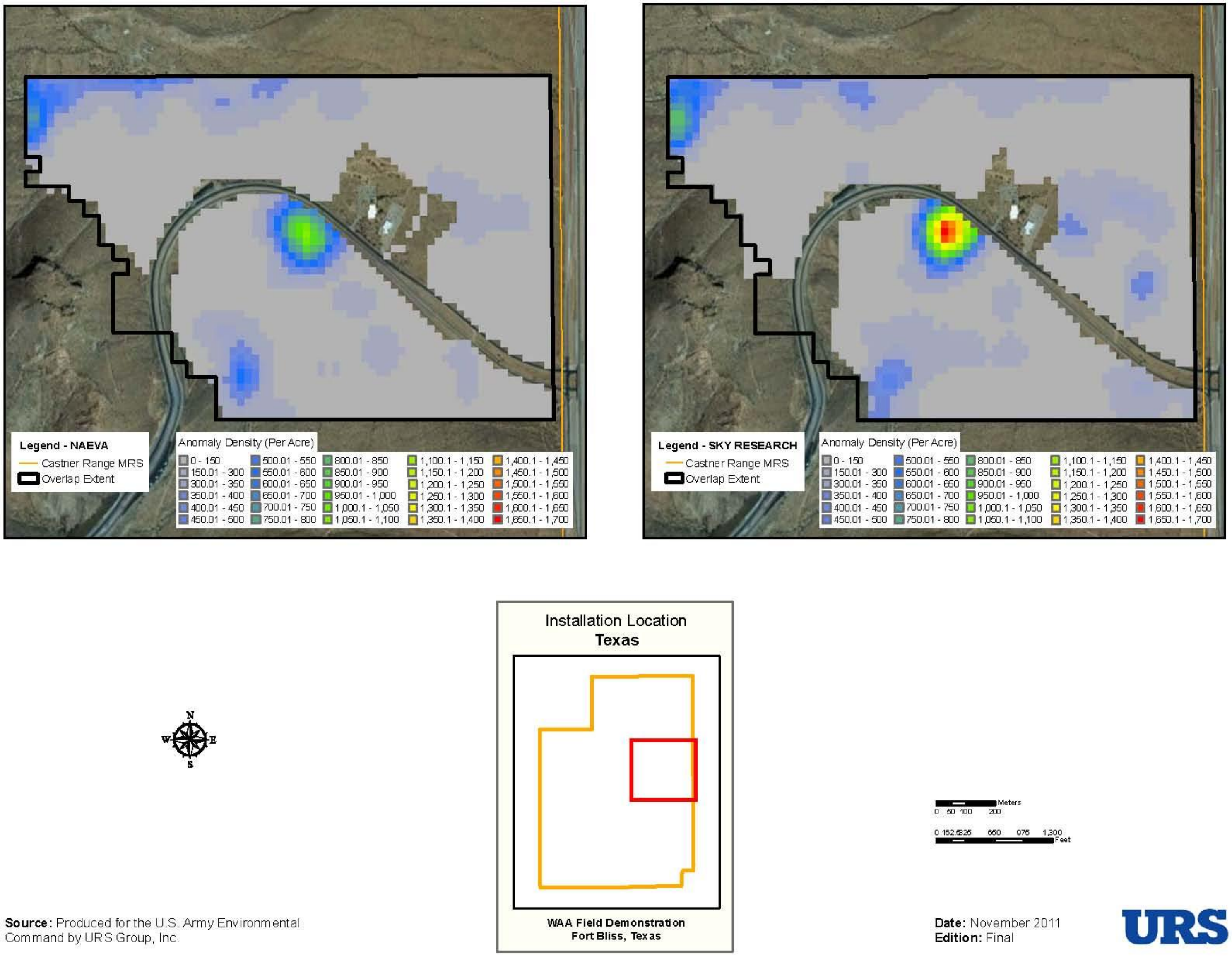


Figure 3-33. Anomaly Density in the Overlap Parcel

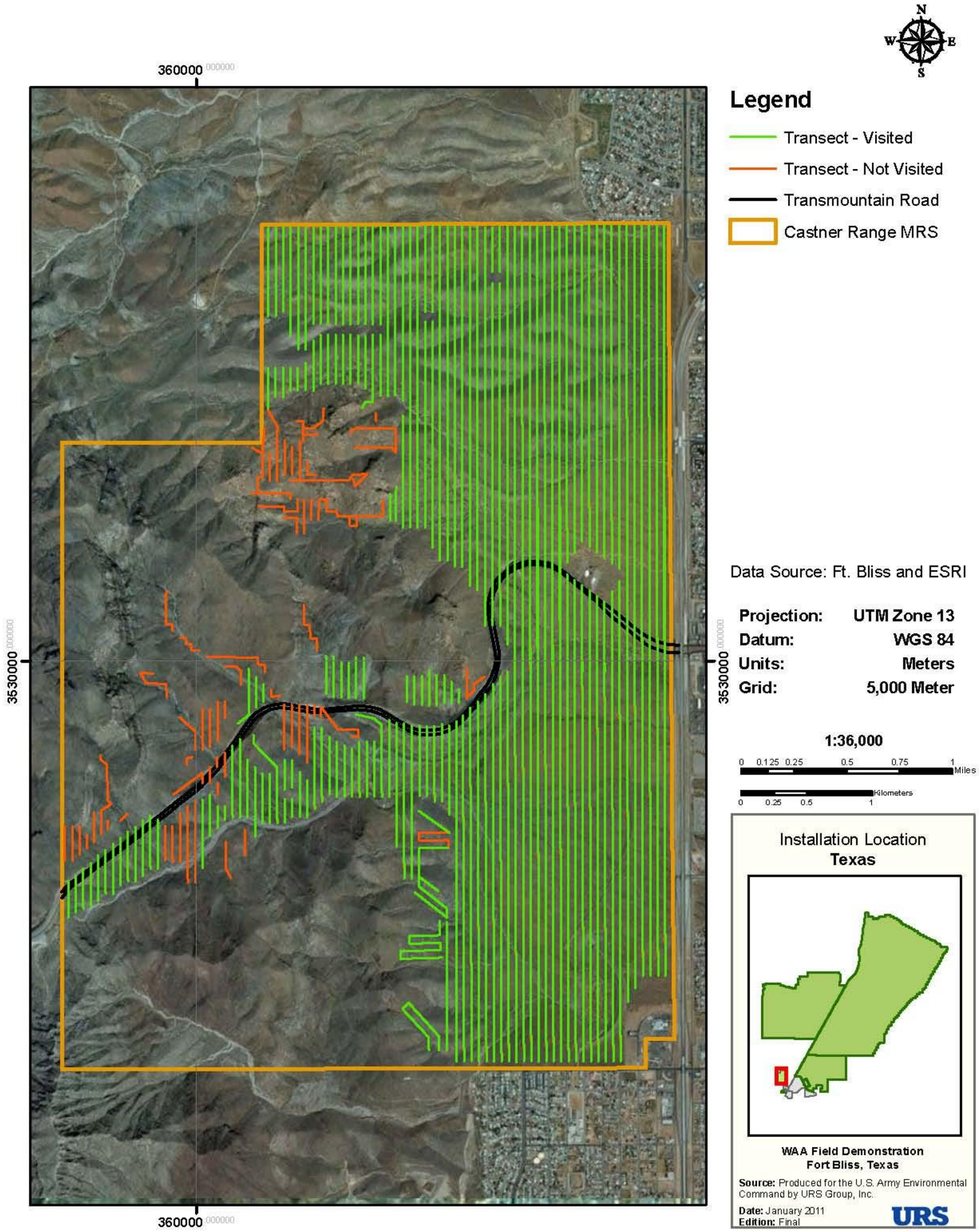


Figure 3-34. Course Over Ground Data Transects

on each set of targets in both the northern and southern survey areas. Density maps, measured in anomalies per acre, were generated for each threshold response within each study area. Each map was exported as a GIS raster image. Each grid cell (pixel) of the raster images contained the density calculated for that location using a search radius of 75 m (see Figure 3-35).

The anomalies were not spread homogeneously but rather clustered in several high density areas. Some of these areas correspond to areas identified in the Historical Records Review as containing trenches or disturbed areas, and generally agree with areas where higher amounts of surface debris were observed or cleaned up in prior removal actions (e2M 2007).

3.2.4 Analog Reconnaissance

As previously noted, terrain features made several areas inaccessible to man-portable geophysical methods. Stakeholders were concerned about potential MEC along the unofficial hiking trails where man-portable DGM data collection was not possible. Stakeholders acknowledged that hikers have been repeatedly warned against intrusion onto the Closed Castner Range MRS; nevertheless, trespassing still occurs and prior incidents with MEC from the Closed Castner Range MRS (e2M 2007) are a cause for concern. Additionally, the steeply eroded arroyos were not accessible to man-portable DGM, but present potential vectors for human exposure to MEC and MD.

In these areas, analog reconnaissance methods were used to identify both surface and subsurface anomaly indications. The analog reconnaissance survey methods were based on the *MEC Reconnaissance Programmatic Work Plan* [U.S. Army Corps of Engineers (USACE) 2008]. The objective of the analog reconnaissance was to identify surface and subsurface metallic anomalies found in the arroyos (eroded gullies) along the eastern portion of the site and unofficial hiking trails in the western or mountainous areas of the site (see Figure 3-36).

The analog approach used handheld metal detectors and operator judgment to identify both surface and subsurface anomalies, and then positional data were collected with handheld GPS units and operator observations in a PDA in roughly uniform intervals. By plotting this georeferenced information on a GIS map, a visual depiction of general anomaly locations was possible. Although similar in appearance to transect maps, these data are not amenable to comparative density mapping. Approximately 22 miles of linear transects were surveyed along the arroyos in the eastern portion of the site and along unofficial hiking trails in the steep western portion of the site.

3.2.4.1 Equipment and Methods

The handheld metal detector used was the Minelab Explorer II, an EMI device that emits an audible tone when a metal object is sensed. The survey teams utilized handheld Trimble GeoXH GPS and PDA units and digital cameras to navigate, record their survey course over ground, collect information on the locations of anomalies and other features of interest, and record operator observations. The GeoXH had a predicted positional error of less than 30 cm. All data were captured in the GPS PDA using standard forms. Anomaly attribute data were geospatially referenced for use in GIS maps.

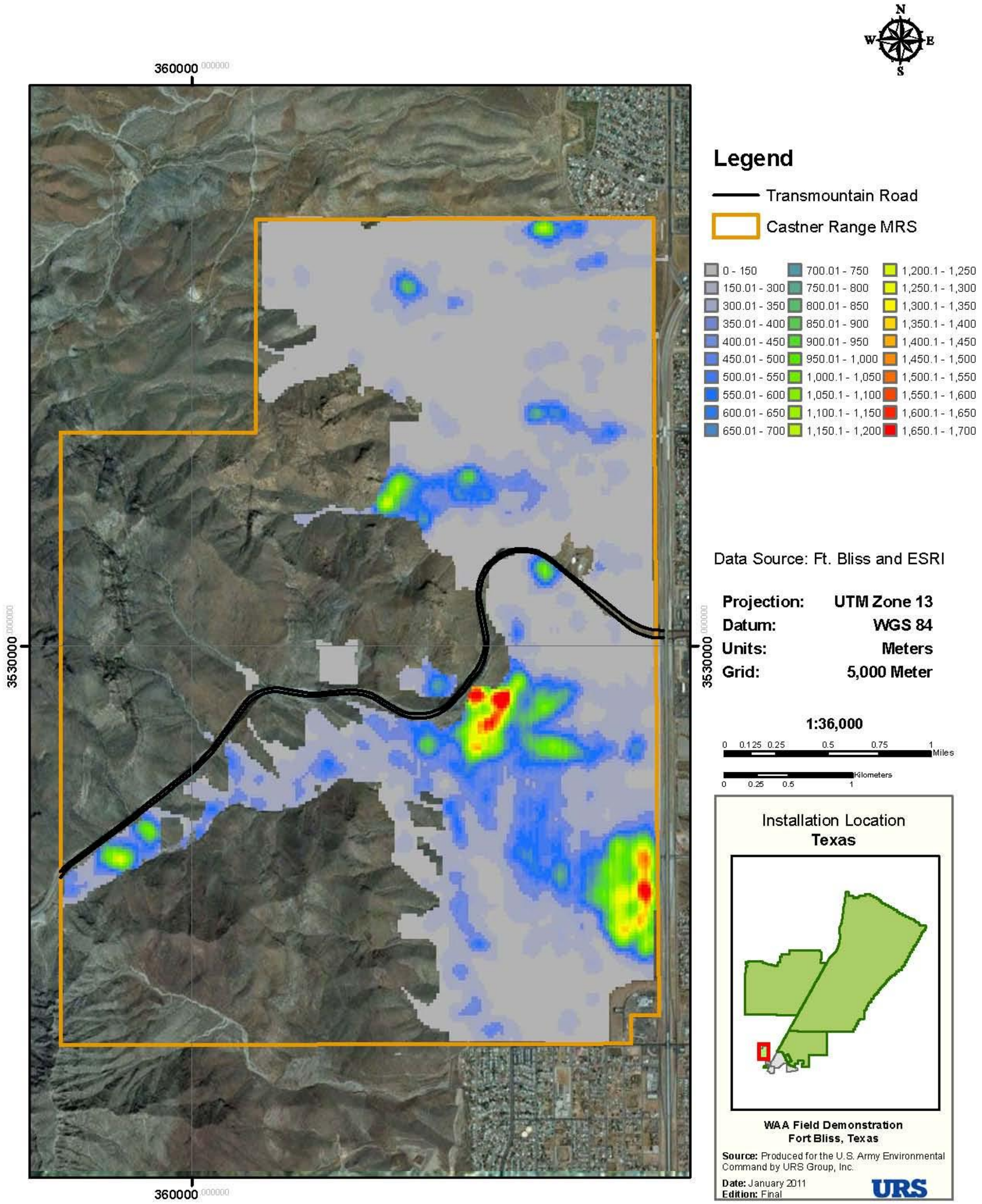


Figure 3-35. Anomaly Density at 4 mV

Figure 3-36. Analog Reconnaissance Employed for Terrain Inaccessible to Other Technologies

Each time the Minelab instrument reported a consistent tone, the UXO technician operator recorded an anomaly and determined whether a corresponding surface object was present. Approximately every 20 m, the UXO team leader would enter the number of anomalies detected into the GPS PDA. For surface objects, anomalies were coded as either range-related debris (RRD), MD, UXO, or non-military debris (NMD) and assigned nomenclature was used to describe the objects where possible (e.g., 75mm HE, 37mm TP, thin shell fragments, metal can, wire).

