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Final

Expanded Range Assessment/ Site Inspection Report

Former Vieques Naval Training Range (VNTR)
Vieques, Puerto Rico

NAVFAC
Naval Facilities Engineering Command

Prepared for

Department of the Navy
Naval Facilities Engineering Command
Atlantic Division

Contract No.
N62470-08-D-1000
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September 2010

CH2MHILL

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Prepared by

CH2MHILL

Virginia Beach, Virginia

Executive Summary

This Expanded Range Assessment and Site Inspection (ERA/SI) Report for the former Vieques Naval Training Range (VNTR), Vieques Island, Puerto Rico, has been prepared to provide the data and recommendations for future investigations/actions at unexploded ordnance (UXO) sites 1 through 17. The findings, recommendations, and the planned future land use will be utilized to determine the specific investigations/actions conducted.

The seventeen UXO sites inspected at the former VNTR are located within the former Eastern Conservation area (ECA), Live Impact Area (LIA), Surface Impact Area (SIA), and Eastern Maneuver Area (EMA). This ERA/SI Report was prepared as part of the phased SI approach implemented for the former VNTR, which is regulated under the Comprehensive Environmental Resource, Conservation, and Liability Act (CERCLA). This document was prepared by CH2M HILL for Naval Facilities Engineering Command (NAVFAC) Atlantic to meet current Department of Defense (DoD) guidelines for the investigation of MEC.

The ERA/ SI information supplements the information previously presented in the Preliminary Range Assessment (PRA) Report (CH2M HILL, 2003). The objectives of the ERA/SI are:

- Conduct ground and aerial based evaluations of specific areas to determine the presence and estimate the quantity of munitions.
- Supplement previous information presented in the PRA Report (CH2M HILL, 2003) about the types and quantities of munitions at the investigation areas.
- Identify potential areas within UXO sites where no further munitions response actions may be considered.
- Identify the type(s) and location(s) of target areas that may have been used at the investigation areas.
- Identify areas requiring further investigation and/or additional munitions response actions.
- Identify high-risk areas that may require interim munitions response actions because of explosives safety concerns

The information presented in this report is not intended to characterize the nature and extent of MEC at each UXO site, but to provide data sufficient to allow for planning and sequencing of future investigations/actions at the sites.

Based on the findings from the ERA/SI, interim removal actions were initiated to reduce the immediate explosive safety risk at the following munitions response sites: UXO 1- Eastern Conservation Area ; UXO 2- LIA Beaches; UXO 3- LIA Roads UXO 4 -LIA Interior UXO 5 - SIA Restricted Roads UXO 6 - EMA/SIA Public Roads; UXO 7 - EMA/SIA North Beaches; UXO 8- SIA South Beaches, UXO 9 -SIA Exterior; UXO 10- SIA Interior; and UXO 11- EMA

Public Roads. Due to the presence of MEC at these sites Remedial Investigations/ Feasibility Studies are recommended for these sites

Additional munitions response sites where MEC has been identified include: UXO 12- EMA Interior; UXO 13- EMA West; UXO 14- EMA South; and UXO 16- Underwater Areas. Remedial Investigations/Feasibility Studies are recommended at these sites to: further characterize the nature and extent of MEC, assess the risk to human health and the environment, and to evaluate mitigative measures to address the risks.

The ERA/SI indicated there may be a potential for MEC to be present at the following sites: UXO 15- Puerto Ferro; and UXO 17- Other Areas. Additional investigations are recommended at these sites to determine if MEC are present and to evaluate the need for an RI/FS

The ERA/SI concluded that the following sites located within UXO 17- Other Sites, are unlikely to contain MEC: PI -14, PAOC FF. As a result, No Further Action is recommended for these sites.

Resumen Ejecutivo

Se ha preparado este Informe de la Evaluación Expandida del Campo de tiro e Inspección del Sitio (ERA/SI por sus siglas en inglés) para el antiguo Campo de Adiestramiento Naval de Vieques (VNTR por sus siglas in ingles), en la isla de Vieques, Puerto Rico, para presentar los datos y recomendaciones para las futuras investigaciones/acciones en los sitios designados

UXO 1 al 17. Se utilizarán los resultados, recomendaciones e información sobre uso futuro de los terrenos para determinar las investigaciones/acciones específicas que se llevarán a cabo.

Los 17 sitios UXO que se inspeccionaron en el antiguo VNTR están localizados dentro de la antigua Área de Conservación Este (ECA por sus siglas inglés), el Área de Impacto con Bala Viva (LIA por sus siglas inglés), Área de Impacto de Superficie (SIA por sus siglas inglés) y el Área de Maniobras del Este (EMA por sus siglas inglés). Este Informe ERA/SI fue preparado como parte del enfoque en fases de las actividades de inspección del sitio que se ha implementado para el antiguo VNTR, el cual está regulado por la Ley Comprensiva de Conservación de Recursos Ambientales y Responsabilidad Ambiental (CERCLA por sus siglas inglés). Este documento fue preparado por CH2M Hill para el Comando de Ingeniería de Facilidades Naval del Atlántico (NAVFAC por sus siglas inglés) para cumplir los con las guias actuales del Departamento de Defensa (DoD) por sus siglas inglés) para la investigación de Municiones y Explosivos de Preocupación (MEC por sus siglas en inglés).

La información ERA/SI complementa la información previamente presentada en el Informe de Evaluación Preliminar del Área (PRA por sus siglas inglés) (CH2M HILL, 2003). Los objetivos del ERA/SI son:

- Conducir evaluaciones terrestres y aéreas en áreas específicas para determinar la presencia de municiones y estimar su cantidad.
- Complementar la información previa presentada en el PRA (CH2M HILL, 2003) sobre los tipos y las cantidades de municiones en las áreas de investigación.
- Identificar áreas potenciales dentro de los sitios UXO donde no se necesite considerar acciones de respuesta a municiones adicionales.
- Identificar el (los) tipo(s) y ubicación(es) de las áreas de tiro al blanco que pudieron haber sido usadas en las áreas de investigación.
- Identificar las áreas que requieren investigaciones adicionales y/o acciones de respuesta a municiones adicionales.
- Identificar áreas de alto riesgo que puedan requerir acciones de respuesta a municiones interinas debido a la preocupación sobre la seguridad por explosivos.

La información que se presenta en este informe no tiene la intención de caracterizar la naturaleza y extensión de los MEC en cada sitio UXO pero intenta proveer suficientes datos para permitir la planificación y poder determinar la secuencia de las investigaciones/acciones futuras en estos sitios.

En base a los resultados del ERA/SI, se iniciaron acciones de remoción interinas para reducir el riesgo inmediato de seguridad por explosivos en los siguientes sitios de respuesta a municiones: UXO 1- ECA; UXO 2 Playas en el LIA; UXO 3 -Carreteras en el LIA; UXO 4- LIA Interior; UXO 5- Carreteras Restringidas del SIA; UXO 6 Caminos Públicos del EMA/SIA; UXO 7- Playas Norte del EMA/SIA; UXO 8- Playas Sur del SIA; UXO 9- SIA Exterior; UXO 10- SIA Interior; y UXO 11- Caminos Públicos del EMA. Debido a la presencia de MEC en estos sitios, se recomiendan Estudios de Factibilidad / Investigaciones de Remediación en estos sitios.

Sitios adicionales de respuesta a municiones donde se han identificado MEC incluyen: UXO 12 -EMA interior; UXO 13- EMA Oeste; UXO 14 EMA- Sur; y UXO 16- Áreas submarinas. Se recomiendan Estudios de Factibilidad / Investigaciones de Remediación (RI/FS por sus siglas en inglés) para estos sitio para: caracterizar más la naturaleza y la extensión de MEC, evaluar el riesgo a la salud humana y al ambiente.

EL ERA/SI indicó que potencialmente puede haber MEC presente en los siguientes sitios: UXO 15- Puerto Ferro; y UXO 17 -Otras Áreas. Se recomiendan investigaciones adicionales en estos sitios para determinar si existe la presencia de MEC y para evaluar la necesidad de un RI/FS.

El ERA/SI concluyó que los siguientes sitios localizados dentro de UXO 17- Otros Sitios son poco probables de contener MEC: PI-14, PAOC FF. Como resultado, se recomienda Ninguna Acción Adicional para estos sitios.

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Acronyms and Abbreviations

AMS	aerial magnetometer survey
amsl	above mean sea level
AOI	Area of Interest
ARS	Archive Records Search
ATG	air-to-ground
ATSDR	Agency for Toxic Substances and Disease Registry
BDU	bomb, dummy unit
CCP	Comprehensive Conservation Plan
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CLEAN	Comprehensive Long-term Environmental Action—Navy
CSM	conceptual site model
CTO	Contract Task Order
°F	degrees Fahrenheit
DGM	digital geophysical mapping
DoD	Department of Defense
DOI	Department of the Interior
DTC	Desert Test Center
DU	Deplete Uranium
EADA	Elevated Anomaly Density Area
ECA	Eastern Conservation Area
EIS	Environmental Impact Statement
EM	electromagnetic
EMA	Eastern Maneuver Area
ERA	Expanded Range Assessment
ERP	Environmental Response Program
FFA	Federal Facilities Agreement
FS	Feasibility Study
GP	gun position
GPO	geophysical prove-out
GPS	global positioning system
HE	high explosive
ID	identification
IRP	Installation Restoration Program
LIA	Live Impact Area
LiDAR	light detection and radar
LUC	land use control

MD	munitions debris
MEC	munitions and explosives of concern
mm	millimeter
MRA	Munitions Response Area
MRP	Munitions Response Program
NASD	Naval Ammunition Support Detachment
NAVFAC	Naval Facilities Engineering Command
NGF	Naval gunfire
NPDES	National Pollution Discharge Elimination System
NPL	National Priorities List
NRHP	National Registry of Historic Places
NTCRA	Non-Time-Critical Removal Action
OB/OD	open burn/open detonation
OP	observation point
PA/SI	Preliminary Assessment/Site Investigation
PAOC	Potential Area of Concern
pCi/g	picocuries per gram
PI	photo-identified
PRA	Preliminary Range Assessment
PRASA	Puerto Rico Aqueduct and Sewer Authority
PREQB	Puerto Rico Environmental Quality Board
RCRA	Resource Conservation and Recovery Act
RI	Remedial Investigation
RRD	range-related debris
RTK	real-time kinetic
RTS	remote tracking station
SAIC	Science Applications International Corporation
SAM	surface-to-air missile
SI	Site Inspection
SIA	Surface Impact Area
TCRA	Time-Critical Removal Action
USEPA	United States Environmental Protection Agency
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
UXO	unexploded ordnance
VNTR	Vieques Naval Training Range
VNWR	Vieques National Wildlife Refuge

SECTION 1

Introduction

This Expanded Range Assessment/Site Inspection (ERA/SI) Report for the 17 unexploded ordnance (UXO) sites at the former Vieques Naval Training Range (VNTR) has been prepared for the Naval Facilities Engineering Command (NAVFAC) Atlantic Division under Contract N62470-08-D-1000, Comprehensive Long-term Environmental Action—Navy (CLEAN) 1000 Program, Contract Task Order (CTO) 023, to meet current Department of Defense (DoD) guidelines for the investigation of munitions and explosives of concern (MEC).

1.1 Objectives and Scope of ERA/SI

This report presents the approach and findings for ERA/SI efforts at the 16 terrestrial sites, includes a discussion of the studies and findings from various underwater MEC studies for the underwater UXO site, and supplements the information presented in the Preliminary Range Assessment (PRA) Report (CH2M HILL, 2003) conducted at the former VNTR, Vieques, Puerto Rico.

1.1.1 Objectives

The objectives of the ERA/SI field investigation were:

- Conduct ground- and aerial-based evaluations of specific areas to determine the presence and estimate the quantity of munitions.
- Supplement previous information presented in the PRA Report (CH2M HILL, 2003) about the types and quantities of munitions at the investigation areas.
- Identify potential areas within UXO sites where no further munitions response actions may be considered.
- Identify the type(s) and location(s) of target areas that may have been used at the investigation areas.
- Identify areas requiring further investigation and/or additional munitions response actions.
- Identify high-risk areas that may require interim munitions response actions because of explosives safety concerns

1.1.2 Scope

The following activities were conducted to achieve the objectives given above. These activities are described in greater detail in Section 3 of this report.

- A ground-based transect magnetometer aided visual survey at UXO Sites 2, 3, 4, 5, 6, 7, 8, 9, 11, 12, 13, 15, and 17. These UXO Sites include Photo Identified (PI) Sites 1 and 17, Potential Areas of Concern (PAOCs) Y, Z, BB, EE, FF, Areas of Interest (AOIs) 1 and 2, and six specific debris areas, which were specifically addressed during the survey.
- Light detection and radar (LiDAR) aerial survey of the entire former VNTR.
- High resolution, color orthophotography was collected over the entire former VNTR.
- Digital geophysical mapping (DGM) of UXO Sites 2, 3, 5, 6, 7, 8, and 11.
- Aerial magnetometer survey (AMS) of UXO Sites 1-15 and portions of UXO 16.
- Desktop slope and landscape analysis to identify areas with landscape features that would make future actions technically difficult to implement.
- Evaluate historical data and various underwater MEC studies conducted at UXO 16.

1.2 Report Organization

This Report contains seven sections in addition to this introduction (**Section 1**) that are organized as follows:

Section 2—Former VNTR Background and Physical Characteristics describes the area and military history of the former VNTR, former and current site designations, and physical setting. The description includes topography, climate, vegetation, wildlife, geology, hydrology and groundwater, land use, cultural resources, and previous investigations.

Section 3—Summary of Field Investigation Procedures describes the approach, methods, and operational procedures employed to perform the field investigation activities.

Sections 4 through 20—UXO Sites 1 through 17. Present the background for UXO Sites 1 through 17, summarizes the findings of the ERA/ SI field investigation for each UXO site, and the recommendations for each UXO site.

Section 21— MEC Conceptual Site Model and Landscape Analysis. This section describes the conceptual site model (CSM) for MEC at the sites developed based on available historical data, site inspection, sources of MEC, potential transport mechanisms of MEC, site accessibility, and potential receptors. Also presented, is an analysis of the slope and vegetation based on the LiDAR and AMS.

Section 22—References lists documents and sources cited or used in the development of this report.

Section 23—Glossary of Terms defines terms used in this report that may be unfamiliar to the reader.

SECTION 2

Former VNTR Background and Physical Characteristics

This section discusses the background and physical characteristics of the former VNTR. The physical characteristics of the site are an important consideration when discussing results of the ERA/SI and future characterization and/or actions, if required.

2.1 Former VNTR Location

Vieques is located in the Caribbean Sea approximately 7 miles southeast of the eastern tip of the island of Puerto Rico and 20 miles southwest of St. Thomas, U. S. Virgin Islands. Vieques is the largest offshore island of the Commonwealth of Puerto Rico. It is approximately 20 miles long and 4.5 miles wide, and has an area of approximately 33,088 acres (51 square miles).

The former VNTR is situated in the eastern half of the Island of Vieques, and is bordered on the west by the community of Isabel Segunda, to the north by Vieques Sound, and to the south by the Caribbean Sea.

Figure 2-1 shows the regional location of Vieques with respect to the island of Puerto Rico. **Figure 2-2** presents a site map of the Munitions Response Sites (MRSs) for the former VNTR. A site map with the site wide grid layout is presented in **Appendix A** for reference. **Appendix B** provides a matrix of the identifying previous site names that may have been used for the sites discussed below.

2.2 Regulatory Status

2.2.1 Eastern Vieques (Former VNTR)

A Resource Conservation and Recovery Act (RCRA) Part B Hazardous Waste Facility Operations Permit Application was submitted by the Navy to United States Environmental Protection Agency (USEPA) in 1988 for the operation of an Open Burn/Open Detonation (OB/OD) unit. A Draft Final Closure Plan for the OB/OD site was submitted to USEPA Region II, Puerto Rico Environmental Quality Board (PREQB), and the Department of Interior (DOI), by the Navy in February 2004 (CH2M HILL, 2004a). Comments from these agencies were addressed and the Draft Final Closure Plan (CH2M HILL, 2004d) was submitted for public comment. The public comment period was held from December 1, 2004 through January 31, 2005. The USEPA prepared responses to the public comments and submitted them on May 17, 2005. The regulatory agencies agreed that the implementation of the Closure Plan will be delayed pending completion of clearance work for MEC throughout the VNTR.

Historically, the Installation Restoration Program (IRP) for the former VNTR has been conducted under a RCRA § 3008(h) Consent Order entered into by the Navy and USEPA on January 10, 2000. However, consistent with the listing of the former VNTR on the National Priorities List (NPL) (**Section 2.1.2**), future IRP activities will be conducted in accordance with Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA).

2.2.2 National Priorities List

In 2003, the Governor of Puerto Rico requested USEPA to list the VNTR (and Naval Ammunition Support Detachment [NASD]) on the NPL. On May 26, 2004, the President of PREQB sent a letter to the Regional Administrator of USEPA acknowledging that USEPA, PREQB, and DOI concurred with the designation of the former Naval facilities as an NPL site and that initial areas of Preliminary Assessment/Site Investigation (PA/SI) under CERCLA will focus on "Agreed Areas" in and around Vieques and Culebra where the Navy conducted operations, including "those waters in and around Vieques where contamination has come to be located." On February 7, 2005, Vieques was placed on the NPL.

As a result of the NPL listing, a Federal Facilities Agreement (FFA) (USEPA, 2008) was developed and signed by the Navy, USEPA, PREQB, and DOI on September 7, 2007. The FFA establishes the procedural framework and schedule for implementing the response activities under CERCLA. With the listing on the NPL and the creation of an FFA, all future installation restoration activities on Vieques will be conducted under CERCLA, with the Navy as the lead agency.

This investigation addresses the former VNTR (east Vieques). West Vieques sites have already been addressed or are in the process of other investigation or remediation.

2.3 Land Use

The former VNTR was transferred to the DOI in 2003 to be managed by DOI as part of the National Wildlife Refuge System, pursuant to section 1049 of the Nation Defense Authorization Act for Fiscal Year 2002 (Public Law 107–107). In addition, the Live Impact Area (LIA), including the OB/OD site and Eastern Conservation Area (ECA), must be managed as a wilderness area and public access restricted. (Public Laws 106–398 and 107–107). A Comprehensive Conservation Plan (CCP) for the Vieques National Wildlife Refuge is being developed, as is done with all other refuges, outlining its land use plan for managing the refuge. While all military activities have ceased at the former VNTR, the Navy retains responsibility for any MEC and/or environmental contaminant concerns that may exist there. Any land use controls (LUCs) such as access restrictions that are planned for the former LIA are expected to be consistent with those established for state and federal wildlife refuges.

2.4 Former VNTR History

2.4.1 Military Operational History

The former VNTR consists of approximately 14,600 acres and historically has been divided into four separate operational areas that include:

- Munitions Response Area (MRA)-Eastern Maneuver Area (EMA) (approximately 11,000 acres)
- MRA-Surface Impact Area (SIA) (approximately 2,500 acres)
- MRA-LIA (approximately 900 acres)
- MRA-ECA (approximately 125 acres)

The EMA was first established in 1947 and provided military maneuvering areas and ranges for the training in exercises of amphibious landings, small arms fire, artillery and tank fire, shore fire control, and combat engineering tasks. **Figure 2-3** presents a map showing the location of the primary target areas, the artillery gun positions (GPs) and the ranges that were established by the 1970s.

The SIA was established in the 1950s when several Marine targets were constructed. Marine artillery ranging from 76mm to 175mm projectiles was directed toward these targets from artillery GPs within the EMA. During 1969, the construction of bulls-eye targets 1 and 2, used for inert bombing, were established the eastern and western boundaries of the SIA.

In 1965, the Navy established the LIA, also known as the air impact area, where they maintained several targets for aerial bombing including old tanks and vehicles which were used as mock-ups, two bulls-eye targets and a strafing target. In addition, several point and area targets for ships to practice naval gunfire (NGF) support were established in the LIA. The location of these targets are shown on **Figure 2-3**.The Environmental Impact Statement (EIS) for Vieques (Tippetts et al., 1979) provides a detailed discussion on the development of training facilities in the former VNTR.

The ECA, located at the eastern tip of Vieques, was not a military operational area; however, due to its close proximity to the LIA, the area has been inspected for MEC impacts.

For this ERA/SI the former VNTR has been divided into 17 UXO sites (**Figure 2-2)** to be addressed as part of the CERCLA process. Additional historical information on military use for each of the sites is provided in the individual report sections for each site.

2.4.2 Use of Biological, Chemical, and Radiological Weapons

The use of biological, chemical, and radiological weapons on Vieques was evaluated during the Archive Records Search (ARS) and personnel interviews completed as part of the PRA (CH2M HILL, 2003).

In May 1969, Desert Test Center (DTC) Test 69-10 was conducted on the beaches of the former VNTR (beaches not identified) to determine the operational effects of a persistent, toxic, chemical agent spray attack on United States amphibious forces and to evaluate performance of protective clothing worn by troops involved in the exercise. The testing

organization was the United States Army DTC, and the participating services were the United States Navy, United States Marine Corps, and DTC personnel. Marine Corps A-4 aircraft equipped with Aero 14B spray tanks were utilized for the dispersal of Tri (2-ethylhexyl)phosphate (a non-toxic simulation substitute for the VX nerve agent). This stimulant can irritate the eyes, skin, and respiratory tract on contact (DoD, 2002).

Although the use of depleted uranium (DU) was not authorized for use on the Vieques ranges, a one-time accidental use of armor piercing incendiary depleted uranium ammunition occurred in February 1999. Records indicate that ground teams surveyed parts of former LIA in the vicinity of the convoy target area (**Figure 2-3**) and recovered 57 of the 263 projectiles (NRC, 2000). Five soil samples from the LIA taken from the walls of the holes in which DU penetrators had been recovered had total uranium levels which indicated the presence of uranium above background levels; the levels ranged from 4.02 picocuries per gram (pCi/g) to 92 pCi/g. The NRC concluded that members of the public were not at risk of being exposed to levels of radiation exceeding the regulatory limits due to this release and the DU contamination was limited to the areas within the LIA immediately surrounding the DU penetrators (NRC, 2000). In addition, a September 2003 Agency for Toxic Substances and Disease Registry (ATSDR) Final Health Assessment concluded that "residents of Vieques are not exposed to levels of radiological contamination that could present a public health hazard, as a result of the Navy's limited past use of depleted uranium penetrators during military training exercises." No other incidences on the use of biological, chemical, or radiological warfare were identified during the record searches for the former VNTR.

2.5 Physical Characteristics

2.5.1 Topography

The topography of Vieques is characterized by gentle to steep rolling hills and valleys throughout the island, with the eastern side exhibiting a more rugged terrain. **Figure 2-4** illustrates the topography of the former VNTR. The LIA is relatively flat with elevations ranging from 0 to approximately 50 feet above mean sea level (amsl). Cerro Matias, located within the SIA as Observation Point (OP)-1 (**Figure 2-3)** is the highest point on former VNTR, at approximately 420 feet amsl. The average elevation across Vieques is approximately 246 feet amsl. The coastal area is relatively narrow; however, the southern coast exhibits wider expanses of beach.

2.5.2 Climate and Weather

The climate of Vieques is tropical-marine. Temperatures are nearly constant, with an annual average of approximately 79 degrees Fahrenheit (°F). August is the warmest month (82°F) and February is the coolest (76°F). Vieques lies directly in the path of the prevailing easterly trade winds that regulate the climate of Puerto Rico and result in a rainfall pattern characterized by a dry season from December through July and a rainy season from August through November. Heavy precipitation may be induced by tropical storms from June to November. The eastern portion of the island is typically drier than the western portion and annual rainfall averages 25 inches per year (USGS, 1989).

2.5.3 Vegetation

Thick vegetation dominates most available land space over the eastern third of Vieques. The canopy consists primarily of deciduous trees, with mesquite trees dominating the species distribution. This non-native species was spread by the herds of cows and horses at the site, which eat the seed pods from the trees year-round and distribute them throughout the area. A variety of thorny tree species and low-lying brush are present throughout eastern Vieques. Tall grasses tend to populate the landscape in areas where the thorny tree and brush species do not exist. Most of the island's vegetation, except in populated areas in the center of the island, tends to form a complete ground cover. Leaves are mostly small and sclerophyllous (hard and dry) (GMI, 1996).

The coastal areas in the island's eastern side contain level terrain made up primarily of lagoons and mangrove swamps. Coastal dunes and associated vegetation, including sea oats, are present throughout open beach areas on both the northern and southern sides of the former VNTR (GMI, 1996).

2.5.4 Geology

The geology of Vieques is characterized by volcanic rocks generally overlain by alluvial deposits and patches of limestone. The upland areas contain three rock types: sedimentary rocks comprised of limestone and volcanic rocks composed of both granodiorite and diorite.

The Upper Cretaceous volcanic rocks in the upland areas appear to be the oldest exposed rocks on Vieques and are believed to have been in a marine environment, as were rocks of the same age on the island of Puerto Rico. Limestone of Upper Tertiary age is found on peninsulas extending into the sea from the southern and eastern coasts. Limestone of the Tertiary-Miocene age is also found along these coasts, and is referred to as the "Puerto Ferro" limestone. Quaternary deposits are found in the valleys and coastal areas and include beach, swamp, and alluvial deposits. Deposits of sand, swamp, and salt mud occur in the coastal areas and floodplains (USGS, 1989).

Limestone occurs in portions of the island's northern, southern, and eastern parts. The most extensive areas of limestone are found on the southern coastal peninsulas. The limestone is generally soft, yellowish, and well-indurated where exposed to the atmosphere. The sedimentary deposits consist of a mixture of sand, silt, and clay.

Alluvial deposits are found in the valleys and coastal areas and include beach, swamp, and alluvial material. Deposits of sand, swamp, and salt mud occur in the coastal areas and floodplains. A recent investigation of the eastern end of Vieques indicated that the alluvial deposits there range from 5 to 50 feet thick (Baker, 1999).

Soils on Vieques Island are primarily residual, due to both climatic and subsurface rock conditions. It is typically classified into five groups and range from rock land soil where bedrock is exposed, to deep, well-drained soils within the alluvial deposits, to shallow soils (USDA, 1977).

2.5.5 Hydrology

The streambeds found on Vieques flow either north to the Atlantic Ocean or south to the Caribbean Sea. No perennial surface drainage exists on Vieques, and, based on statistics from the United States Virgin Islands, approximately 90 percent of the average 36 inches of rainfall received per year is lost to evaporation. Of the remaining 10 percent, approximately 5 percent becomes surface runoff and 5 percent infiltrates into the groundwater system.

Surface Water

Surface water deposits in the former VNTR occur primarily in coastal lagoons and intermittent streams, known locally as arroyos and quebradas, respectively, that channel water downward from hills during rain events. Some of these arroyos and quebradas have standing water year-round, especially in areas abutting the coastline where terrain has leveled sufficiently to allow water to pool. Several mid– to large–sized lagoons are present near the Purple Beach area just east of Puerto Negro and to the south within the Ensonada Honda area, the Bahia de la Chiva area, and the South Coast Bays area.

Some rainwater does pool temporarily in low-lying areas following storm events, but these features typically dissipate within a few days.

Groundwater

The groundwater on Vieques is derived from rainfall. The water flows downhill as intermittent stream runoff or seeps into the soil and underlying deposits. Water in pore space, cracks, and fractures in bedrock eventually flows into alluvial deposits or to the ocean. Annual variations of island-wide rainfall influence groundwater levels locally. Groundwater levels also exhibit fluctuations near the coastline because of tidal influences.

Two types of aquifers are present on Vieques. The first is found in the upper portion of the bedrock and sedimentary rocks in the western portion of the site. At the eastern end of Vieques, a groundwater divide occurs near the center of the island. From this location, the groundwater flow is toward the northeast and the southwest (Baker, 1999). The second type of aquifer is within the alluvial deposits found below the hills in the low flat valleys along the coast. Groundwater flow in these aquifers (such as the Resolución Valley aquifer) is also downhill and generally towards the sea. The Camp Garcia aquifer is an alluvial aquifer within Esperanza Valley, the largest alluvial valley in Vieques.

The groundwater on the island is broken up into two aquifers: the Valle de Resolución, located beneath the island's western portion, and the Valle de Esperanza located beneath the island's southern portion near Camp Garcia. As previously discussed, approximately 5 percent of the annual precipitation infiltrates into the ground and supplies the groundwater aquifers. The Valle de Esperanza is the more productive of the two aquifers and, therefore, was used as a source of drinking water by the Navy. The Puerto Rico Aqueduct and Sewer Authority (PRASA) managed a series of 16 wells which pumped approximately 450,000 gallons of water per day. These wells are no longer active because of the installation of a water line from the island of Puerto Rico to Vieques in 1978.

The United States Geological Survey (USGS) performed a groundwater study on Vieques, including tests on the wells near Esperanza. The results indicated that the groundwater contained high concentrations of sodium bicarbonate. Because of its high sodium content,

the groundwater on Vieques is not suitable for extended use for irrigation or other potable water use. The high levels of sodium result from sea spray infiltrating into the ground and saltwater entering the groundwater supply through excessive groundwater withdrawal (Vargas, 1995).

2.5.6 Natural Resources

The eastern end of Vieques houses a variety of natural resources in the form of wide-ranging plant and wildlife species. A number of conservation zones have been established in the former VNTR to help protect these valuable resources. A Biological Assessment for the LIA was completed (GMI, 2006) presenting the measures that will be implemented to avoid impacts to threatened/endangered species during investigation and removal action activities. This was followed by additional assessment of the ECA and all of the former VNTR and former NASD beaches (GMI, 2007b). The Conservation Zones are illustrated in the Biological Assessment (GMI, 2006) and include:

- The **Punta Este Conservation Zone** is located on the southeastern end of the LIA and consists primarily of drought-resistant scrub that no longer can be found elsewhere in Puerto Rico except on Navy property in Vieques.
- The **Cayo Conejo Conservation Zone** is a small island located southwest of the LIA in the Bahia Salina del Sur area. This area is an important nesting habitat for the endangered brown pelican and one of the last nesting areas for this species in Puerto Rico.
- The **Ensonada Honda Conservation Zone** lies between Blue and Yellow Beaches on the southern coast of Vieques. This area has the best example of lowland forest growth on Vieques and is also home to a variety of extensive mangrove populations that appear to be healthy and expanding.
- The **South Coast Bays Conservation Zone** is located on the southern coastline of Vieques directly south of the Camp Garcia area and western portions of the EMA. Two bays at this location, Bahia Tapon and Puerto Mosquito, have bioluminescent properties and are a valuable tourism resource for the island.

United States DOI has considered the natural resources present at the Vieques National Wildlife Refuge (VNWR), including the conservation zones listed above, to develop a CCP/EIS (DOI, 2007). The CCP/EIS will guide the management of the VNWR and outlines alternatives and proposed alternatives for management for a 15-year period.

Sea turtle nesting occurs primarily from February through August. The sea turtles that have been observed on Vieques are the green, leatherback, and hawksbill sea turtles. The known locations of sea turtle nesting are presented on **Figure 2-5** and in the Biological Assessment (GMI, 2006; 2007b).

2.5.7 Cultural Resources

A number of resources exist in the former VNTR that are of interest from a cultural perspective including a number of conservation zones, cultural resource, and prehistoric (Indian and Spanish historical sites). Navy surveys have located more than 100 sites with the potential to contain significant cultural resources on Vieques. Eleven of the sites are

listed in the National Registry of Historic Places (NRHP). One such area is the Puerto Ferro Lighthouse in the EMA, which has been determined to be eligible for the NRHP (TEC, 2002).

Seventeen archaeological sites and districts currently are listed on the NRHP system for Vieques with approximately a half dozen on the island's eastern end as shown on the land use map of United States Naval facilities on Vieques (GMI, 1996). This information has been confirmed by the review of other cultural resource maps for Vieques recovered during the record search and NRHP web-based searches.

An Archaeological survey of the Former VNTR was completed in 2007 for UXO 1 (former ECA), UXO 2, UXO 7, UXO 8. The survey found no cultural resources listed or eligible for listing on the NRHP within these project areas (SEARCH, 2008).

2.6 Summary of Previous Investigations and Actions

A number of environmental, ecological, public health, and cultural investigations and actions have been conducted at the former VNTR. Numerous studies also have been conducted by the Navy, ranging from economic impacts of military training in Vieques to the ecological impacts of military training on the health of the ecosystem in the waters just off shore from the range. There are current actions ongoing at the former VNTR as well.

Most of the investigations completed at the former VNTR were associated with the storage and handling of petroleum and hazardous substances. However, the report titled *Live Impact Area Soil Sampling Report, U. S. Naval Facility Vieques Island, Puerto Rico* (CH2M HILL, 2000) presented the analytical results of 37 soil samples collected throughout the LIA that were used to assess chemical risk within the LIA. **Figure 2-6** shows these soil sampling locations.

The analytical results of this sampling showed that explosives were detected in only five of the 37 samples. A review of the metals data by the ATSDR concluded "the levels of the metals and other chemicals detected in the soils would not result in harm to the health of either adults or children who might swallow or touch the soil while living in Vieques." In addition, ATSDR concluded that "the maximum levels of some of the metals detected was moderately elevated in comparison to soils elsewhere, but the levels are not consistent with what one would expect from soils also underlain by igneous or volcanic rocks"(ATSDR, 2001). Although the metal levels in the soils were moderately elevated, the concentrations were lower than one would expect in soils derived from or overlying rock that is relatively high in these same metals.

A report entitled *Results of the Hydrogeologic Investigation Vieques Island, Puerto Rico* (Baker, 1999) summarized the findings of a soil and groundwater investigation of the former EMA to assess whether the potential existed for explosive compounds to migrate off the former VNTR. The report concluded that no unacceptable risk to human health existed at the former EMA because no explosive-related compounds were detected in the surface soil or groundwater samples.

Prior to the issuance of the Consent Order for the former VNTR in 2000 and the transfer of the western Vieques former NASD property in 2001, several investigations were conducted on Vieques:

- A PRA was conducted for the former VNTR from mid-October 2003 through early February 2003 (CH2M HILL, 2003). Personnel interviews, ARS, and ground-truthing field investigations were performed to gather data for the PRA. The PRA concluded that additional investigations were needed to characterize the nature and extent of MEC at each UXO site.
- A Time-Critical Removal Action (TCRA) was initiated as an interim removal action in the former LIA in 2005 (CH2M HILL, 2005) to reduce the explosive risk from munitions items located on the surface. The initial area designated for the TCRA was 400 acres of the most westerly portion of the LIA; however, following the first field phase of the ERA/SI it was apparent that the eastern portion of the LIA and the ECA also posed an explosive risk and the TCRA was amended to include these areas (CH2M HILL, 2006a). The field portion of the TCRA was completed February 2009 and 987 acres were cleared of MEC present on the ground surface.
- In February 2009 the field activities for a Non-Time-Critical Removal Action (NTCRA) were initiated as an interim removal action for UXO 9 and UXO 10 (CH2M HILL, 2009). The scope of the NTCRA is to remove surface munitions from the site. Through May 2010 540 acres have been cleared of MEC present on the ground surface. This interim action is currently ongoing.
- In June 2009 the field activities for a second NTCRA (interim action) were initiated for UXO 2 (CH2M HILL, 2008b). The scope of the NTCRA is to remove subsurface munitions from the site. The NTCRA also includes subsurface removal at UXO Sites 1, 3, 5 through 8, 11, and 15. Through May 2010 over 14,300 subsurface anomalies have been excavated and over 320 munitions items have been removed from the subsurface. This interim action is currently ongoing.

All of the final documents and reports related to the Vieques Environmental Response Program (ERP) and Munitions Response Program (MRP) are available on a public web site at the following address: http://public.lantops-ir.org/sites/public/vieques/.

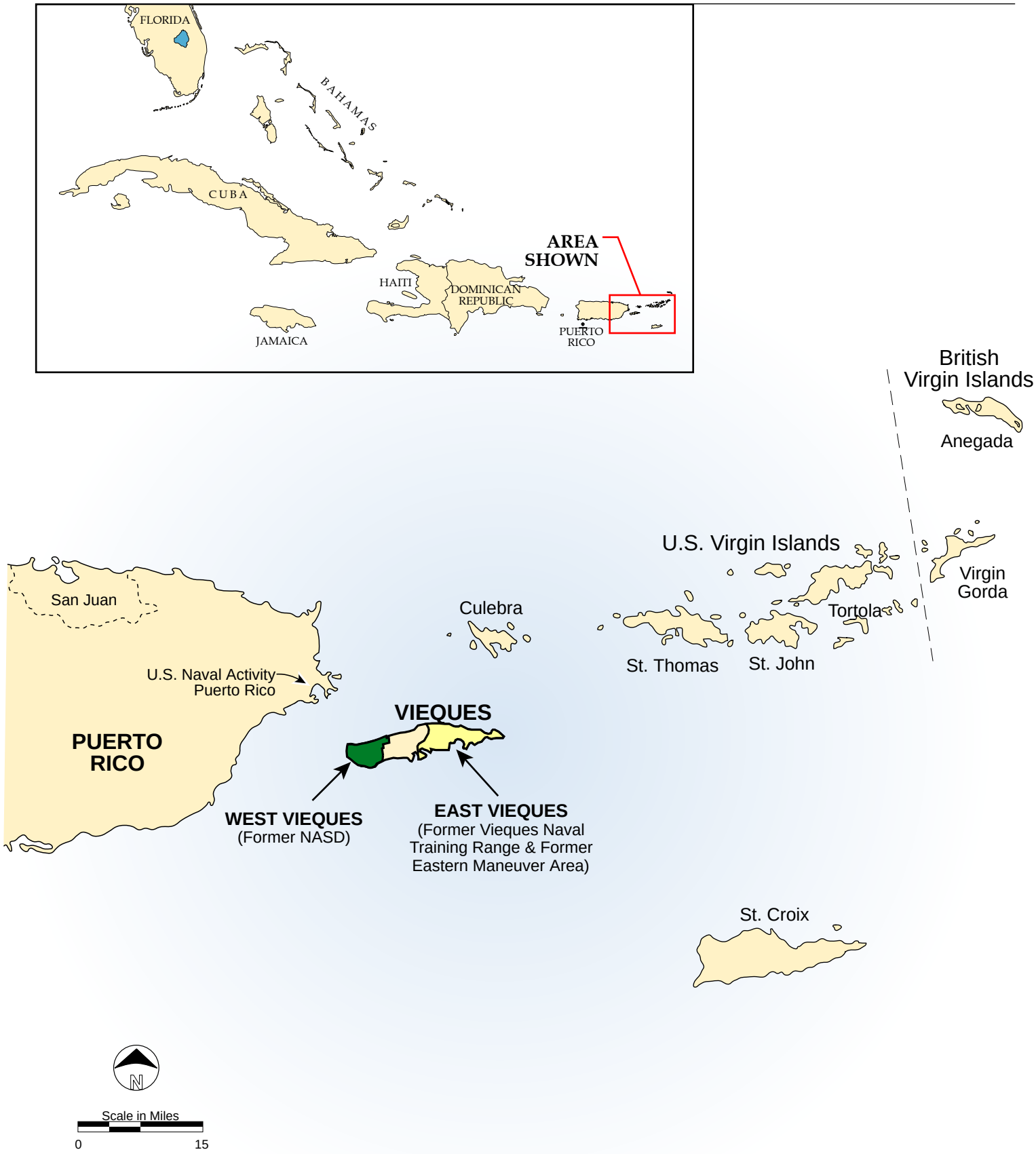

Figure 2-1
Regional Location Map
Former VNTR, Vieques, Puerto Rico

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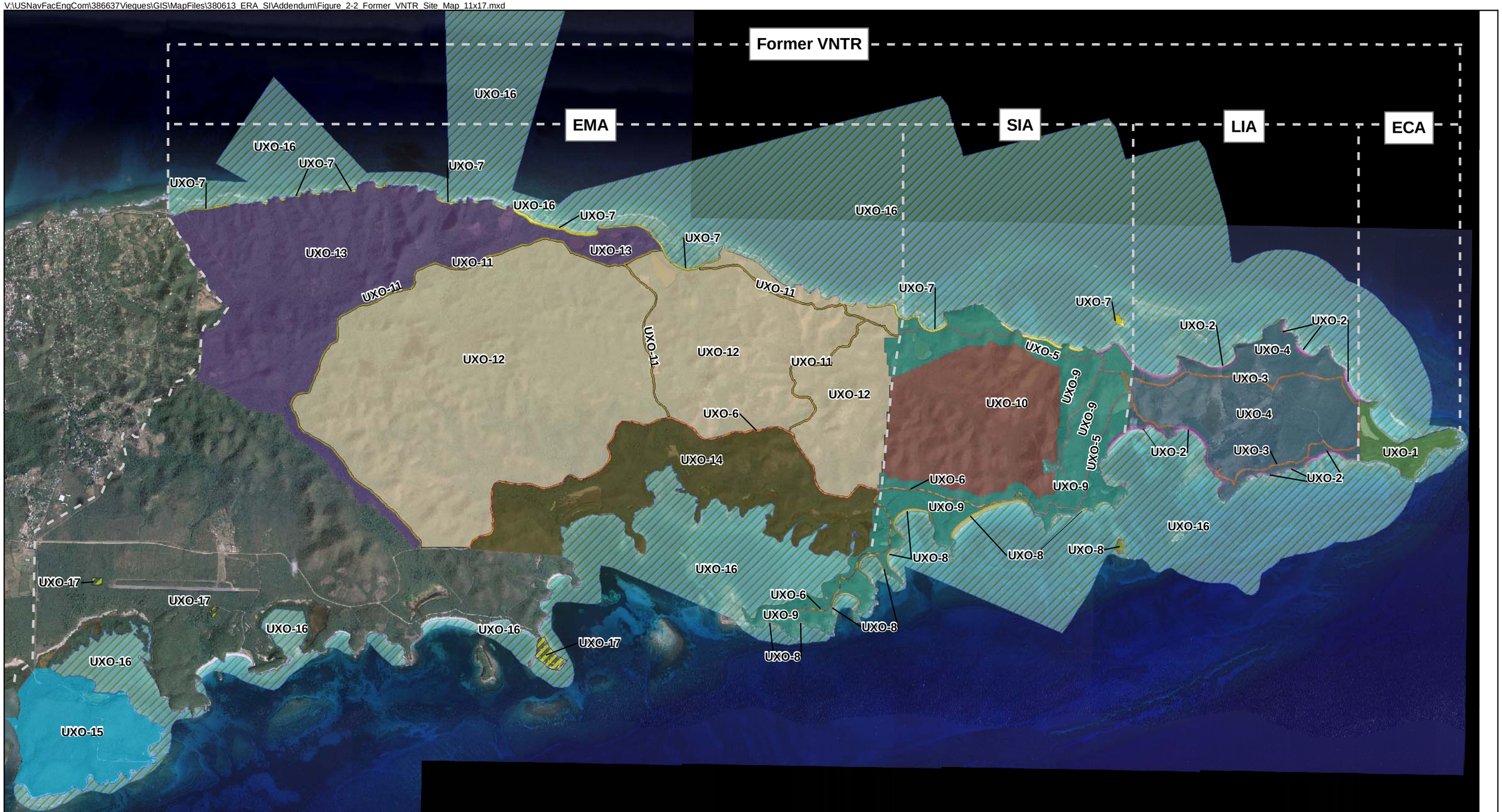

Legend

- UXO-1 - Eastern Conservation Area
- UXO-2 - LIA Beaches
- UXO-3 - LIA Roads
- UXO-4 - LIA Interior
- UXO-5 - SIA Restricted Roads
- UXO-6 - EMA/SIA Public Roads
- UXO-7 - EMA/SIA North Beaches
- UXO-8 - SIA South Beaches
- UXO-9 - SIA Exterior
- UXO-10 - SIA Interior
- UXO-11 - EMA Public Roads
- UXO-12 - EMA Interior
- UXO-13 - EMA West
- UXO-14 - EMA South
- UXO-15 - Puerto Ferro
- UXO-16 -Underwater Areas
- UXO-17 - Other Sites (PI-14, PAOC-EE, PAOC-FF)

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Feet

Figure 2-2
Former VNTR Site Map
Former VNTR, Vieques, Puerto Rico

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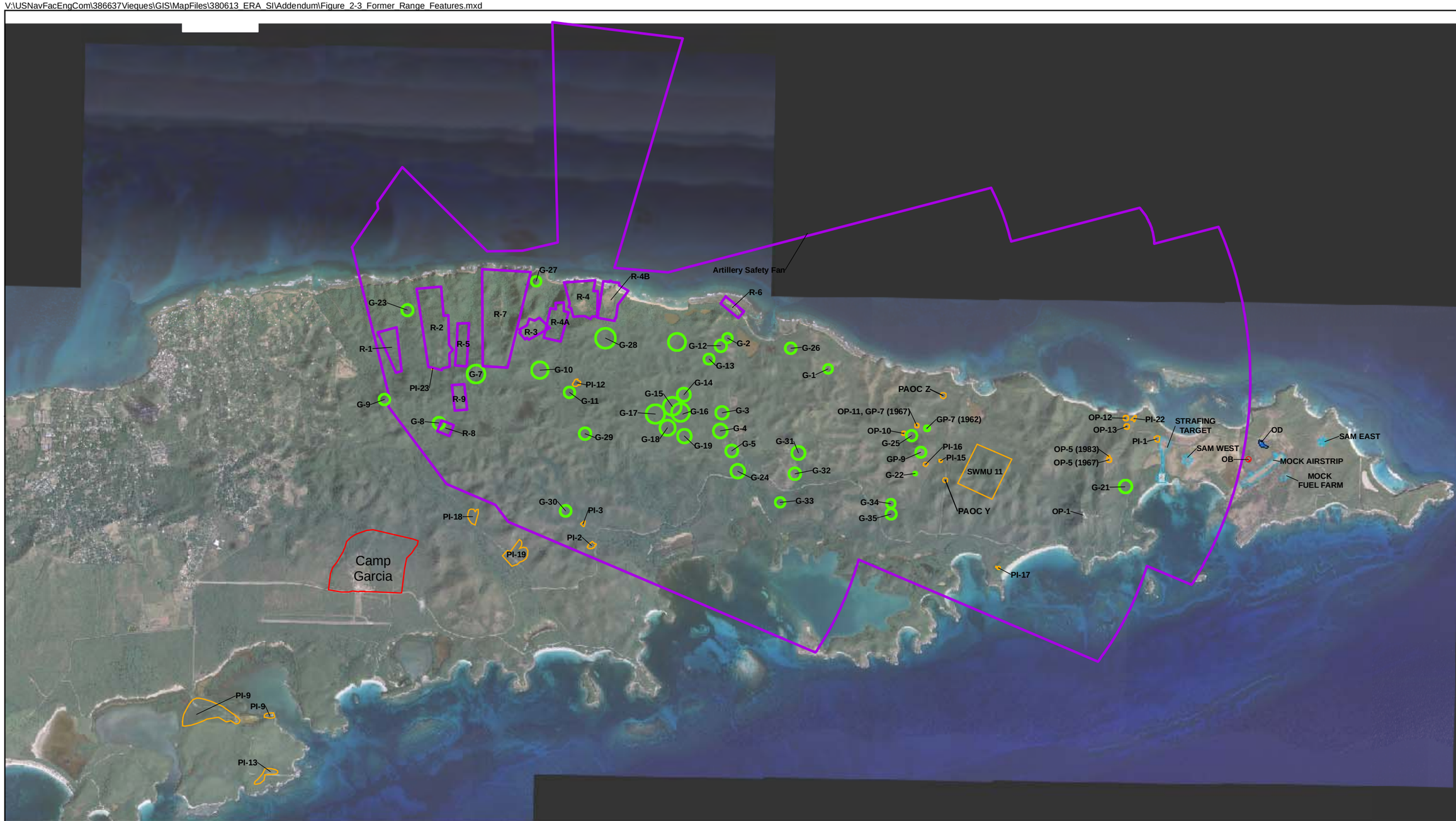

Legend

- Gun Positions
- Range Safety Fan
- Camp Garcia
- Site Screening Areas - Munitions Response Sites
- OB - Open Burn
- Open Detonation Area
- Open Detonation Pits
- Target Features

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0 2,250 4,500 9,000
Feet

Figure 2-3
Former Range Features
Former VNTR, Vieques, Puerto Rico

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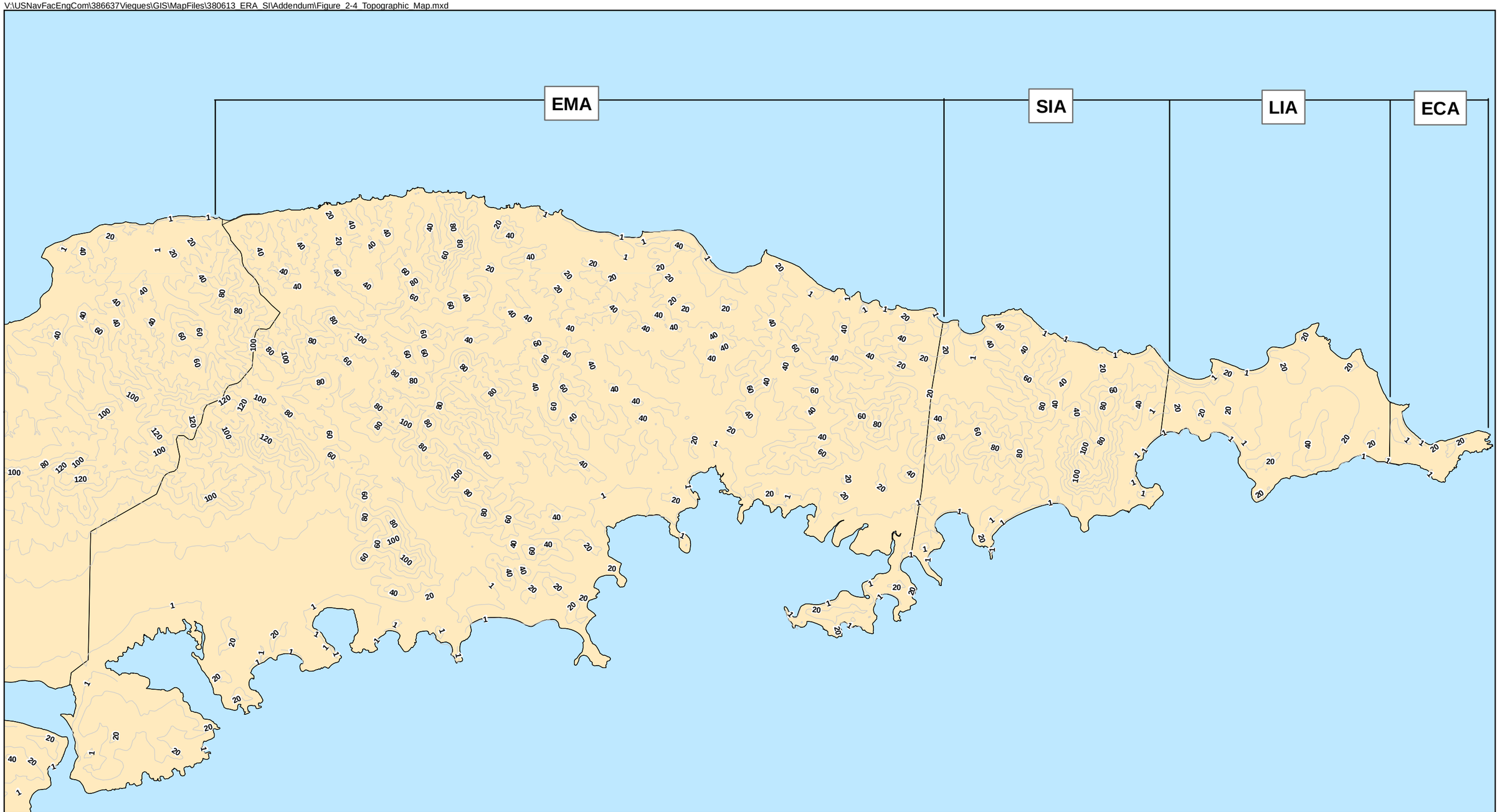

Legend

Elevation Contours (Contour Interval 20 Meters)

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0 2,000 4,000 8,000 Feet

Figure 2-4
Topographic Map
Former VNTR, Vieques, Puerto Rico

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Legend

Turtle Beach Setbacks

- Zone 2 - Minor Restrictions
- Zone 3 - Major Restrictions

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0 2,000 4,000 8,000 Feet

Figure 2-5
Turtle Nesting Areas
Former VNTR, Vieques, Puerto Rico

CH2MHILL

STATION	LATITUDE	LONGITUDE
UPWIND SS-01	18° 8' 06.871296" N	65° 16' 06.756690" W
UPWIND SS-02	18° 8' 5.874789" N	65° 16' 11.547477" W
UPWIND SS-03	18° 8' 04.315938" N	65° 16' 21.887633" W
UPWIND SS-04	18° 8' 01.579221" N	65° 16' 28.838138" W
DOWNWIND SS-01	18° 8' 38.461792" N	65° 18' 49.546102" W
DOWNWIND SS-02	18° 8' 36.313856" N	65° 18' 45.373228" W
DOWNWIND SS-03	18° 8' 38.141333" N	65° 18' 42.286297" W
LIA-SS-01	18° 8' 29.698560" N	65° 18' 25.935388" W
LIA-SS-02	18° 8' 22.828222" N	65° 18' 23.590350" W
LIA-SS-03	18° 8' 23.215382" N	65° 18' 26.161354" W
LIA-SS-04	18° 8' 17.749996" N	65° 18' 24.024484" W
LIA-SS-05	18° 8' 12.263951" N	65° 18' 25.338714" W
LIA-SS-06	18° 8' 12.463880" N	65° 18' 21.482404" W
LIA-SS-07	18° 8' 09.833158" N	65° 18' 10.766270" W
LIA-SS-08	18° 8' 09.498812" N	65° 18' 06.059872" W
LIA-SS-09	18° 7' 50.032634" N	65° 17' 47.264684" W
LIA-SS-10	18° 8' 27.034388" N	65° 17' 23.398177" W
LIA-SS-11	18° 8' 25.131000" N	65° 17' 19.804051" W
LIA-SS-12	18° 7' 54.815964" N	65° 17' 48.162572" W
LIA-SS-13	18° 8' 09.706393" N	65° 17' 24.276525" W
LIA-SS-14	18° 8' 24.996794" N	65° 18' 08.853806" W
LIA-SS-15	18° 8' 30.793317" N	65° 18' 20.665300" W
LIA-SS-16	18° 8' 23.881495" N	65° 18' 09.916331" W
LIA-SS-17	18° 8' 31.496769" N	65° 17' 34.256476" W
LIA-SS-18	18° 8' 22.647411" N	65° 17' 29.121910" W
LIA-SS-19	18° 8' 30.166172" N	65° 17' 46.708450" W
LIA-SS-20	18° 8' 38.920481" N	65° 18' 38.401139" W
LIA-SS-21	18° 8' 19.265777" N	65° 17' 27.145397" W
LIA-SS-22	18° 8' 12.860268" N	65° 17' 40.376391" W
LIA-SS-23	18° 8' 13.161953" N	65° 17' 41.534415" W
LIA-SS-24	18° 8' 07.757835" N	65° 17' 45.954842" W
LIA-SS-25	18° 8' 08.501849" N	65° 17' 45.323852" W
LIA-SS-26	18° 8' 07.086850" N	65° 17' 44.330560" W
LIA-SS-27	18° 8' 14.892437" N	65° 17' 26.306603" W
LIA-SS-28	18° 7' 50.971816" N	65° 17' 27.668832" W
LIA-SS-29	18° 7' 50.852355" N	65° 17' 33.458931" W
LIA-SS-30	18° 7' 42.001624" N	65° 17' 45.396380" W
LIA-SS-30	18° 7' 56.703667" N	65° 17' 07.691201" W

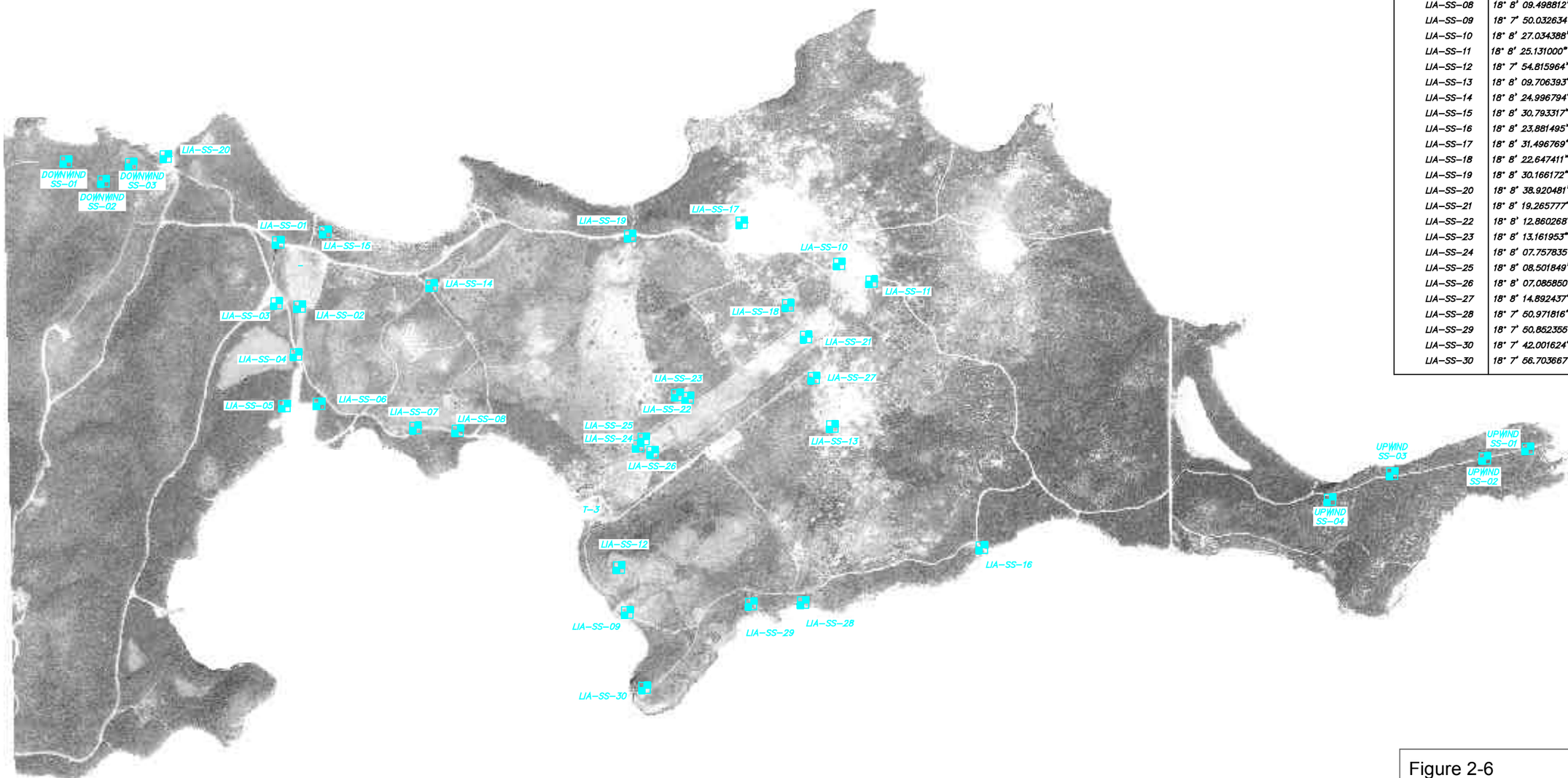


Figure 2-6
Historical Surface Sampling
at the former SIA, LIA, and ECA
Former VNTR, Vieques Puerto Rico

SECTION 3

Summary of Field Investigation Procedures

This section provides details of the investigation actions carried out to complete the ERA/SI. The results of the investigation are presented in Section 4 of this document.

The ERA/SI for the former VNTR was conducted in two Work Plan phases (CH2M HILL, 2004c; 2006b). An amendment to the November 2006 plan was developed to include additional investigation activities (CH2M HILL, 2008a). Multiple mobilizations of field personnel and equipment were required due to the varying activities conducted and the time required to conduct all the activities. The following are the time frames for the various investigation activities:

- **January 2005–June 2005:** Transect inspections and magnetometer survey (mag and flag) at UXO Sites 4, 9, 10, 12, 13.
- **July 2005:** LiDAR and collection of high resolution orthophotography.
- **January 2007:** October 2007: DGM
- March 2008–June 2008 and October 2008 – August 2009: Transect inspections at UXO Sites 9, 10, 12, 13, 14.
- **November 2008–December 2008:** AMS

The following describe the specific field investigation procedures and **Figure 3-1** shows the locations for the various investigation activities. The general field activities that were conducted during the ERA/SI include:

- Transect Inspections—Ground-based detector aided visual transect inspections of "interior" site locations to identify MEC, munitions debris (MD), and range related debris (RRD) present on the ground surface.
- Magnetometer Survey—"Mag and flag" to determine relative densities of subsurface metallic anomalies.
- LiDAR survey
- Collection of high resolution orthophotography
- DGM of road and beach areas
- Aerial Magnetometer Survey

The initial SI of UXO 4 identified a high density of munitions items that would pose a high explosive (HE) safety hazard to United States Fish and Wildlife Service (USFWS) workers and trespassers into the area. Based on this information, a TCRA for the surface removal of MEC was initiated for UXO 1 and UXO 4. As a result, all of UXO 1 and western portion of UXO 4 proposed for investigation (CH2M HILL, 2006a; 2004c) were not completed as part of

the ERA/SI. The TCRA (CH2M HILL, 2005) was initiated prior to the completion of the ERA/SI and provided the data needed to complete the ERA/SI.

Following the initial transect inspections of UXO Sites 9 and 10, significant surface MEC contamination was found and subsequently a NTCRA to remove surface MEC (CH2M HILL, 2009) was implemented. The NTCRA is currently in progress and provides the data needed to complete the ERA/SI. As a result, the transect inspection for the entire 10 percent of the surface area for these sites was not completed.

3.1 Transect Inspections

Inland areas of the former VNTR were assessed using a ground based transect approach. UXO personnel traversed the designated areas to visually inspect the ground surface to identify any MEC, MD, or RRD present. The visual inspection was aided with the use of a handheld magnetometer (Schondstedt® GA-52CX) to locate metallic items that were present on the surface, but were either too small to be recognized or obscured by surface debris (e.g., vegetation).

During the first mobilization vegetation was cleared mechanically in some areas where needed, but during subsequent mobilizations any vegetation clearance required was conducted using hand tools. In most cases a minimum amount of vegetation was cleared to allow the field personnel to access the transects.

The area covered using the transect approach varied between locations. The area of coverage planned was either 5 percent or 10 percent depending on the site. Actual areas surveyed ranged from 2 percent to 11 percent. Transect widths were variable from site to site and were dependent upon the distribution of anticipated MEC, topography (terrain), and vegetation density; the estimated average transect width was 5 feet. In most cases the personnel conducting the transect evaluation could effectively visually survey the ground with the aid of the magnetometer. The specific transect paths were recorded during investigation efforts subsequent to the 2005 mobilization.

When MEC, MD, or RRD were located during the survey the location of the item was recorded as well as a description of the item. Photographs were taken of unique items and the following data points were collected when an item was located:

- Item Identification (ID), given a unique identifier
- Item Group (MD, UXO, RRD)
- Item Class (e.g., bomb, grenade)
- Item Category (e.g., 5-inch projectile, 81 millimeter [mm] mortar)
- Filler Type (if known)
- Fuzed/Unfuzed (if known)
- Quantity of Items
- Weight of Item(s) (not collected during 2005 mobilization)
- Date Found
- Grid Cell (not collected during 2005 mobilization)
- X Coordinate
- Y Coordinate

Figure 3-1 shows the areas where transect inspections were conducted.

In conjunction with the transect inspections a handheld magnetometer survey of the sandy beach areas was conducted to qualitatively assess the subsurface density of metallic items. During the survey the UXO personnel walked lanes for a given beach area while monitoring the subsurface with a handheld magnetometer (Schondstedt® GA-52CX). The field teams traversed the beaches using 5-ft wide lanes from the beach high water line at the time of the investigation to where the vegetation cover as too thick to gain access on foot without the aid of vegetation clearing. Responses from the magnetometer were recorded as high, medium, or low based on the operator's judgment. The locations of the responses were flagged with a pin flag and the locations geographic coordinates were recorded.

3.2 LiDAR and High Resolution Orthophotography

A high-elevation aerial LiDAR survey was conducted and high resolution color orthophotography was collected for approximately 15,000 acres of the former VNTR (**Figure 3-2, Appendix A)**. **Appendix C** presents the Post Collection Report (Sky Research, Inc., 2005) including the specific procedures and equipment utilized for the survey and orthophotography.

The LiDAR data collected at the site was used to create a bare earth digital elevation model to attempt and identify ordnance-related ground features such as bomb craters and target areas, which may indicate the presence of MEC. **Figure 3-3** presents the UXO sites and the LiDAR bare earth model. The orthophotography was used for direct detection and visualization of any ordnance-related features. These technologies were employed to determine areas potentially impacted by MEC and to be used in conjunction with ground truthing for potential footprint reduction.

3.3 Digital Geophysical Mapping

As part of the NTCRA, DGM was conducted along the roads and beaches at UXO Sites 1, 2, 3, 5, 6, 7, 8, and 11. The areas where the DGM was conducted are shown on **Figure 3-4.** The DGM was conducted to collect quantitative data on subsurface anomalies as part of the investigation of these areas and to support a planned subsurface removal action for the roads and beaches at the former VNTR (CH2M HILL, 2008b). **Table 3-1** presents the anomaly density found during the DGM by UXO site.

Appendix D provides the details of the approach utilized for collecting subsurface geophysical data at the sites. In general subsurface geophysical data was collected using electromagnetics (EM) because non-ferrous items are known to be present at the site. To evaluate the performance of the equipment a geophysical prove-out (GPO) and instrument verification strip were utilized.

The main method of surveying was the EM61-MK2 in tandem mode configuration using real-time kinetic (RTK) global positioning system (GPS). However, different configurations (wheel mode) and positioning methods (remote tracking station [RTS] or tape measures with ropes and fiducial markers) were used to achieve the best quality data. The configuration was chosen based on the terrain.

TABLE 3-1
Number of Subsurface Anomalies Identified at Each UXO Site

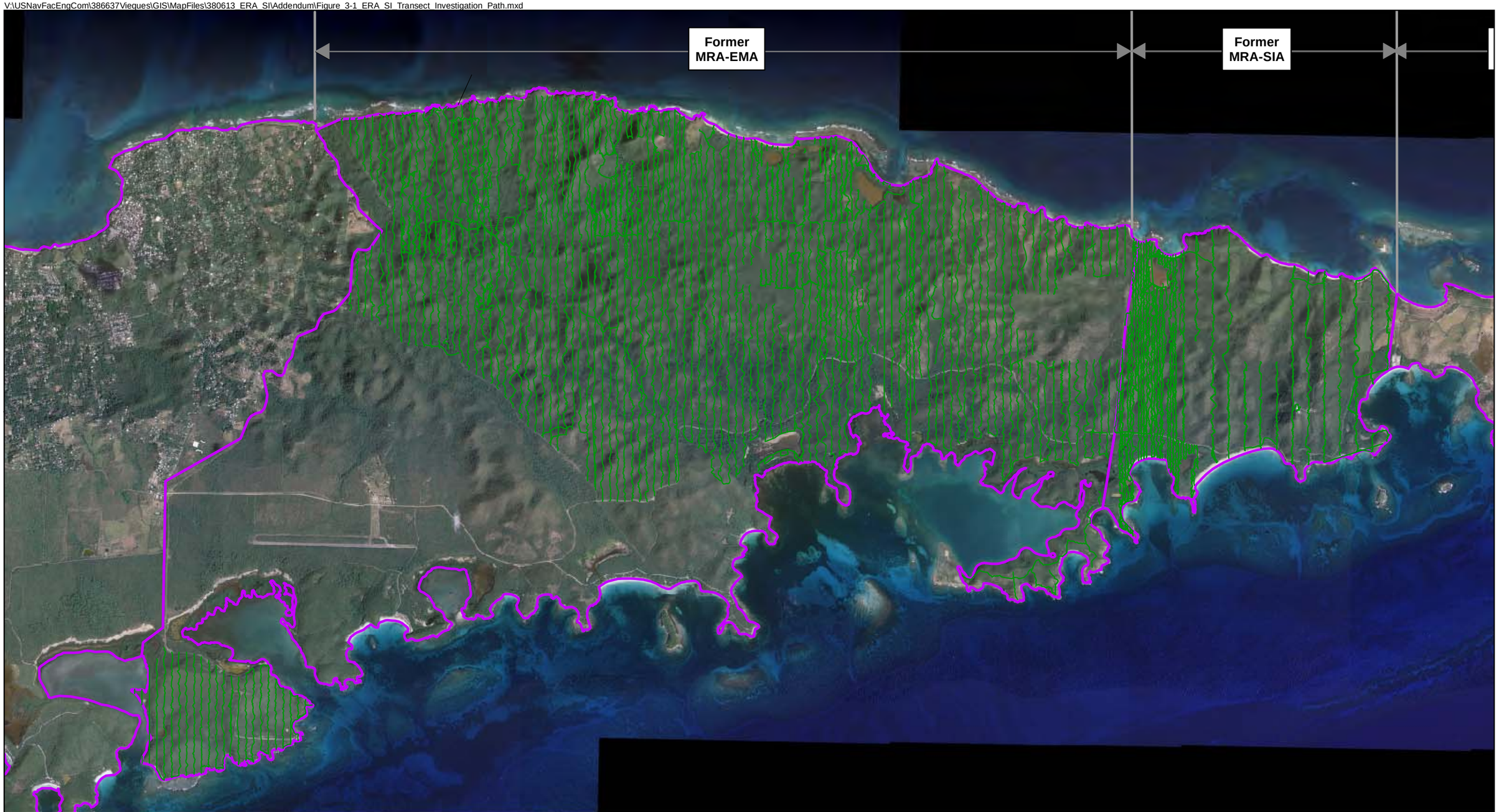
UXO	Number of Anomalies	Number of Anomalies Excavated Through May 2010
1	1515	564
2	13403	3577
3	14060	10
4	16509	2296
5	5836	25
6	258	0
7	2379	661
8	1250	0
9	3310	1297
10	0	0
11	1502	28
12	0	0
13	0	0
14	0	0
15	0	0
16	0	0
17	73	73

3.4 Aerial Magnetometer Survey

An AMS was completed over approximately 15,000 acres of the former VNTR. The survey was conducted using a helicopter equipped with an array of seven magnetometers. Transects spaced approximately 7 meters apart were flown over survey area at an altitude typically ranging from 5 to 10 meters. Although the AMS was conducted properly, site conditions with respect to the geologic response and survey altitude presented limitations on the data interpretation. The survey was also conducted in in shallow water and near-shore areas where altitudes ranging less than 10 meters could be maintained. This analysis identified 46 areas where the AMS identified large clusters/groupings of magnetic anomalies referred to as Elevated Anomaly Density Areas (EADAs). Ground inspections of the EADAs will further refine and or improve the AMS data. **Appendix E** provides details regarding the results and the approach utilized for the AMS.

The intent of the AMS was to identify areas containing high densities of ferrous metallic objects on the surface and/or subsurface. At the former VNTR, the presence of ferrous metallic objects in high densities is suggestive (unless explained by known sources such as buildings or utility-related structures), of an AOI that might contain MEC.

V:\USNavFacEngCom\386637Vieques\GIS\MapFiles\380613_ERA_SI\Addendum\Figure_3-1_ERA_SI_Transect_Investigation_Path.mxd



Legend
- Transect
- Vieques Boundary Sections

Note:
Transect paths were recorded subsequent to the 2005 investigation

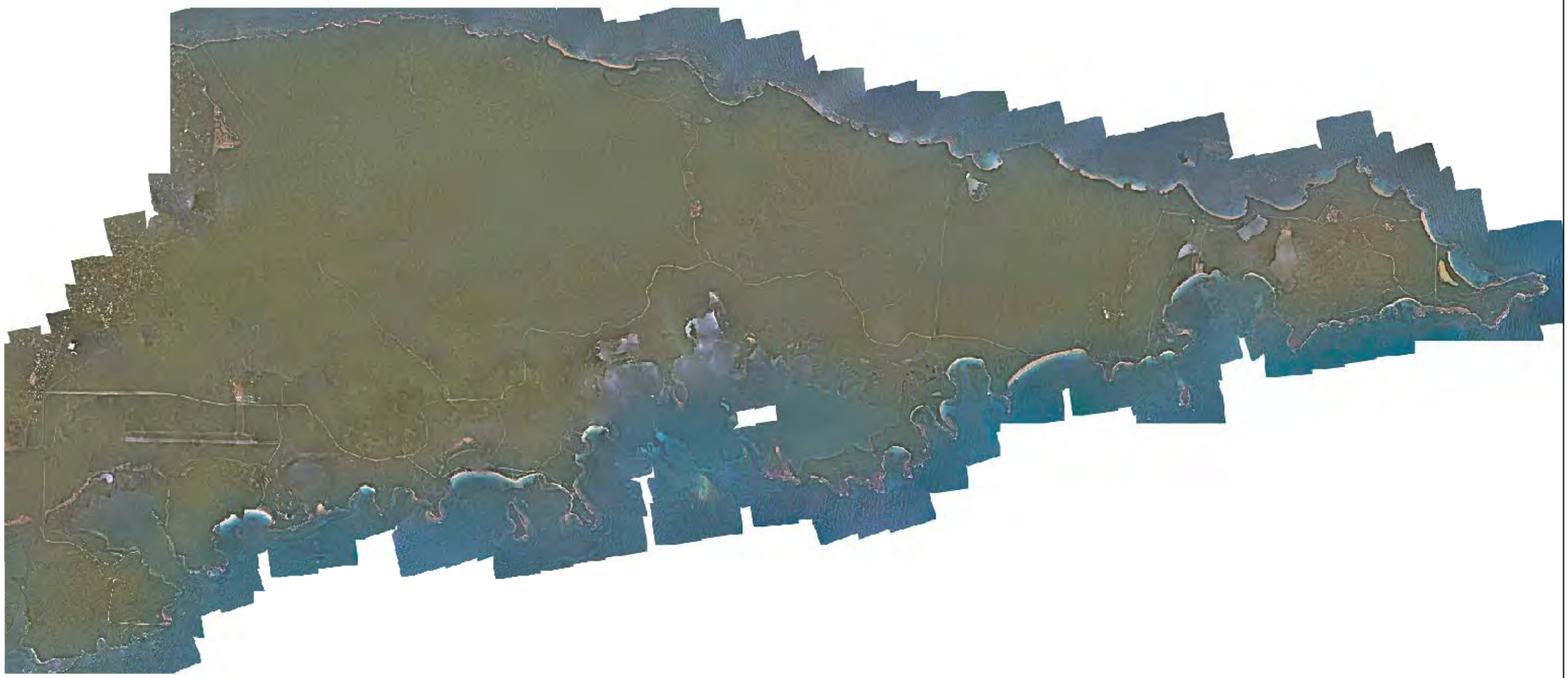
N
W E
S

0 1,750 3,500 7,000
Feet

Figure 3-1
ERA/SI Transect Investigation Paths
Former VNTR, Vieques, Puerto Rico

CH2MHILL

V:\USNavFacEngCom\386637Vieques\GIS\MapFiles\380613_ERA_SI\Addendum\Figure_3-2_Orthophotography_of_the_Former_VNTR.mxd



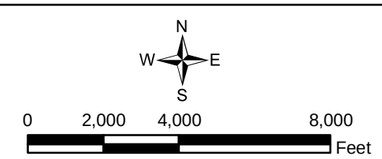


Figure 3-2
Orthophotography of the Former VNTR
Former VNTR
Vieques, Puerto Rico

CH2MHILL

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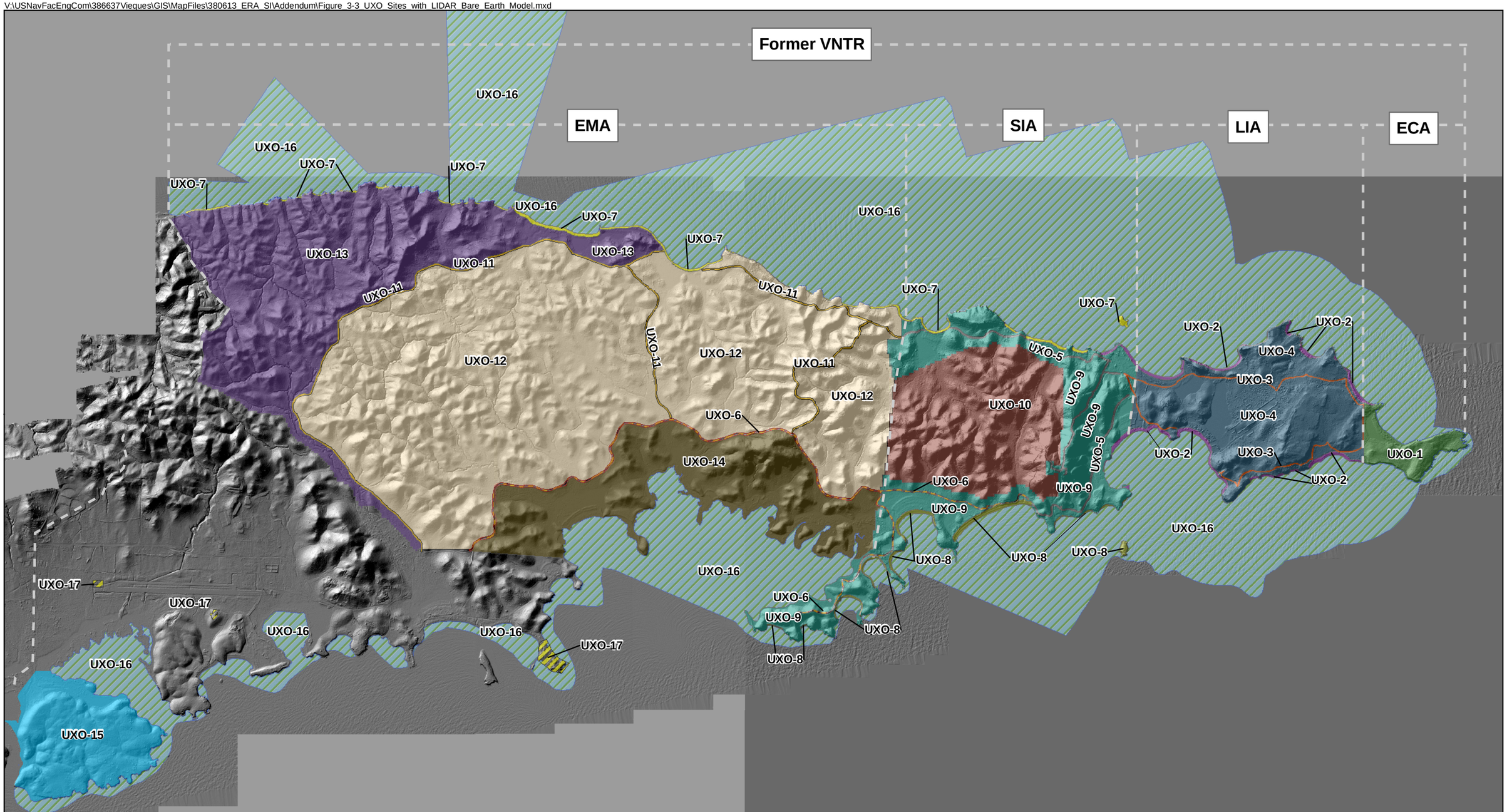

Legend

- UXO-1 - Eastern Conservation Area
- UXO-2 - LIA Beaches
- UXO-3 - LIA Roads
- UXO-4 - LIA Interior
- UXO-5 - SIA Restricted Roads
- UXO-6 - EMA/SIA Public Roads
- UXO-7 - EMA/SIA North Beaches
- UXO-8 - SIA South Beaches
- UXO-9 - SIA Exterior
- UXO-10 - SIA Interior
- UXO-11 - EMA Public Roads
- UXO-12 - EMA Interior
- UXO-13 - EMA West
- UXO-14 - EMA South
- UXO-15 - Puerto Ferro
- UXO-16 -Underwater Areas
- UXO-17 - Other Sites (PI-14, PAOC-EE, PAOC-FF)

N
W E
S

0 2,000 4,000 8,000
Feet

Figure 3-3
UXO Sites with LiDAR Bare Earth Model
Former VNTR
Vieques, Puerto Rico

CH2MHILL

V:\USNavFacEngCom\386637Vieques\GIS\MapFiles\380613_ERA_SI\Addendum\Figure_3-4_DGM_Survey_Areas.mxd

Legend

Digital Geophysical Mapping Area

N
W E
S

0 2,000 4,000 8,000
Feet

Figure 3-4
Digital Geophysical Mapping Area
Former VNTR, Vieques, Puerto Rico

CH2MHILL

SECTION 4

UXO 1—Eastern Conservation Area

4.1 Background

UXO 1, formerly referred to as the ECA, encompasses 125 acres on the eastern end of Vieques (**Figure 2-2**), and was not an operational area for munitions use. UXO 1 includes the interior land area, roadway, and turtle nesting beaches. The turtle nesting beaches are shown on **Figure 2-5**. However, its close proximity to UXO Sites 2, 3, and 4, where extensive NGF and air-to-ground (ATG) bombing took place, identifies UXO 1 as a potential area for MEC impacts. In addition, the OB/OD area within UXO 4 generated an explosive safety arc that extended into UXO 1.

4.2 ERA/SI Findings

4.2.1 TCRA/NTCRA Summary

As stated in Section 3, the TCRA of the LIA and was amended to include the ECA (CH2M HILL, 2006a).The TCRA (CH2M HILL, 2005) for UXO 1 was initiated prior to the completion of the ERA/SI. The objective of the TCRA was to remove surface MEC; therefore, surface MEC information was collected as part of the TCRA removal activities. The field removal activities of the TCRA have been completed at UXO 1. The types of surface MEC removed from the ECA during the TCRA are summarized in **Table 4-1** and the distribution is illustrated on **Figure 4-1.** The approximate density of MEC items removed decreased from 10.5 items per acre at the western portion of the site to 4.5 items per acre for the eastern portion of the site.

As part of the ongoing NTCRA of the Roads and Beaches, DGM was conducted for 2.5 acres of roadway, sandy beach areas, and turtle nesting buffers at Playa Blanca/Beach 15 and Beach 16 in UXO 1. The anomaly density collected during the DGM at UXO 1 is presented on **Figure 4-2**. A total of 1,515 anomalies were detected for the areas mapped (**Table 3-1).** As indicated in **Table 4-1**, over 1,300 surface and subsurface MEC items have been removed from UXO 1 through May 2010.

4.2.2 Transect Inspections

A handheld magnetometer survey, as described in **Section 3,** was conducted for the sandy beach areas of UXO 1 (Playa Blanca/Beach 15, Beach 16). The results identified a number of subsurface anomalies at the beach areas of UXO 1. The hand -held magnetometer responses are shown on **Figure 4-3.**

TABLE 4-1
Summary of MEC Items Identified at UXO 1

	Number of Surface Items Identified During TCRA/ NTCRA through May 2010	Number of Subsurface Items Identified through May 2010
MEC Items		
Bombs	22	1
Flares-Pyrotechnics	17	--
MEC Component	45	1
Projectiles / Mortars	1086	1
Rockets / Guided Missiles	130	1
Sub munitions	6	--
MD		
Scrap	764	20
Range Related Debris		
Scrap	10,514	1,164

4.2.3 Aerial Mapping Results

The LiDAR survey identified craters within the UXO 1 site boundary along the eastern boundary adjacent to UXO 4, which is consistent with historical activities conducted in UXO 4. The orthophotography (**Figure 3-2**) shows craters in the lagoon along the western end of the site that are potentially related to historical military activities at the site.

Figure 4-3-presents the EADAs from the AMS along with results from the hand-held magnetometer survey conducted during the transect inspections. The results of the AMS identified EADA 19 with a moderate anomaly density (5 to 10 anomalies per acre) detected on the eastern half of UXO 1 with an increase to a high density of detections (greater than 10 anomalies per acre) approaching the border of UXO 4. Because the TCRA for UXO 1 began in August 2008 and surface MEC removal activities were completed before the AMS survey took place, the anomalous areas are likely associated with the subsurface.

4.2.4 Summary of Findings

The results of the ERA/SI for UXO 1 indicate that the munitions activities at the former LIA extended over into the ECA, over 1,300 MEC items were identified and removed from UXO 1 during the TCRA. The density of the MEC items decreases from west to east within UXO 1. In addition, the DGM and AMS geophysical survey results indicated that subsurface anomalies remain in UXO 1.

4.3 Recommendations

Surface and subsurface MEC have been removed from UXO 1 as part of the TCRA and NTCRA (interim removal actions). Continued removal of subsurface MEC at the beaches and roads at UXO 1is recommended as part of a NTCRA. Following the completion of the TCRA and NTCRAs a Remedial Investigation/Feasibility Study (RI/FS) should be completed to assess the potential impacts from the MEC on human health and the environment.