To monitor data quality (i.e., instrument function, detection capabilities, reproducibility, and positional accuracy), operators collected data over the IVS before and after each day's data acquisition (see Section 3.1.3).

3.2.4.2 Data Analysis

Analysis consisted of reviewing, tabulating, and plotting the numbers and types of surface anomalies and numbers of subsurface anomalies. Table 3-7 summarizes the numbers and types of anomalies recorded. Rudimentary estimates of anomaly densities were calculated, assuming the swath width of the analog reconnaissance path was approximately 1 m, which was multiplied by the distance surveyed to calculate "surveyed area." These estimated densities are included in Table 3-7.

Table 3-7. Summary of Analog Reconnaissance

	Track Length (ft)	Number of Instrument Indications of Subsurface Anomalies	Number of Surface Items	%MEC	%MD	%RRD	Total % of Surface Items Related to Military
NTA1	0	–	–	–	–	–	–
NTA2	6,613	424	49	0	16	8	49
NTA3	15,489	1,932	35	0	13	0	37
NTA4	13,085	7	2	0	1	0	50
TA1	0	–	–	–	–	–	–
TA2	4,411	411	53	0	34	0	64
TA3	344	27	2	0	2	0	100
TA4	1,661	156	24	0	4	0	17
TA5	0	–	–	–	–	–	–
TA6	0	–	–	–	–	–	–
TA7	0	–	–	–	–	–	–
TA8	0	–	–	–	–	–	–
TA9	14,751	277	122	1	75	0	62
TA10	0	–	–	–	–	–	–
TA11	14,181	49	9	0	100	0	100
TA12	0	–	–	–	–	–	–
TA13	0	–	–	–	–	–	–
TA14	6,691	21	1	0	0	0	0
TA15	14,864	52	19	0	74	5.3	79
TA16	3,403	56	6	0	0	0	0
TA17	6,341	426	78	0	26	1	35
TA18	14,864	363	80	1.3	65	7.5	74

3.2.4.3 Characterization Results

The analog range reconnaissance survey provided additional information about both the nature and extent of MEC by capturing numbers and locations of anomalies as well as metadata about each surface anomaly detected. The anomaly maps from the analog reconnaissance depict the number of anomalies per data entry point (approximately every 20 m). Figures 3-37 and 3-38 display surface and subsurface anomalies, respectively.

No valid comparisons can be made between instrument indications of anomalies recorded in analog reconnaissance data and the anomaly densities from man-portable DGM. There is no discrete instrument threshold setting for defining an “anomaly” detected by the analog instrument as there is for the EM61-MK2, used during man-portable DGM. Minelab Explorer II operators simply recorded an anomaly each time the instrument responded with a consistent tone.

3.3 Preliminary Target Area Delineation

While individual types of data collected on the Closed Castner Range MRS contributed insight and understanding of the density and distribution of potential MEC, the combination of the different data sets enabled a more confident delineation of areas believed to be target areas, as well as areas believed to be non-target areas. The merging and overlay of the data enabled a weight of evidence approach that increased confidence in the outcome.

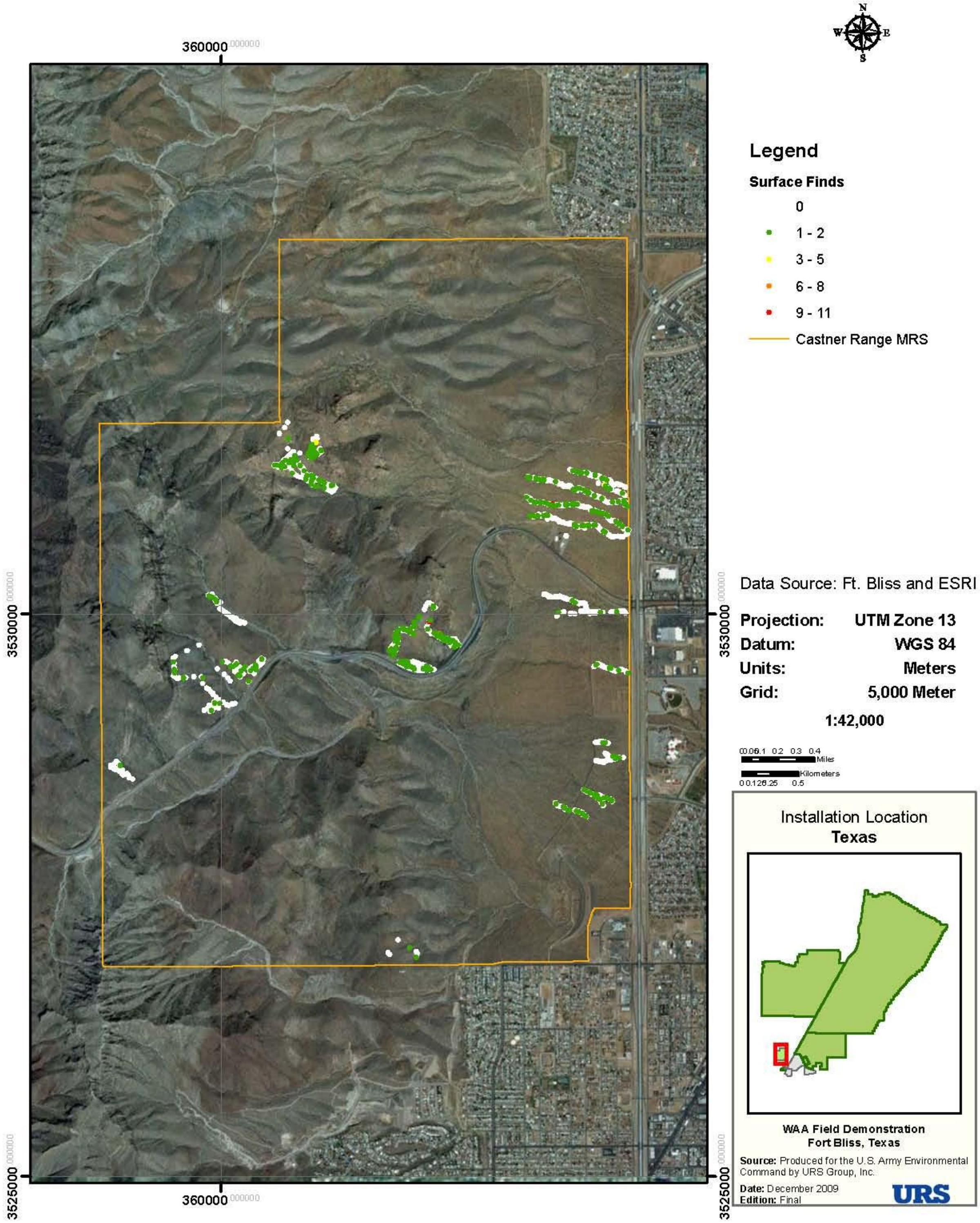


Figure 3-37. Analog Results: Distribution of Surface Anomalies

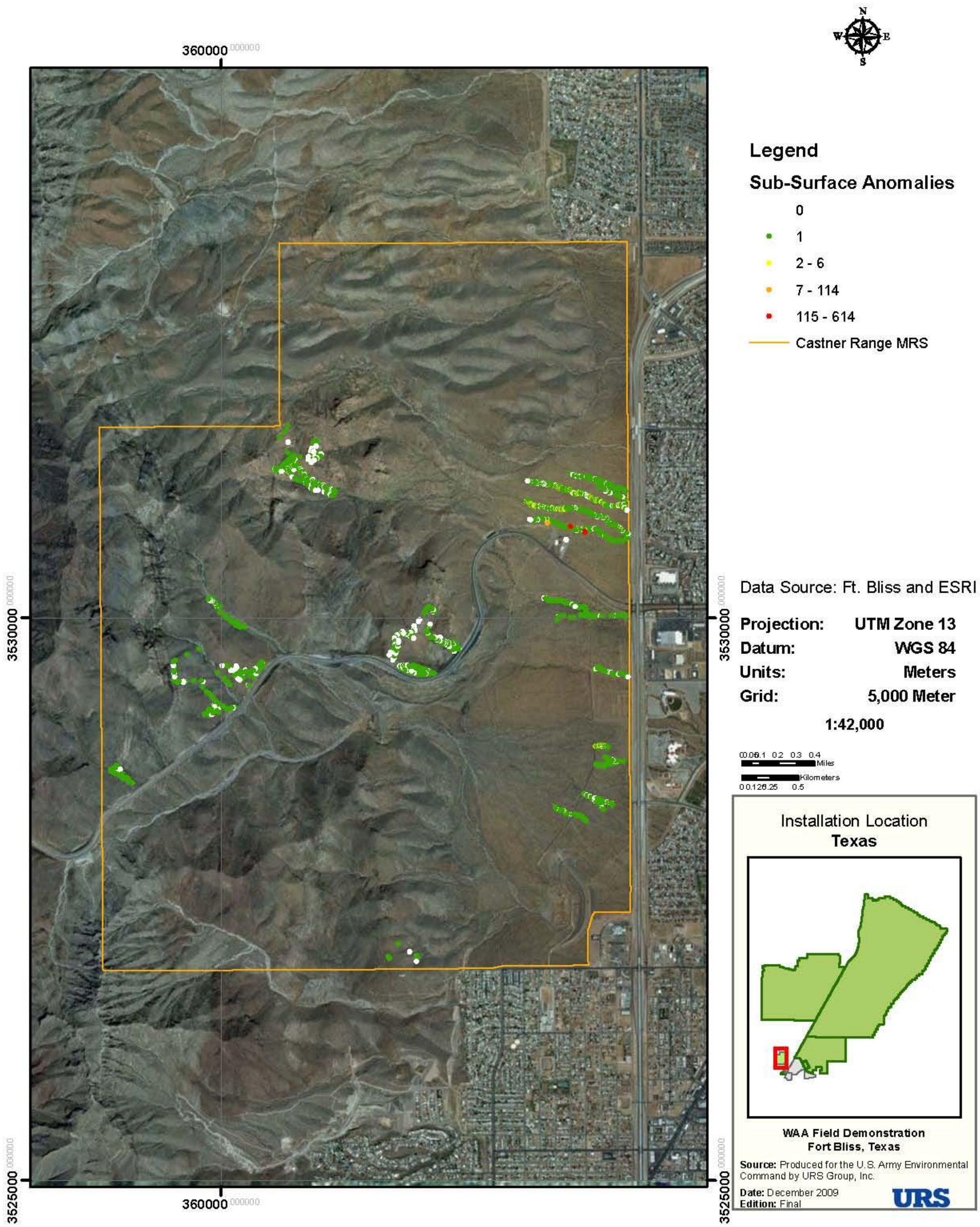


Figure 3-38. Analog Results: Distribution of Subsurface Anomalies

Preliminary target and non-target areas were delineated using multiple data sets, including historical range maps, previous surface and subsurface investigations, lidar areas of interest, helicopter-borne magnetometer areas of interest, and ground-based geophysics (man-portable EM61 DGM and analog reconnaissance). The purpose of discriminating preliminary target areas from non-target areas was to determine where each of the intrusive investigation data quality objectives would be applicable. The purposes of intrusive investigation in the preliminary target areas differed from those of the non-target areas. Therefore, the data quality objectives, sample sizes, and investigation process differed between the preliminary target areas and non-target areas.

3.3.1 Data Analysis

The following step-wise delineation process was used for data analysis.

1. Starting with the historical data, a map of documented ranges and range fans was created. This map used data from not only the historical range records, but also from prior MEC removal actions (see Figure 1-4).

2. Initial target delineation was based on anomaly density maps created from the ground-based geophysics (see Figure 3-35).

3. Polygons were established around distinct areas of elevated anomaly density relative to background (i.e., >300 anomalies per acre).

4. The polygons were refined to be inclusive of lidar/orthophotography features of interest (see Section 3.2.1.4).

5. The polygons were refined to be inclusive of areas where the UXO Technicians observed surface MEC or MD.

6. Polygons were added to include areas along high elevation informal hiking trails and arroyos (areas of stakeholder concern) that were found to contain surface MD or subsurface anomalies.

To allow prioritization of the various preliminary target areas, a scoring system was developed to evaluate the relative importance/significance of the target areas. The weight of evidence for identifying areas of interest provided by each data layer is summarized in Table 3-8. The analysis includes the following

- Scoring for the maximum anomaly density within the area (as determined by man-portable DGM),
- Detection of MEC or MD during previously conducted investigations (EHSI 1994),
- MEC or MD observed by US UXO Technicians while working onsite,
- Findings of subsurface anomalies during analog reconnaissance,
- Presence of surface features indicative of munitions-related activities (as detected by lidar or orthophotography),

Table 3-8. Preliminary Target Area Scoring Matrix

Data Layer	Weighting	Area of Interest																	
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Mean Anomaly Density / acre		**590**	837	410	352	382	284	482	223	396	234		247	316				80	
DGM **MAX** Anomaly density exceeding 300 anomalies/acre	10											NA	10	10	NA	NA	NA		NA
DGM **MAX** Anomaly density exceeding 800 anomalies/acre	15			15				15	15	15	15	NA			NA	NA	NA		NA
DGM **MAX** Anomaly density exceeding 1,200 anomalies/acre	20	20	20		20	20	20					NA			NA	NA	NA		NA
EHSI Surface Investigation Documented MEC	7				7		7		7	7	7	7							
EHSI Surface Investigation Documented MEC or significant MD	3	3		3	3		3		3	3	3	3	3						
UXO Tech Observations Documented MEC	7	7		7	7				7	7			7			7		7	
UXO Tech Observations Documented significant MD	3	3	3	3	3		3		3	3	3	3	3		3	3	3		3
Analog MEC Reconnaissance Indicates significant subsurface anomalies	3	NA	3	3	3	NA	NA	NA	NA	3	NA	3	NA	NA	3	3	3	3	3
Lidar or Orthophotography Indicates surface features potentially related to munitions activities	2	2	2		2	2	2	2	2	2	2		2	2				2	
Historical Range Fans Indicate potential munitions target/demo area	2	2	2	2	2	2	2	2	2	2		2	2	2	2	2	2	2	2
Helicopter-borne Magnetometry Area of interest	2		2	2	2			2			2			2					
Elevated Stakeholder Concerns	3											3			3	3	3		3
Total Score		37	32	35	49	24	37	21	39	42	32	21	27	16	11	18	11	14	11
												High grade/elevation hiking trails							

- Proximity of the area to historic range fans,
- Presence of an area of interest as determined by helicopter-borne magnetometry, and
- Level of stakeholder concern (i.e., unofficial hiking trails).

Also shown on Table 3-8 are the estimates of debris density per acre, as calculated from the man-portable DGM. In theory, the higher the total for a preliminary target area on Table 3-8, the greater the weight of evidence that it is a target area.

3.3.2 Identifying Preliminary Target and Non-Target Areas

Figure 3-39 depicts the preliminary target areas of interest on the Closed Castner Range MRS based on the data compiled from the WAA Technology Demonstration. The blue polygon represents the characterized area. Outside of the blue polygon, insufficient data exist to draw any conclusions. The acreage within the purple polygons (numbered 1–18) are the identified preliminary target areas, and acreage outside the purple polygons but within the blue polygon represents the non-target area. Table 3-9 summarizes the acreage and average anomaly density of the designated target areas.

3.4 Intrusive Investigation

The purpose of the intrusive investigation was to use "dig and verify" methods to determine the sources (e.g., MEC, MD, RRD, or NMD) of metallic anomalies identified during the man-portable geophysical characterization. With statistically valid sampling of anomalies, the objective was to confirm that preliminary target areas had MEC and MD densities that would indicate concentrated munitions use and the presence of a target area; for non-target areas, the objective of the intrusive investigation was to enable confirmation of a density of fewer than 0.5 MEC item per acre, the hypothesis for a non-target area. A successful intrusive investigation would enable conclusions about the density and distribution of MEC at the site, which would enable confident and appropriate decisions about how to manage the site for any planned land use. At the Closed Castner Range MRS, the intrusive investigation reacquired, investigated, characterized (size, depth, orientation, nomenclature), and resolved a statistically sufficient sample size of anomalies in each area of interest to test hypotheses verifying the delineation of target and non-target areas.

The WAA methodology used at the Closed Castner Range MRS was derived from the hypothesis that target areas would not only contain a higher density of metallic anomalies than the surrounding non-target areas, but would also demonstrate a higher proportion of munitions-related anomalies (i.e., MEC or MD) than non-munitions-related anomalies (i.e., RRD, NMD, and hot rock). The goal, therefore, of the intrusive investigation portion of the project was to provide sufficient data about the source and nature of anomalies to determine the proportion of anomalies attributable to munitions. In each preliminary target area where munitions make up a significant proportion of the anomalies, the intrusive investigation would also provide sufficient data to characterize the types of munitions used and to calculate an estimate of munitions-related anomalies per acre.

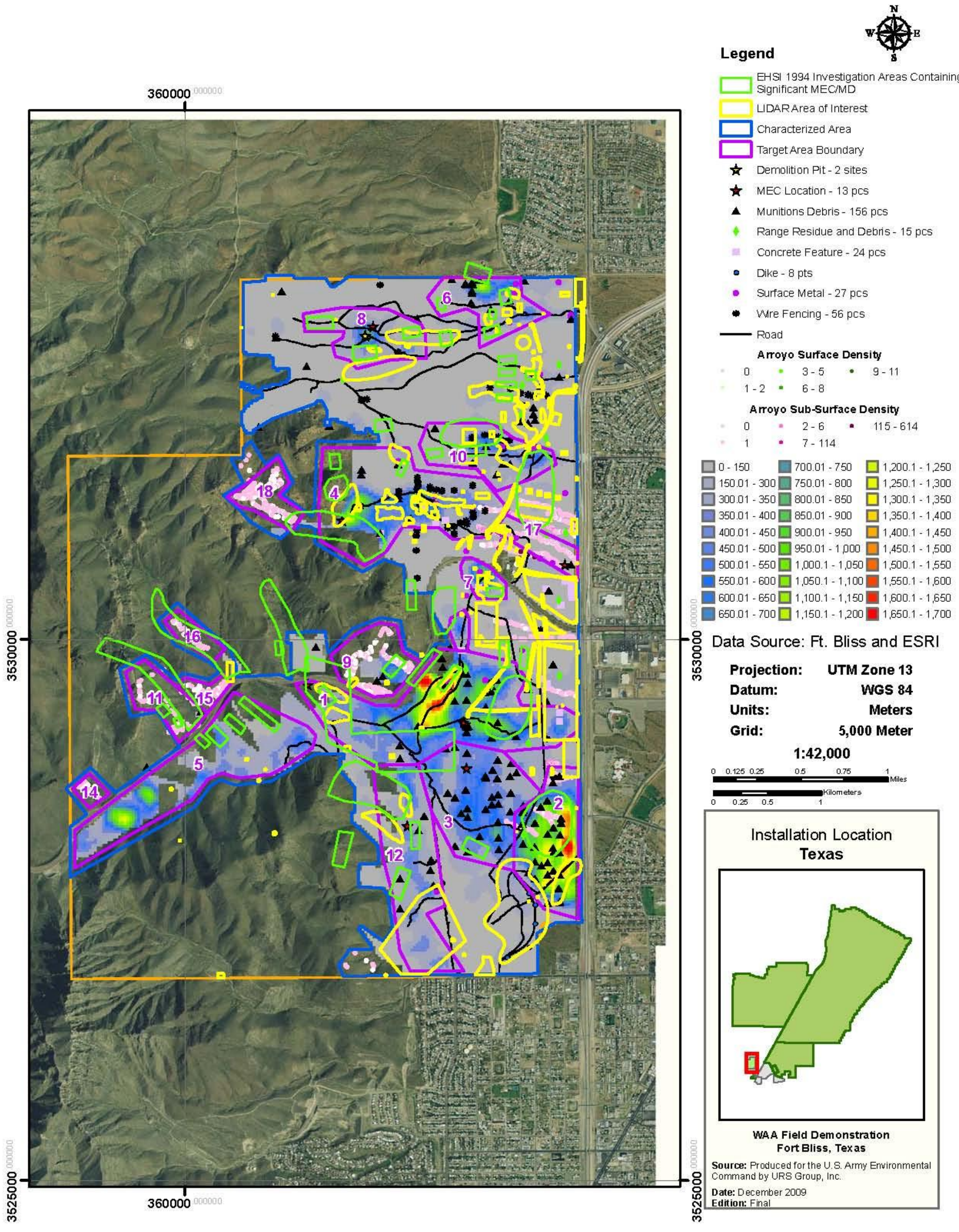


Figure 3-39. Preliminary Target Area Delineation

Table 3-9. Summary of Preliminary Target Area Delineation

Preliminary Target Area	Acreage	Mean Anomalies per acre	Score from Table 3-8
Non-Target	2,084	106	NA
1	378	590	37
2	161.4	837	32
3	209.2	410	35
4	303	352	49
5	268.5	382	24
6	96.9	284	37
7	26.2	482	21
8	106.4	223	39
9	88.9	396	42
10	120.2	234	32
11	63.2	NA	21
12	218	247	27
13	13.4	316	16
14	13.6	NA	11
15	21.6	NA	18
16	26.1	NA	11
17	44.7	80	14
18	51.1	NA	11
Total Characterized Acres	4,294.5		

Verification of an area as a non-target area might result, within the context of an RI and subsequent removal actions, in a recommendation of a less aggressive response (e.g., institutional controls and monitoring) than that recommended for target areas (e.g., additional DGM and some degree of removal). The objective of the intrusive investigation for non-target areas, therefore, was to provide sufficient data to test the hypotheses that MEC densities were no greater than a threshold that would indicate minimal risk and warrant a less aggressive risk management response. The MEC density threshold selected for the Closed Castner Range MRS was 0.5 MEC item per acre at a 90% confidence level. To confirm this hypothesis, a sufficient area needed to be surveyed, the anomalies investigated, characterized, and fully "resolved," and the source and nature of each anomaly confirmed.

3.4.1 Equipment and Methods

The original positions of individual anomalies were reacquired using the Trimble GeoXH. The handheld GeoXH (see Figure 3-40) is accurate to approximately 30 cm and was also used as a PDA for data capture of dig team observations. The handheld Minelab Explorer II EMI unit (see Figure 3-41) was used to relocate anomalies, along with Schonstedt magnetometers, where applicable.

In typical MMRP removal projects the same type of instrument is used in the DGM effort to reacquire dig targets, but this requirement was waived in favor of the GeoXH and Minelab II instruments, instead of the RTK GPS and EM61. The data quality objectives were satisfied and the target anomalies were located and investigated with the alternative instrument set. The equipment was lighter, more portable and more efficient, and a greater number of anomalies were investigated than would have been possible with the original instrument set. The use of the alternative instruments was validated by thorough QC procedures, including a final EM61 check of 10% of the excavated anomalies.

Figure 3-40. Trimble GeoXH Handheld GPS

Figure 3-41. Minelab Explorer II EMI

The anomaly reacquisition team flagged the reacquired position of each anomaly selected from the original DGM data, then used the handheld Minelab Explorer II to pinpoint the actual location of the anomaly. This actual anomaly location was then marked with a different color flag with a unique identification number recorded in indelible ink, and the location recorded in the GeoXH. The intrusive investigation process varied slightly between the preliminary target areas and non-target areas.

In preliminary target areas, the dig teams used the Minelab Explorer II to locate and mark the anomaly—surface or subsurface—closest to the flagged anomaly location. Using non-sparking hand tools, the team excavated the anomaly closest to the flagged location. The team then used the Minelab Explorer II to investigate a 1 m radius around the dig location for additional surface or subsurface anomalies, which were then excavated. Because the number of anomalies in some locations might be high due to a large quantity of fragments or debris, “stop dig” criteria were implemented. The dig team stopped digging when they had excavated metallic objects within a 1 m radius of target anomaly location consistent with the reported mV response value for the target anomaly and there were no additional Minelab Explorer II responses at the excavation site. Alternatively, the dig team stopped digging when they had excavated metallic objects within a 1 m radius of the target anomaly location consistent with the reported mV response value for the target anomaly and they had excavated three metallic objects of similar type (e.g., three pieces of munitions fragments, construction material, fencing, etc.). This latter “stop dig” criteria prevented dig teams from having to completely excavate trash pits or nail pits once the anomaly had been sufficiently characterized. Following excavation, 10% of the anomaly locations were investigated with an EM61 to verify removal of the anomaly.