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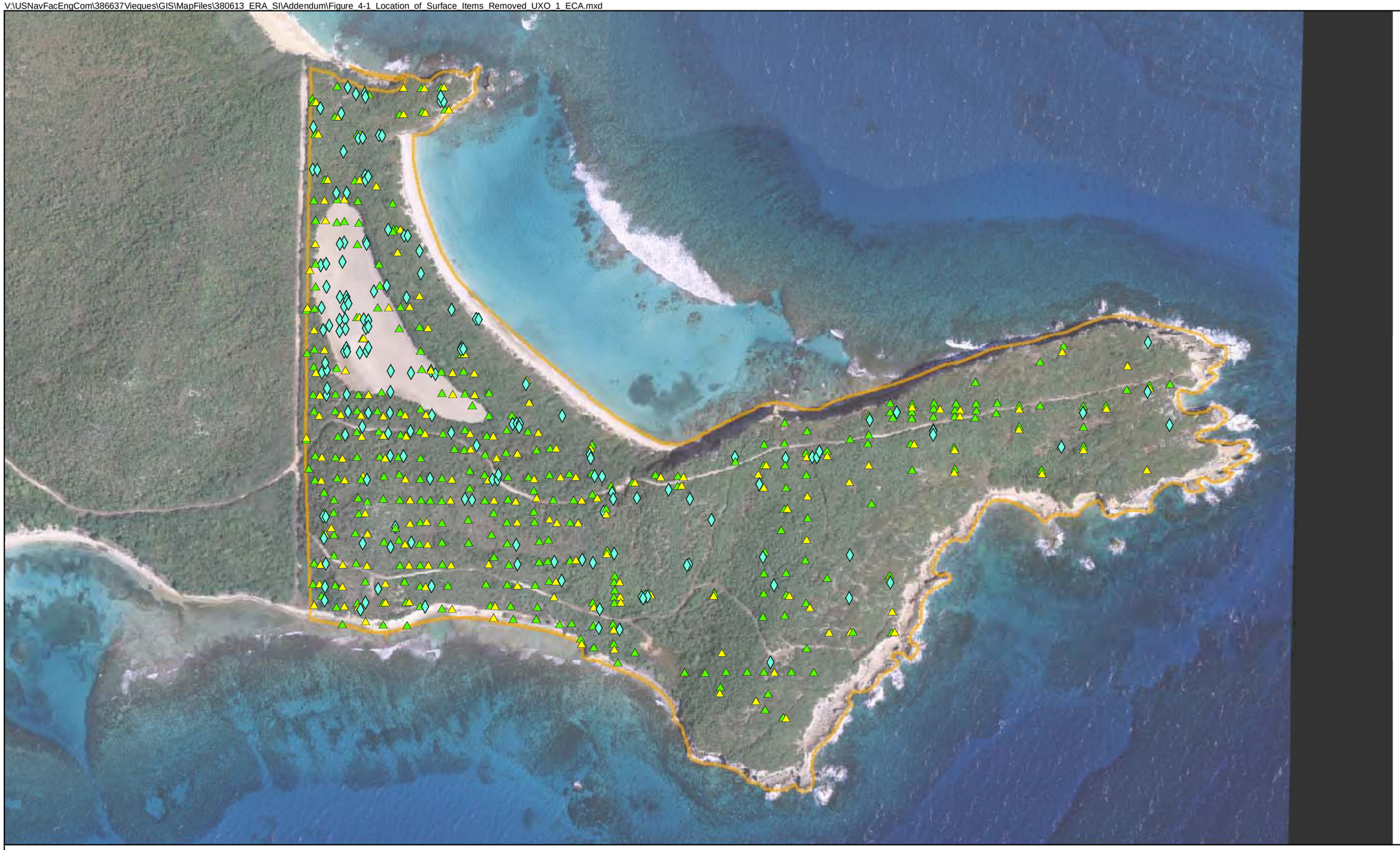

Legend

- Range Related Debris
- Munitions Debris
- Material Potentially Presenting an Explosive Hazard
- UXO Site

N
W E
S

0 225 450 900
Feet

Figure 4-1
Location of Surface MEC Items Removed UXO 1, ECA
Former VNTR, Vieques, Puerto Rico

CH2MHILL

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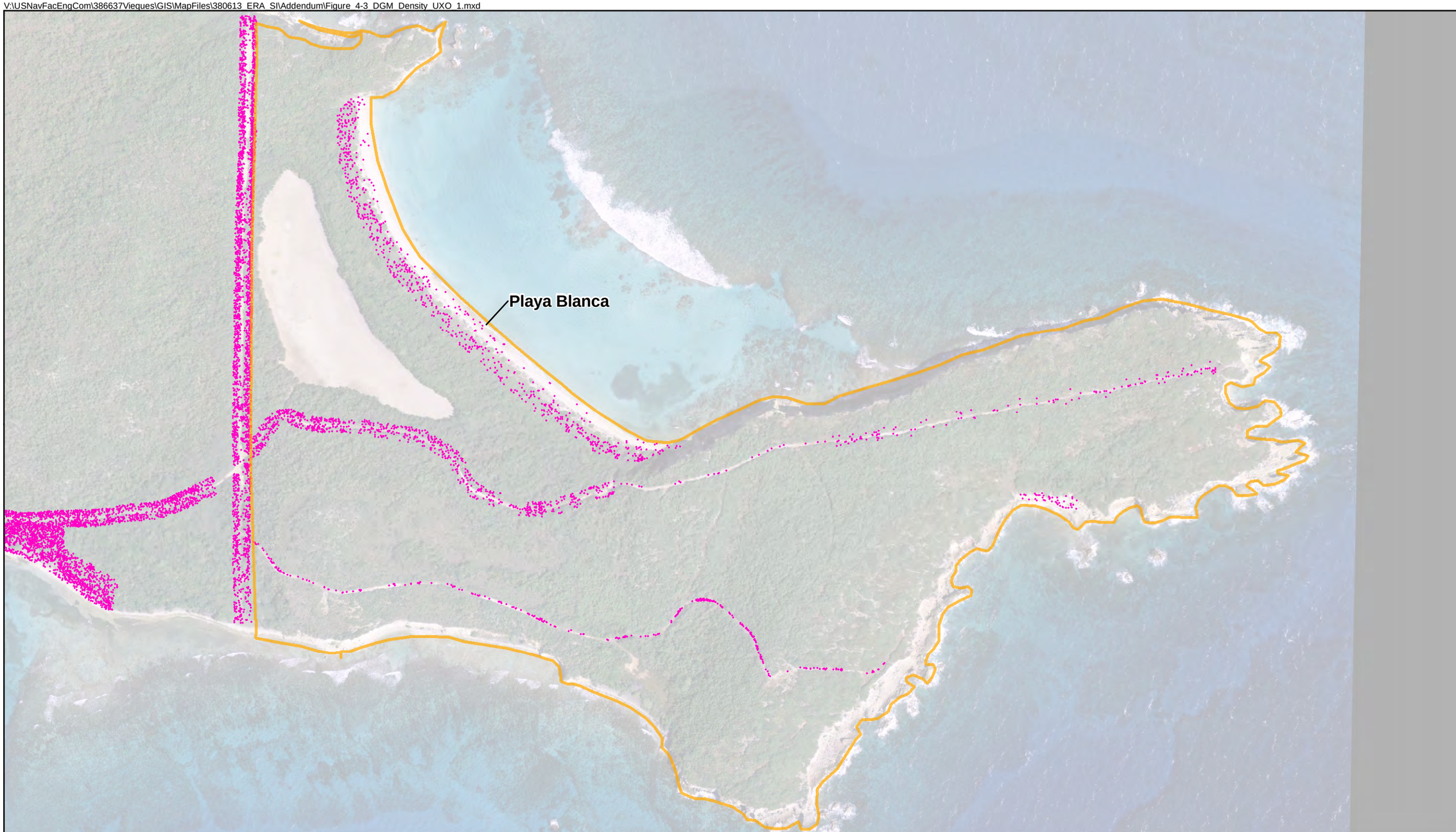

Legend
- DGM Anomaly
- UXO Site

N
W E
S

0 200 400 800
Feet

Figure 4-2
DGM Density UXO 1
Former VNTR, Vieques, Puerto Rico

CH2MHILL

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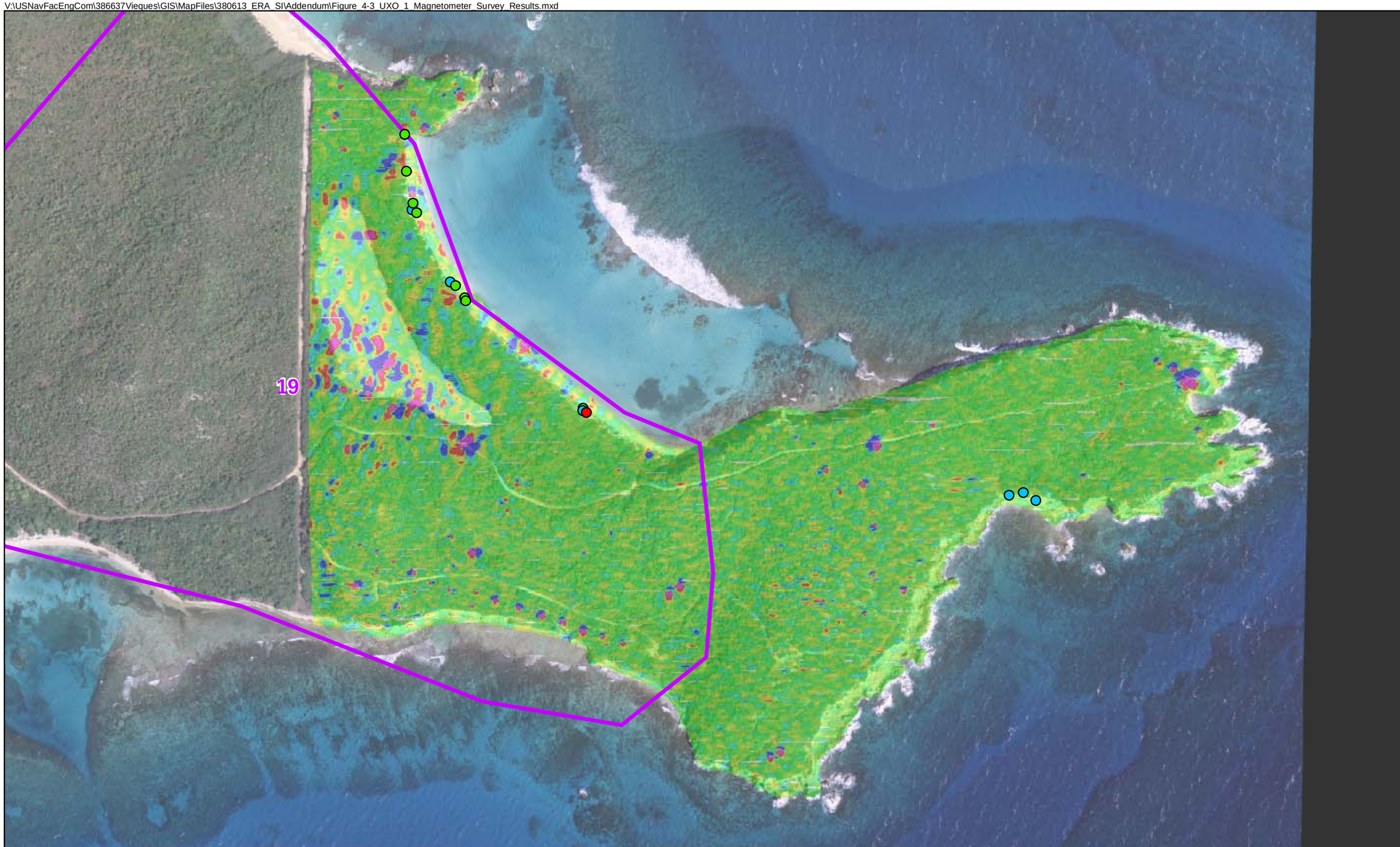

Legend

Magnetometer Response from "Mag and Flag"

- Low
- Medium
- High
- EADA

Aerial Magnetometer Survey Total Magnetic Field

-4.6 -2.3 0.0 1.9 3.8 5.8 7.7 9.6

N
W E
S

0 225 450 900
Feet

Figure 4-3
UXO 1 Magnetometer Survey Results
Former VNTR, Vieques, Puerto Rico

CH2MHILL

SECTION 5

UXO 2—LIA Beaches

5.1 Background

UXO 2 encompasses approximately 58 acres of beaches along the perimeter of the LIA. UXO 2 is further defined as the sandy beach areas extending from the waterline to the inland extent of turtle nesting habitats, as described in the *Final Biological Assessment for the Former Live Impact Area* (GMI, 2006). Beaches located in UXO 2 include: Playa Yallis, Playa Salinas Norte, Playa Brava, Playa Barco, Playa Tamarindo, Playa Carrucho, and Playa Salinas del Sur. There are four additional beaches that have no known historical names included in UXO 2; for tracking and identification purposes these beaches are numbered 11, 13, 34, and 35. **Figure 2-5** shows the beaches that make up UXO 2 with the inland extent of turtle nesting habitat.

For additional information and site history, including historical military use, see the UXO 4 site description in **Section 7**.

5.2 ERA/SI Findings

5.2.1 TCRA/NTCRA Results

The locations of surface MEC removed from UXO 2 during the TCRA are presented on **Figure 5-1**. In June 2009 the field activities for a NTCRA (interim action) were initiated for UXO 2 (CH2M HILL, 2008b). As of May 2010, over 1000 surface and subsurface MEC items have been removed from UXO 2. The types of surface and subsurface MEC removed from UXO 2 during the TCRA and NTCRA are presented in **Table 5-1**.

As part of the NTCRA for the Roads and Beaches a DGM survey was conducted for 28.5 acres of the sandy beach areas and turtle nesting buffers in UXO 2. A total of 13,403 subsurface anomalies were detected during the DGM survey. The highest densities of anomalies detected on any beach in the former VNTR were identified in UXO 2. The distribution of anomalies identified during the DGM survey at UXO 2 is presented on **Figures 5-2 through 5-6.**

5.2.2 Transect Inspections

Prior to the implementation of the TCRA, transect surveys were conducted at the sandy beach areas within UXO 2 (**Figure 5-7).** Approximately 30 MEC items per acre were found on the beaches of UXO 2 during the transect activities.

TABLE 5-1
Summary of MEC Items identified at UXO 2

	Number of Items Identified during Transects	Number of Items Identified during TCRA/ NTCRA through May 2010	Number of Subsurface Items Identified through May 2010
MEC Category			
Bombs	22	275	382
Flares-Pyrotechnics	--	11	2
Grenades	--	5	--
MEC Component	--	23	2
Projectiles / Mortars	37	131	53
Rockets / Guided Missiles	--	3	5
Sub munitions	1	158	1
MD Category			
Scrap		106,258	3,345
Range Related Debris			
Scrap		20,855	20,023,073

Figure 5-7 shows the locations of the MEC items found during the transect inspections on the beaches. During the surface survey 63 MEC items were identified in UXO 2 consisting of bombs and projectiles.. Sixty-two of these items required demolition and were destroyed in March 2005 because they posed an imminent hazard to trespassers on the beach. The results of the handheld magnetometer responses conducted at UXO 2 beaches areas is presented on **Figure 5-8**.

5.2.3 Aerial Mapping Results

The aerial LiDAR survey of UXO 2 shows evidence of impact craters, specifically concentrated on Playa Yallis (Playa Icacos/Beach 5). **Figure 3-3** presents the bare earth models produced from the LiDAR survey.

The orthophotography mapping **(Figure 3-2)** shows craters visible within UXO 2 in the vicinity of Playa Yallis. **Figure 5-8** presents the AMS results. The AMS identified the following EADAs in UXO 2:

- **EADA 17—**Anomaly densities ranging from less than 5 to 10 anomalies per acre.
- **EADA 18—**Anomaly densities ranging from 5 to greater than 10 anomalies per acre consistent with typical responses from UXO-related activity.
- **EADA 19—**Anomaly densities greater than 10 per acre consistent with typical responses from UXO-related activity.
- **EADA 20—**Large discrete anomalies with an anomaly density of 5 to 10 per acre.

- **EADA 24—**Large discrete anomalies along the shoreline region with an anomaly density of 5 to 10 per acre.

5.2.4 Summary of Findings

The results of the ERA/SI for UXO 2 indicate that the munitions activities at the former LIA included the beaches of the former LIA. The TCRA, NTCRA, and ERA/SI identified over 1,100 MEC items within UXO 2.

5.3 Recommendations

Surface MEC have been removed from UXO 2 as part of the TCRA. The NTCRA to remove subsurface MEC is currently being conducted. Based on findings from the TCRA NTCRA, and ERA/SI, continued removal of subsurface MEC is recommended at UXO 2. In addition, a RI/FS is recommended to assess the potential environmental and explosive safety hazards at UXO 2.

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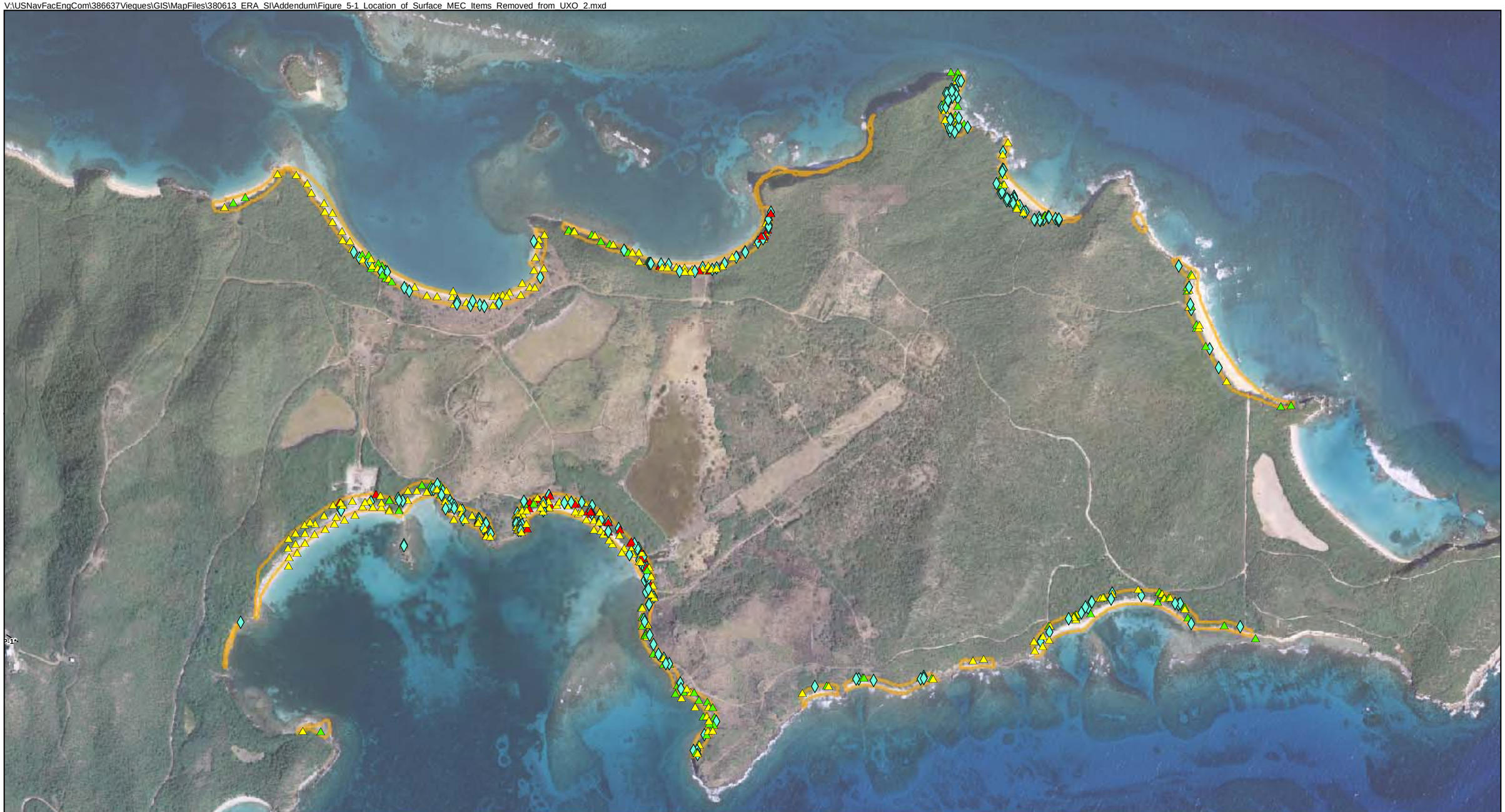

Legend
- Range Related Debris
- Munitions Debris
- Material Potentially Presenting an Explosive Hazard
- Unexploded Ordnance
- UXO Site

N
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S

0 500 1,000 2,000
Feet

Figure 5-1
Location of Surface MEC Items Removed from UXO 2
Former VNTR, Vieques, Puerto Rico

CH2MHILL

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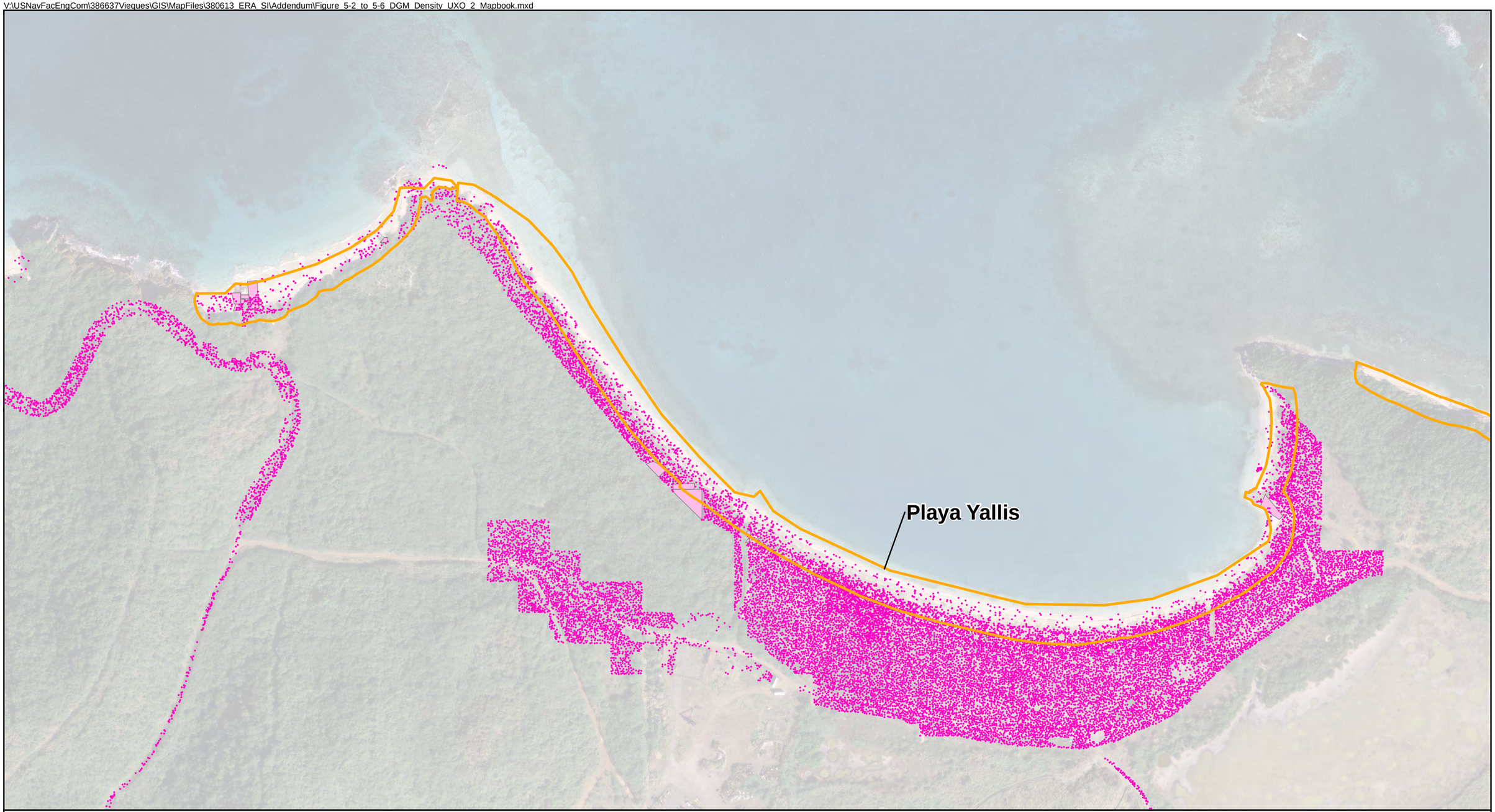
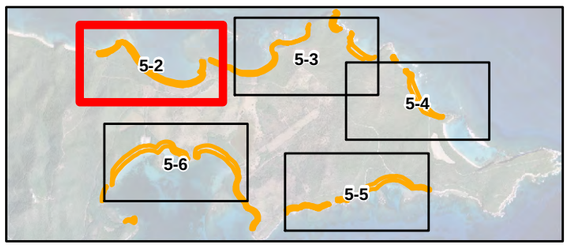


Legend
- DGM Anomaly
- DGM Anomaly Polygon
- UXO Site



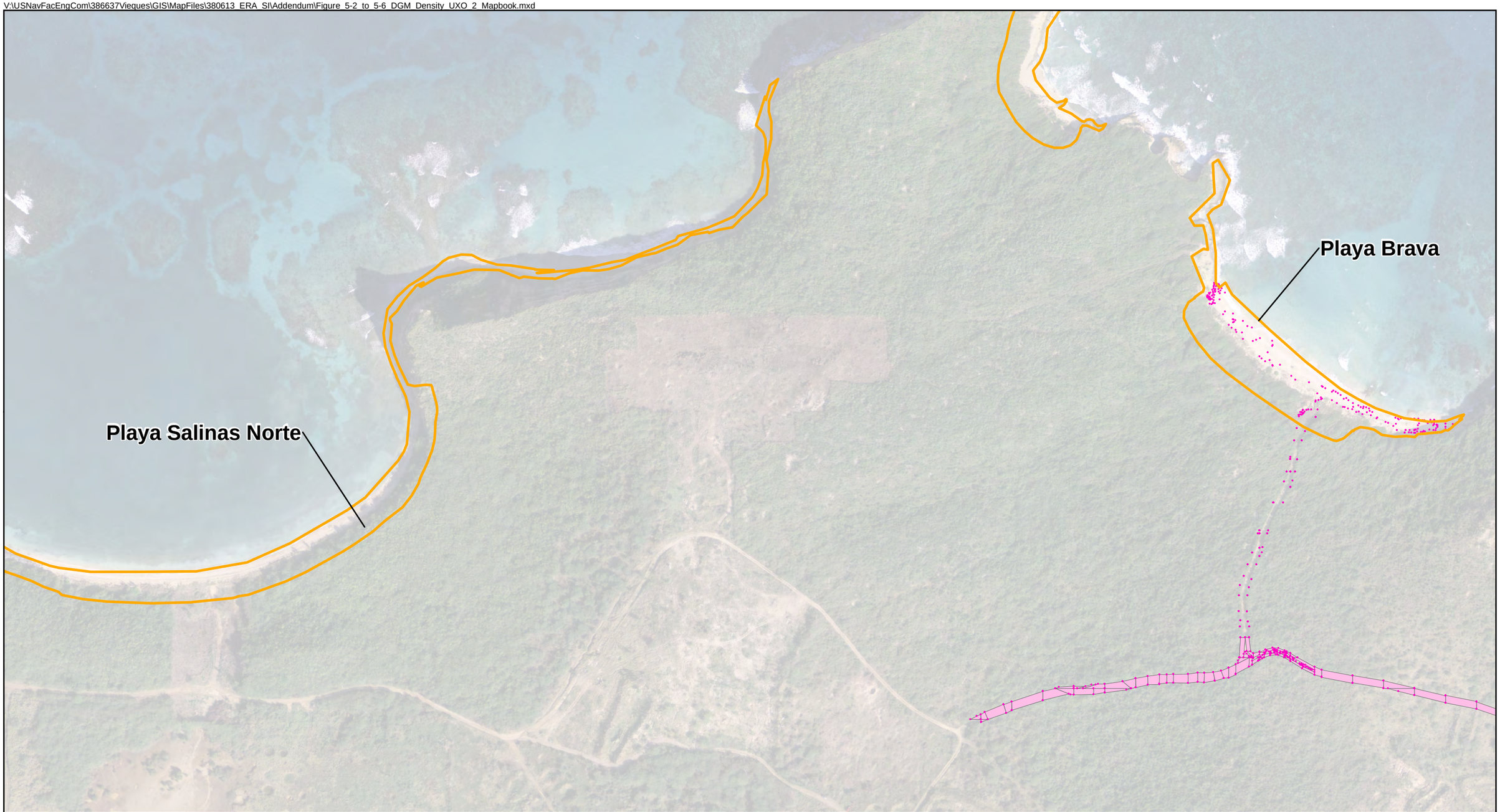
N
W E
S

0 150 300 600
Feet

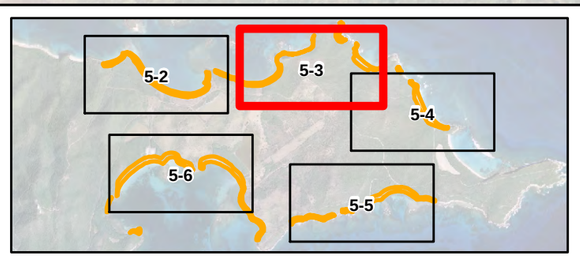
Figure 5-2
DGM Anomaly Density within UXO 2
Former VNTR, Vieques, Puerto Rico

CH2MHILL

V:\USNavFacEngCom\386637Vieques\GIS\MapFiles\380613_ERA_SI\Addendum\Figure_5-2_to_5-6_DGM_Density_UXO_2_Mapbook.mxd



Legend
- DGM Anomaly
- DGM Anomaly Polygon
- UXO Site



N
W E
S

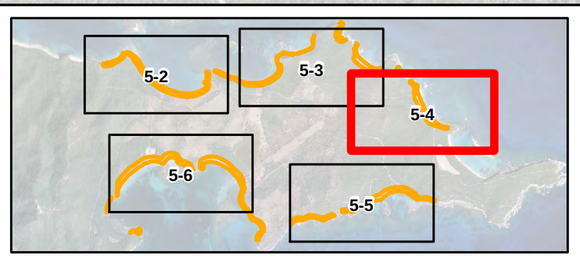
0 150 300 600
Feet

Figure 5-3
DGM Anomaly Density within UXO 2
Former VNTR, Vieques, Puerto Rico

CH2MHILL

V:\USNavFacEngCom\386637Vieques\GIS\MapFiles\380613_ERA_SI\Addendum\Figure_5-2_to_5-6_DGM_Density_UXO_2_Mapbook.mxd

Legend
- DGM Anomaly
- DGM Anomaly Polygon
- UXO Site



N
W E
S

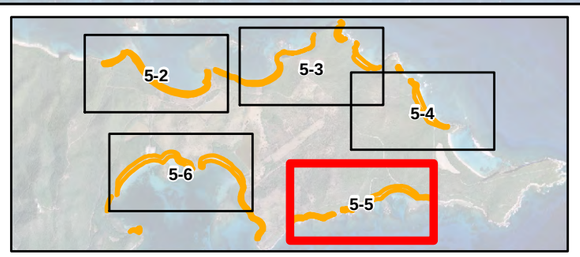
0 150 300 600
Feet

Figure 5-4
DGM Anomaly Density within UXO 2
Former VNTR, Vieques, Puerto Rico

CH2MHILL

V:\USNavFacEngCom\386637Vieques\GIS\MapFiles\380613_ERA_SI\Addendum\Figure_5-2_to_5-6_DGM_Density_UXO_2_Mapbook.mxd

Legend
- DGM Anomaly
- DGM Anomaly Polygon
- UXO Site



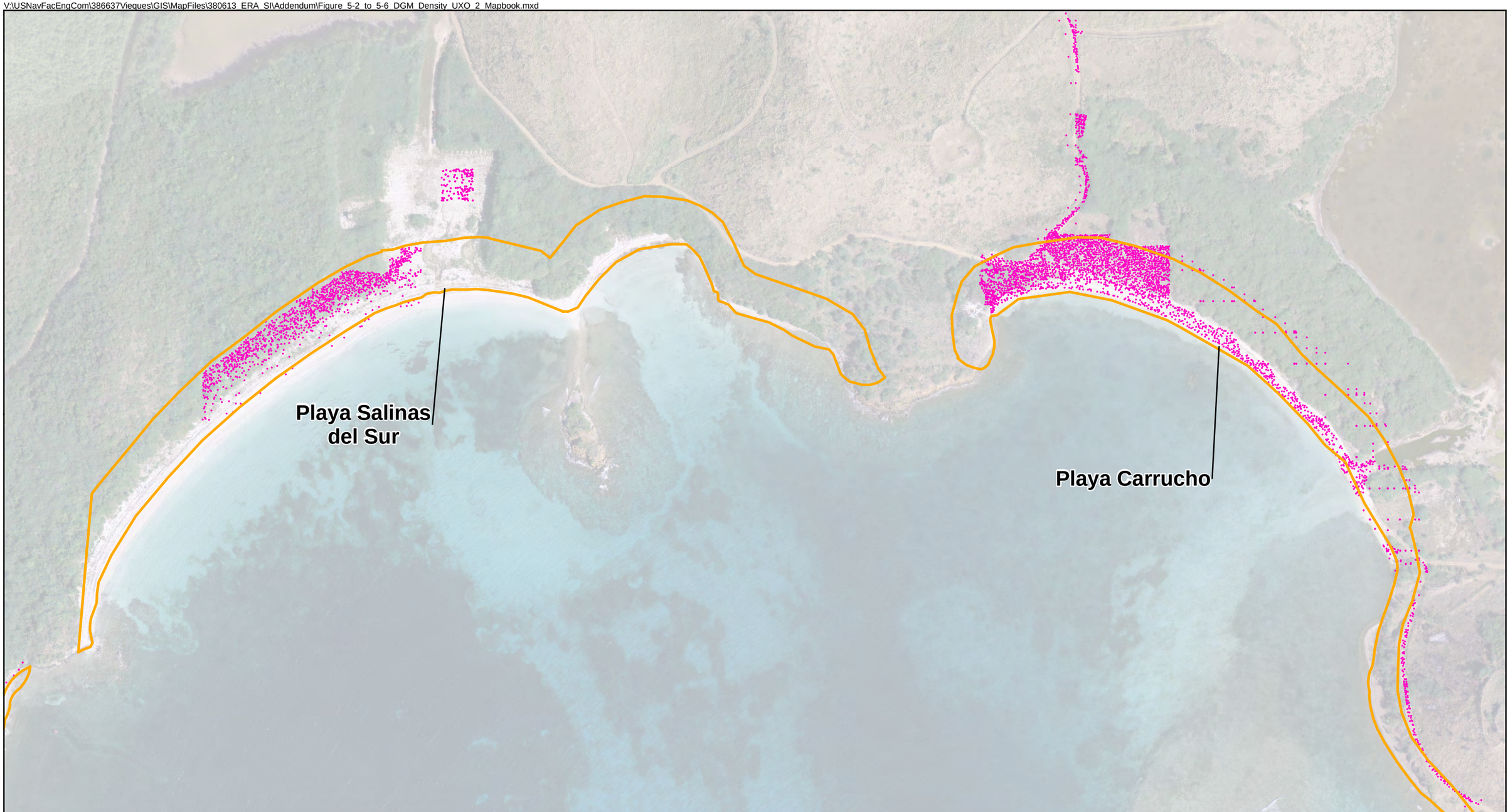
N
W E
S

0 150 300 600
Feet

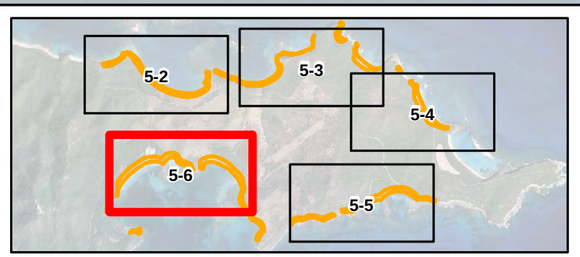
Figure 5-5
DGM Anomaly Density within UXO 2
Former VNTR, Vieques, Puerto Rico

CH2MHILL

V:\USNavFacEngCom\386637Vieques\GIS\MapFiles\380613_ERA_SI\Addendum\Figure_5-2_to_5-6_DGM_Density_UXO_2_Mapbook.mxd



Legend
- DGM Anomaly
- DGM Anomaly Polygon
- UXO Site



N
W E
S

0 150 300 600
Feet

Figure 5-6
DGM Anomaly Density within UXO 2
Former VNTR, Vieques, Puerto Rico

CH2MHILL

V:\USNavFacEngCom\386637Vieques\GIS\MapFiles\380613_ERA_SI\Addendum\Figure_5-7_UXO_2_Transect_Findings.mxd

Legend
- Munitions Debris
- Munitions and Explosives of Concern
- UXO Site

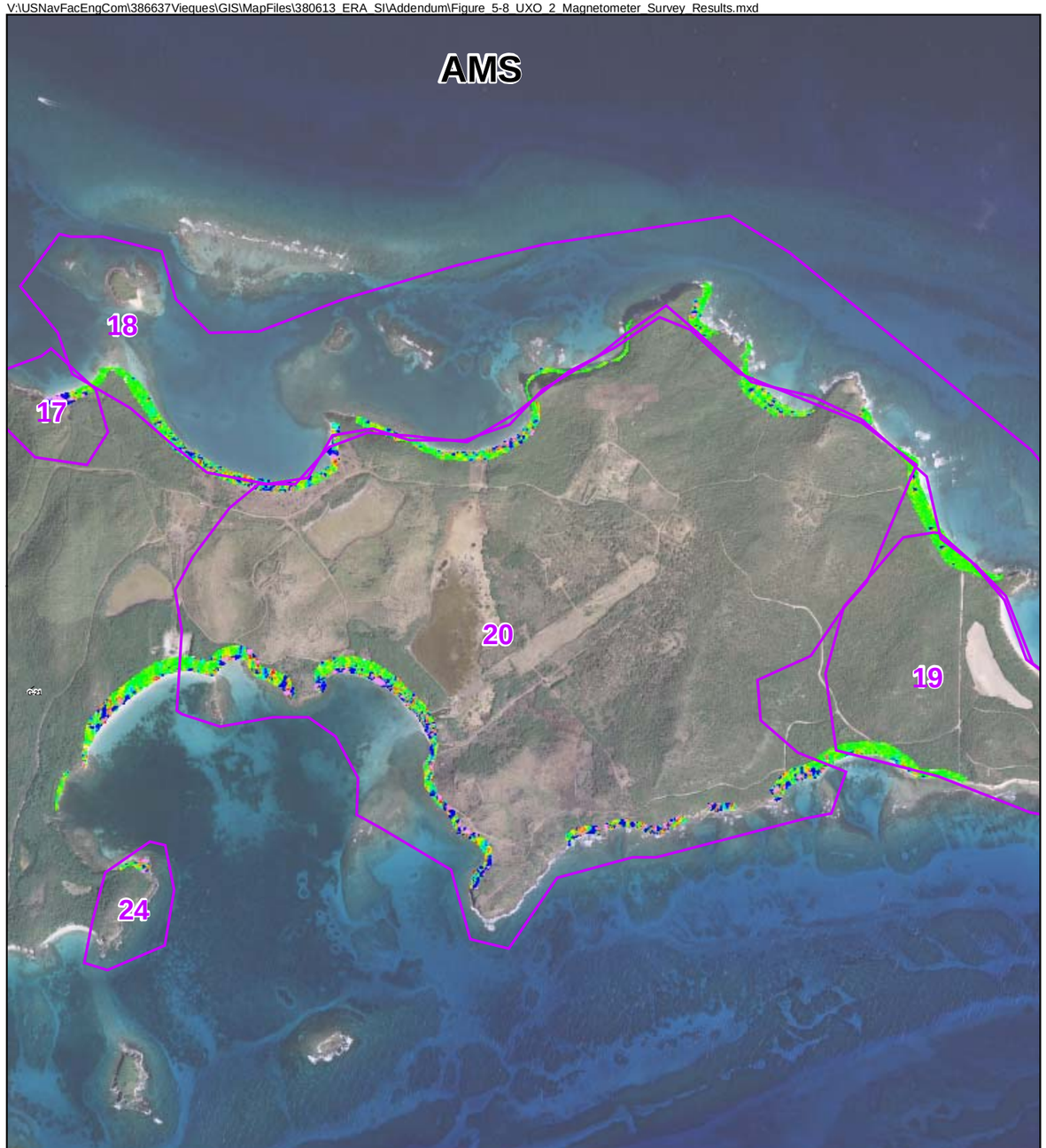
N
W E
S

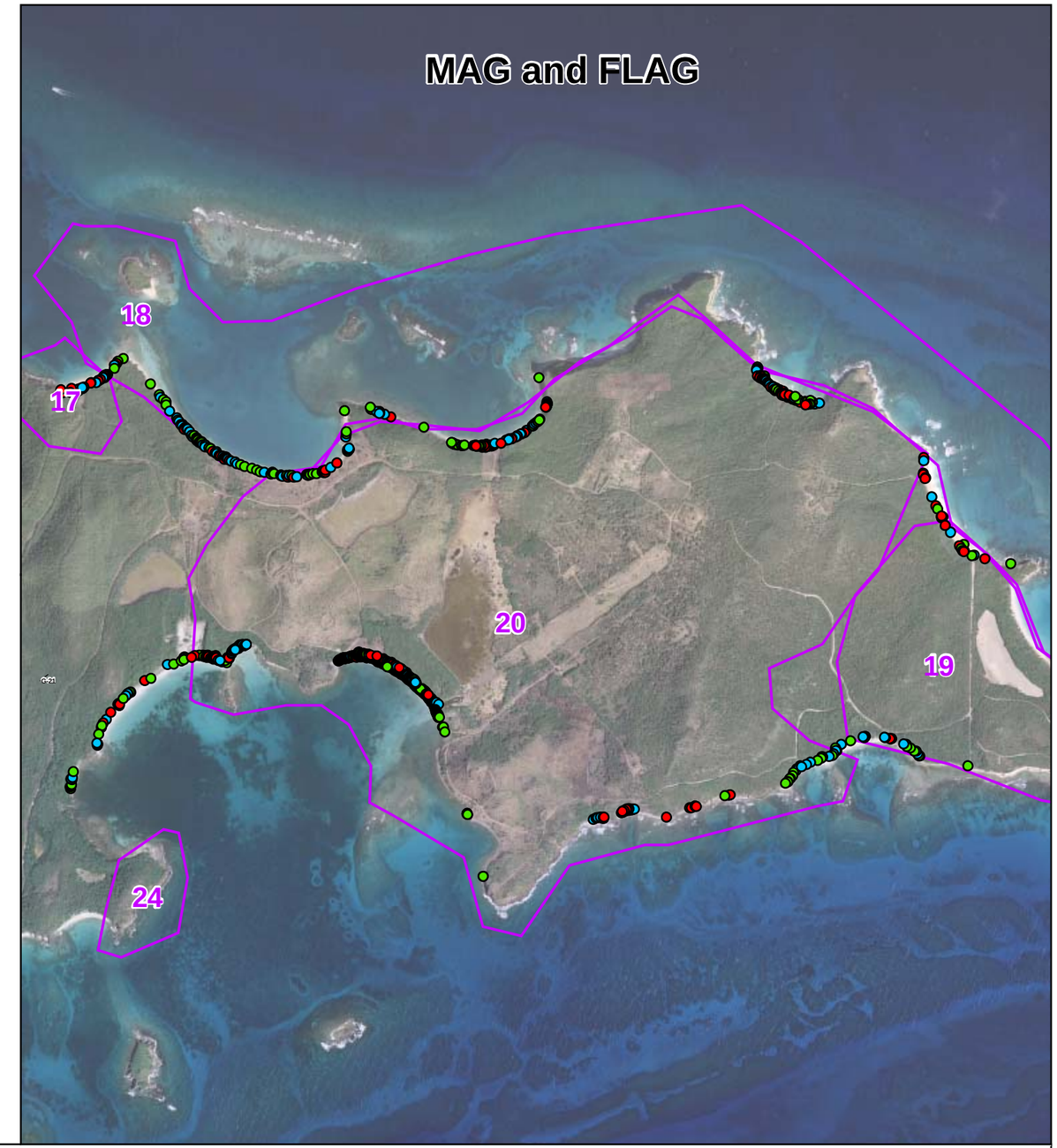
0 500 1,000 2,000
Feet

Figure 5-7
UXO 2 Transect Findings
Former VNTR, Vieques, Puerto Rico

CH2MHILL

V:\USNavFacEngCom\386637Vieques\GIS\MapFiles\380613_ERA_SI\Addendum\Figure_5-8_UXO_2_Magnetometer_Survey_Results.mxd





Legend

Magnetometer Response from "Mag and Flag"

- Low
- Medium
- High
- EADA

Aerial Magnetometer Survey Total Magnetic Field

-4.6 -2.3 0.0 1.9 3.8 5.8 7.7 9.6

N W E S

0 800 1,600 3,200 Feet

Figure 5-8
UXO 2 Magnetometer Survey Results
Former VNTR, Vieques, Puerto Rico

CH2MHILL

SECTION 6

UXO 3—LIA Roads

6.1 Background

UXO 3 encompasses approximately 39 acres throughout the LIA and consists of selected roadways and 25 foot buffers on each side of the selected roads. UXO 3 runs through UXO 4 and adjacent to portions of UXO 2. Most of the roadways that make up UXO 3 are a subset of roads that were utilized across the former LIA.

The scope of the NTCRA is to remove subsurface munitions from the site. The NTCRA also includes subsurface removal at UXO Sites 1, 2, 5 through 8, 11, and 15.

For additional information and site history, including historical military use, see the UXO 4 site description, in **Section 7**.

6.2 ERA/SI Findings

6.2.1 TCRA/NTCRA Results

The field removal activities of the TCRA have been completed at UXO 3. The types and distribution of surface MEC removed from UXO 3 during the TCRA are presented on **Figure 6-1** and summarized in **Table 6-1.** In June 2009 the field activities for a NTCRA (interim action) were initiated that include UXO 3 (CH2M HILL, 2008b). The types and distribution of surface and subsurface MEC removed from UXO 3 during the TCRA and NTCRA are presented on **Figure 6-1** and summarized in **Table 6-1.**

As part of the NTCRA for the Roads and Beaches a DGM survey was conducted for 10 acres of the roadways and buffer area that make up UXO 3. A total of 14,060 subsurface anomalies were detected during the DGM survey. The distribution of anomalies identified during the DGM survey at UXO 3 is presented on **Figures 6-2 through 6-5**. Over 2,100 MEC items have been removed from the surface and subsurface at UXO 3 through May 2010.

6.2.2 Transect Inspections

Prior to initiating the TCRA, transect surveys were conducted over the eastern half of the former LIA, which includes a portion of UXO 3. **Figure 6-6 and Table 6-1** show the results of the transect surveys at UXO 3, which identified multiple types of MEC located on the ground surface (**Table 6-1**).

TABLE 6-1
Summary of MEC items identified at UXO 3

	Number of Items Identified during Transects	Number of Items Identified during TCRA/ NTCRA through May 2010	Number of Subsurface Items Identified through May 2010
MEC Category			
Bombs	6	921	1
Flares-Pyrotechnics	--	10	--
Grenades	--	20	--
MEC Component	--	95	--
Projectiles / Mortars	1	634	2
Rockets / Guided Missiles	--	8	--
Sub munitions	1	458	--
MD Category			
Bombs	3	39	--
Flares-Pyrotechnics	--	2	--
Grenades	--	20	--
MEC Component	--	4	--
Projectiles / Mortars	3	2,560	2
Rockets / Guided Missiles	--	6	--
Sub munitions	--	29	--
Scrap	--	99,747	--
Range Related Debris			
Scrap		79,701	118

6.2.3 Aerial Mapping Results

Due to the periodic regrading of the roads within the LIA, there are no discernable features of military activities on UXO from the LiDAR Survey or orthophotography.

The anomaly maps for the DGM survey are compared to the AMS results for the same area and are presented in **Appendix E**. The following EADAs, shown on **Figure 6-7**, were identified at UXO 3:

- **EADA 19—**Anomaly densities greater than 10 per acre, consistent with typical responses from UXO-related activity.
- **EADA 20—**Large discrete anomalies with an anomaly density of 5 to 10 per acre.
- **EADA 21—**Very large and distinctive anomalies with an anomaly density of 5 to 10 per acre.

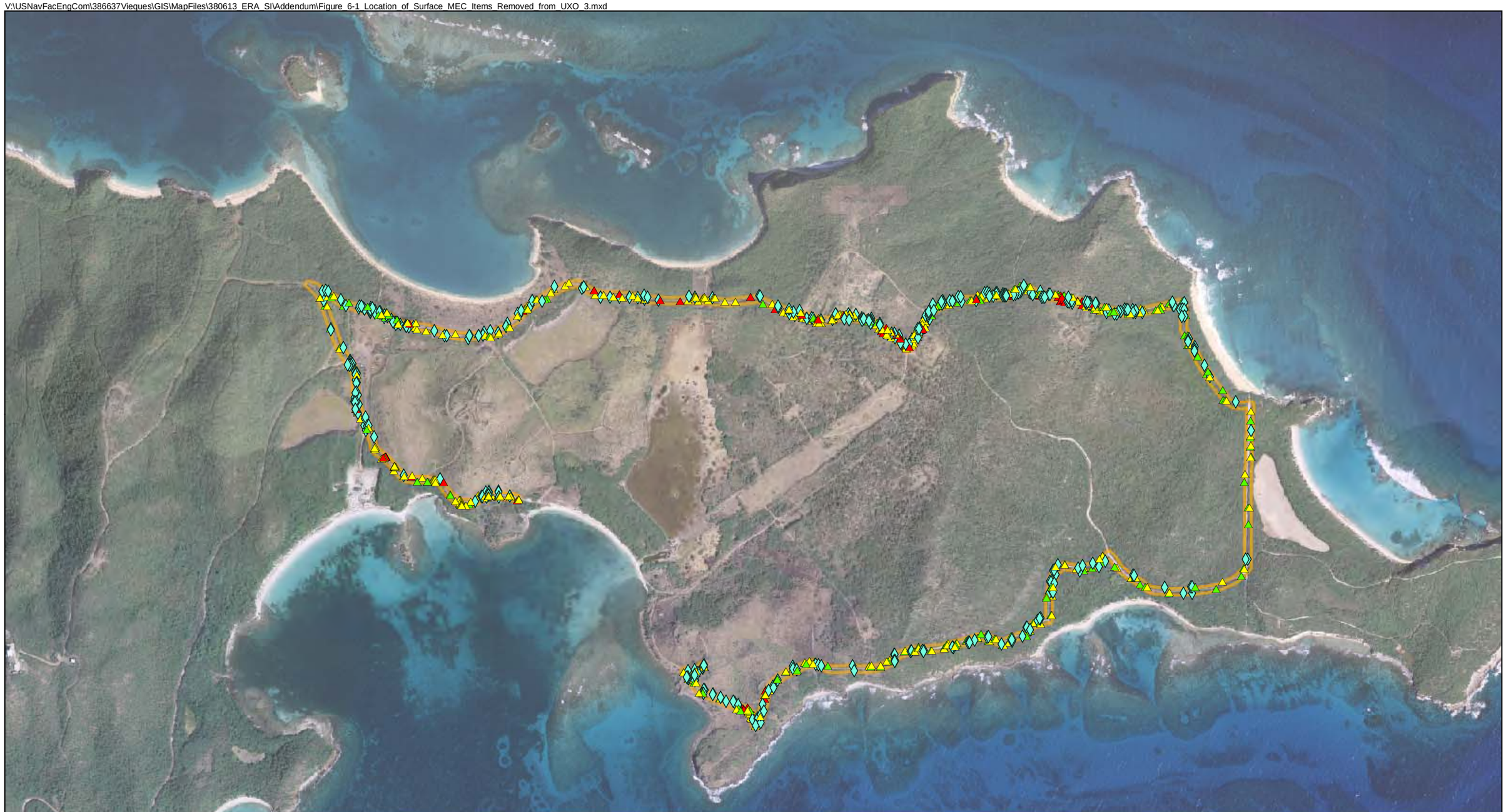
6.2.4 Summary of Findings

The results of the TCRA, NTCRA, and ERA/SI conducted for UXO 3 identified over 2,100 MEC items within UXO 3. The AMS and DGM surveys indicate that several subsurface anomalies, that may be indicative of subsurface MEC, are present at UXO 3.

6.3 Recommendations

Surface MEC have been removed from this site as part of the TCRA (interim action). Continued removal of subsurface MEC is recommended at the roads under the NTCRA. Based on findings from the TCRA and NTCRA a RI/FS should be conducted to assess the potential environmental impacts and explosive safety hazards at UXO 3.

V:\USNavFacEngCom\386637Vieques\GIS\MapFiles\380613_ERA_SI\Addendum\Figure_6-1_Location_of_Surface_MEC_Items_Removed_from_UXO_3.mxd



Legend
- Range Related Debris
- Munitions Debris
- Material Potentially Presenting an Explosive Hazard
- Unexploded Ordnance
- UXO Site

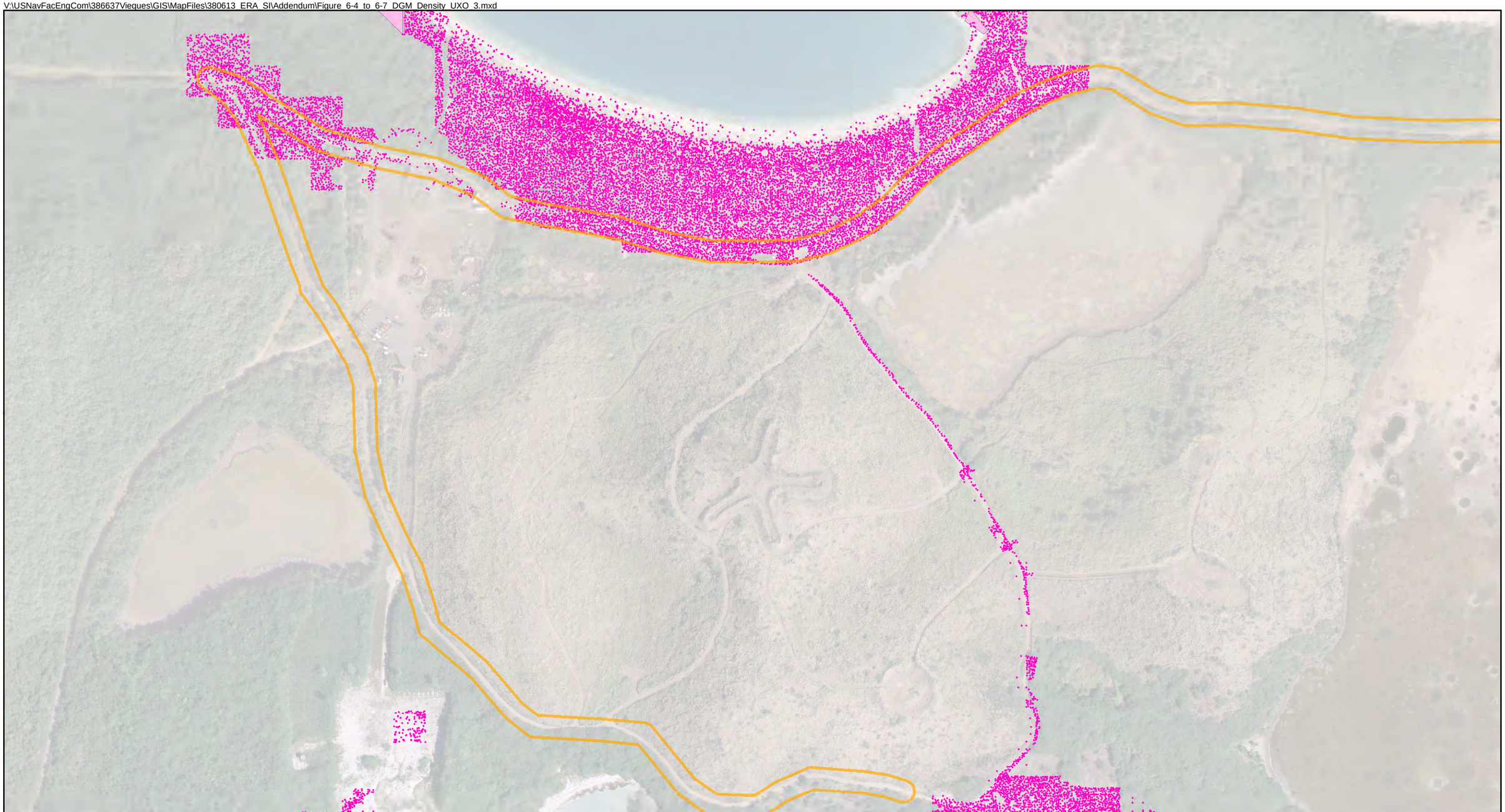
N
W E
S

0 500 1,000 2,000
Feet

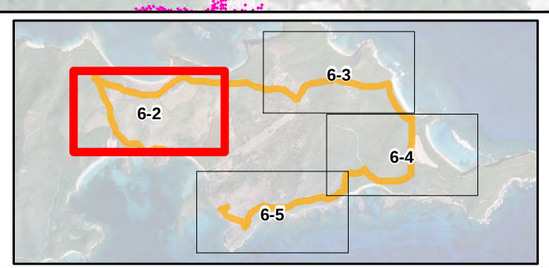
Figure 6-1
Locations of Surface MEC Items Removed From UXO 3
Former VNTR, Vieques, Puerto Rico

CH2MHILL

V:\USNavFacEngCom\386637Vieques\GIS\MapFiles\380613_ERA_SI\Addendum\Figure_6-4_to_6-7_DGM_Density_UXO_3.mxd



Legend
- DGM Anomaly
- DGM Anomaly Polygon
- UXO Site



N
W E
S

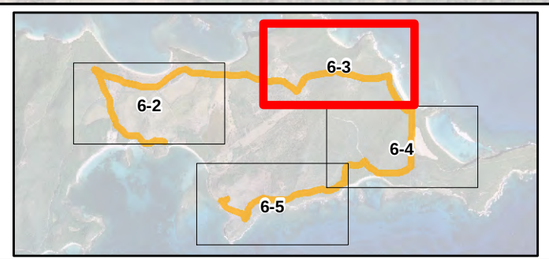
0 150 300 600
Feet

Figure 6-2
DGM Anomaly Density within UXO 3
Former VNTR, Vieques, Puerto Rico

CH2MHILL

V:\USNavFacEngCom\386637Vieques\GIS\MapFiles\380613_ERA_SI\Addendum\Figure_6-4_to_6-7_DGM_Density_UXO_3.mxd

Legend
- DGM Anomaly
- DGM Anomaly Polygon
- UXO Site



N
W E
S

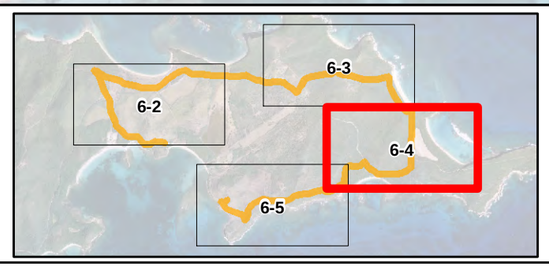
0 150 300 600
Feet

Figure 6-3
DGM Anomaly Density within UXO 3
Former VNTR, Vieques, Puerto Rico

CH2MHILL

V:\USNavFacEngCom\386637Vieques\GIS\MapFiles\380613_ERA_SI\Addendum\Figure_6-4_to_6-7_DGM_Density_UXO_3.mxd

Legend
- DGM Anomaly
- DGM Anomaly Polygon
- UXO Site



N
W E
S

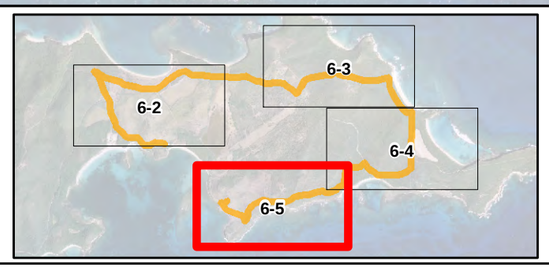
0 150 300 600
Feet

Figure 6-4
DGM Anomaly Density within UXO 3
Former VNTR, Vieques, Puerto Rico

CH2MHILL

V:\USNavFacEngCom\386637Vieques\GIS\MapFiles\380613_ERA_SI\Addendum\Figure_6-4_to_6-7_DGM_Density_UXO_3.mxd

Legend
- DGM Anomaly
- DGM Anomaly Polygon
- UXO Site



N
W E
S

0 150 300 600
Feet

Figure 6-5
DGM Anomaly Density within UXO 3
Former VNTR, Vieques, Puerto Rico

CH2MHILL

V:\USNavFacEngCom\386637Vieques\GIS\MapFiles\380613_ERA_SI\Addendum\Figure_6-2_Location_of_Transect_Items_in_UXO_3.mxd

Legend
- Munitions Debris
- Material Potentially Presenting an Explosive Hazard
- Munitions and Explosives of Concern
- UXO Site

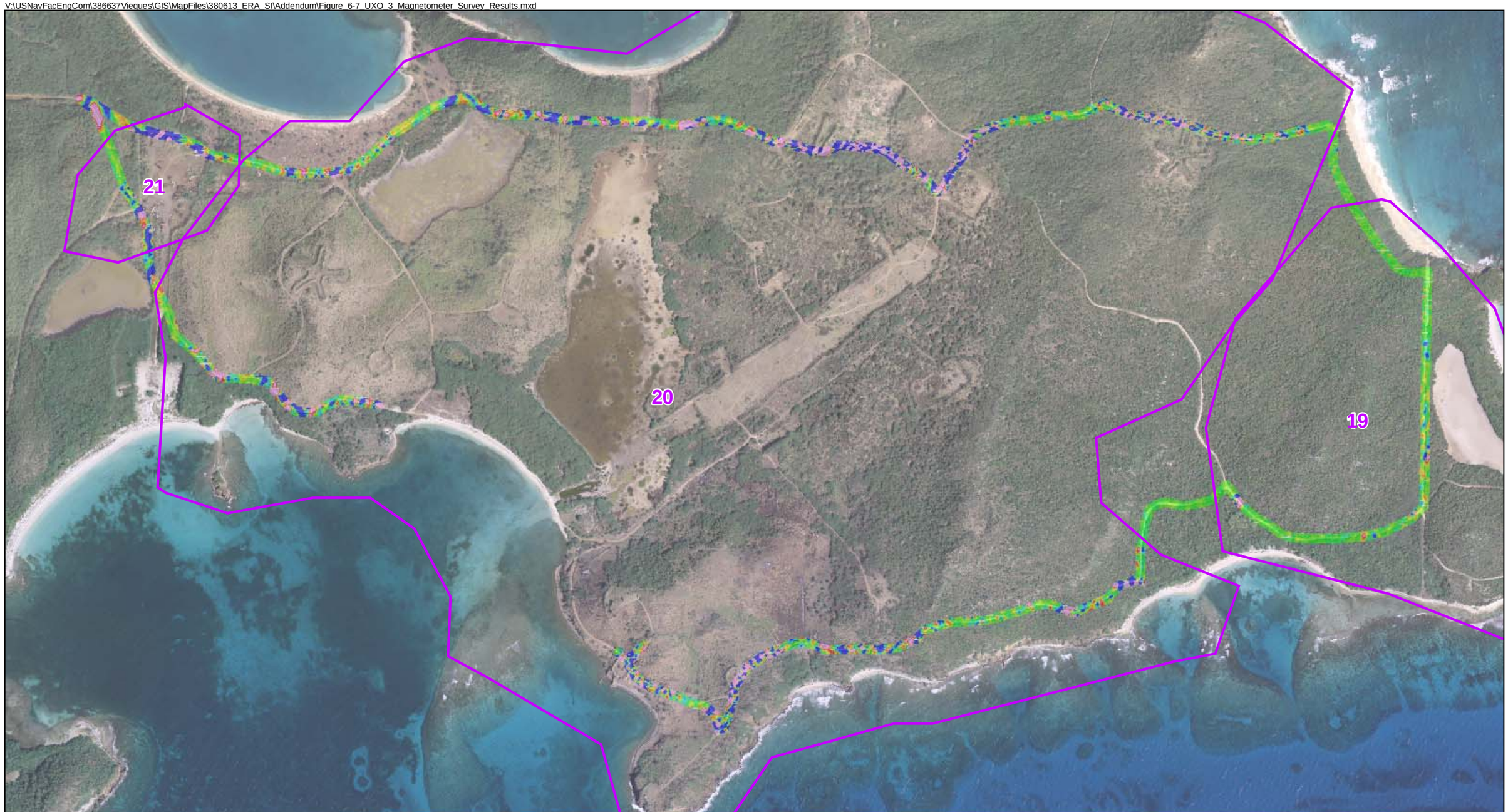
N
W E
S

0 500 1,000 2,000
Feet

Figure 6-6
UXO 3 Transect Findings
Former VNTR, Vieques, Puerto Rico

CH2MHILL

V:\USNavFacEngCom\386637Vieques\GIS\MapFiles\380613_ERA_SI\Addendum\Figure_6-7_UXO_3_Magnetometer_Survey_Results.mxd



Legend
EADA

Aerial Magnetometer Survey Total Magnetic Field

-4.6 -2.3 0.0 1.9 3.8 5.8 7.7 9.6

N
W E
S

0 350 700 1,400
Feet

Figure 6-7
UXO 3 Magnetometer Survey Results
Former VNTR, Vieques, Puerto Rico

CH2MHILL

SECTION 7

UXO 4—LIA Interior

7.1 Background

UXO 4 encompasses approximately 855 acres consisting of a majority of the former LIA, excluding the roads and beaches. The site is composed of the terrestrial area (minus the beaches) situated between the areas formerly referred to as the ECA and SIA. The historical information presented below is for the former LIA and is applicable to UXO 4.

In 1965, training activity began in the LIA where several mock-ups, such as old tanks and vehicles, were used as targets for aerial bombing. Since the mid-1970s, NGF was practiced, where several point and area targets for ships were constructed (Tippets et al., 1979). Locations of the bombing targets and the NGF targets are shown on **Figure 2-3**. Based on the NGF that occurred from the 1970s through 2003 and the results of the TCRA, all 958 (UXO Sites 2, 3, and 4) acres of have been impacted by MEC. Although training was initiated in 1965, live ordnance was not used on a regular basis until December 1974. This does not mean that live bombs were not dropped prior to this date, but there was no significant trend (Tippets et al., 1979). Marine artillery fired from the west likely impacted this area also. A summary of the types and amount of NGF and ATG ordnance fired on Vieques from 1974 to 1998 is provided in **Tables 7-1** and **7-2,** respectively. The activity at Vieques increased after July 1975 when training activities stopped on Culebra.

Information related specifically to the operations in the LIA, including range refurbishment records, after-action reports from training activities, and a variety of miscellaneous information such as Inner Range dimensions and operational functions is discussed in the archive record search (CH2M HILL, 2003).

Two separate locations were designated for treatment of retrograde (unserviceable) ordnance through OB/OD. The retrograde munitions also included the expired ammunition stored at the former NASD located in western Vieques. The OB/OD facility was operated under interim status of RCRA in accordance with the Part B Hazardous Waste Facility Operations Permit Application submitted in 1988. Two separate operation locations were identified for the open detonation area and the open burn area. The OB/OD areas were operational until April 30, 2003 when the Naval facilities on eastern Vieques were closed and the property was transferred to DOI.

The OB area was designated in the permit application for open burning of waste propellants and pyrotechnics. In the OD area retrograde munitions from range refurbishment activities were destroyed by open detonation with high explosives in excavated earthen pits.

TABLE 7-1
NGFS Expended Annually by Type (Number of Items)

Year	5”	4.5”	3”	Total
1974	4,413	1,235	1,308	6,956
1975	6,787	324	691	7,802
1976	6,961	290	679	7,930
1977	8,258	530	1,066	9,854
1982	6,590	41	106	6,737
1983	7,429	0	1044	8,473
1984	6,789	75	274	7,138
1985	7,892	31	331	8,254
1986	7,140	104	42	7,286
1987	14,148	1143	563	15,854
1988	14,025	301	1246	15,572
1989	13,131	1041	862	15,034
1990	12,041	243	563	12,847
1991	3,902	131	196	4,229
1992	3,873	397	413	4,683
1993	523	54	0	577
1994	774	15	0	789
1995	519	361	0	880
1996	3,101	150	0	3,251
1997	4,261	188	0	4,449
1998	7,301	308	0	7,609
Total	139,858	6,962	9,384	156,204
Weight (lb)	2 types: 63 lb and 55 lb	50	50	--
Total Weight	8,671,278	348,100	469,200	9,488,578
Average	6660	332	447	7,438
Percent of Average Total	89.6	4.4	6	100

Notes: lb = pounds, NGFS = Naval gunfire support

TABLE 7-2
ATG Ordnance Expended Annually by Type (Number of Items)

Year	MK-81	MK-82	MK-83	MK-84	Total
1974	12	612	0	0	624
1975	134	2,164	34	40	2,372
1976	186	1,281	127	0	1,594
1977	242	4,771	715	144	5,872
1982	0	762	14	0	776
1983	0	2,547	92	64	2,703
1984	0	857	45	10	912
1985	0	575	72	20	667
1986	0	780	289	75	1,144
1987	0	1,108	160	0	1,268
1988	12	1,486	251	20	1,769
1989	27	1,737	805	66	2,635
1990	23	1,884	494	75	2,476
1991	106	2,441	340	37	2,924
1992	8	1,904	213	145	2,270
1993	0	1,687	192	0	1,879
1994	0	1,458	287	19	1,764
1995	0	939	246	14	1,199
1996	0	1,899	393	14	2,306
1997	121	1,865	329	3	2,318
1998	0	857	246	2	1,105
Total	871	33,614	5,344	748	40,577
Weight (lb)	250	500	1,000	2,000	
Total Wt. (lb)	217,750	16,807,000	5,344,000	1,496,000	23,864,750
Average[1]	41	1,601	254	36	1,932
Percent[2]	2.1	82.9	13.1	1.9	100

Notes:
[1] Average number items dropped per year in which data was recorded.
[2] Percent of the total items dropped in the period of record.
In addition in 1974: 24 MK-77s, 8 MK-78s, and 8 MK-14s or MK-16s were expended.
In 1975: 203 MK-77s and 4 MK-14s or MK-16s were expended.
In 1977 41 MK-77s were expended.

Based on the types of munitions treated and the explosives utilized for detonation, an explosives safety arc was developed for the OB/OD site to assess the maximum distance that munitions and ordnance-related scrap could kick out. The explosive safety arc indicates that MEC/MEC fragments could potentially extend 3,000 feet offshore.

7.2 ERA/SI Findings

7.2.1 TCRA/NTCRA Results

The TCRA (interim action) at UXO 4 was initiated in 2005.. The MEC removed from the ground surface consisted of multiple types of munitions items (e.g., bombs, projectiles, rockets, flares, sub munitions) and the density, although varying from area to area, was approximately 78 MEC items per acre. In June 2009 the field activities for a NTCRA (interim action) were initiated that also include UXO 3 (CH2M HILL, 2008b). The types of surface and subsurface MEC removed from UXO 4 during the TCRA and NTCRA are presented in **Table 7-3** and illustrated on **Figure 7-1.** Over 51,600 MEC items have been removed from UXO 4 through May 2010.

TABLE 7-3
Summary of MEC Items Identified at UXO 4

	Number of Items Identified during Transects	Number of Items Identified during TCRA/ NTCRA through May 2010	Number of Subsurface Items Identified through May 2010
MEC Category			
Bombs	289	14,450	159
Flares-Pyrotechnics	--	428	--
Grenades	--	444	--
MEC Component	--	1,947	--
Projectiles / Mortars	150	21,232	22
Rockets / Guided Missiles	4	591	12
Sub munitions	480	12,382	--
MD Category			
Bombs	410	1,262	2
Flares-Pyrotechnics	--	38	--
Grenades	--	2,481	--
MEC Component	--	127	4
Projectiles / Mortars	244	24,222	7
Rockets / Guided Missiles	1	73	--
Sub munitions	15	2393	--
Scrap	--	3,098,006	13,369
Range Related Debris			
Total	--	2,143,468	22,744

As part of the NTCRA for the Roads and Beaches, a DGM survey was conducted for 7 acres of roadway running through the center of UXO 4. A total of 16,509 anomalies were detected in UXO 4. The DGM anomaly maps are presented in **Figures 7-2 through 7-7**.

7.2.2 Transect Inspections

As part of the ERA/ SI, and prior to the TCRA, the eastern half of UXO 4 was investigated to assess the potential types and densities of MEC within present on the ground surface. Approximately 8 percent (68.4 acres) of the site was evaluated using transects. In some instances, the munitions types (e.g., sub munitions) discovered posed a greater safety risk to the field crews due to the sensitivity of the items and heavy vegetation obscuring the ground surface; therefore, some areas that pose a more significant safety hazard were not inspected as part of the SI. Based on the results of this investigation, the density of MEC items in UXO 4 was estimated to be 3.7 items per acre were found. **Figure 7-8** shows the results of the transect surveys conducted at UXO 4 which included multiple types of MEC located on the ground surface (**Table 7-3**).

During the inspection of UXO 4, 934 MEC items were located. The densities of the various item types varied across the site and can be qualitatively summarized:

- Bomb densities were greatest in the vicinity of the former convoy target.
- Projectile and mortar densities were generally higher in the south central portion of UXO 4 and also in the vicinity of the former convoy target; however, the greatest concentration of projectile sand mortars were in the southeastern portion of UXO 4.
- The munitions items classified as either submunitions, grenades (undifferentiated), or flares/pyrotechnics were present at a lower density than the other MEC classifications. The Surface-to-Air Missile (SAM) East Site in the northeastern portion of UXO 4 had the overall greatest densities of MEC, with the most frequently identified munition being the Mk-118 bomblet. The high concentration and high explosive hazard of these items, combined with dense vegetation, resulted in only being able to inspect approximately 4-5 percent of this area.

The distribution of MEC items across UXO 4 is shown on **Figure 7-1**. Consistent with historical records and the known use of the site, the MEC densities were greater in the central portion of UXO 4 decreased to the east toward the UXO 1 boundary.

7.2.3 Aerial Survey Results

The aerial LiDAR survey of UXO 4 shows evidence of impact craters across the site (**Figure 3-3**). Several AOIs were also identified during the LiDAR survey, which were former known target areas or other known sites where range activities were conducted. The MEC associated with these AOIs was identified during the TCRA. **Figure 3-3** presents the bare earth models produced from the LiDAR survey and includes the AOI locations. **Figure 3-2** is representative of the orthophotography collected at the former VNTR; the selected area is the Convoy Target and vicinity and shows the proximity of target vehicles located at this site and significant numbers of sub-munitions canisters in the area east of the mock runway. These items were cleared as part of the TCRA.

Figure 7-9 presents the AMS results for UXO 4. The AMS identified the following three EADAs in UXO 4:

- **EADA 19—**Anomaly densities greater than 10 per acre, consistent with typical responses from UXO-related activity.
- **EADA 20—**Large discrete anomalies with an anomaly density of 5 to 10 per acre.
- **EADA 21—**Very large and distinctive anomalies with an anomaly density of 5 to 10 per acre.

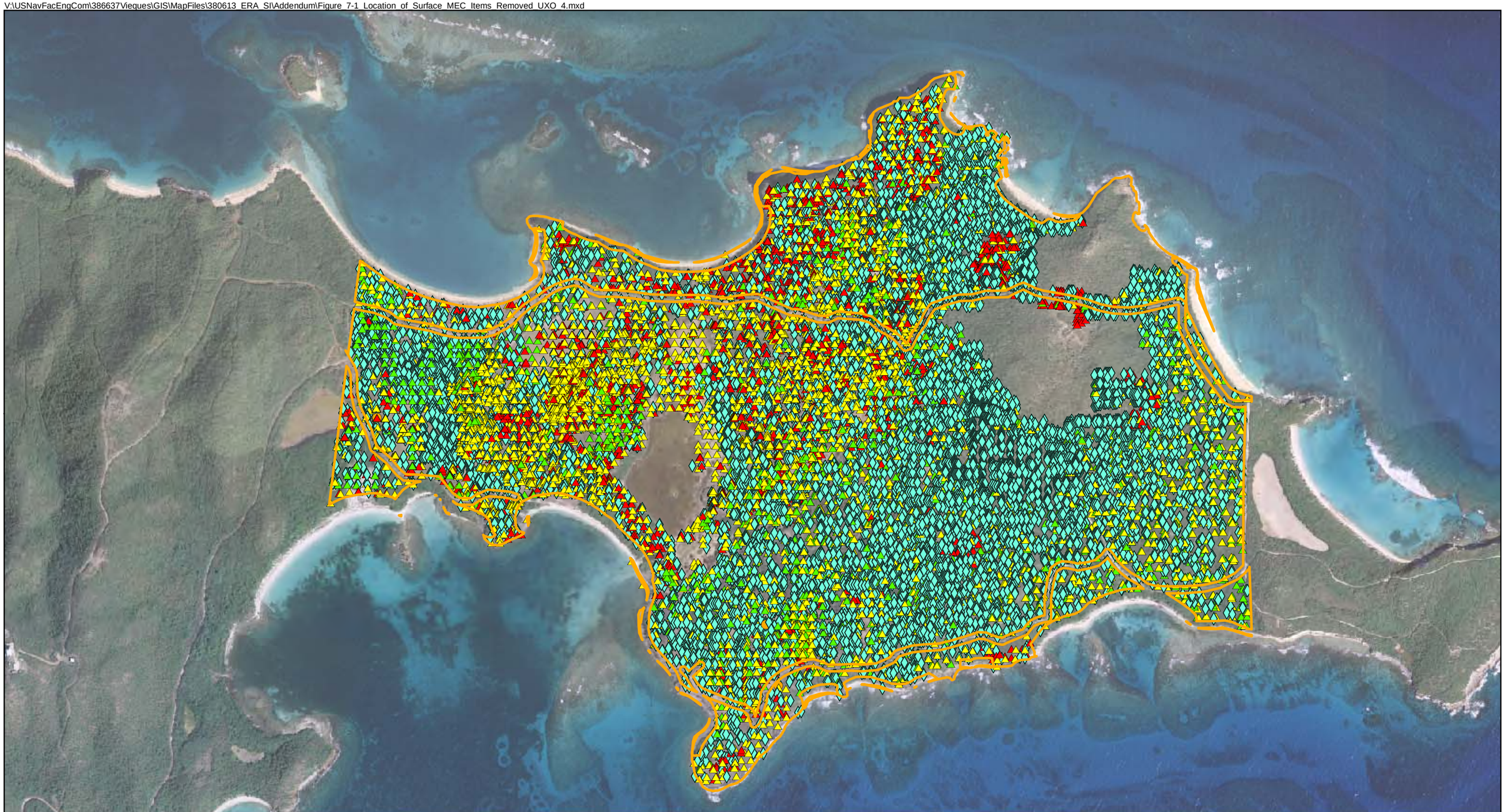
7.2.4 Summary of Findings

The results of the TCRA, NTCRA and ERA/SI for UXO 4 identified over 51,600 MEC items on the surface and within the subsurface throughout the 855 acres of the site. Most of these items were consistent with the MEC items that were historically fired into the former LIA. The majority of the TCRA for UXO 4 was completed before the AMS survey took place therefore the anomalous areas associated with UXO 4 are likely subsurface.

7.3 Recommendations

Surface MEC have been removed from this site as part of the TCRA (interim action). Based on the results of this investigation and the TCRA, a RI/FS should be conducted to assess the explosive safety and environmental impacts at UXO 4.

V:\USNavFacEngCom\386637Vieques\GIS\MapFiles\380613_ERA_SI\Addendum\Figure_7-1_Location_of_Surface_MEC_Items_Removed_UXO_4.mxd



Legend
- Range Related Debris
- Munitions Debris
- Material Potentially Presenting an Explosive Hazard
- Discarded Military Munitions
- Unexploded Ordnance
- UXO Site

N
W E
S

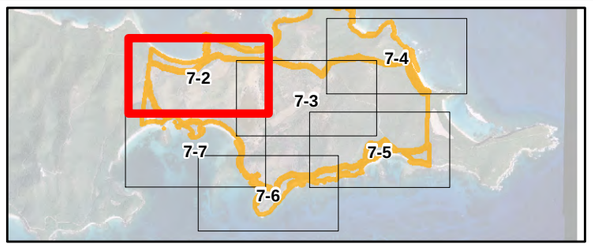
0 500 1,000 2,000
Feet

Figure 7-1
Location of Surface MEC Items Removed from UXO 7
Former VNTR, Vieques, Puerto Rico

CH2MHILL

V:\USNavFacEngCom\386637Vieques\GIS\MapFiles\380613_ERA_SI\Addendum\Figure_7-4_to_7-9_DGM_Density_UXO_4_Mapbook.mxd

Legend
- DGM Anomaly
- DGM Anomaly Polygon
- UXO Site



N
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S

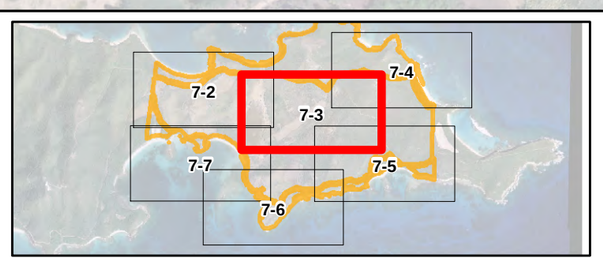
0 150 300 600
Feet

Figure 7-2
DGM Anomaly Density within UXO 4
Former VNTR, Vieques, Puerto Rico

CH2MHILL

V:\USNavFacEngCom\386637Vieques\GIS\MapFiles\380613_ERA_SI\Addendum\Figure_7-4_to_7-9_DGM_Density_UXO_4_Mapbook.mxd

Legend
- DGM Anomaly
- DGM Anomaly Polygon
- UXO Site



N
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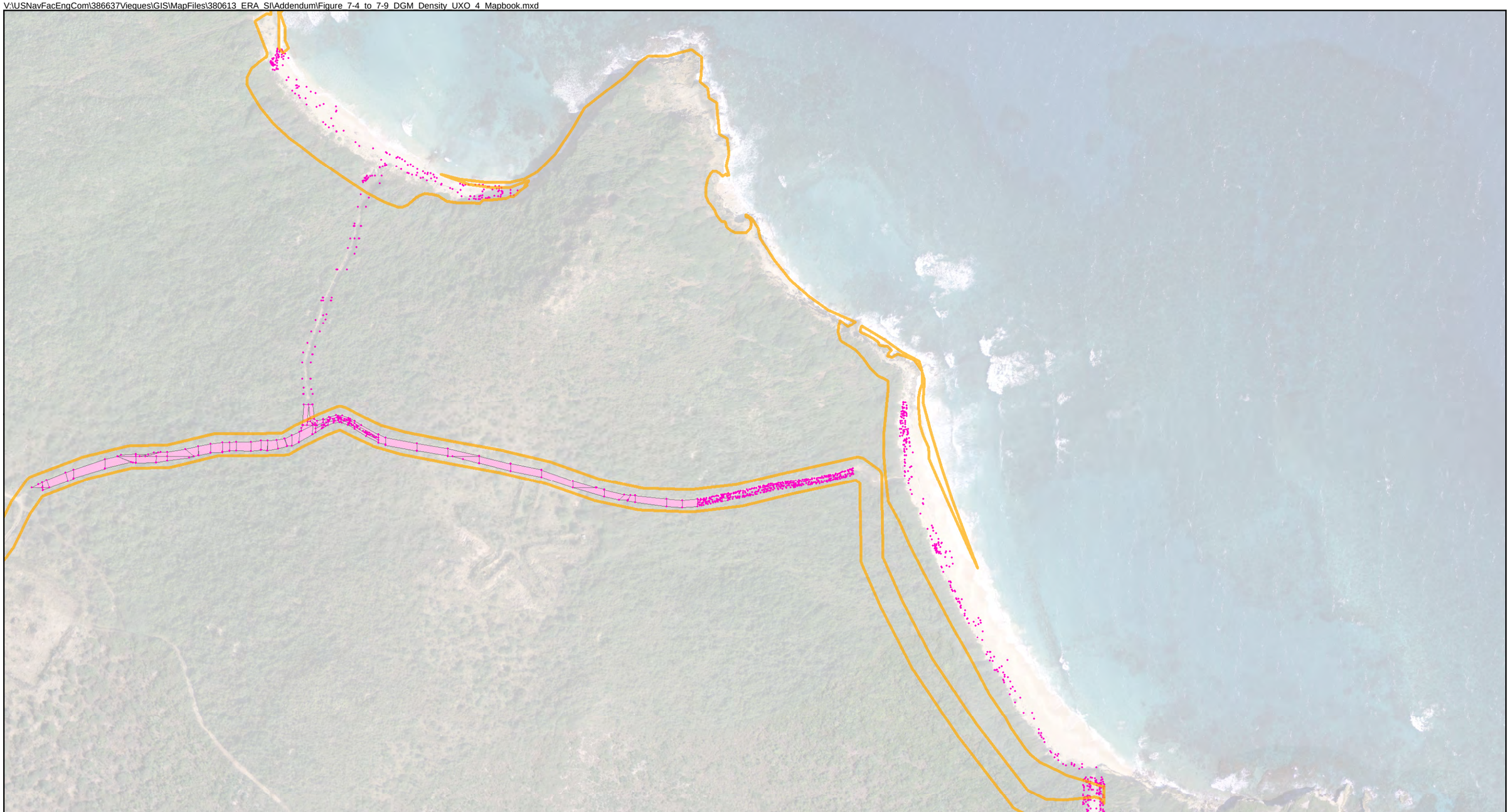
S

0 150 300 600
Feet

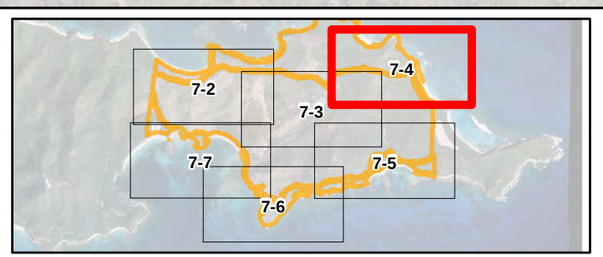
Figure 7-3
DGM Anomaly Density within UXO 4
Former VNTR, Vieques, Puerto Rico

CH2MHILL

V:\USNavFacEngCom\386637Vieques\GIS\MapFiles\380613_ERA_SI\Addendum\Figure_7-4_to_7-9_DGM_Density_UXO_4_Mapbook.mxd



Legend
- DGM Anomaly
- DGM Anomaly Polygon
- UXO Site



N
W E
S

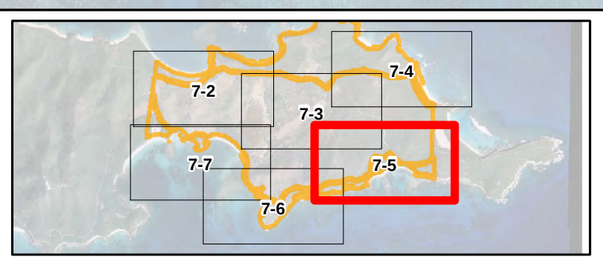
0 150 300 600
Feet

Figure 7-4
DGM Anomaly Density within UXO 4
Former VNTR, Vieques, Puerto Rico

CH2MHILL

V:\USNavFacEngCom\386637Vieques\GIS\MapFiles\380613_ERA_SI\Addendum\Figure_7-4_to_7-9_DGM_Density_UXO_4_Mapbook.mxd

Legend
- DGM Anomaly
- DGM Anomaly Polygon
- UXO Site



N
W E
S

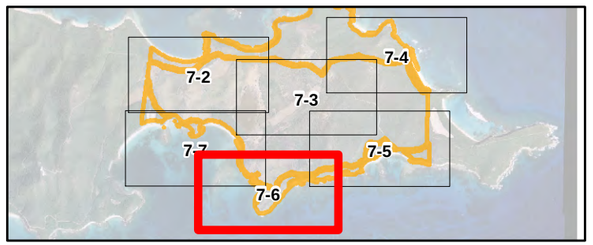
0 150 300 600
Feet

Figure 7-5
DGM Anomaly Density within UXO 4
Former VNTR, Vieques, Puerto Rico

CH2MHILL

V:\USNavFacEngCom\386637Vieques\GIS\MapFiles\380613_ERA_SI\Addendum\Figure_7-4_to_7-9_DGM_Density_UXO_4_Mapbook.mxd

Legend
- DGM Anomaly
- DGM Anomaly Polygon
- UXO Site



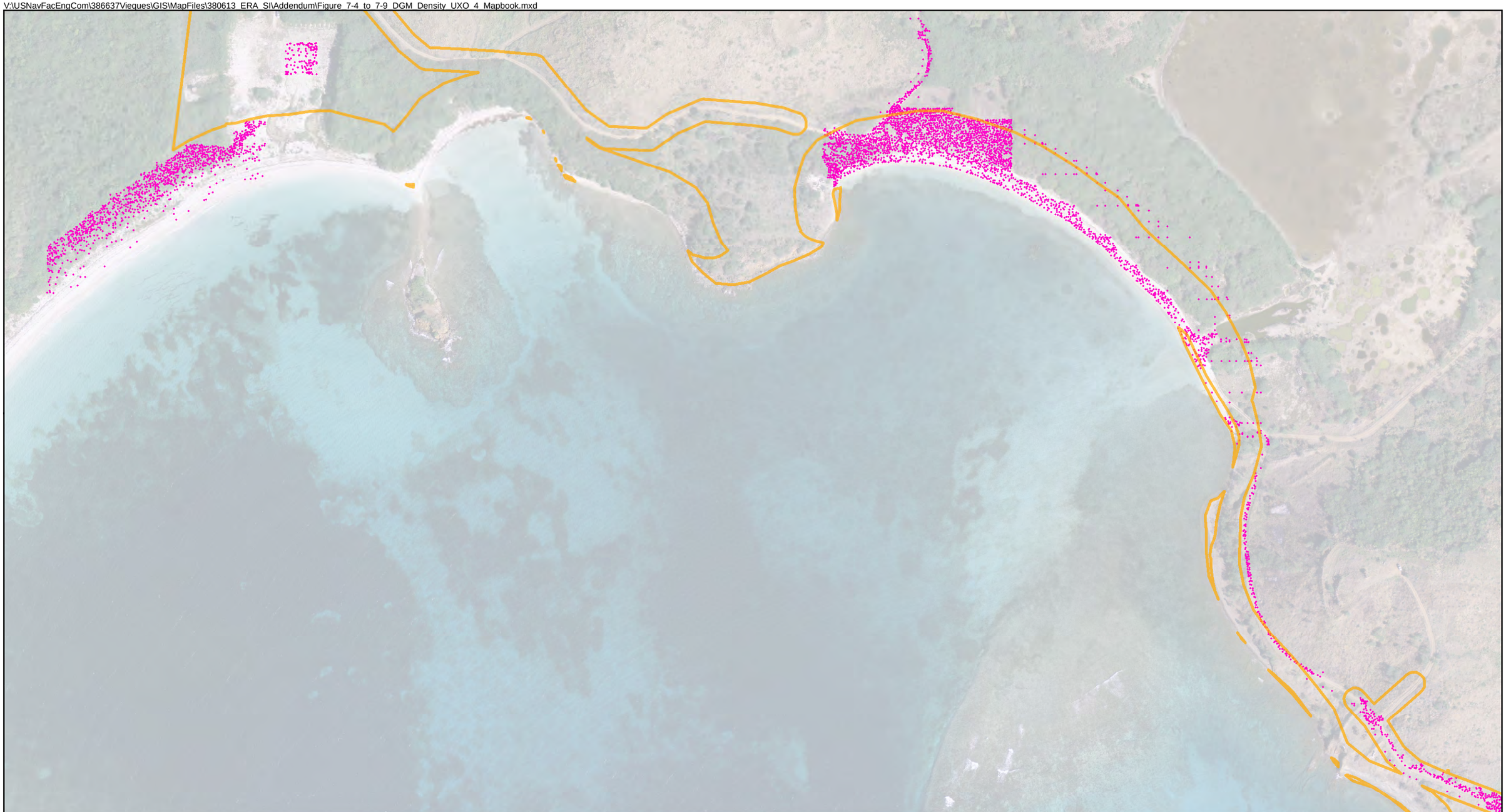
N
W E
S

0 150 300 600
Feet

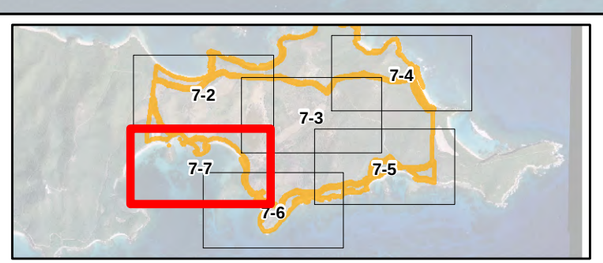
Figure 7-6
DGM Anomaly Density within UXO 4
Former VNTR, Vieques, Puerto Rico

CH2MHILL

V:\USNavFacEngCom\386637Vieques\GIS\MapFiles\380613_ERA_SI\Addendum\Figure_7-4_to_7-9_DGM_Density_UXO_4_Mapbook.mxd



Legend
- DGM Anomaly
- DGM Anomaly Polygon
- UXO Site



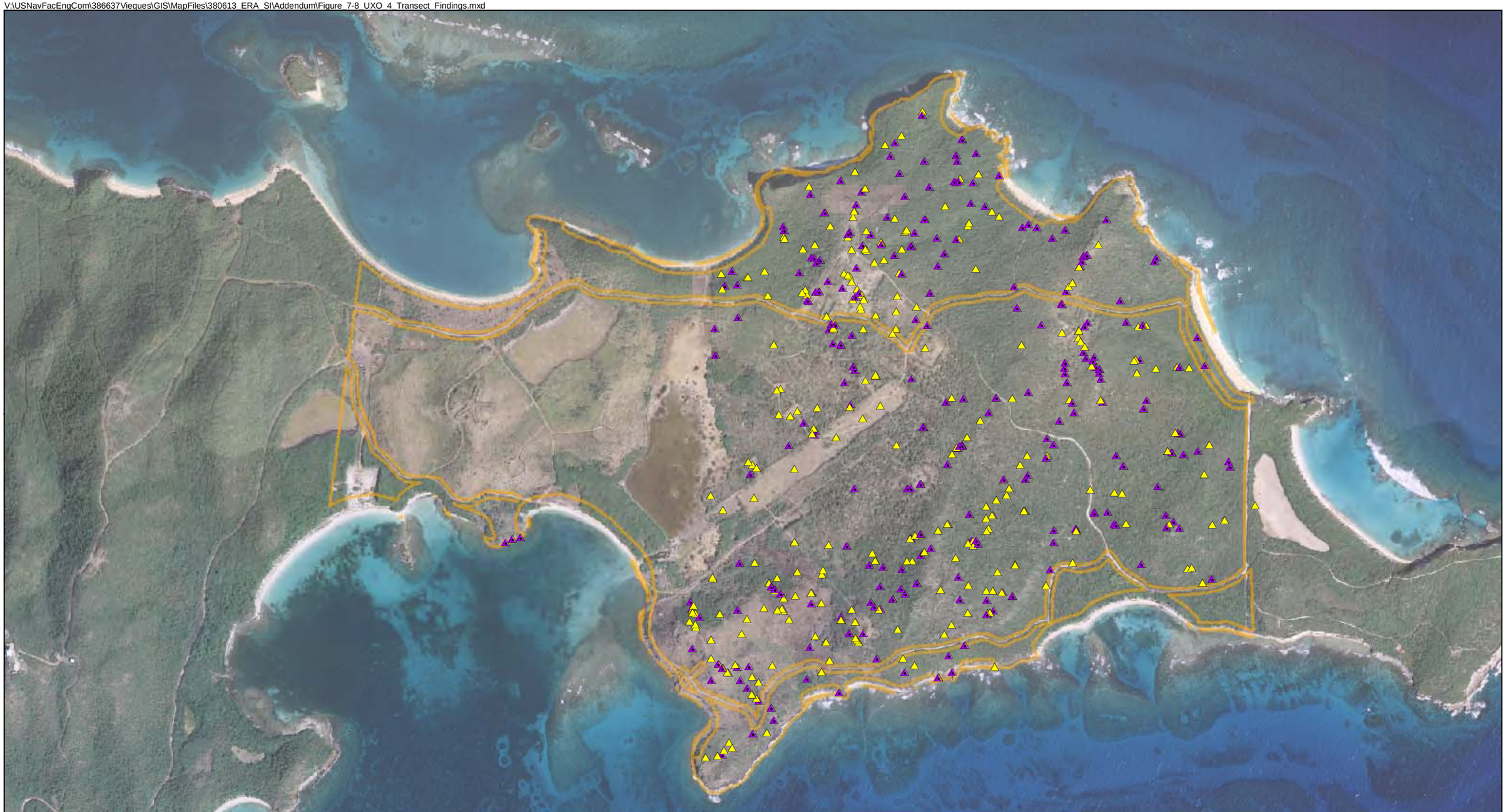
N
W E
S

0 150 300 600
Feet

Figure 7-7
DGM Anomaly Density within UXO 4
Former VNTR, Vieques, Puerto Rico

CH2MHILL

V:\USNavFacEngCom\386637Vieques\GIS\MapFiles\380613_ERA_SI\Addendum\Figure_7-8_UXO_4_Transect_Findings.mxd



Legend
- Munitions Debris
- Munitions and Explosives of Concern
- UXO Site

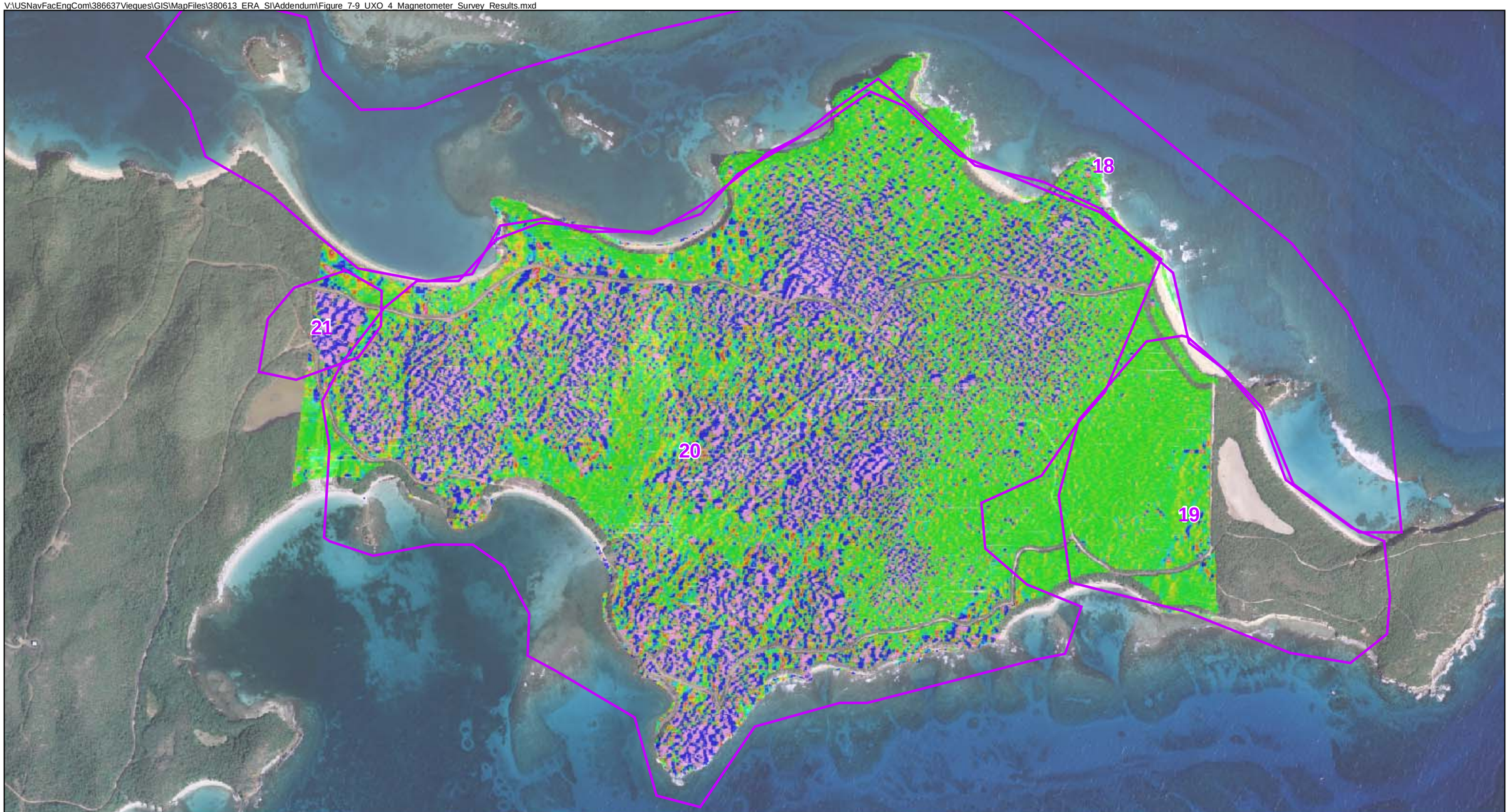
N
W E
S

0 500 1,000 2,000
Feet

Figure 7-8
UXO 4 Transect Findings
Former VNTR, Vieques, Puerto Rico

CH2MHILL

V:\USNavFacEngCom\386637Vieques\GIS\MapFiles\380613_ERA_SI\Addendum\Figure_7-9_UXO_4_Magnetometer_Survey_Results.mxd



Legend
EADA

Aerial Magnetometer Survey Total Magnetic Field

-4.6 -2.3 0.0 1.9 3.8 5.8 7.7 9.6

N
W E
S

0 500 1,000 2,000
Feet

Figure 7-9
UXO 4 Magnetometer Survey Results
Former VNTR, Vieques, Puerto Rico

CH2MHILL

SECTION 8

UXO 5—SIA Restricted Roads

8.1 Background

UXO 3 encompasses approximately 38 acres throughout the SIA and is composed of selected roadways and 25 foot buffers on each side of the selected roads.