In non-target areas, the dig teams used the Minelab Explorer II to locate and mark all surface and subsurface anomalies within a 1 m radius of the marked target anomaly location, which were then excavated using non-sparking hand tools. Because the number of anomalies in some locations might be high due to a large quantity of debris, “stop dig” criteria were also implemented in the non-target area. The dig team stopped digging when they had excavated metallic objects within a 1 m radius of the target anomaly location consistent with the reported mV response value for the target anomaly; and there were no additional Minelab Explorer II responses within 1 m radius of the target anomaly. Alternatively, the dig team stopped digging when they had excavated metallic objects within a 1 m radius of the target anomaly location consistent with the reported mV response value for the target anomaly and they had excavated three metallic objects of non-munitions-related debris (e.g., nails, soda cans, construction material, etc.). When employing this criterion, the UXO QC Specialist independently verified that the source of the anomaly was properly characterized as non-munitions-related debris.

The intrusive teams identified and documented the following information about the excavated and surface metallic objects:

- Distance and direction of the object from the marked target anomaly location;
- Classification of object (MEC, DMM, MD, RRD, NMD, “hot rock,” or false positive);
- Nomenclature (e.g., 37mm TP projectile, horseshoe, heavy fragment, etc.);
- Size (length, depth, and width);
- Depth below ground surface;
- Orientation (e.g., horizontal east-west, pointing down to north, vertical, etc.);
- Photograph (digital format with white board listing anomaly ID); and
- Comments, including information regarding whether the anomaly target location was completely resolved or if it was characterized and some degree of electromagnetic signature remains (e.g., due to a fragment pit, trash pit, hot rocks, or small metallic pieces in spoils).

Approximately 2,950 anomalies were intrusively investigated to test target/non-target area hypotheses and characterize the nature of anomalies within the proposed target areas.

In accordance with the work plan (URS 2010b) and the Explosive Safety Plan (URS 2010a), URS performed demolition operations on MEC items found on the site and performed explosive venting of material potentially presenting an explosive hazard to support visual inspection of all cavities and surfaces. Commercial perforator charges (36 g), electric detonators, and detonation cord were used to perform detonations. Remaining investigation-related debris items were disposed of in accordance with the work plan.

3.4.2 Anomalies Investigated

The selection of the number and locations of anomalies to be investigated was determined based on whether the area was a selected preliminary target area or in the non-target acreage.

In the preliminary target areas, the total population of anomalies in each target area was estimated based on average anomaly densities inferred from the man-portable DGM data. A sufficient number of anomalies within each preliminary target area were selected to enable the statistical estimation of the proportion of MEC and MD related anomalies vs. non-munitions-related anomalies with a 90% confidence level (see Appendix F). The calculated sample sizes for each of the 18 preliminary target areas and the actual number of anomalies excavated are shown in Table 3-10. Once the number of anomalies to be investigated within each preliminary target area was established, the dig list was randomly selected from the total number of anomalies identified during man-portable DGM in each target area. Figure 3-42 is a map of the anomalies investigated in each preliminary target area.

Table 3-10. Number of Anomalies Planned for Reacquisition and Investigation

Preliminary Target or Non-target Area	Number of Anomaly Investigations Planned	Number of Anomaly Investigations Completed
Non-target Area, Lot 1	95 estimated[a]	142
Non-target Area, Lot 2	95 estimated[a]	190
Non-target Area, Lot 3	95 estimated[a]	122
Non-target Area, Lot 4	95 estimated[a]	119
Target Area 1	80 randomly selected anomalies	111
Target Area 2	80 randomly selected anomalies	118
Target Area 3	125 randomly selected anomalies	158
Target Area 4	125 randomly selected anomalies	245
Target Area 5	125 randomly selected anomalies	120
Target Area 6	155 randomly selected anomalies	284
Target Area 7	125 randomly selected anomalies	23 [b]
Target Area 8	155 randomly selected anomalies	173
Target Area 9	125 randomly selected anomalies	151
Target Area 10	155 randomly selected anomalies	238
Target Area 11	175 randomly selected anomalies	78[c]
Target Area 12	155 randomly selected anomalies	177
Target Area 13	155 randomly selected anomalies	115[b]
Target Area 14	175 randomly selected anomalies	15[c]
Target Area 15	175 randomly selected anomalies	40[c]
Target Area 16	155 randomly selected anomalies	44[c]
Target Area 17	175 randomly selected anomalies	136[b]
Target Area 18	125 randomly selected anomalies	144

[a] Actual number depends on actual number of anomalies contained in 668 100-ft sections of transects, randomly selected in the non-target area.
[b] This is the maximum number of anomalies that could be investigated in the area, due to the proximity of the public road, relative to the potential hazard fragment distance.
[c] This represents the total number of anomalies detected in the area. 100% were investigated.

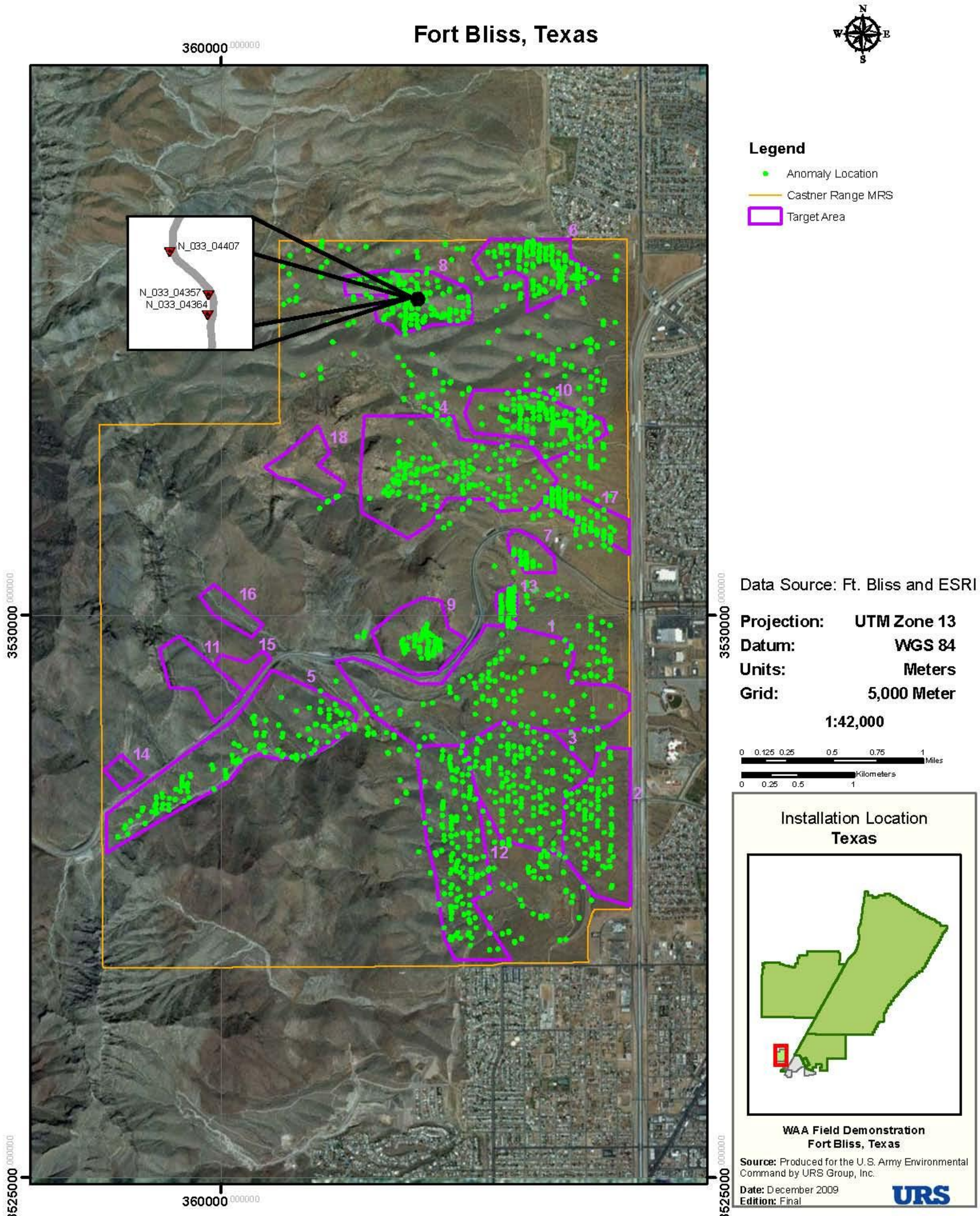


Figure 3-42. Anomalies Planned for Intrusive Investigation

In non-target areas, UXO Estimator, version 2.2, a USACE-developed software tool designed to help determine a field sampling plan for ordnance sites and analyze field data after it has been collected was used. UXO Estimator helped to identify the total acreage requiring investigation to support a statistically valid test of the hypothesis that there were less than 0.5 MEC item per acre within the non-target area (those areas outside discrete target areas) using a 90% confidence level. Figure 3-43 is a computer screen shot of the UXO Estimator output for this sampling area calculation. To test the hypothesis for the non-target area of 2,084 acres, 4.596 acres must be investigated and found to contain no MEC items to support the conclusion that there is less than or equal to 0.5 MEC item per acre with 90% confidence level.

The DGM data were collected in 1 m wide transects; therefore, excavation and investigation of all anomalies along 66,729 linear feet of transects was necessary to satisfy the required acreage to support the hypothesis test. Using the COG file, the DGM transects were divided into 100-ft lengths, and 668 lengths were randomly selected using the ArcGIS randomization function (see Figure 3-44). The anomalies identified in this 66,800-ft transect length totaled 573 items (see Figure 3-45). All anomalies were investigated to test the non-target area hypothesis.

In preliminary target areas established to address stakeholder concerns associated with the unofficial hiking trails in higher elevations of the site, there were no DGM data upon which to base intrusive investigation sampling strategies. These preliminary target areas included 11, 14, 15, 16, and 18. In these preliminary target areas, the dig teams used the Trimble GeoXH and the handheld Minelab II EMI instruments to retrace the original path of the analog range reconnaissance and locate the anomalies along the path. To ensure spatial distribution of the anomalies investigated in each of these preliminary target areas, the entire length of the path in each target area was broken into 10 equal segments and dig teams were instructed to distribute the required number (sample size) of anomalies equally across the 10 segments. However, in all but one preliminary target area, the total number of anomalies identified was less than the required sample size. In these cases, the dig teams investigated all the anomalies they were able to locate.

3.4.3 Data Analysis

Examples of items found during the intrusive investigation are shown in Figure 3-46. The intrusive investigation teams used their military experience and judgment to identify each item discovered, and the Senior UXO Supervisor verified every description. For QC purposes, the non-target acreage was divided into four distinct “lots.”

A three-phased QC process was used to validate the data in every preliminary target area and non-target lot. During the investigation, the Senior UXO Supervisor ensured compliance with procedures, and the Project Geophysicist reviewed the data for consistency with the original DGM response and locational data. The UXO QC Specialist also selected a random sample of anomalies and conducted acceptance inspections consisting of reacquisition of location, re-mapping of location with an EM61-MK2, and evaluation of the reduction of the mV response due to the excavation and removal. All the preliminary target areas and the four non-target area lots passed acceptance testing.

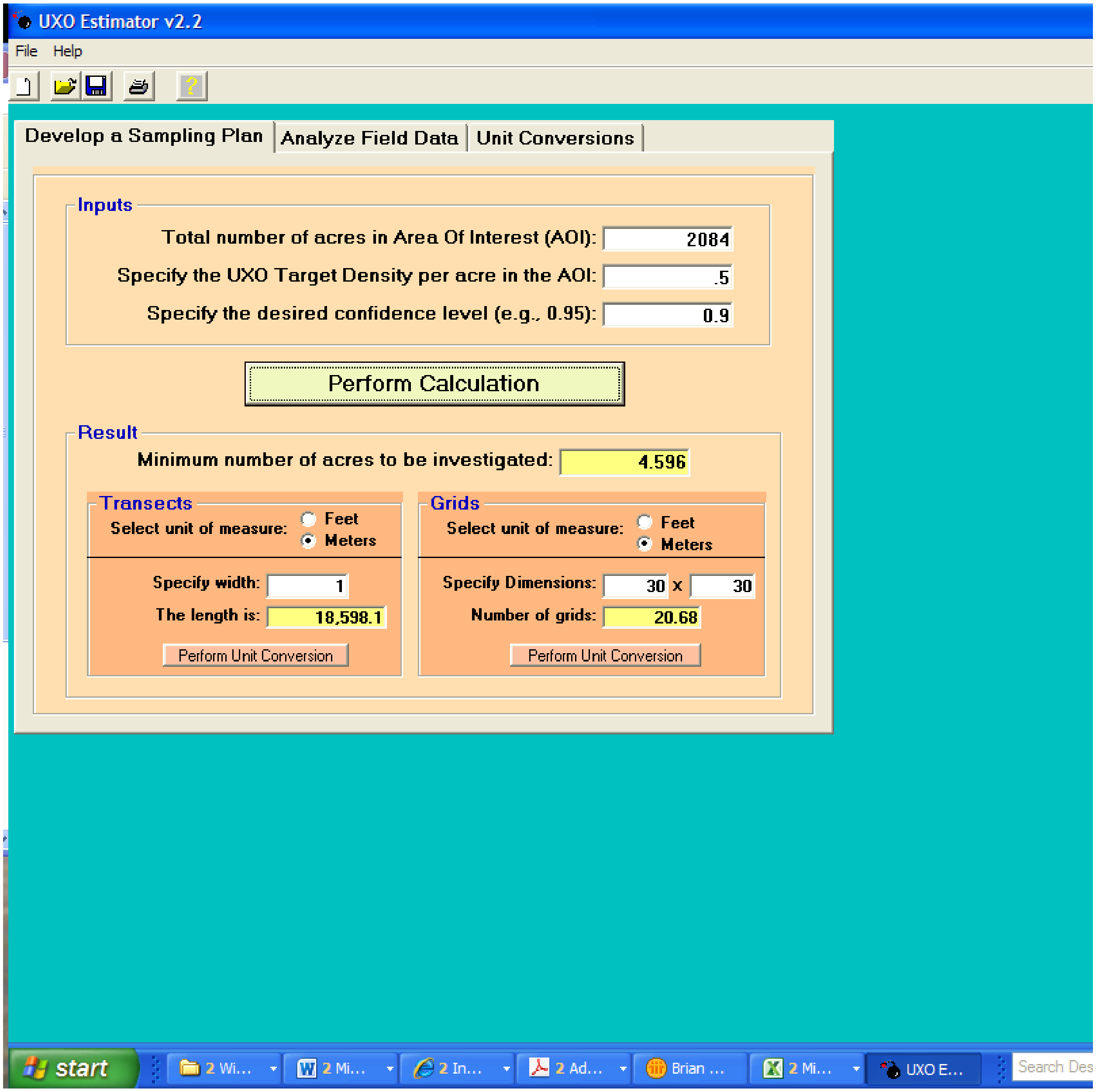


Figure 3-43. Computer Screen Shot From UXO Estimator

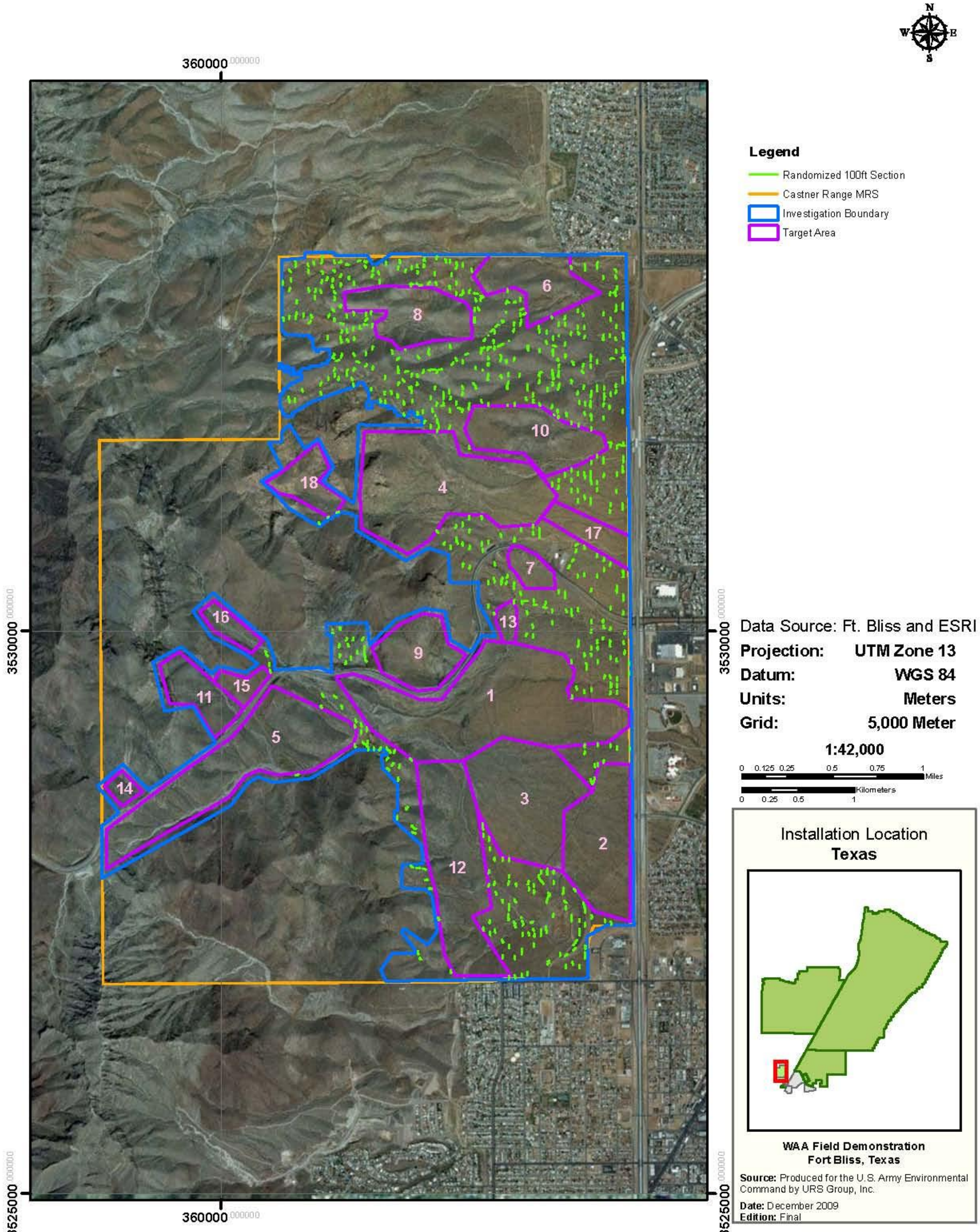


Figure 3-44. 668 Random, 100-ft Sections of Non-Target Area Transects

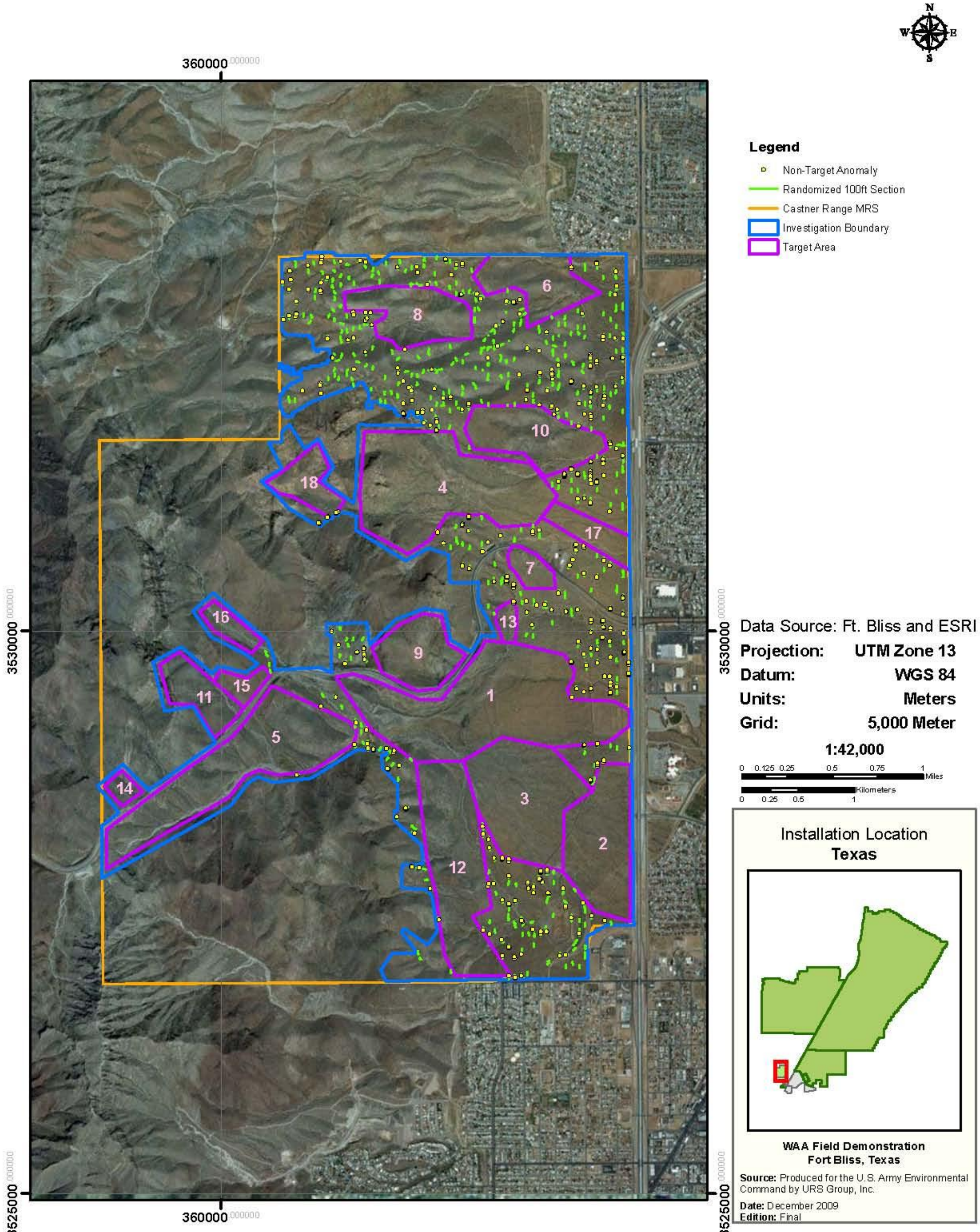


Figure 3-45. 573 Anomalies Investigated in the 668 Random Sections of Non-Target Area Transects

Figure 3-46. Examples of Items Found During the Intrusive Investigation

During the intrusive investigation of anomalies at preliminary target area 5, an unusually high percentage of anomalies with no metallic source were identified. DGM data from the target area were reviewed but did not display excessive noise when compared to the rest of the site. The data from the targeted anomalies exhibited characteristics indicating a common, specific, and repeated cause for the mV responses. A URS geophysical team performed additional investigation to determine the cause. The team focused on a parcel about 70 m x 50 m in one of the few reasonably flat and level areas, and used both cart-mounted and litter mounted EM61-MK2 systems to more carefully examine the area. The cart-mounted unit identified anomalies in completely different locations than the litter-mounted unit (see Figure 3-47). The litter-mounted unit identified anomalies from local topographic highs—the 1–2 ft high ridges resulting from previous flooding—when the distance from the coil to the soil was reduced. The cart-mounted unit identified anomalies on the edges of the topographic highs as the coil dipped close to the soil going over the ridges. It was concluded that the local topography, combined with the interfering geology, contributed to the misidentification of hot rocks as anomalies. In light of these findings, it is recommended that future DGM work in this preliminary target area be specially designed to take into account the geology and to maintain a constant coil height to minimize false positive readings. Full details of the data analysis and supporting field work are contained in Appendix G.