For additional information and site history of the SIA, including historical military use, see the UXO 10 description provided in Section 13.

8.2 ERA/SI Findings

8.2.1 TCRA/NTCRA Results

In June 2009 the field activities for a NTCRA (interim action) were initiated (CH2M HILL, 2008b). The scope of the NTCRA is to remove subsurface munitions from the site. The NTCRA also includes subsurface removal at UXO Sites 1, 2, 3, 5 through 8, 11, and 15. Through August 2009 an average 10.5 MEC items per acre have been located and removed from UXO Sites 5 and 9 during the NTCRA. The types of MEC items removed during the NTCRA are presented in **Figure 8-1** and **Table 8-1**.

TABLE 8-1
Summary of MEC Items Identified at UXO 5

	Number of Items Identified during TCRA/ NTCRA through May 2010
MEC Items	
Bombs	14
Flares-Pyrotechnics	1
MEC Component	13
Projectiles / Mortars	55
Rockets / Guided Missiles	1
Sub munitions	1
MD Category	
Scrap	1,005
Range Related Debris	
Total	4,766

As part of the NTCRA a DGM survey was conducted along the roads and buffer that make up UXO 5. Approximately 5,800 anomalies were identified in the 3.5 acres that were surveyed. The DGM maps are presented in **Figures 8-2 through 8-5**.

8.2.2 Transect Inspections

Prior to initiating the NTCRA, approximately 8 percent (3.0 acres) of transect inspections were conducted across UXO 5. Because of the relatively significant number of MEC items found across UXO Sites 5, 9, and 10 a NTCRA was initiated to remove surface MEC; therefore, the transect evaluations were discontinued at UXO 5 because a 100 percent surface clearance was initiated that includes the entirety of UXO 5. The munitions related items identified during the transect evaluations are shown on **Figure 8-6.**

8.2.3 Aerial Survey Results

Appendix C presents the bare earth models produced from the LiDAR survey. Two AOIs were identified for UXO 5. One of the AOIs is located on the main road to OP-1 near OP-5. The second is located in the southern portion of the site just east of Playa Matias. In addition, an AOI associated with UXO 4 encroaches on UXO 5 along the north portion of the common boundary between UXO Sites 4, 5, and 9.

Figure 8-7 present the AMS results. The AMS identified the following EADAs in UXO 5:

- **EADA 14—**Many large discrete anomalies, possibly associated with geology.
- **EADA 15—**Many large discrete anomalies, possibly associated with geology.
- **EADA 16—**Many large discrete anomalies.
- **EADA 17—**Many large discrete anomalies associated with a cleared area.
- **EADA 21—**Sub region of EADA 18 with distinctive very large discrete anomalies.
- **EADA 25—**Many large discrete anomalies

UXO 5 runs through the former SIA which, based on NTCRA findings, has been impacted by MEC and has targets present. Additionally, the relief of the area is characterized by tall ridges that are likely the result of igneous rock with a high ferrous content that is less resistant to weathering and erosion.

8.2.4 Summary of Findings

A total of 85 surficial MEC items have been identified at UXO 5 during the NTCRAs and the SI. Over 5,900 subsurface anomalies have been identified during the DGM and AMS surveys. UXO 5 is included in the current NTCRA for surface and subsurface clearance of MEC.

8.3 Recommendations

The surface removal of MEC from UXO 5 is ongoing as part of the NTCRA (interim action) (CH2M HILL, 2009). Based on findings from the NTCRA a RI/FS should be conducted at UXO 5 to assess potential environmental impacts and explosive safety hazards.

V:\USNavFacEngCom\386637Vieques\GIS\MapFiles\380613_ERA_SI\Addendum\Figure_8-1_Location_of_Surface_Items_Removed_UXO_5.mxd

Legend
- Range Related Debris
- Munitions Debris
- Material Potentially Presenting an Explosive Hazard
- Discarded Military Munitions
- Unexploded Ordnance
- UXO Site

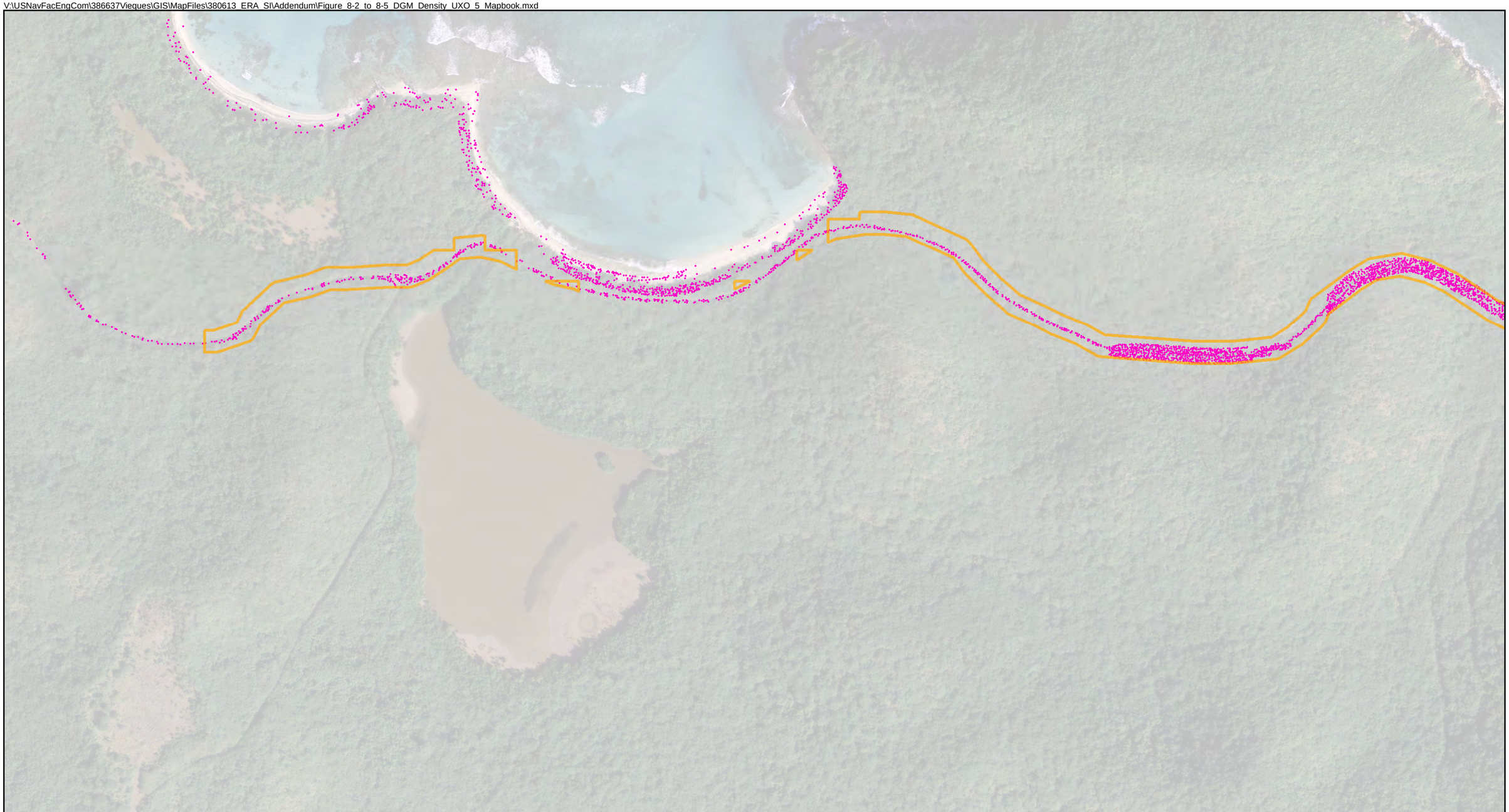
N
W E
S

0 500 1,000 2,000
Feet

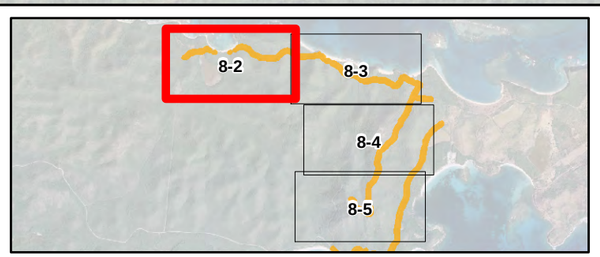
Figure 8-1
Location of Surface MEC Items Removed from UXO 5
Former VNTR, Vieques, Puerto Rico

CH2MHILL

V:\USNavFacEngCom\386637Vieques\GIS\MapFiles\380613_ERA_SI\Addendum\Figure_8-2_to_8-5_DGM_Density_UXO_5_Mapbook.mxd



Legend
- DGM Anomaly
- DGM Anomaly Polygon
- UXO Site



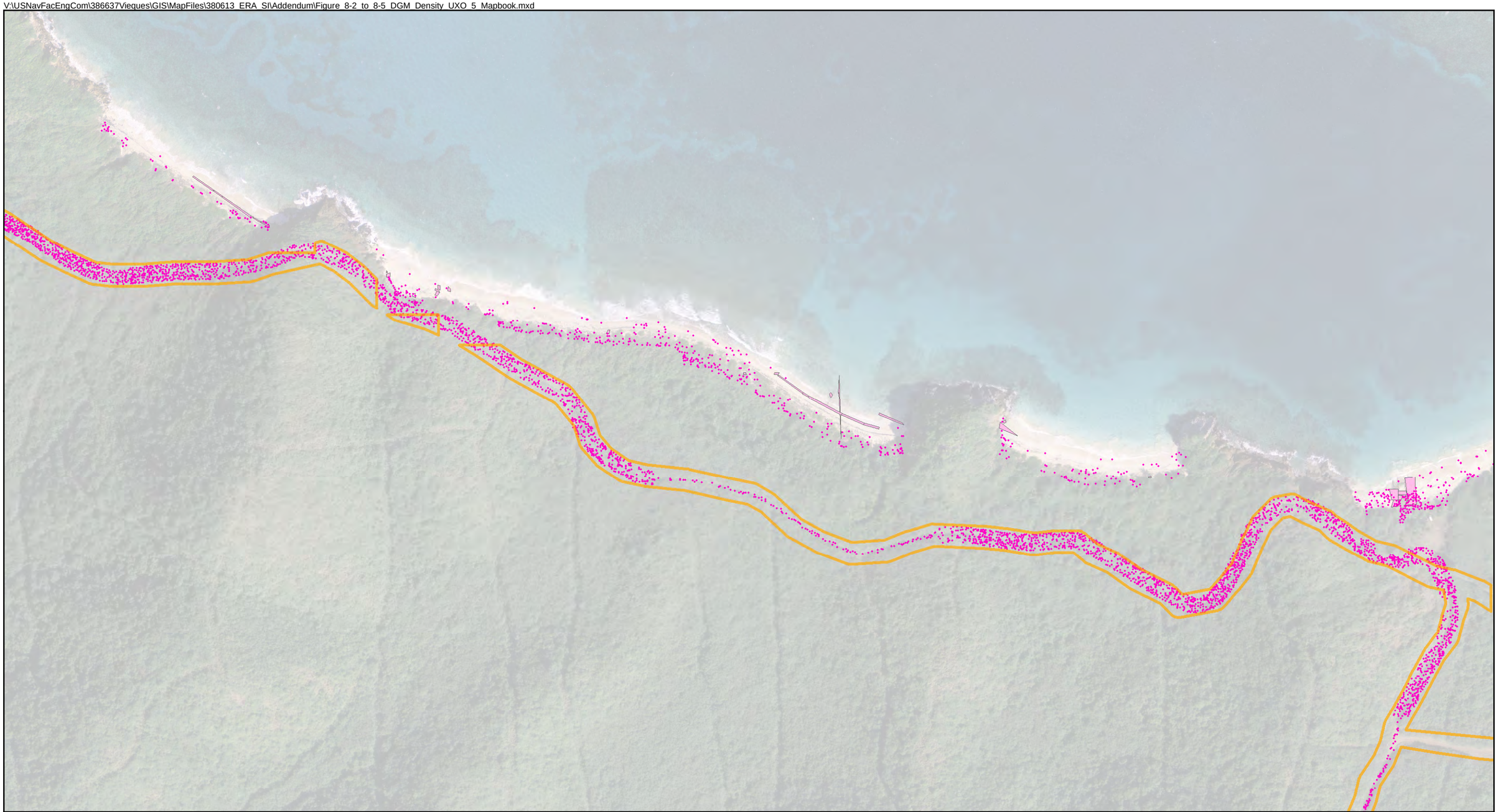
N
W E
S

0 150 300 600
Feet

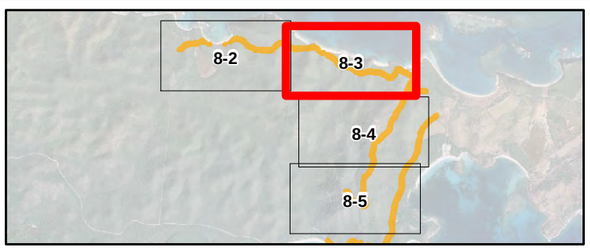
Figure 8-2
DGM Anomaly Density within UXO 5
Former VNTR, Vieques, Puerto Rico

CH2MHILL

V:\USNavFacEngCom\386637Vieques\GIS\MapFiles\380613_ERA_SI\Addendum\Figure_8-2_to_8-5_DGM_Density_UXO_5_Mapbook.mxd



Legend
- DGM Anomaly
- DGM Anomaly Polygon
- UXO Site



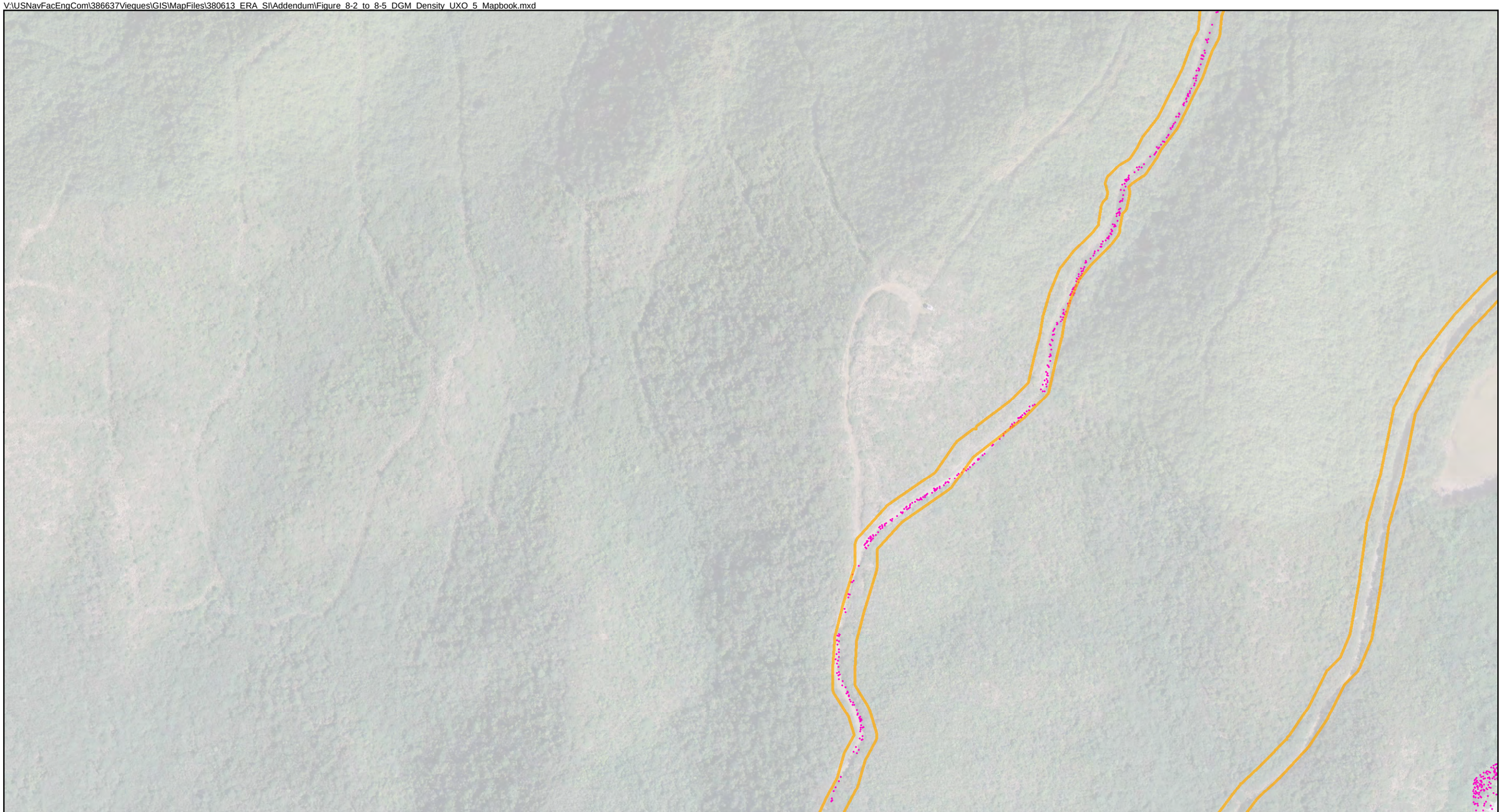
N
W E
S

0 150 300 600
Feet

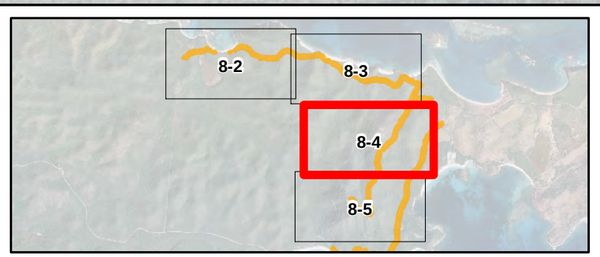
Figure 8-3
DGM Anomaly Density within UXO 5
Former VNTR, Vieques, Puerto Rico

CH2MHILL

V:\USNavFacEngCom\386637Vieques\GIS\MapFiles\380613_ERA_SI\Addendum\Figure_8-2_to_8-5_DGM_Density_UXO_5_Mapbook.mxd



Legend
- DGM Anomaly
- DGM Anomaly Polygon
- UXO Site



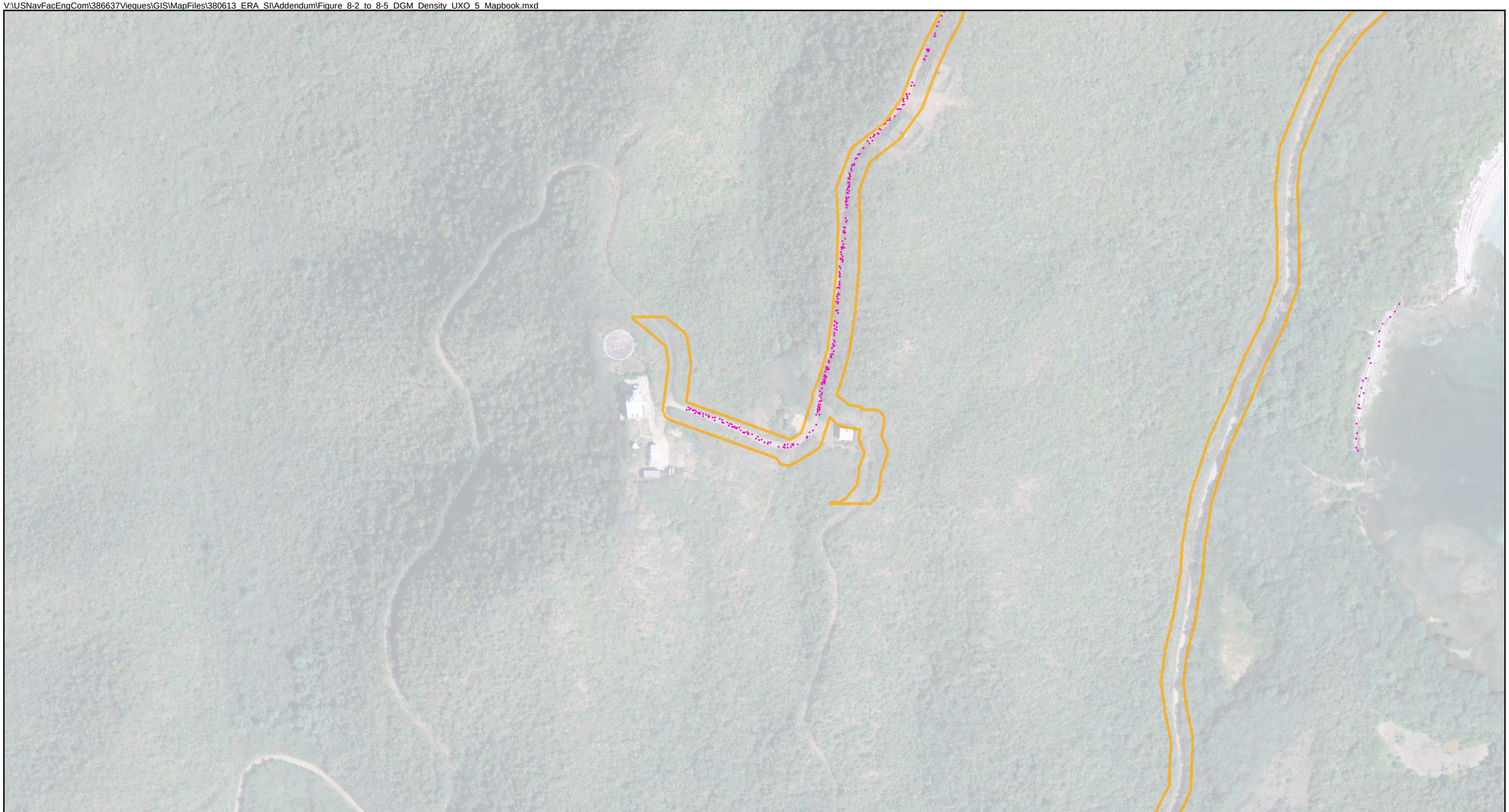
N
W E
S

0 150 300 600
Feet

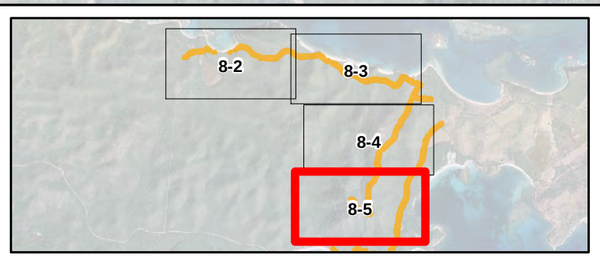
Figure 8-4
DGM Anomaly Density within UXO 5
Former VNTR, Vieques, Puerto Rico

CH2MHILL

V:\USNavFacEngCom\386637Vieques\GIS\MapFiles\380613_ERA_SI\Addendum\Figure_8-2_to_8-5_DGM_Density_UXO_5_Mapbook.mxd



Legend
- DGM Anomaly
- DGM Anomaly Polygon
- UXO Site



N
W E
S

0 150 300 600
Feet

Figure 8-5
DGM Anomaly Density within UXO 5
Former VNTR, Vieques, Puerto Rico

CH2MHILL

V:\USNavFacEngCom\386637Vieques\GIS\MapFiles\380613_ERA_SI\Addendum\Figure_8-6_UXO_5_Transect_Findings.mxd

Legend
- Munitions Debris
- Material Potentially Presenting an Explosive Hazard
- Unexploded Ordnance
- Transect
- UXO Site

N
W E
S

0 500 1,000 2,000
Feet

Figure 8-6
UXO 5 Transect Findings
Former VNTR, Vieques, Puerto Rico

CH2MHILL

V:\USNavFacEngCom\386637Vieques\GIS\MapFiles\380613_ERA_SI\Addendum\Figure_8-7_UXO_5_Magnetometer_Survey_Results.mxd

Legend

EADA

Aerial Magnetometer Survey Total Magnetic Field

-4.6 -2.3 0.0 1.9 3.8 5.8 7.7 9.6

N
W E
S

0 500 1,000 2,000
Feet

Figure 8-7
UXO 5 Magnetometer Survey Results
Former VNTR, Vieques, Puerto Rico

CH2MHILL

SECTION 9

UXO 6—EMA/SIA Public Roads

9.1 Background

UXO 6 encompasses approximately 62 acres of roads including the road surface and 25 foot buffers on each side of the roads. The western portion of UXO 6 lies in the former EMA and the eastern portion lies in the former SIA. For additional information and site history, including historical military use, see the site descriptions for the former SIA (UXO 10) and the former EMA (UXO 12 and UXO 13) in Sections 13, 15, and 16, respectively.

9.2 ERA/SI Findings

9.2.1 NTCRA Results

UXO 6 runs through the western portion of UXO 6 (former EMA) and approximately 1.5 miles of UXO 6 runs through UXO 10 (former SIA) where the NTCRA is being conducted. Through May 2010, a total of six MEC items have been located and removed from UXO 6. The types of MEC items removed during the NTCRA are presented in **Figure 9-1**. The types of surface items removed at UXO 6 during the NTCRA are presented in **Table 9-1**.

TABLE 9-1
Summary of MEC Items Identified at UXO 6

	Number of items identified during transects	Number of items identified during TCRA/ NTCRA through May 2010
MEC Category		
Flares-Pyrotechnics	--	2
Projectiles / Mortars	--	3
Rockets / Guided Missiles	--	1
MD Category		
Bombs	1	--
Scrap	--	145
Range Related Debris		
Total	1	721

A DGM survey was conducted along the roads and buffer that make up UXO 6. Approximately 258 anomalies were identified in the 2 acres where DGM were conducted. The DGM anomaly map for UXO 6 is presented as **Figure 9-2.**

9.2.2 Transect Inspections

Transect inspections were conducted over approximately 10 percent (6 acres) of UXO 6. During the transect evaluations no MEC items were identified on the surface (**Figure 9-3** and **Table 9-1**).

The western section of UXO 6 is relatively free of MEC, MD, and RRD, which would be expected from the past activities carried out in this area and the frequent use of this roadway for access to the site.

9.2.3 Aerial Survey Results

The aerial LiDAR survey and orthophotography of UXO 6 do not indicate the presence of craters or AOIs. **Appendix C** presents the bare earth models produced from the LiDAR survey.

Results of the AMS show that UXO 6 does pass through portions of EADAs 30, 31 and 37; which are described as having large discrete anomalies (Sky Research, Inc., 2009). **Figure 9-4** shows the AMS results..

9.2.4 Summary of Findings

A total of six MEC items were identified at UXO 6 during the current NTCRA for surface and subsurface clearance.

9.3 Recommendations

The surface removal of MEC from this site is currently being conducted as part of the NTCRA (interim action). Based on findings from the NTCRA a RI/FS should be conducted at UXO 6.

V:\USNavFacEngCom\386637Vieques\GIS\MapFiles\380613_ERA_SI\Addendum\Figure_9-1_Location_of_Surface_MEC_Items_Removed_UXO_6.mxd

Legend
- Range Related Debris
- Munitions Debris
- Material Potentially Presenting an Explosive Hazard
- Unexploded Ordnance
- UXO Site

N
W E
S

0 750 1,500 3,000
Feet

Figure 9-1
Location of Surface MEC Items Removed from UXO 6
Former VNTR, Vieques, Puerto Rico

CH2MHILL

V:\USNavFacEngCom\386637Vieques\GIS\MapFiles\380613_ERA_SI\Addendum\Figure_9-2_DGM_Density_UXO_6.mxd

Legend
- DGM Anomaly
- UXO Site

N
W E
S

0 200 400 800
Feet

Figure 9-2
DGM Anomaly Density within UXO 6
Former VNTR, Vieques, Puerto Rico

CH2MHILL

V:\USNavFacEngCom\386637Vieques\GIS\MapFiles\380613_ERA_SI\Addendum\Figure_9-3_UXO_6_Transect_Findings.mxd

Legend
- Range Related Debris
- Munitions Debris
- Transect
- UXO Site

N
W E
S

0 750 1,500 3,000
Feet

Figure 9-3
UXO 6 Transect Findings
Former VNTR, Vieques, Puerto Rico

CH2MHILL

V:\USNavFacEngCom\386637Vieques\GIS\MapFiles\380613_ERA_SI\Addendum\Figure_9-4_UXO_6_Magnetometer_Survey_Results.mxd

Legend
EADA

Aerial Magnetometer Survey Total Magnetic Field

-4.6 -2.3 0.0 1.9 3.8 5.8 7.7 9.6

N
W E
S

0 750 1,500 3,000
Feet

Figure 9-4
UXO 6 Magnetometer Survey Results
Former VNTR, Vieques, Puerto Rico

CH2MHILL

SECTION 10

UXO 7—EMA/SIA North Beaches

10.1 Background

UXO 7 encompasses approximately 54 acres and is comprised of the sandy beach areas located along the north shore of the former VNTR across UXO sites 10, 12, and 13 (formerly referred to as the SIA and EMA); the western portion of UXO 7 lies in UXO 12 and UXO 13 (former EMA) and the eastern portion lies in UXO 10 (former SIA). The sandy beach areas are defined as the beaches that are predominantly sand and extend from the waterline to the vegetation line or the inland extent of turtle nesting habitats, as described in Amendment 1 to *the Final Biological Assessment for the Former Live Impact Area* (GMI, 2007a). Beaches located in UXO 7 include Puerto Diablo, Puerto Negro, and Playa Capana. There are 10 additional beaches that have no known historical names included in UXO 7; for tracking and identification purposes these beaches are numbered 21 and 25 through 33. **Figure 10-1** shows the beaches that make up UXO 7 with the inland extent of turtle nesting habitat.

For additional information and site history, including historical military use, see the site descriptions for the former SIA (UXO 10) and the former EMA (UXO 12 and UXO 13) in Sections 13, 15, and 16, respectively.

10.2 ERA/SI Findings

10.2.1 NTCRA Results

In June 2009 the field activities for a NTCRA (interim action) were initiated (CH2M HILL, 2008b). The scope of the NTCRA is to remove subsurface munitions from UXO Sites 1, 2, 3, 5 through 8, 11, and 15. Through May 2010 a total of 72 MEC items have been located and removed from UXO 7 during the NTCRA. The types of MEC items removed during the NTCRA are presented in **Figure 10-1** and **Table 10-1**.

As part of the NTCRA a DGM survey was conducted over approximately 14 acres of the sandy beach areas and turtle nesting buffers in UXO 7. A total of 2,379 subsurface anomalies were detected during the DGM. The DGM anomaly maps for UXO 7 are shown on **Figures 10-2 though 10-6**.

TABLE 10-1
Summary of MEC items identified at UXO 7

	Number of Items Identified during Transects	Number of Items Identified during NTCRA through May 2010
MEC Category		
Bombs	1	59
Flares-Pyrotechnics	--	1
MEC Component	--	1
Projectiles / Mortars	1	10
Rockets / Guided Missiles	--	1
MD Category		
Grenades	2	--
Projectiles / Mortars	2	--
Scrap	--	155
Range Related Debris		
Total	3	275

10.2.2 Transect Inspections

Transect inspections were conducted at UXO 7 sandy beach areas as shown on **Figure 10-7**. The objective of the inspections for the beaches was to locate, catalog, and remove munitions items at the surface and locate and catalog subsurface metallic anomalies with a handheld magnetometer. A summary of the items found during the transect inspections at UXO 7 are presented in **Figure 10-7** and **Table 10-1**. Two MEC items and four MD items (ordnance fragments) were located during the transect evaluations (**Figure 10-7**).

A handheld magnetometer survey was conducted for the sandy beach areas at UXO 7. Data compiled during this survey showed a moderate number of anomalies at beaches in the eastern and western portions of UXO 7 and a slightly higher concentration at the central beaches. A summary of the qualitative magnetometer responses compared to AMS data at UXO 7 beach areas is presented on **Figure 10-8**.

10.2.3 Aerial Survey Results

The aerial LiDAR survey or orthophotography did not identify any craters or AOIs. **Appendix C** presents the bare earth models produced from the LiDAR survey.

During the AMS investigation 11 EADAs were partially associated with UXO 7. **Figure 10-8** shows the AMS results. The Sky Research report (2009) describes the EADAs as:

- **EADA 4—**Some geology associated with shoreline, but numerous large discrete anomalies indicate probable presence of ferrous material particularly at the Eastern extent.
- **EADA 6—**Presence of large discrete anomalies and high target density, possibly related to geology. The dipole angle distribution is moderate and may indicate UXO.
- **EADA 7—**Although geologically active, the presence of large discrete anomalies, high anomaly density, and apparent clearing indicate the presence of ferrous material. The dipole angle distribution is high and may indicate UXO.EADA 9—Well defined concentration of anomalies (possibly associated with shallow sea floor) large discrete anomalies along shoreline are likely ferrous material. The dipole angle distribution is high and may indicate UXO. Lies adjacent to a target area (Range 4B) which was established next to the shoreline. Significant metallic debris is visually present in the cliff face in this area and there are also still large target vehicles present in this area.
- **EADA 10—**Large discrete anomalies and associated high anomaly density area.
- **EADA 11—**Large discrete anomalies may be associated with geology.
- **EADA 12—**Many large discrete anomalies possibly associated with geology. The dipole angle distribution is high and may indicate UXO.
- **EADA 13—**Localized grouping of small anomalies just off shore.
- **EADA 14—**Many large discrete targets possibly associated with geology.
- **EADA 16—**Many large discrete anomalies.
- **EADA 17—**Many large discrete anomalies associated with clearing.
- **EADA 18—**Many small anomalies consistent with typical responses from UXO-related activity. The dipole angle distribution is high and may indicate UXO.

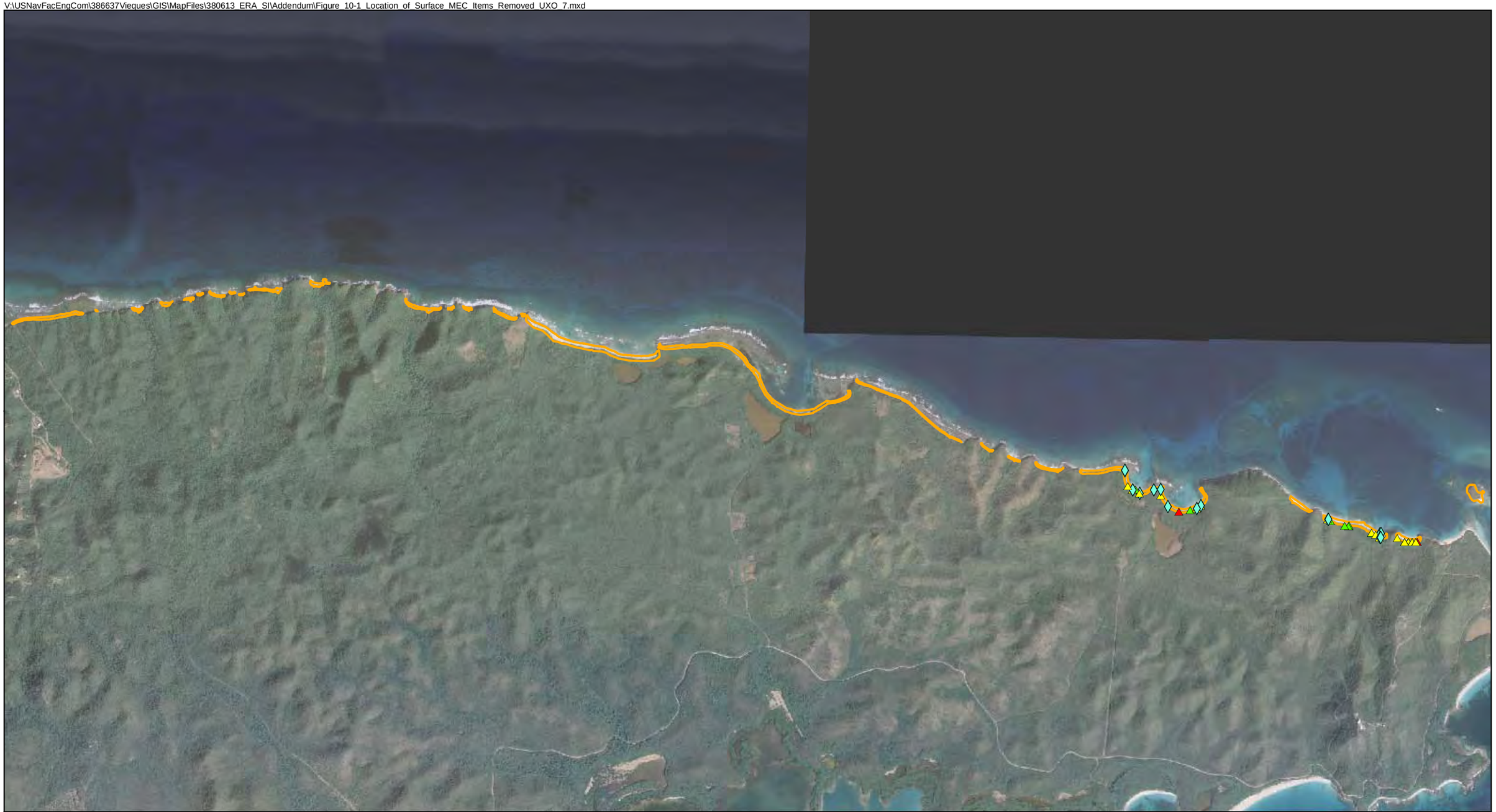
10.2.4 Summary of Findings

A total of 72 MEC were found at UXO 7.The DGM and AMS identified over 2,300 subsurface anomalies, which corresponds to less than 100 anomalies per acre. UXO 7 is included in the current NTCRA for surface and subsurface clearance.

10.3 Recommendations

The removal of subsurface MEC at the beaches is currently being completed under the NTCRA. Based on the results of this investigation and the NTCRA a RI/FS should be completed for UXO 7.

V:\USNavFacEngCom\386637Vieques\GIS\MapFiles\380613_ERA_SI\Addendum\Figure_10-1_Location_of_Surface_MEC_Items_Removed_UXO_7.mxd



Legend
- Range Related Debris
- Munitions Debris
- Material Potentially Presenting an Explosive Hazard
- Unexploded Ordnance
- UXO Site

N
W E
S

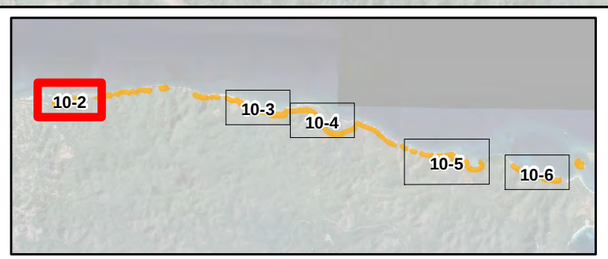
0 1,250 2,500 5,000
Feet

Figure 10-1
Location of Surface MEC Items Removed from UXO 7
Former VNTR, Vieques, Puerto Rico

CH2MHILL

V:\USNavFacEngCom\386637Vieques\GIS\MapFiles\380613_ERA_SI\Addendum\Figure_10-4_to_10-8_DGM_Density_UXO_7.mxd

Legend
- DGM Anomaly
- DGM Anomaly Polygon
- UXO Site



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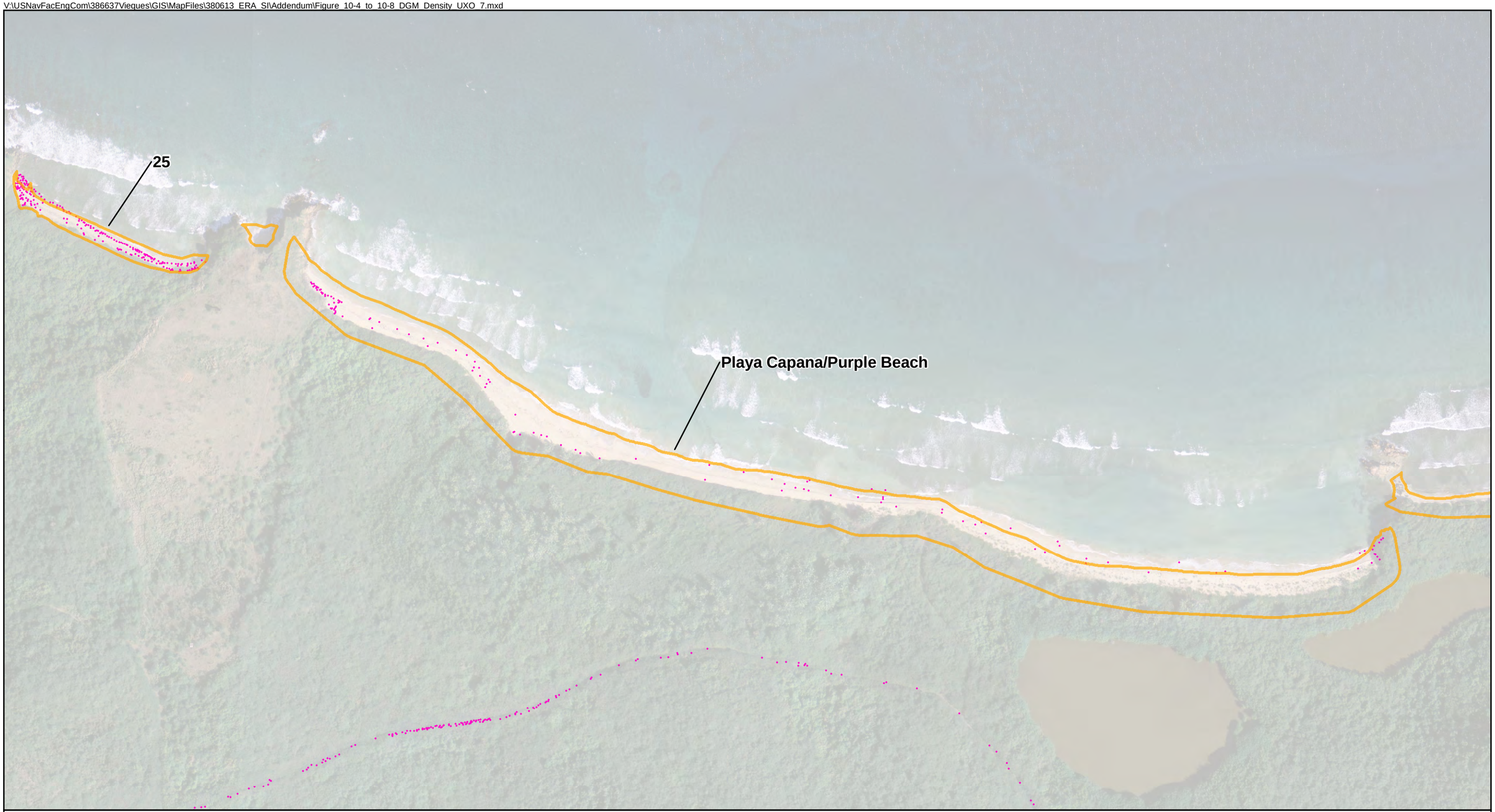
0 150 300 600
Feet

Figure10-2
DGM Anomaly Density within UXO 7
Former VNTR, Vieques, Puerto Rico

CH2MHILL

V:\USNavFacEngCom\386637Vieques\GIS\MapFiles\380613_ERA_SI\Addendum\Figure_10-4_to_10-8_DGM_Density_UXO_7.mxd



Legend
- DGM Anomaly
- DGM Anomaly Polygon
- UXO Site

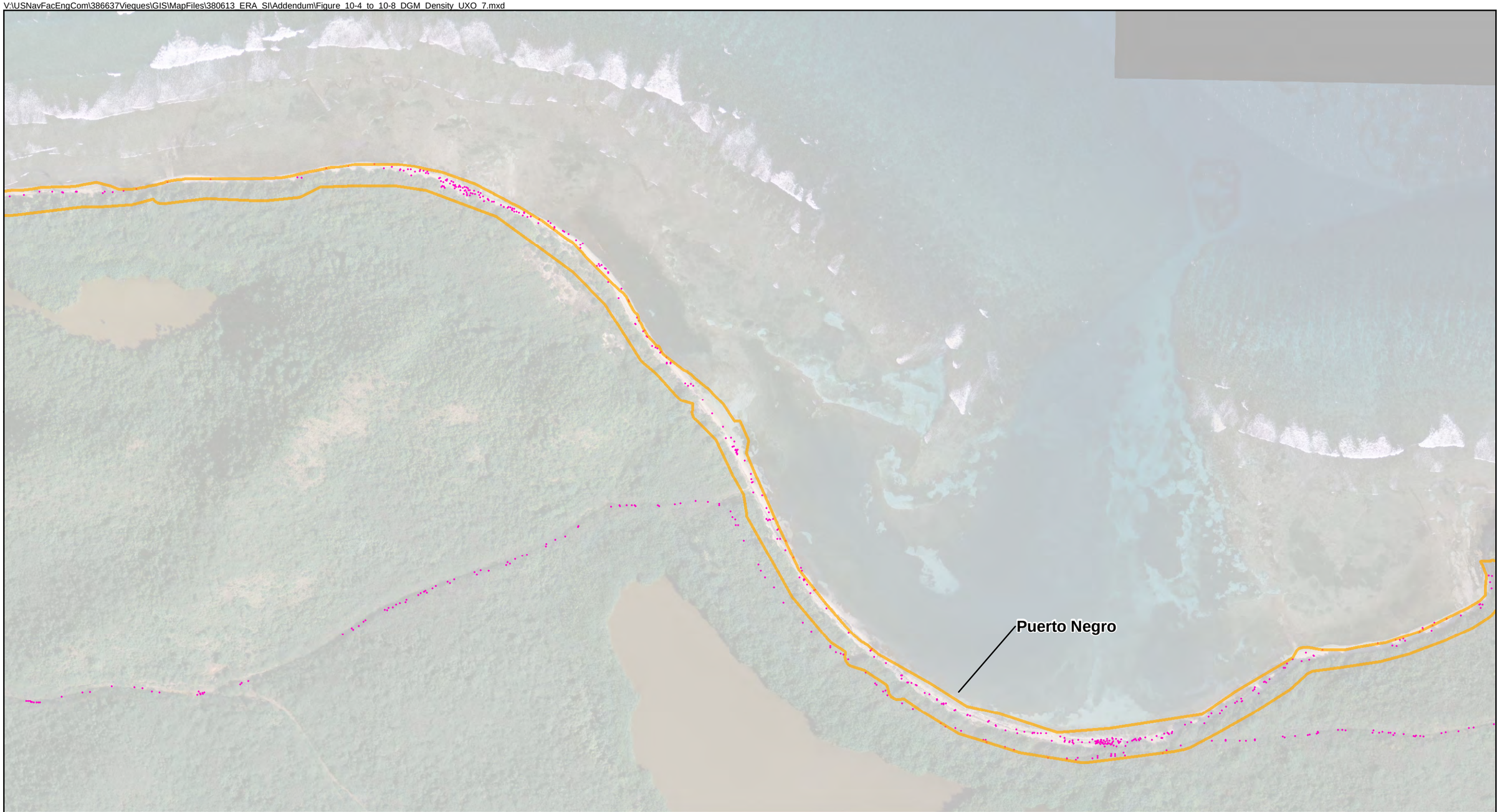
N
W E
S

0 150 300 600
Feet

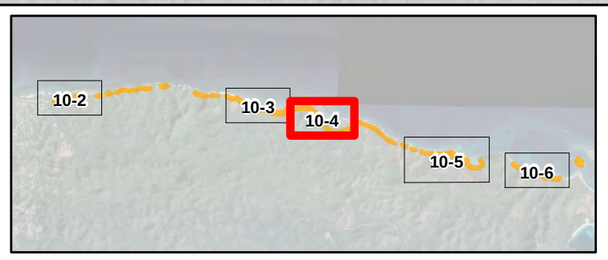
Figure10-3
DGM Anomaly Density within UXO 7
Former VNTR, Vieques, Puerto Rico

CH2MHILL

V:\USNavFacEngCom\386637Vieques\GIS\MapFiles\380613_ERA_SI\Addendum\Figure_10-4_to_10-8_DGM_Density_UXO_7.mxd



Legend
- DGM Anomaly
- DGM Anomaly Polygon
- UXO Site



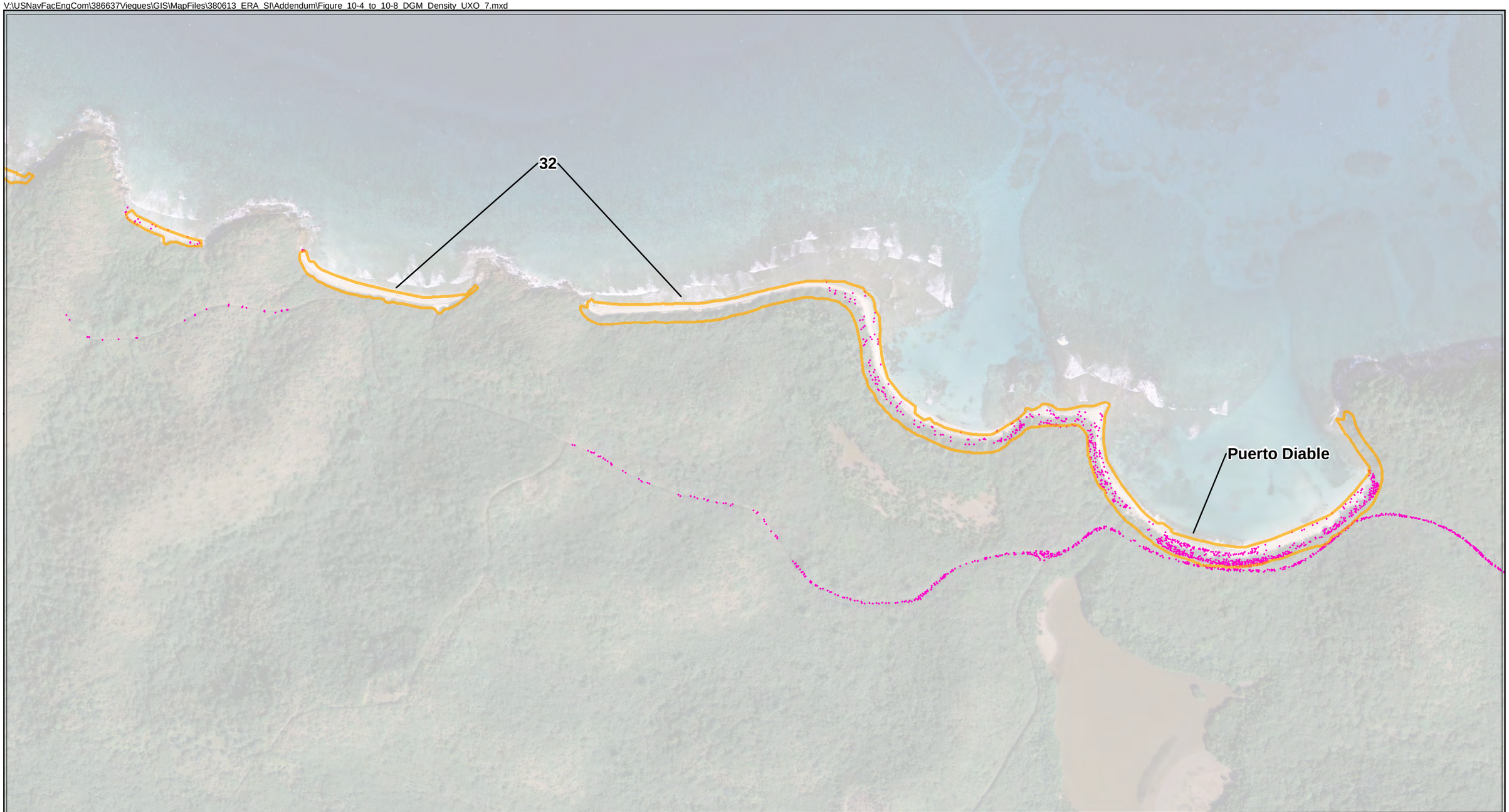
N
W E
S

0 150 300 600
Feet

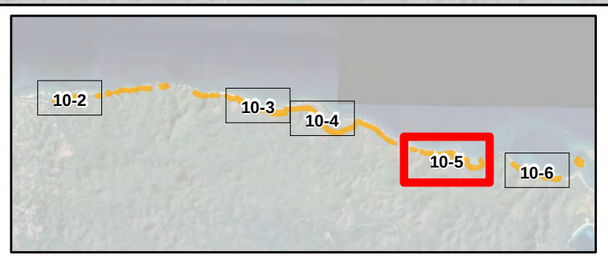
Figure10-4
DGM Anomaly Density within UXO 7
Former VNTR, Vieques, Puerto Rico

CH2MHILL

V:\USNavFacEngCom\386637Vieques\GIS\MapFiles\380613_ERA_SI\Addendum\Figure_10-4_to_10-8_DGM_Density_UXO_7.mxd



Legend
- DGM Anomaly
- DGM Anomaly Polygon
- UXO Site



N
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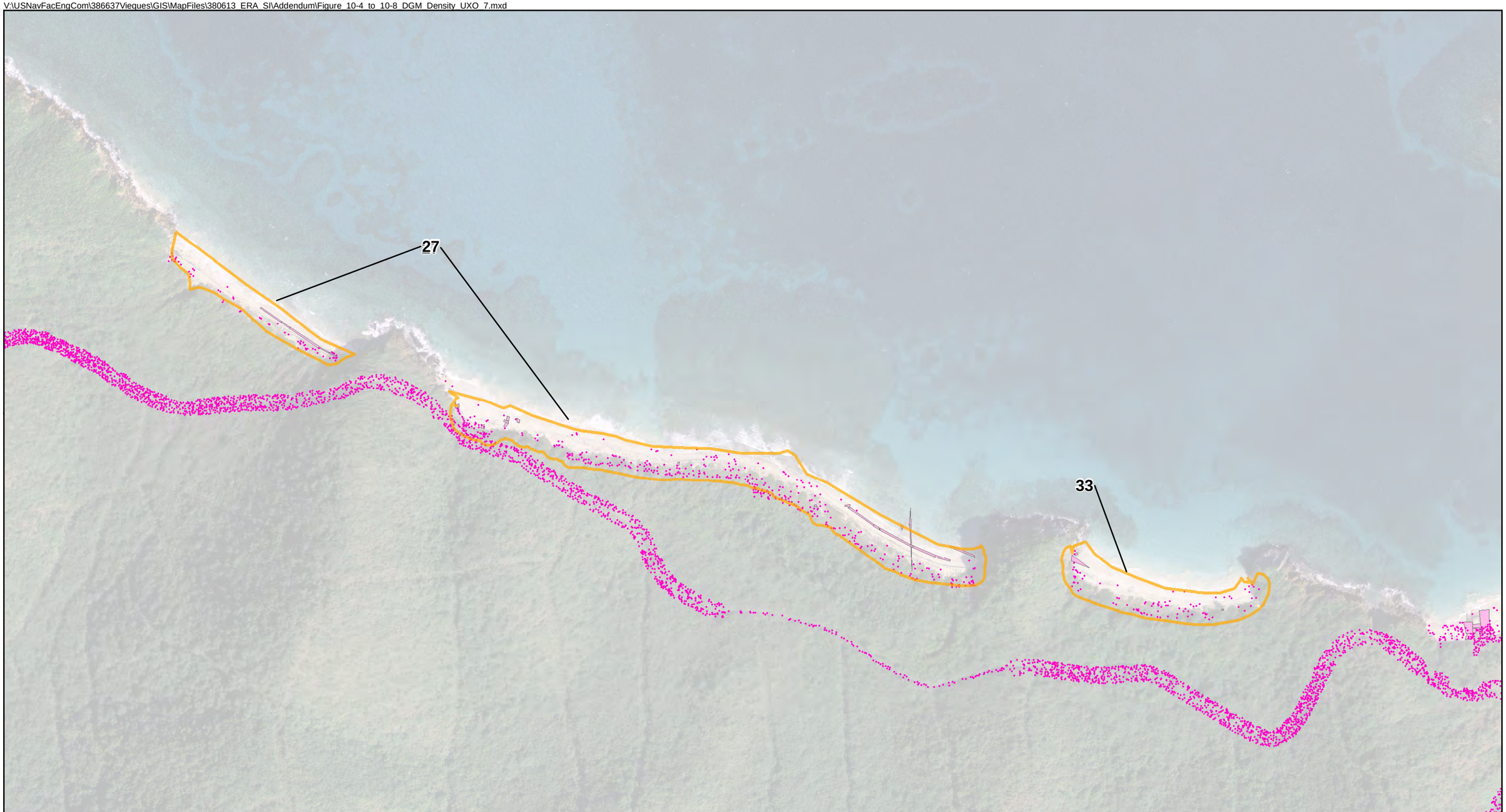
0 150 300 600
Feet

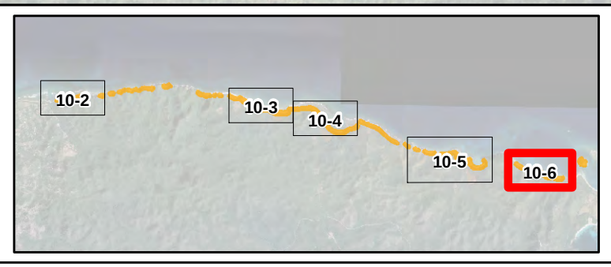
Figure10-5
DGM Anomaly Density within UXO 7
Former VNTR, Vieques, Puerto Rico

CH2MHILL

V:\USNavFacEngCom\386637Vieques\GIS\MapFiles\380613_ERA_SI\Addendum\Figure_10-4_to_10-8_DGM_Density_UXO_7.mxd



Legend
- DGM Anomaly
- DGM Anomaly Polygon
- UXO Site



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0 150 300 600
Feet

Figure10-6
DGM Anomaly Density within UXO 7
Former VNTR, Vieques, Puerto Rico

CH2MHILL

V:\USNavFacEngCom\386637Vieques\GIS\MapFiles\380613_ERA_SI\Addendum\Figure_10-7_UXO_7_Transect_Findings.mxd

Legend
- Range Related Debris
- Munitions Debris
- Munitions and Explosives of Concern
- Unexploded Ordnance
- Transect
- UXO Site

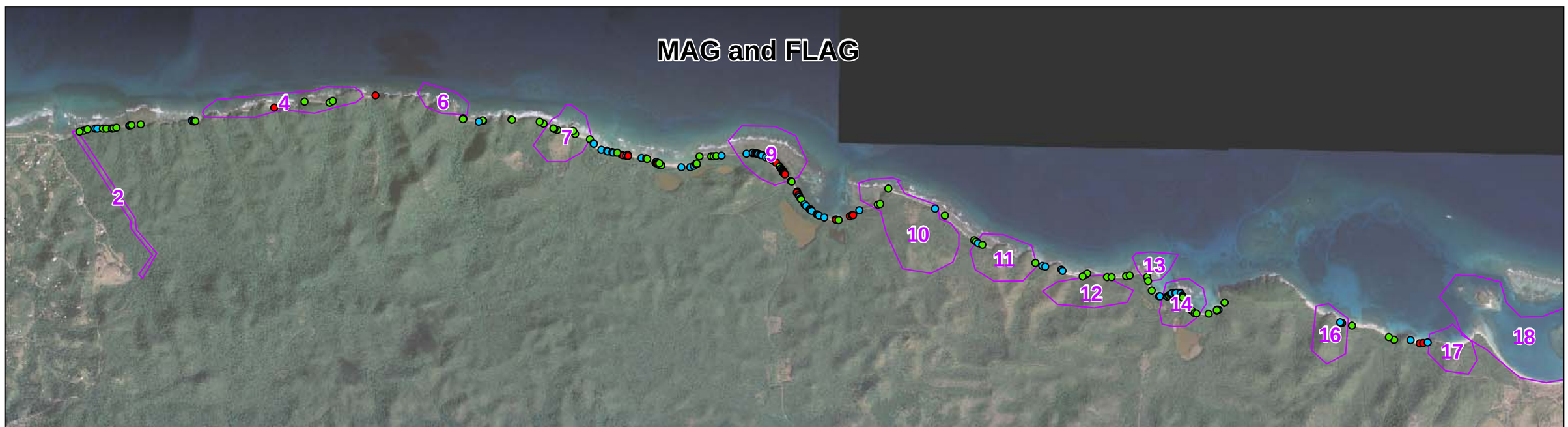
N
W E
S

0 1,250 2,500 5,000
Feet

Figure 10-7
UXO 7 Transect Findings
Former VNTR, Vieques, Puerto Rico

CH2MHILL

V:\USNavFacEngCom\386637Vieques\GIS\MapFiles\380613_ERA_SI\Addendum\Figure_10-8_UXO_7_Magnetometer_Survey_Results.mxd



Legend

Magnetometer Response from "Mag and Flag"

- Low
- Medium
- High
- EADA

Aerial Magnetometer Survey Total Magnetic Field

-4.6 -2.3 0.0 1.9 3.8 5.8 7.7 9.6

N W E S

0 1,250 2,500 5,000 Feet

Figure 10-8
UXO 7 Magnetometer Survey Results
Former VNTR, Vieques, Puerto Rico

CH2MHILL

SECTION 11

UXO 8—SIA South Beaches

11.1 Background

UXO 8 encompasses approximately 45 acres and is comprised of the sandy beaches located along the southern shore of the area formerly referred to as the SIA. The sandy beach areas are defined as the beaches that are predominantly sand and extend from the waterline to the vegetation line or the inland extent of turtle nesting habitats, as described in Amendment 1 to *the Final Biological Assessment for the Former Live Impact Area* (GMI, 2007a). Beaches located in UXO 8 include Playa Matias, Playa Jalova, Playa Jalovita, Paya Yoye, and Playa Fanduca. There are 10 additional beaches that have no known historical names included in UXO 7. **Figure 11-1** shows the beaches that make up UXO 8 with the inland extent of turtle nesting habitat.

For additional information and site history, including historical military use, see the UXO 10 site description in Section 13.

11.2 ERA/SI Findings

11.2.1 NTCRA Results

In June 2009 the field activities for a NTCRA (interim action) were initiated (CH2M HILL, 2008b). The scope of the NTCRA is to remove subsurface munitions from UXO Sites 1, 2, 3, 5 through 8, 11, and 15. Three MEC items have been located and removed from UXO 8 during the NTCRA through May 2010. The types of MEC items removed during the NTCRA are presented in **Figure 11-1** and **Table 11-1**.

As part of the NTCRA a DGM survey was conducted over approximately 13 acres of the sandy beach areas and turtle nesting buffers in UXO 8. A total of 1,250 subsurface anomalies were detected during the DGM survey. Due to the dynamic nature of the sandy beach area, the DGM data will serve as a guide for determining the need for future investigations or actions. DGM anomaly densities are shown in **Figures 11- 2 through 11- 5**.

11.2.2 Transect Inspections

A limited number of transects were completed for the turtle nesting areas (vegetated areas) of UXO 8 because the NTCRA was implemented to remove surface MEC in these areas. Transects were also complete on Isla Conejo due to its proximity to the former training area. The results of the transect activities are presented on **Figure 11-6**. Three MEC items were located during the transect evaluations and are shown on **Figure 11-6**. During the survey of Isla Conejo, 1 MEC item (25mm projectile) and one MPPEH (Mk-24 flare) item were located along with MD and RRD.

During the handheld magnetometer survey a high concentration of possible subsurface anomalies were detected throughout UXO 8. The locations and qualitative magnetometer responses are shown on **Figure 11-7**.

TABLE 11-1
Summary of MEC Items identified at UXO 8

	Number of Items Identified during Transects	Number of Items Identified during TCRA/ NTCRA through May 2010
MEC Category		
Bombs	2	--
Flares-Pyrotechnics	--	1
MEC Component	--	1
Projectiles / Mortars	1	--
Rockets / Guided Missiles	--	1
MD Category		
Bombs	1	--
MEC Component	1	--
Projectiles / Mortars	6	--
Rockets / Guided Missiles	1	--
Scrap	1	100
Range Related Debris		
Total	15	376

11.2.3 Aerial Survey Results

The aerial LiDAR survey or orthophotography did not identify any craters, but three AOIs were identified for UXO 8. The AOIs are very small and are in areas that will be addressed by currently planned interim removal actions (**Figure 3-3**).

Five EADAs were identified during the AMS that fall, at least partially, within UXO 8. A comparison of the DGM survey at UXO 8 and the AMS results is shown on **Figure 11-7**. The Sky Research report (2009) **(Appendix E)** describes these EADAs as:

- **EADA 24—**Large discrete anomalies along shoreline.
- **EADA 25—**Many large discrete anomalies indicate the presence of ferrous material.
- **EADA 29—**Large discrete anomalies and numerous small anomalies indicate presence of ferrous material. The dipole angle distribution is moderate and may indicate UXO.
- **EADA 30—**Large discrete anomalies indicate presence of ferrous material.
- **EADA 31—**Large discrete anomalies indicate presence of ferrous material.

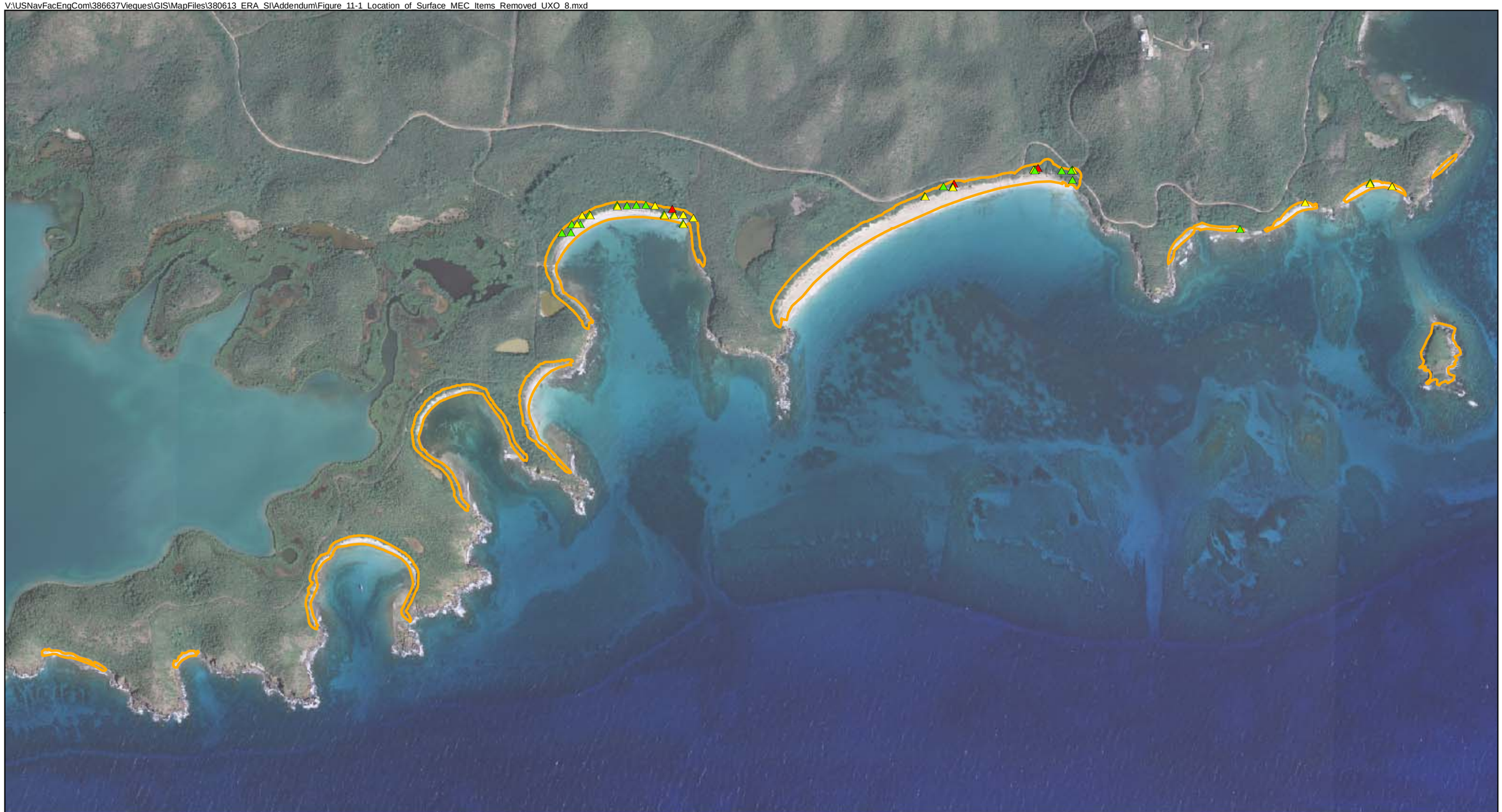
11.2.4 Summary of Findings

A total of three MEC items were found at UXO 8 on Isla Conejo. UXO 8 is included in the current NTCRA for surface and subsurface clearance. The AMS and DGM survey identified over 1,200 subsurface anomalies within UXO 8.

11.3 Recommendations

The removal of subsurface MEC at the beaches is currently being completed under the NTCRA Based on the results of this investigation and the NTCRA a RI/FS should be conducted for UXO 8.

V:\USNavFacEngCom\386637Vieques\GIS\MapFiles\380613_ERA_SI\Addendum\Figure_11-1_Location_of_Surface_MEC_Items_Removed_UXO_8.mxd



Legend
- Range Related Debris
- Munitions Debris
- Unexploded Ordnance
- UXO Site

N
W E
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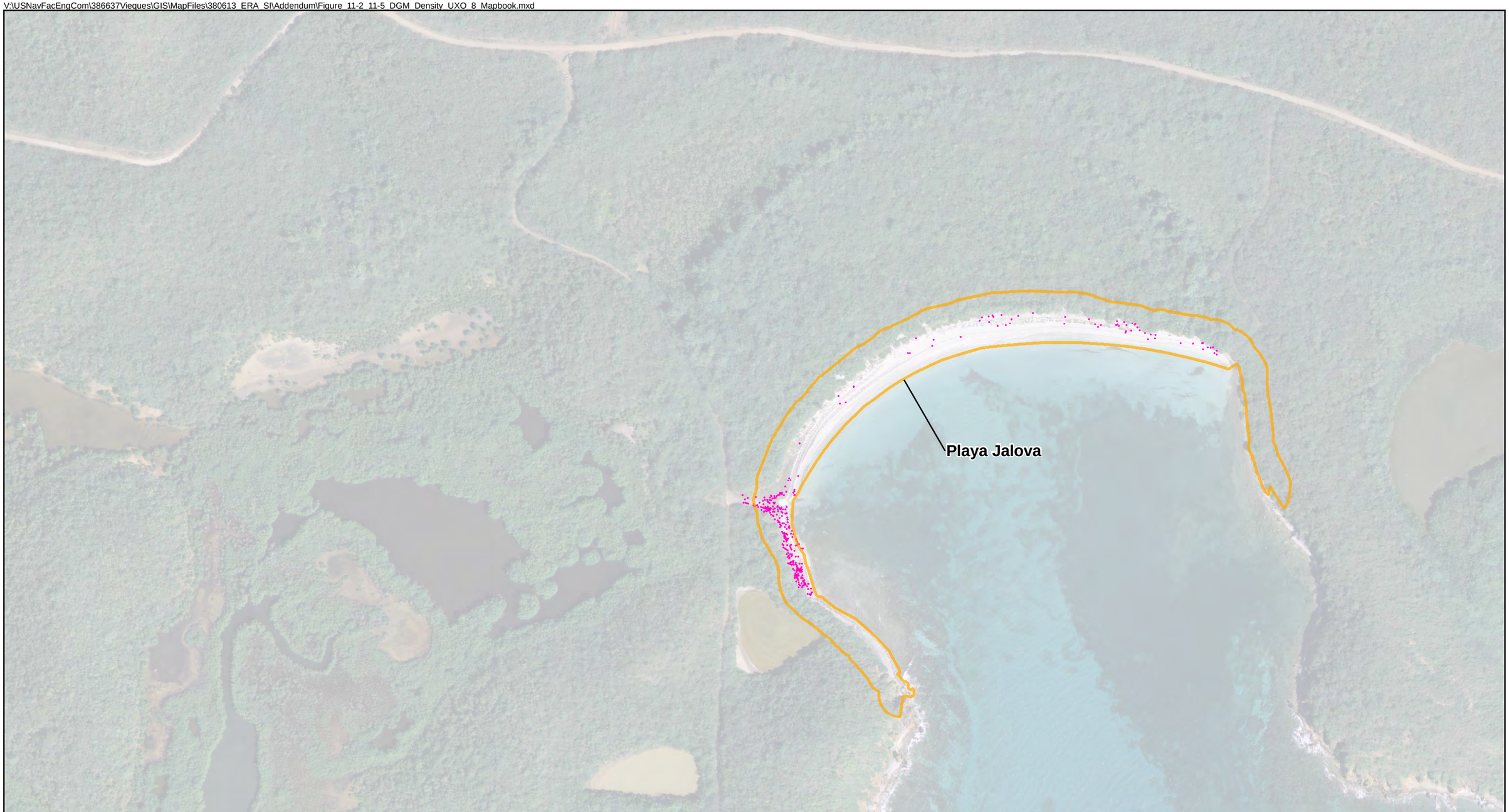
0 500 1,000 2,000
Feet

Figure 11-1
Location of Surface MEC Items Removed from UXO 8
Former VNTR, Vieques, Puerto Rico

CH2MHILL

V:\USNavFacEngCom\386637Vieques\GIS\MapFiles\380613_ERA_SI\Addendum\Figure_11-2_11-5_DGM_Density_UXO_8_Mapbook.mxd



Legend
- DGM Anomaly
- DGM Anomaly Polygon
- UXO Site

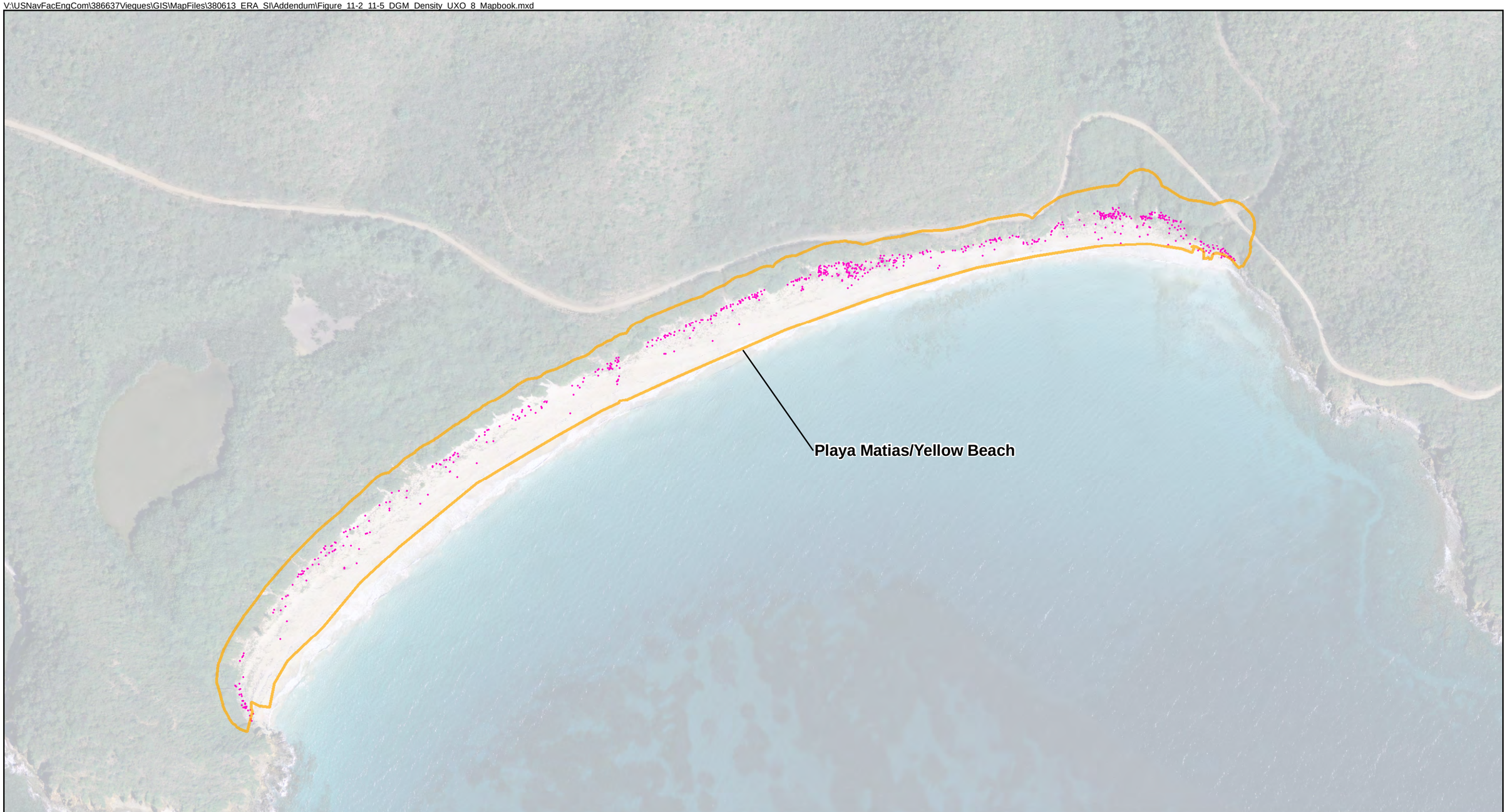
N
W E
S

0 150 300 600
Feet

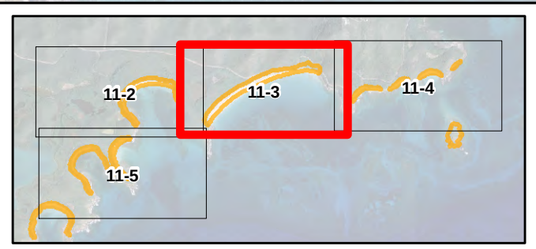
Figure11-2
DGM Anomaly Density within UXO 8
Former VNTR, Vieques, Puerto Rico

CH2MHILL

V:\USNavFacEngCom\386637Vieques\GIS\MapFiles\380613_ERA_SI\Addendum\Figure_11-2_11-5_DGM_Density_UXO_8_Mapbook.mxd



Legend
- DGM Anomaly
- DGM Anomaly Polygon
- UXO Site



N
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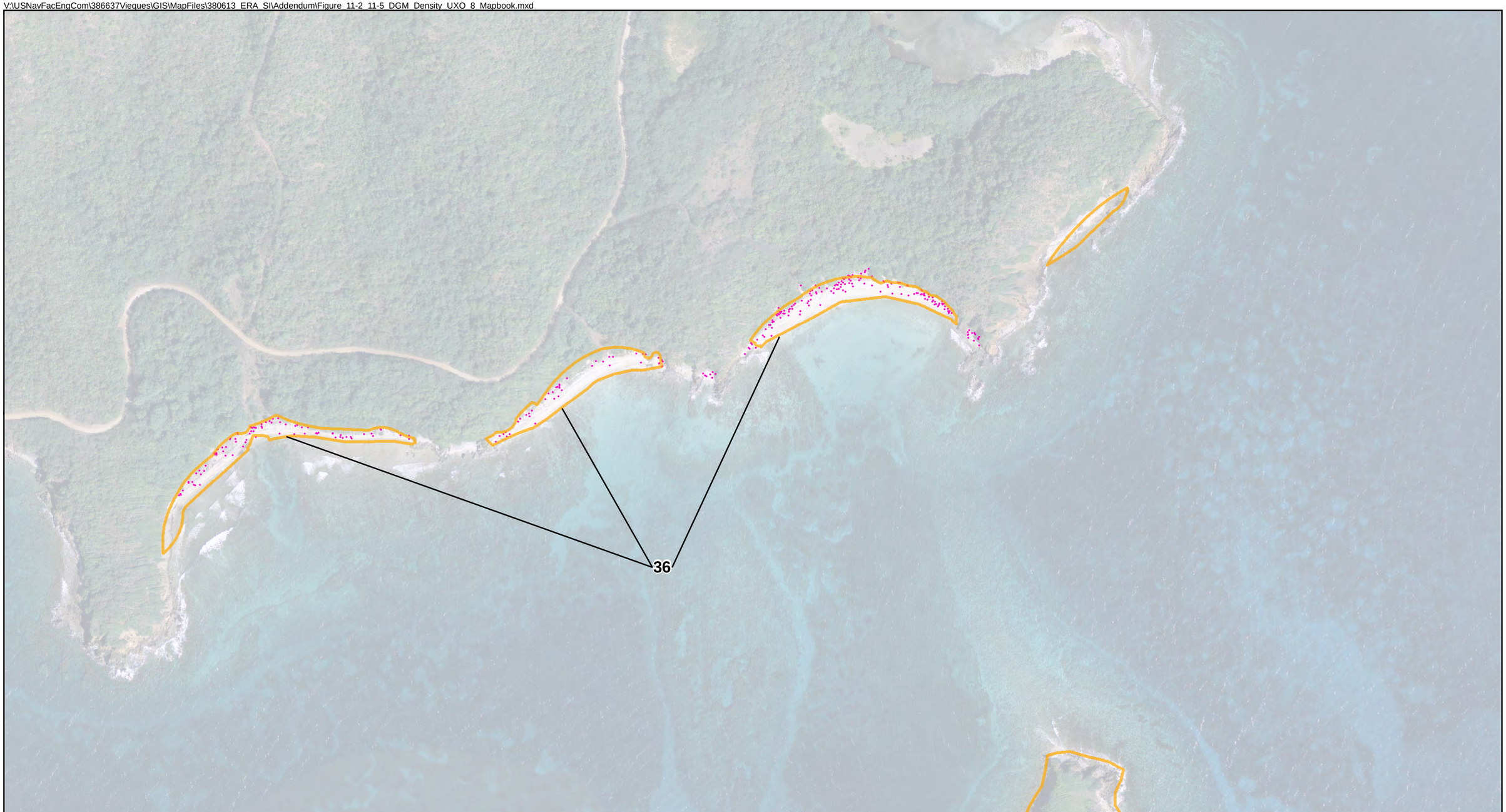
0 150 300 600
Feet

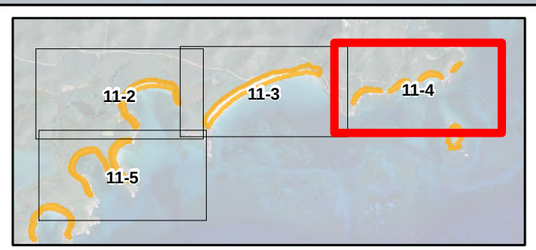
Figure11-3
DGM Anomaly Density within UXO 8
Former VNTR, Vieques, Puerto Rico

CH2MHILL

V:\USNavFacEngCom\386637Vieques\GIS\MapFiles\380613_ERA_SI\Addendum\Figure_11-2_11-5_DGM_Density_UXO_8_Mapbook.mxd



Legend
- DGM Anomaly
- DGM Anomaly Polygon
- UXO Site



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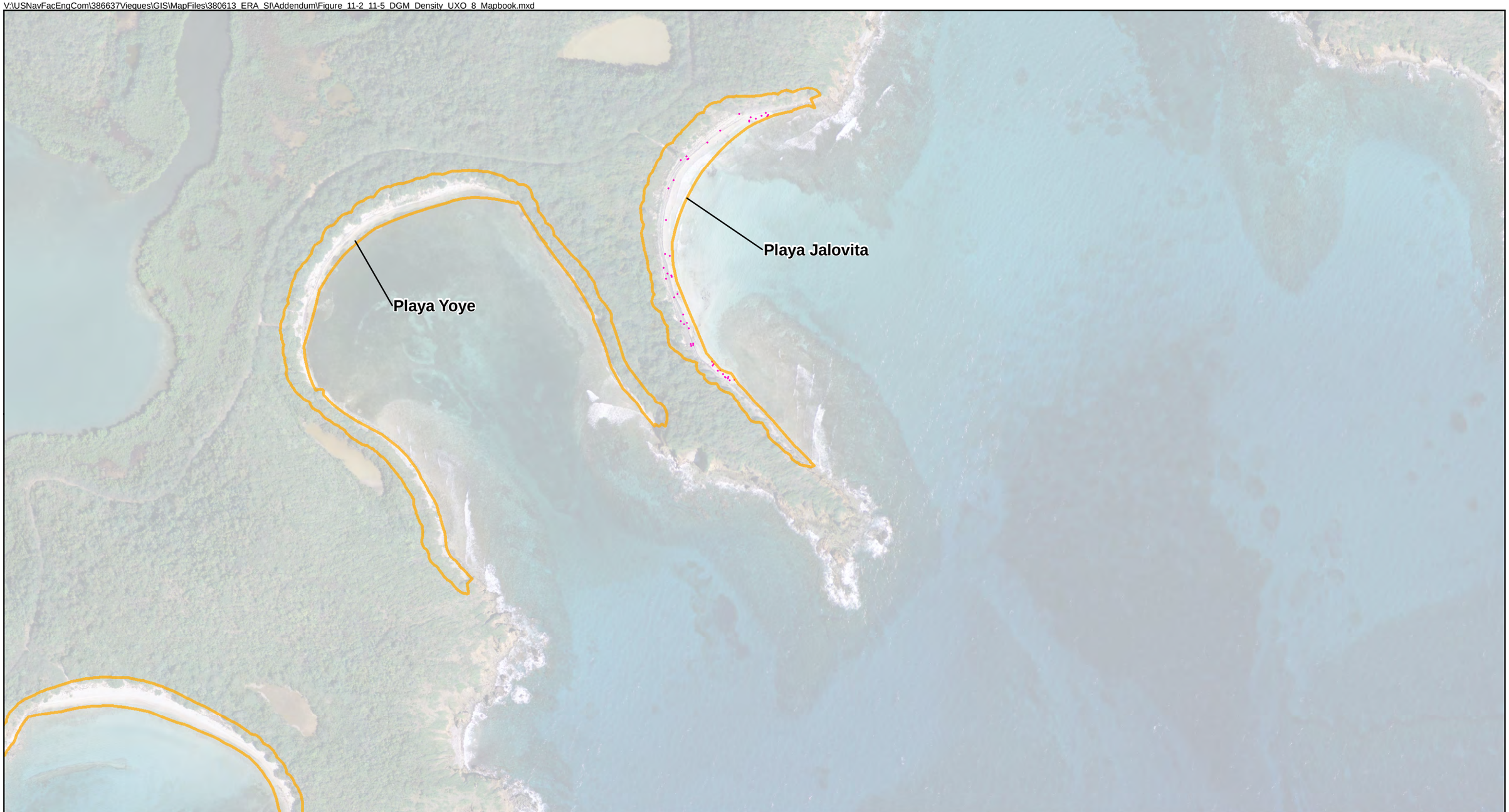
0 150 300 600
Feet

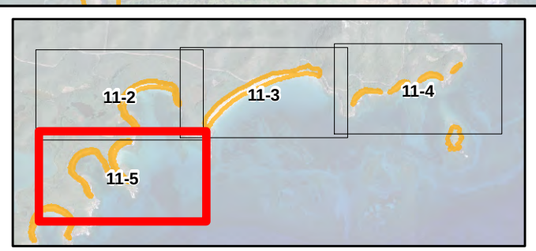
Figure11-4
DGM Anomaly Density within UXO 8
Former VNTR, Vieques, Puerto Rico

CH2MHILL

V:\USNavFacEngCom\386637Vieques\GIS\MapFiles\380613_ERA_SI\Addendum\Figure_11-2_11-5_DGM_Density_UXO_8_Mapbook.mxd



Legend
- DGM Anomaly
- DGM Anomaly Polygon
- UXO Site



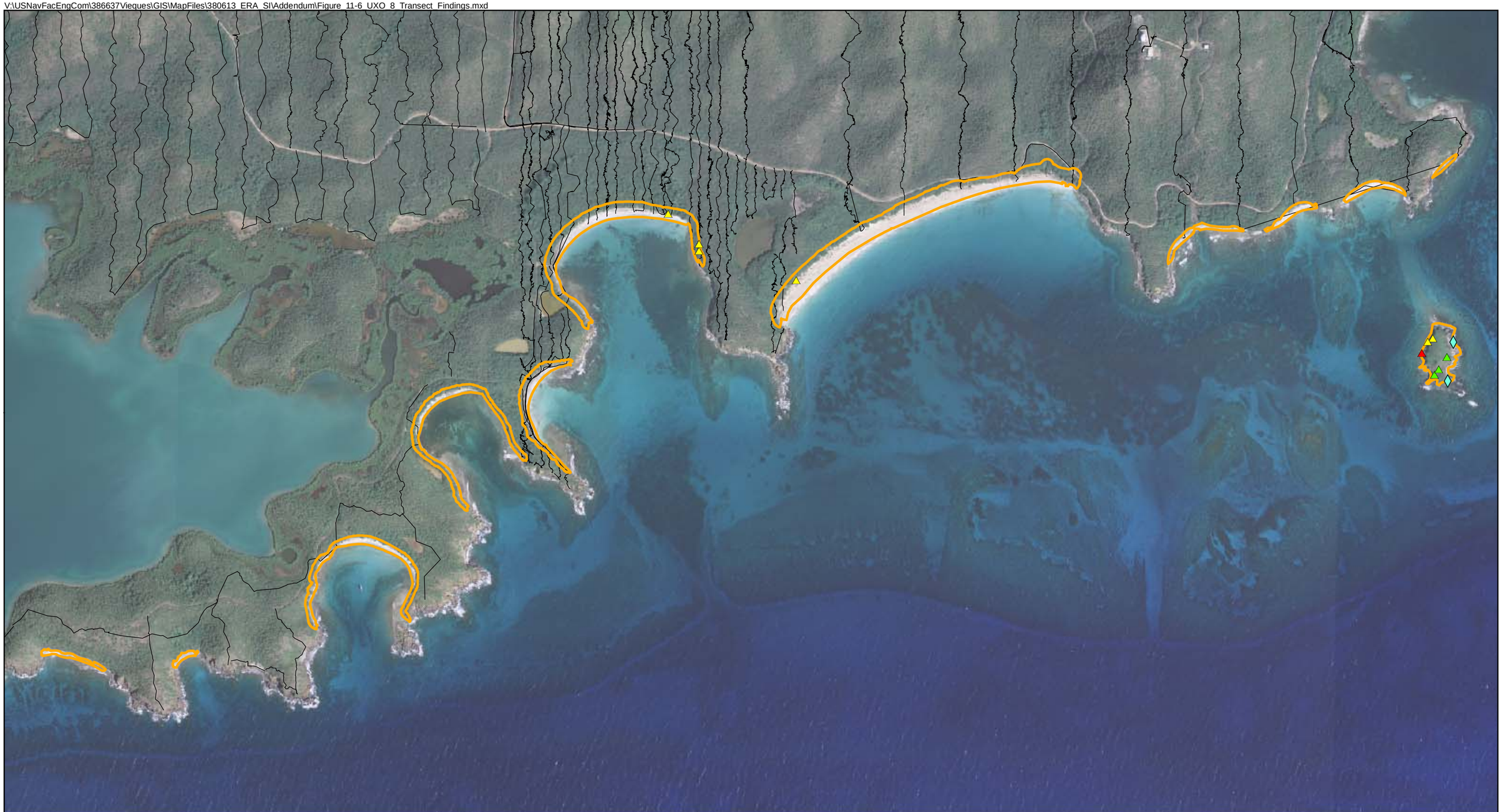
N
W E
S

0 150 300 600
Feet

Figure11-5
DGM Anomaly Density within UXO 8
Former VNTR, Vieques, Puerto Rico

CH2MHILL

V:\USNavFacEngCom\386637Vieques\GIS\MapFiles\380613_ERA_SI\Addendum\Figure_11-6_UXO_8_Transect_Findings.mxd



Legend
- Range Related Debris
- Munitions Debris
- Material Potentially Presenting an Explosive Hazard
- Unexploded Ordnance
- Transect
- UXO Site

N
W E
S

0 500 1,000 2,000
Feet

Figure 11-6
UXO 8 Transect Findings
Former VNTR, Vieques, Puerto Rico

CH2MHILL

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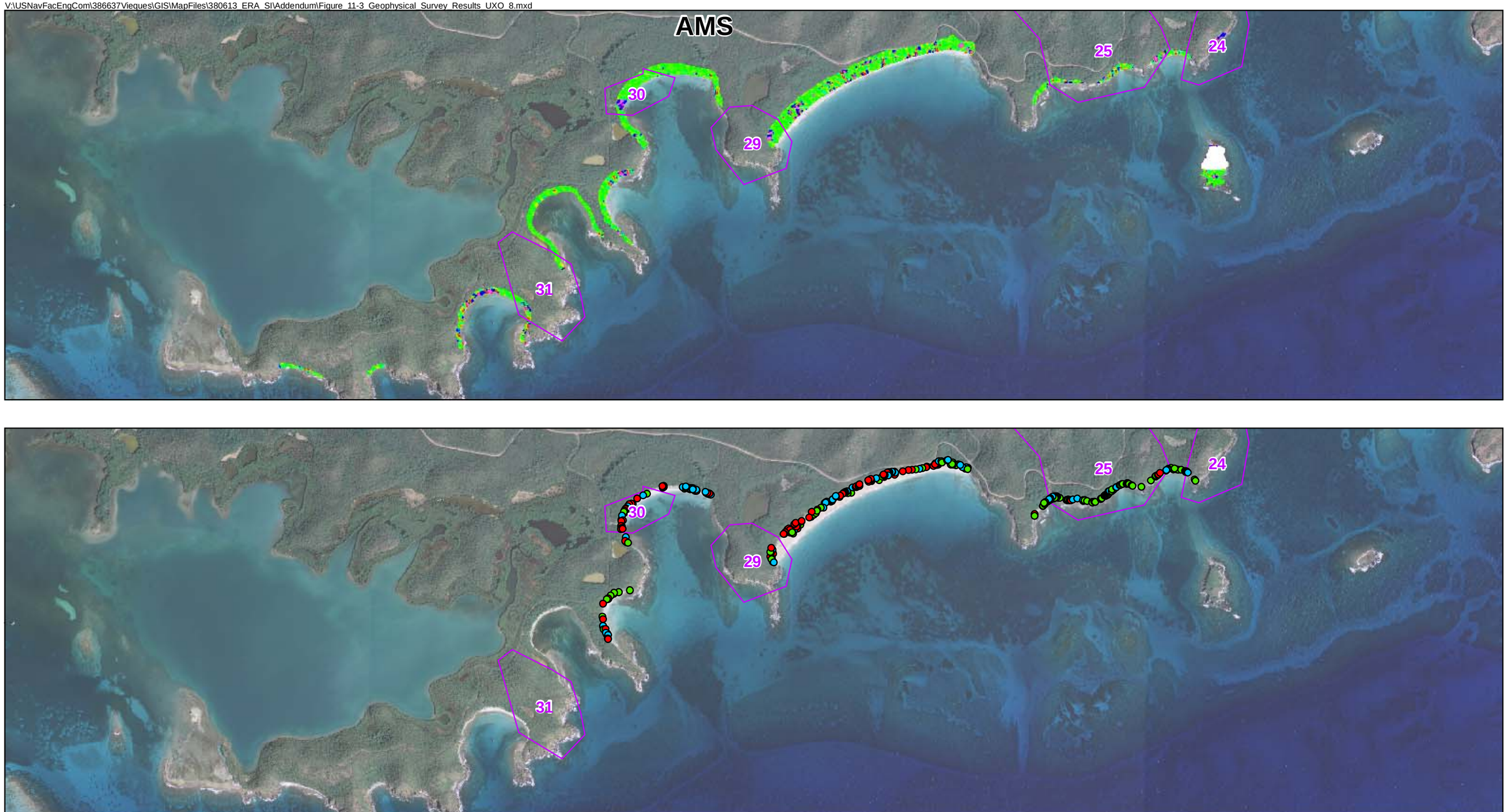


Legend

Magnetometer Response from "Mag and Flag"

- Low
- Medium
- High
- EADA

Aerial Magnetometer Survey Total Magnetic Field

-4.6 -2.3 0.0 1.9 3.8 5.8 7.7 9.6

N W E S

0 750 1,500 3,000 Feet

Figure 11-7
UXO 8 Magnetometer Survey Results
Former VNTR, Vieques, Puerto Rico

CH2MHILL

SECTION 12

UXO 9—SIA Exterior

12.1 Background

UXO 9 encompasses approximately 943 acres and is comprised of the accessible areas of the (former SIA or additional information and site history, including historical military use, see the UXO 10 site description in Section 13.