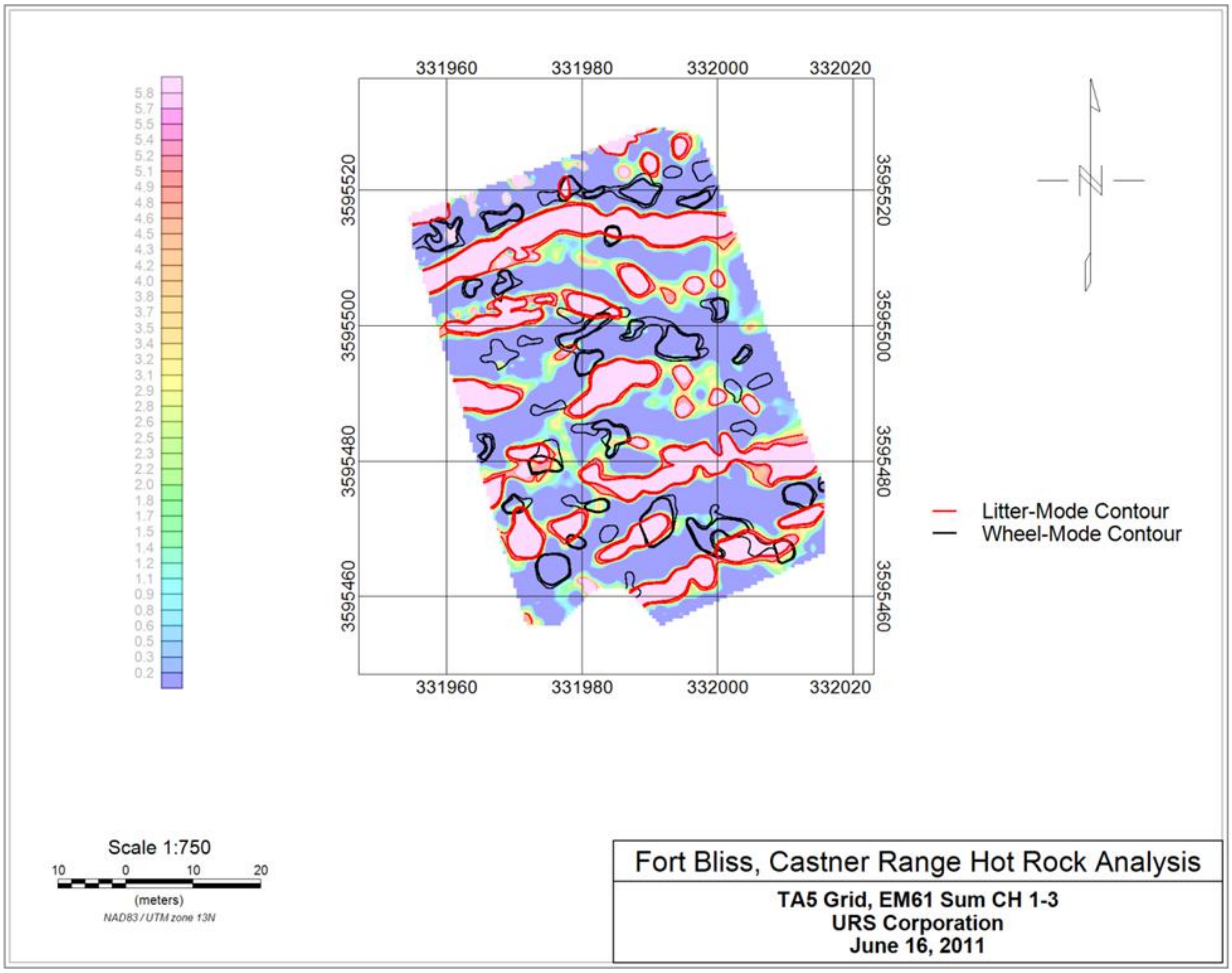


Figure 3-47. Comparison of Cart-Mounted and Litter-Mounted Anomaly Results

3.4.4 Characterization Results

The characterized anomaly locations on the Closed Castner Range MRS are depicted in Figures 3-48 and 3-49 for preliminary target areas and non-target areas, respectively. Table 3-11 summarizes the results of the intrusive investigation by preliminary target area and non-target area lot, excluding the preliminary target areas (11, 14, 15, 16, 18) created to accommodate the unofficial hiking paths. Table 3-12 summarizes the result of areas 11, 14, 15, 16, and 18, which are not comparable to the other preliminary target areas because they were assessed only with analog reconnaissance techniques, and not the more statistically rigorous DGM approach. Preliminary target areas 11, 14, 15, 16, and 18 (see Table 3-12) were created in response to concerns expressed by stakeholders about the lack of DGM possible along the unofficial hiking trails in higher elevation/high gradient areas. These preliminary target areas were characterized using analog range reconnaissance employing handheld equipment and single transects through difficult terrain or arroyos. These areas cannot be strictly treated in the same way as target areas characterized by transect-based DGM data. The data in the analog preliminary target areas are not representative of acreage outside the single transects, although high percentages of munitions-related instrument hits may still be indicative of areas deserving additional investigation in the future.

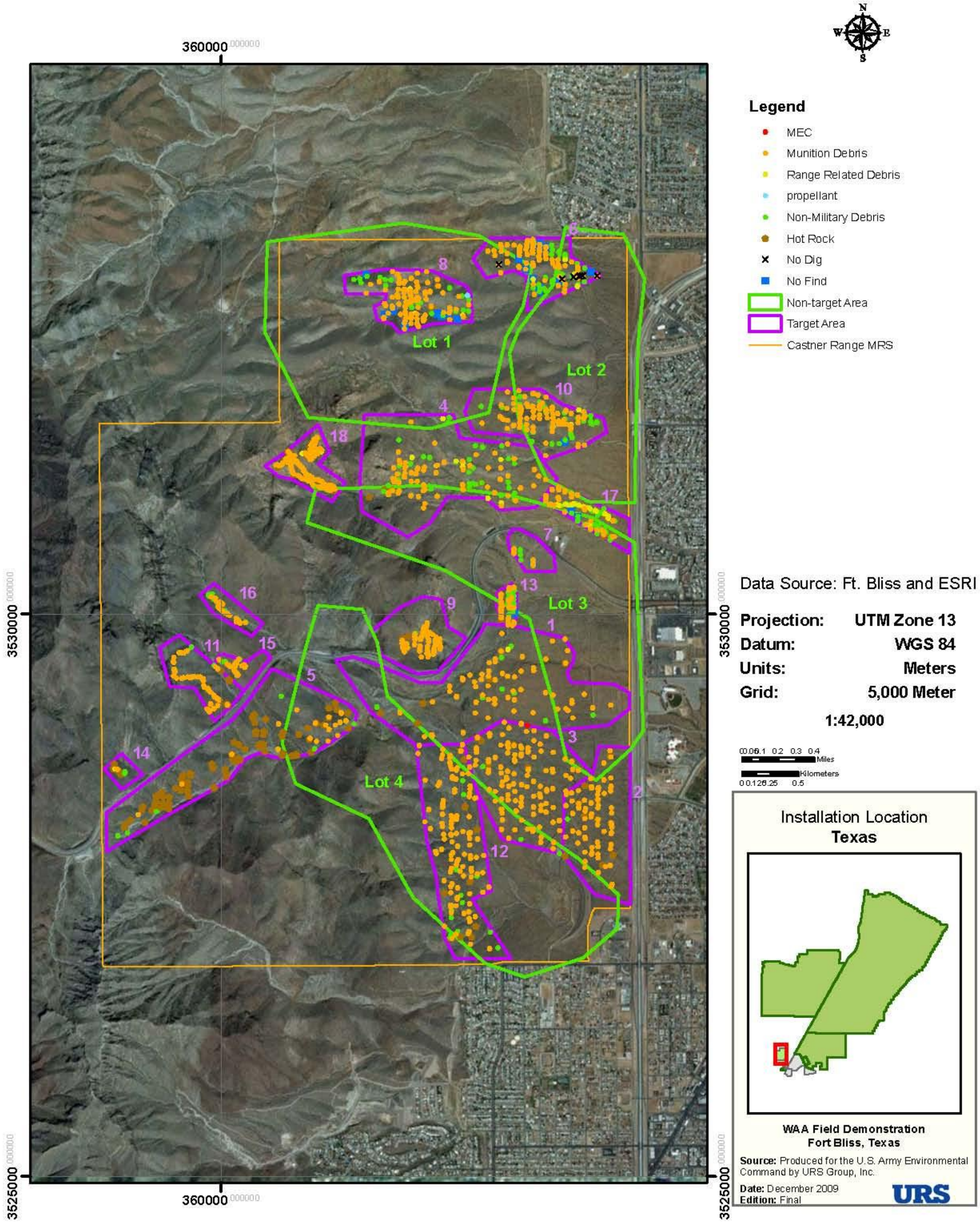


Figure 3-48. Classification of Excavated Anomalies—Preliminary Target Areas

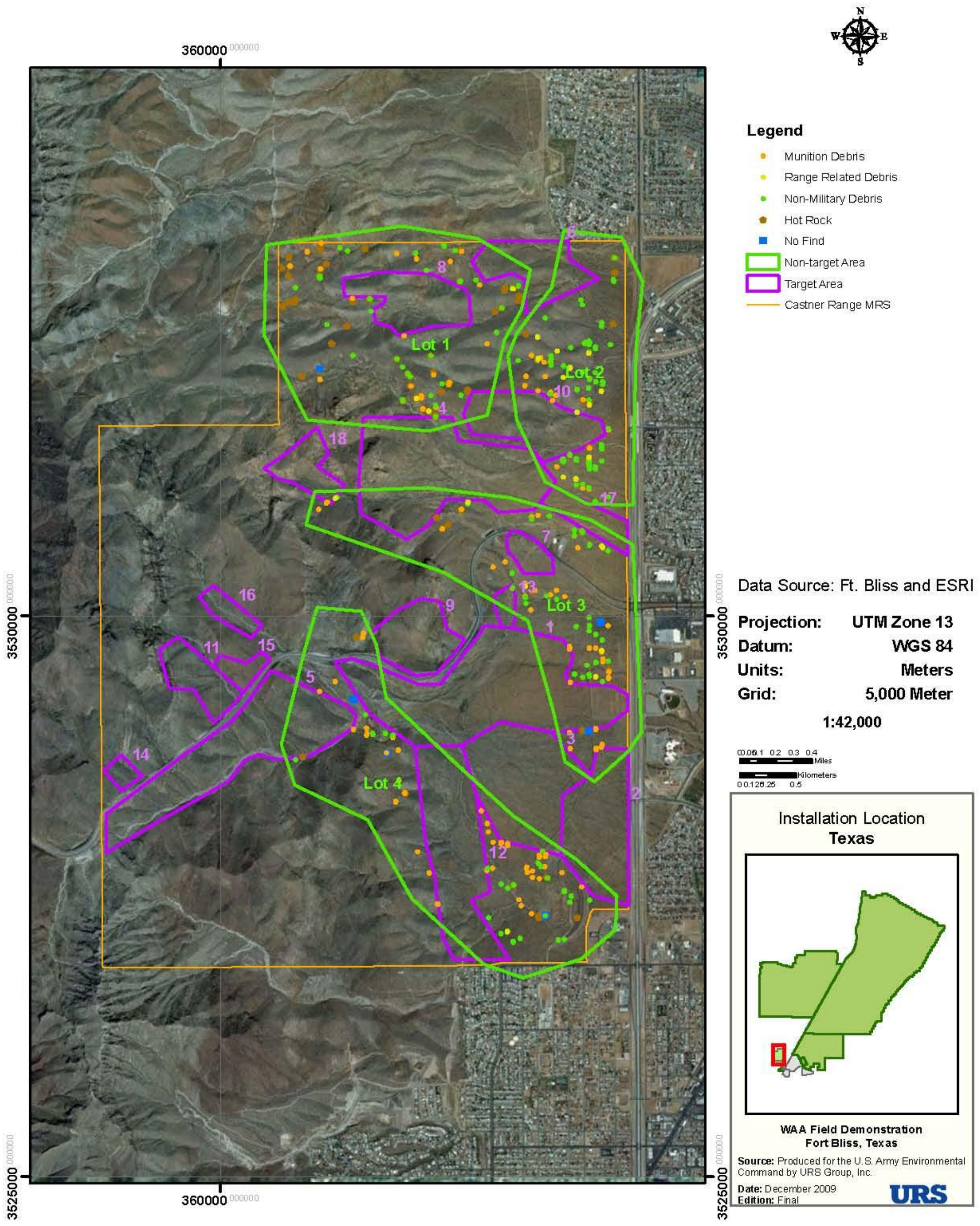


Figure 3-49. Classification of Excavated Anomalies—Non-Target Areas

Table 3-11. Intrusive Investigation Summary: Anomaly Classification by Location

(blue) =	0–87 anomalies per acre attributable to munitions (MEC or MD)
(green) =	87–300 anomalies per acre attributable to munitions (MEC or MD)
(yellow) =	300+ anomalies per acre attributable to munitions (MEC or MD)

	Number of Anomalies Investigated	MEC	MD	RRD	NMD	Hot Rock	No Find	No Dig	Seed	Percentage of Munitions-Related Anomalies	Acres	Anomaly Density (per acre)	Munitions-Related Anomaly Density (per acre)	Primary MD Descriptions
Lot 1	142	0	34	3	43	61	1	0	0	24%	567	64	15	small arms bullets, few frag
Lot 2	190	0	46	16	117	11	0	0	0	24%	394	105	25	small arms bullets, some frag, and 2 projos
Lot 3	122	0	58	8	42	10	4	0	0	48%	518	146	70	small arms bullets, some frag
Lot 4	119	0	72	1	35	8	3	0	0	61%	606	142	87	small arms, frag, and 2 projos
1	111	0	85	2	18	6	0	0	0	77%	378	590	454	frag, fuze components, and small arms bullets
2	118	0	106	0	2	10	0	0	0	90%	161	837	753	frag and small arms bullets
3	158	1	146	0	6	5	0	0	0	93%	209	410	369	small arms bullets, frag, and a few projos
4	245	0	122	19	96	7	0	0	1	50%	303	352	176	small arms bullets and little frag
5	120	0	21	0	10	89	0	0	0	18%	269	382	69	small arms bullets and little frag
6	284	0	160	9	92	1	13	7	0	57%	97	284	162	frag
7	23	0	10	0	11	1	1	0	0	43%	26	482	207	small arms bullets
8	173	0	115	5	36	4	12	0	0	67%	106	223	149	frag and fuze components
9	151	0	146	0	2	3	0	0	0	97%	89	396	384	frag, some small arms, and few projos
10	238	0	120	22	95	0	1	0	0	50%	120	234	117	frag, some small arms, and fuze components
12	177	0	142	0	24	11	0	0	0	80%	218	247	198	frag, small arms, some fuze components, and projos
13	115	0	41	2	64	7	1	0	0	36%	13	316	114	small arms and little frag
17	136	0	42	24	57	11	2	0	0	31%	45	80	25	grenade frag, spoons/pins, and small arms bullets
	2622													

Table 3-12. Intrusive Investigation Summary: Potential Target Areas Characterized Only by Analog Reconnaissance

	Number of Instrument Hits Investigated	MD	MEC	RRD	NMD	Hot Rock	No Find	No Dig	Seed	Percentage of Munitions-Related Anomalies	Primary MD Descriptions
11	78	63	0	0	6	9	0	0	0	81%	small arms and frag
14	15	2	0	1	2	10	0	0	0	13%	one AP projo
15	40	31	0	0	9	0	0	0	0	78%	small arms, little frag, 2 projos
16	44	26	0	0	15	3	0	0	0	59%	small arms some frag
18	144	109	0	9	3	23	0	0	0	76%	frag, small arms bullets, few projos
	321										

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For all four of the non-target area lots, the results of the intrusive investigation support the hypothesis that the density of MEC items is lower than 0.5 MEC item/acre. However, Table 3-11 shows that lots 3 and 4 (the non-target areas in the southern half of the site) of the non-target area contain a higher proportion of munitions-related anomalies than in lots 1 and 2 (the non-target areas in the northern half of the site). This is consistent with the presence of many historical small arms ranges and historical evidence of overall greater range usage in the southern half of the site. Even though the percentages of munitions-related anomalies in lots 3 and 4 are relatively high (48% and 61%, respectively), the densities of munitions-related anomalies per acre in these areas are still quite low (70 per acre and 87 per acre, respectively) when compared to the densities of most of the preliminary target areas.