12.2 ERA/SI Findings

12.2.1 TCRA/ NTCRA Results

In February 2009 the field activities for a NTRCA were initiated to remove surface munitions from the site. In addition, in June 2009 the field activities for a NTCRA (interim action) were initiated (CH2M HILL, 2008b) to remove subsurface munitions from UXO Sites 1, 2, 3, 5 through 8, 11, and 15. Over 4,700 surface and subsurface MEC items have been located and removed from UXO 9 during the NTCRA through May 2010. The types of MEC items removed during the NTCRAs are presented in **Figure 12-1** and **Table 12-1**.

As part of the NTCRA a DGM survey was conducted at UXO 9. A total of 1,250 subsurface anomalies were detected during the DGM survey of UXO 9. DGM anomaly densities are shown in **Figures 12-2 through 12-6**.

12.2.2 Transect Inspections

Transect surveys were conducted for the entire former SIA, which includes UXO 9 (**Figure 12-7**). Approximately 5 percent (47 acres) of UXO 9 was assessed during the transect inspections. Since MEC items were indentified throughout the site, it was determined the goal of the ERA/SI had been met (determining the presence or absence of MEC) because the transect data collected provided sufficient information that a munitions removal action was warranted to reduce the explosive risk at the site. As a result, a NTCRA was initiated to clear MEC from the surface of UXO 9.

The results of the transect surveys included identification of MD, RRD (including targets), and MEC located on the ground surface. **Figure 12-7** shows the MEC items identified and **Table 12-1** lists the items located at UXO 9 during the transect surveys. Over 200 MEC items were identified during the transect inspection. The western portion of UXO 9 is at the location of the former Bulls Eye Target where aircraft practice bombs were used. Site reconnaissance and transects found numerous practice bombs in this area.

TABLE 12-1
Summary of MEC Items Identified at UXO 9

	Number of Items Identified during Transects	Number of Items Identified during NTCRA through May 2010	Number of Subsurface Items Identified through May 2010
MEC Category			
Bombs	128	2,491	41
Flares-Pyrotechnics	6	81	--
Grenades	1	7	--
MEC Component	53	130	--
Projectiles / Mortars	48	1,942	12
Rockets / Guided Missiles	18	65	2
Sub munitions	--	1	--
MD Category			
Bombs	89	--	3
Flares-Pyrotechnics	73	--	--
Grenades	4	--	--
MEC Component	40	1	--
Projectiles / Mortars	209	11	4
Rockets / Guided Missiles	34	--	--
Scrap	42	82,168	2,136
Range Related Debris			
Total	60	83,553	1,308

12.2.3 Aerial Survey Results

A small number impact craters and AOIs were identified at UXO 9 during the LiDAR survey (**Appendic C**). A significant AOI lies along the boundary of UXO 9 and UXO 4, but is associated with UXO 4 and is consistent with the historical activities carried out at that site.

The orthophotography collected at the former VNTR identifies the Bulls Eye Target and vicinity.

During the AMS, ten EADAs were identified are partially or wholly identified with UXO 9 (**Figure 12-8**). The Sky Research report (2009) describes these EADAs as:

- **EADA 14—**Large discrete anomalies with an anomaly density greater than10 per acre, possibly associated with geology.
- **EADA 15—**Large discrete anomalies with an anomaly density of 5 to 10 per acre, possibly associated with geology.

- **EADA 16—**Large discrete anomalies with an anomaly density of 5 to more than 10 per acre.
- **EADA 17—**Small anomalies and large discrete anomalies associated with clearing and density of less than 10 per acre.
- **EADA 21 –** Very large and distinctive discrete anomalies with an anomaly density of 5 to 10 acre.
- **EADA 24—** Large discrete anomalies.
- **EADA 25—**Small anomalies and large discrete anomalies with anomaly density of 5 to more than 10 per acre.
- **EADA 29—**Large discrete anomalies and numerous small with an anomaly density of 5 to more than 10 per acre. The dipole angle distribution is moderate and may indicate UXO.
- **EADA 30—**Large discrete anomalies with anomaly density of less than 5 per acre.
- **EADA 31—**Large discrete anomalies with an anomaly density of 5 to 10 per acre.

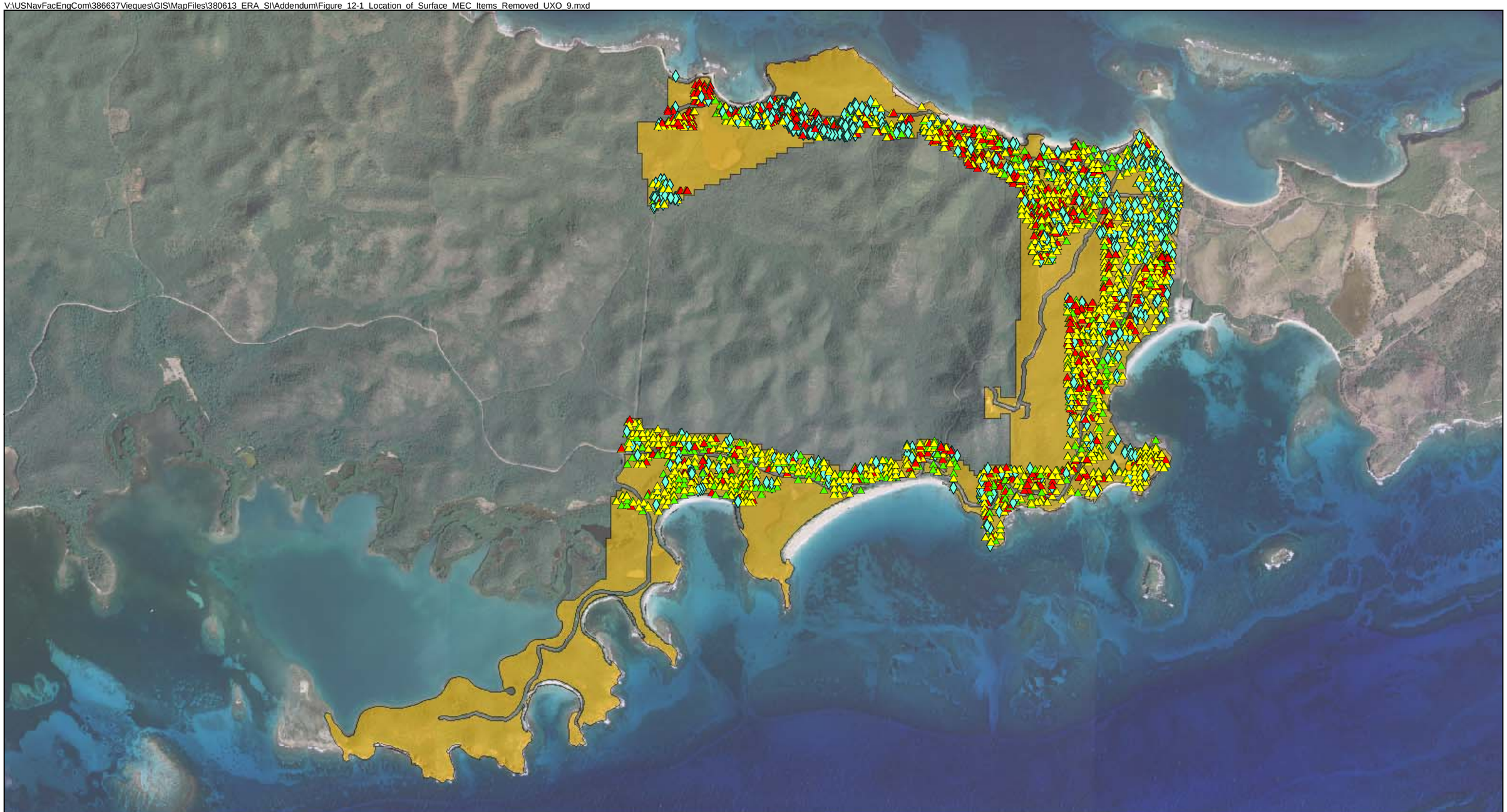
12.2.4 Summary of Findings

The NTCRA and transects conducted in UXO 9 confirmed that the SIA was used as target areas for marine artillery and air-ground bombing of practice munitions. Over 4,700 MEC items have been identified at the site.

12.3 Recommendations

Surface MEC have been removed from a portion of this site as part of the NTCRA (interim action) and work will continue until the interim action is completed throughout UXO 9. Based on findings from this investigation and the NTCRA, a RI/FS should be conducted for UXO 9.

V:\USNavFacEngCom\386637Vieques\GIS\MapFiles\380613_ERA_SI\Addendum\Figure_12-1_Location_of_Surface_MEC_Items_Removed_UXO_9.mxd



Legend

- Range Related Debris
- Munitions Debris
- Material Potentially Presenting an Explosive Hazard
- Discarded Military Munitions
- Unexploded Ordnance
- UXO Site

N
W E
S

0 900 1,800 3,600
Feet

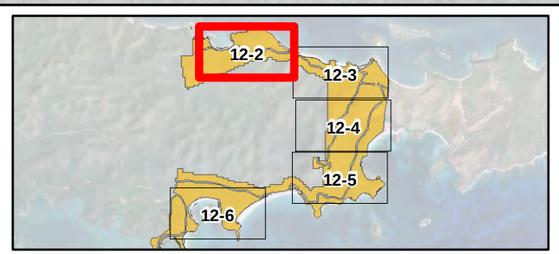
Figure 12-1
Location of Surface MEC Items Removed from UXO 9
Former VNTR, Vieques, Puerto Rico

CH2MHILL

V:\USNavFacEngCom\386637Vieques\GIS\MapFiles\380613_ERA_SI\Addendum\Figure_12-2_to_12-6_DGM_Density_UXO_9_Mapbook.mxd

Legend

- DGM Anomaly
- DGM Anomaly Polygon
- UXO Site



N
W E
S

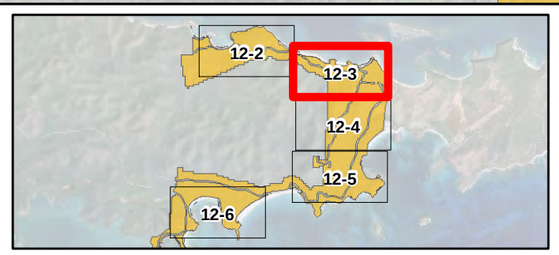
0 150 300 600
Feet

Figure12-2
DGM Anomaly Density within UXO 9
Former VNTR, Vieques, Puerto Rico

CH2MHILL

V:\USNavFacEngCom\386637Vieques\GIS\MapFiles\380613_ERA_SI\Addendum\Figure_12-2_to_12-6_DGM_Density_UXO_9_Mapbook.mxd

Legend
- DGM Anomaly
- DGM Anomaly Polygon
- UXO Site



N
W E
S

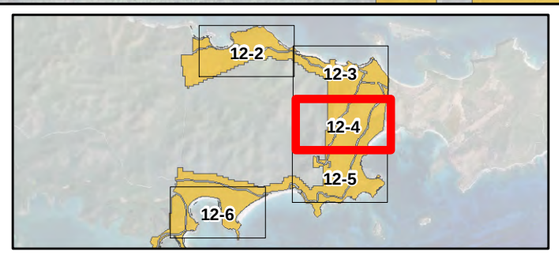
0 150 300 600
Feet

Figure12-3
DGM Anomaly Density within UXO 9
Former VNTR, Vieques, Puerto Rico

CH2MHILL

V:\USNavFacEngCom\386637Vieques\GIS\MapFiles\380613_ERA_SI\Addendum\Figure_12-2_to_12-6_DGM_Density_UXO_9_Mapbook.mxd

Legend
- DGM Anomaly
- DGM Anomaly Polygon
- UXO Site



N
W E
S

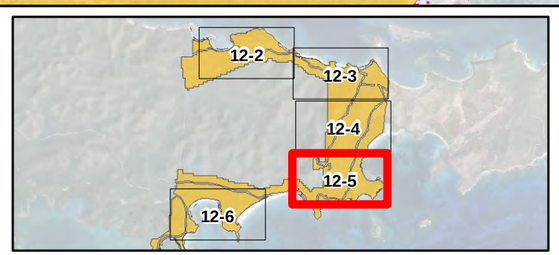
0 150 300 600
Feet

Figure12-4
DGM Anomaly Density within UXO 9
Former VNTR, Vieques, Puerto Rico

CH2MHILL

V:\USNavFacEngCom\386637Vieques\GIS\MapFiles\380613_ERA_SI\Addendum\Figure_12-2_to_12-6_DGM_Density_UXO_9_Mapbook.mxd

Legend
- DGM Anomaly
- DGM Anomaly Polygon
- UXO Site



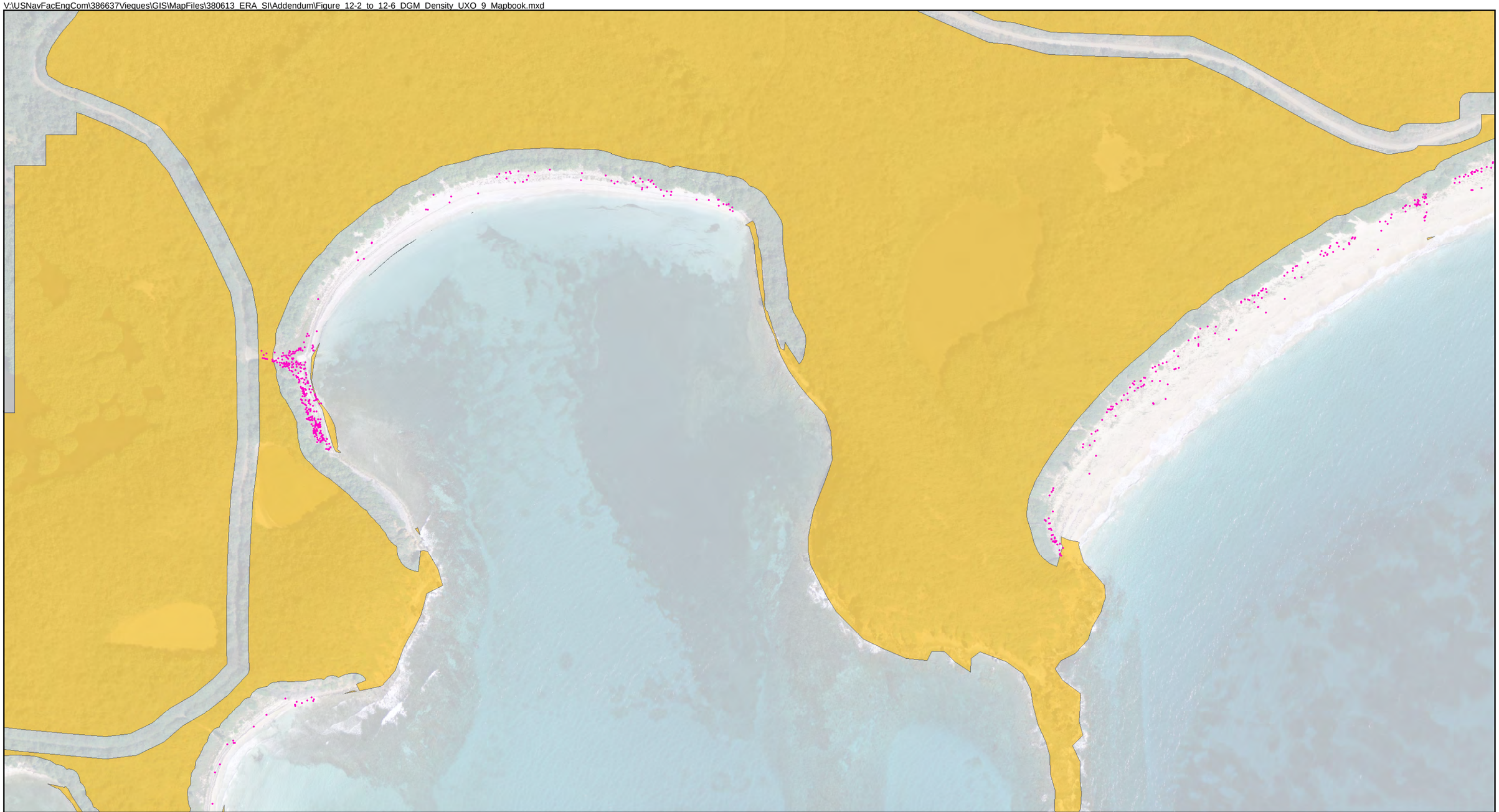
N
W E
S

0 150 300 600
Feet

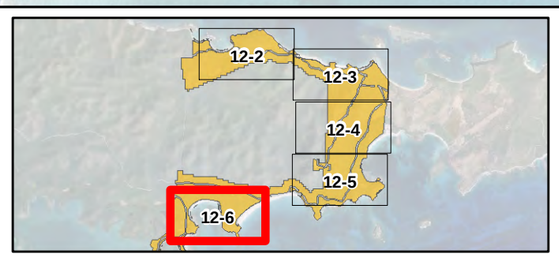
Figure12-5
DGM Anomaly Density within UXO 9
Former VNTR, Vieques, Puerto Rico

CH2MHILL

V:\USNavFacEngCom\386637Vieques\GIS\MapFiles\380613_ERA_SI\Addendum\Figure_12-2_to_12-6_DGM_Density_UXO_9_Mapbook.mxd



Legend
- DGM Anomaly
- DGM Anomaly Polygon
- UXO Site



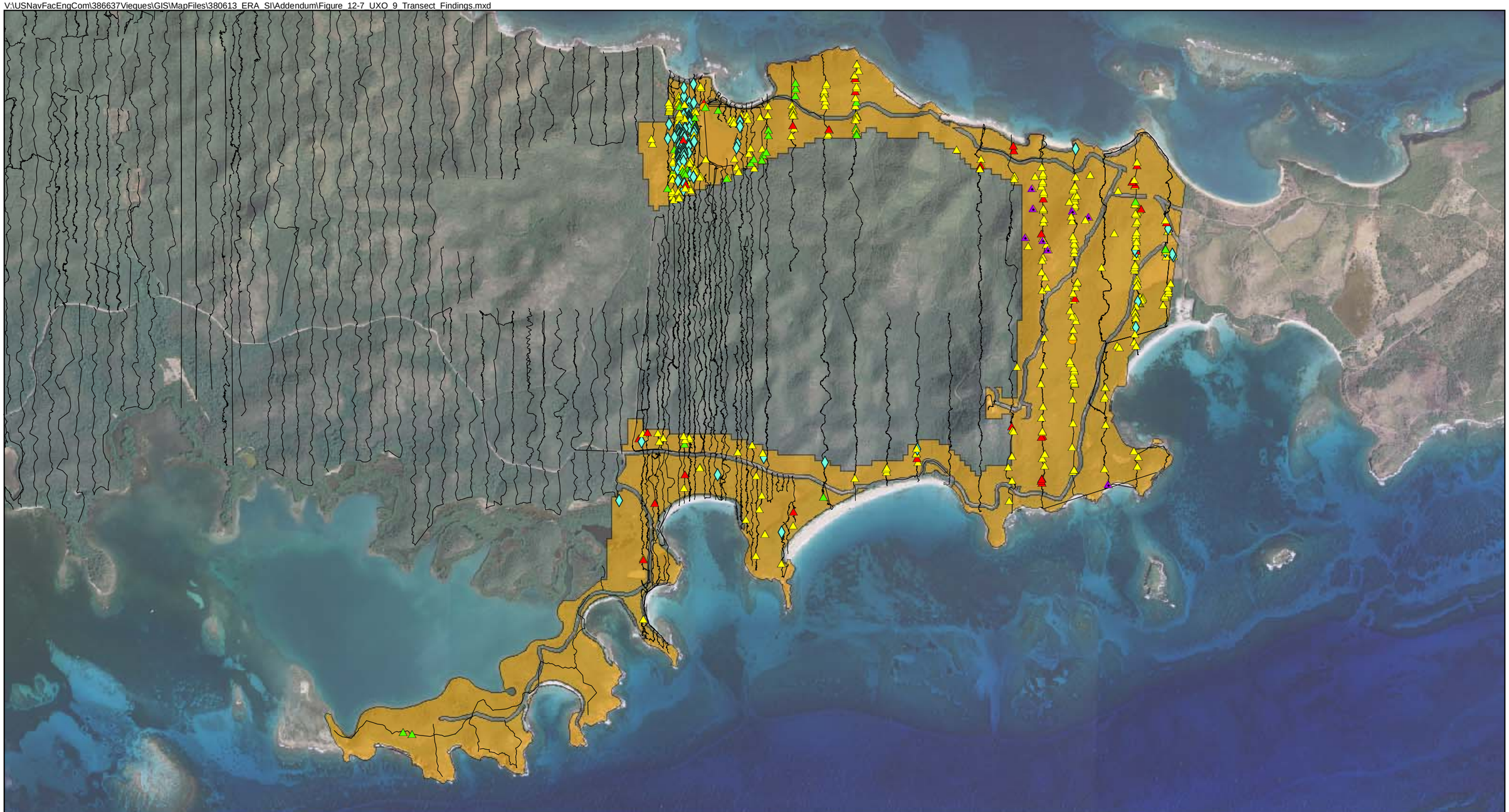
N
W E
S

0 150 300 600
Feet

Figure12-6
DGM Anomaly Density within UXO 9
Former VNTR, Vieques, Puerto Rico

CH2MHILL

V:\USNavFacEngCom\386637Vieques\GIS\MapFiles\380613_ERA_SI\Addendum\Figure_12-7_UXO_9_Transect_Findings.mxd



Legend

- Range Related Debris
- Munitions Debris
- Material Potentially Presenting an Explosive Hazard
- Discarded Military Munitions
- Munitions and Explosives of Concern
- Unexploded Ordnance
- Transect
- UXO Site

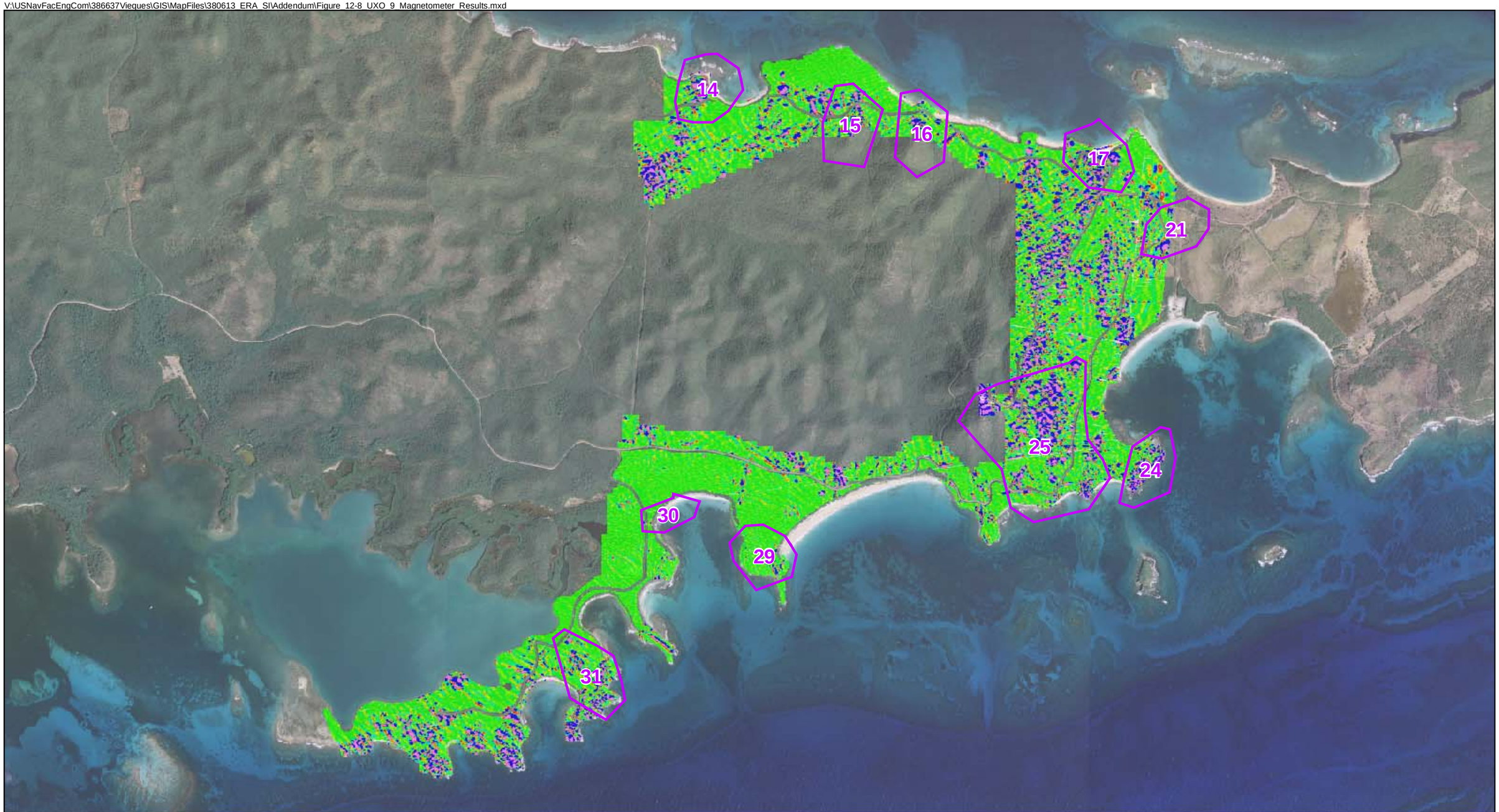
N
W E
S

0 900 1,800 3,600
Feet

Figure 12-7
UXO 9 Transect Findings
Former VNTR, Vieques, Puerto Rico

CH2MHILL

V:\USNavFacEngCom\386637Vieques\GIS\MapFiles\380613_ERA_SI\Addendum\Figure_12-8_UXO_9_Magnetometer_Results.mxd



Legend
EADA

Aerial Magnetometer Survey Total Magnetic Field

-4.6 -2.3 0.0 1.9 3.8 5.8 7.7 9.6

N
W E
S

0 900 1,800 3,600
Feet

Figure 12-8
UXO 9 Magnetometer Survey Results
Former VNTR, Vieques, Puerto Rico

CH2MHILL

SECTION 13

UXO 10—SIA Interior

13.1 Background

UXO 10 encompasses approximately 900 acres and is comprise of the interior section of the area formerly known as the SIA; UXO 10 is surrounded by UXO 9. The area formerly known as the EMA lies to the west and the area formerly known as the LIA lies to the east. The SIA was established in the 1950s when several Marine targets were constructed. Marine artillery ranging from 76mm to 175mm projectiles was directed toward these targets from artillery GPs within UXO 10 and UXO 12. A summary of the types and amount of Marine artillery ordnance fired on Vieques from 1974 to 1998 is provided in **Table 13-1.** During 1969, the construction of bulls-eye targets 1 and 2, used for inert bombing, established the eastern and western boundaries of the SIA (Tippetts et al., 1979). At that time, a permanent OP with a helicopter pad was also constructed on Cerro Matias. In 1971, a strafing target was installed adjacent to one of the targets. The aerial photograph analysis, conducted when the area was not heavily vegetated, identified numerous craters within the eastern two-thirds that were potentially caused by mortar and artillery fire, NGF, and aerial bombing. The craters were most visible on the 1962 aerial photographs (Environmental Research, Inc., 2000). In addition, the aerial photograph analysis identified several artillery GPs and OPs that may have been used for artillery fire. The locations of artillery GPs and the artillery targets are shown on **Figure 2-3.**

TABLE 13-1
Marine Ordnance Expended Annually by Type (Number of Items)

Year	175mm	155mm	106mm	105mm	90mm	81mm	76mm	Total
1974	4,933	3,508	2,741	15,100	1,996	5,947	0	34,255
1975	0	2,388	305	8,162	440	1,422	78	12,795
1976	1,066	3,124	0	5,525	0	244	1,957	11,916
1977	0	0	0	212	0	16	3,928	4,156
1982	NA	100	NA	1,343	NA	2,599	12	4,054
1983	NA	177	NA	NA	NA	1,007	NA	1,184
1984	NA	146	NA	186	NA	1,049	223	1,604
1985	NA	311	NA	253	NA	288	44	896
1986	NA	165	NA	538	NA	855	70	1,628
1987	NA	817	NA	144	NA	869	139	1,969
1988	NA	1,336	NA	698	NA	2,342	891	5,267
1989	NA	667	NA	464	NA	1,333	442	2,906
1990	NA	1,505	NA	1,088	NA	620	306	3,519

Year	175mm	155mm	106mm	105mm	90mm	81mm	76mm	Total
1991	NA	515	NA	NA	NA	1,073	155	1,743
1992	NA	NA	NA	49	NA	471	470	990
1993	NA	156	NA	351	NA	1,002	625	2,134
1994	NA	NA	NA	NA	NA	639	355	994
1995	NA	517	NA	NA	NA	273	468	1,258
1996	NA	223	NA	397	NA	1,199	757	2,576
1997	NA	NA	NA	320	NA	625	700	1,645
1998	NA	816	NA	NA	NA	1,364	641	2,821
Total	5,999	16,471	3,046	34,830	2,436	25,237	12261	100,280
Weight (lb)	130	95	41	33	23	10	28	
Total Weight	779,870	1,564,745	124,886	1,149,390	56,028	252,370	343,308	4,270,597

Notes: lb = pounds, mm = millimeter, NA = data not available
Data was not available for the years 1978-1981
Possibility of 8-inch projectiles fired in unspecified type, quantity, area, and period of time.

13.2 ERA/SI Findings

13.2.1 NTCRA Results

In February 2009 the field activities for a NTCRA were initiated as an interim removal action for UXO 9 and UXO 10 (CH2M HILL, 2009). The scope of the NTCRA is to remove surface munitions from the site. Through May, 2010; a total of 388 MEC items have been removed from UXO 10. The types of MEC items removed during the NTCRA are presented in **Figure 13-1** and **Table 13-2**.

13.2.2 Transect Inspections

Transect surveys were conducted for the entire former SIA, which includes UXO 10 (**Figure 3-1**). Approximately 7 percent (61 acres) of UXO 10 was assessed during the transect inspections. Since MEC items were indentified throughout the site, it was determined the goal of the ERA/SI had been met (determining the presence or absence of MEC) because the transect data collected provided sufficient information that a munitions removal action was warranted to reduce the explosive risk at the site. As a result, a NTCRA was initiated to clear MEC from the surface of UXO 9. **Figure 13-2** shows the results of the transect surveys which included identification significant MD, RRD (including targets), and MEC located on the ground surface. **Table 13-2** provides a summary of the item types identified during the transect inspection.

During the handheld magnetometer survey for a small portion of UXO 10, a low concentration of possible subsurface anomalies were detected. The locations and qualitative magnetometer responses are shown on **Figure 13-3**.

TABLE 13-2
Summary of MEC Items Identified at UXO 10

	Number of Items Identified during Transects	Number of Items Identified during NTCRA through May 2010
MEC Category		
Bombs	7	138
Flares-Pyrotechnics	2	9
MEC Component	110	61
Projectiles / Mortars	145	169
Rockets / Guided Missiles	7	11
MD Category		
Bombs	52	--
Flares-Pyrotechnics	75	--
MEC Component	18	--
Projectiles / Mortars	818	7
Rockets / Guided Missiles	79	1
Scrap	54	6,351
Range Related Debris		
Total	181	3,884

13.2.3 Aerial Survey Results

A small number of impact craters were identified at UXO 10 during the LiDAR survey possibly due to the dense vegetation (**Appendix C**). The craters are in the vicinity of the former Bulls Eye Target at the boundary between UXO Sites 9 and 10.

During the AMS, five EADAs were identified that are partially or wholly associated with UXO 10 (**Figure 13-3**). The Sky Research report (2009) describes these EADAs as:

- **EADA 25—**Small anomalies and large discrete anomalies with an anomaly density of 5 to more than 10 per acre.
- **EADA 26—**Large discrete anomalies with an anomaly density of 5 to 10 per acre.
- **EADA 27—**Large discrete anomalies with an anomaly density of 5 to 10 per acre.
- **EADA 28—**Large discrete anomalies with an anomaly density of 5 to more than 10 per acre.
- **EADA 32—**Large discrete anomalies with an anomaly density of 5 to 10 per acre.

13.2.4 Summary of Findings

The NTCRA and transects inspections identified over 300 MEC items across the site. The munitions items were likely associated with targets used for ATG bombing, and targets used for marine artillery training. In addition, munitions associated with NGF that were targeted into the SIA, were identified. Munitions and munitions-related items have been found across EADAs 25, 26, 27, 28, and 32.

13.3 Recommendations

Surface MEC have been removed from a portion of this site as part of the NTCRA (interim action) and work will continue until the interim action is completed throughout UXO 10. Based on findings from this investigation and the NTCRA, a RI/FS should be conducted for UXO 10.

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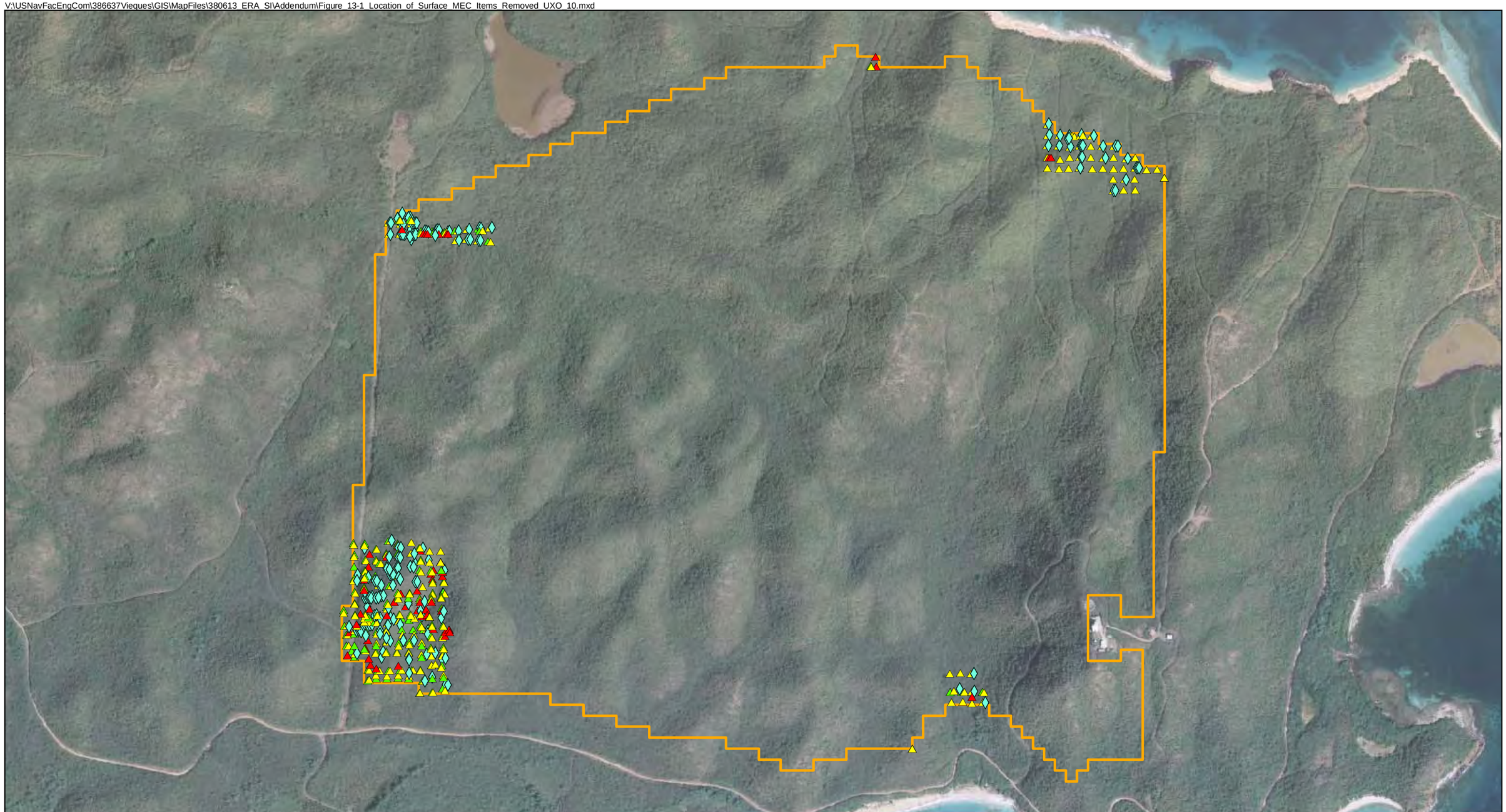


Legend
- Range Related Debris
- Munitions Debris
- Material Potentially Presenting an Explosive Hazard
- Unexploded Ordnance
- UXO Site

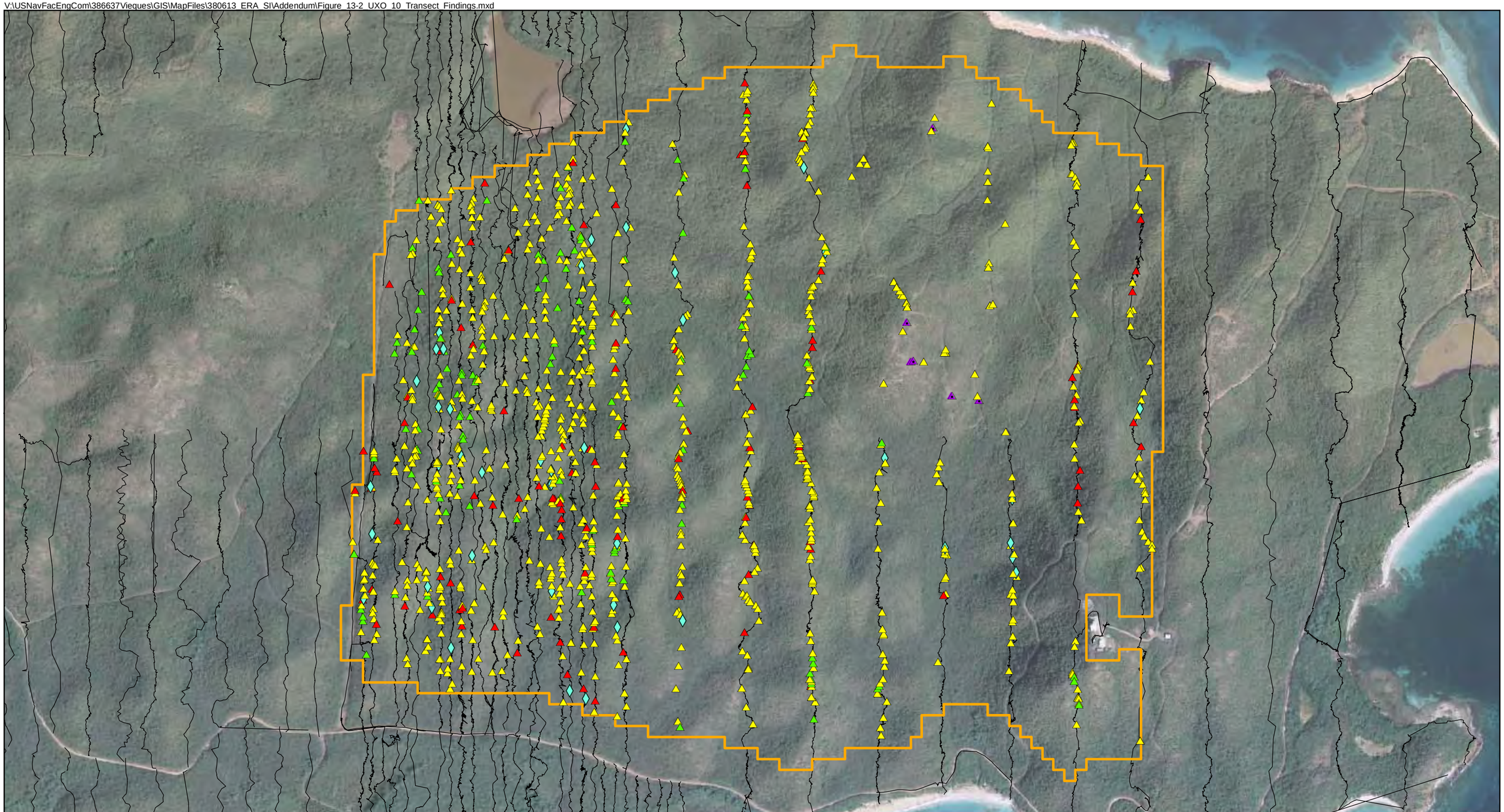
N
W E
S

0 425 850 1,700
Feet

Figure 13-1
Location of Surface MEC Items Removed from UXO 10
Former VNTR, Vieques, Puerto Rico

CH2MHILL

V:\USNavFacEngCom\386637Vieques\GIS\MapFiles\380613_ERA_SI\Addendum\Figure_13-2_UXO_10_Transect_Findings.mxd



Legend

- Range Related Debris
- Munitions Debris
- Material Potentially Presenting an Explosive Hazard
- Munitions and Explosives of Concern
- Unexploded Ordnance
- Transect
- UXO Site

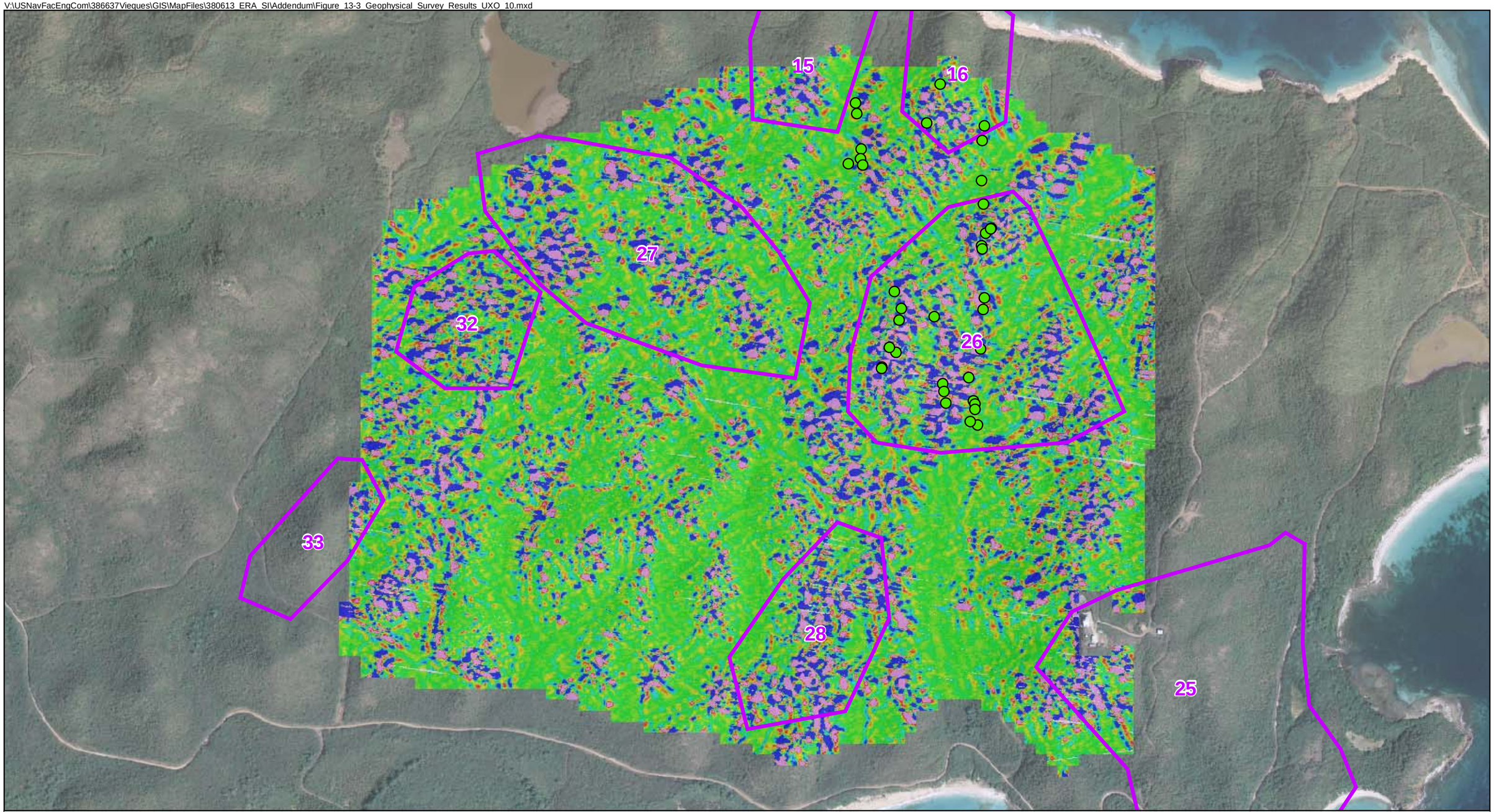
N
W E
S

0 425 850 1,700
Feet

Figure 13-2
UXO 10 Transect Findings
Former VNTR, Vieques, Puerto Rico

CH2MHILL

V:\USNavFacEngCom\386637Vieques\GIS\MapFiles\380613_ERA_SI\Addendum\Figure_13-3_Geophysical_Survey_Results_UXO_10.mxd



Legend

Magnetometer Response from "Mag and Flag"

- Low
- Medium
- High
- EADA

Aerial Magnetometer Survey Total Magnetic Field

-4.6 -2.3 0.0 1.9 3.8 5.8 7.7 9.6

N W E S

0 425 850 1,700 Feet

Figure 13-3
UXO 10 Magnetometer Survey Results
Former VNTR, Vieques, Puerto Rico

CH2MHILL

SECTION 14

UXO 11—EMA Public Roads

14.1 Background

UXO 11 encompasses approximately 86 acres and is comprised of roadways anticipated to be used by the public within the former EMA, the total footprint of this site includes the road surface and 25 foot buffers on each side of the roads.

For additional information and site history of the EMA, including historical military use, see the description of UXO 12(EMA Interior) and UXO 13 (EMA West) in Sections 15 and 16, respectively.

14.2 ERA/SI Findings

14.2.1 NTCRA Results

In June 2009 the field activities for a NTCRA (interim action) were initiated (CH2M HILL, 2008b) to remove subsurface munitions from UXO Sites 1, 2, 3, 5 through 8, 11, and 15. The types of MEC items removed during the NTCRA are presented in **Figure 14-1** and **Table 14-1**. A total of 152 MEC items along the eastern end of UXO 11 have been removed from the site through May 2010.

A DGM survey was conducted along the roadway and buffer for UXO 11. A total of 1502 anomalies have been identifies at UXO 11. The anomaly densities are consistent throughout the site. The anomaly distribution at UXO 11 is shown on **Figures 14-2 through 14-10**.

14.2.2 Transect Inspections

Approximately 9 percent (8 acres) of transect inspections were conducted across UXO 11. **Figure 14-11** and **Table 14-1** present the items found during the transect evaluations. A total of 4 MEC items and 4 MD items were identified during the transect survey.

14.2.3 Aerial Survey Results

No craters or AOIs were identified at UXO 11 from the LiDAR survey. **Appendix C** presents the bare earth models produced from the LiDAR survey.

TABLE 14-1
Summary of MEC items identified at UXO 11

	Number of Items Identified during Transects	Number of Items Identified during NTCRA through May 2010	Number of Subsurface Items Identified through May 2010
MEC Category			
Bombs	3	152	--
Rockets / Guided Missiles	1	--	--
MD Category			
Flares-Pyrotechnics	3	--	--
Grenades	1	--	--
Scrap	--	30	--
Range Related Debris			
Total	17	70	23

During the AMS, six EADAs were identified and include portions of UXO 11 (**Figure 14-12).** The Sky Research report (2009) describes these EADAs as:

- **EADA 3—**High geologic return and high survey altitude prevented meaningful conclusions. Anomaly density greater than10 per acre.
- **EADA 8—**High target density appears to follow the north coast road, but, could be related to geology. Some large discrete anomalies are identified that are not likely due to geology. Anomaly density of 5 to 10 per acre.
- **EADA 10—**Large discrete anomalies and an associated high anomaly density area. Anomaly density greater than 10 per acre.
- **EADA 11—**Large discrete anomalies might be associated with localized geology. Anomaly density greater than 10 per acre.
- **EADA 12—**Large discrete anomalies possibly associated with geology. Anomaly density greater than 10 per acre.
- **EADA 42—**Large discrete anomalies with an anomaly density of 5 to more than 10 per acre.

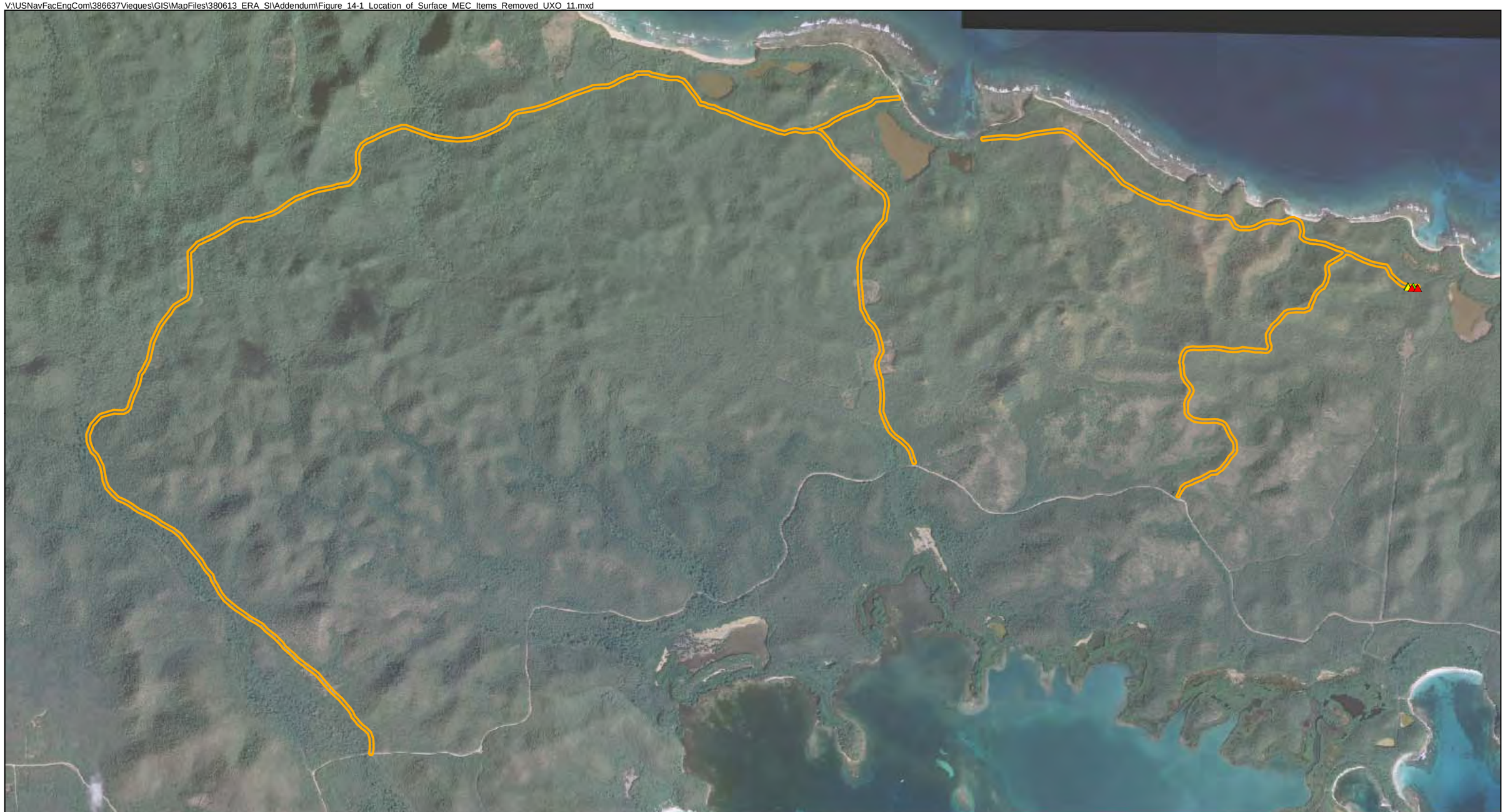
14.2.4 Summary of Findings

The NTCRA removed 152 MEC items from the site and the DGM identified approximately 1500 subsurface anomalies. The eight acres of transects inspected in UXO 11 identified four MEC items.

14.3 Recommendations

The NTCRA for removal of subsurface MEC confirmed that subsurface MEC is present at UXO 11. As a result, the NTCRA is recommended to be completed at the site as planned. Based on the results of this investigation and the NTCRA, a RI/FS should be conducted for UXO 11.

V:\USNavFacEngCom\386637Vieques\GIS\MapFiles\380613_ERA_SI\Addendum\Figure_14-1_Location_of_Surface_MEC_Items_Removed_UXO_11.mxd



Legend
- Range Related Debris
- Munitions Debris
- Unexploded Ordnance
- UXO Site

N
W E
S

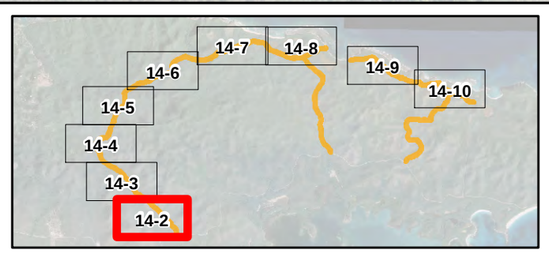
0 900 1,800 3,600
Feet

Figure 14-1
Location of Surface MEC Items Removed from UXO 11
Former VNTR, Vieques, Puerto Rico

CH2MHILL

V:\USNavFacEngCom\386637Vieques\GIS\MapFiles\380613_ERA_SI\Addendum\Figure_14-2_to_14-10_DGM_Density_UXO_11_Mapbook.mxd

Legend
- DGM Anomaly
- DGM Anomaly Polygon
- UXO Site



N
W E
S

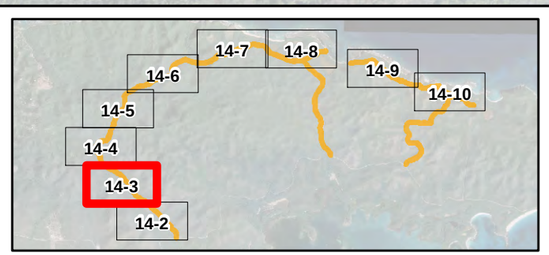
0 150 300 600
Feet

Figure 14-2
DGM Anomaly Density within UXO 11
Former VNTR, Vieques, Puerto Rico

CH2MHILL

V:\USNavFacEngCom\386637Vieques\GIS\MapFiles\380613_ERA_SI\Addendum\Figure_14-2_to_14-10_DGM_Density_UXO_11_Mapbook.mxd

Legend
- DGM Anomaly
- DGM Anomaly Polygon
- UXO Site



N
W E
S

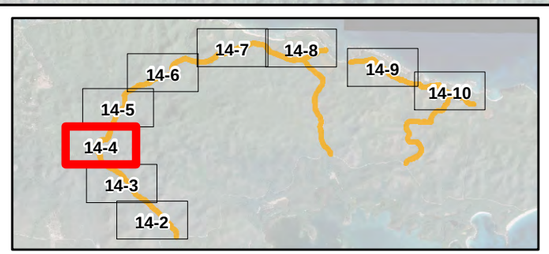
0 150 300 600
Feet

Figure 14-3
DGM Anomaly Density within UXO 11
Former VNTR, Vieques, Puerto Rico

CH2MHILL

V:\USNavFacEngCom\386637Vieques\GIS\MapFiles\380613_ERA_SI\Addendum\Figure_14-2_to_14-10_DGM_Density_UXO_11_Mapbook.mxd

Legend
- DGM Anomaly
- DGM Anomaly Polygon
- UXO Site



N
W E
S

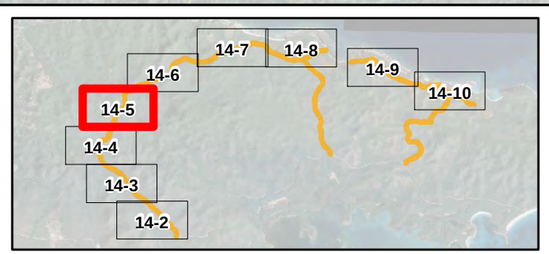
0 150 300 600
Feet

Figure 14-4
DGM Anomaly Density within UXO 11
Former VNTR, Vieques, Puerto Rico

CH2MHILL

V:\USNavFacEngCom\386637Vieques\GIS\MapFiles\380613_ERA_SI\Addendum\Figure_14-2_to_14-10_DGM_Density_UXO_11_Mapbook.mxd

Legend
- DGM Anomaly
- DGM Anomaly Polygon
- UXO Site



N
W E
S

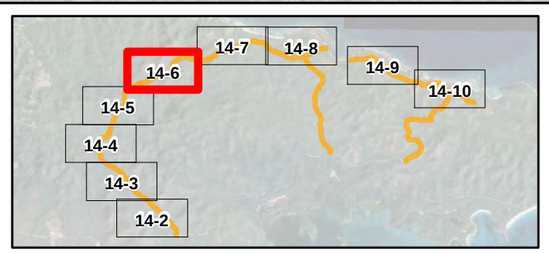
0 150 300 600
Feet

Figure 14-5
DGM Anomaly Density within UXO 11
Former VNTR, Vieques, Puerto Rico

CH2MHILL

V:\USNavFacEngCom\386637Vieques\GIS\MapFiles\380613_ERA_SI\Addendum\Figure_14-2_to_14-10_DGM_Density_UXO_11_Mapbook.mxd

Legend
- DGM Anomaly
- DGM Anomaly Polygon
- UXO Site



N
W E
S

0 150 300 600
Feet

Figure 14-6
DGM Anomaly Density within UXO 11
Former VNTR, Vieques, Puerto Rico

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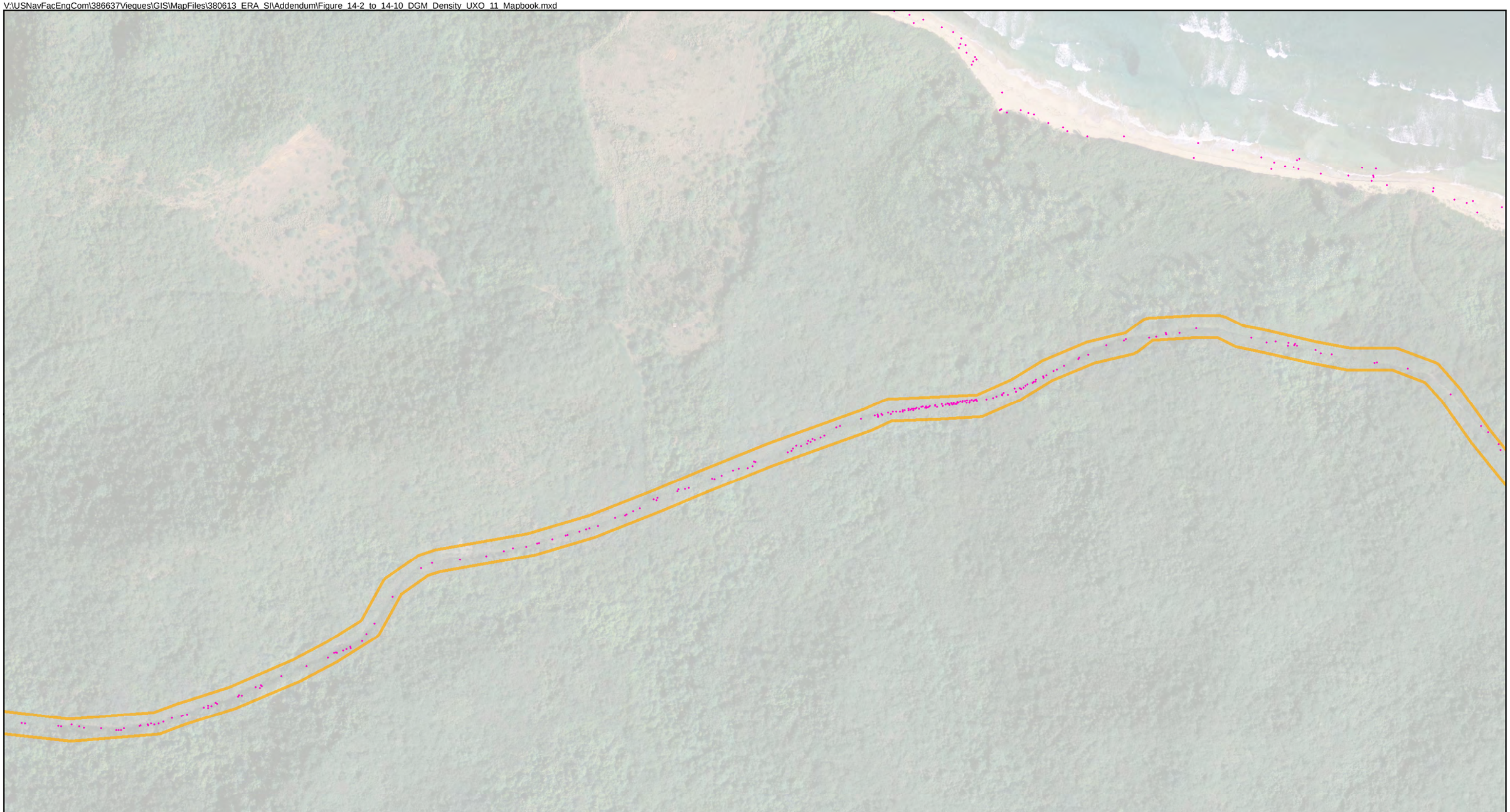

Legend
- DGM Anomaly
- DGM Anomaly Polygon
- UXO Site

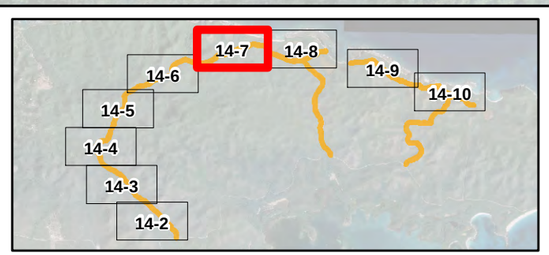

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Figure 14-7
DGM Anomaly Density within UXO 11
Former VNTR, Vieques, Puerto Rico

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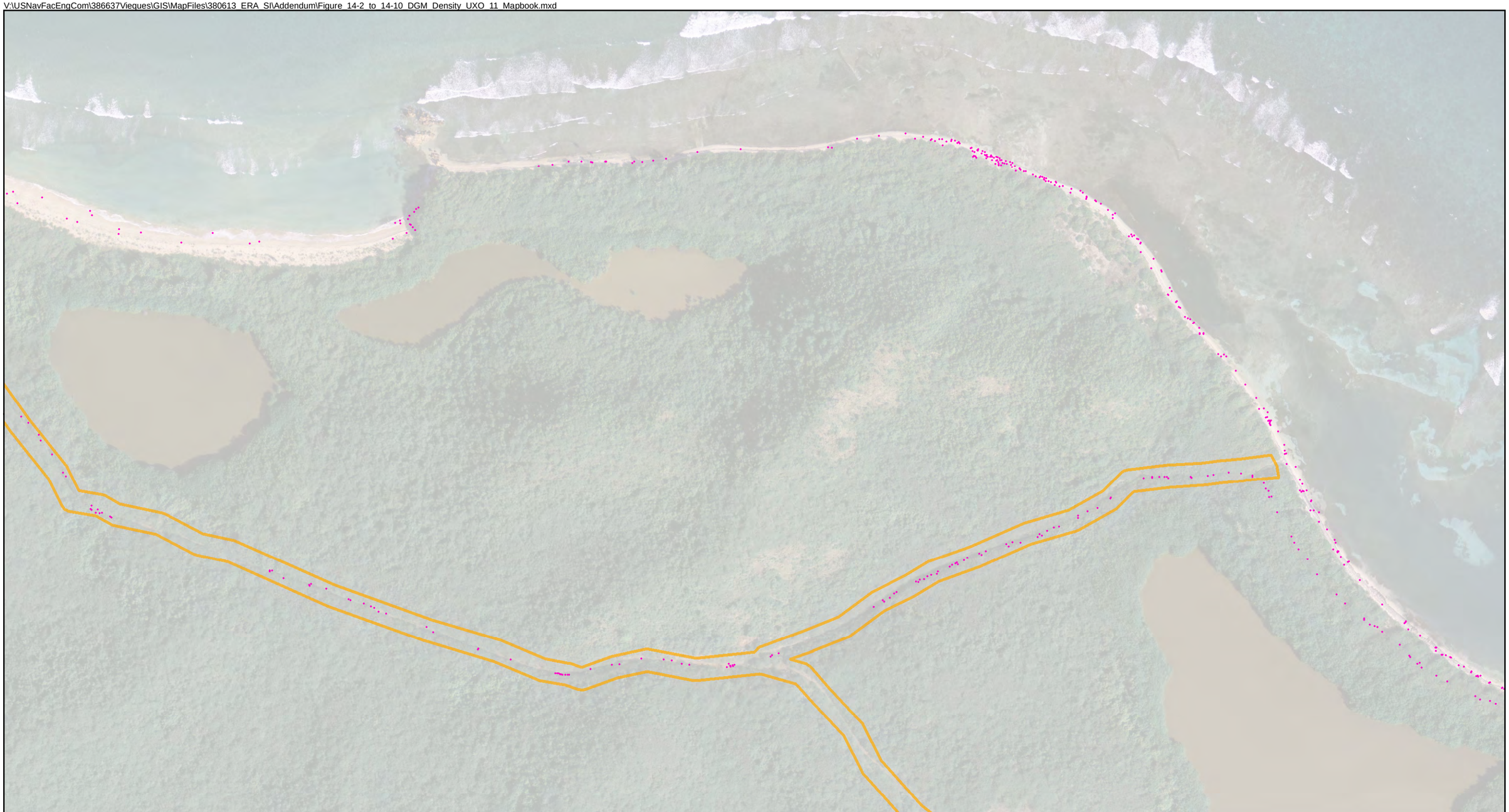

Legend
- DGM Anomaly
- DGM Anomaly Polygon
- UXO Site

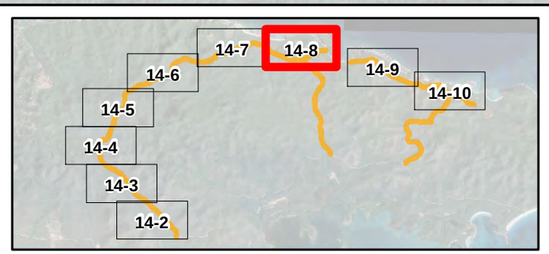

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Figure 14-8
DGM Anomaly Density within UXO 11
Former VNTR, Vieques, Puerto Rico

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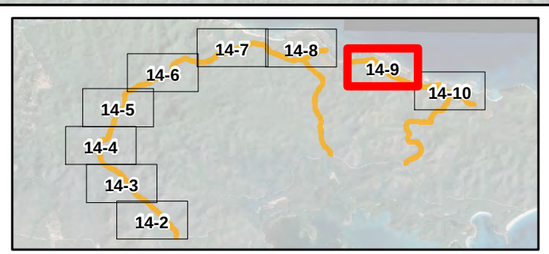
Legend
- DGM Anomaly
- DGM Anomaly Polygon
- UXO Site



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Feet

Figure 14-9
DGM Anomaly Density within UXO 11
Former VNTR, Vieques, Puerto Rico

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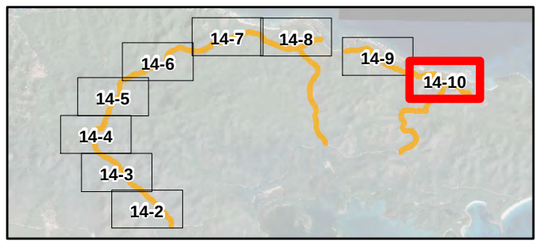
Legend
- DGM Anomaly
- DGM Anomaly Polygon
- UXO Site



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0 150 300 600
Feet

Figure 14-10
DGM Anomaly Density within UXO 11
Former VNTR, Vieques, Puerto Rico

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Legend

- Range Related Debris
- Munitions Debris
- Material Potentially Presenting an Explosive Hazard
- Transect
- UXO Site

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0 900 1,800 3,600
Feet

Figure 14-11
UXO 11 Transect Findings
Former VNTR, Vieques, Puerto Rico

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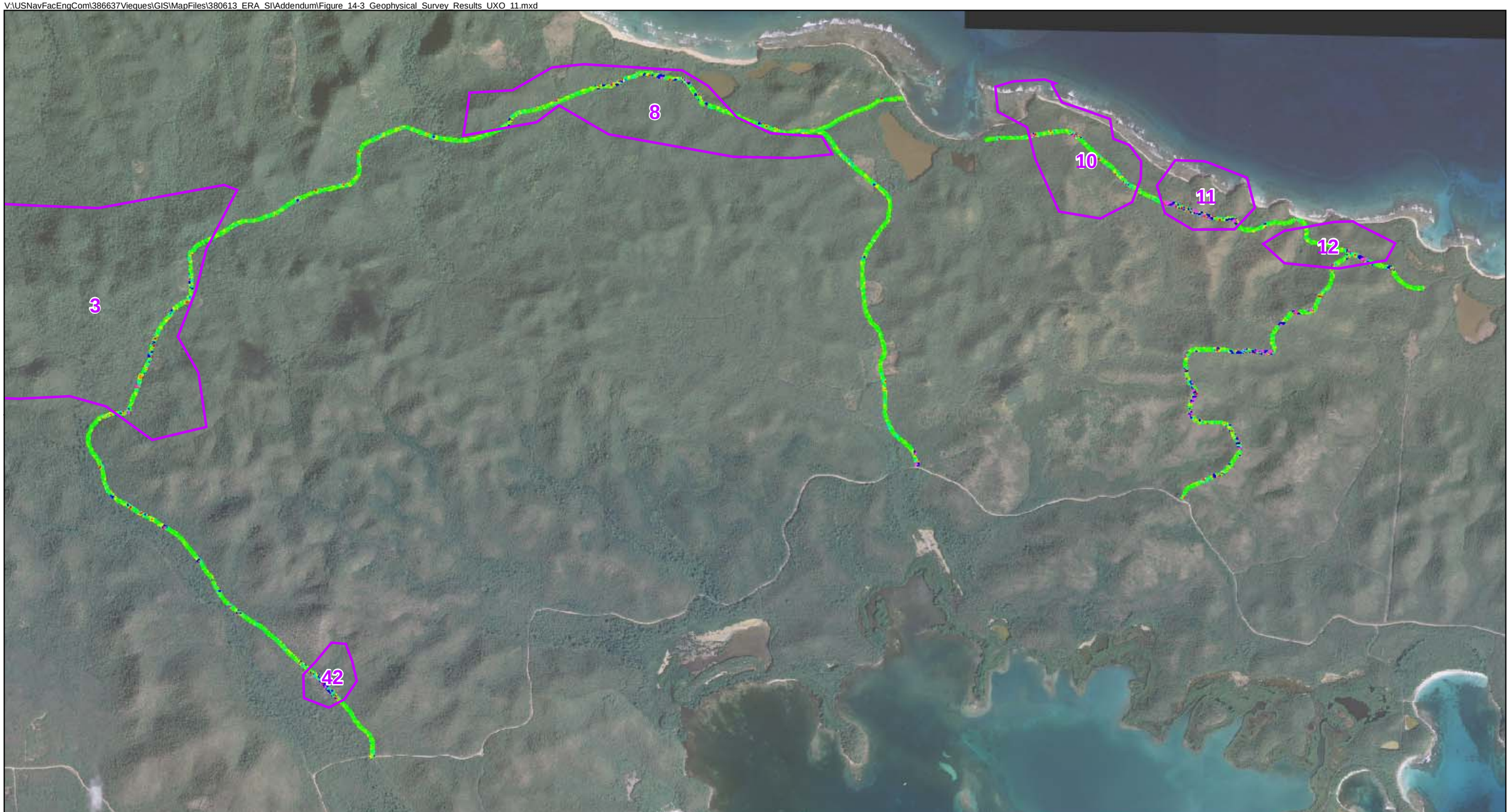

Legend
EADA

Aerial Magnetometer Survey Total Magnetic Field

-4.6 -2.3 0.0 1.9 3.8 5.8 7.7 9.6

N
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0 900 1,800 3,600
Feet

Figure 14-12
UXO 10 Magnetometer Survey Results
Former VNTR, Vieques, Puerto Rico

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SECTION 15

UXO 12—EMA Interior

15.1 Background

UXO 12 encompasses approximately 4,465 acres and is comprised of interior portions of the former EMA. The former EMA is approximately 10,900 acres, and was established in 1947 to provide areas and ranges for the training of Marine amphibious units and battalion landing teams in exercises that included amphibious landings, small-arms fire, artillery and tank fire, shore fire control, and combat engineering tasks. The 1979 EIS Report (Tippetts et al., 1979) provides a detailed description of historical training trends and indicates that the heaviest training occurred from the mid-1950s until early 1960s. Over the years, Range 11 was an established range with all firing from a single point. This range was used by tanks, 106 recoilless rifles, artillery and 50 caliber machine guns. The firing was generally in an eastward direction towards the SIA (NAVFAC, 1972).

Marine forces simulated amphibious assault operations over suitable beachheads that included Playa la Chiva (Blue Beach), Playa Capana (Purple Beach), Playa Caracas (Red Beach), and Playa Matias (Yellow Beach). These simulated assaults involved pre-assault operations, ship-to-shore movement, assault, consolidation, and withdrawal. Battalion teams would spend an average of 3 weeks operating, and the exercise would involve two to four amphibious landings on Red, Blue, and Purple Beaches that could last 3 to 5 days. While amphibious assaults were conducted with blank ammunition, Marine forces would conduct live firing on ranges in the area with various weapons including pistols, rifles, machine guns, hand grenades, 40mm projected grenades, tanks, artillery, recoilless rifles, and mortars. NGF and close air support was executed in conjunction with these exercises at the former SIA and LIA.

Large-scale artillery exercises were completed in the EMA using live marine artillery including 76mm, 81mm, 90mm, 105mm, 106mm, and 175mm rounds). The artillery was fired from GPs primarily, located throughout the EMA, towards targets located within the SIA and LIA. A summary of the types and amount of Marine artillery ordnance fired on Vieques from 1974 to 1998 is provided in **Table 15-1.** The exercises included Marine amphibious unit (1,200 to 1,500 Marines) and battalion landing team (1,200 to 1,500 Marines) (Tippetts et al., 1979).

TABLE 15-1
Marine Ordnance Expended Annually by Type (Number of Items)

Year	175mm	155mm	106mm	105mm	90mm	81mm	76mm	Total
1974	4,933	3,508	2,741	15,100	1,996	5,947	0	34,255
1975	0	2,388	305	8,162	440	1,422	78	12,795
1976	1,066	3,124	0	5,525	0	244	1,957	11,916
1977	0	0	0	212	0	16	3,928	4,156
1982	NA	100	NA	1,343	NA	2,599	12	4,054
1983	NA	177	NA	NA	NA	1,007	NA	1,184
1984	NA	146	NA	186	NA	1,049	223	1,604
1985	NA	311	NA	253	NA	288	44	896
1986	NA	165	NA	538	NA	855	70	1,628
1987	NA	817	NA	144	NA	869	139	1,969
1988	NA	1,336	NA	698	NA	2,342	891	5,267
1989	NA	667	NA	464	NA	1,333	442	2,906
1990	NA	1,505	NA	1,088	NA	620	306	3,519
1991	NA	515	NA	NA	NA	1,073	155	1,743
1992	NA	NA	NA	49	NA	471	470	990
1993	NA	156	NA	351	NA	1,002	625	2,134
1994	NA	NA	NA	NA	NA	639	355	994
1995	NA	517	NA	NA	NA	273	468	1,258
1996	NA	223	NA	397	NA	1,199	757	2,576
1997	NA	NA	NA	320	NA	625	700	1,645
1998	NA	816	NA	NA	NA	1,364	641	2,821
Total	5,999	16,471	3,046	34,830	2,436	25,237	12261	100,280
Weight (lb)	130	95	41	33	23	10	28	
Total Weight	779,870	1,564,745	124,886	1,149,390	56,028	252,370	343,308	4,270,597

Notes: lb = pounds, mm = millimeter, NA = data not available
Data was not available for the years 1978-1981
Possibility of 8-inch projectiles fired in unspecified type, quantity, area, and period of time.

The analysis of historical aerial photographs identified 29 GPs that were used for either mortar or artillery gunfire. The locations of these GPs are shown on **Figure 2-3** as G-1 through G-20, G-22, G-24 through G-26, G-28 through G-32, G-34, G-35, GP-7, and GP-9. The estimated artillery safety fans, identifying the potential impact areas from these GPs, are also shown on **Figure 2-3.** The number of Marine artillery ordnance items fired on Vieques ranged from a high of 34,255 projectiles in 1974 to a low of 896 projectiles in 1985 (**Table 15-1**), with an average of 4,775 projectiles per year for 25 years. An aerial photograph analysis of the EMA and SIA (ERI, 2002) indicates that as many as nine ranges and up to 30 gun emplacements and positions may have existed at the site.

For additional information and site history of the former EMA, including historical military use, see the UXO 13 site description in Section 16.

15.2 ERA/SI Findings

15.2.1 NTCRA Results

In February 2009 the field activities for a non-Time Critical Removal Action (NTCRA) were initiated to remove surface munitions from the site. The only area addressed by the NTCRA is the eastern border of UXO 12. A total of 424 MEC items and over 700 MD items have been removed from UXO 10 through May 2010. The types of MEC items removed during the NTCRA are presented in **Figure 15-1** and **Table 15-2**.

TABLE 15-2
Summary of MEC and MD Items Identified at UXO 12

	Number of Items Identified during Transects	Number of Items Identified during NTCRA through May 2010
MEC Category		
Bombs	--	336
Flares-Pyrotechnics	3	7
MEC Component	50	13
Projectiles / Mortars	17	67
Rockets / Guided Missiles	1	1
MD Category		
Bombs	159	--
Flares-Pyrotechnics	52	--
Grenades	11	--
MEC Component	9	2
Projectiles / Mortars	221	9
Rockets / Guided Missiles	24	--
Scrap	32	727
Range Related Debris		
Total	429	2251

15.2.2 Transect Inspections

Transect surveys were conducted for the entire former EMA, which includes UXO 12 (**Figure 15-2**). Approximately 6 percent (274 acres) of UXO 12 was covered during the transect inspections. **Table 15-2** shows the items found during the transect surveys.

A total of 71 MEC items were identified, as shown in **Table 15-2,** with MEC present in the vicinity of Range 7 or broader at the boundary of UXO 12 and UXO Sites 9 and 10. The Range 7 range fan is oriented east-west with the firing direction toward the east and the

former SIA boundary. The highest concentrations of items are located in the eastern portion of UXO 12 in close proximity to the former SIA (**Figure 15-2**).

In addition to the transect surveys across UXO 12, PI sites 2, 3, 15, 16, 18, and 19 were specifically investigated during the transect inspections. At PI sites 2 and 3, fence posts, barbed wire, and metal banding were identified. The transect investigation at PI-15 found scrap portions of a tank target, MD, and a 3.5-inch rocket classified as MPPEH. At PI-16 approximately 100 pounds of RRD and 10 MD items were found. The investigation at PI-18 found approximately 150 pounds of metal debris (RRD). At PI-19 approximately 3,000 pounds of RRD were found along with one hand grenade and 1 40mm projectile. Both munitions items were classified as MD.

PAOCs Y and Z were also investigated during the transect inspections. MEC, MD, and RRD items were identified at both PAOC-Y and PAOC Z. PAOC Y lies near the lead in to the Bulls Eye Target and PAOC Z.

15.2.3 Aerial Survey Results

During the aerial LiDAR survey eight AOIs were identified. Seven of the AOIs were previously known areas where military munitions were potentially used. **Appendix C** presents the bare earth models produced from the LiDAR survey.

During the AMS, 12 EADAs were identified that lie either partially or wholly within UXO 12 (**Figure 15-3**). The Sky Research report (2009) describes these EADAs as:

- **EADA 3—**High geologic return and high survey altitude prevented meaningful conclusions. Anomaly density greater than10 per acre.
- **EADA 8—**High target density appears to follow the north coast road, but, could be related to geology. Large discrete anomalies are identified that are not likely due to geology. Anomaly density of 5 to 10 per acre.
- **EADA 10—**Large discrete anomalies and an associated high anomaly density area. Anomaly density greater than 10 per acre.
- **EADA 11—**Large discrete anomalies might be associated with localized geology. Anomaly density greater than 10 per acre.
- **EADA 12—**Large discrete anomalies possibly associated with geology. Anomaly density greater than10 per acre.
- **EADA 33—**Large discrete anomalies indicate with an anomaly density of 5 to 10 per acre.
- **EADA 34—**Large discrete anomalies with an anomaly density of 5 to 10 per acre.
- **EADA 35—**Large discrete anomalies with an anomaly density of 5 to 10 per acre.
- **EADA 36—**Large discrete anomalies with an anomaly density of 5 to 10 per acre.
- **EADA 37—**Large discrete anomalies with an anomaly density of 5 to 10 per acre.

- **EADA 41—**Large discrete anomalies and elevated anomaly density possibly associated with topography and/or geology. Anomaly density of greater than 10 per acre.
- **EADA 42—**Large discrete anomalies with an anomaly density of 5 to 10 per acre.

15.2.4 Summary of Findings

A total of 424 MEC items have been identified from UXO 12 as part of the NTCRA through May 2010. In addition, over 70 MEC items have been identified from transects that have been traversed across the site. The AMS has identified high concentrations of subsurface anomalies at 12 locations.

15.3 Recommendations

Based on the results of this investigation a RI/FS should be conducted at UXO 12.

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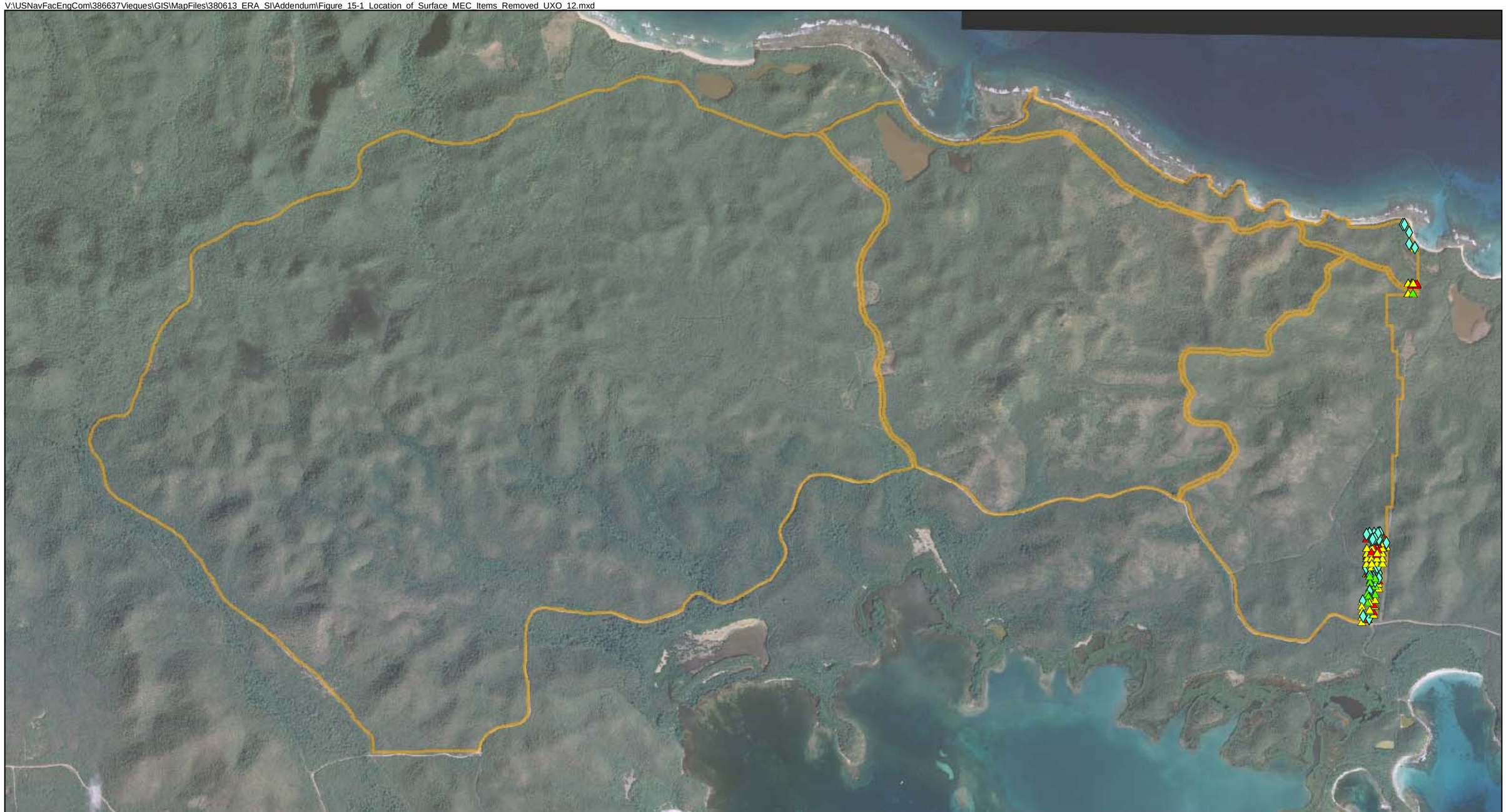

Legend

- Range Related Debris
- Munitions Debris
- Material Potentially Presenting an Explosive Hazard
- Unexploded Ordnance
- UXO Site

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0 900 1,800 3,600
Feet

Figure 15-1
Location of Surface MEC Items Removed from UXO 12
Former VNTR, Vieques, Puerto Rico

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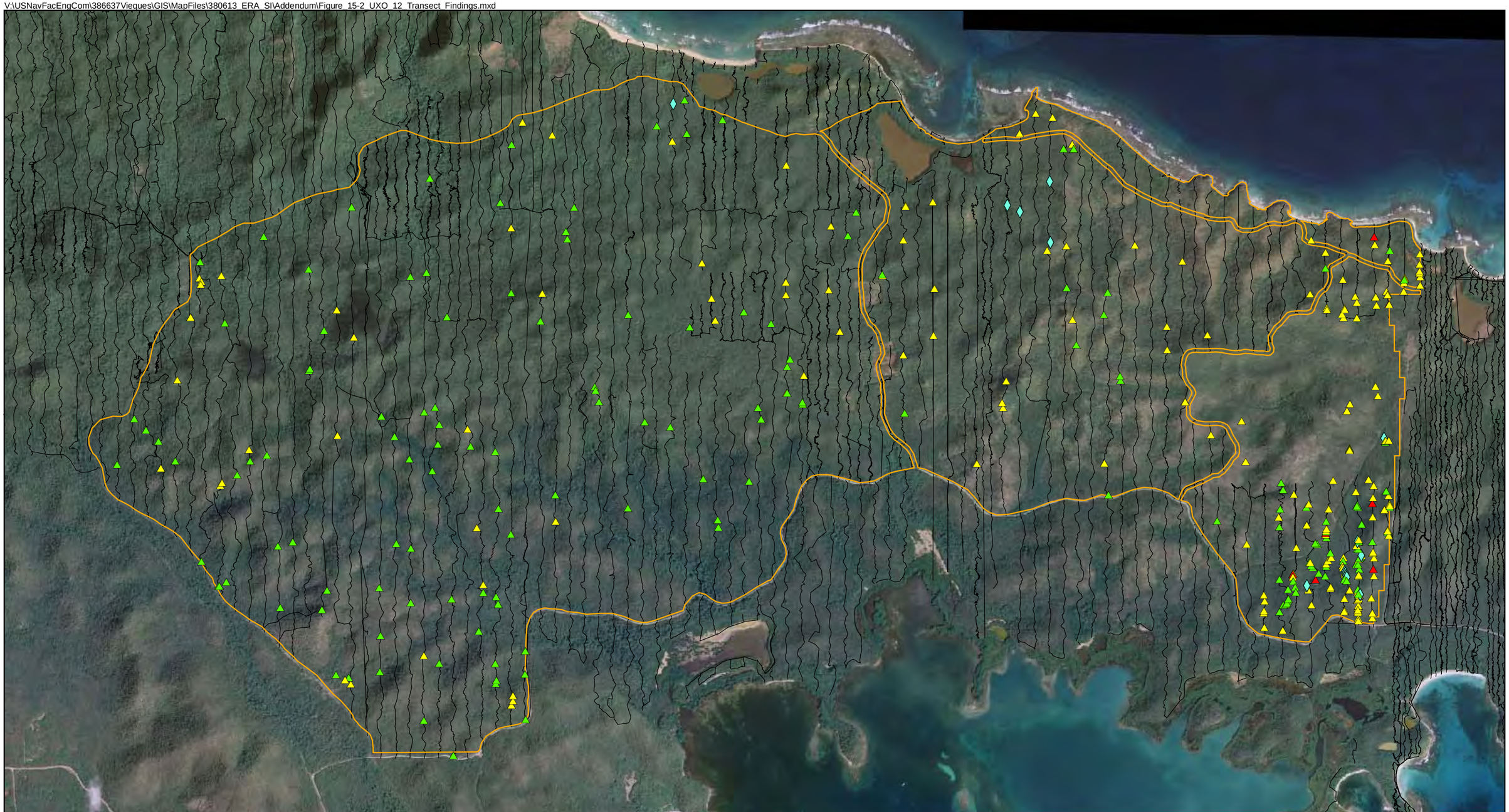

Legend

- Range Related Debris
- Munitions Debris
- Material Potentially Presenting an Explosive Hazard
- Unexploded Ordnance
- Transect
- UXO Site

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Feet

Figure 15-2
UXO 12 Transect Findings
Former VNTR, Vieques, Puerto Rico

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Legend
EADA

Aerial Magnetometer Survey Total Magnetic Field

-4.6 -2.3 0.0 1.9 3.8 5.8 7.7 9.6

N
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0 900 1,800 3,600
Feet

Figure 15-3
UXO 12 Magnetometer Survey Results
Former VNTR, Vieques, Puerto Rico

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SECTION 16

UXO 13—EMA West

16.1 Background

UXO 13 encompasses approximately 2,434 acres in size and is located in the northwest of the former EMA. During 1966, six ranges were established in the area along the north coast in the area identified as UXO 13. These ranges remained operational through February 1999 when they were deactivated until further notice by the Commanding Officer of AFWTF. Over the years a total of eight ranges, were established as fixed, static ranges with all firing from a single point. The ranges include (NAVFAC, 1972):

- **Range 1** identified as a small arms range from the analysis of historical aerial photographs during the PRA (CH2MHILL, 2003)
- **Range 2** (identified as Range 1 in the 1972 EIS): Combat Rifle Range: Training in the firing of M-1 and M-14 rifles, M-1 and M-2 Carbines, Browning automatic rifles and 45 caliber submachine guns.
- **Range 3** (identified as Range 4 in the 1972 EIS): Hand Grenade Range: Fragmentation hand grenades were fired from a control pit, seaward towards the target area. The target area was a trench like opening in the ground with some empty steel drums imbedded into the sides of the trench. The target area was approximately 100 feet in length and at a lower elevation than the firing pit. All duds were detonated after each exercise by EOD personnel.
- **Range 4** (identified as Range 4B in the 1972 EIS): M-79 Grenade Launcher/ Rifle Grenade Range: 40mm rifle grenades were fired in a seaward direction into an area adjacent to the beach. The duds that remained after each exercise were disposed of by detonation.
- **Range 4A** (identified from historical aerial photographs in the 2003 PRA) Flame Range: Flame thrower equipment was authorized for use but was apparently seldom used.
- **Range 4B** (identified as Range 5 in the 1972 EIS): 3.5 inch Rocket Launcher Range: 3.5-inch rocket launchers were fired in a seaward direction into a dune area adjacent to the beach.
- **Range 5** (identified as Range 2 in the 1972 EIS): Pistol Range: Training in the firing of service pistols by firing at targets located at 15 and 25 yards away
- **Range 7** (identified as Range 3 in the 1972 EIS): M-60 Machine Gun Range: Training in the firing of machine guns and Browning automatic rifles. Weapons were fired at fixed targets consisting of old military vehicles and rock out-croppings.
- **Range 6:** On this range shape charges were exploded. The size of the charges did not exceed 40 pounds. This range was located on the beach (1972 EIS).

An example of the small arms ammunition used at the ranges from 1995 through 1998 is presented in **Table 16-1**.

TABLE 16-1
Small Arms Ammunition Fired at the EMA Ranges by Type (Number of Items)

Year	5.56 mm	7.62 mm	9 mm	.38 CAL	.50 CAL	12 Gage	Grenades	Total
1995	139,964	207,680	17,951	2,450	38,364	174	739	407,322
1996	99,424	147,692	3,480	2,592	50,846	2,000	292	306,326
1997	161,070	491,534	9,205	NA	54,605	200	240	716,854
1998	207,605	147,712	30,390	3,825	80,759	3,427	720	474,438

Notes: CAL = caliber, mm = millimeter, NA = data not available

An aerial photograph analysis identified the size and orientation of the ranges and their variation over the years. The analysis also identified ranges that were not documented in archive records search. The locations of the ranges are shown on **Figure 16-1**.

The analysis of historical aerial photographs identified five GPs that were used for either mortar or artillery gunfire. The locations of these GPs are shown on **Figure 2-3** as G-7, G-8, G-9, G-23, and G-27. The estimated artillery safety fans, identifying the potential impact areas from these GPs is also shown on **Figure 2-3.** From 1974 to 1998 the number of Marine artillery ordnance items fired on Vieques ranged from a high of 34,255 projectiles in 1974 to a low of 896 projectiles in 1985 (**Table 16-2**). The average for the 25 years was 4,775 projectiles per year.

For additional information and site history of the former EMA, including historical military use, see the UXO 12 site description in Section 15.

16.2 ERA/SI Findings

16.2.1 Transect Inspections

Transect surveys were conducted for the entire former EMA, which includes UXO 13 (**Figure 16-1**). Approximately 5 percent (116 acres) of UXO 13 was covered during the transect inspections. **Table 16-3** shows the results of the transect surveys. Over 40 MEC items were identified at the site. A majority of the items found are located around Ranges 2 and 4. The area south of the ranges in UXO 13 had very few items present relative to the northern portion of the site. PAOC–BB, located within UXO 13, was investigated during the transect inspections and 3 MD and 2 RRD items were identified.

TABLE 16-2
Marine Ordnance Expended Annually by Type (Number of Items)

Year	175mm	155mm	106mm	105mm	90mm	81mm	76mm	Total
1974	4,933	3,508	2,741	15,100	1,996	5,947	0	34,255
1975	0	2,388	305	8,162	440	1,422	78	12,795
1976	1,066	3,124	0	5,525	0	244	1,957	11,916
1977	0	0	0	212	0	16	3,928	4,156
1982	NA	100	NA	1,343	NA	2,599	12	4,054
1983	NA	177	NA	NA	NA	1,007	NA	1,184
1984	NA	146	NA	186	NA	1,049	223	1,604
1985	NA	311	NA	253	NA	288	44	896
1986	NA	165	NA	538	NA	855	70	1,628
1987	NA	817	NA	144	NA	869	139	1,969
1988	NA	1,336	NA	698	NA	2,342	891	5,267
1989	NA	667	NA	464	NA	1,333	442	2,906
1990	NA	1,505	NA	1,088	NA	620	306	3,519
1991	NA	515	NA	NA	NA	1,073	155	1,743
1992	NA	NA	NA	49	NA	471	470	990
1993	NA	156	NA	351	NA	1,002	625	2,134
1994	NA	NA	NA	NA	NA	639	355	994
1995	NA	517	NA	NA	NA	273	468	1,258
1996	NA	223	NA	397	NA	1,199	757	2,576
1997	NA	NA	NA	320	NA	625	700	1,645
1998	NA	816	NA	NA	NA	1,364	641	2,821
Total	5,999	16,471	3,046	34,830	2,436	25,237	12261	100,280
Weight (lb)	130	95	41	33	23	10	28	
Total Weight	779,870	1,564,745	124,886	1,149,390	56,028	252,370	343,308	4,270,597

Notes: lb = pounds, mm = millimeter, NA = data not available
Data was not available for the years 1978-1981
Possibility of 8-inch projectiles fired in unspecified type, quantity, area, and period of time.

TABLE 16-3
Summary of MEC Items Identified at UXO 13

	Number of Items Identified during Transects
MEC Category	
Flares-Pyrotechnics	3
Grenades	4
MEC Component	1
Projectiles / Mortars	3
Rockets / Guided Missiles	37
MD Category	
Flares-Pyrotechnics	38
Grenades	35
MEC Component	3
Projectiles / Mortars	61
Rockets / Guided Missiles	182
Scrap	44
Range Related Debris	
Total	245

16.2.2 Aerial Survey Results

The aerial LiDAR survey of UXO 13 identified four AOIs (**Appendix C**). These AOI areas were known historical range areas (**Figure 2-3**).

During the AMS, 11 EADAs were identified and include portions of UXO 13 (**Figure 16-2**). The Sky Research report (2009) describes these EADAs as:

- **EADA 2—**Apparent infrastructure. Anomaly density of less than 5 per acre.
- **EADA 3—**High geologic return and high survey altitude prevent meaningful conclusions. Anomaly density greater than 10 per acre.
- **EADA 4—**Some geology associated with the shoreline, but, numerous large discrete anomalies exist with an anomaly density greater than10 per acre.
- **EADA 5—**Presence of large discrete anomalies and apparent clearing indicate probable presence of ferrous material. Anomaly density of 5 to 10 per acre.
- **EADA 6—**Presence of large discrete anomalies and high target density possibly related to shoreline geology. Anomaly density of >10 per acre.
- **EADA 7—**Anomaly density greater than 10 per acre.

- **EADA 8—**Anomaly density of 5 to 10 per acre.
- **EADA 9—**Dipole angle distribution indicates there may be a high percentage of UXO. Anomaly density greater than 10 per acre.
- **EADA 42—**Large discrete with an anomaly density less than 10 per acre.
- **EADA 43—**Large discrete anomalies indicate ferrous material, possibly linear extending northward (fence line). Anomaly density of 5 to 10 per acre.

16.2.3 Summary of Findings

Five percent of UXO 13 was evaluated utilizing a transect approach and the average density of MEC items located was estimated to be 0.1 item per acre. Over 40 MEC items were identified in the SI.

16.3 Recommendations

Based on the results of this investigation a RI/FS should be conducted for UXO 13.

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Legend

- Range Related Debris
- Munitions Debris
- Material Potentially Presenting an Explosive Hazard
- Unexploded Ordnance
- Transect
- Gun Position
- Range
- Artillery Safety Fan
- UXO Site

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Figure 16-1
UXO 13 Transect Findings
Former VNTR, Vieques, Puerto Rico

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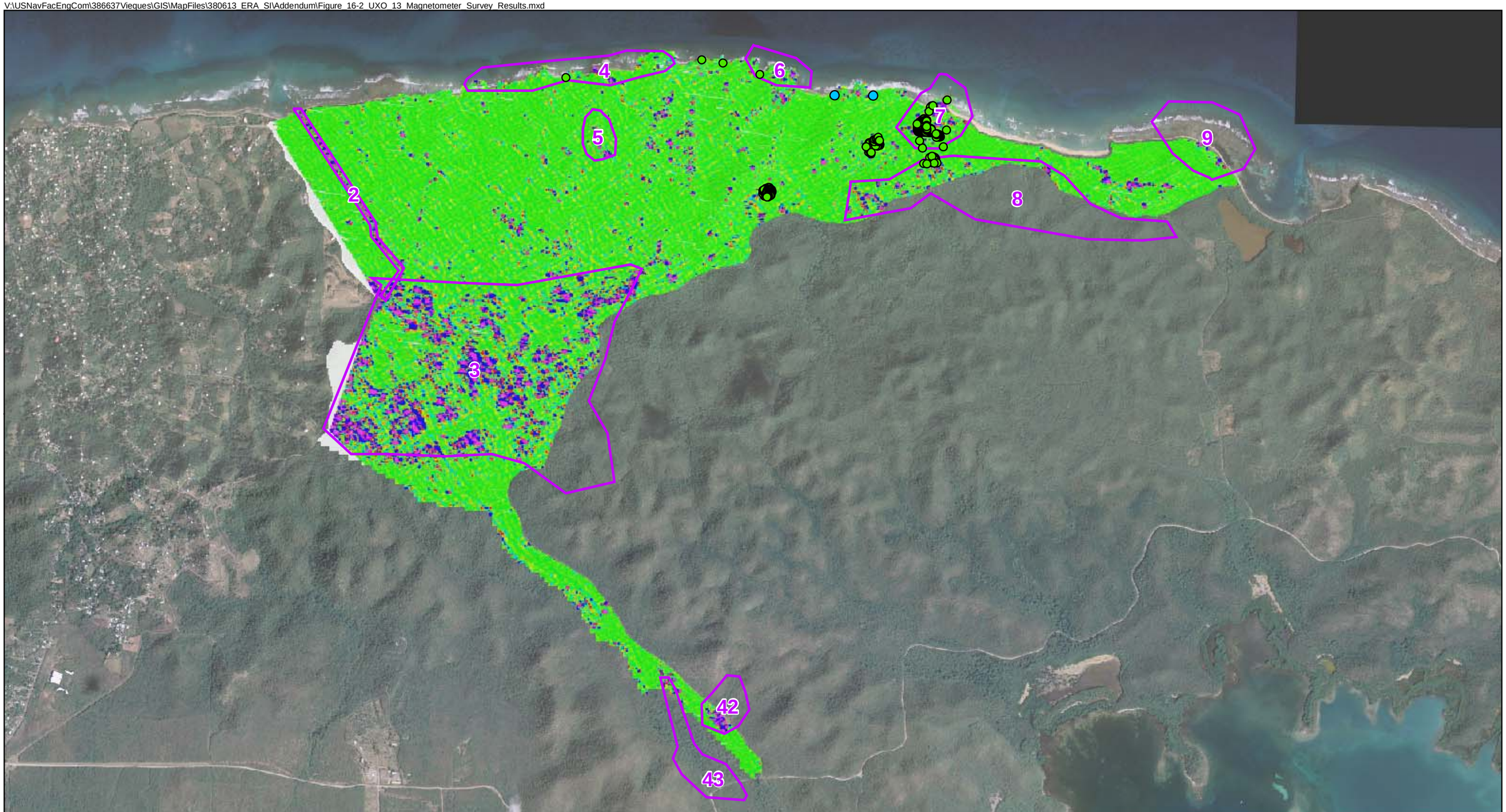

Legend

Magnetometer Response from "Mag and Flag"

- Low
- Medium
- High
- EADA

Aerial Magnetometer Survey Total Magnetic Field

-4.6 -2.3 0.0 1.9 3.8 5.8 7.7 9.6

N
W E
S

0 1,000 2,000 4,000
Feet

Figure 16-2
UXO 13 Magnetometer Survey Results
Former VNTR, Vieques, Puerto Rico

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SECTION 17

UXO 14—EMA South

17.1 Background

UXO 14 encompasses 1,050 acres and is located in the southern portion of the former EMA; the site is south of UXO 11 and adjacent to Ensenada Honda. Over the years a Range 10 was established as fixed, static range with all firing from a single point. This range was located adjacent to Ensenada Honda adjacent to a mangrove area. It was used for frontal assaults using M-1, M-14 rifles; M-2 carbines, Browning Automatic rifles, service pistols, and 45 caliber machine guns. Demolition charges up to a quarter pound were detonated to simulate combat. In addition to this range two GPs (G-33 and G-36) have been identified at this site.

For additional information and site history, including historical military use, see the site descriptions for UXO 12 and UXO 13 site descriptions in Sections 15 and 16, respectively.

17.2 ERA/SI Findings

17.2.1 Transect Inspections

Transect surveys were conducted for the entire former EMA, which includes UXO 14 (**Figure 17-1**). Approximately four percent (42 acres) of UXO 14 was evaluated utilizing a transect approach. **Table 17-1** presents a summary of the items found during the transect evaluations. A total of 21 munitions related items were identified at UXO 14.

TABLE 17-1
Summary of MEC Items Identified at UXO 14

	Number of Items Identified during Transects
UXO/MEC Items	
Projectiles / Mortars	4
Rockets / Guided Missiles	--
MD Items	
Flares-Pyrotechnics	6
Grenades	1
MEC Component	1
Projectiles / Mortars	8
Rockets / Guided Missiles	1
Total	21

17.2.2 Aerial Survey Results

AOI 2, identified during the LiDAR survey,

The aerial LiDAR survey of UXO 14 identified one AOI (AOI 2), which is **described in Appendix C**.The location was investigated during the transect survey. Only one item of RRD item was located at the site and was near a former well.

During the AMS, three EADAs were identified and include portions of UXO 14 (**Figure 17-2**). The Sky Research report (2009) describes these EADAs as:

- **EADA 38—**Presence of large discrete anomalies indicate probable ferrous material—apparent density variation may be a result of topography and/or geology. Anomaly density of 5 to 10 per acre.
- **EADA 39—**Collection of small anomalies with an anomaly density of 5 to 10 per acre.
- **EADA 40—**Large discrete anomalies and cluster of anomalies indicate ferrous material. Anomaly density greater than 10 per acre.

17.2.3 Summary of Findings

Four percent of UXO 14 was evaluated utilizing a transect approach and MEC was found at the site. A total of 21 MEC items were identified at the site. .

17.3 Recommendations

Based on the ERA/SI data surface items (MD, RRD, MPPEH) are present in the eastern half of UXO 14 and limited numbers of MD and RRD are present in the western portion of the site. A Remedial Investigations/Feasibility Study is recommended at these sites to: further characterize the nature and extent of MEC, assess the risk to human health and the environment

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Legend
- Range Related Debris
- Munitions Debris
- Material Potentially Presenting an Explosive Hazard
- Transect
- UXO Site

N
W E
S

0 600 1,200 2,400
Feet

Figure 17-1
UXO 14 Transect Findings
Former VNTR, Vieques, Puerto Rico

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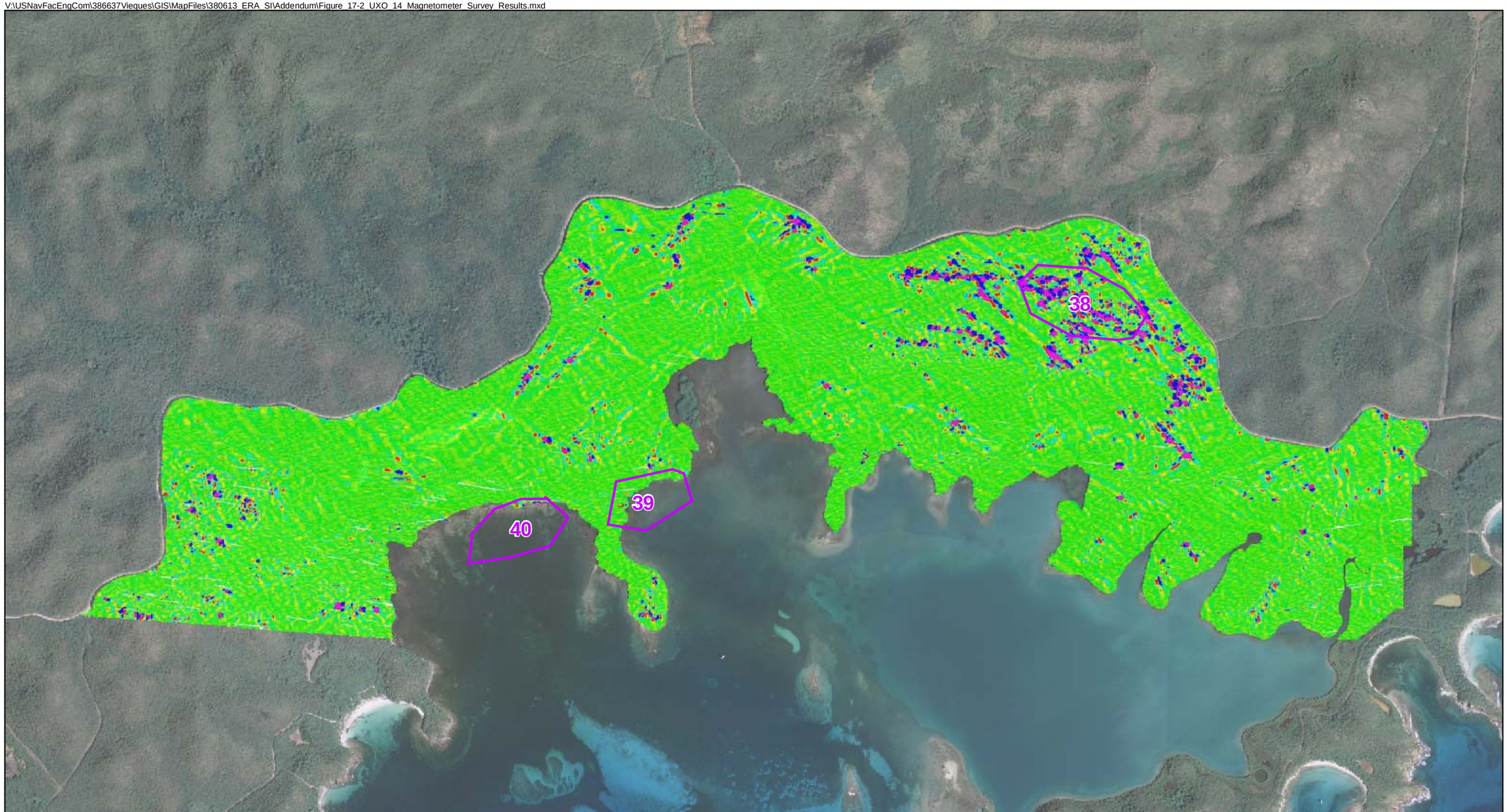

Legend
EADA

Aerial Magnetometer Survey Total Magnetic Field

-4.6 -2.3 0.0 1.9 3.8 5.8 7.7 9.6

N
W E
S

0 600 1,200 2,400
Feet

Figure 17-2
UXO 14 Magnetometer Survey Results
Former VNTR, Vieques, Puerto Rico

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SECTION 18

UXO 15—Puerto Ferro

18.1 Background

UXO 15 encompasses approximately 535 acres and is located to the southeast of the area formerly referred to as the EMA . There are two PI sites (9 and 13) within UXO 15 and are described in detail in the *Phase I RCRA Facility Investigation Repor*t (CH2M HILL, 2004b). PI 9 is described from interviews and aerial photograph analysis as an area of loading and offloading of munitions and as an area used for storage of munitions within earthen berms. In addition, potential open burning/open detonation was conducted at the site. PI 13 has been described as firing point for rocket-related ordnance in the 1950s-1960s where ordnance were possibly fired from the site toward the LIA/SIA. Aerial photographs identified "light-toned material present in excavation and linear excavations and/or pits line an access road to the southwest." Additionally, UXO 15 has a historical and culturally significant light house at the southeast extent of the site.

For additional information and site history, including historical military use, see the UXO 12 site description in Section 15

18.2 ERA/SI Findings

18.2.1 Transect Inspections

Transect surveys were conducted for the entire former EMA, which includes UXO 15 (**Figure 18-1**). Approximately six percent (32 acres) of UXO 15 was evaluated utilizing a transect approach. **Table 18-1** presents a summary of the munitions-related items found during the transect evaluations. In addition, several debris piles and PI-9 and PI-13 were investigated as part of UXO 15. Small caliber casings and surface debris were located during the investigation of the debris piles. The location and description of the items identified in the debris piles are shown on **Figure 18-2**. A visual inspection of the items off PI-9, in the water at the eastern extent, was conducted qnd identified as empty munitions casings that have been incorporated into the reef material. Visual and magnetometer transects across UXO 15 identified 32 MD items, mostly empty marine artillery casings from 106 mm projectiles (27), 105 mm projectiles (2), 120 mm projectiles (1), 155 mm round (1), and 3 ½-inch rocket casing (1)(see **Figure 18-1**).

TABLE 18-1
Summary of MEC Items Identified at UXO 15

	Number of Items Identified during Transects
MD Category	
Projectiles / Mortars	30
Rockets / Guided Missiles	2
Range Related Debris	
Total	26

18.2.2 Aerial Survey Results

The aerial LiDAR survey of UXO 15 identified one AOI. This AOI is the Puerto Ferro lighthouse area.

During the AMS, two EADAs were identified and include portions of UXO 15 (**Figure 18-2**). The Sky Research report (2009) describes these EADAs as:

- **EADA 44—**Large discrete anomalies and smaller anomalies with an anomaly density of less than 5 per acre.
- **EADA 45—**Large discrete anomalies indicate ferrous material, possibly linear extending northward (fence line). Anomaly density of less than 10 per acre.

18.2.3 Summary of Findings

Although 32 MD items were identified at the site, no UXO items were identified at UXO 15. EADAs 44 and 45 identify subsurface anomalies, however, field investigations have not been completed to assess if these anomalies are munitions related or are related to the subsurface geology.

18.3 Recommendations

Further investigation/assessment of the debris piles, near shore MD and subsurface anomalies should be conducted to determine if UXO is present at the site.

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Legend

- Range Related Debris
- Munitions Debris
- Material Potentially Presenting an Explosive Hazard
- Transect
- PI SIte
- UXO Site

N
W E
S

0 350 700 1,400
Feet

Figure 18-1
UXO 15 Transect Findings
Former VNTR, Vieques, Puerto Rico

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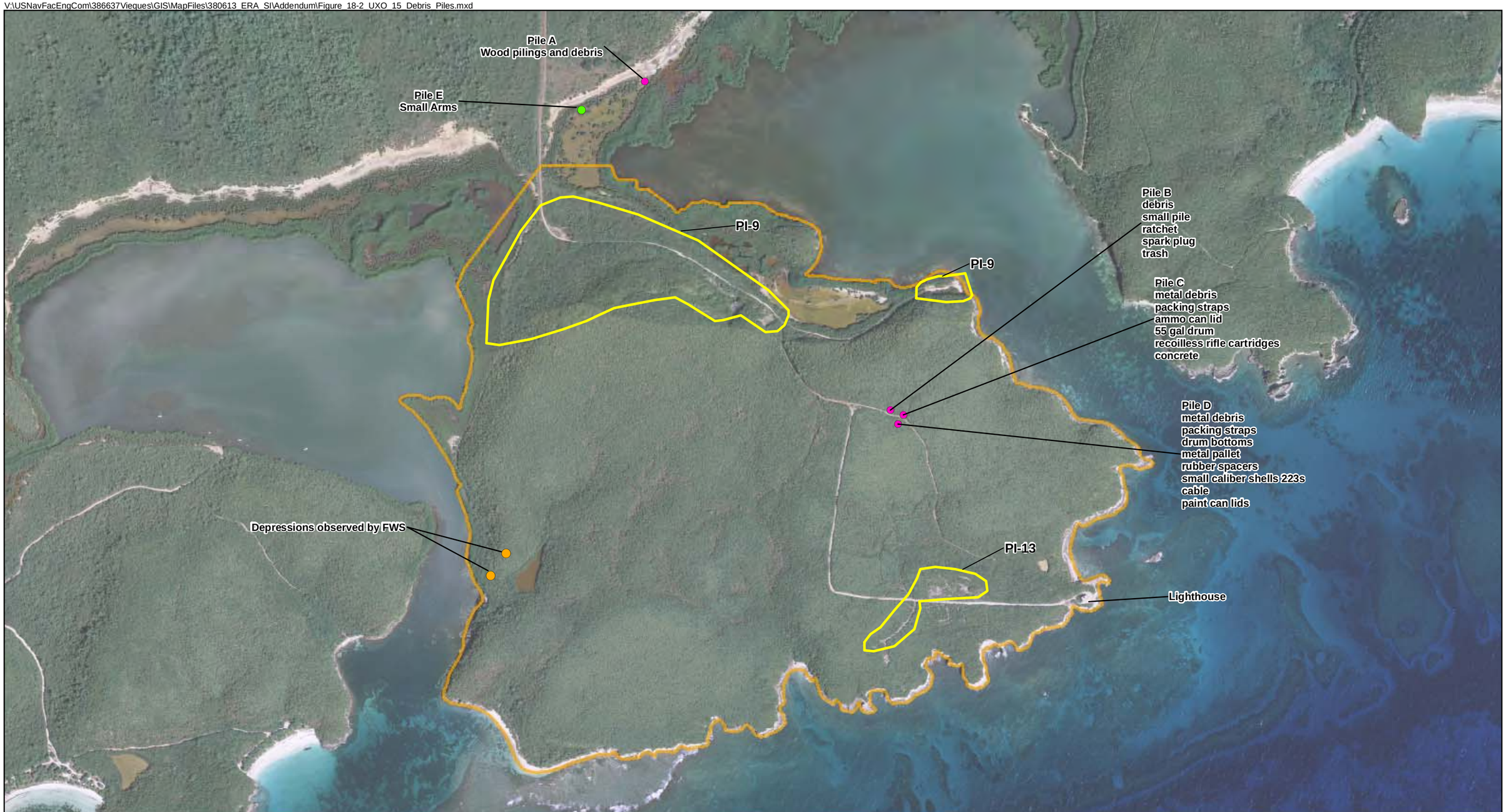

Legend
- GPS Debris Piles
- Depressions observed by FWS
- Small Arms
- PI SIte
- UXO Site

N
W E
S

0 425 850 1,700
Feet

Figure 18-2
UXO 15 Debris Piles
Former VNTR, Vieques, Puerto Rico

CH2MHILL

V:\USNavFacEngCom\386637Vieques\GIS\MapFiles\380613_ERA_SI\Addendum\Figure_18-3_UXO_15_Magnetometer_Survey_Results.mxd

Legend

Magnetometer Response from "Mag and Flag"

- Low
- Medium
- High
- PI SIte
- EADA

Aerial Magnetometer Survey Total Magnetic Field

-4.6 -2.3 0.0 1.9 3.8 5.8 7.7 9.6

N W E S

0 350 700 1,400 Feet

Figure 18-3
UXO 15 Magnetometer Survey Results
Former VNTR, Vieques, Puerto Rico

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SECTION 19

UXO 16—Underwater Areas

19.1 Background

UXO 16 is defined as water areas that surround the former VNTR and former NASD where the Navy conducted operations and would be assessed under CERCLA, as agreed by the Navy, USEPA, DOI and PREQB. These areas of assessment include: ship anchoring points where munitions may have been transferred, areas where munitions may have been inadvertently fired into the water from NGF or ATG bombing, and areas where the explosive safety arc from open burning/ open detonation activities may have extended into the water. **Figure 19-1** presents the site location map of UXO 16 in its entirety, which is estimated to be approximately 11,534 acres in size.

As part of a National Pollution Discharge Elimination System (NPDES) permit, the Navy was required to record the location, date, and type of munitions that were inadvertently fired into the water from 1989 to 1999. The records of offshore munitions hits indicate there were 811 offshore hits from 1989 to 1999 (Baker, 2001). A map illustrating the locations of the offshore munitions hits is shown as **Figure 19-2**. Of the 811 offshore hits, 85 percent originated from ships, 14 percent were from aircraft, and 1 percent was from other sources. **Figure 19-2** also shows general locations of non-explosive ordnance skips and misses from training activities in 2002 when 2,526 projectiles from NGF were fired (Navy, 2002). Data for the training activities at the range in 2002 indicate that 12 percent (303 projectiles) of the non-explosive NGF skipped off the land and ultimately landed in the water and 1.4 percent (35 projectiles) missed the intended target and landed in the water. The data is for only non-explosive ordnance over a limited time period; therefore, no extrapolation of the data can be made for unexploded ordnance that may be present in the water.

19.2 Previous Investigations

The summary of the results of previous MEC investigations for underwater areas are shown on **Figure 19-3**. Investigations that have been conducted for UXO 16 that have focused on the identification of MEC include:

- **November 2006:** Sidescan and multi-beam sonar; magnetometer; and underwater videography and photography conducted in Bahia Salina del Sur. (No report is currently available.) (NOAA, 2006)
- **November 2006:** Automated underwater vehicle sonar and videography conducted in the Bahia Icacos area. The report for this investigation is included as **Appendix F** (NOAA, 2006).
- **June 2007:** Underwater magnetometry conducted in Bahia Salina del Sur (SAIC, 2008).

- **November 2006:** Underwater visual verification of SAIC and NOAA findings in the Bahia Salina del Sur area (GMI, 2007a). The report is provided as **Appendix G**.
- **March 2009:** Remote-operated vehicle underwater videography (USAE, 2009). The report for this investigation is included as **Appendix H**.

In general each of these studies identified either MEC (or potential MEC) lying on the sea floor surface or, in the case of magnetometry identified metallic anomalies (603 anomalies) on and beneath the sea floor over approximately 275 acres. Both the Bahia Salina del Sur and Bahia Icacos areas, which are adjacent to the former LIA, had a number of identifiable munitions items present. **Appendix G** presents photographs of underwater items and the munitions items identified by Geo-Marine (GMI, 2007a). Munitions items identified included projectiles and bombs as well as assorted MD and RRD. A majority of the items found were 5 inch projectiles (82 items) and 24 Mk 82 bombs. Appendix 4 of the GMI report summarizes the munitions-related items and munitions debris in the nearshore area of Bahia Del Sur (GMI, 2007a).

In addition to the studies described above, the AMS was conducted for near shore areas. The AMS identified twelve EADAs that lie wholly or partially in the water (**Figure 19-4**). Most of these EADAs are described in other sections of this report along with the other sites with which they are associated. The EADAs not previously described (18, 22, and 23) are described in the Sky Research report (2009) as:

- **EADA 18—**Small anomalies consistent with typical responses from UXO-related activity, dipole angle distribution percentage that may be indicative of UXO. Anomaly density of 5 to greater than 10 per acre.
- **EADA 22—**Large discrete anomalies with a shoal region. Dipole angle distribution percentage may indicate UXO. Anomaly density greater than 10 per acre.
- **EADA 23—**Very large distinct anomalies with an anomaly density less than 5 per acre.

19.2.1 Summary of Findings

Visual observations, including photography and videography, indicate the presence of MEC (or potential MEC) within underwater areas adjacent to the former LIA, specifically in Bahia Salina del Sur. EADAs 22 and 23 are found in the area of shipwreck of the *USS Killen,* which would result in anomalous magnetic responses.

19.3 Recommendations

Investigations of the underwater areas have been limited to assess the MEC in the bay south of the LIA. The data collected during these investigations identify the need for additional investigations and an RI/FS to further characterize nature and extent of the MEC in the underwater areas and to evaluate the risk to human health and the environment.

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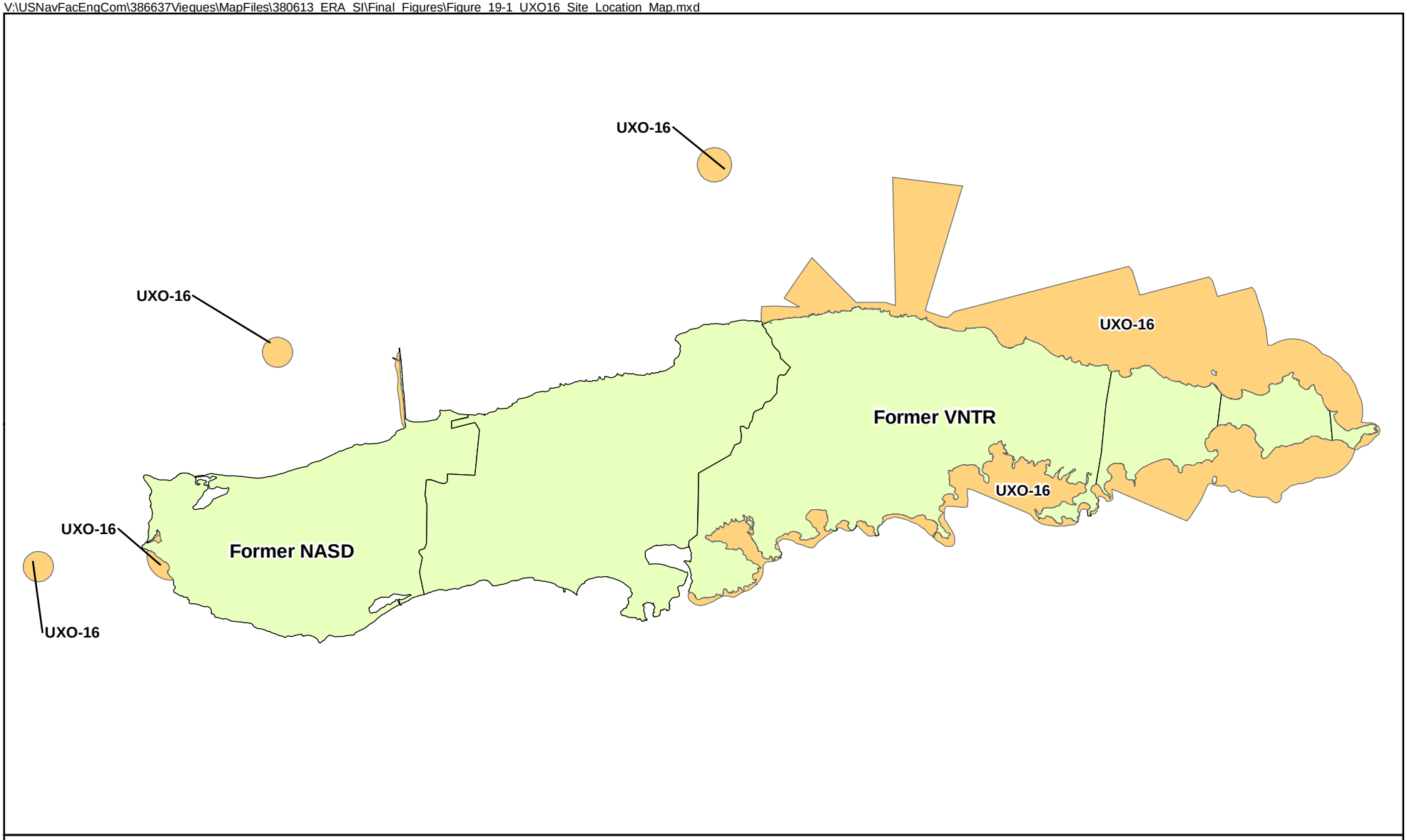

Legend

- UXO 16
- Site Boundary

N
W E
S

0 6,000 12,000 Feet

1 inch = 12,000 feet

Figure 19-1
UXO 16 Site Location
Former VNTR, Vieques, Puerto Rico

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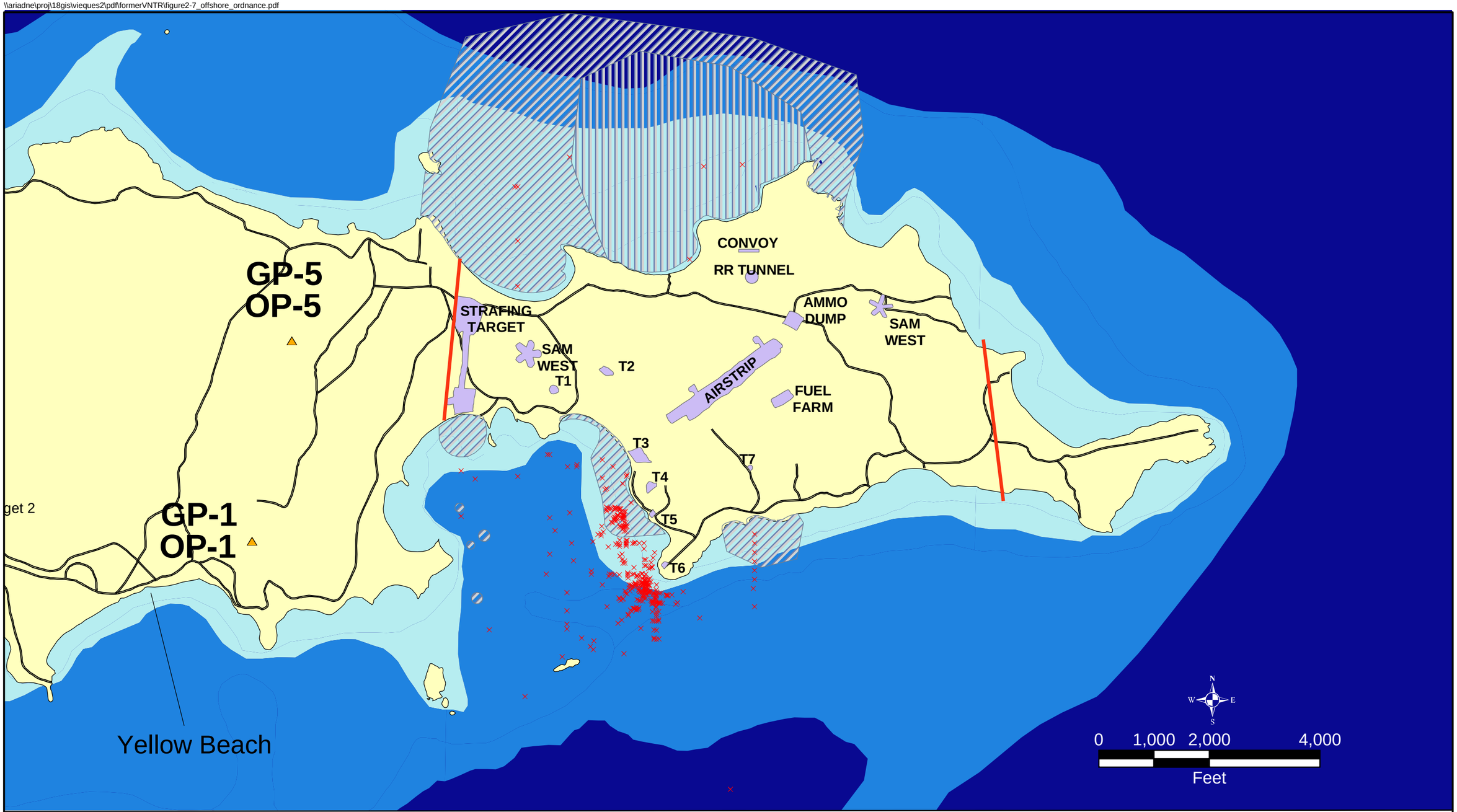

LEGEND

- Naval Gunfire Support (NGFS) Area Target
- Property Line
- Gun Position
- In-Water Ordance Hits (Baker)

Water Depth

- 0 - 10
- 10 - 50
- > 50

- Non Explosive Ordnance Locations (Dept. of Navy 2001)
- Concentration Non Explosive Ordnance Locations (Dept. of Navy 2001)

Definitions:
LIA - Live Impact Area
SIA - Surface Impact Area
ECA - Eastern Conservation Area

Figure 19-2
Off Shore Ordnance Locations
Former VNTR, Vieques, Puerto Rico

Legend

- GMI - Groundtruthing Data Points
- GMI - Munitions Debris
- GMI - Non-Surveyed NOAA Data Points
- SAIC - Target Depths
- SAIC - Target Depths by Skiff
- NOAA - Row Targets
- SAIC - Calibration Line

N

0 100 200 400 600 800 1,000 Feet

Figure 19-3
UXO 16 Summary of Previous Investigations Findings
Former VNTR, Vieques, Puerto Rico

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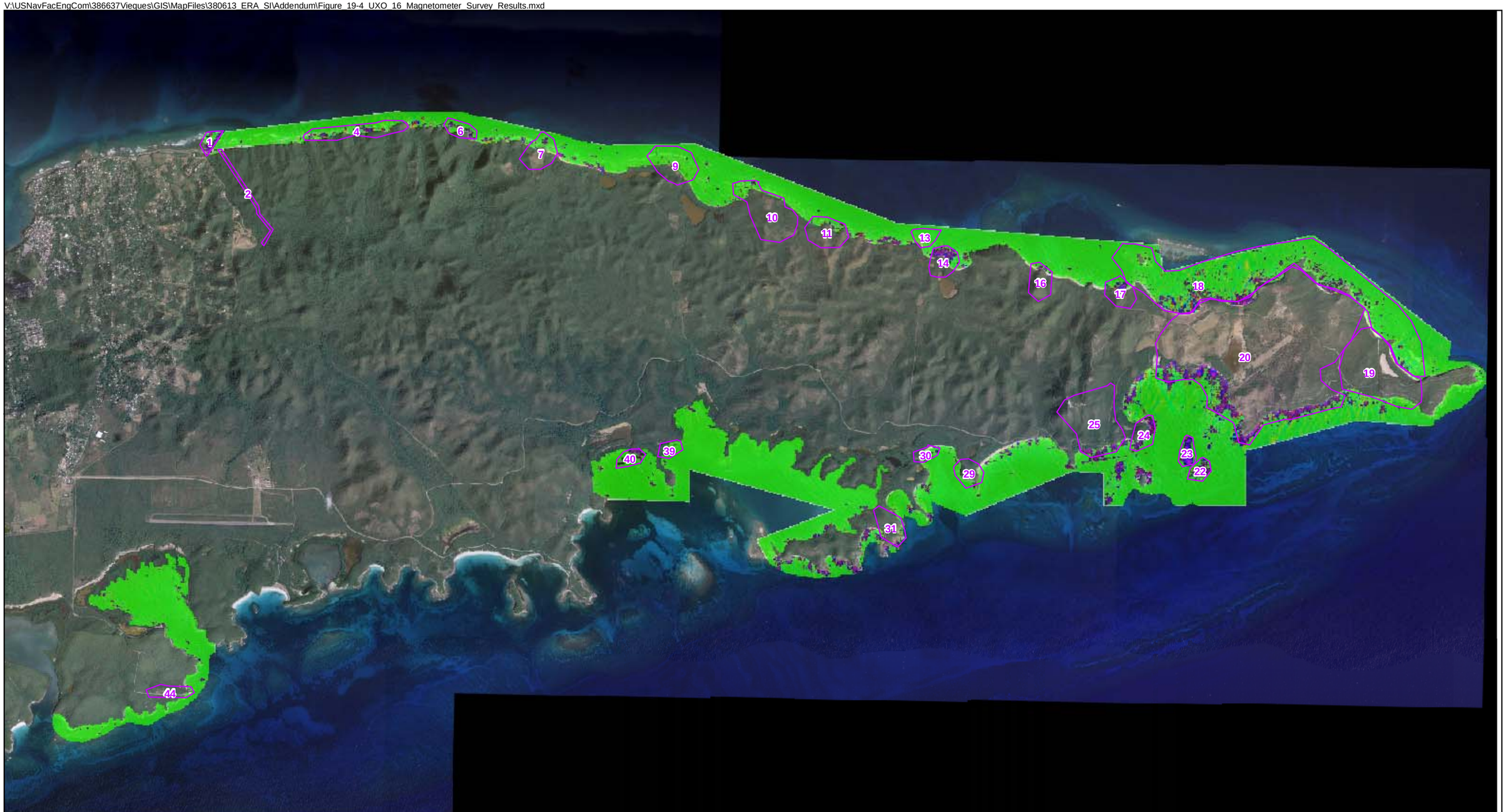

Legend
EADA

Aerial Magnetometer Survey Total Magnetic Field

-4.6 -2.3 0.0 1.9 3.8 5.8 7.7 9.6

N
W E
S

0 2,000 4,000 8,000
Feet

Figure 19-4
UXO 16 Magnetometer Survey Results
Former VNTR, Vieques, Puerto Rico

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SECTION 20

UXO 17—Other Sites

20.1 Background

UXO 17 is located to the south of the area formerly referred to as the EMA. There are one PI sites (PI-14) and one PAOC site (PAOC EE) within UXO 17 and are described in the Phase I RCRA Facility Investigation Report (CH2M HILL, 2004b). The historical aerial photograph analysis described PI-14 from a 1970 aerial photograph as "two pits with light toned material and possible debris." The EBS (2003) in interviews described PI-14 as "possible disposal area for scrap metal, ammunition boxes, shell casings, and miscellaneous debris." EBS interviews conducted October 2002 indicated PAOC EE was the site of former storage of munitions in earthen berms.EBS interviews conducted October 2002 indicated PAOC FF was the site of a former artillery gun placement. Additionally, UXO 17 has a historical and culturally significant light house at the southeast extent of the site. The results of the transect surveys at UXO 17 are shown on **Figure 20-1**.

20.2 ERA/SI Findings

20.2.1 PI-14

PI–14 was investigated using a transect approach. The items identified on the ground surface during the investigation were 13 slap flares (11 expended and two unused) and several pounds of metal banding and communications wire. The slap flares were collected and taken to the onsite Central Processing Center for disposal.

20.2.2 PAOC-EE

PAOC-EE is a suspect location of former storage of munitions in earthen berms (CH2M HILL, 2004b). The site was investigated using a transect approach and handheld magnetometer survey for the Beach areas. Seventeen subsurface anomalies were found during the survey. No surface MEC items were located during site inspection. Metallic construction debris and small arms ammunition was identified across the eastern portion of the site.

In 2010 an expanded SI was conducted at the beaches of PAOC EE which included a DGM survey and subsequent removal of the geophysical anomalies. The locations of the anomalies are shown on **Figure 20-2.** None of the anomalies removed were MEC.

20.2.3 PAOC-FF

PAOC–FF was identified as a potential former artillery firing point (CH2M HILL, 2004b). The site was investigated using a transect approach. The items identified on the ground surface during the investigation consisted of an estimated 400 pounds of rebar, fencing and fence posts.

20.3 Findings and Recommendations

20.3.1 PI-14

PI-14 is less than 3.5 acres in size based on the site identification (CH2M HILL, 2004b).Flare casings and two unused flares were identified at the site along with other metal debris. The flares were identified as the only munitions related items at the site and have been removed. Therefore the site is recommended for no further action.

20.3.2 PAOC-EE

Removal of matting, metallic debris and small arms blanks from the site is recommended. Following removal, the site is recommended to be investigated to assess if any MEC is present.

20.3.3 PAOC-FF

PAOC–FF is less than 5 acres in size based on the site identification (CH2M HILL, 2004b) and no munitions-related items have been found at the site. No further action is recommended for this site.

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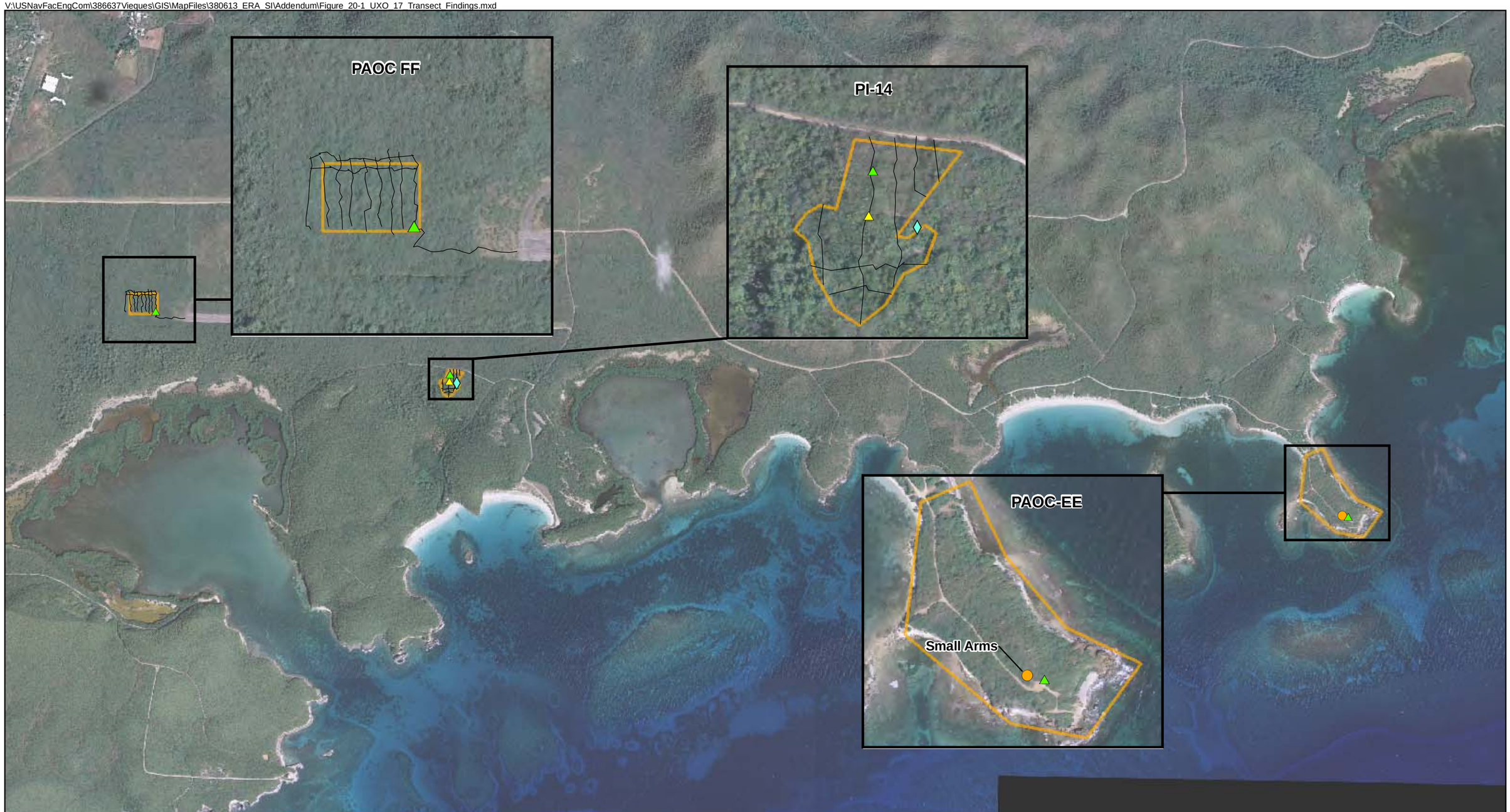

Legend

Transect Items

- Range Related Debris
- Munitions Debris
- Material Potentially Presenting an Explosive Hazard
- Discarded Military Munitions
- Transect
- UXO Site

N
W E
S

0 750 1,500 3,000
Feet

Figure 20-1
UXO 17 Transect Findings
Former VNTR, Vieques, Puerto Rico

CH2MHILL

V:\USNavFacEngCom\386637Vieques\GIS\MapFiles\380613_ERA_SI\Addendum\Figure_20-2_DGM_Density_UXO_17.mxd

Legend
- DGM Anomaly
- UXO Site

N
W E
S

0 250 500 1,000
Feet

Figure 20-2
DGM Anomaly Density within UXO 17
Former VNTR, Vieques, Puerto Rico

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SECTION 21

Conceptual Site Model

This section presents the CSM for the former VNTR. The CSM qualitatively combines and interprets the site MEC data and information presented in previous sections of this document. Potential migration of MEC and the future land use plan was also considered for development of this CSM. Because of the lack of MC data, potential MC contamination and exposure routes are not presented. The CSM is a living document used to support potential risk management decisions and aids in assessing the effectiveness of remedial alternatives that may be considered if necessary. As new data is obtained about the site, the CSM will be updated as appropriate.

Two representative areas were chosen to develop the representative CSMs. The representative CMSs are presented in **Figures 21-1** and **21-2**. **Figure 21-1** identifies the areas that have been designated as Wilderness Areas. **Figure 21-2** represents the areas that have been designated as Wildlife Refuge.

21.1 Source Areas

The former VNTR consists of approximately 14,600 acres that was comprised of four munitions operational areas which included:

- MRA-Eastern Maneuver Area (EMA; approximately 11,000 acres)
- MRA-Surface Impact Area (SIA; approximately 2,500 acres)
- MRA-LIA (approximately 900 acres)
- MRA-ECA (approximately 200 acres)

The former EMA is approximately 11,000 acres, and was established in 1947 to provide areas and ranges for the training of Marine amphibious units (1,200 to 1,500 Marines and battalion landing teams (1,200 to 1,500 Marines) in exercises that included amphibious landings, small-arms fire, artillery and tank fire, shore fire control, and combat engineering tasks. Large-scale artillery exercises were completed in the EMA using live marine artillery (including 76mm, 86mm, 90mm, 105mm, 106mm, and 175mm rounds). The artillery was fired from gun positions primarily, located throughout the EMA, towards targets located within the SIA and LIA. The aerial photograph analysis of the SI identified 34 potential GPs within the EMA. The results of the SI transects indicate that it appears there were very few artillery rounds that fell short of the targets in the SIA. The SI identified 46 artillery rounds in the EMA, primarily along the EMA/SIA boundary. The Marine exercises also included live firing on ranges with various weapons including pistols, rifles, machine guns, hand grenades; 40mm projected grenades, tanks, artillery, recoilless rifles, and mortars. Aerial photograph analysis and the SI confirmed the location of the eight ranges (Ranges 1, 2, 3, 4, 4A, 4B, 5, and 6) identified in the historical records. However, three additional ranges (Ranges 7, 8, and 9) were also identified during an aerial photograph analysis of the former EMA and SIA (ERI, 2002). And Ranges 10 and 11 were identified in the 1972 EIS (NAVFAC, 1972). The SI transects at the ranges identified only five MEC items, indicating that the

entire target areas of the ranges were surface cleared of MEC during range refurbishment. The AMS identified numerous metallic anomalies throughout the EMA. However, the relatively low number of metallic items identified in the SI transects indicate that most of the anomalies are associated with the ferrous bedrock in the EMA.

The SIA was established in the 1950s when several Marine Corps targets were constructed. Marine Corps artillery ranging from 76mm to 175mm projectiles was directed toward these targets from artillery GPs within the EMA (UXO 10 and UXO 12). During 1969, the construction of bulls-eye targets 1 and 2, used for inert bombing, established the eastern and western boundaries of the SIA. In 1971, a strafing target was installed adjacent to one of the targets. The SI transects confirmed the location of the bulls eye and strafing target areas, where high densities of BDUs and 20mm were identified respectively. The SI also identified aircraft bombs, aircraft gun projectiles, aircraft launched rockets, and naval gun projectiles in the SIA. Aerial photograph analysis for the SI also identified several artillery GPs in the SIA that may have been used for artillery fire.

The LIA, where several old tanks and vehicles, were used as targets, was used for aerial bombing training activities from 1965 until 2003. Since the mid-1970s, NGF was also practiced in the LIA, where several targets for ships were constructed along the southern shoreline. The results of the SI and TCRA, confirmed the extensive training in the LIA indicating that all 958 (UXO Sites 2, 3, and 4) acres of have been impacted by MEC (an average of 10.5 MEC items per acre have been removed). The SI and TCRA also identified Marine artillery rounds in the LIA, indicating that GPs in the SIA and EMA fired at targets in the LIA, as well as at targets in the SIA. Aerial and land-based geophysical surveys conducted during the SI indicted that although MEC has been surface cleared from the LIA, several hundred thousand subsurface metallic anomalies remain in the LIA, many of which are likely MEC.

The former ECA is a 200-acre area on the eastern tip of Vieques that was established as a conservation zone where no munitions operations were to be conducted. However the SI transects confirmed that the munitions activities on adjacent Live Impact Area have had an impact on the ECA. However, the density of the MEC surface items decreased significantly from the western boundary to the east in the ECA. The AMS conducted for the SI showed that the subsurface metallic anomalies remaining in the ECA are significantly lower in density than the anomalies in the LIA.

21.2 Exposure Assessment

The areas that pose the highest explosive safety hazards are those areas where human activity may be exposed to munitions on the ground surface. These areas include the LIA, ECA, and accessible areas of the SIA. As a result, TCRA and NTCRA MEC surface removal actions have been initiated at these areas. Other areas where high explosive safety hazards are present include roads and beaches where intrusive activities may be conducted. A NTCRA subsurface MEC removal action has been initiated at these areas to reduce the explosive safety risk. The SI identified several other areas where surface munitions have been identified that may pose an explosive safety risk. These areas include the interior to the SIA and the SIA/EMA border where Marine artillery round were identified. Receptors to the risks may include, but are not limited to, trespassing recreational boaters into the LIA,

trespassers of horseback riders into the MEC restricted areas of the EMA and SIA and potential exposure to explosive safety hazard of munitions response contractors into the LIA. Additional investigations of these areas will be needed to characterize the nature and extent of the MEC, including MC at these areas. In addition, risk assessments will need to be performed in these areas to assess the explosive safety risk and environmental contamination risk for each of these areas, based on the anticipated land use.

21.3 Terrain Analysis

Using the LiDAR data (Sky Research, Inc., 2005) slope maps were developed for the site. These maps categorize the terrain according to steepness of slope to assist with project planning and assessments of accessibility. The slope maps are presented as **Figures 21-3 through 21-5.**

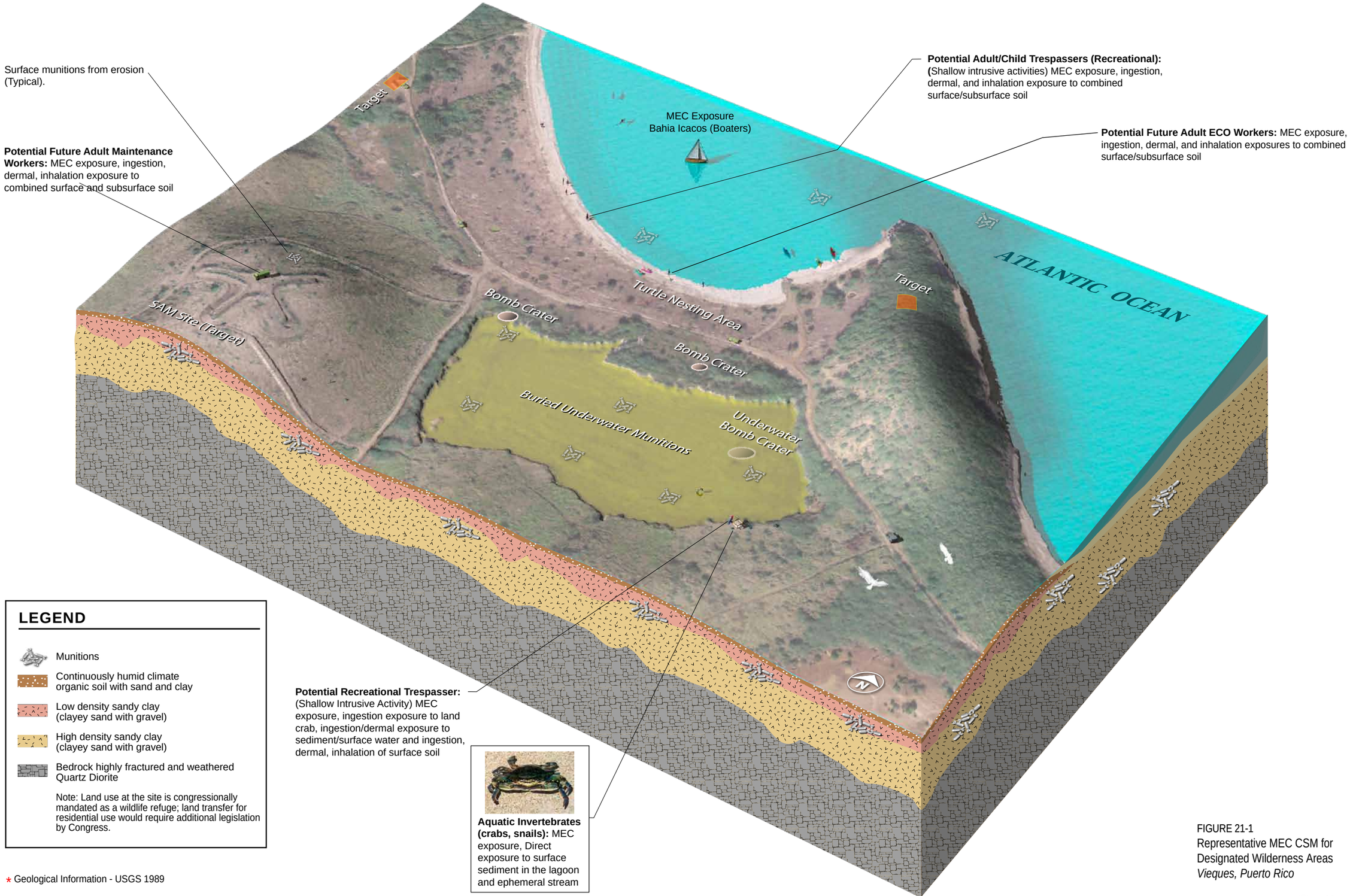


FIGURE 21-1
Representative MEC CSM for Designated Wilderness Areas
Vieques, Puerto Rico

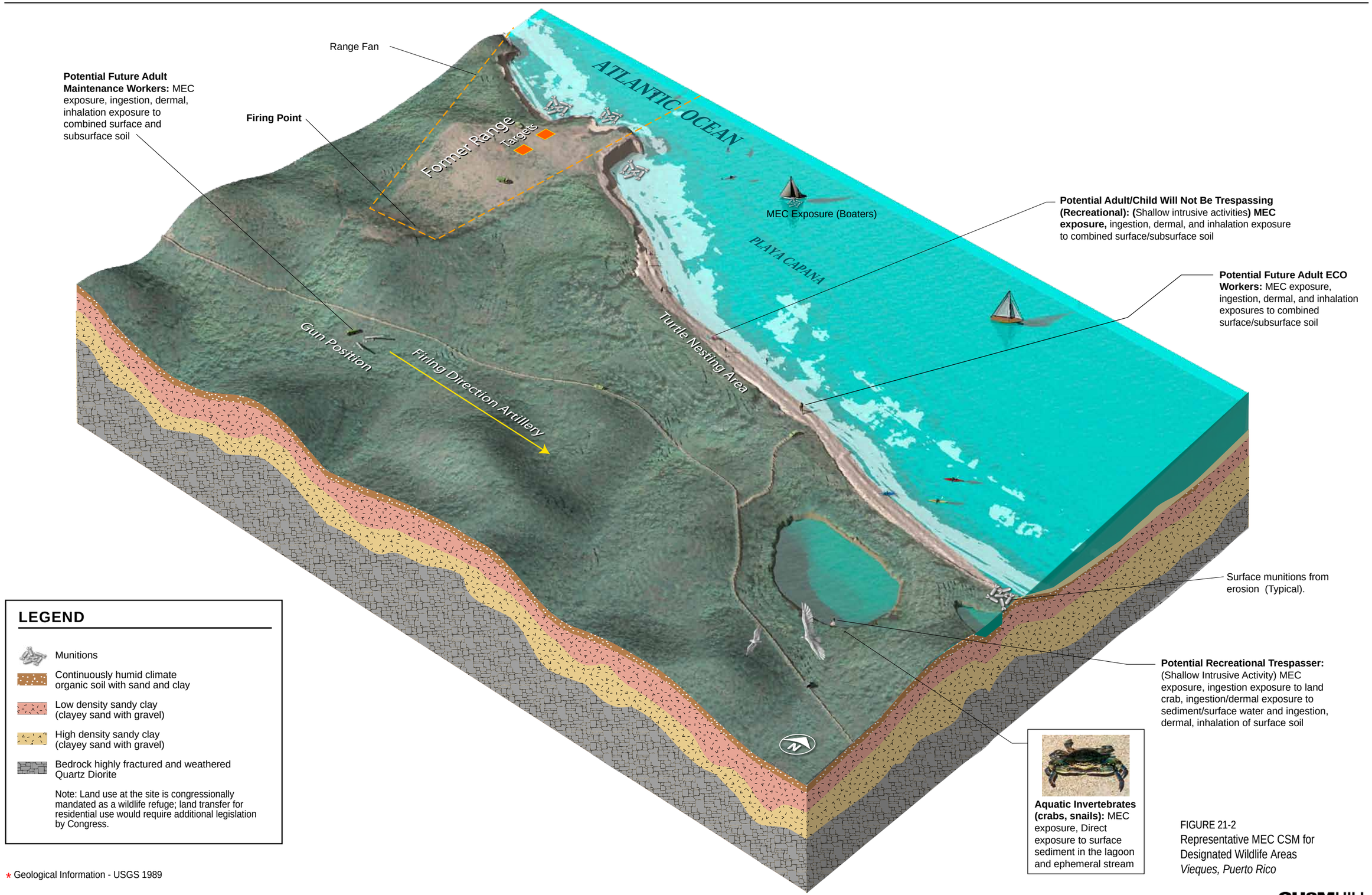
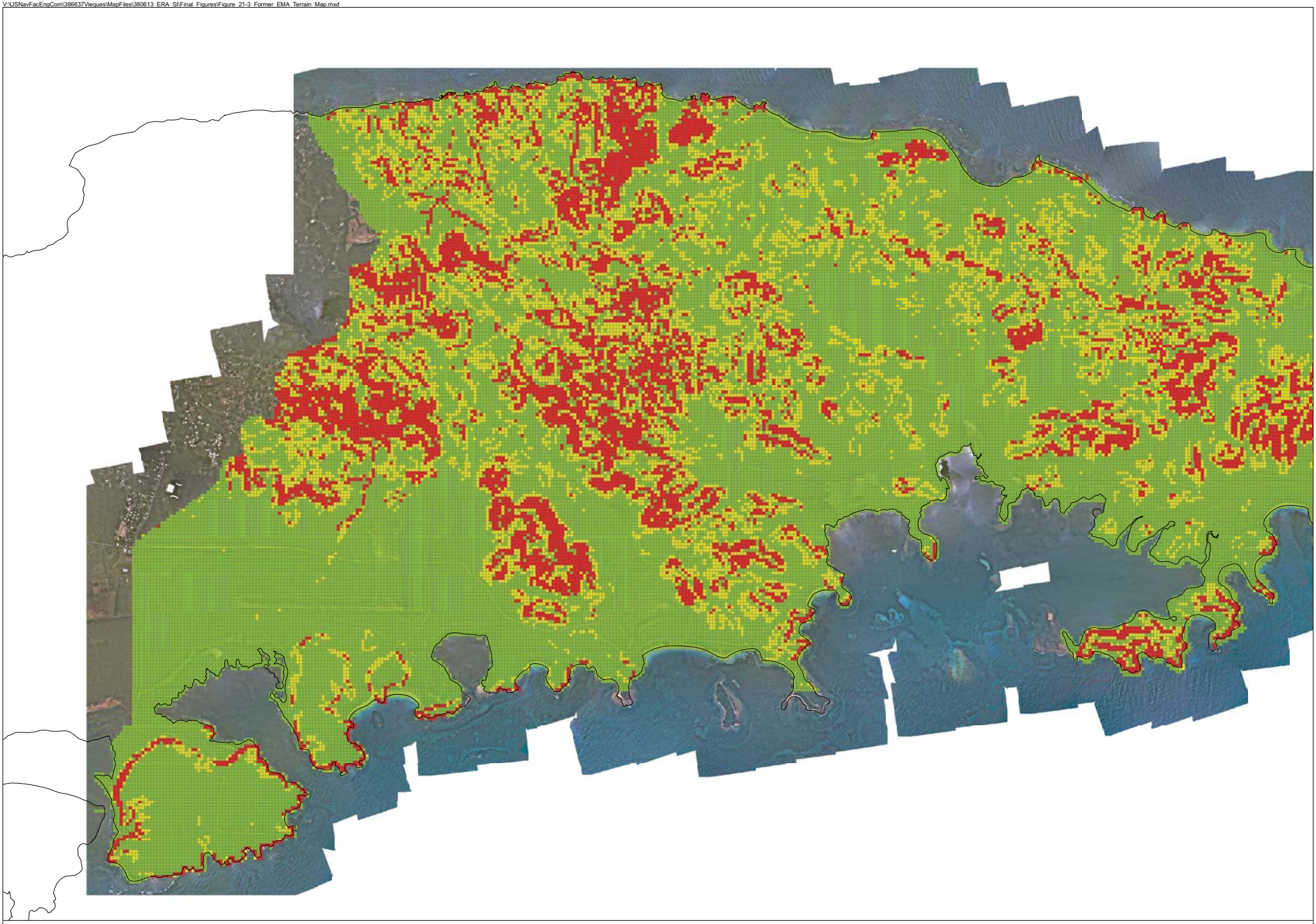


FIGURE 21-2
Representative MEC CSM for Designated Wildlife Areas
Vieques, Puerto Rico

V:\USNavFacEngCom\386637Vieques\MapFiles\380613_ERA_SI\Final_Figures\Figure_21-3_Former_EMA_Terrain_Map.mxd



Legend

Island Boundary

Slope % Score

1= Slope % 0-20

2= Slope % 21-30

3= 31 or Greater

N
W E
S

0 487.5975 1,950 2,925 3,900
Feet

Figure 21-3
Former EMA Terrain Map
Former VNTR, Vieques, Puerto Rico

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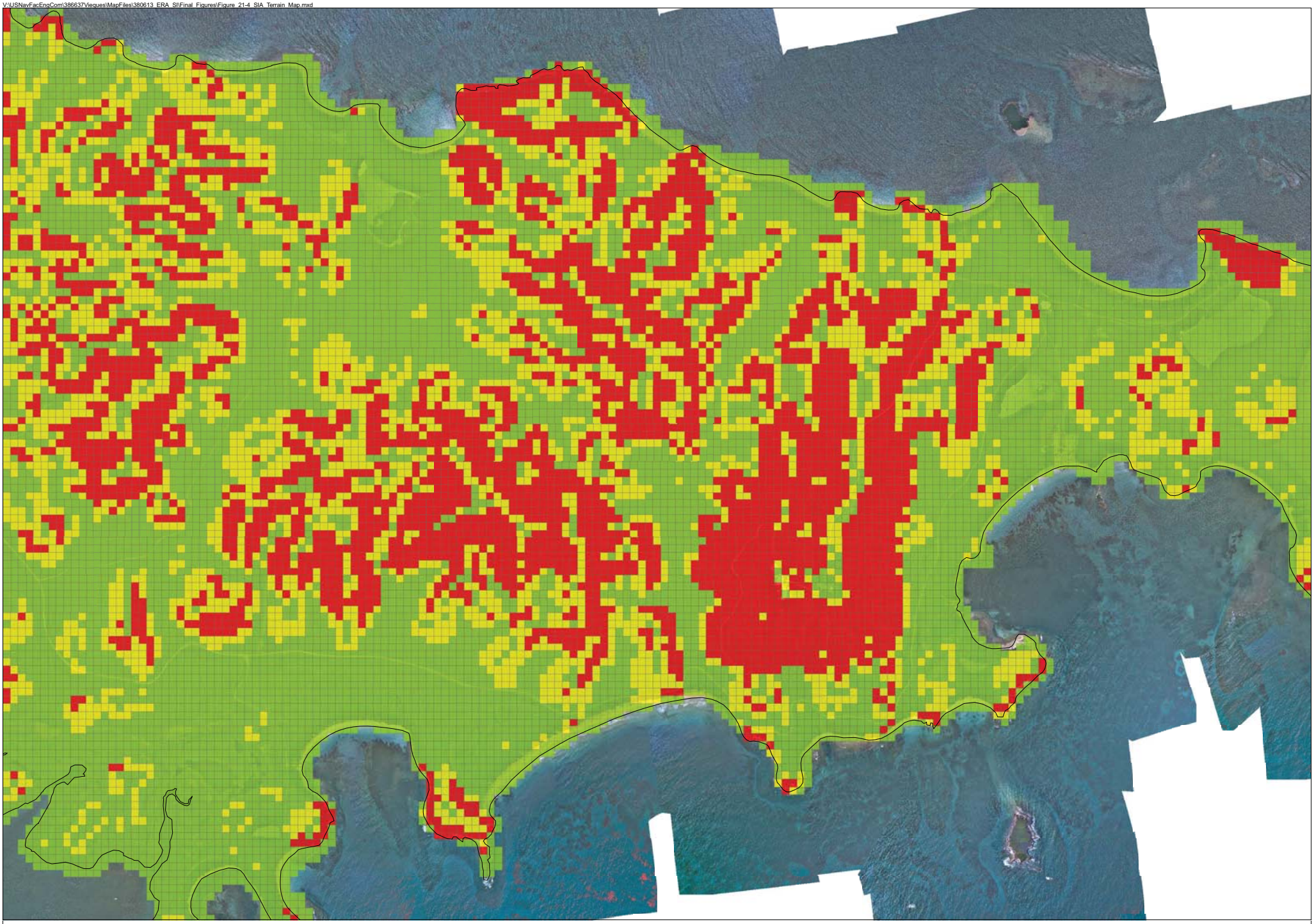
V:\USNavFacEngCom\386637Vieques\MapFiles\380613_ERA_SI\Final_Figures\Figure_21-4_SIA_Terrain_Map.mxd



Legend

Island Boundary

Slope % Score

1= Slope % 0-20

2= Slope % 21-30

3= 31 or Greater

N
W E
S

0 200 400 800 1,200 1,600
Feet

Figure 21-4
Former SIA Terrain Map
Former VNTR, Vieques, Puerto Rico

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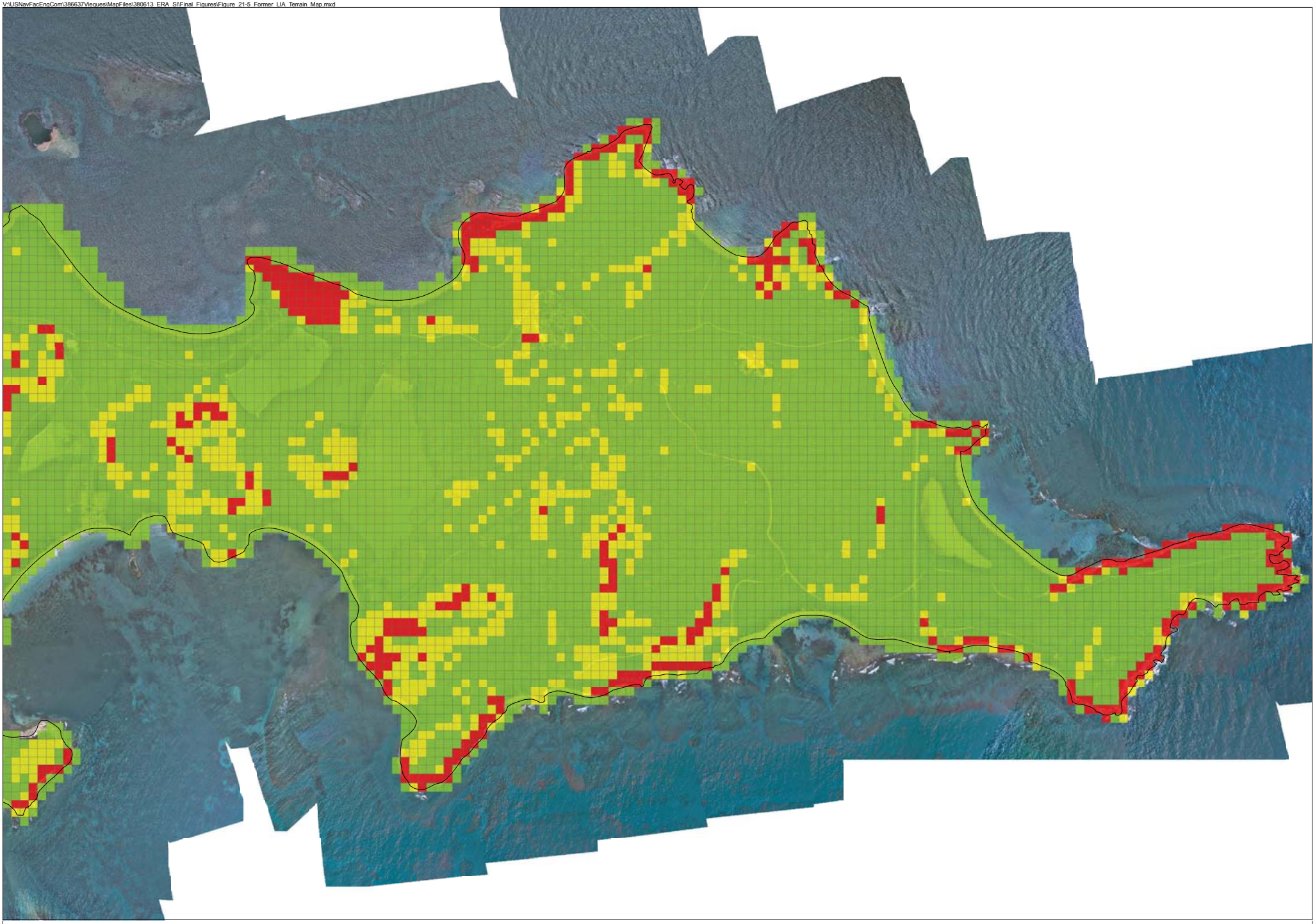
V:\USNavFacEngCom\386637Vieques\MapFiles\380613_ERA_SI\Final_Figures\Figure_21-5_Former_LIA_Terrain_Map.mxd



Legend

Island Boundary

Slope % Score

1= Slope % 0-20

2= Slope % 21-30

3= 31 or Greater

N
W E
S

0 175 350 700 1,050
Feet

Figure 21-5
Former LIA Terrain Map
Former VNTR, Vieques, Puerto Rico

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SECTION 22

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SECTION 23

Glossary of Terms

This glossary of terms is provided as a tool for better understanding the terminology used in the delivery of Ordnance Explosives (OE) type projects, including preliminary assessments. As such, not all terms provided here may be utilized in the contents of this report.