Table 3-11 provides some insight as to the nature of each of the preliminary target areas. As noted previously, the preliminary target areas were delineated after examination of multiple data sources, including historical range use data, previous removal action reports, and data collected in this project.

Table 3-11 shows that, of the four non-target areas, lot 4 has the highest mean munitions-related anomaly density (87 anomalies/acre). Because the results of the intrusive investigation support the hypothesis that the density of MEC items is lower than 0.5 MEC item per acre for all four lots, it is reasonable to conclude that preliminary target areas (and the four non-target areas) that have a munitions-related density lower than 87 anomalies/acre are candidates for classification as non-target areas, with little evidence of concentrated munitions use. The preliminary target areas that meet this criterion include 5 and 17.

A number of preliminary target areas have mean munitions-related anomalies exceeding 300 anomalies per acre. The data indicate with high confidence that these are likely target areas with evidence of concentrated munitions use. The preliminary targets that meet this criterion include 1, 2, 3, and 9.

The remaining preliminary target areas have mean munitions-related anomaly densities ranging from 87 to 300 anomalies per acre, including 4, 6, 7, 8, 10, 12, and 13. This suggests there was likely some concentrated munitions use in these areas. Because these are average anomaly densities, additional consideration might be appropriate to determine whether portions of the areas can be more confidently determined to be target or non-target areas.

As noted, preliminary target areas 11, 14, 15, 16, and 18 (see Table 3-12) are not directly comparable to the other designated areas in terms of anomaly density since they were characterized with analog range reconnaissance methods, which did not yield a reliable anomaly density based on the methodology used at the Closed Castner Range MRS. Based on intrusive investigation results, however, only area 18 had both a large number of instrument hits and a high fraction (76%) of hits related to munitions. The other four areas had fewer hits; all hits in each of the other four areas were excavated and investigated during the intrusive investigation.

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4. CONCLUSIONS

For each technology studied in this project, conclusions are drawn with respect to the study questions. Where additional lessons were learned regarding implementation of any of the study technologies, they are discussed following the conclusions.

4.1 Lidar and Orthophotography

4.1.1 Conclusions

To what degree does lidar/orthophotography detect surface features indicative of munitions-related activities?

Craters/crater fields: Lidar/orthophotography technologies delineate crater fields and individual craters to a resolution of about 1 m diameter. By themselves, lidar and orthophotography technologies cannot always identify the origin or usage of these features, and human reconnaissance may be required to confirm whether it is related to munitions activities.

Target features: No specific target shapes were identified on the Closed Castner Range MRS, but, as evidenced by the clear images of linear features, such as the firing lines of the former KD range, it is clear that any surface disturbance required to establish a target would be visible with lidar technology.

Berms: Berms and trenches are visible with lidar technology, and contribute importantly to the understanding of human activities on the range. Orthophotographs showed tire tracks on some of the berms. Man-made trenches are also clear in the lidar data, and although orthophotography can answer the purpose of some of them, human reconnaissance is frequently required.

Demolition pits: Circular depressions over 1 m in diameter were visible, and explosive ordnance disposal nearly always creates pits larger than 1 m. Project staff familiar with military disposal operations were frequently able to identify disposal areas by their visible characteristics, such as grouping and spacing, and related roads, but human reconnaissance is required to confirm the use as disposal.

Burial pits: No burial pits were specifically identified in the data, but the mechanical earth-moving required to create, use, and refill burial pits and trenches is typically visible in lidar data. Associated vegetation disturbance would also likely be visible in the high-resolution orthophotographs.

Do lidar/orthophotography images provide sufficient evidence to:

Reliably identify areas of concentrated munitions use?
Lidar and orthophotography can reliably identify some areas of concentrated munitions use. Certain features detected in lidar data and orthophotographs (e.g., outlines of small

arms ranges, demolition pits) provide high confidence that the area was the location of concentrated munitions use. However, for many features (e.g., berms, trenches, holes) lidar and orthophotography do not contain sufficient information to confirm them as areas of concentrated munitions use. When used in conjunction with historical records, features visible with lidar and orthophotography are used to add insight, but lidar and orthophotography cannot determine the origins of many features recognized.

Reliably identify areas with no indication of munitions use?
Because many munitions, including items used on the Closed Castner Range MRS, do not leave features, such as craters, large enough to be identified with lidar and orthophotography, the lack of features of interest in the data set is not reliable evidence that there was no munitions use in the area. Other indications of munitions use, such as targets, firing positions, support roads, etc., may also not be present if the targeting was random, as was sometimes the practice at this range.

Improve the understanding of relative densities and distributions of MEC across the MRS?
Lidar and orthophotography were used as one data layer in the identification and delineation of target and non-target areas. They do not directly identify MEC, but the surface features potentially resulting from its use. Lidar data were used to plan and execute other investigative methods, which did directly measure MEC. These two technologies were the only investigation method capable of collecting data about the western, mountainous portion of the range.

How confident are stakeholders in these conclusions?

Stakeholders were presented with the data and agreed that the features identified were highly suggestive of human use, which given the history of the range likely means military use. Stakeholders agreed that these data were not sufficient to confirm MEC presence or absence.

To what degree do lidar/orthophotography data make subsequent characterization steps (e.g., helicopter-borne magnetometry) more efficient and cost effective?

Lidar data have proven to be very useful in subsequent planning and execution of site characterization methods. The topographical mapping is used to identify areas that are accessible by helicopter-borne sensors, magnetometers in this project. Helicopter-borne magnetometry requires average slopes of about 5% or less. Similarly, lidar data are used in planning man-portable DGM, which requires a slope of about 18% or less.

The bare earth image produced by lidar, along with high resolution orthophotography, may be used to identify features requiring additional reconnaissance or investigation by any technology, including airborne or ground-based DGM, and analog reconnaissance. In this project, lidar/orthophotography data were used to adjust the boundaries of the areas of interest, adding approximately 10% to the acreage of proposed target areas.

What are the total cost, cost per surveyed acre, and cost per characterized acre associated with lidar/orthophotography?

Because lidar and orthophotography results in data collection over 100% of the characterized area (i.e., no transects or sampling a subset of the area), the characterized acreage equals the surveyed acreage. Total surveyed/characterized acreage was approximately 7,007 acres.

Lidar and orthophotography vendor costs included data acquisition and production of lidar point locations, orthophotographs, index files, and vendor's after action and QA/QC report.

Task	Cost
Mobilization/demobilization	$11,029
Data Acquisition	$15,223
Data Processing	$21,013
Total vendor data collection costs	$47,265
Vendor cost per surveyed/characterized acre	$6.75

Data analysis costs included surface model creation, initial identification of features of interest, and field maps. Data analysis costs do not include final reports, peer review, public involvement, or the subsequent use of lidar and orthophotographs in remediation planning.

Task	Cost
Data Analysis	$35,000
Vendor Data Collection	$47,265
Total data collection and analysis cost	$82,265
Total cost per surveyed/characterized acre	$11.74

4.1.2 Lessons Learned

Other lessons learned from the deployment of lidar and orthophotography:

- Lidar should be implemented as early in the project as practical because the data are helpful in planning subsequent assessment technologies.
- Many installation engineering and management functions are enhanced by lidar data, and installation entities other than environmental management may already have obtained a lidar dataset suitable for planning an MMRP investigation. It may not be necessary to collect new data.
- Because the incremental cost of higher density data is small, seek the highest density the site conditions will allow. A minimum of 5 points per m^2 is recommended.
- 100% coverage is highly effective and easily obtained.

4.2 Helicopter-Borne Magnetometry

4.2.1 Conclusions

Can helicopter-borne magnetometry reliably detect the munitions types expected on the MRS?

At typical survey altitudes, helicopter-borne magnetometry can reliably detect items larger than 60mm. Because of vegetation, the survey altitude at the Closed Castner Range MRS was at the high end of the acceptable range, resulting in lower signal strength and lower probability of detection. Munitions types expected on the MRS included 20mm, 37mm, 40mm, 57mm, 2.36-in. rockets, and a variety of flares, grenades, and other small items. These items were not reliably detected.

Can helicopter-borne magnetometry:

Reliably identify areas of concentrated munitions use?
Although under optimum conditions helicopter-borne magnetometry can detect areas with high amounts of ferrous metals, the combination of a high survey altitude and high noise from ferrous geology considerably reduced the reliability at the Closed Castner Range MRS.

Reliably identify areas with no indication of munitions use?
The detection of munitions smaller than 60mm is problematic for this technology, and a report of a non-detect would not rule out the presence of smaller munitions.

Improve the understanding of relative densities and distributions of MEC across the MRS?
Much of the survey area was masked by geologic noise and/or contained vegetation that necessitated survey altitudes greater than the effective altitude of the system. In these areas the data do not support any conclusions with respect to the density and distribution of ferrous material at the site.

How confident are stakeholders in these conclusions?

Stakeholders agreed that the data were not definitive under the conditions present at the Closed Castner Range MRS, but might be more appropriate under more conducive conditions.

To what degree does helicopter-borne magnetometry data make subsequent characterization steps (e.g., ground-based geophysics) more efficient and cost-effective?

For the Closed Castner Range MRS, the data were not used to refine or modify the planned collection of ground-based DGM; it was originally planned to have the man-portable DGM transects cover as much of the range as physically possible. In other applications, helicopter-borne magnetometry over 100% of accessible surface might be used to guide subsequent steps in the investigation.

Over what percentage of the MRS can helicopter-borne magnetometry data be collected?

The physical criterion for safe collection of helicopter-borne magnetometry is an average slope of 5%. At the Closed Castner Range MRS, this included approximately 1,742 acres, representing approximately 25% of the 7,007 total acres.

For what percentage of the MRS can statistically valid conclusions be drawn based on helicopter-borne magnetometry data?

None under the conditions found at the Closed Castner Range MRS.

What are the total cost, cost per characterized acre, and cost per surveyed acre associated with helicopter-borne magnetometry?

Task	**Cost**
Work Plan and Project Management	$13,119
Mobilization/Demobilization, Instrument Verification	$73,800
Data Collection	$90,374
Data Processing/Analysis	$29,054
DGM Report/Detailed Cost Report	$14,115
Total	$220,462
Cost per surveyed/characterized acre (1,742 acres)	$126.56

The surveyed and characterized acreage were the same.

4.2.2 Lessons Learned

Other lessons learned from helicopter-borne magnetometry:

- Although the helicopter-borne magnetometry on the Closed Castner Range MRS did not result in reliable data sets due to the height of vegetation and the ferrous geology, it should not be ruled out of other sites with differing site conditions. Because it can cover a large area quickly and completely (approximately 435 acres per day at the Closed Castner Range MRS), it should be considered at locations with conducive conditions.
- Vegetation height concerns might be addressed by using lidar data to produce a vegetation height and distribution map as one of the deliverables, in addition to the bare earth model. Vegetation concerns might also be addressed through a pre-deployment site visit by the data acquisition team and/or pilot.
- Magnetic geology concerns might be addressed through a pre-deployment site visit to collect small-scale magnetometry data and establishing background noise level. DGM surveys using both magnetometers and EMI equipment on a number of randomly placed plots would provide insight into underlying geology.
- Establishment of the IVS should consider both the background geology and the spacing of IVS seed items to provide the clearest verification of target acquisition and interpretation. It is recommended that the spacing of seed items on the IVS be increased from 5 m between seeds to 20 m.