Abandoned Ordnance and Explosives—Ordnance and explosives (OE), which were disposed by abandonment, to include land or water dumping/burial. The OE may or may not have been fuzed, could be armed or unarmed, but were not employed as designed.

Active Range—An operational military range that is currently in service and is being regularly used for training, demonstrations, research, development, testing or evaluation.

Ammunition and Explosives—Includes (but is not necessarily limited to) all items of U. S.-titled (owned by the U.S. Government through Department of Defense [DoD] Components) ammunition; propellants, liquid and solid; pyrotechnics; high explosives; guided missiles; warheads; devices; devices, and chemical agent substances and components presenting real or potential hazards to life, property and the environment. Excluded are wholly inert items and nuclear warheads and devices, except for considerations of storage and stowage compatibility, blast, fire, and non-nuclear fragment hazards associated with the explosives. (DoD6055.9-STD, October 5, 2004)

Ammunition, Explosives, and Dangerous Articles (AEDA)—As defined in DoD 4160.21-M, this is any substance that by its composition and chemical characteristics, alone or when combined with another substance, is or becomes an explosive or propellant or is hazardous or dangerous to personnel, animal or plant life, structures, equipment or the environment as a result of blast, fire, fragment, radiological or toxic effects. It includes, but is not limited to, ammunition and explosives as defined in DoD6055.9-STD, DoD Ammunition and Explosive Safety Standards. AEDA is not a criterion for-demilitarization. Only items of AEDA which are included on the Munitions List have been assigned a demilitarization code other than "A." (DoD6055.9-STD, October 5, 2004)

Blank Ammunition—Ammunition that consists of a cartridge case with primer and powder charge but which does not contain a projectile. Blank ammunition is used for simulated fire, for signaling, and for training exercises.

Bomb—An explosive or other lethal agent, together with its container or holder, which is planted or thrown by hand, dropped from an aircraft, or projected by some other slow-speed device and used to destroy, damage, injure, or kill.

Caliber (Cal)—The diameter of a projectile or the bore of a gun or launching tube. In rifled arms, the caliber is measured from the surface of one land to the surface of the land directly

opposite. The bore diameter (caliber) of a gun used as a unit for indicating the length of its bore, measured from the breech face of the tube to the muzzle. (i.e., .50 cal, 3-inch, 90mm).

Cartridge—A complete round of ammunition in which the primer, propelling charge and projectile or bullet are completely assembled to the cartridge case as fixed ammunition; or the primer and the propelling charge are assembled in the cartridge case and closed by a friable plug. (DoD 4145)

Debris—Any solid particle thrown by an explosion or other strong energetic reaction. For aboveground detonations, debris usually refers to secondary fragments. For underground storage facilities, debris refers to both primary and secondary fragments, which are transported by a strong flow of detonation gases. (DoD6055.9-STD, October 5, 2004)

Dud—Explosive munition that is not armed as intended, or that has failed to function after being armed.

Empty Ammunition—An ammunition item or component that does not contain explosive material or inert material. Empty ammunition items and components include:

a) Ammunition items or components that were manufactured empty or without the components that contain the explosive material.

b) Ammunition items or components that have had their explosive material completely removed by disassembly, firing, thermal treatment or other means.

Expended Ordnance—Ordnance that has functioned as designed, leaving a shell or container behind. This shell or container may or may not contain explosive/pyrotechnic/ toxic residue. This material would not be considered inert, and could not be salvaged as scrap without appropriate visual inspection, sampling, and/or treatment.

Explosive Material—Any chemical material or chemical mixture with hazard-producing characteristics, loaded into ammunition and/or ammunition components. This includes explosives, propellants, white phosphorous, incendiary mixtures, pyrotechnic mixtures, tracer mix, toxic materials, riot control agents.

Explosive Ordnance—All munitions containing explosives. This includes bombs and warheads, guided and ballistic missiles, artillery, mortar, rocket and small arms ammunition; all mines, torpedoes and depth charges; demolition charges; pyrotechnics; clusters and dispensers; cartridges and propellant-actuated devices; clandestine and improvised explosive devices; and similar or related items or components explosive in nature.

Explosive Ordnance Disposal (EOD)—The detection, identification, on- evaluation, rendering safe, recovery, and final disposal of explosive ordnance which has been fired, dropped, launched, projected, or placed, in such a manner as to constitute a hazard to operations, installations, personnel, or material. It may also includes the rendering safe or disposal of ordnance which has become hazardous or unserviceable by damage or

deterioration when disposal of such ordnance is beyond the capabilities of personnel normally assigned the responsibility for routine disposition.

Explosive Ordnance Disposal -- (DOD, NATO) The detection, identification, onsite evaluation, rendering safe, recovery, and final disposal of unexploded explosive ordnance. It may also include explosive ordnance which has become hazardous by damage or deterioration. Also called EOD. (dtic DoD glossary)

Explosive Ordnance Disposal (EOD) Personnel— Active duty military personnel who have completed the training course at the U.S. Naval School, Explosive Ordnance Disposal, and are currently assigned to a military EOD unit.

Explosives—The term "explosive" or "explosives" includes any chemical compound or mechanical mixture which, when subjected to heat, impact, friction, detonation or other suitable initiation, undergoes a very rapid chemical change with the evolution of large volumes of highly heated gases which exert pressures in the surrounding medium. The term applies to high explosives, propellants and pyrotechnics that either detonate, deflagrate, burn vigorously, and generate heat, noise, smoke, or sound. Also see High Explosives.

Flare— A pyrotechnic designed to produce a single source of intense light for illumination or a pyrotechnic device designed to produce infrared radiation of greater intensity than that produced by jet engine exhaust for a sufficient time to decoy and divert enemy heat-seeking missiles from launching aircraft.

Fragment or Fragmentation (Frag)—The breaking up of the confining material of a chemical compound or mechanical mixture when an explosion takes place. Fragments may be complete items, subassemblies, pieces thereof, or pieces of equipment or buildings containing the items. (DoD6055.9-STD, October 5, 2004 and DoD 4145.26M of Sep '97)

Grenade— Munitions capable of producing fragmentation, chemical or blast and used offensively or defensively to incapacitate or kill. Grenades are capable of being thrown by hand, projected with a rifle, or placed as a booby trap device.

High Explosive (HE)— A substance which, in its application as a primary explosive, booster or main charge, in warheads and other applications, is generally required to detonate. This material may also be used as an energetic ingredient in propellants, pyrotechnics or other applications. Royal demolition explosive (RDX), high melting point explosive (HMX) and Tri-nitro Toluene (TNT) are examples of high explosives.

Howitzer— 1. A cannon that combines certain characteristics of guns and mortars. The howitzer delivers projectiles with medium velocities, either by low or high trajectories. 2. Normally a cannon with a tube length of 20 to 30 calibers; however, the tube length can exceed 30 calibers and still be considered a howitzer when the high angle fire zoning solution permits range overlap between charges. See also gun; mortar. (from dtic-DoD glossary website.)

Impact Area—The primary danger area for indirect fire weapons that is established for the impact of all rounds. When applied to direct fire weapons, it is the area located between established range limits. The impact area is within the approved surface danger zone.

Inactive Range—An operational range that is not currently being used, but that is still under military control and which the military considers to be a potential range area, and that has not been put to a new use that is incompatible with range activities.

Inert Ammunition— Ammunition and components that contain no explosive material. Inert ammunition and components include:

a) Ammunition and components with all explosive material removed and replaced with inert material.

b) Empty ammunition or components.

c) Ammunition or components that were manufactured with inert material in place of all explosive material.

Military Munitions—Military munitions means all ammunition products and components produced for or used by the Armed Forces for national defense and security, including ammunition products or components under the control of the Department of Defense, the Coast Guard, the. Department of Energy, and the National Guard. The term includes confined gaseous, liquid, and solid propellants, explosives, pyrotechnics, chemical and riot control agents, smokes, and incendiaries, including bulk explosives and chemical warfare agents, chemical munitions, rockets, guided and ballistic missiles, bombs, warheads, mortar rounds, artillery ammunition, small arms ammunition, grenades, mines, torpedoes, depth charges, cluster munitions and dispensers, demolition charges, and devices and components thereof.

The term does not include wholly inert items, improvised explosive devices, and nuclear weapons, nuclear devices and nuclear components, other than non-nuclear components of nuclear devices that are managed under the nuclear weapons program of the Department of Energy after all required sanitization operations under the Atomic Energy Act of 1954 (42 U.S.C. 2011 et seq.) have been completed. (10U.S.C. 101(e)(4)

Military Range—Designated land and water areas set aside, managed, and used to conduct research on, develop, test, and evaluate military munitions and explosives, other ordnance, or weapons systems, or to train military personnel in their use and handling. Ranges include firing lines and positions, maneuver areas, firing lanes, test pads, detonation pads, impact areas and buffer zones with restricted access and exclusionary areas.

Mortar—(DOD) A muzzle-loading, indirect fire weapon with either a rifled or smooth bore. It usually has a shorter range than a howitzer, employs a higher angle of fire, and has a tube with a length of 10 to 20 calibers. See also gun; howitzer. (DoD glossary)

Munitions and Explosives of Concern (MEC)—This term, which distinguishes specific categories of military munitions that may pose unique explosive safety risks, means:

- Unexploded Ordnance (UXO), as defined in 10U.S.C. 2710(e)(9);
- Discarded military munitions (DMM), as defined in 10 U.S.C. 2710 (e)(2); or
- Munitions constituents (e.g., TNT, RDX) present in high enough concentrations to pose an explosive hazard.

Munitions Constituents (MC)—Any materials originating from unexploded ordnance, discarded military munitions, or other military munitions, including explosive and non-explosive materials, and emission, degradation, or breakdown elements of such ordnance or munitions. (10 U.S.C. 2710(e)(4))

Non-Intrusive Investigation—Locating/investigating ordnance on the surface of the ground where excavation is not required.

Open Detonation (OD)—A process used for the treatment of unserviceable, obsolete, and or waste munitions whereby an explosive donor charge initiates the munitions to be detonated.

Ordnance and Explosives (OE) consists of:

- Ammunition, ammunition components, chemical or biological warfare materials that have been abandoned, expelled from demolition pits or burning pads, lost, discarded, buried or fired. Such ammunition, ammunition components, and explosives are no longer under accountable record control of any DoD organization or activity.
- Explosive Soil. See definition under "explosive soils."
- OE market includes: Unexploded Ordnance (UXO), Chemical Weapons Materials (CWM), OE Contaminated Soils and Groundwater, Range Maintenance, Ordnance Demilitarization (Demil), and Demining (DM).

Ordnance Related Scrap (ORS)—Material including, but not limited to, practice bombs, expended artillery, small arms and mortar projectiles, aircraft bombs and missiles, rockets and rocket motors, hard targets, grenades, incendiary devices, experimental devices, and other material fired on, or upon a military range.

Practice Ammunition—Ammunition specifically designed or modified for use in exercises, practice or operational training. Practice ammunition may be either expendable or recoverable. Practice ammunition is not inert and may contain all the explosive material normally contained in service ammunition. Practice ammunition may contain additional explosive material such as pyrotechnics, spotting charges or flotation devices to assure destruction, location or recovery.

Projectile— An object projected by an applied exterior force and continuing in motion by virtue of its own inertia, as a bullet, bomb, shell, or grenade. Also applied to rockets and to guided missiles.

Pyrotechnic— Substances or mixtures of substances which, when ignited, undergo an energetic chemical reaction at a controlled rate intended to produce, on demand and in various combinations, specific time delays or quantities of heat, noise, smoke, light or IR radiation. Pyrotechnics must be capable of functioning in their application without undergoing a deflagration-to-detonation transition (DDT).

Range (Active)—Designated air, land, and water areas set aside, managed, and used to research, develop, test, and evaluate military munitions, other ordnance, or weapons systems or to train personnel in their use and handling. Ranges include firing areas, and buffer zones with restricted access and exclusionary areas. This includes the airspace above the range.

Range (Inactive)—An area that at one time had been active and is necessary or required for training, testing, and mobilization requirements but is currently not being used.

Range Residue—Material including, but not limited to, practice bombs, expended artillery, small arms and mortar projectiles, aircraft bombs and missiles, rockets and rocket motors, hard targets, grenades, incendiary devices, experimental devices, and other material fired on, or upon a military range.

Service Ammunition—Ammunition intended for combat rather than for training is classified as service ammunition. This ammunition has been approved for service use and contains explosives, pyrotechnics, or chemical agent filler and the propellant, if required, is of service or reduced charge weight.

Service Explosives—High, initiating, or low explosives that are used principally and primarily in the loading, preparation, and assembly of ammunition of all types for the U.S. Armed Forces as contracted by explosives for commercial use such as dynamite, blasting gelatin, black powders, or permissible explosives which are granulated or prepared for blasting, mining, and construction purposes.

Shape Charge—A cylindrical (conical) or linear (rectangular) explosive charge that focuses energy of a detonation, enabling penetration of very thick and hard targets such as armor plate.

Small Arms Ammunition—Ammunition for small arms (i.e., all ammunition up to and including .60 caliber and all gauges of shotgun cartridges). Also includes 14.5mm and 20mm ammunition which does not have high explosive or incendiary loaded projectiles.

Tracer—A burning pyrotechnic element which produces bright light and/or smoke to aid in visual tracking of the munition in flight. A device that fits into or is attached to ordnance. It normally contains a starting mixture and illuminant, and leaves a trail of flame or smoke to show the trajectory of the ordnance.

Unexploded Ordnance (UXO)—Military munitions that:

- (A) have been primed, fused, armed or otherwise prepared for action;
- (B) have been fired, dropped, launched, projected, or placed in such a manner as to constitute a hazard to operations, installations, personnel, or material; and
- (C) remains unexploded whether by malfunction, design or any other cause. (10 U.S.C. 101(e)(5)

Unexploded Ordnance (UXO) Personnel—Any individual who has graduated from a DoD-approved UXO specialist course. Examples are the U.S. Naval School, Explosive Ordnance Disposal or International UXO Training Program, Texas A&M.

White Phosphorus (WP)—A screening smoke, WP burns on contact with air and can be used as an incendiary.

Appendix A
E-size Site Maps

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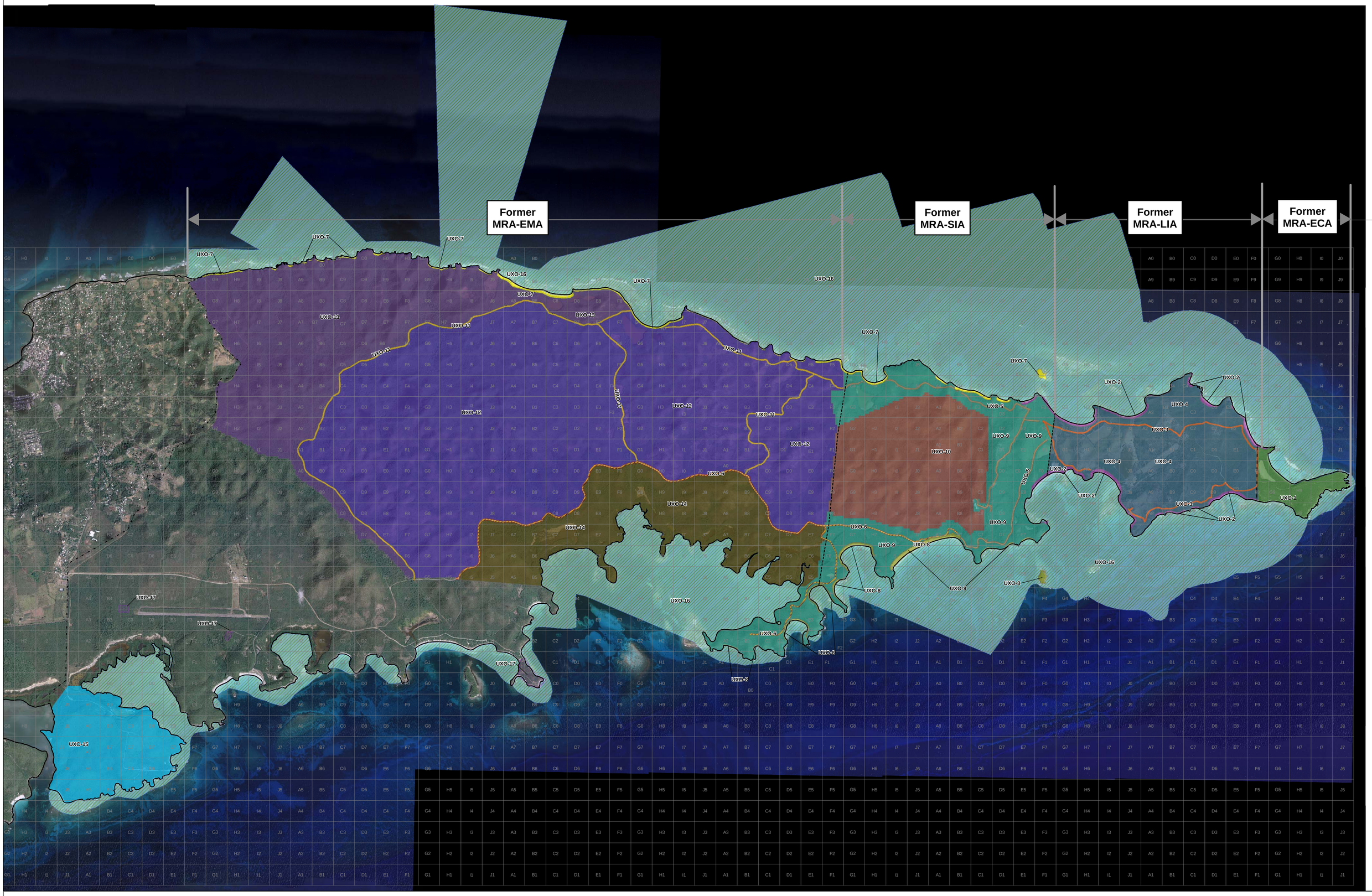

Legend

- 300 Meter Grid
- UXO-1 - Eastern Conservation Area
- UXO-2 - LIA Beaches
- UXO-3 - LIA Roads
- UXO-4 - LIA Interior
- UXO-5 - SIA Restricted Roads
- UXO-6 - EMA/SIA Public Roads
- UXO-7 - EMA/SIA North Beaches
- UXO-8 - SIA South Beaches
- UXO-9 - SIA Exterior
- UXO-10 - SIA Interior
- UXO-11 - EMA Public Roads
- UXO-12 - EMA Interior
- UXO-13 - EMA West
- UXO-14 - EMA South
- UXO-15 - Puerto Ferro
- UXO-16 -Underwater Areas
- UXO-17 - Other Sites (PI-14, PAOCC-EE, PAOC-FF)

N
W E
S

0 1,500 3,000
Feet

Figure A-1
Grid Map
Former VNTR, Vieques, Puerto Rico

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Appendix B
Site Name and Historical Site Use/Name Matrix

APPENDIX B
Site Name and Historical Site Use/Name Matrix
Former VNTR, Vieques, Puerto Rico

UXO Site	UXO Site Name	Former MRA	Former Associated MRS Number	Associated Historical Site Use/Name
UXO 1	Eastern Conservation Area (ECA)	MRA-ECA Eastern Conservation Area	MRS 1	
		MRA-Beach Area		Playa Blanca/Beach 15 Beach 16
UXO 2	Live Impact Area (LIA) Beaches	MRA-LIA Live Impact Area	MRS 3 MRS 4,5,6,7,8,9,10,12,14,18,20,21,22,28 MRS 13 MRS 30	Strafing Run/ATG Target ATG Target Mock Runway/ATG Target ATG Target, EOD Range (SWMU 3)
		MRA-Beach Area		Playa Yallis/Icacos/Beach 5 Playa Salinas Norte/Beach 6 Playa Brava/Beach 12 Playa Barco/Beach 14 Playa Tamarindo/Beaches 7 through 10 Playa Carrucho/Beach 4/Turtle Beach Playa Salinas del Sur/Beaches 2 and 3 Beach 11 Beach 13 Beach 34 Beach 35
		MRS-SIA Surface Impact Area	MRS 2,3	
UXO 3	Live Impact Area (LIA) Roads	MRA-LIA Live Impact Area	MRS 1 MRS 2,4,5,6,7,8,9,12,14,15,16,17,18,19,20,21,22,25,26,27,28 MRS 3 MRS 11 MRS 13 MRS 23 MRS 29 MRS 30	SAM West/ATG Target ATG Target Strafing Run/ATG Target Convoy Target/ATG Target Mock Runway/ATG Target SAM East/ATG Target OB/OD/ATG Target ATG Target, EOD Range (SWMU 3)
UXO 4	Live Impact Area (LIA) Interior	MRA LIA Live Impact Area	MRS 1 MRS 2,4,5,6,7,8,9,10,12,14,15,16,17,18,19,20,21,22,24,25,26,27,28 MRS 3 MRS 11 MRS 13 MRS 23 MRS 29 MRS 30	SAM West/ATG Target ATG Target Strafing Run/ATG Target Convoy Target/ATG Target Mock Runway/ATG Target SAM East/ATG Target OB/OD/ATG Target ATG Target, EOD Range (SWMU 3)
UXO 5	Surface Impact Area (SIA) Restricted Roads	MRA SIA Surface Impact Area	MRS 1 MRS 2 MRS 3 MRS 4 MRS 5 MRS 7	Marine and Naval Target Areas, Gun Positions, Aerial Bombing Target Areas, Observation Point 5, 12, 13, 14, Gun Position GP 5. PIs 22, 35. Marine and Naval Target Areas, Gun Positions, Aerial Bombing Target Areas Gun Position 21. PIs-1, 22. Marine and Naval Target Areas, Gun Positions, Aerial Bombing Target Areas Marine and Naval Target Areas, Gun Positions, Aerial Bombing Target Areas PI-34, Observation Point 1, Gun Position GP 1. SWMUs 5, 8, 12. AOC-A Marine and Naval Target Areas, Gun Positions, Aerial Bombing Target Areas Non-Explosive Ordnance Firing Range (SWMU 11) Marine and Naval Target Areas, Gun Positions, Aerial Bombing Target Areas, PIs-32, 33. PAOC Y.

APPENDIX B
Site Name and Historical Site Use/Name Matrix
Former VNTR, Vieques, Puerto Rico

UXO Site	UXO Site Name	Former MRA	Former Associated MRS Number	Associated Historical Site Use/Name
UXO 6	Eastern Maneuver Area (EMA)/Surface Impact Area (SIA) Public Roads	MRA SIA Surface Impact Area	MRS 6 MRS 7	Marine and Naval Target Areas, Gun Positions, Aerial Bombing Target Areas PI-17 Non-Explosive Ordnance Firing Range (SWMU 11) Marine and Naval Target Areas, Gun Positions, Aerial Bombing Target Areas, PIs-32, 33. PAOC Y.
		MRA EMA Eastern Maneuver Area	MRS 14,17,23,24,25,26,28,43 MRS 17 MRS 23 MRS 24 MRS 25 MRS 26 MRS 28 MRS 43	PI-3 Gun Positions 3,4,5,24; PI-27 and PI-28 Gun Position 32 Gun Position 33 Gun Position 20 Gun Position 34 Gun Position 35, Artillery shortfall area. PI-30 Area of Interest, PIs-24, 25, 26. C-3 Bunker/OP, Gun positions 20, 30, 31, 36. AOIs 1, 2.
UXO 7	Eastern Maneuver Area (EMA)/Surface Impact Area (SIA) North Beaches	MRA SIA Surface Impact Area	MRS 5 MRS 7	Marine and Naval Target Areas, Gun Positions, Aerial Bombing Target Areas Non-Explosive Ordnance Firing Range (SWMU 11) Marine and Naval Target Areas, PIs-32-33, PAOC Y.
		MRA Beach Area		
		MRA EMA Eastern Maneuver Area	MRS 2 MRS 4 MRS 18 MRS 19 MRS 20 MRS 21 MRS 29 MRS 35 MRS 36 MRS 37 MRS 38 MRS 43	Range 4 - 40mm Rifle Grenade Range, PAOC CC Range 4B - Rocket Range, PAOC DD Gun Positions 2, 6, 12, and 13 Area adjacent to Range 6 Range 6 - Demolition and small arms range Gun Position 26 PI-29, 31. Artillery shortfall area, Gun Position GP-9, Observation Point 7, PAOC Z. Gun Position 27 Range 2 - Small Arms Range using pistols and shotguns, PI-23, PAOC AA. Range 1 - Small Arms Range using service rifles, pistols, and machine guns, Gun Position 23. Range 7 with impact areas, PAOC BB Area of Interest, PIs-24, 25, 26. C-3 Bunker/OP, Gun positions 20, 30, 31, 36. AOIs 1, 2.
UXO 8	Surface Impact Area (SIA) South Beaches	MRA SIA Surface Impact Area	MRS 2 MRS 4 MRS 6 MRS 7	Marine and Naval Target Areas, Gun Positions, Aerial Bombing Target Areas, Gun Position 21. PIs 1, 22. Marine and Naval Target Areas, Gun Positions, Aerial Bombing Target Areas PI-34, Observation Point 1, Gun Position GP 1. SWMUs 5, 8, 12. AOC-A. Marine and Naval Target Areas, Gun Positions, Aerial Bombing Target Areas, Gun, PI-17. Non-Explosive Ordnance Firing Range (SWMU 11) Marine and Naval Target Areas, PIs-32-33, PAOC Y.
UXO 9	Surface Impact Area (SIA) Exterior	MRA SIA Surface Impact Area	MRS 1 MRS 2 MRS 3, 5 MRS 4 MRS 6 MRS 7	Marine and Naval Target Areas, Gun Positions, Aerial Bombing Target Areas, Observation Point 5, 12, 13, 14, Gun Position GP 5. PIs 22, 35. Marine and Naval Target Areas, Gun Positions, Aerial Bombing Target Areas Gun Position 21. PIs-1, 22. Marine and Naval Target Areas, Gun Positions, Aerial Bombing Target Areas Marine and Naval Target Areas, Gun Positions, Aerial Bombing Target Areas PI-34, Observation Point 1, Gun Position GP 1. SWMUs 5, 8, 12. AOC-A. Marine and Naval Target Areas, Gun Positions, Aerial Bombing Target Areas, PI-17 Non-Explosive Ordnance Firing Range (SWMU 11) Marine and Naval Target Areas, Gun Positions, Aerial Bombing Target Areas, PIs-32, 33. PAOC Y.

APPENDIX B
Site Name and Historical Site Use/Name Matrix
Former VNTR, Vieques, Puerto Rico

UXO Site	UXO Site Name	Former MRA	Former Associated MRS Number	Associated Historical Site Use/Name
UXO 10	Surface Impact Area (SIA) Interior	MRA SIA Surface Impact Area	MRS 1	Marine and Naval Target Areas, Gun Positions, Aerial Bombing Target Areas, Observation Point 5, 12, 13, 14, Gun Position GP 5. PIs 22, 35.
			MRS 4	Marine and Naval Target Areas, Gun Positions, Aerial Bombing Target Areas PI-34, Observation Point 1, Gun Position GP 1. SWMUs 5, 8, 12. AOC-A.
			MRS 5	Marine and Naval Target Areas, Gun Positions, Aerial Bombing Target Areas
			MRS 7	Non-Explosive Ordnance Firing Range (SWMU 11) Marine and Naval Target Areas, Gun Positions, Aerial Bombing Target Areas, PIs-32, 33. PAOC Y.
UXO 11	Eastern Maneuver Area (EMA) Public Roads	MRA EMA Eastern Maneuver Area	MRS 1	Range 3 - Hand Grenade Range
			MRS 2	Range 4 - 40mm Rifle Grenade Range, PAOC CC
			MRS 4	Range 4B - Rocket Range, PAOC DD
			MRS 6	Artillery shortfall area, Target Area, Observation Points 9, 10, 11, Gun Positions 22, 25, GP-7, GP-9. PIs 15-16.
			MRS 17	Gun Positions 3,4,5,24; PI-27 and PI-28
			MRS 18	Gun Positions 2, 6, 12, and 13
			MRS 19	Area adjacent to Range 6
			MRS 20	Range 6 - Demolition and small arms range
			MRS 21	Gun Position 26
			MRS 22	Gun Position 1
			MRS 25	Gun Position 20
			MRS 27	Gun Position 38
			MRS 29	PI-29, 31. Artillery shortfall area, Gun Position GP-9, Observation Point 7, PAOC Z. Gun Position 27.
			MRS 30	Part of Range 8, Gun Position 8
			MRS 32	Range 9, Gun Position 7
			MRS 34	Gun Position 10, part of Range 4a
			MRS 38	Range 7 with impact areas, PAOC BB
			MRS 40	PIs 10, 19
			MRS 43	Area of Interest, PIs-24, 25, 26. C-3 Bunker/OP, Gun positions 20, 30, 31, 36. AOIs 1, 2.
			MRS 44	PIs 2, 4, 5, 6, 7, 10, 11, 18, 20, 21. PAOCs U, V, W, X, FF, EE. SWMUs 1, 2, 4, 6, 7, 10. AOCs F,
			MRS 45	Camp Garcia, Gun Positions 8, 9, part of Range 8.
UXO 12	Eastern Maneuver Area (EMA) Interior	MRA EMA Eastern Maneuver Area	MRS 6	Artillery shortfall area, Target Area, Observation Points 9, 10, 11, Gun Positions 22, 25, GP-7, GP-9. PIs 15-16.
			MRS 7, 8	
			MRS 9	PI- Gun Position 17
			MRS 10	PI- Gun Position 18
			MRS 11	PI- Gun Position 19
			MRS 13	Observation point/bunker
			MRS 14	PI-3
			MRS 15	Gun Positions 14, 15, 16
			MRS 17	Gun Positions 3, 4, 5, 24; PI-27, PI-28
			MRS 18	Gun Positions 2, 6, 12, 13
			MRS 21	Gun Position 26
			MRS 22	Gun Position 1
			MRS 23	Gun Position 32
			MRS 25	Gun Position 20
			MRS 26	Range 11, Range 8 in the 1972 EIS, G-34
			MRS 27	Gun Position 28
			MRS 28	Gun Position 25, Artillery Shortfall area, Gun Position GP-9, Observation Point 7, PAOC Z
			MRS 29	PI-29, 31. Artillery shortfall area, Gun Position GP-9, Observation Point 7, PAOC Z. Gun Position 27.
			MRS 30	Part of Range 8, Gun Position 8
			MRS 31	Gun Position 29
			MRS 32	Range 9, Gun Position 7
			MRS 33	PI-12, Gun Position 11
			MRS 34	Gun Position 10, part of Range 4a
			MRS 40	PIs 10-19
			MRS 43	Area of Interest, PIs-24, 25, 26. C-3 Bunker/OP, Gun positions 20, 30, 31, 36. AOIs 1, 2.
			MRS 44	PI-2, 4, 5, 6, 7, 10, 11, 18, 20, 21. PAOCs U, V, W, X, FF, EE. SWMUs 1, 2, 4, 6, 7, 10. AOCs F, G, Camp Garcia, Gun Positions 8, 9. Part of Range 8.

APPENDIX B
Site Name and Historical Site Use/Name Matrix
Former VNTR, Vieques, Puerto Rico

UXO Site	UXO Site Name	Former MRA	Former Associated MRS Number	Associated Historical Site Use/Name
UXO 13	Eastern Maneuver Area (EMA) West	MRA EMA Eastern Maneuver Area	MRS 1 MRS 2 MRS 3 MRS 4 MRS 5 MRS 16 MRS 19 MRS 20 MRS 32 MRS 35 MRS 36 MRS 37 MRS 38 MRS 44	Range 3 - Hand Grenade Range, Range 4 in 1972 EIS. Range 4 - 40mm Rifle Grenade Range, PAOC CC, Range 4B in 1972 EIS. Range 4A - Rocket Range Range 4B - Rocket Range, PAOC DD, Range 5 in 1972 EIS Range 5 - Hand Grenade Range, Range 2 in 1972 EIS. Gun Position 9 Adjacent to Range 6 Range 6 - Demolition and small arms range Range 9, Gun Position 7 Gun Position 27 Range 2 - Small Arms Range using pistols and shotguns, PI-23, PAOC AA, Range 1 in 1972 EIS. Range 1 - Small Arms Range using service rifles, pistols, and machine guns, Gun Position 23. Range 7 with impact areas, PAOC BB, Range 3 in 1972 EIS. PIs 2, 4, 5, 6, 7, 10, 11, 18, 20, 21. PAOCs U, V, W, X, FF, EE. SWMUs 1, 2, 4, 6, 7, 10. AOCs F, Camp Garcia, Gun Positions 8, 9, part of Range 8.
UXO 14	Eastern Maneuver Area (EMA) South	MRA EMA Eastern Maneuver Area	MRS 24 MRS 43 MRS 44	Gun Position 33 Area of Interest, PIs-24, 25, 26. C-3 Bunker/OP, Gun positions 20, 30, 31, 36. AOIs 1, 2, Range 11, Range 8 in 1972 EIS. PI-2, 4, 5, 6, 7, 10, 11, 18, 20, 21. PAOCs U, V, W, X, FF, EE. SWMUs 1, 2, 4, 6, 7, 10. AOCs F, G, Camp Garcia, Gun Positions 8, 9. Part of Range 8.
UXO 15	Puerto Ferro	MRA EMA Eastern Maneuver Area	MRS 12 MRS 46	PI-9 PI-13
UXO 16	Underwater Areas			Water areas that surround the former VNTR and NASD

Appendix C
LiDAR Report

SKY RESEARCH INC.

September 30, 2005

POST COLLECTION FINAL REPORT

Former Vieques Naval Training Range
LiDAR / Orthophotography Collection

Contract No. 909421

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Acronyms and Abbreviations

AGL	Above Ground Level
AOI	Area(s) of Interest
ASCII	American Standard Code for Information Interchange
C	Celsius
CFR	Code of Federal Regulations
CCD	Charged Couple Device
CORS	Continuously Operating Reference Stations
cm	Centimeter(s)
DEM	Digital Elevation Model
DTM	Digital Terrain Model
ft	Foot or Feet
GIS	Geographic Information Systems
GPS	Global Positioning System
HARN	High Accuracy Reference Network
Hz	Hertz – Samples per second
ID	Identification
IDL	Interactive Data Language
in	Inch(es)
IMU	Inertial Measurement Unit
ISAT	ImageStation Auto Triangulation
kHz	Kilohertz
LiDAR	Light Detection and Ranging
m	Meter(s)
mm	Millimeter(s)
MMRP	Military Munitions Response Program
MRA	Munitions Response Area
NAD83	1983 North American Datum
NAD83/2002	1983 North American Datum, 2002 adjustment
NAVFAC	Naval Facilities Engineering Command
NGS	National Geodetic Survey
ORF	Ordnance Related Feature
PDOP	Position Dilution of Precision
POS	Position and Orientation System

PPK	Post Process Kinematic
PRVD02	Puerto Rico Vertical Datum of 2002
QA	Quality Assurance
QC	Quality Control
RMSE	Root Mean Square Error
SKY	Sky Research, Inc.
SBET	Smoothed Best Estimate Trajectory
URE	User Range Error
UTM	Universal Transverse Mercator
UXO	Unexploded Ordnance
VNTR	Vieques Naval Training Range

1.0 Introduction

In support of the on-going Military Munitions Response Program (MMRP) activities being conducted at the Former Vieques Naval Training Range (VNTR), Vieques, Puerto Rico, Sky Research, Inc. (SKY) conducted high altitude airborne surveys of munitions response investigation areas over the site in July 2005 (Figure 1). These surveys collected Light Detection and Ranging (LiDAR) terrain data and high resolution color orthophotography in support of work being performed for the Naval Facilities Engineering Command (NAVFAC) Atlantic by CH2M Hill and Advent Environmental.

The LiDAR data collected at VNTR was used to create an accurate high-resolution bare earth digital elevation model (DEM) and hill shade used in extracting preliminary ordnance related features (ORFs). ORFs are visible and micro-topographic features that correlate with prior ordnance activity and may include surface Unexploded Ordnance (UXO), fragments, debris, bombing target structures, berms, craters, access roads, vegetation characteristics, or any other features that aid in the statistical definition of correlated subsurface UXO. The orthophotography collected simultaneously with the LiDAR data has been mosaiced and used for direct detection and visualization of ORFs. Integrated within the project Geographic Information System (GIS), these data can be used to: Provide a good picture of possible UXO contamination; assist in the delineation of surface impact areas in the footprint reduction of Munitions Response Areas (MRAs); and establish a starting point for subsequent deployment of technologies used for individual target detection.

This document summarizes the data collection, image processing and analysis activities associated with the LiDAR and orthophotography data collected for VNTR. This report and final data delivery are the final deliverables associated with this project.

Figure 1. Survey area (in yellow) on the island of Vieques

2.0 Project Schedule

This project began in June of 2005 and ended in October of 2005 (Table 1). Pre-deployment project planning consisted of developing a deployment plan, a health and safety plan, and a data collection flight plan.

Following project planning, mobilization to Vieques commenced and included the following:

- Mobilizing the ortho / LiDAR sensors mounted on the C-208 aircraft, pilots, and operators to Vieques;
- Deploying ground support personnel to establish ground fiducials, establish and operate Global Positioning System (GPS) base stations, and provide logistical support; and
- Establishing a base of field operations to provide fuel and temporary hangar space during operations at the site.

The airborne surveys conducted for data acquisition required three days and took place on July 21st, 23rd and July 24th. Additional stand-by days on site (July 19th, 20th, and 22nd) were due to inclement weather conditions. The flight lines were established during project planning and achieved the objective of covering the target area in minimal flight time, while achieving the required spatial resolution, overlap, etc.

After demobilization, the data were processed and analyzed, and draft data uploaded to the Vieques Information Portal for review. Final data delivery and reporting concluded in October of 2005.

Table 1. Project Schedule

ACTIVITY	***DATE***
Project Planning and Data Acquisition	
Project planning	June/July
Mobilization to Vieques	July 16th-18th
Data acquisition	July 21st-24th
Demobilization	July 25th
Data Processing and Analysis	
LiDAR	August - September
Orthophotos	August - September
Preliminary ORF analysis	September
Draft LiDAR/Ortho Datasets Delivered via Web Services	August 29th
Final Data and Report Delivery	October 11th

3.0 Description of Technologies Utilized

3.1 LiDAR

LiDAR is a scanning and ranging laser system that is capable of producing precise high-resolution topographic data. The technology has been in existence for twenty years, although the commercial application for topographic maps has developed only within the last five.

The basic components of a LiDAR data collection system follows: Laser scanner, GPS, and Inertial Measurement Unit (IMU). The laser scanner is mounted in an aircraft and emits high frequency infrared laser beams. The scanner records the time difference between the emission of the laser pulses and the reception of the reflected signal. A

mirror mounted in front of the laser rotates, directing the laser pulses to sweep back and forth perpendicular to the flight direction, which allows the laser scanner to collect swaths of topographic data as the aircraft moves forward. The position of the aircraft is determined by processing differential, dual frequency, kinematic GPS observations. The GPS located in the aircraft is supported by several ground stations that are located within the vicinity of the acquisition area. The IMU determines the orientation of the aircraft (pitch, roll and yaw) during data collection. By combining the IMU data with the post-processed GPS data, the exact trajectory of each laser pulse is determined during data processing.

3.2 High-Resolution Digital Color Orthophotography

High resolution digital color aerial photography is collected by mounting a digital camera with high resolution Charged Couple Device (CCD) backing into an aircraft. The camera is linked to either a computer or a manual trigger device which controls the frequency and length of exposures and results in overlapping high quality aerial photographs of the earth. In addition to the camera, a GPS and IMU are mounted in the same aircraft. Information collected from the GPS and IMU are used to rectify the aerial photographs. This is accomplished by assigning a geographic coordinate to each image derived from the processing of the GPS data. In addition, distortions created by camera tilt, lens distortion, and terrain displacement are removed to produce an orthophoto. This ortho-rectification is accomplished by employing the following techniques: using the IMU data to remove the distortion due to camera tilt; calibrating lens distortion based on camera lens parameters; and removing terrain displacement by using a Digital Terrain Model (DTM). Once rectified, orthophotos are typically mosaicked together to create a seamless and accurate representation of an entire site area.

3.3 Data Processing

Data processing for the raw data sets employs a variety of software technologies. SKY uses the following technologies for processing LiDAR data sets:

- GPS data processing using POSPac/POSGPS® software
- Post-processed GPS combined with IMU data using POSProc software
- Initial processing and output of LiDAR point cloud data using Optech's REALM software
- Classification of points into vegetation, ground, other is completed in TerraScan software from Terrasolid
- DEM and shaded relief imagery are created from the classified point data using ArcGIS
- Feature Analyst and custom IDL software algorithms are used to locate, detect, and characterize topographic features including bomb craters and other features

SKY uses the following technologies for processing orthophoto data sets:

- GPS data processing using POSPac/POSGPS® software
- Post-processed GPS combined with IMU data using POSProc software
- Raw photos are developed into TIFF format with manufacturer calibrated true color (VIS) filter
- Download of images from removable drives using DSS MissionView 2.0
- Processing of photos to sync with GPS data in POSEO 4.1
- ZI Imaging ImageStation Auto Triangulation (ISAT) software used to combine formatted image files with exterior orientation files
- Aerial photos rectification to the DTM using ImageStation OrthoPro software

After image processing, the photos ortho-corrected using the LiDAR mass points as the DTM according to the methods described in section 7.2.

3.4 Advanced Discrimination

Extraction of the ORFs from the LiDAR and orthophoto datasets is both an automated and analyst-performed task that combines multiple-overlay image interpretation with automated spatial feature recognition processes utilizing ESRI GIS and Visual Learning Systems' software.

4.0 Sensor Specifications

The LiDAR sensor specifications are provided in Table 2. For detailed specifications, please see Appendix A. The specifications for the camera used to generate aerial photos are provided in Table 3. For detailed specifications on the camera, please see Appendix B.

Table 2. LiDAR Specifications

Detector type:	Optech® LiDAR ALTM 3100.
Spacing:	30 centimeters (cm) to 5 meters (m) spot spacing.
Contour Interval:	Dependent on spot spacing with an approximate 1 m (spacing) to 30.5 cm (contour interval) ratio.
Operating Altitude:	80-3,500 m above ground level (AGL) nominal
Elevation Accuracy:	<15 cm at 1200 m; 1 sigma <25 cm at 2000 m; 1 sigma <35 cm at 3000 m; 1 sigma
Horizontal Accuracy:	Better than 1/3,000 x altitude; 1 sigma
Range Accuracy:	2-3 cm, single shot.
Range Resolution:	1 cm
Measurement Rate:	33,000 to 100,000 measurements per second.
Scan Angle:	0 to ±25°
Swath Width:	Variable from 0 to 0.93 x altitude.
Scan Frequency:	0-70 Hertz (Hz), depending on scan angle
Laser Classification:	Class IV (FDA Code of Federal Regulations (CFR) 21)
Laser Repetition Rate:	33 kilohertz (kHz) (max. altitude above ground level (AGL) 3500 m) 50 kHz (max. altitude (AGL) 2500 m) 70 kHz (max. altitude (AGL) 1700 m) 100 kHz (max. altitude (AGL) 1100 m)
Operating Temperature:	10-35° Celsius (C)
Humidity:	0-95% non-condensing

Table 3. Camera Specifications

Detector Type:	OPTECH ALTM 4K02 Digital Metric Camera (co-mounted with the LiDAR system) DSS 301 SN0046- 55 millimeters (mm) lens
Lens Type:	Zeiss Distagon
Focal length:	55.073 mm
Field of View:	36°
CCD Specifications:	4,092 (along flight) x 4,079 (cross flight) Pixel size of 0.000138 inches (in)
Shutter Speed:	1/125 to 1/4000 second
Principal Point	Xppac(mm) -0.390, Accuracy 0.0036 Yppac 0.222, Accuracy 0.0036 Measured from image center (pixel size = 9 microns)
Pixel Non-Squareness	1.0, Accuracy 0.0000001
VIS Calibrated Gain Value	0.98
VIS Calibrated ISO	300
VIS Calibrated Exposure Compensation	-0.70

5.0 Data Acquisition

SKY acquired elevation data using an ALTM 3100 airborne LiDAR system for approximately 15,000 acres of VNTR at an average altitude of 1,000 meters and a laser repetition rate of 100 kHz (100,000 measurements per second). The vertical and horizontal accuracies of these data are less than 15 cm and 50 cm root mean square error (RMSE), respectively. The average spot spacing exceeds the required 50 cm.

In conjunction with LiDAR data collection, high resolution color orthophotography was collected with a co-mounted OPTECH ALTM 4K02 Digital Metric camera. Aerial imagery was obtained simultaneously with GPS ground control insuring a horizontal precision of less than 50 cm RMSE.

5.1 Acquisition Platform

The ALTM 3100 LIDAR system, ALTM 4K02 Digital Metric Camera, and the Position and Orientation System (POS) were mounted in the belly of a Cessna Caravan 208 (Figures 2 and 3) for all data collections. The Cessna Caravan, a non-pressurized high-

wing, single-engine turbo prop with fixed gear, is designed for general utility purposes. A removable composite cargo pod provides housing for the ALTM 3100 LiDAR system and the ALTM 4K02 Digital Metric Camera.

Figure 2. Cessna Caravan 208 (N288SR) LiDAR / Orthophoto platform.

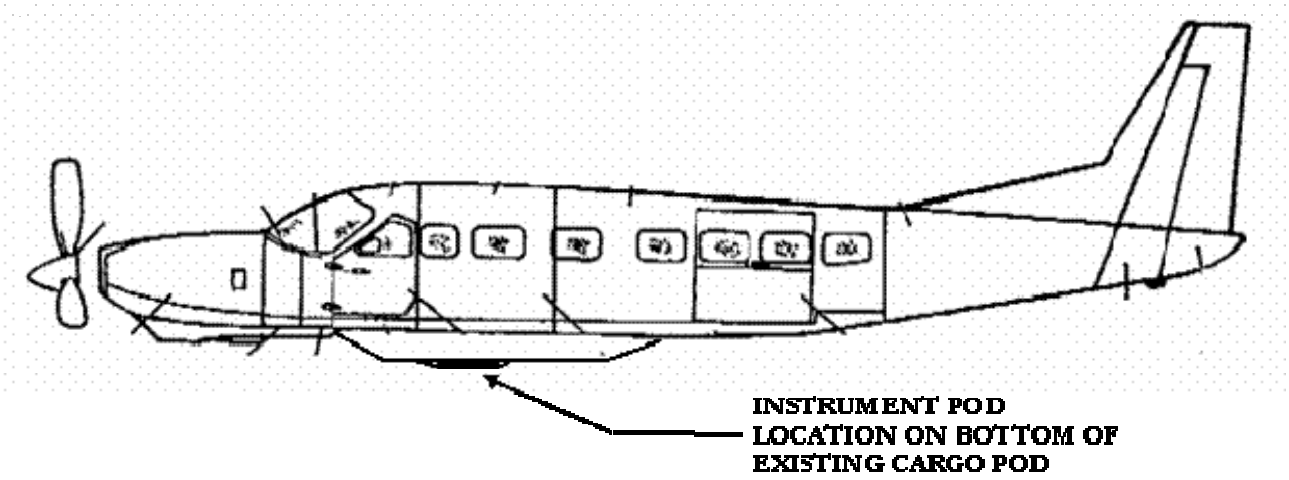

Figure 3. Schematic of the Cessna Caravan 208.

5.2 Acquisition Parameters

The data acquisition configuration and parameters are indicated in Tables 4-6 below. Table 4 shows the flight survey parameters, which are the same for both the LiDAR and

orthophoto data acquisition, since the two sensors were collecting data simultaneously during the survey flights. The LiDAR data collection parameters are shown in Table 5 and the orthophotography parameters in Table 6. The data collection parameters achieved during the survey met both the survey requirements and expectations.

Table 4. Flight Survey Parameters

Altitude:	1000 meters AGL
Airspeed:	105 knots

Table 5. LiDAR Data Acquisition Parameters

Measurements per second:	100,000
Scan Width:	460 m
Scan Overlap:	50%
Scan Frequency:	54 Hz
Scan Angle:	+/- 13°
Spot Spacing:	0.49 m
Vertical Accuracy:	< 15 cm
Horizontal Accuracy:	< 50 cm

Table 6. Color Ortho-photography Data Acquisition Parameters

Field of View:	36°
Imaging Swath/Photo Coverage:	45% forward lap, 65% side lap
Ortho-rectified Pixel Size, Re-sampled:	0.16 meters/pixel

Dual Frequency GPS data were collected simultaneously onboard the aircraft and at strategically located ground stations. The ground stations were located so that the longest baseline (distance between aircraft and ground station) was no more then 18 miles (m). Three ground stations were operated during airborne LiDAR data acquisition.

5.3 Position Dilution of Precision (PDOP) Summary

PDOP is a mathematical function expressing the relative quality of solutions based on the geometry of the satellites. A PDOP value of one indicates optimal geometry of available satellites, while higher values are scaled to the dilution of precision related to in-optimal geometry. The best PDOP would occur with one satellite directly overhead and three

others evenly spaced about the horizon. PDOP could theoretically be infinite, if all the satellites were in the same plane.

PDOP has a multiplicative effect on the User Range Error (URE) value. A URE of 10 feet (ft) with a PDOP of one would give a user an assumed best accuracy of 10 ft. A PDOP of two would result in an assumed accuracy of 20 ft. Due to this multiplicative effect of PDOP on the URE, LiDAR data collection took place only when the PDOP was below a value of 3.0 (see Figures 4-6 for PDOP values on the survey days). This limits the URE and allows the LiDAR to meet the required accuracies.

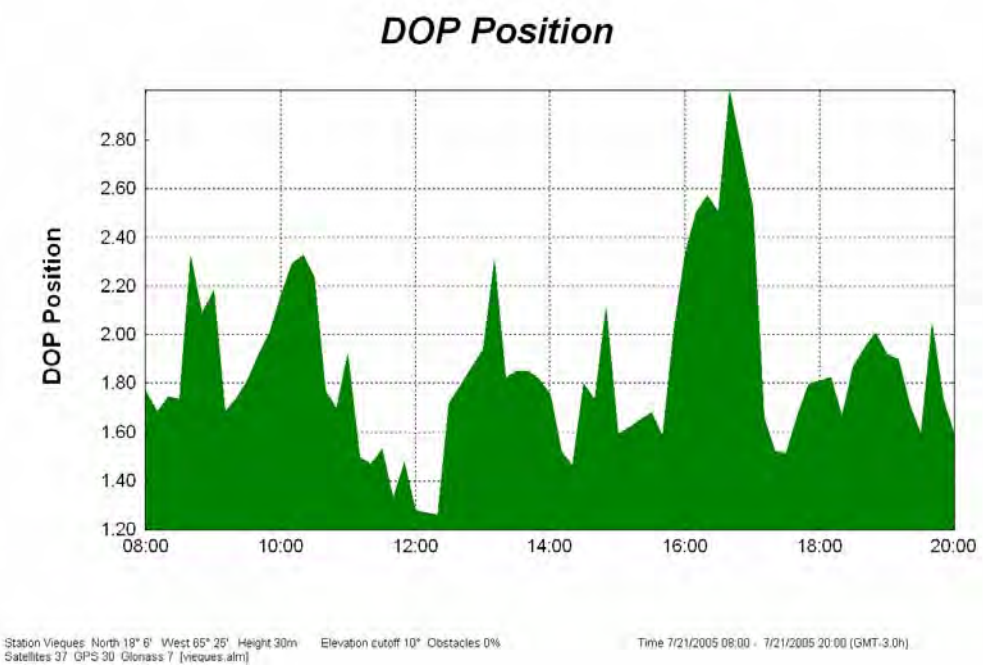

Figure 4. PDOP between the hours of 8am and 8pm Atlantic Time for July 21, 2005

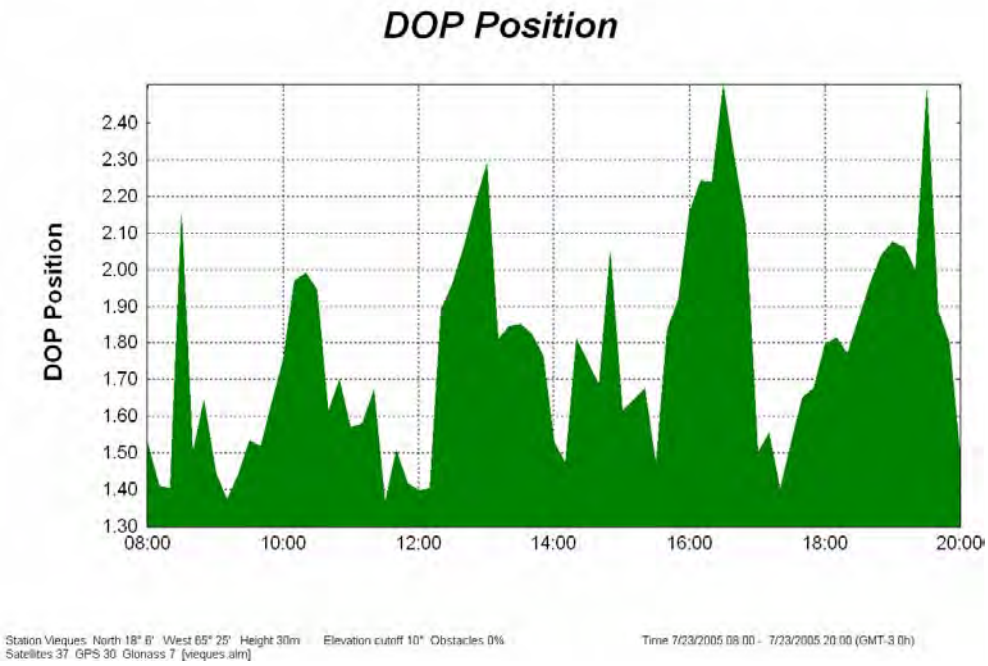

Figure 5. PDOP between the hours of 8am and 8pm Atlantic Time for July 23, 2005

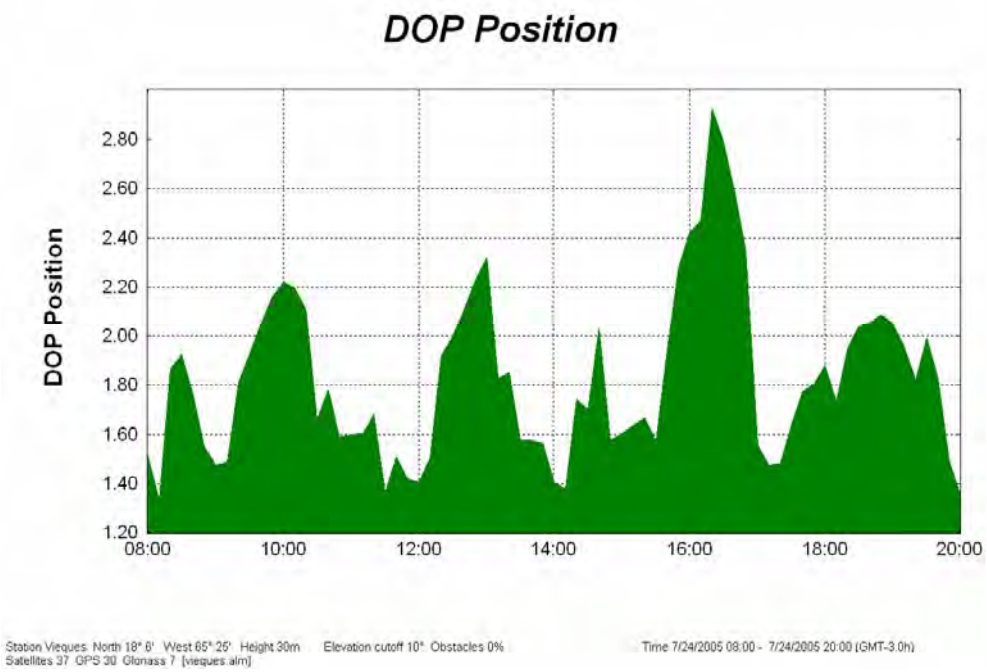

Figure 6. PDOP between the hours of 8am and 8pm Atlantic Time for July 24, 2005

6.0 Data Quality Assessment

6.1 LiDAR

During each data acquisition flight, the sensor operator observed the real-time LiDAR swath coverage to assure full coverage of the survey area. The operator also monitored for adequate in-flight PDOP and GPS satellite coverage. If tolerance thresholds of either were exceeded, data acquisition activities were put on hold until acceptable conditions resumed. After each data acquisition flight, data from GPS base stations were checked against in-flight GPS data for concurrence. Once data quality assessments were completed, all data (image and ancillary) were transferred to a centralized location for pre-processing and quality control.

6.2 High-Resolution Color Orthophotography

During each data acquisition flight, the sensor operator observed the real-time photo footprint coverage to assure required percentage of overlap for the survey area. The operator observed real time photo display for verification of image quality. The operator also monitored for adequate in-flight PDOP and GPS satellite coverage. If tolerance thresholds of either were exceeded, data acquisition activities were put on hold until acceptable conditions resumed. After each data acquisition flight, data from GPS base stations were checked against in-flight GPS data for concurrence. Once data quality assessments were completed, all data (image and ancillary) were transferred to a centralized location for pre-processing and quality control.

7.0 Data Processing Techniques

7.1 LiDAR Processing

LiDAR processing transforms raw binary data into functional DEM. LiDAR processing was conducted in the following seven steps:

1. **GPS post-processing:** Post processing of GPS datasets was performed by SKY using POSPac/POSGPS® software; multiple baseline solutions were combined to determine the x,y,z position of the aircraft within 4 in.

2. **IMU/GPS SBET processing:** The post-processed GPS data were then combined with the IMU data using a processing technique commonly referred to as smoothed best estimate trajectory (SBET) processing. This method combines information about orientation and velocity from the IMU with positioning and velocity information from the GPS data using kalman filters. The result is a determination of the x,y,z and ω,κ,ϕ parameters for the aircraft at any particular point (position in Universal

Transverse Mercator (UTM) 1983 North American Datum (NAD83) meters and the angular orientation of the aircraft). This processing is performed in the proprietary software POSProc.

3. **LiDAR raw data extraction:** The raw LiDAR data were copied from tape and extracted from the raw data acquisition format into a preprocessed format for output into x,y,z points. Information from the sensor calibration was input into the processing at this point.

4. **LiDAR data calibration:** The variations in altitude and temperatures encountered in normal aircraft operations change the physical characteristics of the LiDAR optics to such a degree that corrections are required. These corrections were completed using manual data calibration techniques created in-house by SKY.

5. **LiDAR data output:** Pre-processed LiDAR data were combined with the SBET IMU/GPS data to form the final x,y,z data cloud. This data cloud included all the returns collected during data acquisition, with each return having an exact x,y,z location.

6. **LIDAR classification:** The x,y,z data cloud was imported into TerraScan LiDAR processing software. Next, it was classified into point classes. First, all points that were beyond the known elevations of the survey area (known as error points) were removed. The remaining points were then classified automatically and manually into two separate classes: (1) points that represent the ground surface; and (2) all other points that are above the ground surface.

7. **Points were output into two data formats:** ***a)*** Key points which were used to ortho-rectify the photographs, and ***b)*** bare earth and surface mass points which were input into GIS software for conversion to ESRI formatted DEMs.

7.2 High-Resolution Color Orthophoto Processing

1. **Photo development:** Raw photos were developed into TIFF format with manufacturer calibrated true color (VIS) filter.

2. **GPS post-processing:** Post processing of GPS datasets was performed by SKY using POSPac/POSGPS® software; multiple baseline solutions were combined to determine the x,y,z position of the aircraft within 4 in.

3. **IMU/GPS SBET processing:** The post-processed GPS data were then combined with the IMU data using SBET. This method combined information about orientation and velocity from the IMU with positioning and velocity information from the GPS data using kalman filters. The result was a determination of the x,y,z and ω,κ,ϕ parameters for the aircraft at any particular point (position in UTM NAD83 meters and the angular orientation of the aircraft). Also extracted from this process was an event file documenting the GPS time and POS event identification (ID) for each photo exposure. This processing was performed in the proprietary software POSProc.

4. **Camera Photo ID extraction:** A camera specific event file was extracted from Camera Mission Folder using DSS Mission View 2.0 containing GPS time and camera photo ID.

5. **Exterior orientation extraction:** POS photo event ID and camera photo ID documents were synced by GPS time and processed in POSEO 4.1. This process incorporated the SBET file with event IDs to create an exterior orientation file assigning x and y center point locations, pitch, roll, and heading to each photo.

6. **Auto triangulation:** Formatted image files were combined with the exterior orientation file in ISAT software. Tie points were generated automatically using intensity values within designated von gruber areas. Thirty-two von gruber areas were assigned per photo, and approximately eight tie points were generated per von gruber area. RMSE for each tie point was calculated using control. RMSE and residuals were calculated for all photos using survey control. Solution for triangulation was accepted when RMSE is less than $1/10{,}000^{th}$ of flying height and residual was less than $1/5000^{th}$ of flying height. Each photo was then adjusted according to individual triangulation results as well as adjusted to the entire data set.

7. **Orthophoto creation:** Triangulation results were loaded into ortho-processing software along with a LiDAR derived digital DTM, and aerial photography. Aerial photos were rectified to the DTM using ImageStation Ortho Pro software. Each photo was tone balanced, and mosaicked into tiles.

8.0 Accuracy Assessment

8.1 Procedures Employed for Ground Survey Control

In order to provide differential kinematic GPS solutions for the aircraft positioning system, rectify digital orthophotography and obtain quality control data, horizontal and vertical ground survey control was established throughout the site. Reconnaissance of the available survey control on the island of Vieques determined that both horizontal and vertical survey control would be established from the main island of Puerto Rico.

The horizontal positions of the survey control are referenced to the 1983 North American Datum, 2002 adjustment (NAD83/2002). The horizontal survey control stations were established using fast static GPS observations referencing National Geodetic Survey (NGS) Continuously Operating Reference Stations (CORS) and the NGS High Accuracy Reference Network (HARN). A simultaneous analysis of the two different reference frames yielded results indicating consistency between the CORS and HARN.

Elevations of the survey control are referenced to the Puerto Rico Vertical Datum of 2002 (PRVD02) established by static GPS measurements and a high resolution geoid model. GPS observations were performed on NGS first order vertical control stations located on the main island of Puerto Rico. The Geoid99 model was locally corrected by applying a mean vertical shift of -2.304 m determined from GPS observations performed on NGS first order vertical control stations. The independently determined vertical shift from the SKY survey network was analyzed against computed shift values from published control stations. An observed deviation of 0.017 m indicates consistency of the project vertical constraints. Table 7 includes the NGS control stations that were used in the establishment of the SKY survey network.

Table 7. NGS Control Stations Utilized

Mark Designation	*NGS PID*	*Network Constraint*
Puerto Rico 3 CORS ARP	AF9624	Horizontal, Ellipsoid Height
Marel Bayamon Inc CORS ARP	DH3840	Horizontal, Ellipsoid Height
San Juan WAAS 1 CORS ARP	DF8978	Horizontal, Ellipsoid Height
Diaz	DE5469	Elevation
Sanabria	DE5470	Horizontal, Ellipsoid Height, Elevation
ZSU B	AA7662	Horizontal, Ellipsoid Height, Elevation

Photo panel control points were geometrically dispersed at eight locations throughout the site to control the digital orthophotography. The panel point locations consist of a 4'x4' plastic white "+" with either a 24 inch long ½ inch diameter steel pin or a 10 inch galvanized metal spike.

Quality control and assurance (QA/QC) data was obtained using post process kinematic (PPK) GPS observations from a minimum of two survey control base stations. No radial GPS vectors were used in the computation of the QA/QC survey positions. QA/QC data was taken throughout the project site for horizontal and vertical checks of the airborne acquired data.

All GPS survey data were analyzed and adjusted using least squares methods. Final coordinates and positional uncertainties were computed from a properly weighted, full constraint least squares adjustment fixing the aforementioned NGS control stations. The final adjustment yielded the positional uncertainties relative to true datum shown in Table 8. Tables 9 and 10 show the accuracies of the control points for the orthophotography and LiDAR respectively.

Table 8. Primary Survey Control

Maximum Horizontal RMSE:	0.014 m
Maximum Vertical RMSE:	0.028 m
Minimum Horizontal RMSE:	0.005 m
Minimum Vertical RMSE:	0.007 m
Average Horizontal RMSE:	0.010 m
Average Vertical RMSE:	0.020 m

Table 9. Orthophotography Panel Points

Maximum Horizontal RMSE:	0.018 m
Maximum Vertical RMSE:	0.034 m
Minimum Horizontal RMSE:	0.006 m
Minimum Vertical RMSE:	0.007 m
Average Horizontal RMSE:	0.010 m
Average Vertical RMSE:	0.015 m

Table 10. LiDAR QA/QC Positions

Maximum Horizontal RMSE:	0.053 m
Maximum Vertical RMSE:	0.097 m
Minimum Horizontal RMSE:	0.010 m
Minimum Vertical RMSE:	0.012 m
Average Horizontal RMSE:	0.022 m
Average Vertical RMSE:	0.030 m

8.2 Procedures Employed for LiDAR Control

The accuracy of LiDAR elevation data was evaluated by comparison with the QA/QC data. A total of 216 QA/QC control points were collected at different locations across the project site. An accuracy report created from the comparison of the QA/QC control points to the final LiDAR data was produced and is shown in Appendix C. Table 11 summarizes the accuracy report.

Table 11. RMSE for LiDAR data

Average Dz (meters)	-0.098
Minimum Dz (meters)	-0.363
Maximum Dz (meters)	0.066
Average Magnitude (meters)	0.101
Root Mean Square (meters	0.116
Standard Deviation (meters)	0.062

8.3 Procedures Employed for Orthophotography Control

The horizontal accuracy of orthophotography was evaluated by comparison of locations of known secondary stations with the same targets visible in the photos (see Figure 7 for these locations). The RMSE was calculated and average horizontal errors are listed in Table 12. Auto triangulation results represent cumulative RMSE calculations for tie points used in orthorectification as well as RMSE values for photo position (See Table 13).

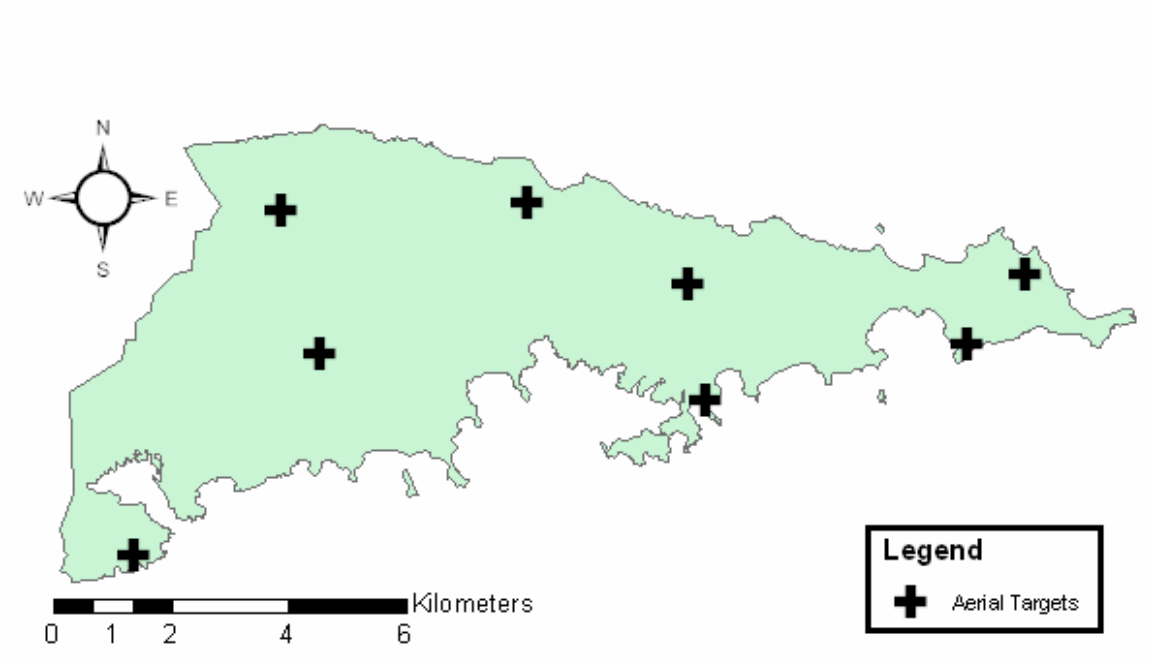

Figure 7. Location of Secondary Stations used for Photo Control.

Table 12. RMSE for Orthophotography

Linear Error 95% confidence interval (meters)	*X coordinate deviation*	*Y coordinate deviation*
	0.475	0.487
Horizontal Radial Error 95% confidence level (meters)	0.600	

Table 13. Auto Triangulation Results

Parameters (meters)	X/Omega	Y/Phi	Z/Kappa	XY
RMS Control	0.0526	0.0621	0.0569	0.0575
RMS Limits	0.1	0.1	0.1	n/a
Max Ground Residual	0.0738	0.1118	0.1045	n/a
Residual Limits	0.2	0.2	0.2	n/a
Mean Std Dev Object	0.0776	0.0893	0.266	n/a
RMS Photo Position	0.0633	0.0605	0.1015	n/a
RMS Photo Attitude	0	0	0	n/a
Mean Std Dev Photo Position	0.1015	0.1018	0.068	n/a
Mean Std Dev Photo Attitude	0.0084	0.0079	0.0112	n/a

9.0 Advanced Discrimination

9.1 LiDAR Terrain Data and Orthophotography

SKY analyzed the processed LiDAR terrain data and orthophotography both manually and with advanced algorithms for the detection of cultural features and ORFs such as bomb craters, firing berms, and historic building foundations to aid in the delineation of areas of interest (AOI). To analyze the data sets, the analyst manipulated the basic image rasters using hillshading, contrast stretching, band-mapping to the red, green, blue (RGB) color model, and other techniques to assist in detecting and visualizing features; digitized reference points and polygons into vector feature classes; and attributed these feature classes with positional and geometric attributes describing the feature using geoprocessing tools. For some features, such as craters, automated feature detection tools were used to efficiently generate candidate features that were interactively selected and confirmed by the analyst.

9.2 Area of Interest Delineation

SKY georeferenced historic mapping overlays derived from selected existing site mapping to provide context for known range fans, target zones, firing points and other munitions-relevant features. The various density and proximity models derived from

ORFs were individually thresholded and sliced to generate boundaries for areas of interest associated with each model. These potential new AOI and existing AOI were described in terms of features identified in the LiDAR and orthophotography datasets. ESRI shape files were created of the AOI derived from this process. In order to prevent inadvertent exclusion of potential AOIs, SKY took an approach that erred on the conservative side in the selection of the AOIs. A brief description of each AOI is contained within the shape files that are included with this report. Table 14 summarizes the number of ORFs used to determine AOI that were located across the site.

Table 14. Numbers of ORFs used for AOI Location (see shape files for descriptions)

Crater Features	1,406
Ground Feature	41
Structures	13
Target Features	9

10.0 Project Deliverables Review

The following deliverables are completed and included with this report:

1. A copy of all field notes collected during data acquisition, describing methods used;
2. Bare Earth and Surface DEM gridded with a 0.5 meter cell size in ArcInfo-compatible format;
3. LiDAR Bare Earth and Surface DEMs in shaded relief geotiff format;
4. LiDAR Bare Earth and Surface point cloud data in ASCII format;
5. ESRI Shape files delineating areas containing ORF;
6. True color digital orthophoto tiles in geotiff format;
7. ESRI Shape file showing orthophoto tiling scheme;
8. Mosaic of all orthophoto tiles in MrSID compressed format; and
9. Final report describing and documenting data collection, image processing, and QA/QC analyses performed.

Appendix A: Optech ALTM 3100 Specifications

ALTM 3100: 3,500 m altitude! 100,000 laser pulses per second!

ALTM 3100 Specifications

Airborne Module

Operating altitude	80 - 3,500 m nominal
Horizontal accuracy	1/2,000 x altitude; 1 sigma
Elevation accuracy	<15 cm at 1.2 km; 1 sigma <25 cm at 2.0 km; 1 sigma <35 cm at 3.0 km; 1 sigma
Range resolution	1 cm
Range capture	Up to 4 range measurements for each pulse including last
Intensity capture	12 bit dynamic range for each measurement
Scan frequency	Variable; maximum 70 Hz
Scan angle	Variable from 0 to ±25°, in increments of ±1°
Scanner Product	Scan angle x scan frequency ≤1,000
Roll compensation	5 Hz update rate (Scan angle + Roll comp. angle = 25°, i.e., ±20° scan allows ±5° compensation)
Swath width	Variable from 0 to 0.93 x altitude m
Position Orientation System	Applanix - POSAV 510 including Internal 12 channel dual frequency 2 Hz GPS receiver
Spot distribution	Sawtooth, uniform across 96% of scan
Laser repetition rate	33 kHz (max. altitude (AGL) 3.5 km) 50 kHz (max. altitude (AGL) 2.5 km) 70 kHz (max. altitude (AGL) 1.7 km) 100 kHz (max. altitude (AGL) 1.1 km)
Data storage hard drives	Ruggedized removable hard drive Minimum 7 hr. continuous log time @ 100 kHz
Beam divergence	Dual divergence 0.3 mrad (1/e) or 0.8 mrad (1/e)
Laser classification	Class IV (FDA CFR 21)
Power requirements	28 VDC, 35 A (maximum)
Operating temperature (air temperature)	Control rack: +10°C to +35°C Sensor head: -10°C to +35°C (assuming the use of thermal jacket)
Storage temperature	-10°C to +50°C
Humidity	0 - 95% non-condensing

Control Rack

Vibration-isolated case:	
Dimensions/weight (in-flight)	65 cm x 59 cm x 49 cm/53.2 kg covers removed, with removable hard drive installed
Cables/laptop	7.6 kg/3 kg

Sensor Head

Fits standard camera mounts or mounts directly to floor

Overall dimensions/ weight (in-flight)	26 cm x 19 cm x 57 cm/23.4 kg (incl. sensor insulating jacket)
Minimum opening	19.2 cm x 25.5 cm (flight direction)

Processing Software

REALM Survey Suite	Differential kinematic GPS solution Trajectory optimization from multiple base stations XYZ point calculations module Vegetation classification/ extraction feature Windows NT/2000/XP compatible

GPS Ground Support

Multiple base stations	Any dual frequency receiver with Rinex output

Available Options

4k x 4k Digital camera	Integrated metric frame camera to deliver geo-referenced (X,Y,Z) color or color-IR images with sub-pixel accuracy
Intelligent Waveform Digitizer	8 bits @ 1 nsec sample interval per pulse (maximum 50 kHz)

Note: to meet its stated accuracy, the ALTM must receive GPS data of sufficient quality. GPS data quality shall be viable only when all of the following conditions are met:

- At least four satellites are in lock (tracked by the reciever) throughout the survey
- Elevation of the satellites is good (i.e., PDOP <4)
- Aircraft stays within 30 km of the GPS base station

If one or more of these conditions is not met, or if any source of electromagnetic interference causes the GPS receivers to repeatedly lose lock, the specified accuracy of the ALTM will be compromised.

Specifications subject to change without notice.

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Appendix B: ALTM 4K X 4K Digital Camera Specifications

ALTM 4K02 - The Digital Image Collection and Processing Solution

Specifications

Camera

Array size	4,092 (along flight) x 4,079 (cross flight) pixels
Pixel size	0.009 mm
Premium grade CCD*	Point defects <= 2000 Cluster defects <= 30 Single column Defects <=10 Dead columns = none Radiometric and geometric profile included
Filter array	Interchangeable color or color-IR
Lens	Zeiss Distagon 55.0 mm, 36° FOV
Exposure control	Automatic: aperture or shutter priority
Shutter	Electronically controlled focal plane
Shutter speed	1/125 - 1/4,000 seconds
Exposure compensation	± 2 EV in 1/3 EV steps
Exposure rate	Maximum 4 seconds**
Housing	Proprietary ruggedized and individually profiled CCD array mount. Ruggedized exoskeleton, capable of <1 pixel geometric accuracy over RTCA/DO-160D shock and vibration
Calibration	Terrestrial and airborne calibration with full report
Modular replaceability	Includes spare exoskeleton, pre-calibrated camera body and lens for instant field servicing

Images: Camera and Data Recorder

Ruggedized Data Recorder

- Integrated with ALTM control rack
- Internal pressurized 80 GB disk
- Removable 80 GB disks (2)
- Mission planning & camera trigger via ALTM-NAV
- QC thumbnail image display on ALTM-NAV

Image Performance

Typical at 1,500 m, 120 knots and 1/2,000 exp.

GSD: 0.25 m
Smear: 15%

Bands	1	2	3
Color Mode, nm	400-500	500-600	600-680
CIR mode, nm	510-600	600-720	720-800

Physical

Size	Camera	16 x 18 x 41 cm
	Data recorder	19" rack, 3U height
Weight	Camera	5 kg
	Data recorder	10 kg
Power	Camera/data recorder	28 VDC, 4 A
	Auxiliary power unit	115 VAC
Operating temperature	0 to + 40° C	
Humidity	5 to 90% RH non-condensing	
Altitude	maximum 6,000 m	

Processing Software (included)

MissionVue - downloads images from removable drives

ImageVue - develops digital image
- Applies fall-off corrections and color balance
- Formats: TIFF, JPEG, IMG
- Quantization: 8 or 16 bit

POS Cal and POS EO from Applanix Corp.

ImageStation Suite from Z/I Imaging
- ISAT Aerial Triangulation Software***

Option
- OrthoPro/Geomedia for orthorectification and mosaicing

Specifications subject to change without notice

**Specially selected from Class 1 (see Kodak KAF-16801CE V4.pdf)*
***Two seconds available in a future release*
****Microstation not supplied*

ALTM

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Appendix C: LiDAR Accuracy Report

C:\LIDAR\Jobs\Vieques\lidar_control1.txt

Number	Easting	Northing	Known Z	Laser Z	Dz
pp1	245559.012	2008418.079	4.490	4.380	-0.110
pp2	243463.416	2002514.687	-31.917	-32.050	-0.133
pp3	246206.847	2005981.766	-20.047	-20.170	-0.123
pp4	248054.079	2009347.177	-35.775	-35.960	-0.185
pp5	252904.580	2007458.344	-19.185	-19.410	-0.225
pp6	252707.704	2005956.316	-37.829	-37.960	-0.131
pp7	258061.381	2007417.402	-26.810	-26.980	-0.170
pp8	256875.616	2006480.718	-41.401	-41.580	-0.179
qc001	254857.321	2006231.198	92.062	91.960	-0.102
qc002	254857.864	2006230.977	92.056	91.900	-0.156
qc003	254858.404	2006230.818	92.049	91.890	-0.159
qc004	254859.046	2006230.582	92.040	91.920	-0.120
qc005	254859.759	2006230.328	92.024	91.940	-0.084
qc006	254859.483	2006229.753	92.049	91.960	-0.089
qc007	254858.816	2006229.948	92.051	91.950	-0.101
qc008	254858.214	2006230.161	92.061	91.930	-0.131
qc009	254857.514	2006230.384	92.056	91.970	-0.086
qc010	254857.019	2006230.512	92.062	91.990	-0.072
qc011	254856.839	2006229.940	92.064	91.990	-0.074
qc012	254857.565	2006229.579	92.068	91.950	-0.118
qc013	254858.203	2006229.238	92.067	91.940	-0.127
qc014	254858.896	2006228.924	92.060	91.960	-0.100
qc015	254859.465	2006228.652	92.061	91.920	-0.141
qc016	254859.208	2006228.015	92.066	91.970	-0.096
qc017	254858.567	2006228.227	92.071	91.980	-0.091
qc018	254857.961	2006228.415	92.080	91.890	-0.190
qc019	254857.294	2006228.617	92.080	91.980	-0.100
qc020	254856.657	2006228.793	92.071	92.010	-0.061
qc021	254855.944	2006229.047	92.088	92.000	-0.088
qc022	254847.162	2006229.118	91.578	91.470	-0.108

qc023	254847.306	2006229.751	91.516	91.440	-0.076
qc024	254847.461	2006230.512	91.491	91.420	-0.071
qc025	254847.635	2006231.265	91.413	91.290	-0.123
qc026	254847.773	2006231.863	91.366	91.250	-0.116
qc027	254847.917	2006232.431	91.325	91.200	-0.125
qc028	254848.049	2006233.034	91.306	91.100	-0.206
qc029	254848.174	2006233.676	91.261	91.060	-0.201
qc030	254848.312	2006234.266	91.243	91.080	-0.163
qc031	254848.433	2006235.034	91.135	91.020	-0.115
qc032	254848.306	2006234.445	91.223	91.090	-0.133
qc033	254848.601	2006235.593	91.052	90.880	-0.172
qc034	254848.739	2006236.190	90.937	90.770	-0.167
qc035	254848.899	2006236.893	90.821	90.690	-0.131
qc036	254849.030	2006237.532	90.704	90.550	-0.154
qc037	254849.202	2006238.285	90.581	90.470	-0.111
qc038	254849.337	2006238.911	90.484	90.430	-0.054
qc039	254849.530	2006239.731	90.366	90.170	-0.196
qc040	254849.657	2006240.328	90.235	90.120	-0.115
qc041	254849.809	2006240.966	90.133	90.040	-0.093
qc042	254849.962	2006241.579	90.054	89.810	-0.244
qc043	254850.095	2006242.213	89.936	89.790	-0.146
qc044	254850.242	2006242.854	89.819	89.690	-0.129
qc045	254850.404	2006243.557	89.695	89.560	-0.135
qc046	254850.575	2006244.339	89.564	89.380	-0.184
qc066	243469.163	2002502.737	-31.971	-31.990	-0.019
qc069	243473.913	2002500.385	-31.980	-32.230	-0.250
qc072	243479.421	2002524.388	-32.017	-32.080	-0.063
qc073	243480.020	2002524.717	-32.014	-32.090	-0.076
qc074	243480.520	2002524.972	-32.031	-32.110	-0.079
qc075	243481.180	2002525.314	-32.030	-32.150	-0.120
qc076	243481.910	2002525.645	-32.027	-32.170	-0.143
qc077	243482.578	2002525.970	-32.054	-32.130	-0.076
qc078	243483.305	2002526.378	-32.024	-32.110	-0.086
qc079	243483.890	2002526.628	-32.012	-32.140	-0.128
qc080	243484.439	2002526.866	-31.998	-32.080	-0.082
qc081	243484.971	2002527.086	-31.986	-32.080	-0.094

qc082	243485.517	2002527.276	-31.992	-32.090	-0.098
qc083	243486.127	2002527.508	-31.988	-32.070	-0.082
qc084	243486.632	2002527.781	-31.971	-32.070	-0.099
qc085	243487.090	2002527.951	-32.010	-32.110	-0.100
qc086	243487.527	2002528.245	-31.989	-32.120	-0.131
qc087	243503.592	2002532.025	-31.198	-31.410	-0.212
qc088	243503.197	2002531.825	-31.180	-31.300	-0.120
qc089	243503.202	2002531.330	-31.184	-31.330	-0.146
qc090	243503.625	2002531.516	-31.160	-31.250	-0.090
qc091	243503.851	2002531.186	-31.140	-31.250	-0.110
qc092	243503.459	2002530.983	-31.170	-31.220	-0.050
qc093	243503.604	2002530.613	-31.128	-31.180	-0.052
qc094	243504.028	2002530.787	-31.094	-31.200	-0.106
qc095	243504.167	2002530.417	-31.082	-31.220	-0.138
qc096	243503.830	2002530.249	-31.119	-31.190	-0.071
qc097	243503.440	2002532.957	-31.267	-31.630	-0.363
qc098	243502.411	2002532.468	-31.241	-31.530	-0.289
qc099	243504.496	2002527.853	-30.930	-31.160	-0.230
qc100	243505.552	2002528.239	-30.954	-31.240	-0.286
qc101	243528.509	2002516.683	-31.054	-31.090	-0.036
qc102	243528.963	2002516.033	-31.029	-31.100	-0.071
qc103	243529.354	2002515.414	-31.024	-31.110	-0.086
qc104	243528.931	2002515.109	-31.035	-31.160	-0.125
qc105	243528.486	2002515.706	-31.054	-31.100	-0.046
qc106	243528.095	2002516.213	-31.036	-31.090	-0.054
qc107	243527.642	2002515.895	-31.020	-31.100	-0.080
qc108	243528.047	2002515.420	-31.068	-31.150	-0.082
qc109	243528.597	2002514.887	-31.056	-31.160	-0.104
qc110	243538.651	2002508.353	-31.359	-31.440	-0.081
qc111	243538.260	2002507.709	-31.424	slope	*
qc112	243539.757	2002510.192	-31.527	-31.630	-0.103
qc114	243540.353	2002511.034	-31.519	-31.580	-0.061
qc115	243540.125	2002511.601	-31.548	-31.800	-0.252
qc116	248059.438	2009372.821	-36.504	-36.630	-0.126
qc117	248059.298	2009372.082	-36.483	-36.580	-0.097
qc118	248059.180	2009371.464	-36.470	-36.560	-0.090

qc119	248059.036	2009370.883	-36.442	-36.550	-0.108
qc120	248058.871	2009370.311	-36.426	-36.560	-0.134
qc121	248058.687	2009369.781	-36.382	-36.570	-0.188
qc122	248058.532	2009369.181	-36.366	-36.530	-0.164
qc123	248058.329	2009368.515	-36.324	-36.430	-0.106
qc124	248058.154	2009367.878	-36.311	-36.390	-0.079
qc125	248058.070	2009367.386	-36.286	-36.410	-0.124
qc126	248057.938	2009366.769	-36.253	-36.380	-0.127
qc127	248057.801	2009366.134	-36.229	-36.360	-0.131
qc128	248057.705	2009365.563	-36.208	-36.280	-0.072
qc129	248057.550	2009364.960	-36.182	-36.280	-0.098
qc130	248057.397	2009364.237	-36.175	-36.260	-0.085
qc131	248057.293	2009363.621	-36.164	-36.230	-0.066
qc132	248057.166	2009362.939	-36.140	-36.180	-0.040
qc133	248057.008	2009362.409	-36.144	-36.150	-0.006
qc134	248056.846	2009361.869	-36.136	-36.170	-0.034
qc135	248056.724	2009361.275	-36.144	-36.210	-0.066
qc136	248057.255	2009361.059	-36.198	-36.260	-0.062
qc137	248057.951	2009360.843	-36.254	-36.370	-0.116
qc138	248058.592	2009360.601	-36.323	-36.280	+0.043
qc139	248059.279	2009360.391	-36.326	-36.300	+0.026
qc140	248059.877	2009360.247	-36.381	-36.330	+0.051
qc141	248060.399	2009360.122	-36.425	-36.420	+0.005
qc142	248060.960	2009359.972	-36.439	-36.430	+0.009
qc143	248061.562	2009359.749	-36.531	-36.490	+0.041
qc144	248062.100	2009359.564	-36.536	-36.550	-0.014
qc145	248062.682	2009359.331	-36.566	-36.500	+0.066
qc146	248063.394	2009359.128	-36.594	-36.550	+0.044
qc147	248064.075	2009358.976	-36.640	-36.670	-0.030
qc148	248064.708	2009358.825	-36.685	-36.710	-0.025
qc149	248065.310	2009358.668	-36.740	-36.750	-0.010
qc150	248065.903	2009358.522	-36.771	-36.820	-0.049
qc151	248058.986	2009367.785	-36.397	-36.430	-0.033
qc152	248059.408	2009367.700	-36.448	-36.490	-0.042
qc153	248059.934	2009367.612	-36.473	-36.550	-0.077
qc154	248060.492	2009367.499	-36.501	-36.600	-0.099

qc155	248061.027	2009367.319	-36.517	-36.630	-0.113
qc156	248061.618	2009367.200	-36.555	-36.690	-0.135
qc157	248062.159	2009367.079	-36.643	-36.720	-0.077
qc158	248062.707	2009366.989	-36.673	-36.750	-0.077
qc159	248063.304	2009366.898	-36.726	-36.760	-0.034
qc160	248064.005	2009366.752	-36.744	-36.830	-0.086
qc161	248064.644	2009366.629	-36.770	-36.810	-0.040
qc162	248065.283	2009366.507	-36.824	-36.820	+0.004
qc163	248066.047	2009366.388	-36.882	-36.970	-0.088
qc164	248066.665	2009366.277	-36.911	-36.980	-0.069
qc165	248067.264	2009366.194	-36.952	-37.010	-0.058
qc166	248067.945	2009366.072	-37.021	-37.060	-0.039
qc167	248068.624	2009365.938	-37.092	-37.120	-0.028
qc168	248060.107	2009373.203	-36.622	-36.710	-0.088
qc169	248060.747	2009373.085	-36.651	-36.760	-0.109
qc170	248061.423	2009372.887	-36.707	-36.770	-0.063
qc171	248062.074	2009372.702	-36.728	-36.810	-0.082
qc172	248062.746	2009372.506	-36.786	-36.820	-0.034
qc173	248063.392	2009372.356	-36.886	-36.880	+0.006
qc174	248063.976	2009372.207	-36.916	-36.960	-0.044
qc175	248064.617	2009372.029	-36.996	-37.030	-0.034
qc176	248065.168	2009371.834	-37.016	-37.050	-0.034
qc177	248065.881	2009371.650	-37.071	-37.110	-0.039
qc178	248066.503	2009371.502	-37.101	-37.150	-0.049
qc179	248067.187	2009371.387	-37.175	-37.230	-0.055
qc180	248067.833	2009371.250	-37.217	-37.250	-0.033
qc181	248068.355	2009371.129	-37.248	-37.310	-0.062
qc182	248069.071	2009370.977	-37.314	-37.330	-0.016
qc183	248069.809	2009370.706	-37.346	-37.420	-0.074
qc184	252700.212	2005961.006	-37.529	-37.650	-0.121
qc185	252699.425	2005961.126	-37.513	-37.680	-0.167
qc186	252698.722	2005961.183	-37.497	-37.570	-0.073
qc187	252698.000	2005961.262	-37.484	-37.580	-0.096
qc188	252697.303	2005961.284	-37.480	-37.580	-0.100
qc189	252696.596	2005961.304	-37.471	-37.520	-0.049
qc190	252695.875	2005961.313	-37.462	-37.540	-0.078

qc191	252695.157	2005961.349	-37.444	-37.610	-0.166
qc192	252694.566	2005961.368	-37.434	-37.620	-0.186
qc193	252693.875	2005961.403	-37.421	-37.600	-0.179
qc194	252693.165	2005961.446	-37.401	-37.560	-0.159
qc195	252692.466	2005961.451	-37.396	-37.490	-0.094
qc196	252691.714	2005961.424	-37.385	-37.460	-0.075
qc197	252690.930	2005961.427	-37.352	-37.480	-0.128
qc198	252690.222	2005961.436	-37.353	-37.450	-0.097
qc199	252689.468	2005961.414	-37.335	-37.390	-0.055
qc200	252688.661	2005961.461	-37.316	-37.400	-0.084
qc201	252687.907	2005961.468	-37.304	-37.400	-0.096
qc202	252687.217	2005961.480	-37.284	-37.360	-0.076
qc203	252686.514	2005961.490	-37.261	-37.390	-0.129
qc204	252685.821	2005961.505	-37.244	-37.370	-0.126
qc205	252685.129	2005961.506	-37.231	-37.300	-0.069
qc206	252684.420	2005961.491	-37.189	-37.290	-0.101
qc207	252683.621	2005961.524	-37.191	-37.180	+0.011
qc208	252682.855	2005961.531	-37.172	-37.270	-0.098
qc209	252682.097	2005961.544	-37.156	-37.260	-0.104
qc210	252681.326	2005961.548	-37.123	-37.240	-0.117
qc211	252680.515	2005961.551	-37.107	-37.170	-0.063
qc212	252679.664	2005961.603	-37.069	-37.170	-0.101
qc213	252678.766	2005961.675	-37.051	-37.190	-0.139
qc214	252677.975	2005961.683	-37.028	-37.140	-0.112
qc215	252677.137	2005961.719	-37.010	-37.080	-0.070
qc216	252676.362	2005961.682	-36.971	-37.100	-0.129
qc217	252675.584	2005961.688	-36.945	-37.040	-0.095

Summery Statistics:

Average dz	-0.098
Minimum dz	-0.363
Maximum dz	+0.066
Average magnitude	0.101
Root mean square	0.116
Std deviation	0.062

Appendix D
Digital Geophysical Mapping Report

NAeVA GEOPHYSICS INC.

THE LEADER IN SUBSURFACE DETECTION

Subsurface Geophysical Surveys

GPR
MAGNETICS
ELECTROMAGNETICS
SEISMICS
RESISTIVITY
UTILITY LOCATION
UXO DETECTION
BOREHOLE CAMERA
STAFF SUPPORT

Results of Geophysical Investigation

Former Vieques Naval Training Range (VNTR), Vieques Island, Puerto Rico

Dates of Investigation:

January 23rd – October 11th, 2008

FINAL SUBMITTAL
March 28, 2008

PREPARED FOR

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Acronyms and Abbreviations

DGM	Digital Geophysical Mapping
ECA	Eastern Conservation Area
EM61-MK2	Electromagnetic 61 Mark 2
EMA	Eastern Maneuver Area
EOD	Explosive Ordnance Disposal
GPO	Geophysical Prove Out
GPS	Global Positioning System
LIA	Live Impact Area
MEC	Munitions and Explosives of Concern
MOA	Master Ordering Agreement
MRP	Munitions Response Program
MRA	Munitions Response Area
NAD	North American Datum
QC	Quality Control
OP	Observation Post
RTK	Real Time Kinematic
RTS	Robotic Total Station
SIA	Surface Impact Area
UTM	Universal Transverse Mercator
VNTR	Vieques Naval Training Range

1.0 INTRODUCTION

NAEVA Geophysics, Inc. (NAEVA) was contracted by CH2M HILL to conduct Digital Geophysical Mapping (DGM) of the former Vieques Naval Training Range (VNTR), Vieques Island, Puerto Rico. The area to be surveyed was estimated at approximately 300 acres. Field operations were conducted from January 23rd to October 11th, 2007.

1.1 Background and objectives

The purpose of this investigation was to detect and map subsurface metal associated with potential Munitions of Explosive Concern (MEC) along the eastern side of Vieques Island, Puerto Rico. Various military operations were previously conducted at the former VNTR and the range has shown a wide variety of military munitions.

1.2 Scope of Work

NAEVA Geophysics provided all personnel and geophysical survey equipment to perform DGM surveys, reacquisition and Quality Control (QC) for all anomalies on the beaches and unpaved roadways at the former VNTR.

Geophysical investigations were proposed for all sandy beaches from the waterline to vegetation line, with surveys on selected beaches including turtle setback areas ranging from 15 meters to 30 meters. The variety of setback sizes were determined by a biological assessment with a 5 m buffer added to the recommended distance. DGM surveys were also proposed on all unpaved roadways and an adjacent 7.62 meter (25 ft) buffer area. Vegetation removal was to be completed prior to the geophysical investigation for both the roads and the beaches.

All production data was to be processed, interpreted and delivered to the CH2M HILL Project Geophysicist on the schedule and in the formats specified in the DGM Master Ordering Agreement (MOA).

1.3 Site Location and Description

The former VNTR is situated in the eastern third of the Island of Vieques, and is bordered to the west by the community of Isabel Segunda, to the north by the Vieques Sound, and to the south by the Caribbean Sea. The entire former VNTR consists of approximately 14,600 acres and is divided operationally into four Munitions Response Areas which from west to east include: Eastern Maneuver Area (MRA-EMA), which comprises an area approximately 10,673 acres; the Surface Impact Area (MRA-SIA) comprised of approximately 2,500 acres; the Live Impact Area (MRA-LIA) comprised of approximately 900 acres; and the 200-acre Eastern Conservation Area

(MRA-ECA), which is situated on the easternmost tip of Vieques (see Figure 1).

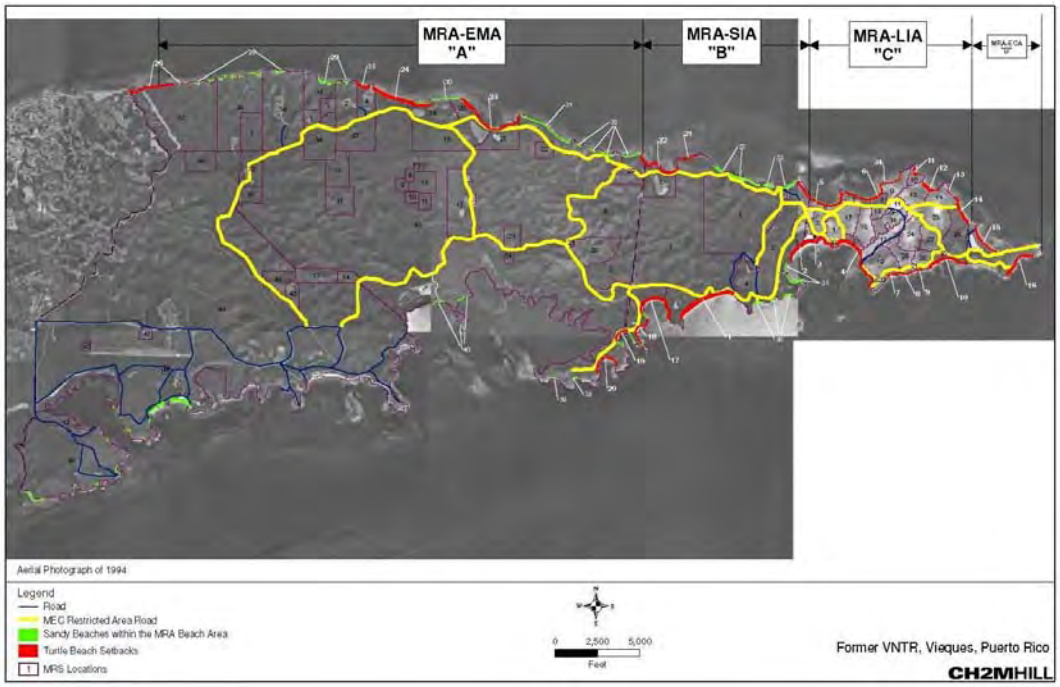


Figure 1: Site overview of VNTR

The largest portion of the former VNTR has been designated a Wildlife Refuge and the Live Impact Area has been designated as a wilderness area. Public access is permitted in select areas of the wildlife refuge; however there is no public access for the wilderness area.

2.0 EQUIPMENT

2.0.1 Geonics EM61-MK2

The EM61-MK2 is a high resolution time-domain electromagnetic instrument designed to detect with high spatial resolution, shallow ferrous and non-ferrous metallic objects. In comparison with other metal detectors, especially magnetometers, it is much better suited for work in close proximity to man-made structures and in areas of dense subsurface metallic debris (i.e. impact ranges). The EM61-MK2 system consists of two air-cored coils, a digital data recorder, batteries and processing electronics. The EM61-MK2's transmitter generates a pulsed primary magnetic field, which then induces eddy currents in nearby metallic objects. The receivers either measure the eddy currents at three distinct time intervals in the bottom coil and one time interval in the top coil; or four intervals in the bottom coil if no top coil measurements are recorded. For the work in Vieques the latter method was chosen. Earlier time gates provide enhanced detection of smaller metallic objects. Secondary voltages induced in both coils are measured in millivolts (mV). The arrangement of coils is such that there is a vertical separation of 40 cm from the

ground to the bottom coil. Assuming accurate data positioning, target resolution of approximately 0.5 meters can be expected. The data is collected using Geomar's Nav61MK2 program and temporarily stored in an Allegro CX prior to downloading to a laptop computer.

2.0.2 Trimble 5700 Real Time Kinematic Global Positioning System

Trimble's 5700 Real Time Kinematic (RTK) Global Positioning System (GPS) is a 24-channel dual frequency RTK receiver that uses both L1 and L2 satellites. This system operates with a base and a rover unit; the base sends corrections to the rover via radio link, thus maintaining a 3cm horizontal accuracy and a 5cm vertical accuracy. For configuration with the EM61-MK2, the rover is set to output a GGA NMEA string at 1 Hz, which is captured into the NAV61MK2 program and temporarily stored in the Allegro CX.

2.0.3 Trimble S6 Robotic Total Station

Trimble's S6 Robotic Total Station (RTS) is a total station with the ability to track real time the movement of the prism via a laser. The S6 consists of a "Gun" (the base) and a Prism. The Gun tracks the Prism and the positions are sent via radio to a handheld computer (TSC2) that sends a data string via a cable to the Allegro CX. The data is logged real time with the EM61-MK2 data into the NAV61MK2 program.

2.0.4 Geometrics G858 Magnetometer

The vertical gradient magnetometer used during the Geophysical Prove Out (GPO) was the Geometrics G858, a highly sensitive cesium vapor magnetometer. Advantages of the cesium vapor magnetometer as compared with typical electromagnetic methods are: greater depth of exploration for large items, higher mobility in rough terrain, more easily deployed in vegetated areas, and a one person operator, even in difficult terrain.

Each sensor measures the sum of the earth's primary magnetic field plus the response from any secondary fields generated by local ferromagnetic materials in the subsurface. The amplitude of the response decays quickly as the distance increases from the ferrous objects detected by the gradiometer. Compared to a total field magnetometer the vertical gradient setup offers greater spatial resolution of detected anomalies. Additionally, no diurnal correction need be applied to the data, as diurnal drift in the magnetic field affects both sensors equally.

3.0 METHODOLOGY

3.1 DGM Survey Activities

The main method of surveying at the former VNTR was the EM61-MK2 in tandem mode

configuration using RTK GPS. However, different configurations (wheel mode) and positioning methods (RTS or tape measures with ropes and fiducial markers) were used to achieve the best quality data. The configuration was chosen based on the terrain. All data collected at the former VNTR was recorded at a sample rate of 10 readings per second.

A survey line spacing of 0.75 meters was used for the all Geophysical Prove Outs and DGM survey areas. This spacing results in coil overlap on successive lines, reducing the likelihood of data gaps and improving the chance of detecting small MEC items.

While conducting DGM operations NAEVA used non-intrusive methods (cones, flagging, etc.) for marking locations during the geophysical investigation. When stakes or flags needed to be placed in the ground, a qualified UXO escort cleared the locations with a White XLT all-metals detector prior to any intrusive activity.

3.1.1 Tandem Mode

In tandem configuration, the coils were supported with 12-foot long fiberglass poles and transported by two operators. The electronics included the data logger and backpack controlled by the operator to the rear of the system. A tripod for mounting the GPS antennae or RTS prism was attached to the top coil and the operator at the front of the system wore the backpack containing the GPS rover. Coil height was consistent with the wheeled method at 40cm and was maintained throughout DGM operations. This configuration is more suitable in areas with uneven terrain (deadfall, ridges, ruts, rocks, cutbanks and stumps) as shown in Figure 2.

Figure 2: Tandem configuration with RTK GPS

3.1.2 Wheel Mode

In wheel mode, the EM61-MK2 bottom coil (the receiver coil) is mounted on two manufacturer supplied 40cm wheels and has four plastic spacers which are used to separate the top coil from the bottom coil. A tripod for mounting the GPS antennae or RTS prism is attached to the top coil and a U-shaped handle for pulling or pushing is attached to the bottom coil. Wheel mode is most effective in areas of relatively level terrain.

Figure 3: Wheel mode with RTK GPS

3.1.3 Positioning Configurations

RTK GPS was utilized for the majority of the data collection. In areas where the RTK GPS proved ineffective due to limited satellite coverage from overhanging trees and/or poor radio link caused by extreme distance from the base station or topography, the Robotic Total Station (RTS) system was used for positioning.

Traditional surveying methods (tapes and ropes) were employed in areas unsuitable for both RTK GPS and RTS methods. This method uses a series of ropes positioned at 10 meter intervals across the survey lines. Alternating color codes painted on the ropes were spaced at 0.75 meter intervals and used to facilitate straight line profiling with the instrumentation during data collection. Additionally, the ropes served as a point where the operator manually marked the data stream. The data was then repositioned between the data marks to account for the changes in velocity that occurred as the instrument was passed through variable terrain conditions (i.e. slope, deadfall, vines, etc.). Corner locations were recorded using Trimble's 5700 RTK GPS and the local coordinates were later converted to match the recorded NAD83 (North American Datum)

UTM (Universal Transverse Mercator) Zone 20N locations in Geosoft during processing.

3.2 Data Storage and Preliminary Processing

EM61-MK2 data are temporarily stored in an Allegro data logger via Geomar's NAV61 software and then downloaded into a laptop computer for further on-site processing using Geomar's Trackmaker and Geosoft Oasis Montaj software version 6.3.1.

All daily logs, field notes, and sketches were input digitally into the Munitions Response Program (MRP) Enterprise field device (Trimble GeoXT). At the end of each day, this information was uploaded to the project database for use in processing the geophysical data.

Initial data processing was performed by the field team which included reviewing data for integrity and repeatability. In the case of fiducial surveying methods, positional data were edited based on the known locations of fiducial marks.

3.3 Preprocessing

Converted raw data files were imported into Geosoft's Oasis Montaj to perform the following:

- Review and finalize all QC tests (cable shake, personnel, static and latency) prior to processing of the DGM data for that day
- Set projection of NAD83 UTM Zone 20N coordinates
- Evaluate data density and GPS quality
- Apply auto leveling and instrument drift corrections
- Apply of default lag correction
- Generate preliminary contour map(s) from gridded data
- Generate preliminary original vs. repeat profiles by grid block
- Generate formatted ASCII files containing preprocessed data by grid block

3.4 Final Processing

After completion of preprocessing, the data were further evaluated and processed to generate final processed data files. Final processing steps included:

- Evaluation and refinement of auto leveling and instrument drift corrections in the channel selected for target analysis (Channel 3)
- Evaluation and refinement of lag correction in the channel selected for target analysis (Channel 3)

- Additional digital filtering and enhancement, as necessary, in the channel selected for target analysis (Channel 3)
- Targeting of data, as described in Section 3.5
- Generation of formatted ASCII files containing processed data by grid block
- Generation of final maps for each grid showing contoured gridded data, target locations, and culture
- Generation of final original vs. repeat profiles by grid block

3.5 Analysis and Target Selection

The UX-Detect module within Oasis Montaj identifies peak amplitude responses associated with, but not limited to, MEC items. Single-source anomalies may generate multiple target designations depending on shape and orientation. Initial target selections were made based on the gridded data. Data profiles corresponding to the anomalies selected by Geosoft were then analyzed by trained 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 UX-Detect module, yet deemed to represent a potential MEC target, were manually selected. All target selection was performed on final processed data from Channel 3 of the bottom coil of the EM61-MK2.

Final processed XYZ (ASCII) files were created by grid block and individual geophysical maps and target lists were created for 30 meter x 30 meter grids. All anomalies occurring at or above the targeting threshold of 2.5 mV in Channel 3 were identified using a unique ID number. However, in some situations when the background geophysical response was “quiet”, a smaller amplitude anomaly exhibiting a good decay below the 2.5 mV threshold was also picked and assigned a unique ID number. Large areas of significant response in which individual target selection was not possible were bounded by a four point polygon and no individual targets were selected. All four points of the polygons were recorded in the target lists.

Each target list provides a Target ID, Grid Cell ID, Target Type, Easting (x) and Northing (y) UTM coordinate location for each target, and the recorded peak response in millivolts. The target IDs were prioritized by designating the highest amplitude response as the number one target in each grid. There are six types of designations for targets: Type 1 (high priority), Type 2 (medium priority), Type 3 (low priority), Type 4 (suspected culture), Type 5 (culture), and Type 6 (heavily saturated areas). Types 1-3 were initially setup by NAEVA and CH2M HILL but never implemented. Polygon areas were designated a Type 6 classification (sometimes Type 5 if it was

known culture) and assigned a response of 999 mV.

All raw and processed data including target lists have been submitted to CH2M HILL's geophysicist and can be found on the DVD in Appendix C. Also included are processing reports, a copy of the database and target lists in MRP Enterprise format.

4.0 RESULTS

4.1 Summary of Work Performed

The digital geophysical mapping of the former VNTR took place from February 1st, 2007 to October 11 th, 2007 and totaled approximately 97.2 acres. Work began with the mapping of beach areas and progressed to the mapping of unpaved roads.

4.2 Mobilization and Setup

NAEVA mobilized one field crew and one on-site processor to Vieques, PR on January 19th, 2007. All equipment had been shipped to Camp Garcia the week of January 15th – 19th and was inspected, setup, and tested by NAEVA in Vieques prior to the start date of field operations.

4.3 Geophysical Prove Out (GPO)

The purpose of surveying the Geophysical Prove Out (GPO) area was to demonstrate the effectiveness of all instrumentation, methods, and personnel prior to the initiation of fieldwork and document the site-specific capabilities of a DGM system. Serial number identifications were recorded for all instrumentation (i.e. data logger, coils, EM61-MK2 electronics, GPS and RTS equipment), and the GPO areas were mapped using the same personnel, equipment, and methodologies employed for the DGM survey. Three different GPO sites were mapped at the former VNTR.

Initially NAEVA surveyed two existing GPO grids just north of Beach 2 (Figure 4) from January 23rd – January 31st, 2007 (see Figure 4). These grids had been established by the Naval EOD (Explosive Ordnance Disposal) Technology Division for previous work performed on the site. Both grids were 30 meters by 30 meters and had been seeded with inert MEC items at various depths and orientations. Therefore, it was determined they meet the standards set forth in the Final Expanded Range Assessment and Phase II Site Inspection Work Plan for the former VNTR.

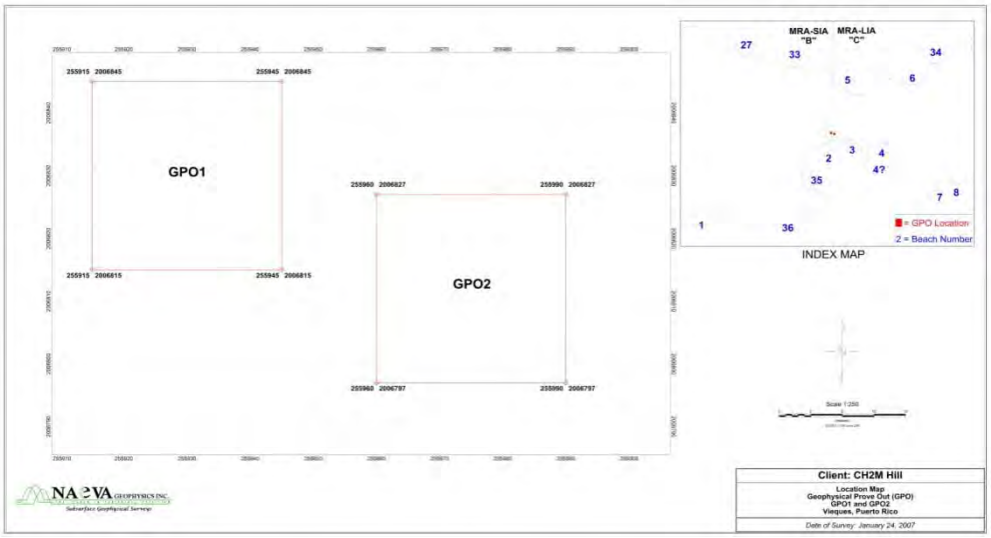


Figure 4: GPO1 and GPO2 locations

The EM61-MK2 was used to survey the GPO grids in all configurations and positioning systems described in the methodology section (3.0) with the assumption different collection methods would work better than others in different areas of the former VNTR. However, the magnetometer data was only collected using one positioning system (GPS) due to the EM61-MK2 results, which proved to be more sensitive to small, near-surface metal than the vertical gradient magnetics method. It was determined the EM61-MK2 would be the appropriate method of detection for the survey given the need to detect small, near-surface munitions.

Data for Channels 2 and 3 were processed and presented with a targeting threshold of 2mV for both channels in the GPO. Figures 5 and 6 are color contour maps for the GPO1 and GPO2 respectively, which depict Channel 3 at 2mV (see Appendix A for the rest of the color contour maps and all target lists). It was determined by CH2M HILL, after comparing the blind seeded targets to NAEVA's targeted locations, a threshold of 2.5mV in Channel 3 would detect the majority of the items of interest without targeting too many noise anomalies.

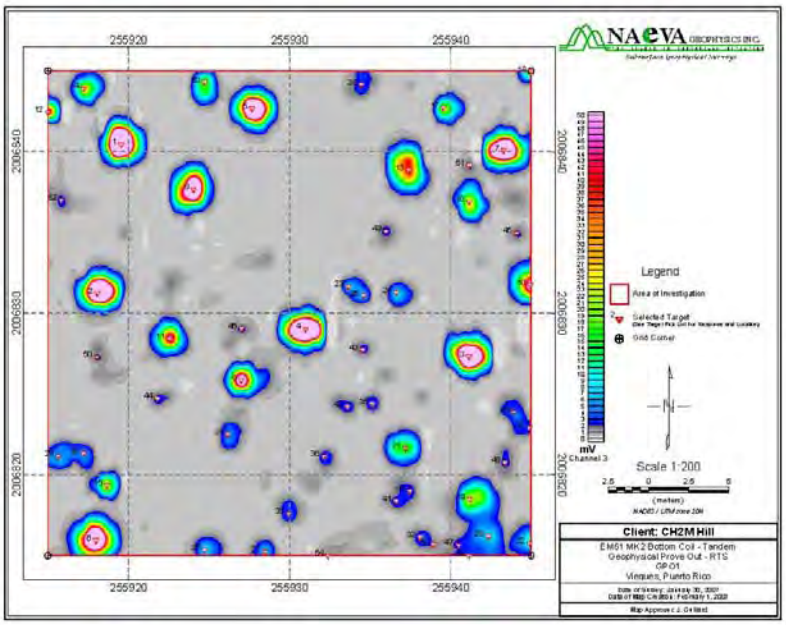


Figure 5: GPO1

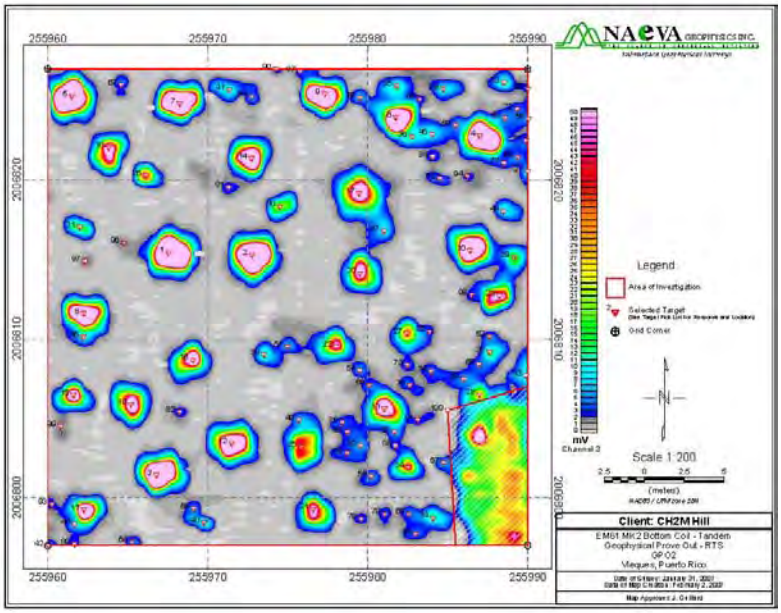


Figure 6: GPO2

A third GPO (Road GPO), located in the EMA just past the gate leading to the alternate northern access road, was mapped to determine whether any difference in geological conditions would result in different targeting thresholds for MEC items on the roads (see Figure 7). The Road GPO was 10 meters by 30 meters and the processed data showed no significant mV differences between the seeded items in the Road GPO and the seeded items in GPO One and GPO Two. Only two configurations (EM61-MK2 in tandem and wheel mode with RTK GPS and RTS positioning) were evaluated at the Road GPO since the other configurations had already been

proven in the Beach GPO's to have shown very little variation in the response between the methods. The data collected in the GPO's were provided to CH2M HILL for final review (see Figure 8).

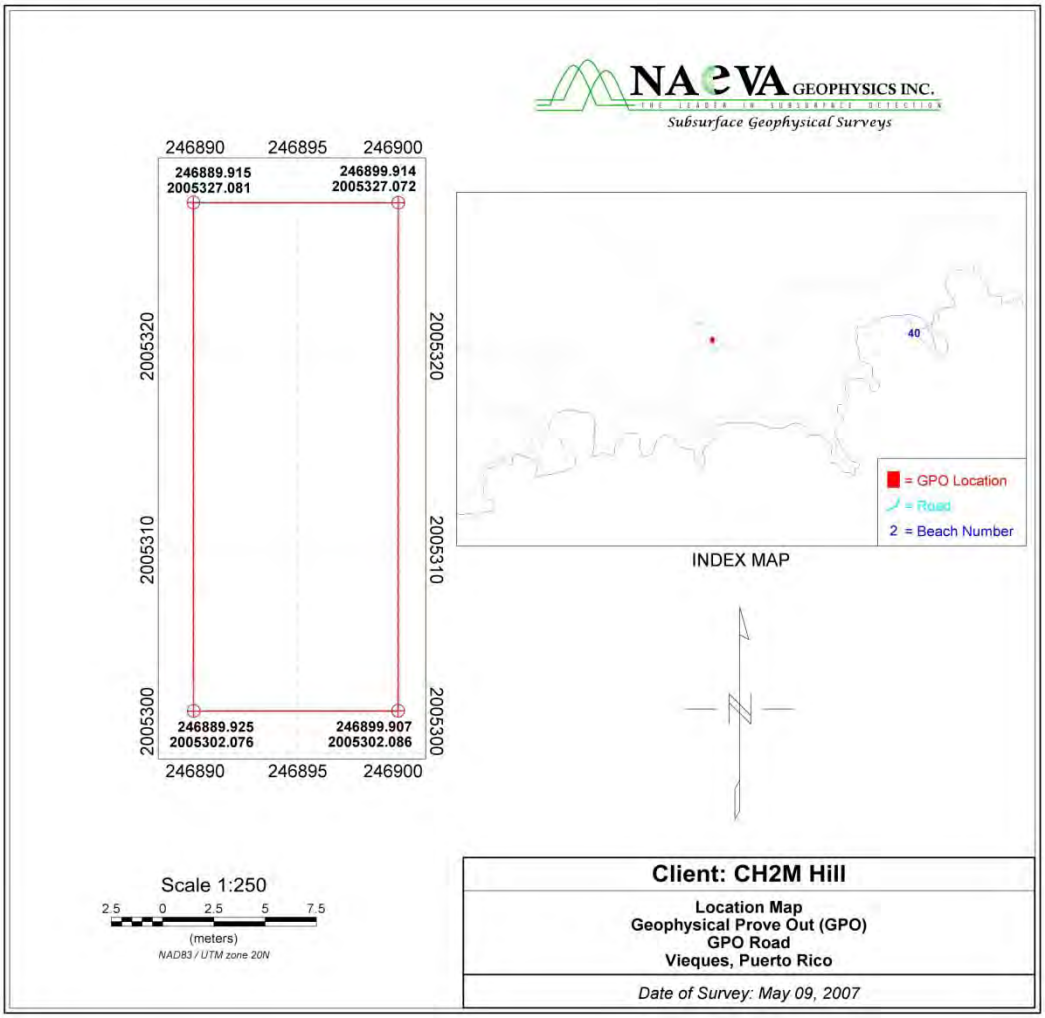


Figure 7: Road GPO location

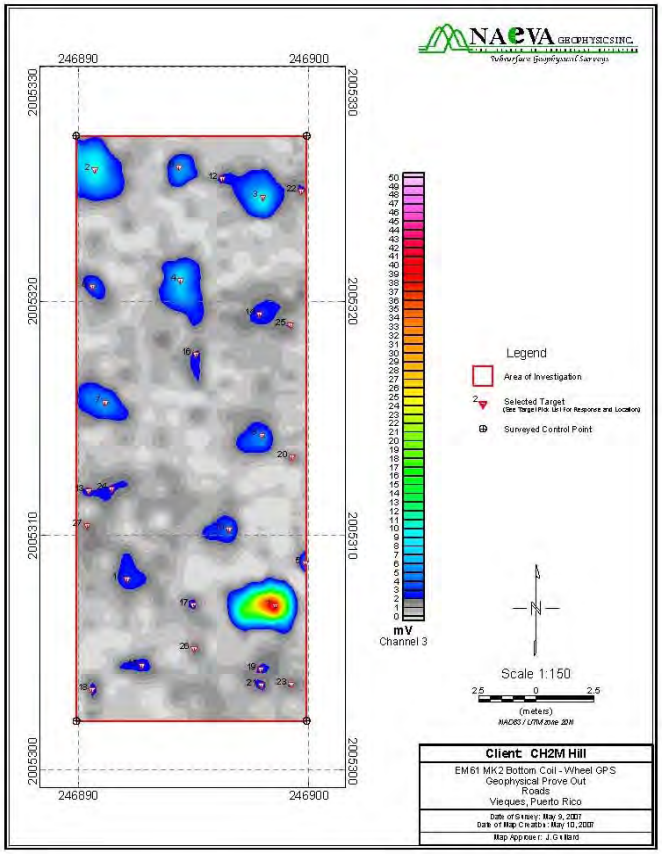


Figure 8: Road GPO

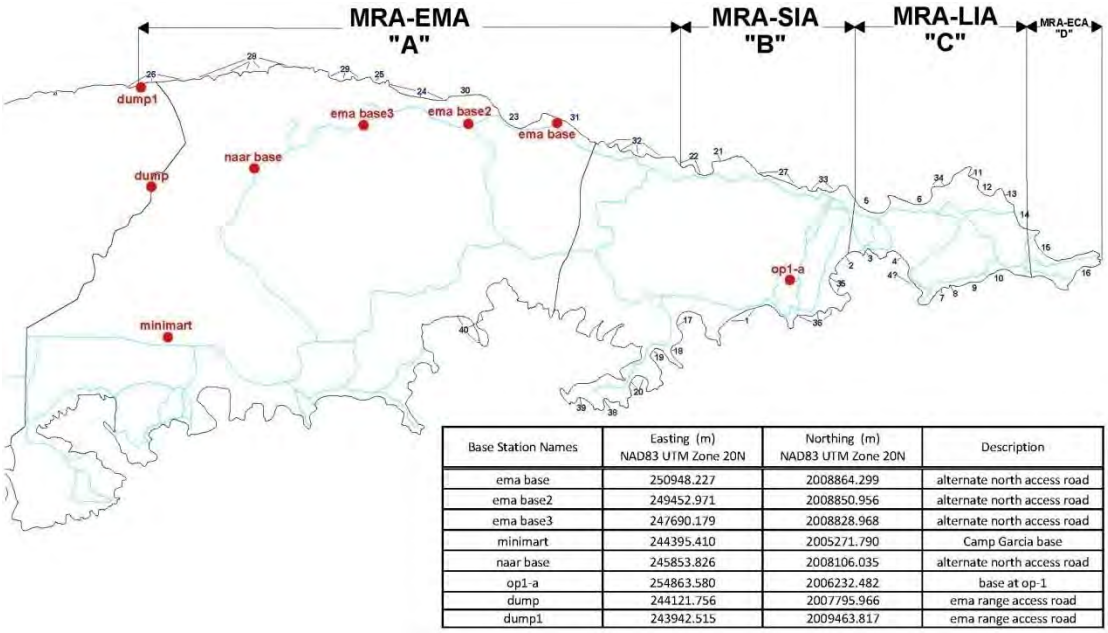
4.4 DGM SURVEY ACTIVITIES

4.4.1 Positioning Systems

Data positioning was mainly conducted using a direct radio link with a RTK GPS system. Excellent line of sight with a base station located at Observation Post 1 (OP-1), the use of radio repeaters and setting the Trimble 5700 base station to an output level of 25 watts enabled NAEVA to use RTK GPS for most DGM surveying at the site.

The establishment of additional base station locations positioned along the alternate northern access road also extended the use of the RTK GPS for most DGM activities at the former VNTR (Figure 9).

If RTK GPS could not be used due to tree coverage or poor line of sight with the RTK GPS base station, the Trimble S6 Robotic Total Station or fiducial ropes and tape measures were used for positioning.



Base Station Names	Easting (m) NAD83 UTM Zone 20N	Northing (m) NAD83 UTM Zone 20N	Description
ema base	250948.227	2008864.299	alternate north access road
ema base2	249452.971	2008850.956	alternate north access road
ema base3	247690.179	2008828.968	alternate north access road
minimart	244395.410	2005271.790	Camp Garcia base
naar base	245853.826	2008106.035	alternate north access road
op1-a	254863.580	2006232.482	base at op-1
dump	244121.756	2007795.966	ema range access road
dump1	243942.515	2009463.817	ema range access road

Figure 9: Base station locations with UTM coordinates

4.4.2 Beach Areas

The Beach MRA consists of the beach areas on the north and south sides of the former VNTR (See Figure 9). The sandy portions of the beach and the turtle setback areas were investigated to determine the presence of subsurface metallic anomalies. Turtle setback areas (habitat regions where vegetation removal was needed beyond the sandy areas) varied from 10-30 meters, were surveyed when vegetation removal had been performed by the brush crews. Beaches had been assigned numbers for naming purposes and were prioritized for DGM based on turtle nesting habits and from the amount of use from local Viequese who frequent the beaches by boat.

Throughout the duration of the project NAEVA remained focused on total coverage of the site, however, in many cases, data gaps were unavoidable. Gaps in the data appear around obstructions, such as a trees, brush piles, cultural features and turtle nests. The DGM field crew had been instructed to avoid all turtle nests. All obstacles that potential could cause data gaps were logged into the GeoXT by taking GPS points or by cataloguing them with a GPS polygon. All the recorded information was placed on the processed data contoured maps.

Table 2 provides the completion status and results of the geophysical investigation for each beach and their associated buffer. Not all the beaches and buffer areas were completed due to vegetation, access, turtle nests, and time.

Beach	Start Collection Date	Sandy Area End Collection Date	Buffer Area End Collection Date	Veg Clearance Required (Y/N)	Acreage Completed	Status	Comments	Point Targets	Polygon Targets	Total Targets	Acreage	Targets per acre
1	20-Feb-2007	5-Mar-2007		Y	8.34	Sandy area complete	Awaiting Vegatation Clr for buffer	665	0	665	8.34	79.78
2	1-May-2007	7-May-2007		Y	3.08	Partially complete	Waiting Veg clearance and Turtle Nests	1105	5	1110	3.08	360.39
3				Y			Waiting Veg clearance and Turtle Nests					
4	10-Apr-2007	10-May-2007		Y	6.76	Partially complete	Awaiting Vegetation Clr for small area in the East	2474	82	2556	6.76	378.11
5	6-Mar-2007	30-Apr-2007	30-Apr-2007	Y	10.15	Complete		6293	11	6304	10.15	621.08
6	15-Mar-2007	21-Mar-2007	21-Mar-2007	Y	2.45	Complete		2168	10	2178	2.45	888.98
7	2-Apr-2007	2-Apr-2007		Y	0.24	Sandy area complete	Awaiting Vegetation Clr for buffer	123	1	124	0.24	516.67
8	2-Apr-2007	2-Apr-2007		Y	0.2	Sandy area complete	Awaiting Vegetation Clr for buffer	188	0	188	0.20	940.00
9				Y			Waiting for USA to finish					
10	9-Aug-2007	27-Sep-2007	27-Sep-2007	Y		Partially complete	Awaiting vegetation Clr for small area in the East	3818	1	3819	5.52	691.85
11				Y			Awaiting access to beaches and Turtle walks					
12	25-Jun-2007	27-Jun-2007		Y	0.99	Sandy area complete	Awaiting Vegetation Clr for buffer	154	9	163	0.99	164.65
13				Y			Awaiting access to beaches and Turtle walks					
14	6-Feb-2007	8-Feb-2007		Y	1.57	Sandy area complete	Awaiting Vegetation Clr for buffer	226	3	229	1.57	145.86
15	8-Feb-2007	19-Feb-2007		Y	1.82	Sandy area complete	Awaiting Vegetation Clr for buffer	143	0	143	1.82	78.57
16	22-Mar-2007	22-Mar-2007		Y	0.21	Sandy area complete	Awaiting Vegetation Clr for buffer	45	0	45	0.21	214.29
17	5-Feb-2007	29-Mar-2007		Y	2.08	Sandy area complete	Awaiting Vegetation Clr for buffer	313	2	315	2.08	151.44
18	14-Jun-2007	14-Jun-2007		Y	0.7	Sandy area complete	Awaiting Vegetation Clr for buffer	48	0	48	0.70	68.57
19				Y			Accessible with 1/2 day vegetation cutting					
20				Y			Inaccessible by land unless a path is cut					
21				Y			Inaccessible by land unless a path is cut					
22	5-Jun-2007	6-Jun-2007		Y	2.04	Sandy Area Complete	Awaiting Vegetation Clr for buffer	343	0	343	2.39	143.51
23	24-May-2007	29-May-2007		Y	1.86	Sandy area complete	Awaiting Vegetation Clr for buffer	329	4	333	2.33	142.92
24	15-May-2007	22-May-2007		Y	4.07	Sandy area complete	Awaiting Vegetation Clr for buffer	121	0	121	4.07	29.73
25	25-Jun-2007	25-Jun-2007		Y		Sandy area complete	Awaiting Vegetation Clr for buffer and access to secluded small beach to the east	203	0	203	0.51	398.04
26	19-Jun-2007	19-Jun-2007		Y	1.27	Sandy area complete		111	9	120	1.27	94.49
27	7-Jun-2007	12-Jun-2007		N	2.76	Complete		145	0	145	2.76	52.54
28				N			Inaccessible by land unless a path is cut					
29				N			Inaccessible by land unless a path is cut					
30	23-May-2007	24-May-2007		N	1.04	Complete		35	0	35	0.56	62.50
31				N			Inaccessible by land unless a path is cut					
32	4-Jun-2007	13-Jun-2007		N	1.24	3 Eastern Beaches	4th Beach inaccessible by land w/o a path	93	0	93	0.88	105.68
33	1-Feb-2007	26-Mar-2007		N	1.9	Complete		269	9	278	1.90	146.32
34				Y			Access needs to be checked - possible no sandy beach					
35	9-Apr-2007	9-Apr-2007		N	0.17	Eastern Beach Complete	Western Beach only accessable by boat	24	0	24	0.17	141.18
36	3-Apr-2007	5-Apr-2007		N	1.95	Complete		286	0	286	1.95	146.67
37				N		NO BEACH 37						
38				N			Inaccessible by land unless a path is cut					
39				N			Inaccessible by land unless a path is cut					
40				N			Inaccessible by land unless a path is cut					
		Sandy Area Complete			Beach Complete			**19722**	**146**	**19868**	**62.90**	**315.89**

Table 1: Beach Statistics

4.4.3 Unpaved Roadways

The roadways where NAEVA conducted DGM operations were located throughout the former VNTR by names and numbers as shown in Figures 10 and 11. The roadways were mapped and additional 7.62 meter (25 ft) buffers on each side of the roads were also surveyed, if sufficient vegetation removal had occurred.

DGM surveying along the unpaved roadways began on the Alternate Northern Access Road and progressed east from the EMA toward the LIA. The buffer areas along this route had not had vegetation removal and only the road itself was surveyed.

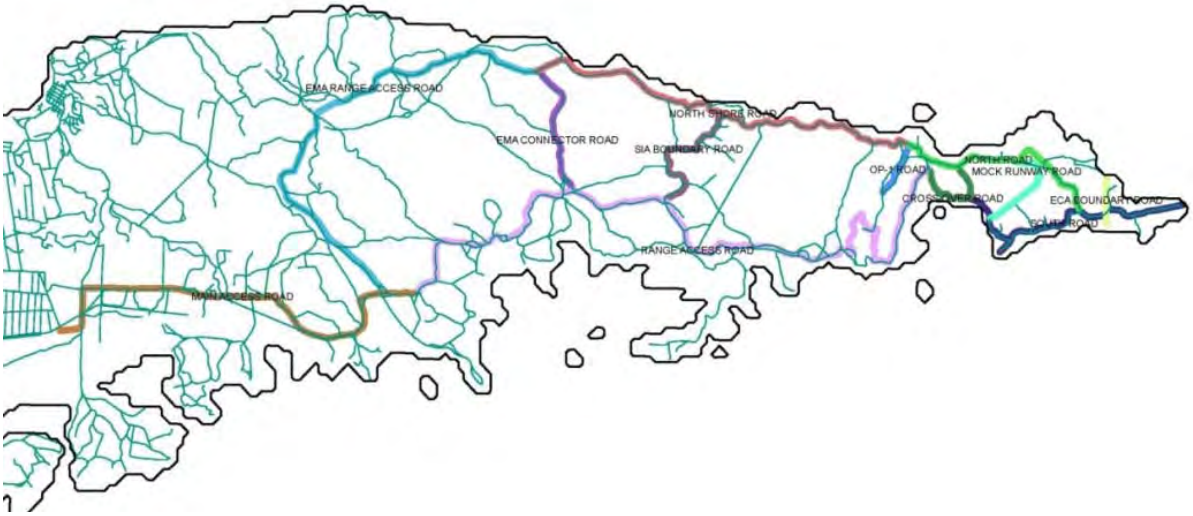


Figure 10: Names for unpaved roadways

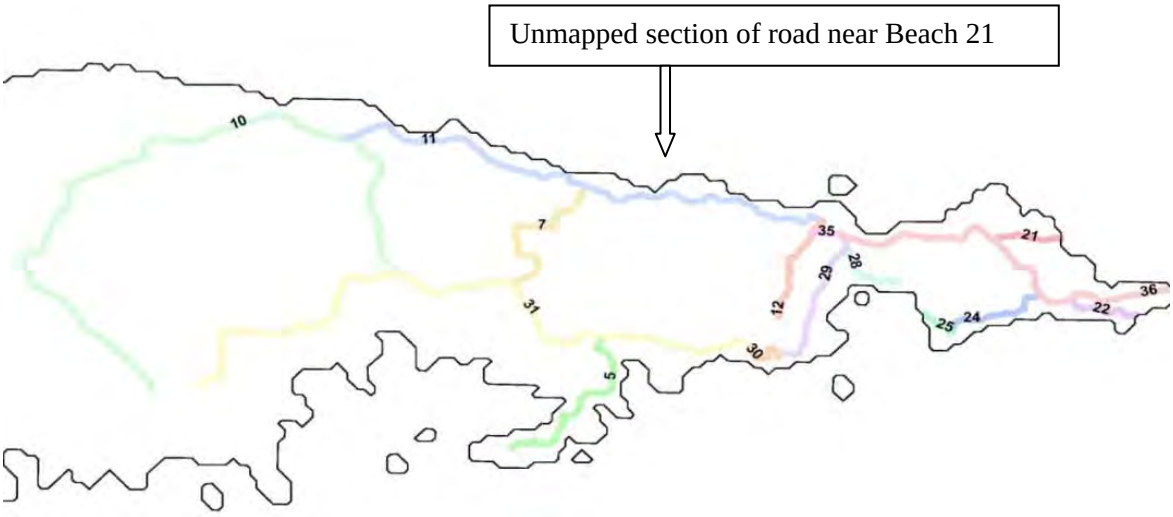


Figure 11: Numbers of unpaved roadways

For the Alternate Northern Access Road, OP-1 Road, and the Range Access Road, only the unpaved roadways were surveyed (no buffers). All other unpaved roadways had vegetation clearance in the portions of the buffer areas and were mapped on each side to 7.62 meters or to the edge of the brush if it was less than the 7.62 meters. One section of the Alternate North Access Road, south of Beach 21, was not surveyed due to vegetation which had re-grown since the original brush cutting operations. Table 2 provides the completion status and results of the geophysical investigation for each road and their associate buffer.

Road	Start Collection Date	End Collection Date	Buffer Area End Collection Date	Veg Clearance Required (Y/N)	Acreage Completed	Status	Comments	Point Targets	Polygon Targets	Total Targets	Acreage	Targets per acre
Submunition/Road 21	20-Jun-2007	5-Jul-2007		Y	1.17	Road Bed Complete	Awaiting Vegetation Clr for buffer	407	93	500	2.1	**238.10**
Alternate North Access/ Road 10 & 11	28-Jun-2007	1-Aug-2007		Y	12.641		North Alternate Access Road - Started at Gate in between gates 1 and 2 working East. One small section by beach 21 not complete due to vegetation	2427	33	2460	13.64	**251.46**
OP-1 /Road 12	1-Aug-2007	2-Aug-2007		Y	1.403	Road Bed Complete	From Beach 33 up to OP-1	725	10	735	0.4	**1837.50**
Route 13/Road 35 & 36	2-Aug-2007	2-Oct-2007		Y			Awaiting Vegetation Clr for road and buffer	2621	57	2678	3.91	**1384.60**
ECA Boundary Road	12-Sep-2007	8-Oct-2007	8-Oct-2007	Y		Road Bed and Buffer Complete	Separates the LIA from the ECA. Runs North-South from Beach 10 to Beach 14.	2351	1	2352	4.23	**556.03**
Range Access - Road 31	31-Aug-2007	31-Aug-2007		Y		Road Bed is partially Complete	Awaiting Vegetation Clr for road and buffer	242	4	246	1.93	**127.46**
Southern Access - Road 24	27-Aug-2007	11-Sep-2007		Y			Awaiting Vegetation Clr for road and buffer	5116	46	5162	4.76	**1084.45**
		Road Bed Complete				Road Complete		**13889**	**244**	**14133**	**30.97**	**456.34**

Table 2: Road Statistics

4.4.4 Storm Impact Analysis

During the month of August, 2007 a major hurricane (Hurricane Dean) came within 200 miles of the island of Vieques. Hurricane Dean was rated a Category 5 and caused waves to reach heights of 10-15ft on the south side of the island (see figure 12). CH2M HILL requested that NAEVA re-map areas on four different beaches to determine if the storm had any impact on the previously selected targets of those beaches.

The beaches selected for the storm impact analysis were Beaches 1 and 4 on the south side of the island and Beaches 5 and 6 on the north side. Beach 1 was chosen for its habitually large waves and Beach 4 because of its location in a cove, which protected it from high surf during normal conditions.

Beaches 5 and 6 were selected based on their location on the north side of the island and the high density of anomalies. All data was delivered to CH2M HILL geophysicist for the comparison study.

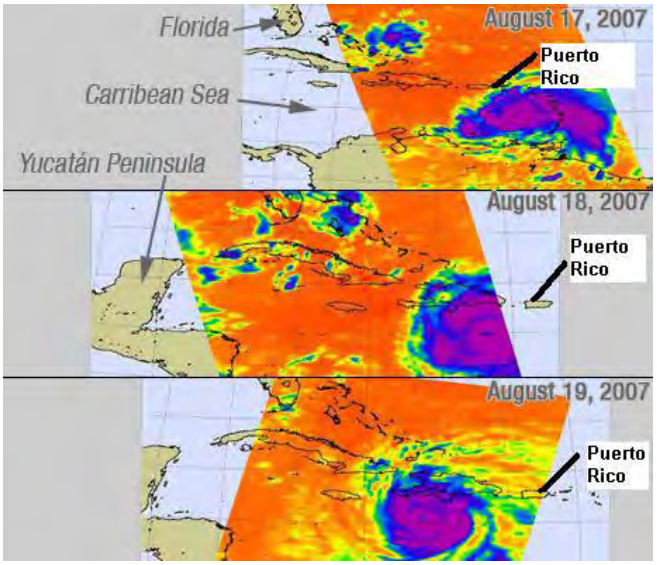


Figure 12: Hurricane Dean Radar Image

5.0 QUALITY CONTROL DATA

To establish confidence in the data reliability, Quality Control (QC) tests were conducted throughout the project. Tests were conducted prior to, during, and after all data collection sessions. All QC tests for the EM61-MK2 were conducted after a minimum 15 minute warm-up period for the electronics. Sample graphical displays of QC data are included in Appendix B.

5.1 QC Test Descriptions and Acceptance Criteria

The following QC procedures were performed and documented during the data collection process

and reviewed by a qualified geophysicist on a daily basis.

1. **GPS QC:** Positioning accuracy of the final processed data was demonstrated by operating the equipment over one or more known points. The accuracy of the data positioning was assessed by calculating the difference between the known location over which a positioning instrument is held and the recorded position. The sensor position test was conducted at the beginning of the survey operation for each workday.

2. **Personnel Test:** This test checks the response of instruments to personnel and their clothing/proximity to the system. On a daily basis, the instrument coils/sensors for those instruments being used that day were checked for their response to the personnel operating the system. The response was observed in the field for immediate corrective action and transmitted back to a processor, and analyzed and checked for spikes in the data that can possibly create false anomalies. The personnel test was conducted at the beginning of the survey operation for each workday.

3. **Cable Shake Test:** On a daily basis, the instrument coils/sensors for those instruments being used that day were checked for their response to vibrations in the cables. The response was observed in the field for immediate corrective action, transmitted back to a processor, analyzed, and checked for spikes in the data that can possibly create false anomalies. The cable shake test was conducted at the beginning of the survey operation for each workday.

4. **Static Background and Static Spike:** Static tests were performed by positioning the survey equipment within or near the survey boundaries in an area free of metallic response and collecting data for a 3-minute period. During this time, the instrument was held in a fixed position through the use of a stand made out of PVC pipe. The static tests consisted of one minute without a spike (known standard), one minute with a spike (a wood board fitted to the bottom coil with a bolt secured through the center), and then one minute without a spike. The purpose of the static test is to determine whether unusual levels of instrument or ambient noise exist. The static background and static spike test were conducted at the beginning and end of each grid block (see figure 13).

Figure 13: Static spike with coil stand and wood spike board

5. **Latency Test:** A 10 meter long single survey line was established in a convenient location near the grid with a test item placed at approximately 5 meter. A line of data was collected back and forth along the test line prior to and following the collection of each grid block to demonstrate consistency in instrument performance (both response and positioning) throughout the course of the survey.

6. **Repeat Data:** This test is performed to verify repeatability of the data and was performed after the initial survey over an area. At least 2% of the survey lines were repeated and evaluated for consistency.

7. **Six Line Test:** This is a standard response test consisting of a pre-determined route (survey line) on or near the site in an area free of metallic contacts. The beginning, midpoint, and end of the line were marked; data was collected along the line. The line was traversed a total of six times as follows: 1) normal data collection speed without a spike at the center point; 2) normal data collection speed without a spike at the center point; 3) normal data collection speed with a spike at the center point; 4) normal data collection speed with a spike at the center point; 5) fast data collection speed with a spike at the center point; 6) slow data collection speed with a spike at the center point (speed of data collection will also be evaluated as part of the GPO analysis process.) The Six Line Test was conducted the first time a system was used at the site.

5.2 QC Test Results

QC data were evaluated using Geosoft's QA/QC software. Static, cable shake, and personnel test profiles were plotted with an acceptance criterion of ± 2 mV from the mean. Any readings outside this range were flagged on the profiles and an associated failure percentage was reported. The following provides a summary of the QC results:

1. **GPS QC:** All daily checks of GPS accuracy were within 4 inches (10 cm) and were recorded in the MRP Enterprise hand-held data logger.
2. **Personnel Test:** No deviation from background response was observed.
3. **Cable Shake Test:** No spikes were observed in any of the tests.
4. **Static Background / Spike Test:** Most static and spike tests were well within acceptance criteria; stable, repeatable, and without spikes.
5. **Latency Test:** Latency tests were plotted showing the line path and gridded response. A comparison of tests shows that response amplitudes are consistent and test item positions are accurate.
6. **Repeat Data:** Repeat lines generally showed good repeatability. Discrepancies in repeat lines were often a result of line path deviation.
7. **Six Line Test:** Latency corrected profiles were plotted to evaluate the effect of movement speed on response repeatability and positioning accuracy. Both amplitude and positioning were within tolerance.

During the first week of DGM, the personnel, cable shake and static tests had some data spikes due to the instrument movement during the tests. This problem was identified and corrected through the use of a coil stand and a wood board fitted to the coil with a bolt through the center. Also, lightning caused some spikes but these were noted by the field crew and entered into the MRP Enterprise database. On the one occasion suspected lightning spikes caused the failure of a static test but the operators failed to take notes and the grid block was remapped the following day.

6.0 CONCLUSIONS

The geophysical survey successfully investigated 97.2 acres of the originally proposed 300 acres within the former VNTR. These 97.2 acres constitutes an excellent representation of the roads and beaches throughout the VNTR. This information will allow for reasonable prediction of MEC throughout the remainder of the 300 acres.

Considering the results of the geophysical investigations in the LIA, SIA, EMA and ECA, the greatest density of subsurface metal is concentrated in the LIA. These concentrations clearly decrease toward the west through the SIA, with the lowest levels of metal contamination found in the EMA. This pattern is consistent with historical documentation of the VNTR. The LIA was used most extensively for training with numerous hard targets fired upon from both land and air.

Within the SIA, ECA, and EMA discrete targets were identified that can be reacquired and intrusively investigated. A significant portion of the area mapped within the LIA produced anomalous geophysical response to great to identify individual targets for intrusive investigations. These areas were identified as SRA's and will require an alternative method of remediation.

Near the end of the geophysical survey effort, four different beaches were re-mapped to determine if storms and common wind driven wave action had any impact on the previously selected targets of those beaches. The data was provided to CH2M HILL for detailed analysis. Field observations, such as MEC visibly moving in the surf zone and significant changes in beach morphology recognized from one visit to the next, suggests a high potential for MEC re-distribution over time.

Access to beach survey areas remained a continuing challenge throughout the project. Initially the plan was to access many of the isolated beaches by boat. Due to incidents unrelated to the geophysical survey regarding access to the beaches by boat, it was determined that the only safe way to transport personnel and equipment was by land. Accepting that the beaches must be accessed by land, future investigation should plan for the additional vegetation clearance required to gain this access in advance of the geophysical survey.

Appendix E
Aerial Magnetometer Survey Report

HeliMag Survey Report
Aerial Magnetometer Survey

Former Vieques Naval Training Range (VNTR)
Vieques, Puerto Rico

Contract No. 930425

Prepared by:
Sky Research, Inc.

Prepared for:
CH2M HILL

June 26, 2009

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EXECUTIVE SUMMARY

This survey report documents the acquisition, processing, analysis, and interpretation of the Helicopter Magnetometry (HeliMag) survey that was performed in support of the Expanded Range Assessment and Phase II Site Inspection of the Former Vieques Naval Training Range (VNTR) at Vieques, Puerto Rico. The explicit purpose of this project is to identify areas containing high densities of ferrous metallic objects on the surface (under vegetation canopy) and/or subsurface that might contain munitions related material, including unexploded ordnance (UXO), and range related targets. The overall objective of the aerial magnetometer survey (AMS) was to identify any existing Areas of Interest (AOI) to assist in prioritizing munitions response actions at the former VNTR. Results of the AMS are not intended to be used for eliminating areas from the possibility of containing munitions and explosives of concern (MEC).

Sky Research, Inc. (SKY) personnel mobilized to Vieques on November 12, 2008, with the helicopter having arrived on island the day before. Data acquisition started on November 14, and finished, including re-flights, on December 20. A total of 15,531 acres of survey data were collected at an average of 518 acres per survey day. Production was interrupted for 6 days due to unscheduled aircraft maintenance. Due to logistical difficulties gaining full coverage with the Real-Time-Kinematic Global Positioning System (RTK-GPS) radio link, some small gaps in survey coverage were unavoidable. The total area affected was less than 15 acres.

Although the HeliMag system performed properly, site conditions with respect to geologic response and survey altitude presented limitations for detection of magnetic anomalies over much of the area, other than the shallow water the near-shore areas. The analysis of suspected Elevated Anomaly Density Areas (EADAs) was performed by an experienced geophysicist. The Helimag survey did not differentiate the source of the anomalies (i.e., munitions items, munitions target areas 55-gallon drums, vehicles, tanks). In addition, based on the detection limits of the equipment, the size of the anomalies detected are associated with items (or groupings of items) larger than a 55-gallon drum or 155mm munitions projectile.

This analysis identified a total of 46 EADAs. These EADA's were prioritized based upon factors such as survey altitude, apparent geologic response, evidence of large, distinct anomalies (LDA's) and features present in the ortho-photography. Where appropriate, an advanced analysis technique, based upon derived target dipole features, was used to supplement the geophysicist's analysis. This technique is assumed to be more reliable for areas flown at relatively low survey altitudes, including most of the areas identified as 'water' areas. In these areas, the statistical distribution of the derived dipole angle relative to the Earth's field is used to identify areas of suspected MEC activities.

As more information is discovered through ground inspection of the EADA's and individual anomalies, the analysis of the data presented may be refined and improved. Of particular interest is identification of a number of targets that may or may not be due to geology. It is possible that, given sufficient ground truth, derived dipole features may be used to improve discrimination between anomalies of geologic or anthropogenic origin.

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ACRONYMS AND ABBREVIATIONS

3D	3-Dimensional
A/D	Analog to Digital
AGL	Above Ground Level
AMS	Aerial Magnetometer Survey
AMSOP	Aerial Magnetometer Survey Operations Plan
AOI	Area of Interest
cm	centimeter(s)
Cs	Cesium
DAD	Dipole Angle Distribution
DAS	Data Acquisition System
DGM	Digital Geophysical Mapping
EADA	Elevated Anomaly Density Area
FBO	Fixed Base Operator
FPGA	Field Programmable Gate Array
GPS	Global Positioning System
HeliMag	Helicopter Magnetometry
Hz	Hertz
IMU	Inertial Measurement Unit
IVS	Instrument Validation Survey
lb	pound(s)
LDA	Large, Distinct Anomaly
LiDAR	Light Detection and Ranging
MEC	Munitions and Explosives of Concern
m	meter(s)
mm	millimeter
m/s	meter(s) per second
nT	nanotesla
OP1	Observation Point 1
PPS	Pulse Per Second
QC	Quality Control
RTK GPS	Real Time Kinematic Global Positioning System
SKY	Sky Research, Inc.
S/N	Signal to Noise
TMF	Total Magnetic Field
UTM	Universal Transverse Mercator
UXO	Unexploded Ordnance
VLS	Validation Lane Survey
VNTR	Vieques Naval Training Range
VQS	Antonio River Rodriguez Airport
WAA	Wide Area Assessment

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1. INTRODUCTION

This report describes the airborne geophysical survey utilizing helicopter magnetometry (HeliMag) that was performed in support of the Expanded Range Assessment and Phase II Site Inspection of the Former Vieques Naval Training Range (VNTR) at Vieques, Puerto Rico. This work was performed by Sky Research Inc. (SKY), under contract to CH2M HILL on behalf of the Department of the Navy, Naval Facilities Engineering Command Atlantic. This survey included the collection of HeliMag data, which provides efficient low-altitude digital geophysical mapping (DGM) capabilities for ferrous metal detection and feature discrimination. This document summarizes the technology, data collection, processing, analysis, and quality control (QC) activities associated with the survey. The Aerial Magnetometer Survey Operations Plan (AMSOP) (Sky Research, 2008) described the data collection procedures, QC specifications, data processing and target analysis process for the survey.

1.1. Background and Objectives

The explicit purpose of this project is to identify areas containing high densities of ferrous metallic objects on the surface and/or subsurface. At the former VNTR an area of interest (AOI) that might contain munitions-related metallic material and explosives of concern (MEC), including unexploded ordnance (UXO), MEC, and targets. The survey did not differentiate metallic anomalies associated with munitions related material from other manmade ferrous metallic objects such as drums, fences, tanks and buildings. Also, the magnitude and extent of the anomalies detected may have been affected by the altitude of the magnetometer survey and ferrous geologic conditions. The overall objective of the aerial magnetometer survey (AMS) is to identify any existing AOI to assist in prioritizing munitions response actions at the former VNTR. Results of the AMS are not intended to be used to eliminate areas from the possibility of containing MEC.

1.2. Scope of Work

SKY performed 100% coverage surveys over accessible areas for the detection of surface and subsurface ferrous material consistent with possible MEC items of interest. These data were used to characterize the site with respect to the density distribution of ferrous material across the site. Following completion of data collection activities, processing, analysis and target picking were performed to identify areas of interest. The results of the analysis and assessment are presented in this report. Geophysical maps have been prepared to visually represent the results and identify the areas that may require further investigation and clearance.

1.3. Site Location and Description

Vieques Island has a land area of approximately 33,000 acres, and is located in the Caribbean Sea approximately 7 miles southeast of the eastern coast of the main island of Puerto Rico (Figure 1). The former VNTR facilities are located on the eastern one-third of the island. The aerial survey area is presented in Figure 1.

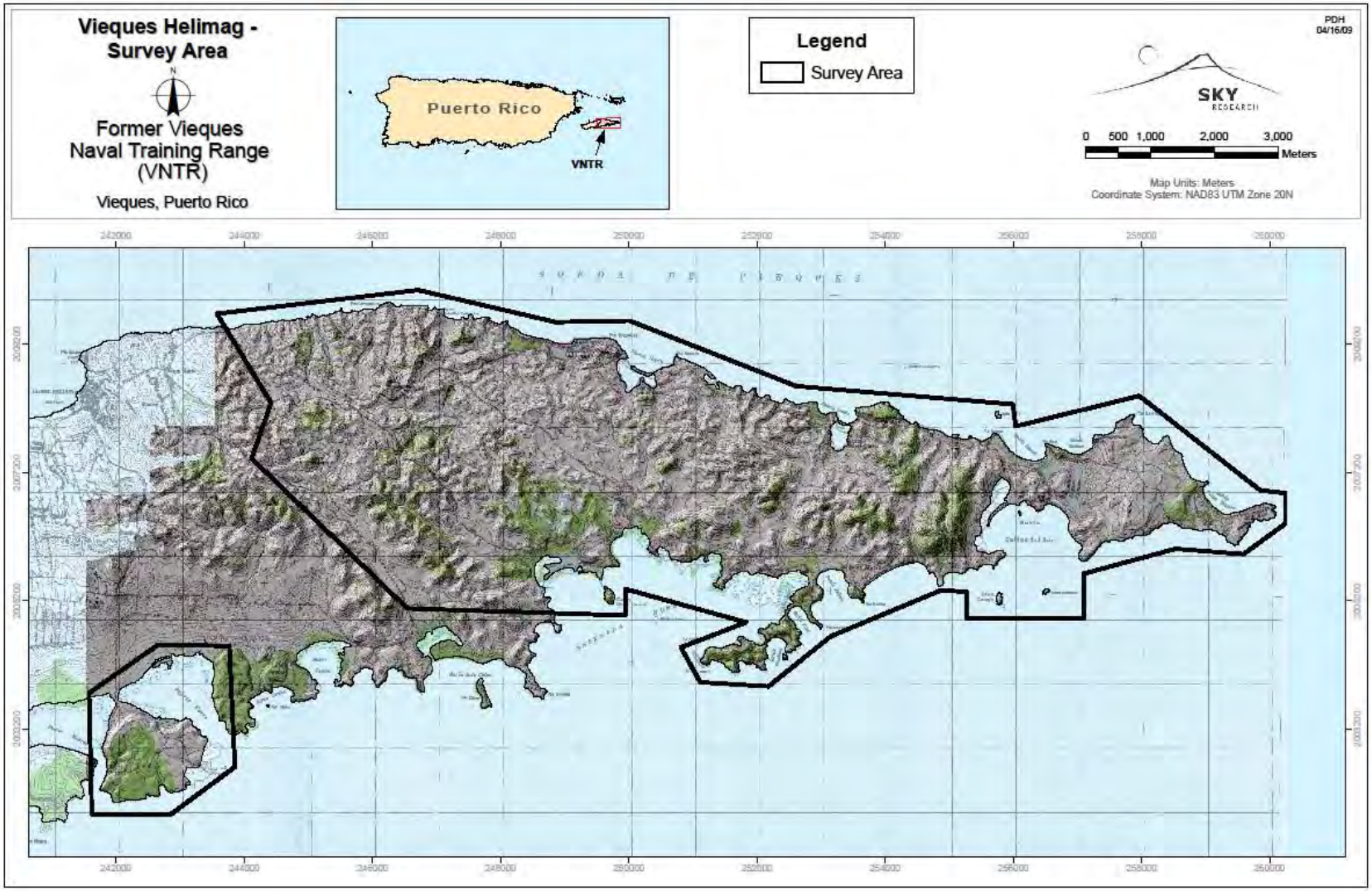

Figure 1. Site map and HeliMag data collection area at the Former VNTR

2. EQUIPMENT AND METHODOLOGY DESCRIPTION

The HeliMag system includes a helicopter-borne array of magnetometers and system specific hardware and software designed to process data and perform physics-based analyses (Table 1). These technologies are described in greater detail in the following subsections.

Table 1. Sky Research HeliMag Technology Components

Technology Component	Specifications
Geophysical Sensors	7 Geometrics 822 cesium vapor magnetometers, 0.001 nanotesla (nT) resolution
GPS Equipment	2 Trimble MS750 GPS receivers, 2-3 centimeter horizontal precision
Altimeters	1 Optech laser altimeter and 4 acoustic altimeters, 1 centimeter resolution
Inertial Measurement Unit	Crossbow AH400, 0.1 degree resolution
Data Acquisition System	SKY Data Acquisition System
Aircraft	Hughes MD530F

2.1. System Components

2.1.1. Helicopter Survey Platform

SKY uses a Hughes MD530F helicopter (Figure 2) for data collection. The helicopter platform deploys the geophysical sensors, global positioning system (GPS) equipment, altimeters, inertial measurement unit (IMU), and data acquisition system (DAS) technologies listed in Table 1.

An onboard navigation display (Figure 3) supported by a navigational computer provides pilot guidance. The computer delivers real-time kinematic global positioning system (RTK GPS) data streams to both the pilot display and the DAS. On the pilot display screen, the survey course is plotted in real time. The sensor operator monitors the DAS display presentation which shows the data quality for the altimeter and GPS and the GPS navigation fix quality. Via limited communication between the pilot and sensor operator, the pilot is able to respond to both visual cues on the ground and to the survey guidance information.

2.1.2. Sensors and Boom

The airborne HeliMag system hardware includes an array of seven DAS-interfaced cesium (Cs) vapor total-field magnetometers (a variant of the Geometrics 822 sensor, designated as the Model 822A) mounted in a Kevlar boom affixed to the helicopter. The sensor boom is mounted forward of the helicopter to minimize interference from the

aircraft rotor blades, engine components, and avionics. This design puts the boom in clear view of the pilot allowing precise, safe low-level flying. The boom is 9 meters (m) long and the sensors are mounted 1.5 m apart. Two GPS receivers (see next section) are mounted at either end of the boom and allow the magnetometer data to be precisely positioned.

2.1.3. Positioning Technologies

Two Trimble MS750 RTK-GPS receivers provide real-time position updates (at 20 Hertz [Hz]) and platform attitude updates (at 10 Hz) while four acoustic altimeters record platform altitude. The GPS receivers provide positions with a horizontal accuracy of ~2 centimeters (cm) and a vertical accuracy of ~4 cm. The GPS satellite clock time is used to time-stamp position and sensor data, allowing seamless merging of these asynchronous data streams.

In addition to serving as the platform velocity and positioning method, RTK GPS is also used to compute ground survey positions. Procedures for GPS measurements are overseen by an in-house professional land surveyor to ensure that geospatial data maintains accurate ties to the local coordinate system(s).

Figure 2. Helicopter platform and sensor boom used for the VNTR survey.

Figure 3. The airborne helicopter data acquisition system is mounted in the back seat of the helicopter. The track guidance system provides flight traverse information to the pilot.

2.1.4. Data Acquisition System

The DAS for the helicopter is made up of two primary components: 1) the Linux CerfCube and Field Programmable Gate Array (FPGA), which provide the timing and controlling procedures for the platform sensors, and 2) the magnetometer power distribution unit, which provides clean 28-volt power for the magnetometer Larmor frequency counters. A Panasonic Toughbook Tablet PC laptop operated by the sensor operator controls the CerfCube/FPGA and is used to start and stop surveys. In addition, it displays sensor data in graphical and numerical formats.

All data are time stamped to 10-microsecond accuracy, slaved to the pulse per second (PPS) input from the GPS, ensuring a rigorous master-slave relationship between the positioning and sensor subsystems. This precision results in constant, unambiguous synchronization of the GPS positions and sensor readings, which facilitates precise positioning of the sensor data. The system has eight serial ports, eight frequency counters, and seven 16-bit analog-to-digital (A/D) converters. The DAS supports fully-adjustable data collection parameters to optimize data resolution and sampling rates for various deployment needs.

The magnetometer data are acquired at 400 Hz and then decimated to 100 Hz, providing a nominal down-the-track sample interval of 0.15 m at a standard survey speed of 15 m/second (m/s).

2.2. AMS Survey Activities

Survey altitude is a critical parameter for this type of investigation as the ability to detect objects of a given size is dependent upon the survey altitude above the object. Therefore, the objective for any HeliMag data collection survey is to maintain a safe altitude while still supporting a significant level of detection. Under ideal topographic and vegetation conditions, survey data are collected at a nominal sensor altitude of 1 to 3 m above ground level (AGL). Rugged topography and tall vegetation cover can present significant challenges to the collection of low-level survey data. Flying at extremely low altitudes above the ground is much more challenging than conventional helicopter surveys. Although the helicopter can hover, the 'lift' available to a helicopter in a hover is significantly less than that available when the helicopter is traveling faster than its 'translation' speed (i.e., the speed at which the aircraft is gaining additional lift from its forward speed). During HeliMag survey operations a minimum speed must be maintained to ensure safety of the aircraft and crew. Maintaining this minimum speed means that the ability to 'drape' the topography/vegetation is compromised in favor of maintaining a reasonable safety margin. Rugged terrain will also result in complex and dangerous wind conditions, thus exacerbating the difficulties of maintaining survey altitudes and adding to the need for airspeed sufficient to maintain a prudent safety margin. The final decision of survey altitude/speed is made by the helicopter pilot. Although the pilot is made aware of the technical importance of maintaining low survey altitudes, it is SKY's policy to never request that a pilot fly at altitudes/speeds below his personal and professional comfort level. Violation of this policy elevates the inherent risk involved in HeliMag surveys to an unacceptable level.

Theoretical survey lines are generated at 7 m line spacing, which allows for significant overlap between adjacent lines so that complete coverage is achieved with a minimal number of re-flights.

Initial data processing is completed daily. Daily processing of the data involves a series of standardized and quality controlled procedures to transform raw sensor data into a geo-referenced total magnetic field data set. SKY utilizes custom application software (SkyNet) to merge the position data with the magnetometer and altitude sensor data. During each day of the survey, the on-site Airborne Survey Geophysicist conducts an initial review of the geophysical data to ensure that these data are within a reasonable range, free from excessive dropouts/spikes and timing errors, and otherwise appear to be valid. These data are then reviewed by the Project QC Geophysicist.

2.3. HeliMag System Quality Control

The QC procedures typically used for the HeliMag system are described in the following subsections.

2.3.1. Instrument Validation Survey Lane

An Instrument Validation Survey (IVS) test lane is used to validate the system response prior to the commencement of data acquisition as well as daily monitoring of system performance. The IVS test lane is comprised of a number of targets of interest or suitable surrogates emplaced along a line approximately 500 m long that may be conveniently flown at the start and end of each survey day. Precise 'ground truth' location measurements, made using established surveying techniques, are used to assess the performance of the system with respect to accuracy of detected target positions.

2.3.2. Instrument Standardization

To document the proper operation of the sensors and data processing, the Airborne Survey Geophysicist performed the following QC checks and procedures. These tests documented the functionality of the airborne survey equipment and monitored the instruments for noise, stability, and repeatability.

2.3.2.1. Validation Lane Test

The IVS is surveyed twice daily for testing and verification of system performance. In addition, the IVS is surveyed after any sensor changes that are required during a day's survey activities.

2.3.2.2. Equipment Warm-up

Most geophysical instrument readings drift for a couple of minutes after starting up. All sensors are allowed to warm up for at least 10 minutes prior to testing or data collection. Each time the instrument is started (e.g., at the start of the day, after breaks, refuelling, etc.), this procedure is followed.

2.3.2.3. Record Sensor Position

Proper sensor geometry is important to the spatial registration of data during processing. The sensor positions relative to the helicopter and master GPS antenna are measured and recorded prior to the survey system installation. These spatial relationships remain fixed. At the beginning of the survey, the field crew performs a spike test under each sensor to ensure that the sensors cables are connected to the appropriate data input channel. This test is repeated every time the system is disassembled and reassembled.

2.3.2.4. Standard Logs

All field and data processing activities are reported. The following reports are generated:

Validation Lane Survey Log: This log documents the results from the Daily Validation Lane Flights and QC checks. Validation Lane Survey (VLS) logs are prepared and delivered on a daily basis during the deployment.

Data Acquisition Log: This log documents information about each survey event and summarizes crew, equipment, filenames, and surveyed areas. It is updated and delivered on a daily basis.

Data Processing Log: This log documents by sortie the data processing steps performed as well as visual and statistical data quality checks. It is updated and delivered on a daily basis. The tracking sheet incorporates the sortie tracking information, as well as the processing steps and output.

2.4. Data Processing and Interpretation

Data are downloaded via computer disks and uploaded via the Internet after each survey mission. SKY's custom in-house software call SkyNet is used to transcribe, filter, decimate, and position the airborne geophysical data. The output from SkyNet is an ASCII xyz file that can then be imported into the Geosoft Oasis Montaj geophysical ,processing environment. Oasis is used to visualize the data and apply advanced processing where required. The SkyNet/Montaj combination facilitates data review, merging, correction, filtering, interpolation, and target picking while also providing an industry-standard data management system. The advanced analysis of all detected HeliMag anomalies is conducted with the UXOLab software package, which is a validated, UXO discrimination package developed jointly by SKY and the University of British Columbia. The following sections describe the processing and QC steps that were used for data processing and analysis. The Data Analysis Log (Appendix D) documents the parameters used and statistics from the review and processing steps.

2.4.1. Data Transcription/Merge

The raw data are transcribed from their native data file formats into ASCII xyz files using SkyNet. At this point, the geophysical data are subjected to a lowpass/notch filter and decimated to a sample rate of 100 Hz and assigned 3-dimensional (3D) positions based upon the GPS master antennae position, aircraft attitude, and the system geometry. Each magnetometer reading is positioned in three dimensions by interpolating and translating the master GPS antenna position to a position for each sensor, based upon the system geometry and attitude. Because the geophysical and position data are collected asynchronously, they must be aligned with respect to their time of applicability. This is performed automatically during the merge process based upon highly precise time stamps associated with each data channel.

2.4.2. Initial Data Review/Processing

The Data Processor performs the initial review of the geophysical data. If problems exist, the Data Processor notifies the Airborne Survey Geophysicist. The Airborne Survey

Geophysicist assesses the problem(s) and makes adjustments to the field operations or data processing as needed to ensure quality data collection. The sections below detail the initial review of each data type.

2.4.2.1. Geophysical Data

The initial review of geophysical (magnetometry) data ensures that the data are within a reasonable range (35,000 – 75,000 nanoteslas [nT]), are free from dropouts/spikes, and timing errors and otherwise appear to be valid. Invalid data are removed and, where appropriate, requests for re-flights are passed to the acquisition team.

2.4.2.2. Positional Data

The initial review of positional data involves checking line profiles for position dropouts/spikes. A GPS fix quality indication is recorded as part of the GPS data string. Data tagged with a fix status that indicates the GPS was not operating in 'RTK-fix' mode (nominally 2 cm level accuracy) are rejected automatically.

2.4.3. Site Specific Processing

After the initial data review described above, the data follows a site-specific processing procedure, as discussed below.

2.4.3.1. Sensor Data Filtering

Spatial and/or time based filters are used to remove long wavelength signal from the dataset. Some of the sources of this long wavelength response are diurnal variations, geologic response, sensor heading errors, and aircraft maneuver noise. The specific parameters of the filters are determined by site conditions such as geologic response and survey altitude above ground.

2.4.3.2. Gridding and Visualization

To convert the data into an image map, an interpolation algorithm converts xyz data into an evenly-spaced grid image at 1 m intervals. The Data Processor reviews the grids to determine the completeness and accuracy of prior data manipulation steps. A color distribution range is selected to accentuate the areas/anomalies of interest. The same color scheme is used for each block in order to avoid confusion and to enhance the ability to easily compare the anomaly densities across the site.

2.5. Data Interpretation and Analysis

HeliMag data are used in UXO investigations to characterize a site with respect to the distribution and character of detected ferrous material. Limits to the detection performance imposed by the sensor stand-off distance, physical obstacles and geologic responses limit the size and density of metallic items that can be detected. Anomaly

density maps are used to augment existing knowledge about historical site usage to provide a preliminary assessment of the location and extent of large munitions related materials to guide future munitions response actions.

These maps can be simple density analyses of all of the ferrous material detected, or they can be 'refined' density maps. Each target can be classified based upon inferred features (e.g., target size, depth, dipole orientation) derived through analysis of the magnetic response of each target. These classifications are used to create subsets of 'targets of interest' that are then used to create the refined density maps.

2.5.1. Anomaly Selection

For each dataset, the Data Processor assesses each of the following factors prior to generating an anomaly list: (a) geophysical response (amplitude) of targets of interest, as measured in the validation lane; and (b) the local geologic/anthropogenic background conditions after filtering.

Based upon the site conditions, the Data Processor elects to select targets using automated or manual techniques. Under most conditions, automatic picking algorithms perform well; however, in areas with challenging background magnetic response or a great deal of anthropogenic clutter, manual selection techniques are required. The automated technique uses a 'peak detection' algorithm to select anomalies based upon the magnitude of the geophysical response. Because the total magnetic field response to ferrous material is dipolar in nature, the peak detection is performed on an 'analytic signal' grid derived from the gridded total magnetic field grid. The 'analytic signal' is the square root of the sum of the squares of the derivatives in the x, y, and z directions and thus is monopolar in nature. A manual review of the data and targets is used to locate additional anomalies or to delete anomalies. Anomalies are deleted if they are obviously due to cultural features or are well outside of the size/depth envelopes of the targets of interest.

2.5.2. Target Analysis/Classification

Each selected anomaly is analyzed. The target analysis algorithms have been adapted to run within the University of British Columbia UXOLab software environment developed specifically to conduct target analysis and picking. Within the analysis environment, the processor selects mapped anomalies interpolated from the magnitude-corrected XYZ sensor data points. The software extracts sensor data points associated with the selected target. Each sensor reading is an input datum used in a seven-parameter, iterative calculation to derive the parameter values that describe a dipole model that best fits the observed data. These parameters include dipole position (3 dimensions), dipole angle (2 dimensions), dipole magnitude (size) and an offset parameter to account for any bias in the magnetometer data. These derived dipole parameters are then compared to training datasets developed from inert ordnance to perform target classification (discussed further

in section 3). Final outputs from this step are XYZ points in ASCII format, which have associated dipole parameters and target classification declarations.

2.5.3. Target Density Distribution Analysis

Target density distribution maps represent a final product of the HeliMag data processing. To aid in visualizing the distribution of metallic items across the site, a density raster is computed using a 100 m radius neighborhood kernel that assigns anomaly densities (in anomalies per hectare) to each cell in the raster. The target classification results are used to provide refined target lists and density distributions.

Although it is not possible to determine which specific anomalies are due to the targets of interest, it is possible to refine the list by excluding some anomalies based upon the character or 'features' of the anomaly. Each anomaly is characterized by performing a dipole fit analysis as described in section 2.5.2. The dipole parameters are then used as 'feature' estimates for each target (e.g., the dipole model positions are accurate estimates of the object position and depth of each target). The target list can then be refined by excluding anomalies based upon one or more of these features. Dipole size and orientation with respect to the Earth's field are the most useful features for refining targets lists.

The utility of the dipole orientation relative to the Earth's field is as follows: The magnetic response of ferrous material has two sources, 'induced' magnetism and 'remanent' magnetism. Objects that have undergone mechanical shock (such as ordnance that have been fired) will become demagnetized – i.e., the remanent magnetization is removed. In addition, 'induced' magnetic dipoles are aligned within 75° of the Earth's magnetic field vector, while remanent dipole responses are not similarly constrained. Thus <u>targets with dipole orientations greater than 75° from parallel with the Earth's field can be assumed to have significant remanent magnetization and as such, are not likely to be associated with ordnance usage</u>.

Dipole size is an obvious feature to use to refine the target list. Unfortunately the dipole fit size estimate for any given object will depend heavily on the orientation of the object in question. Figure 4 presents feasibility curves for an example list of items. These curves show how the dipole response for any given ordnance item can vary depending upon its physical orientation with respect to the Earth's field. The dipole response is non-unique for any shape other than a sphere. The maximum moment is achieved when the target is aligned with the Earth's field and the minimum moment is achieved when the target is normal to the Earth's field. (Note the image in Figure 4 depicts the dipole angle, not the physical angle of the object). It is also apparent from this image that multiple ordnance types occupy the same location on the graph, thus they may provide identical responses. Furthermore, there are an infinite number of non-ordnance ferrous objects whose responses may also overlap with responses of the objects of interest. For this reason <u>total magnetic field techniques cannot be used to definitively declare an object as</u>

ordnance. However, to the extent that a given target response does not come close to the feasibility curves of the objects of interest, these features can be used to exclude these targets from the refined target list.

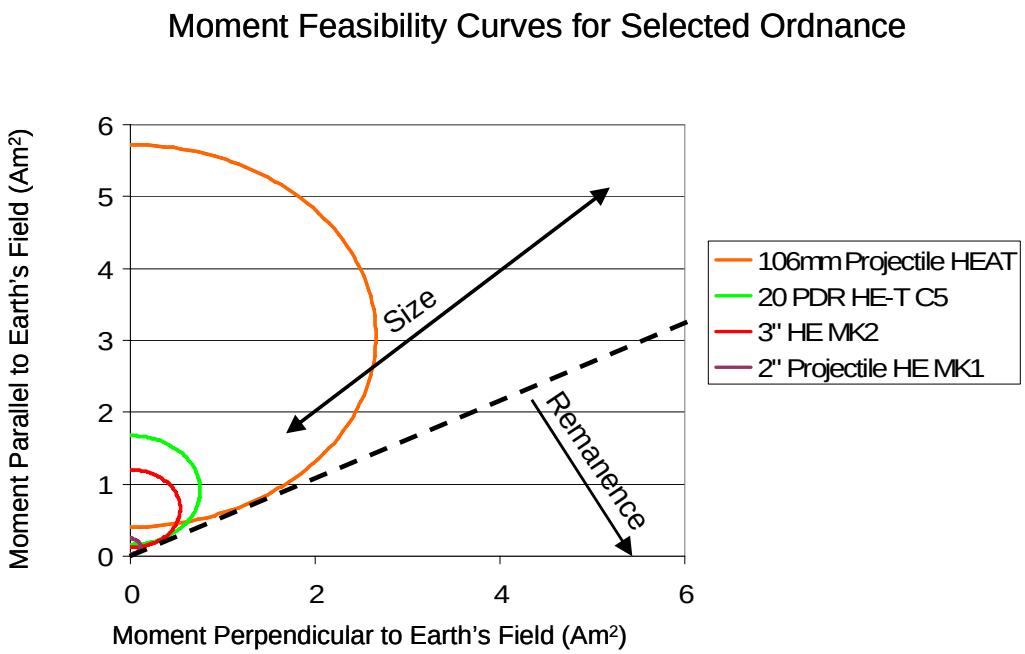

Figure 4. Dipole response feasibility curves. The predicted dipole moment for given UXO types are plotted relative to the Earth's magnetic field vector. Dipole response angles greater than 75º indicate the presence of remanent magnetization. Note that the dipole angle presented here, although related, does not directly represent the physical angle of the object.

3. DATA ACQUISITION

The data collection effort was carried out in accordance with the AMSOP developed during the planning phase prior to mobilization to the site. The following sections describe in detail the data acquisition, including mobilization, initial validation lane testing, and survey data acquisition activities and challenges.

3.1. Mobilization

SKY personnel mobilized to the site on Nov. 12, 2008. The helicopter was reassembled, the HeliMag system was installed and the validation lane was established and flown on November 13 and 14. Data acquisition started on Nov. 14 and was completed, including re-flights, on Dec. 20.

3.2. Base of Operations

The Helicopter was based out of Antonio River Rodriguez Airport (VQS), in the middle of the Island of Vieques and daily operations (refueling and crew changes) made use of the facilities at Camp Garcia. Fuel was procured from the Fixed Base Operator (FBO), Million Air San Juan (Million Air) based at the VQS Airport. Million Air also provided a 2,200 gallon fuel truck to allow refueling at Camp Garcia.

The main GPS base station was set up at the top of the observation facility located at Observation Point 1 (OP1) to optimize the GPS radio link coverage across the site. Mobile radio repeater stations were used to fill in ‘shadows’ in the main radio signal. Base station coordinates in WGS84 Universal Transverse Mercator (UTM) Zone 19 are:

Northing:	2006232.48 meters
Easting:	254863.58 meters
Height above Ellipsoid:	133.48 meter

3.3. Instrument Validation Survey

The initial IVS was conducted over two validation lanes established by CH2M HILL personnel at the eastern end of the site. Data collected over these lines were used for initial instrument validation as well as daily monitoring of the system performance.

3.3.1. Validation Lane Description

The validation lane was located near the eastern tip of the main survey area. The Lane was originally seeded with representative 155 millimeter (mm) and 5 inch projectiles, placed at various orientations and groupings as listed in Table 2. All targets were placed on the surface.

Table 2. Validation Lane Seed Items

ID	Type	Orientation (Approximate)	Easting	Northing
IVS-01	155mm Projectile (Practice)	E-W	258887.4	2006413.6
IVS-02	155mm Projectile (Practice)	N-S	258910.1	2006402.3
IVS-03	155mm Projectile (Practice)	Vertical (nose up)	258932.1	2006390.1
IVS-04	Two 155mm Projectiles (Practice)	E-W, N-S	258959.5	2006375.7
IVS-05	155mm Projectile (Base Ejecting)	E-W	258986.6	2006360.7
IVS-06	155mm Projectile (Base Ejecting)	N-S	259016.0	2006344.1
IVS-07	155mm Projectile (Base Ejecting)	Vertical (nose up)	259042.2	2006329.0
IVS-08	Two 155mm Projectiles (Base Ejecting)	E-W, N-S	259073.7	2006338.5
IVS-09	5-inch Projectile (Practice)	E-W	259107.6	2006326.7
IVS-10	5-inch Projectile (Practice)	N-S	259137.5	2006316.3
IVS-11	5-inch Projectile (Practice)	Vertical (nose up)	259168.2	2006306.6
IVS-12	Two 5-inch Projectiles (Practice)	E-W, N-S	259195.1	2006296.9
IVS-13	5-inch Projectile (Base Ejecting)	E-W	259224.1	2006287.9
IVS-14	5-inch Projectile (Base Ejecting)	N-S	259251.9	2006278.7
IVS-15	5-inch Projectile (Base Ejecting)	Vertical (nose up)	259276.9	2006269.1
IVS-16	Two 5-inch Projectiles (Base Ejecting)	E-W, N-S	259304.1	2006260.3

Figure 5 shows the results of data collected at between 1 and 3 m above the targets. The line to the west was unchanged throughout the survey and was used for the daily validation of the system. The items in the line to the east were replaced with larger targets to determine the sensitivity of the system at higher altitudes.