4.3 Ground-Based Geophysics

4.3.1 Conclusions

Can man-portable EMI reliably detect the munitions types expected on the MRS?

From the results of the intrusive investigation, man-portable EMI located items as small as small arms bullets and located many 37mm projectiles and small fragments from HE detonations. Man-portable EMI can reliably detect the munitions items expected on the Closed Castner Range MRS to a depth of 11x the item diameter.

Can man-portable EMI:

Reliably identify areas of concentrated munitions use?
Yes. Man-portable DGM data, combined with intrusive investigation results, were the primary source of information defining the areas of concentrated munitions use. The man-portable EMI identified anomalies of interest, and the intrusive investigation identified the source as munitions related or non-munitions related. Although the data were transect-based, the underlying statistics enabled extrapolation to the mapped area.

Reliably identify areas with no indication of munitions use?
Yes. Man-portable DGM data, combined with intrusive investigation results, were the primary source of information defining the areas of concentrated munitions use. The man-portable EMI identified anomalies of interest, and the intrusive investigation identified the source as munitions related. The statistical tool UXO Estimator was used to select a sufficient number of anomalies to produce a 90% confidence level that the MEC density was less than 0.5 MEC item per acre, the threshold for defining a non-target area. Although the data were transect-based, the underlying statistics enabled extrapolation to the mapped area.

Improve the understanding of relative densities and distributions of MEC across the MRS?
Yes. The anomaly detections from the man-portable EMI were all spatially located. When the DGM data were combined with a statistically sufficient number of intrusive investigations in each area, there was a 90% confidence that the intrusive results were representative of all anomalies across the mapped area. Although the data were transect-based, the underlying statistics enabled extrapolation to the mapped area. Because the anomalies were not evenly distributed, it was possible to produce data density maps from these data. These maps correlated to historical data and visual observations of surface debris.

How confident are stakeholders in these conclusions, particularly based on the transect survey approach?

The stakeholders were briefed on the methods and results of the man-portable EMI investigation and expressed a high degree of confidence in the data and conclusions.

Over what percentage of the MRS can man-portable EMI data be collected?

The physical criterion for safe collection of man-portable EMI data is an average slope of 18% or less. At the Closed Castner Range MRS, this included approximately 4,020 acres, representing approximately 57.4% of the 7,007 total acres. Of this acreage, 3,521 acres were actually surveyed; the remaining acreage was either inaccessible or made up of isolated areas meeting the 18% criterion. Because this approach was based on 1-m transects, spaced 57 m apart, the actual number of acres surveyed was about 1%.

For what percentage of the MRS can statistically valid conclusions be drawn based on man-portable EMI data?

The careful planning and application of statistical techniques allowed the extrapolation of the transect survey results to the entire characterized area, or 57.4% of the total MRS acreage.

What are the total cost, cost per characterized acre, and cost per surveyed acre associated with man-portable EMI?

SKY Research Cost Analysis

Task	Cost
Work Plan and Project Management	$5,323
Mobilization/Demobilization, Instrument Verification	$23,071
Data Collection	$130,887
Data Processing/Analysis	$9,320
DGM Report/Detailed Cost Accounting	$394
Total	$168,995
Cost per surveyed acre (40.9 acres)	$4,132
Cost per characterized acre (1,989 acres)	$84.96

NAEVA Geophysics Cost Analysis

Task	Cost
Work Plan and Project Management	$3,015
Mobilization/Demobilization, Instrument Verification	$33,093
Data Collection	$99,290
Data Processing/Analysis	$40,375
DGM Report/Detailed Cost Accounting	$5,592
Total	$187,366
Cost per surveyed acre (42.5 acres)	$4,409
Cost per characterized acre (1,906 acres)	$98.30

The average cost per surveyed acre is $4,273. The average cost per characterized acre is $91.49. This cost per acre is specific to the Closed Castner Range MRS because it is dependent on the transect spacing.

4.3.2 Lessons Learned

Other lessons learned from man-portable EMI include:

- Each contractor fielded two survey teams. SKY Research estimated an average production rate of 4.7 miles per team per day. NAEVA Geophysics estimated an average production rate of 3.8 miles per team per day. The average production rate for both contractors was approximately 4.2 miles per day. Note that the acreage associated with the transect length is dependent on the calculation of transect spacing by VSP and will vary from site to site.
- Although the assumed transect width for the man-portable EMI was 1 m, additional study may determine that a wider transect width may be used. While the 1 m assumption is conservative, a wider transect would enable more precise calculation of statistics.
- When screening EM61 data to identify anomalies, it may be appropriate to use not only a minimum mV threshold, but also a maximum threshold or other time decay parameter to filter out non-munitions signals that are not of interest to the subsequent investigation. This decision should be based on site-specific conditions and knowledge of the expected response of munitions items of interest.
- The work plan called for man-portable DGM transects to be marked and pre-cleared by UXO technicians for safe traversal by the DGM teams, which was completed. Additionally, UXO teams accompanied each DGM team during the actual collection of data. In a site like the Closed Castner Range MRS, where the ground surface is relatively clear and visible, cost savings might be realized by eliminating the preliminary clearance and just employing MEC avoidance through the support of a UXO technician, walking ahead of the DGM team.
- Because the VSP calculations use the difference in anomaly density between background and the target area, the estimation of anomaly densities in planning an RI may benefit from prior or preliminary DGM of known or suspected target areas to establish a credible anomaly density to be used in planning calculations.

4.4 Analog Reconnaissance

4.4.1 Conclusions

Can analog range reconnaissance reliably detect the munitions types expected on the MRS?

From the results of the instruments' performance on the IVS and the intrusive investigation, it was concluded that analog reconnaissance located items as small as small arms bullets and several inches below ground surface. Since the expected explosive munitions items at this site are larger than small arms, analog reconnaissance can reliably detect the munitions items expected on the Closed Castner Range MRS.

Can analog range reconnaissance:

Reliably identify areas of concentrated munitions use?
Its limited use on this project and its application to a single transect along the unofficial hiking trails and arroyos makes a true calculation of anomaly density difficult. A more widespread and rigorous transect-based application would be needed to properly answer this study question. Although each instrument hit was identified by an audible alarm that required operator judgment to assess, the sensitivity of the handheld Minelab Explorer II detector was sufficient to identify items of interest. Each instrument hit location was recorded with GPS coordinates. Although the lack of a permanent geophysical record of each hit is not optimal, analog reconnaissance is useful for filling in data gaps in extreme terrain that is inaccessible to other technologies.

Reliably identify areas with no indication of munitions use?
This objective was not demonstrated on this project, but would be possible when analog reconnaissance is coupled with intrusive investigation, provided the same statistical techniques to establish plots or transects are used and appropriate QC measures are implemented.

Improve the understanding of the types and quantities of MEC across the arroyos and unofficial hiking trails?
Yes, when coupled with intrusive investigation. Analog reconnaissance may be the only technique available to assess the types and quantities of MEC and munitions-related items in the arroyos and unofficial trails.

How confident are stakeholders in these conclusions?

The stakeholders were particularly interested in the methods and results of the analog reconnaissance because of the potential unauthorized use of hiking trails within the range. Stakeholders were briefed on the limitations of the analog work when compared to man-portable DGM, and concurred with the conclusions presented.

Over what percentage of the MRS can analog range reconnaissance data be collected?

Theoretically, analog reconnaissance can be used anywhere the operator can reach, which is not fully 100% of the range. Practical limits of accessibility apply; however, it is possible to survey areas up to 25% slope, which equates to about 6,522 acres at the Closed Castner Range MRS.

At the Closed Castner Range MRS, approximately 22 miles of 1 m wide transects were surveyed, equaling approximately 10 acres.

For what percentage of the MRS can statistically valid conclusions be drawn based on analog range reconnaissance data?

Statistically valid conclusions were not achieved at the Closed Castner Range MRS for preliminary target areas 11, 14, 15, 16, and 18, because data were only collected along a single transect. The number of intrusive targets was selected such that there would be 90% confidence that the proportion of munitions-related items excavated would be representative of other anomalies in the area.

What are the total cost, cost per characterized area, and cost per surveyed area associated with analog range reconnaissance?

The analog range reconnaissance task was added to the project in progress in response to stakeholder concerns about the unofficial trails at the Closed Castner Range MRS. Costs were not collected separately but were estimated to be approximately $28,750. This equates to approximately $1,307 per linear mile (22 miles total), or about $2,875 per acre (approximately 10 acres total). Because only a single transect was used, the surveyed and characterized areas were the same.

4.4.2 Lessons Learned

When applying analog reconnaissance for purposes of establishing relative anomaly densities, a statistical based transect design should be followed (similar to that applied in this project for man-portable EMI method).

4.5 Intrusive Investigation

4.5.1 Conclusions

For preliminary target areas:

What is the source/identity of each anomaly investigated?
2,370 anomalies were excavated in 18 suspected target areas. Each excavated item was identified and recorded (size, depth, orientation, nomenclature). Thirty items were classified as “no finds.”

What is the proportion of metallic anomalies attributable to munitions vs. non-munitions in each target area?
Each excavated anomaly was classified as munitions-related (MEC, MD) or non-munitions-related, and a percentage of munitions-related items was calculated for each of 18 preliminary target areas (see Tables 3-11 and 3-12).

For non-target areas:

What is the source/identity of each anomaly investigated?
573 anomalies were excavated in 4 suspected non-target lots. Each excavated item was identified and recorded (size, depth, orientation, nomenclature). Eight items were classified as “no finds.”

Is the MEC density less than or equal to 0.5 MEC item per acre in the non-target area, at 90% confidence level?
Each non-target area lot passed the threshold of having less than 0.5 MEC item per acre.

What are the total cost, cost per excavated item, and cost per surveyed area associated with intrusive investigation?

Total cost for intrusive investigation: $732,934
Cost per excavated item (2,943 anomalies): $249.04
Cost per characterized acre (4,294 acres): $170.69

4.5.2 Lessons Learned

Other lessons learned from intrusive investigation included:

- Production rates associated with intrusive investigation of randomly selected anomalies on transects across a large site are significantly lower than production rates typical of intrusive investigations in a grid setting. Large portions of time are spent moving people and equipment from one anomaly to another. Alternate equipment sets (different from the equipment originally used to collect the DGM data) can be applied to intrusive investigation. This can save time (not hauling EM61 and RTK around the site) and money (lower equipment rental costs and fewer people hauling equipment).
- Establishing “stop dig” criteria in the work plan will limit the number of trash pits, etc., that need to be fully excavated, when they provide little benefit to characterizing the anomaly.
- The Minelab Explorer II settings were initially optimized for the site conditions, including the objects of interest and background geology, but kept changing unexpectedly. Instead of making an audible response over an anomaly location, the instrument instead made no sound, or made erratic responses. This reduced the ability of the teams to properly investigate and clear their target locations. Troubleshooting determined that this was caused by the technicians holding down the power button for more than two seconds when starting the instrument, causing the settings to revert to the default. All team members were instructed to be aware of this issue, and were informed on how to reload the customized site parameters if necessary.

4.6 Stakeholder Lessons Learned

Engagement and involvement of the stakeholders was a key element of this project, and key to its ultimate success. To complete the record, the presentations and minutes from each of the stakeholder meetings are included in Appendix H. Because the TPP process was used, each meeting was labeled TPP 1 through 5. Lessons learned through this project included:

- Identifying stakeholders was a somewhat iterative process, where conventional stakeholders were asked to recommend other potentially interested participants, through existing local networks. All recommended participants were invited and allowed to self-select their level of involvement.
- Stakeholder meetings should be frequent enough to maintain engagement, and certainly at key milestones, such as the completion of plans, or key field activities.
- Stakeholder briefing materials can be technically detailed, and should assume the capability to understand complex issues. Jargon and acronyms should be avoided, but where software tools and programs are used, such as VSP, stakeholders should be informed as to the assumptions/inputs, as well as the results. There may be knowledge and experience in the stakeholder group that can refine assumptions through local knowledge.
- Candor and completeness in describing the methodologies and their limitations are key. Failures as well as successes should be briefed. Productive stakeholder involvement is built upon a relationship of mutual trust built through candor without manipulation. This will be especially evident in performance-based projects where stakeholder approval is required at milestones.
- Stakeholders in this project benefitted from visiting the site, meeting the staff, and observing the equipment and methods in use.
- Stakeholders also participated in arrangements and logistics, frequently suggesting accommodations and appropriate refreshments that made the atmosphere more relaxed, comfortable, and productive.

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Appendix A
Brock & Bustillos Inc. Survey Report

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Appendix B
URS Instrument Validation Strip Report

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Appendix C
SKY Research, Inc. HeliMag Survey Report

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Appendix D
NAEVA Geophysics Inc. Geophysical Investigation Report

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Appendix E
SKY Research, Inc. Ground-Based Geophysics and Associated Activities Report

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Appendix F
Proposed Anomaly Reacquisition, Intrusive Investigation, and Characterization

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Appendix G
Target Area 5 Hot Rocks Investigation Report

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Appendix H
Technical Project Planning Presentations and Minutes

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