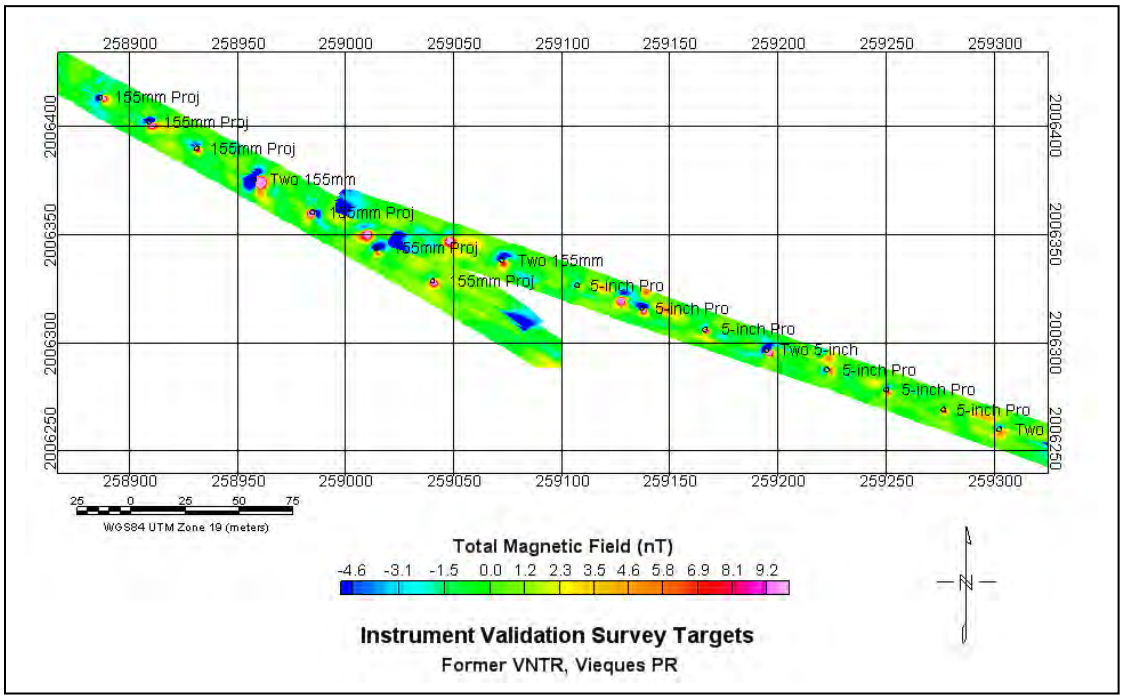

Figure 5. Instrument Validation Survey target responses

3.3.2. Initial Validation Lane Results

One of the purposes of the initial validation survey was to determine the maximum altitude at which the HeliMag system can detect the ordnance of interest. The validation lane was flown at altitudes from 2 to 10 m and the data were analyzed to determine the peak anomaly amplitude. In Figure 6 the results for a representative target show that, assuming a detection threshold of 2 nT, this target is not detectable if the sensor/target separation is greater than 5 m.

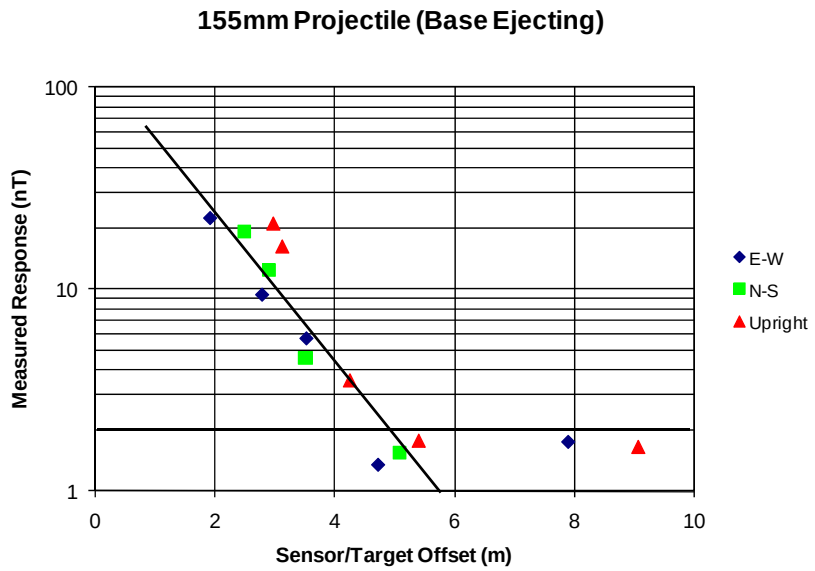

Figure 6. Measured response to a typical 155mm projectile as a function of sensor/ target offset distance.

As data acquisition commenced it became apparent that the survey altitude for much of the area was going to be much higher than predicted during the planning phase. In response, a number of larger targets were placed in the eastern validation lane to test the system response amplitude to these targets at higher altitudes. Figure 7 shows that 55 gallon drums are detectable to 8m and items the size of a Jeep are detectable to 15m.

3.4. Survey Data Acquisition

Data acquisition activities commenced on November 14th and were completed on December 20th. Daily production logs for each data acquisition day are provided in Appendix A. A total of 15,531 acres of survey data was collected. The SKY field team performed the data acquisition as prescribed in the AMSOP where possible. The survey was flown at the lowest altitude possible, consistent with the safety of the aircraft and crew. The survey data quality was monitored on a daily basis in accordance with the QC procedures outlined in the AMSOP.

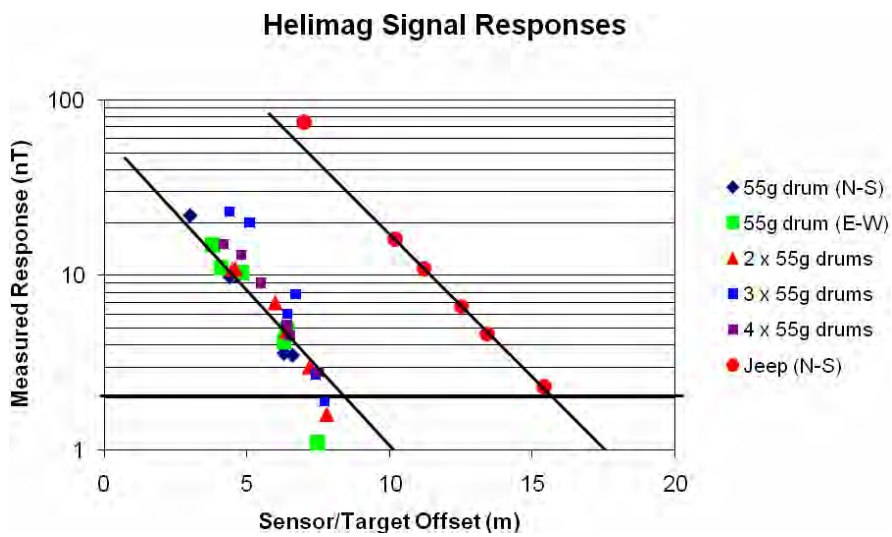

Figure 7. Large target /sensor separation results

3.4.1. Quality Control Results

At the beginning and end of each survey day, flight lines were flown over the validation lane in order to confirm that all system components were operating within required parameters. In addition, two daily high altitude sensor noise tests were performed to guarantee that all magnetic sensors are operating within pre-established threshold limits. The following subsections briefly describe the tests performed. There were two QC 'failures' – both related to the repeatability of the dipole angle estimates. The cause of these failures was traced to poor spatial coverage of the validation lane. These failures were fully analyzed and all other tests indicated no problems with the system performance. There were also several occasions where the end of day QC checks were not performed due to weather/site access or other logistical considerations. These omissions were discussed with the CH2M HILL Project Geophysicist and were agreed to be acceptable because they are beyond the control of SKY and do not indicate problems with the system performance.

3.4.1.1. Validation Lane

The validation lane, described above in Section 3.3, was established to function as an initial instrument validation as well as to validate the proper operation of the system at the start and end of each data acquisition day. The SKY Airborne Survey Geophysicist used the validation lane data 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 a sufficient signal to noise (S/N) ratio to support accurate dipole fit analysis, a model dipole was fit to the observed data. The parameters describing this model are 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 the Validation Lane Positioning and Standardization Report (Appendix C).

3.4.1.2. Lag Test

Accurate positioning of the geophysical data requires that the time of applicability of the magnetometer sensor data is aligned with that of the positioning data. The architecture of the HeliMag data acquisition system is designed to automatically ensure that these data are aligned appropriately. Misalignment of these data results in a recognizable 'herringbone' pattern of distortion where reciprocal passes are flown over the same anomaly. The Validation Lane tests were performed at reciprocal headings and images of the data were inspected to ensure that no apparent lag existed. The results of these tests are summarized as part of the Validation Lane Positioning and Standardization Report (Appendix C).

3.4.1.3. High Altitude Magnetic Sensor Noise Test

Two daily high altitude magnetic sensor noise tests were performed; the first after the initial validation lane flight and the second before the final validation lane flight. These tests are conducted at altitudes where ground source response is negligible for a minimum duration of 20 seconds. The high altitude test results are presented in the Validation Lane Positioning and Standardization Report (Appendix C).

3.4.2. Survey Production

The survey area was divided into sub areas (Figure 8) that were used for daily planning coordination as well as convenient demarcations of survey blocks to keep data processing file sizes within reason. Figure 9 presents a chart used to track the daily production rate of the HeliMag team at the former VNTR. The total area surveyed was estimated during production at 15,545 acres. Due to logistical difficulties gaining full coverage with the RTK GPS radio link, some small gaps in survey coverage were unavoidable. Areas where poor GPS quality persisted after a second attempt at data acquisition were determined to be unsurveyable. The total area affected was less than 15 acres. An additional gap in coverage located over a small island in the 'Water 10 area' was due to the presence of birds on the island. After accounting for these areas, the final deliverable survey area was 15,531 acres. There were 31 survey days which translates to an average production rate of 501 *acres per survey day*. Production was interrupted for 6 days due to unscheduled aircraft maintenance. Thus the average production rate was 420 *acres per day on site*.

Figure 8. Survey areas used for daily planning, coordination, and data handling**.**

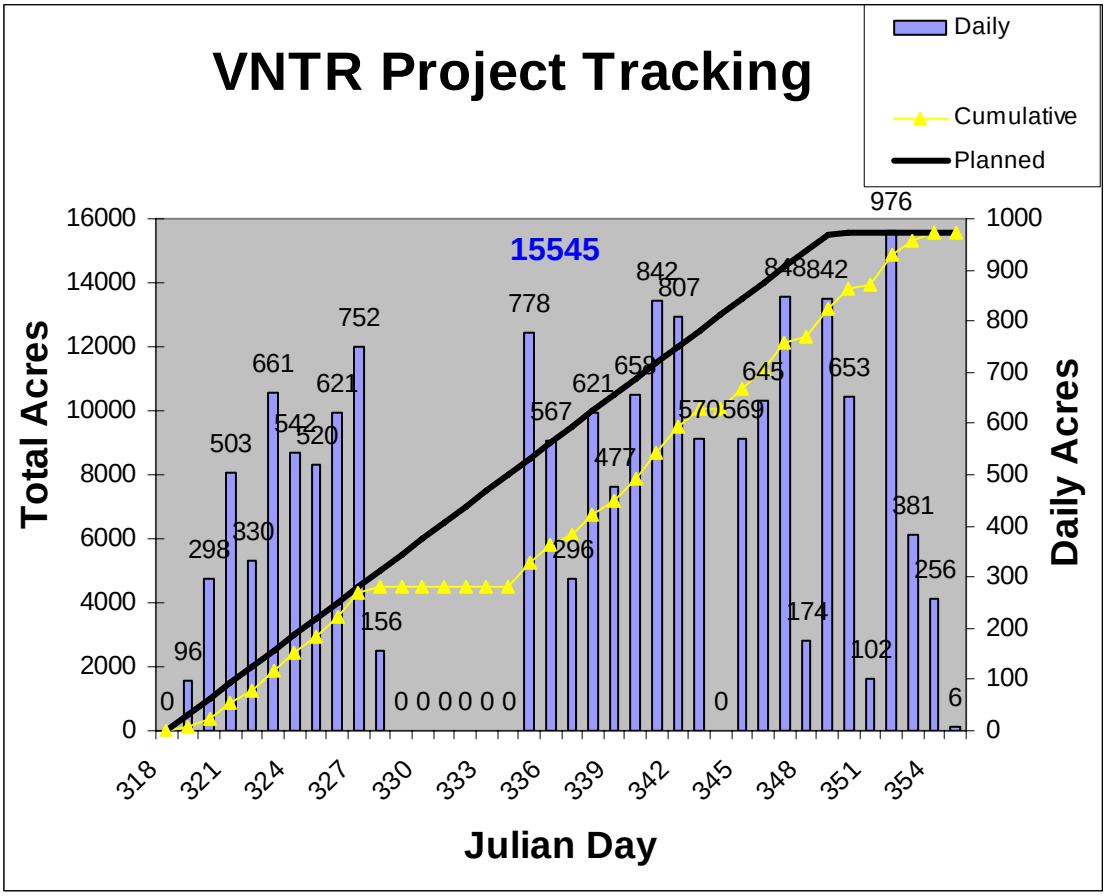

Figure 9 Graph illustrating the survey progress, showing both daily and cumulative acreage.

3.4.3. Data Quality

The quality of geophysical survey data as it relates to the survey objectives is determined by both the intrinsic quality of the instrumentation and methodologies used (as monitored by the QC program described above) as well as extrinsic site conditions that are beyond control of the survey team. During performance of this project, two aspects of the site conditions, the vegetation cover and the localized geologic magnetic response, had detrimental effects on the quality of the survey data.

3.4.3.1. Vegetation Cover

The vegetation cover in the survey area limited the average attained survey altitude to approximately 11m AGL. The ‘water’ areas including area ‘Water 6’ (Figure 8) were generally flown at the planned altitude of 5 meters. Figure 10 (top and bottom) shows the planned survey altitude and the achieved survey altitudes respectively.

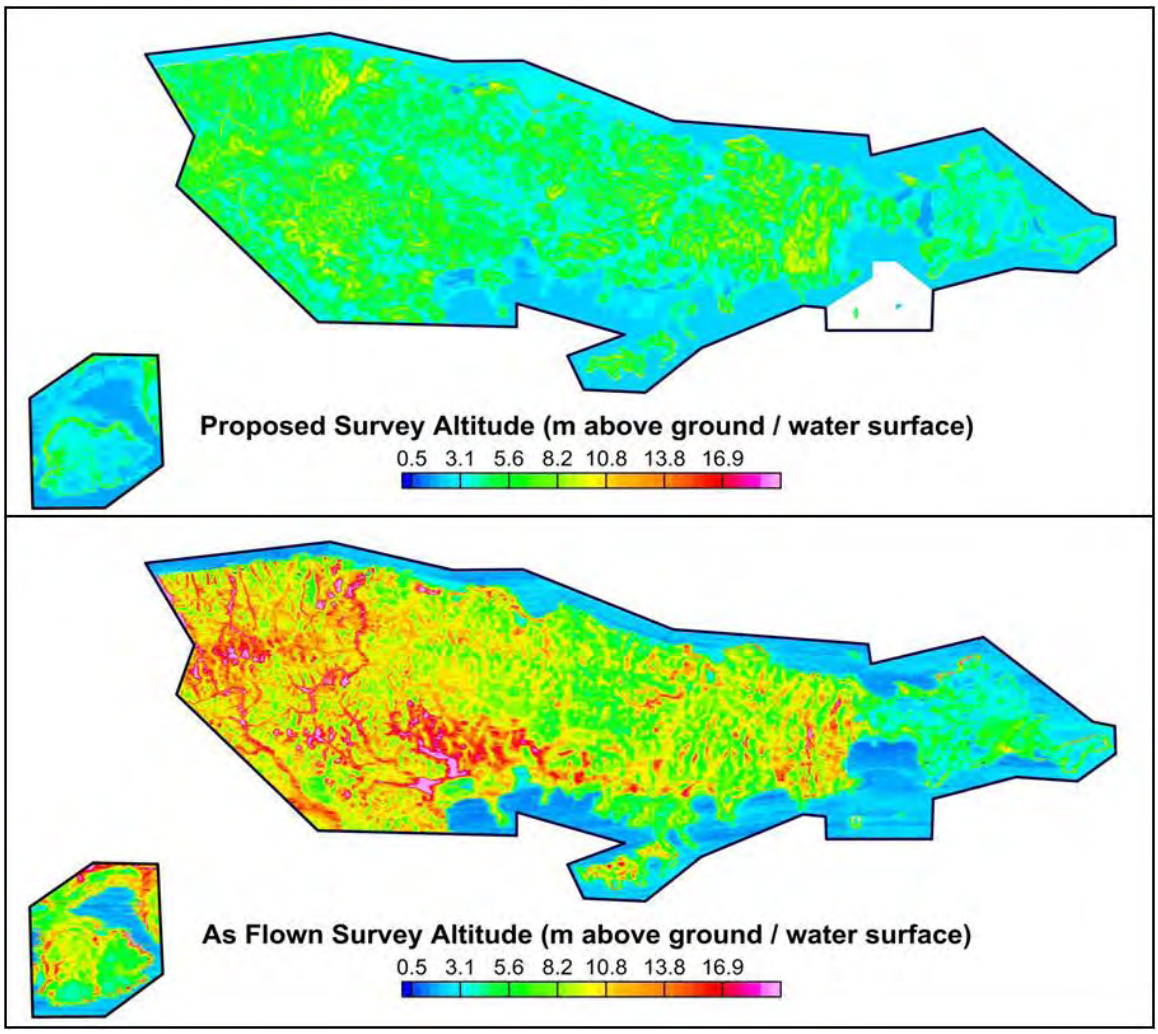

Figure 10. Planned survey altitude (top panel) and survey altitude flown (bottom panel). Vegetation extending above the Light Detection and Ranging (LiDAR)-measured canopy prevented lower survey altitudes.

3.4.3.2. Geologic Response

Some geologic structures will distort the Earth's magnetic field, due to their ferrous content. While most of this magnetic geologic signal is removed from the HeliMag data through the use of a modified 1D de-median filter, localized geologic response occurring at wavelengths similar to that of the targets of interest (i.e. discrete man-made ferrous objects) cannot be removed in this manner. Furthermore, the component of geologic response transverse to the direction of flight is also not removed with this filter. In an effort to reduce the effect of geology on the final analysis of the geophysical data, a 2D filter was applied to the gridded data. This filter effectively removes longer wavelength

geologic features that are transverse to the direction of flight. The results of this filter are presented in section 4.1.2.

The deleterious effects of local geology on the effectiveness of magnetometry for mapping of ferrous material are well known, however in areas like the former VNTR that have marginal geologic response signatures, the magnitude of this effect cannot be predicted prior to collection of data during a detailed magnetic survey.

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4. DATA ANALYSIS

4.1. Data Processing, Enhancements

4.1.1. Data Pre-Processing

As described previously, an initial processing step was completed daily. During this stage, raw data were down-sampled to 100 Hz, reviewed as part of the initial QC, time-aligned, transcribed into a database, and mapped to x, y, and z UTM coordinates accurate to better than 5 cm. The data were positioned in UTM Zone 19 coordinates projected from the WGS84 ellipsoid. After processing, the along-track sample interval was nominally 0.15 – 0.25 m. The maximum across track interval is 1.5 m but, due to the overlap required to ensure complete coverage, the average cross track sample density was significantly higher.

A site-specific 'de-median' filter was applied to the magnetic data to remove unwanted, long wavelength signals (primarily due to geology and diurnal variations in the Earth's magnetic field). Due to the increased survey altitude imposed by the vegetation, the length of this filter had to be adjusted. Figure 11 presents the relationship between filter length and survey altitude. As the survey altitude increases, the length of the de-median filter must also be increased to prevent attenuation of individual target signals. This lengthening of the de-median filter resulted in poorer rejection of both geologic signal and aircraft maneuver noise.

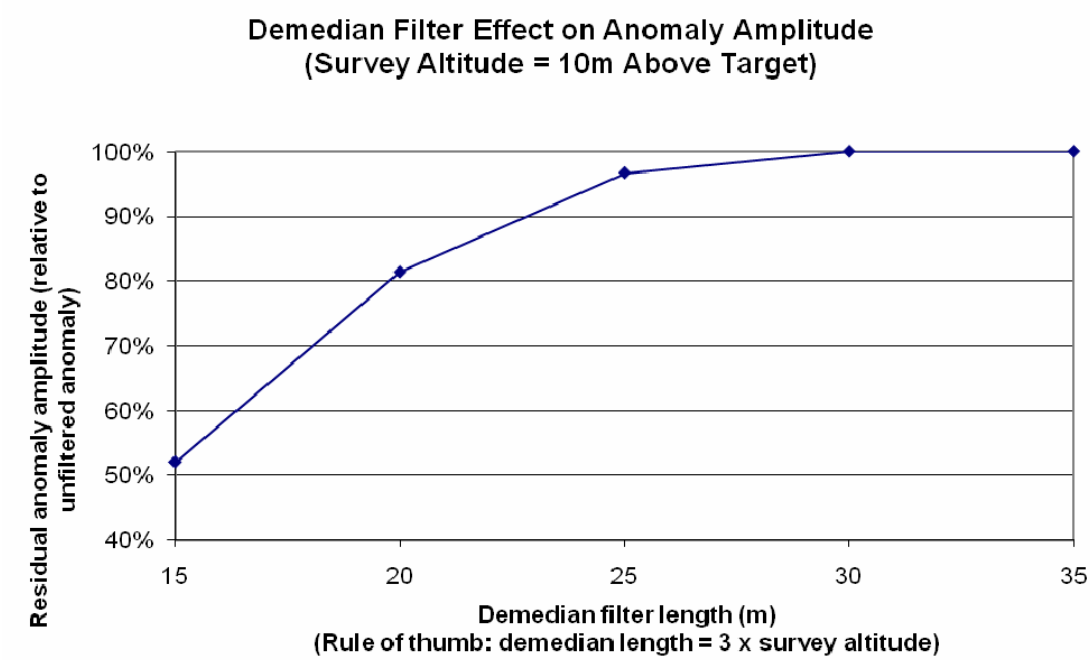

Figure 11. Relationship between filter length and survey altitude

4.1.2. Geology Removal Filter

As discussed in section 3.4.3.2, some of the area surveyed was characterized by magnetically active geology that was not removed with the original de-median filter. An additional 2D filter was applied to the gridded data in an effort to remove the component of the geologic signal transverse to flight direction. Figure 12 presents a qualitative comparison of the gridded data before and after application of the 2D filter.

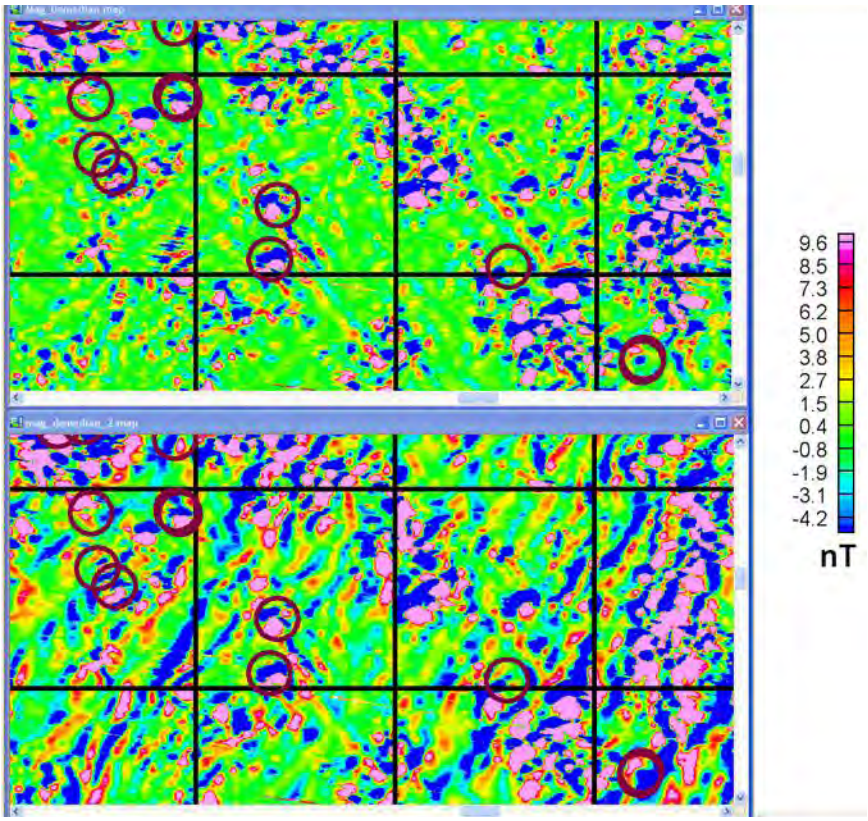

Figure 12. Gridded data before (bottom) and after (top) applying 2D filter to remove geologic signal

4.1.3. Aircraft Maneuver Noise Compensation

Each of the magnetometers on the boom of the helicopter senses not only the magnetic field of the earth, but also distortions caused by the helicopter platform itself. The platform magnetic field is of no interest and can represent a significant noise source. Because the platform magnetic field depends primarily on the attitude of the vehicle relative to the earth's magnetic field, the effects of the platform are often called "heading errors". For low-level surveys for detection of ordnance there is only concern about changes in the magnetic field of the helicopter that have spatial scales comparable to the wavelengths of the items of interest. Thus, the term maneuver noise is preferred. When flying at low ground-clearances (< 5 m) the maneuver noise has a longer wavelength than that of near-surface buried metallic items and can effectively be removed using a high-pass de-median filter. The wavelengths of the maneuver noise and objects of interest start

to overlap at about 5 m above the ground. At the former VNTR, survey heights generally exceeded 5 m due to dense vegetation, thus it was difficult to remove the maneuver noise effects without distorting the spatial response from the targets of interest. To resolve this issue, SKY installed a flux-gate magnetometer in the helicopter and conducted an aeromagnetic compensation calibration.

There are three major components to the maneuver noise in a helicopter:

1. Permanent magnetization: So-called "permanent fields" actually arise from two sources: the permanently magnetized material in the helicopter, and the effects of current-carrying conductors, usually the major electrical feeds in the aircraft. As far as a magnetometer is concerned, these are indistinguishable.
2. Induced magnetization: The induced fields arise because of the interaction between the earth's magnetic field and the magnetically permeable material in the helicopter.
3. Eddy currents: Metallic surfaces of the helicopter act as conductive loops. When the helicopter orientation in the earth's magnetic field changes, so does the magnetic flux contained by these loops, and a secondary magnetic field is generated according to Lenz's Law. Unless the magnetometer is very close to a large conductive surface, these eddy current effects are generally at most a few tenths of a nanoTesla under normal survey conditions.

The first two effects can be modeled with knowledge of the attitude of the helicopter (easily measured with a flux-gate magnetometer), while the eddy current effect requires the rate of change of the helicopter attitude (obtained through the time-history of the flux-gate data).

In order to evaluate the components of the helicopter magnetic field as just described, it is necessary to acquire data in which these effects are enhanced and the interference of other sources, such as geology, is minimized. For this purpose, a compensation flight is performed in an area with low geological gradients. For aircraft, the compensation flight is carried out at as high an altitude as is feasible. The aircraft flies along the four sides of a square surrounding the compensation point, turning sharply at the end of each leg. Along each leg of the pattern, it is desirable to acquire roughly 30 seconds of data while performing each of: yaws of at least 5 degree amplitude, pitches of at least 5 degree amplitude, and rolls of at least 10 degree amplitude.

Finding an area with low geological gradients can be challenging. Fortunately, the ability of the helicopter to hover considerably simplifies the compensation flight process. Instead of flying along the four cardinal directions, the helicopter can simply hover in one spot. At each of four headings, the helicopter executes a series of yaw, pitch and roll maneuvers. The magnetic field data from each sensor, along with the aircraft attitude and altitude are continuously recorded. A well-known 18 term model is then fit to the observed data and defines the maneuver noise characteristics of the helicopter. As shown in Figure 13, the maneuver effects are on the order of ± 25 nT for the outer sensors and ±

150-200 nT for the inner sensors. After compensation, the standard deviation in each of the sensors was around 0.4 to 0.5 nT, with Improvement Ratios (ratio of standard deviations before/after compensation) of between 40 and 220. It is of note that the maneuvers conducted during the compensation calibration flights are much more severe than those generally encountered during data acquisition. Thus the residual signal of 0.4 to 0.5 nT are expected to be well beyond the 'worst case' scenario encountered during the course of the survey.

Figure 14 presents the final, de-median filtered, total magnetic field image that was used as the basis for the anomaly selections.

(a) Outer sensor (b) Inner sensor

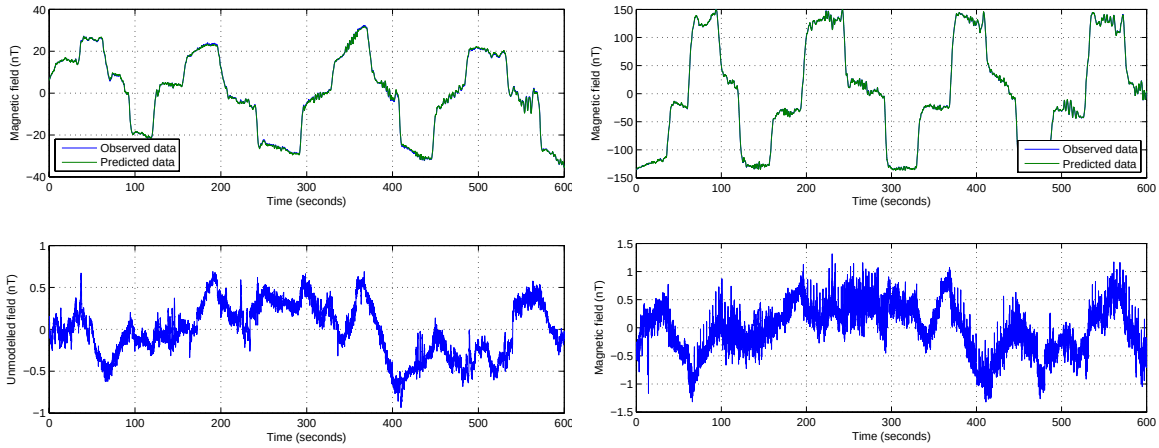

Figure 13. Top panels show the observed and predicted data during the aeromagnetic compensation calibration flight for (a) outer sensor and (b) inner sensor. The bottom panels show the corrected magnetic field data (observed minus predicted data). For the outer sensor the standard deviation was 18.5 nT before compensation and 0.45 nT afterwards (giving an Improvement Ratio of 41). For the inner sensor the Improvement Ratio was 219, with before/after standard deviations of 94 nT and 0.43 nT respectively.

4.2. Anomaly Selection and Density Mapping

4.2.1.1. Anomaly Selection

Anomaly selection for VNTR was challenging due to the high survey altitude, exposure of magnetically responsive geology, and the often rugged terrain. Upon comparing the various target picking methodologies, it was concluded that the auto-picking method (peak detection using the output of Geosoft's analytic signal filter) supplemented with manual target selection provided the best results.

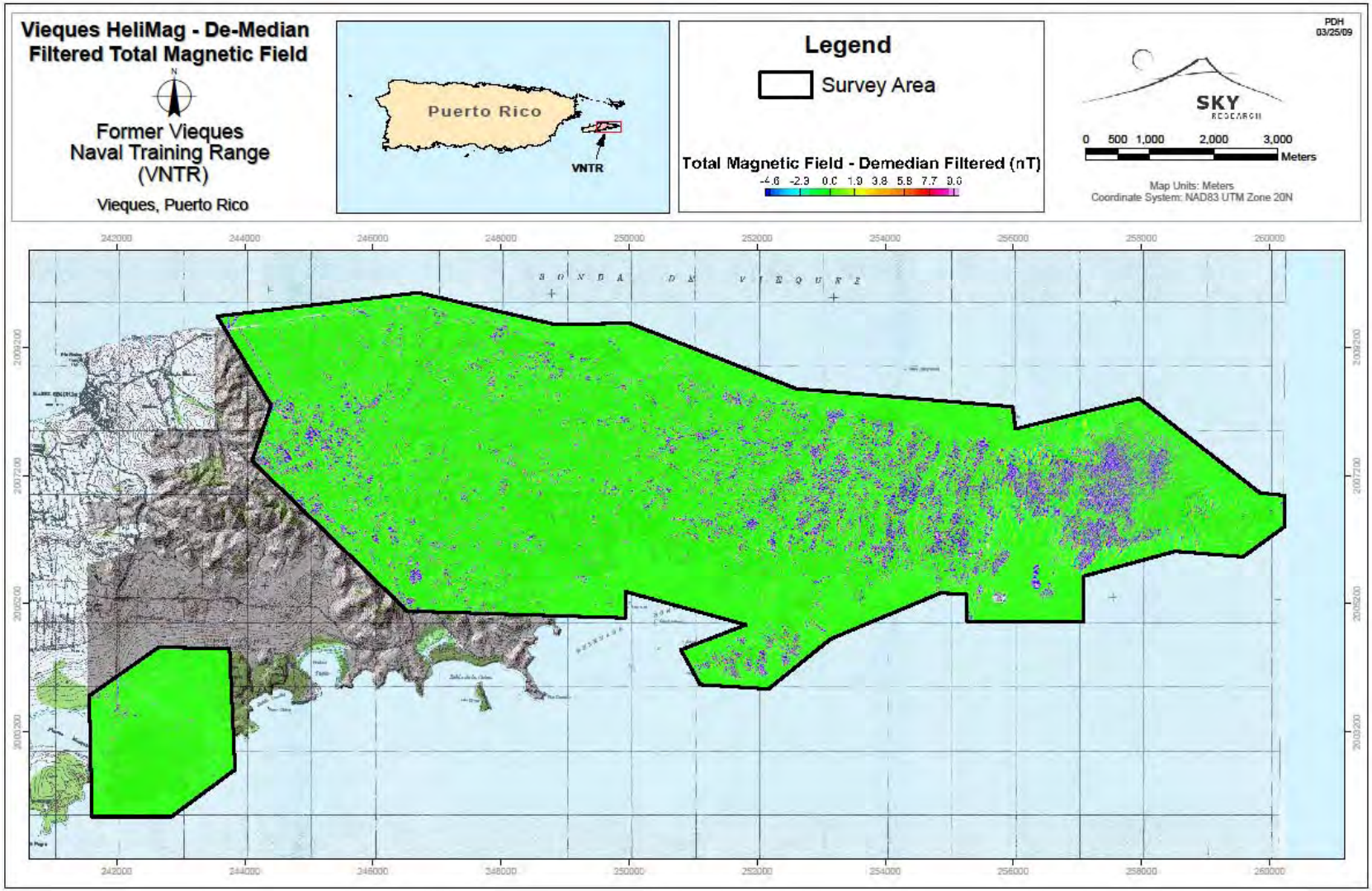

Figure 14. Total Magnetic Field image after applying de-median filter.

The target selection process was performed using Geosoft's Oasis Montaj software. As with all target selection methods, a total magnetic field grid was generated for each area. An analytical signal grid was derived from the total magnetic field grid. After application of two passes of the 3x3 Hanning filter (in order to reduce the number of multiple picks over the same anomaly) all peaks over a predefined threshold were automatically selected. A threshold of 1.25 nT/m was found to maximize the number of valid selections while minimizing the number of false, geology-related picks.

Because the responses to the targets of interest were at times less than the geologic noise levels, additional manual target selections were made by an experienced analyst. In many cases, the analyst can discriminate between valid anomalies and those due to geology. Additionally many of the auto-detected targets that were obviously associated with linear features were removed from the target list. A total of 32,687 targets were initially selected. A list of the final selected targets and their locations is provided in the spreadsheet file 'VNTR Target_Analysis.xls' delivered with the final deliverables data drive as described in Section 6, HeliMag Deliverables.

4.2.1.2. Target Density Mapping

The initial set of anomalies consists of those anomalies potentially due to the targets of interest (i.e. any man-made ferrous material) as well as anomalies caused by localized geology. As alluded to above, a large number of targets were selected in an effort to ensure that all possible targets of interest were selected. The spatial distribution of these targets is presented as density images in Figure 15. These maps are 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.

In general, 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. Site conditions restricting survey altitude and areas of high geologic response at the former VNTR diminish the utility of these 'raw' density maps because they distort the results. Areas with active geology will result in more anomalies related to geologic sources, thus artificially raising the density estimates in these areas. Conversely, areas where the survey altitude is increased due to terrain and vegetation will result in a lower detection rate, thus artificially lowering the density estimates. Although these distortions are mitigated by filtering the geology and masking the data where the survey altitude is too high, these effects cannot be totally removed from the data. Furthermore, attempts to refine these density maps by rejection of anomalies based upon features derived through dipole fit analyses did not provide significantly improved knowledge about the site.

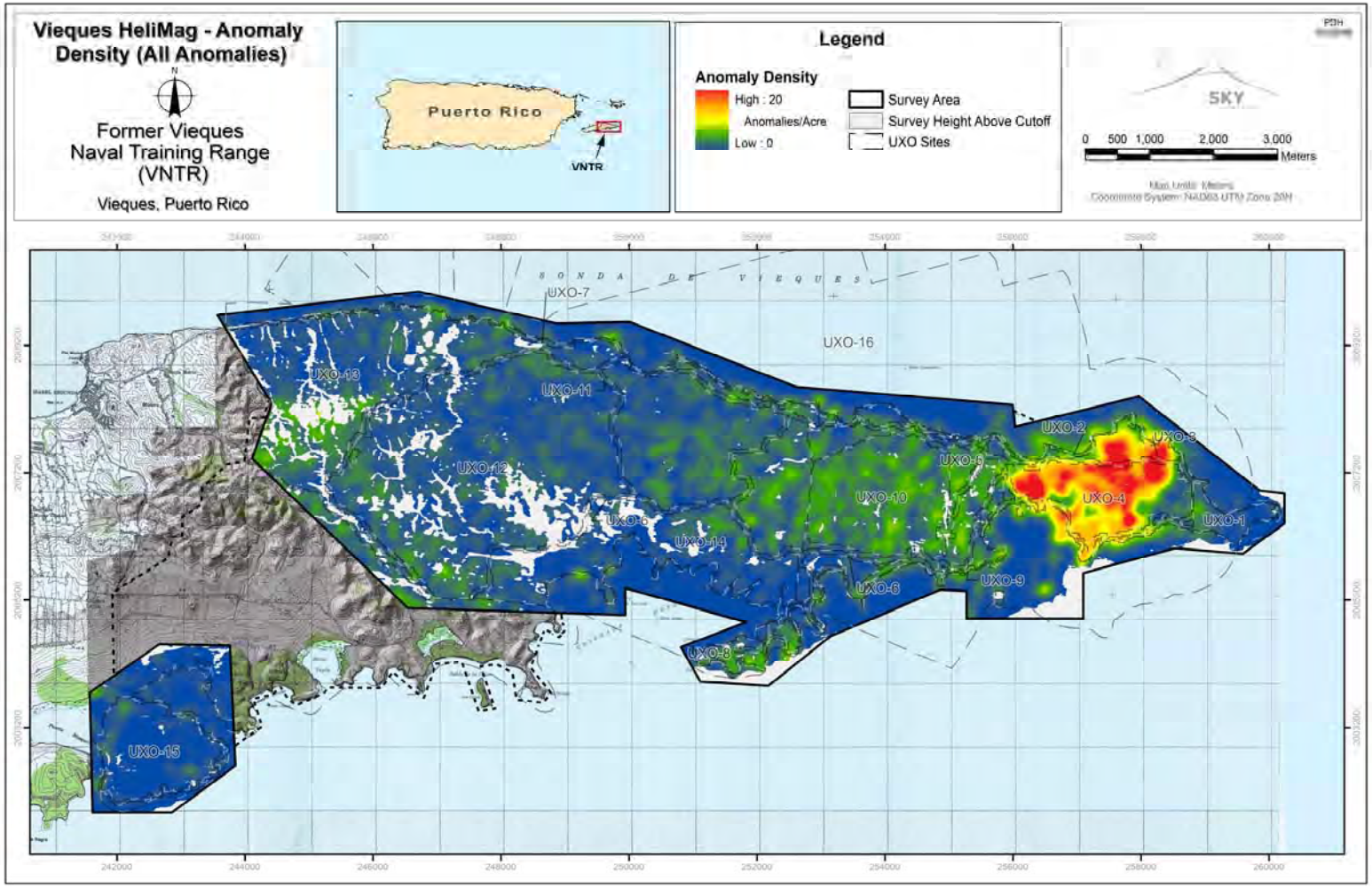

Figure 15 Anomaly density map over the VNTR. Areas flown above 14 m AGL are masked out of the presentation.

4.3. Advanced Analysis and Results

Because of the ambiguity in the anomaly density products, an additional analysis of the geophysical results was performed by an experienced geophysicist.

The fact that this survey was a departure from standard site characterization surveys due to the survey altitude, geologic response, and size of the detectable targets of interest, alternative methodologies were required. As a preliminary step, a 'non de-median filtered' (or 'full') Total Magnetic Field map was produced (Figure 16).

This map was originally developed to help identify regions of magnetically active geology. However, inspection of this map revealed that a large number of very large, distinct anomalies (LDAs) of anthropogenic origin were identifiable. The character of these anomalies was distorted by the de-median filter (originally designed to extract signals from objects limited to the size of potential MEC) rendering them difficult to recognize in the conventional, de-median filtered, total magnetic field data.

Even with the ability to identify LDAs it became apparent that the selections of areas of interest, and the discrimination of geology from real anomalies, would be a subjective judgment. Figure 17 illustrates the difficulty faced in making this distinction. This image contains symbols showing the location of selected LDAs (small black circles) and a number of large known objects (large purple circles) greater than 1000 pounds (lbs) in size, superimposed over the full total magnetic field (bottom panel) and de-median filtered total magnetic field. The presence of the large magnetic high in the middle of the bottom panel may lead one to believe that most of the anomalies in this region could be due to geology, however the anomalies at the location of known large objects are indistinguishable from the surrounding anomalies.

It is possible that, as more ground truth data is acquired, a correlation may be found between objects of interest and some derived anomaly features, but without this ground truth it is difficult to draw absolute conclusions based upon the data collected.

In regions where the system could be flown at more conventional survey altitudes it is possible to use the derived dipole features, particularly the dipole angle (relative to the Earth's magnetic field vector – this angle is also referred to as the 'solid angle'), to infer information about the site. Briefly stated, dipole angles greater than 75° indicate the presence of remanent magnetization. The process of 'shock demagnetization' removes the remanent magnetization from ferrous objects, so all that is remains is an induced magnetic dipole, and the angle of the induced dipole generally remains less than 75°. In the absence of any activity resulting in shock demagnetization the target dipole angles would be expected to be normally distributed around 90°, and the percentage of dipole angles < 75° would be relatively small (<40%). Areas where the percentage of dipole angles < 75° is elevated (i.e. >50%) can be assumed to have been subjected to some form of causal activity – in the case of UXO investigations, this causal activity is assumed to be related to UXO. This relationship between dipole angle and UXO activity is illustrated

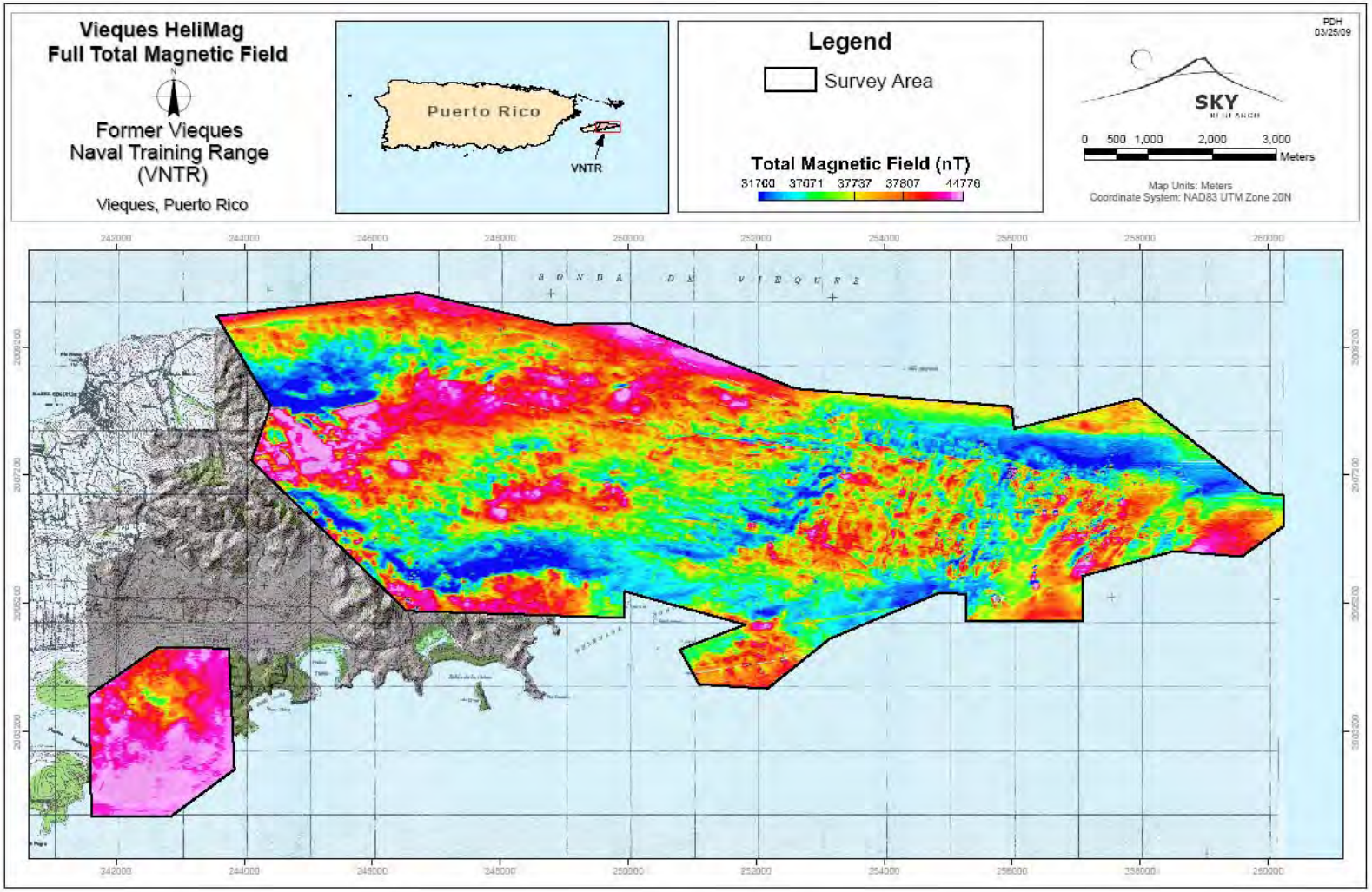

Figure 16. **‘**Full’ total magnetic field (no de-median filter applied to the data).

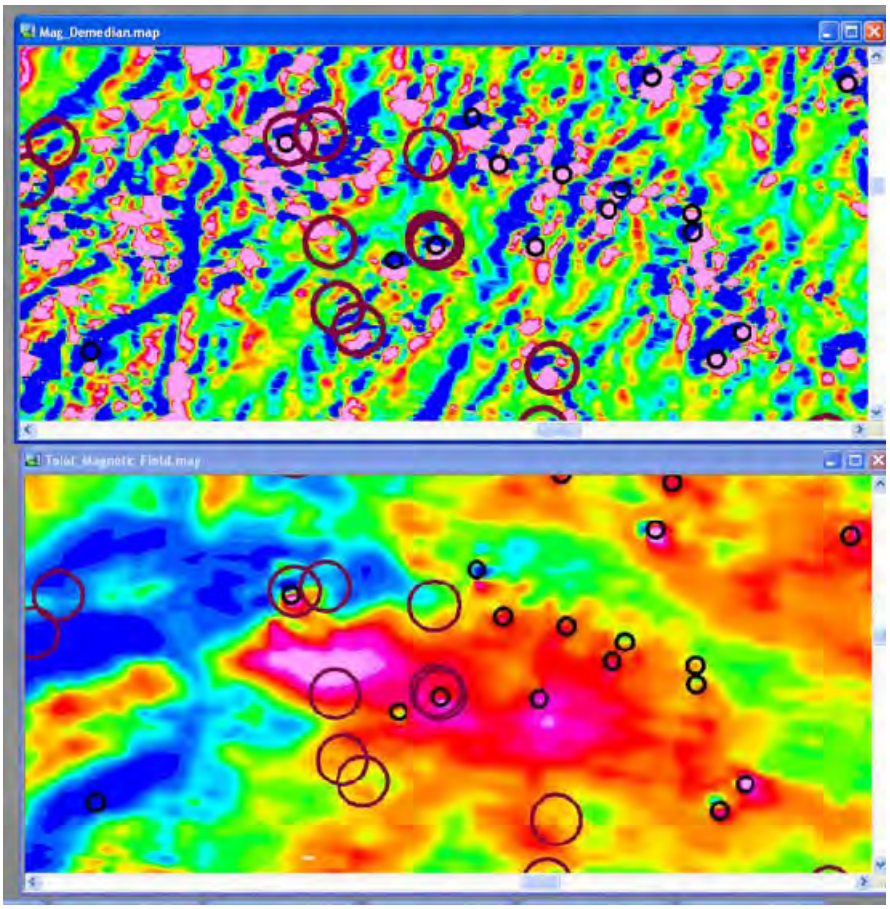

Figure 17. Comparison showing LDAs (small black circles) and known large ferrous items (large purple circles) over 1000 lbs in weight.

in the example data presented in Figure 18 (Sky Research, Inc, 2008). The top set of charts show the dipole angle distributions for subset areas of the survey and the bottom chart shows the ultimate dig results for the same sites. Clearly, sites exhibiting a high percentage of targets with the dipole angle < 75% were associated with UXO activity.

Figure 19 presents the distribution of the percentage of targets with a dipole angle less than 75° at the former VNTR. Regions where this percentage is elevated are more likely to be associated with UXO activity. The dipole angle distribution parameter is much more compelling when the data were collected at altitudes low enough to detect UXO sized targets – such as area 'Water 6' and along the shorelines. Regions where the number of targets does not provide a large enough sample to be considered statistically valid are excluded from this analysis.

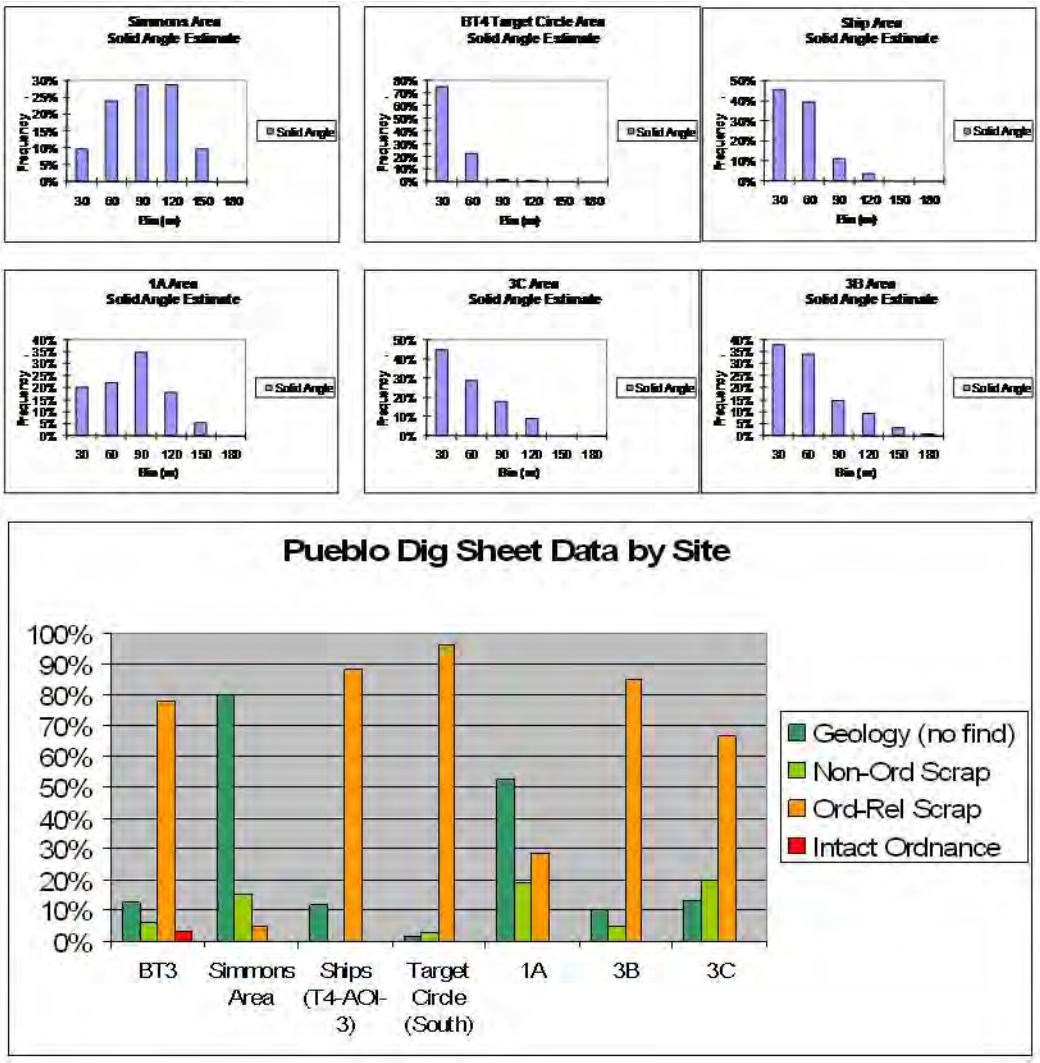

Figure 18. Example of the relationship between dipole angle and UXO activity for an ordnance site (Sky Research, 2008).

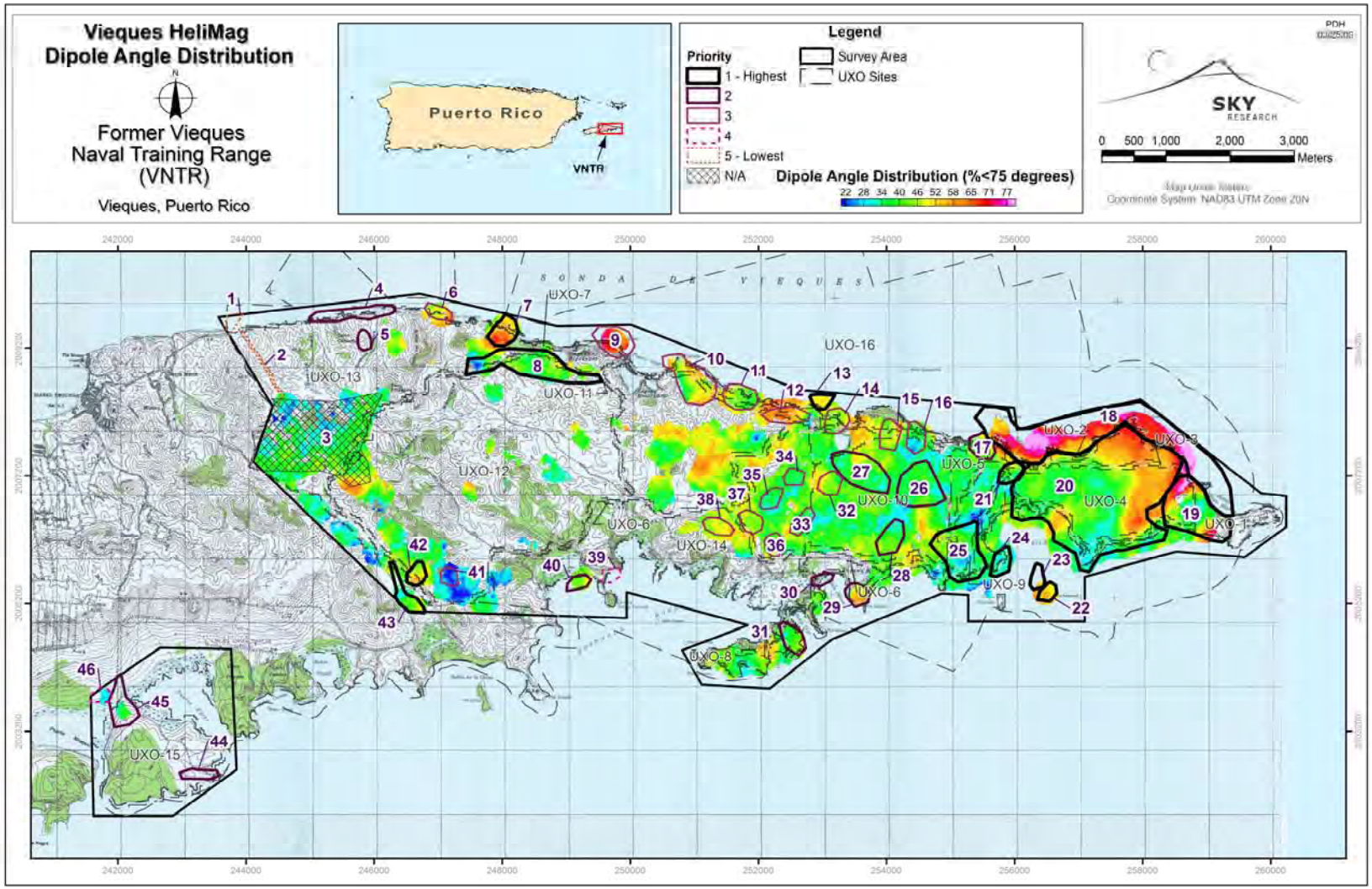

Figure 19. Dipole angle distribution image, former VNTR 2008 survey

Because the dipole angle distribution (DAD) analysis was not appropriate for the entire site, it was not used as the primary analysis tool – it was only used to supplement the final analysis observations (described below). Information from the dipole angle distribution was incorporated into the final analysis for those elevated anomaly density areas (EADAs) where applicable.

In the final analysis, the geophysicist identified 46 EADAs and rated them with respect to the likelihood that these areas contain significant man-made ferrous material. Although based upon the geophysical results, the delineation of these areas is based on the experience and judgment of the geophysicist, and these areas are intended to be used as a guide only. The analysis was based primarily on information presented in six map products:

1. Ortho-photography: - used to identify features such as shorelines, roadways, clearings, etc. that are clues with regard to the source of the anomalies;
2. Topography/Bathymetry: - used to identify possible geology with the assumption of topography/geology correlation;
3. Survey Altitude (above ground/sea floor): - used to evaluate magnetic response/sensitivity to various size targets;
4. De-median filtered Total Magnetic Field (TMF): - standard UXO detection product used as the primary basis for all preliminary anomaly selections;
5. Total Magnetic Field (no de-median filter applied): - used to assess geologic signal as well as identify very large discrete anomalies that are distorted by the de-median filter; and
6. Anomaly Density map (standard Wide Area Assessment product): - used to identify EADAs.

These map products are shown in combined form in Figure 20 (more detailed versions of these maps are provided in Appendix F).

During the analysis, the geophysicist examined expanded images of each of these maps. From these images, each EADA was evaluated using the following criteria:

- Geologic Response – a qualitative assessment of the localized geologic variability (Low, Medium, High);
- Survey Altitude – a qualitative assessment of the average survey altitude (L:<=5m, M: 5-10m, H: >10m);
- Anomaly Density – a qualitative assessment of the anomaly density (L: <5, M: 5-10, H : >10 anomalies/acre);
- Large Discrete Anomalies (LDAs) - Anomalies that are recognizable in the Total magnetic Field (no de-median filter) other than where the survey altitude was <5m, these are usually due to objects the size of a large vehicle or larger; and

- Dipole Angle Distribution (DAD); where applicable elevated percentages of targets <75° is noted.

Based upon this evaluation, a priority value was assigned to the area and comments were provided. The results of these analyses are provided in Table 3. Figure 21shows all of the EADAs identified. It is of note that there are many individual man-made ferrous targets that lie outside of the EADAs.

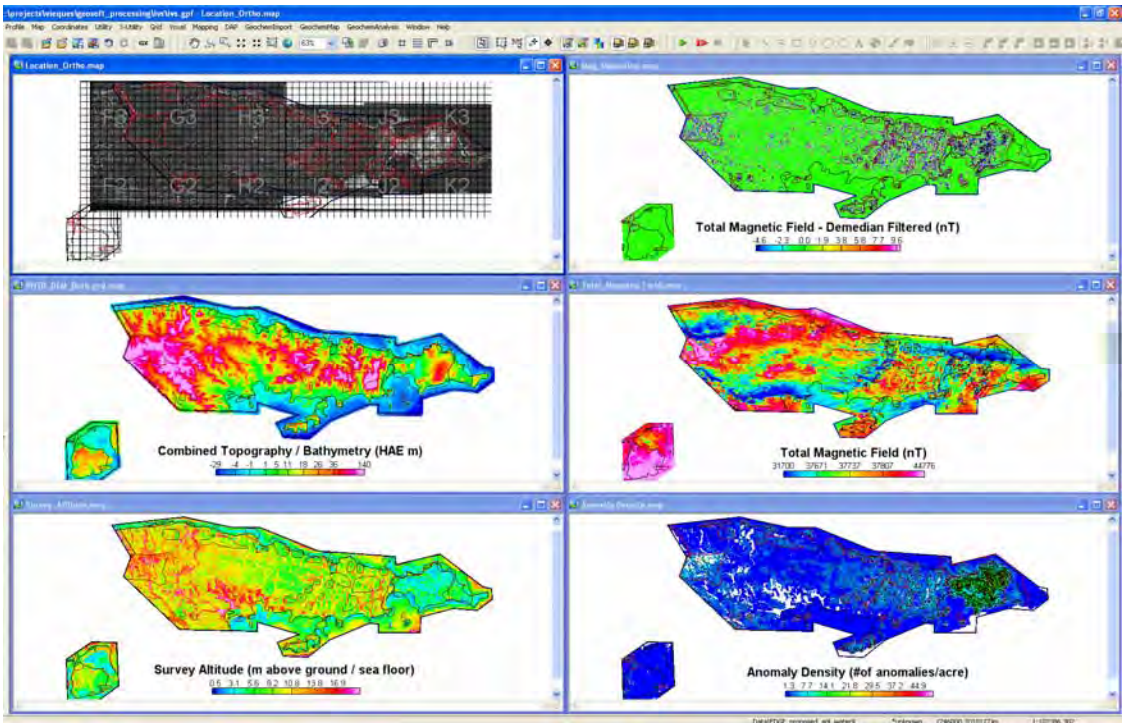

Figure 20. Map products used to develop EADAs. Clockwise from the top left: Ortho-photography/CH2M HILL grid system, De-median Filtered TMF, Full TM, Anomaly Density Distribution, Survey Altitude, Topography/Bathymetry. Individual map products are presented in more detail in Appendix F.

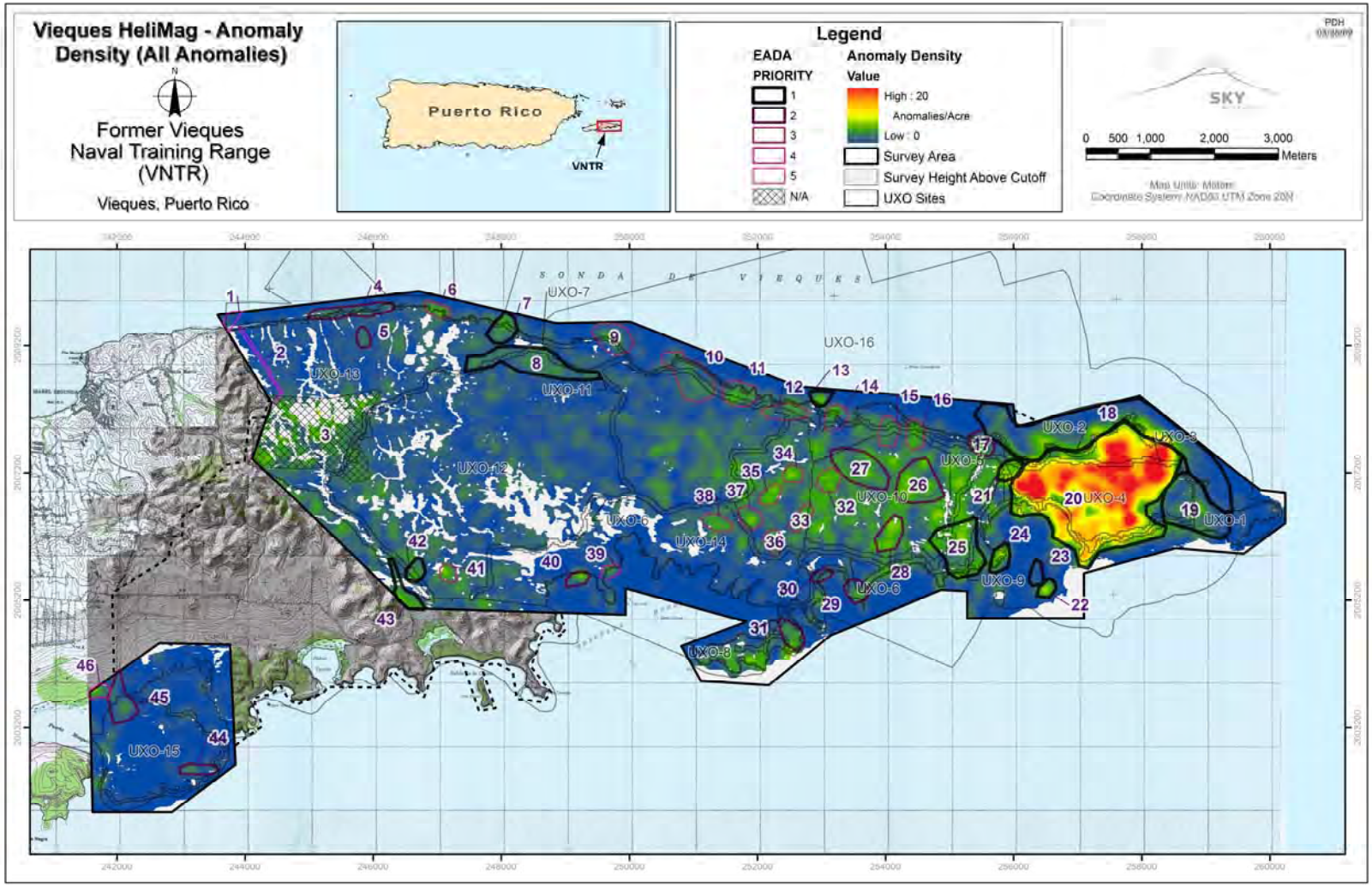

Figure 21. Map showing the location of all identified EADAs superimposed upon the anomaly density results.

Table 3. EADA Analysis Summary

EADA	Geologic Response (Low [L], Med [M], High [H])	Survey Altitude (L:<=5m, M:5-10m, H: >10m)	Anomaly Density (L: <5, M: 5-10, H : >10 anomalies/acre)	Large Discrete Anomalies (Y=Yes, N = No)	Priority (1=High, 5=Low)	Comments
1	M	L	L	Y	5	Apparent infrastructure – linear features running offshore
2	M	M	L	Y	5	Apparent infrastructure
3	H	H	H	N	N/A	High geologic return and high survey altitude prevent meaningful conclusions
4	M	L-M	L-M	Y	2	Some geology associated with shoreline, but numerous LDAs indicate probable presence of ferrous material – particularly at the eastern extent
5	M	M-H	M	Y	2	Presence of LDAs and apparent clearing indicate probable presence of ferrous material
6	M	L-M	H	Y	2.5	Presence of LDAs and high target density – possibly related to shoreline geology. DAD indicates moderate % less than 75°
7	M	L	H	Y	1	Although geologically active, the presence of LDAs, high anomaly density and an apparent clearing indicate the presence of ferrous material. DAD indicates high % less than 75°

EADA	Geologic Response (Low [L], Med [M], High [H])	Survey Altitude (L:<=5m, M:5-10m, H: >10m)	Anomaly Density (L: <5, M: 5-10, H : >10 anomalies/acre)	Large Discrete Anomalies (Y=Yes, N = No)	Priority (1=High, 5=Low)	Comments
8	H	M-H	M	Y	3	High target density appears to follow road, but this could also be due to geology – there are some LDAs that are not likely to be geology(located in cell G3J8)
9	M	M	H	Y	1	Well defined concentration of anomalies (possibly associated with shallow sea-floor) LDAs along shoreline are likely ferrous material. DAD indicates high % less than 75°
10	M	M	H	Y	3	LDAs and associated high anomaly density area
11	H	M	H	Y	3	LDAs might be associated with localized geology
12	M-H	M	H	Y	3	Many LDAs (possibly associated with geology). DAD indicates high % less than 75°
13	M	L	H	Y	1	Localized grouping of small anomalies just off shore
14	M-H	L-M	H	Y	3	Many large discrete targets (possibly associated with geology)
15	M	M	M	Y	3	Many large discrete targets (possibly associated with geology)
16	M	M	M-H	Y	3	Many LDAs
17	L-M	L-M	H	Y	2	Many LDAs associated with a clearing

EADA	Geologic Response (Low [L], Med [M], High [H])	Survey Altitude (L:<=5m, M:5-10m, H: >10m)	Anomaly Density (L: <5, M: 5-10, H : >10 anomalies/acre)	Large Discrete Anomalies (Y=Yes, N = No)	Priority (1=High, 5=Low)	Comments
18	L	L	M-H	Y	1	Many small anomalies consistent with typical responses from UXO related activity. DAD indicates high % less than 75°
19	L	L	M-H	Y	1	Many small anomalies consistent with typical responses from UXO related activity. DAD indicates high % less than 75°
20	L-M	L	H	Y	1	Area encompasses most of cleared area on eastern tip of the island – there are many sub-regions of very high anomaly density and very large LDAs
21	L	M	M	Y	1	Sub region of area 18 – with distinctive very large discrete anomalies
22	L-M	L	H	Y	1	LDAs associated with a shoal region. DAD indicates moderate % less than 75°
23	L	M	L	Y	1	A few very large distinct anomalies
24	L-M	L	H	Y	1	Large discrete anomalies along shoreline region
25	L-M	M-H	M-H	Y	1	Many LDAs indicate presence of ferrous material
26	M	M-H	M	Y	2	LDAs and medium anomaly density indicate possible ferrous material

EADA	Geologic Response (Low [L], Med [M], High [H])	Survey Altitude (L:<=5m, M:5-10m, H: >10m)	Anomaly Density (L: <5, M: 5-10, H : >10 anomalies/acre)	Large Discrete Anomalies (Y=Yes, N = No)	Priority (1=High, 5=Low)	Comments
27	H	M-H	M	Y	2	LDAs and medium anomaly density indicate possible ferrous material
28	L-M	M-H	M	Y	2	LDAs and medium anomaly density indicate possible ferrous material
29	L	L-M	M	Y	2	LDAs and numerous small anomalies indicate presence of ferrous material. DAD indicates moderate % less than 75°
30	L	L	L	Y	2	LDAs indicate presence of ferrous material
31-37	M	M	M	Y	2	LDAs indicate presence of ferrous material
38	M	M	M	Y	3	Presence of LDAs indicate probable ferrous material - apparent density variation resulting is separation of these areas may be a result of topography (32,33,34,37) and/or geology (35,36)
39	M	L	M	N	4	Collection of small anomalies – possible ferrous material
40	M	L	H	Y	2	LDAs and cluster of anomalies indicate ferrous material
41	M	H	M	Y	3	LDAs and elevated anomaly density possibly associated with topography/geology
42	L	M	L-M	Y	1	LDAs indicate ferrous material

EADA	Geologic Response (Low [L], Med [M], High [H])	Survey Altitude (L:<=5m, M:5-10m, H: >10m)	Anomaly Density (L: <5, M: 5-10, H : >10 anomalies/acre)	Large Discrete Anomalies (Y=Yes, N = No)	Priority (1=High, 5=Low)	Comments
43	H	H	M	Y	1	LDAs indicate ferrous material – possible linear feature extending northward may be a fence line
44	M	L-M	L	Y	2	LDAs and smaller anomalies indicate probable ferrous material
45	M-H	M	L-M	Y	2	LDAs indicate ferrous material – possible linear feature extending northward may be a fence line
46	M-H	L-M	M	N	4	Cluster of small anomalies may be geologic in origin

Appendix F contains large-format plates of the following figures:

Plate #	Description
Plate 1	Figure 8. Survey Sections
Plate 2	Figure 14. De-median Filtered Total Magnetic Field Image
Plate 3	Figure 15. Anomaly Density Map
Plate 4	Figure 16. ‘Full’ Total Magnetic Field
Plate 5	Figure 19. Dipole Angle Distribution image
Plate 6	Altitude Above Ground/Sea Floor
Plate 7	Vieques HeliMag Orthophotography

5. CONCLUSIONS

The goal of the AMS at VNTR was to identify areas containing high densities of ferrous metallic objects on the surface and/or subsurface that may be indicative of munitions related metal objects. The overall objective of the AMS is to identify these high density metallic anomalies to assist in prioritizing future munitions response actions at the former VNTR. Results of the AMS are not intended to be used to eliminate areas from the possibility of containing MEC.

Over 15,000 acres of land were surveyed with the HeliMag system. Although the HeliMag system performed properly, site conditions with respect to geologic response and survey altitude presented limitations on the data interpretation. The survey was most effective in shallow water and near-shore areas where altitudes of less than 10 meters could be maintained. This analysis identified a total of 46 EADAs. These EADA's were prioritized based upon factors such as survey altitude, apparent geologic response, evidence of LDA's and features present in the ortho-photography. Where appropriate, an advanced analysis technique based upon derived target dipole features was used to supplement the geophysicist's analysis. This technique is assumed to be more reliable for areas flown at relatively low survey altitudes, including most of the areas identified as 'water' areas. In these areas, the statistical distribution of the derived dipole angle relative to the Earth's field is used to identify areas of suspected MEC activities.

As more information is discovered through ground inspection of the EADA's and individual anomalies, the analysis of the data presented may be refined and improved. It is possible that, given sufficient ground truth, derived dipole features may be used to improve our ability to discriminate between anomalies of geologic or anthropogenic origin.

6. HELIMAG DATA DELIVERABLES

The following data deliverables specific to the HeliMag survey are provided as part of the overall project deliverables package:

- An Excel™ workbook containing a list of the raw target selections, the dipole analysis fit results, and the refined target list.
- A spreadsheet describing the contents of each column of the target list spreadsheets is included.

For the VNTR survey area, a high resolution jpg of:

a) The raw density image

b) The refined density image

c) The final magnetometer data

For each individual sub area listed in Table 4:

a) HeliMag geophysical data archives (zipped ASCII Geosoft XYZ format including headers). These data are presented in WGS84 UTM Zone 19 coordinates.

b) Geosoft™ grids of the final magnetic data.

For each flight over the validation lane:

c) HeliMag geophysical data archives (zipped ASCII Geosoft XYZ format including headers) and a Geosoft™ grid of the final data. These data are presented in WGS84 UTM Zone 19 coordinates (filenames are provided in the Validation Lane and Positioning Standardization Report, Appendix C).

d) Images of the dipole fit results (filenames are provided in the Validation Lane and Positioning Standardization Report, Appendix C).

7. REFERENCES

Sky Research, Inc., 2008. Aerial Magnetometer Survey Operations Plan. Final.

Sky Research, Inc. 2005. Post Collection Final Report, Former Vieques Naval Training Range, LiDAR / Orthophotography Collection. Final. September

Sky Research, Inc. 2008. Final Report: Demonstration of Helicopter Multi-Towed Array Detection System (MTADS) Magnetometry Technology at Pueblo Precision Bombing Range #2, Colorado. ESTCP Project No. 200535: Innovative Multi-Sensor Airborne Wide Area Assessment of UXO Sites. August

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APPENDIX A – DATA ACQUISITION LOG (EXAMPLE)

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Date	Day of Week	Day of Year	Sortie	Site	Line File	Lines	Field Notes Sensor Operator	Pilot	Gound Support	Data Processor	Project Geophysicist	Comments
11/14/2008	Friday	319	AA	Validation Lane	IVSA	1-2	Raul Fonda	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	1m
11/14/2008	Friday	319	AB	Validation Lane		1-2	Raul Fonda	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	2m
11/14/2008	Friday	319	AC	Validation Lane		1-2	Raul Fonda	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	3m
11/14/2008	Friday	319	AD	Validation Lane		1-2	Raul Fonda	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	4m
11/14/2008	Friday	319	AE	Validation Lane		1-2	Raul Fonda	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	5m
11/14/2008	Friday	319	AF	Validation Lane	IVSB	1-2	Raul Fonda	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	1m
11/14/2008	Friday	319	AG	Validation Lane		1-2	Raul Fonda	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	2m
11/14/2008	Friday	319	AH	Validation Lane		1-2	Raul Fonda	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	3m
11/14/2008	Friday	319	AI	Validation Lane		1-2	Raul Fonda	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	4m
11/14/2008	Friday	319	AJ	Validation Lane		1-2	Raul Fonda	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	5m
11/14/2008	Friday	319	AK	Validation Lane		1-2	Raul Fonda	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	6m
11/14/2008	Friday	319	AL	Validation Lane		1-2	Raul Fonda	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	7m
11/14/2008	Friday	319	AM	Validation Lane		1-2	Raul Fonda	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	8m
11/14/2008	Friday	319	AN	Validation Lane		1-2	Raul Fonda	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	8m
11/14/2008	Friday	319	AO	Validation Lane		1-2	Raul Fonda	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	8m
11/14/2008	Friday	319	AP	Validation Lane		1-2	Raul Fonda	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	9m
11/14/2008	Friday	319	AQ	Validation Lane		1-2	Raul Fonda	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	10m
11/14/2008	Friday	319	AR	Validation Lane	IVSA	1-2	Raul Fonda	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	6m
11/14/2008	Friday	319	AS	Validation Lane		1-2	Raul Fonda	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	7m
11/14/2008	Friday	319	AT	Validation Lane		1-2	Raul Fonda	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	8m
11/14/2008	Friday	319	AU	Validation Lane		1-2	Raul Fonda	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	9m
11/14/2008	Friday	319	AV	Validation Lane		1-2	Raul Fonda	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	10m
11/14/2008	Friday	319	AW	Land 8	Land8_3	1-5	Raul Fonda	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	
11/14/2008	Friday	319	AX	Land 8	Land8_3	6-7	Raul Fonda	John Olson	Josh DeFrates	Robert Mehl	Raul Fonda	
11/14/2008	Friday	319	AY	Land 8	Land8_3	6-12	Raul Fonda	John Olson	Josh DeFrates	Robert Mehl	Raul Fonda	
11/14/2008	Friday	319	AZ	Land 8	Land8_3	13-14	Raul Fonda	John Olson	Josh DeFrates	Robert Mehl	Raul Fonda	
11/14/2008	Friday	319	BA	Land 8	Land8_3	15-21	Raul Fonda	John Olson	Josh DeFrates	Robert Mehl	Raul Fonda	
11/14/2008	Friday	319	BB	Static	IVSA	1-2	Raul Fonda	John Olson	Josh DeFrates	Robert Mehl	Raul Fonda	Static
11/15/2008	Saturday	320	AA	Static	IVSA	1	Lars Lofgren	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	
11/15/2008	Saturday	320	AB	Noise	IVSA	1	Lars Lofgren	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	
11/15/2008	Saturday	320	AC	IVSA	IVSA	1-2	Lars Lofgren	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	
11/15/2008	Saturday	320	AD	Land 8	Land8_2	1-12	Lars Lofgren	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	
11/15/2008	Saturday	320	AE	Land 8	Land8_2	13-15	Raul Fonda	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	
11/15/2008	Saturday	320	AF	Land 8	Land8_2	15-31	Raul Fonda	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	
11/15/2008	Saturday	320	AG	Land 8	Land8_2	32-39	Lars Lofgren	John Olson	Josh DeFrates	Robert Mehl	Raul Fonda	
11/15/2008	Saturday	320	AH	Land 8	Land8_2	40-47	Lars Lofgren	John Olson	Josh DeFrates	Robert Mehl	Raul Fonda	
11/15/2008	Saturday	320	AI	Land 8	Land8_2	48	Lars Lofgren	John Olson	Josh DeFrates	Robert Mehl	Raul Fonda	
11/15/2008	Saturday	320	AJ	Land 8	Land8_2	49-50	Lars Lofgren	John Olson	Josh DeFrates	Robert Mehl	Raul Fonda	
11/15/2008	Saturday	320	AK	Land 8	Land8_1	1-8	Lars Lofgren	John Olson	Josh DeFrates	Robert Mehl	Raul Fonda	
11/15/2008	Saturday	320	AL	Land 8	Land8_1	9-15	Lars Lofgren	John Olson	Josh DeFrates	Robert Mehl	Raul Fonda	
11/15/2008	Saturday	320	AM	IVSA	IVSA	1-2	Lars Lofgren	John Olson	Josh DeFrates	Robert Mehl	Raul Fonda	bad RTK
11/15/2008	Saturday	320	AN	IVSA	IVSA	1-2	Lars Lofgren	John Olson	Josh DeFrates	Robert Mehl	Raul Fonda	
11/15/2008	Saturday	320	AO	IVSB	IVSB	1	Lars Lofgren	John Olson	Josh DeFrates	Robert Mehl	Raul Fonda	5m
11/15/2008	Saturday	320	AP	IVSB	IVSB	1	Lars Lofgren	John Olson	Josh DeFrates	Robert Mehl	Raul Fonda	6m
11/15/2008	Saturday	320	AQ	IVSB	IVSB	1	Lars Lofgren	John Olson	Josh DeFrates	Robert Mehl	Raul Fonda	7m
11/15/2008	Saturday	320	AR	IVSB	IVSB	1	Lars Lofgren	John Olson	Josh DeFrates	Robert Mehl	Raul Fonda	8m
11/15/2008	Saturday	320	AS	IVSB	IVSB	1	Lars Lofgren	John Olson	Josh DeFrates	Robert Mehl	Raul Fonda	9m
11/15/2008	Saturday	320	AT	IVSB	IVSB	1	Lars Lofgren	John Olson	Josh DeFrates	Robert Mehl	Raul Fonda	10m
11/15/2008	Saturday	320	AU	IVSB	IVSB	1	Lars Lofgren	John Olson	Josh DeFrates	Robert Mehl	Raul Fonda	11m
11/15/2008	Saturday	320	AV	IVSB	IVSB	1	Lars Lofgren	John Olson	Josh DeFrates	Robert Mehl	Raul Fonda	12m
11/15/2008	Saturday	320	AW	IVSB	IVSB	1	Lars Lofgren	John Olson	Josh DeFrates	Robert Mehl	Raul Fonda	13m
11/15/2008	Saturday	320	AX	IVSB	IVSB	1	Lars Lofgren	John Olson	Josh DeFrates	Robert Mehl	Raul Fonda	14m
11/15/2008	Saturday	320	AY	IVSB	IVSB	1	Lars Lofgren	John Olson	Josh DeFrates	Robert Mehl	Raul Fonda	15m
11/16/2008	Sunday	321	AA	Static	IVSA	1	Raul Fonda	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	
11/16/2008	Sunday	321	AB	Noise	IVSA	1	Raul Fonda	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	
11/16/2008	Sunday	321	AC	IVSA	IVSA	1-2	Raul Fonda	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	
11/16/2008	Sunday	321	AD	Water 6	Water6_4	1	Raul Fonda	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	
11/16/2008	Sunday	321	AE	Water 6	Water6_4	2-12	Raul Fonda	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	
11/16/2008	Sunday	321	AF	Water 6	Water6_4	13-18	Raul Fonda	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	
11/16/2008	Sunday	321	AG	Water 6	Water6_4	19-32	Raul Fonda	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	
11/16/2008	Sunday	321	AH	Water 6	Water6_4	33-40	Raul Fonda	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	
11/16/2008	Sunday	321	AI	Water 6	Water6_4	41-50	Raul Fonda	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	

Date	Day of Week	Day of Year	Sortie	Site	Line File	Lines	Sensor Operator	Pilot	Gound Support	Data Processor	Project Geophysicist	Comments
11/16/2008	Sunday	321	AJ	Water 6	Water6_5	1-10	Raul Fonda	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	
11/16/2008	Sunday	321	AK	Water 6	Water6_5	11-19	Lars Lofgren	John Olson	Josh DeFrates	Robert Mehl	Raul Fonda	
11/16/2008	Sunday	321	AL	Water 6	Water6_5	20-24	Lars Lofgren	John Olson	Josh DeFrates	Robert Mehl	Raul Fonda	
11/16/2008	Sunday	321	AM	Water 6	Water6_5	25-32	Lars Lofgren	John Olson	Josh DeFrates	Robert Mehl	Raul Fonda	
11/16/2008	Sunday	321	AN	Water 6	Water6_5	33-42	Lars Lofgren	John Olson	Josh DeFrates	Robert Mehl	Raul Fonda	
11/16/2008	Sunday	321	AO	Water 6	Water6_5	43-50	Lars Lofgren	John Olson	Josh DeFrates	Robert Mehl	Raul Fonda	
11/16/2008	Sunday	321	AP	Water 6	Water6_6	1-10	Lars Lofgren	John Olson	Josh DeFrates	Robert Mehl	Raul Fonda	
11/16/2008	Sunday	321	AQ	Water 6	Water6_6	11-19	Lars Lofgren	John Olson	Josh DeFrates	Robert Mehl	Raul Fonda	
11/16/2008	Sunday	321	AR	IVSA	IVSA	1-2	Lars Lofgren	John Olson	Josh DeFrates	Robert Mehl	Raul Fonda	
11/16/2008	Sunday	321	AS	Noise	IVSA	1	Lars Lofgren	John Olson	Josh DeFrates	Robert Mehl	Raul Fonda	
11/17/2008	Monday	322	AA	Static	IVSA	1	Raul Fonda	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	
11/17/2008	Monday	322	AB	Jeep	IVSA	1	Raul Fonda	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	
11/17/2008	Monday	322	AC	Jeep	IVSA	1	Raul Fonda	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	**Bad File**
11/17/2008	Monday	322	AD	Jeep	IVSA	1	Raul Fonda	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	8m
11/17/2008	Monday	322	AE	Jeep	IVSA	1	Raul Fonda	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	9m
11/17/2008	Monday	322	AF	Jeep	IVSA	1	Raul Fonda	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	10m
11/17/2008	Monday	322	AG	Jeep	IVSA	1	Raul Fonda	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	11m
11/17/2008	Monday	322	AH	Jeep	IVSA	1	Raul Fonda	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	12m
11/17/2008	Monday	322	AI	Jeep	IVSA	1	Raul Fonda	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	13m
11/17/2008	Monday	322	AJ	Jeep	IVSA	1	Raul Fonda	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	14m
11/17/2008	Monday	322	AK	Noise	IVSA	1	Raul Fonda	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	15m
11/17/2008	Monday	322	AL	Validation Lane	IVSA	1	Raul Fonda	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	16m
11/17/2008	Monday	322	AM	Water 9	Water9_5	1-13	Raul Fonda	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	
11/17/2008	Monday	322	AN	Water 9	Water9_5	14-21	Lars Lofgren	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	
11/17/2008	Monday	322	AO	Water 9	Water9_5	22-32	Lars Lofgren	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	
11/17/2008	Monday	322	AP	Water 9	Water9_5	33-47	Lars Lofgren	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	
11/17/2008	Monday	322	AQ	Water 9	Water9_5	48-50	Lars Lofgren	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	
11/17/2008	Monday	322	AR	Water 9	Water9_6	1-9	Lars Lofgren	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	
11/17/2008	Monday	322	AS	Water 9	Water9_6	10-26	Lars Lofgren	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	
11/17/2008	Monday	322	AT	Water 9	Water9_6	27-40	Raul Fonda	John Olson	Josh DeFrates	Robert Mehl	Raul Fonda	
11/17/2008	Monday	322	AU	Water 9	Water9_6	41-50	Raul Fonda	John Olson	Josh DeFrates	Robert Mehl	Raul Fonda	
11/17/2008	Monday	322	AV	Water 9	Water9_7	1-21	Raul Fonda	John Olson	Josh DeFrates	Robert Mehl	Raul Fonda	
11/17/2008	Monday	322	AW	Water 9	Water9_7	22-50	Lars Lofgren	John Olson	Josh DeFrates	Robert Mehl	Raul Fonda	
11/17/2008	Monday	322	AX	Water 9	Water9-4	1-17	Lars Lofgren	John Olson	Josh DeFrates	Robert Mehl	Raul Fonda	
11/17/2008	Monday	322	AY	IVSA	IVSA	1-2	Lars Lofgren	John Olson	Josh DeFrates	Robert Mehl	Raul Fonda	
11/17/2008	Monday	322	AZ	Noise	IVSA	1	Lars Lofgren	John Olson	Josh DeFrates	Robert Mehl	Raul Fonda	
11/18/2008	Tuesday	323	AA	Static	IVSA	1	Lars Lofgren	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	
11/18/2008	Tuesday	323	AB	Noise	IVSA	1	Lars Lofgren	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	
11/18/2008	Tuesday	323	AC	Validation Lane	IVSA	1-2	Lars Lofgren	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	
11/18/2008	Tuesday	323	AD	Water 9	Water9_4	18-29	Lars Lofgren	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	
11/18/2008	Tuesday	323	AE	Water 9	Water9_4	30-48	Lars Lofgren	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	
11/18/2008	Tuesday	323	AF	Water 9	Water9_4	49-50	Lars Lofgren	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	
11/18/2008	Tuesday	323	AG	Water 9	Water9_3	1-25	Lars Lofgren	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	
11/18/2008	Tuesday	323	AH	Water 9	Water9_3	26-50	Lars Lofgren	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	
11/18/2008	Tuesday	323	AI	Water 9	Water9_2	1-10	Lars Lofgren	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	
11/18/2008	Tuesday	323	AJ	Water 9	Water9_2	11-38	Raul Fonda	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	
11/18/2008	Tuesday	323	AK	Water 9	Water9_2	39-50	Raul Fonda	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	
11/18/2008	Tuesday	323	AL	Water 9	Water9_1	1-13	Raul Fonda	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	
11/18/2008	Tuesday	323	AM	Water 9	Water9_1	14-36	Raul Fonda	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	
11/18/2008	Tuesday	323	AN	Water 9	Water9_1	37-50	Raul Fonda	John Olson	Josh DeFrates	Robert Mehl	Raul Fonda	
11/18/2008	Tuesday	323	AO	Land 8	Land8_1	16-19	Raul Fonda	John Olson	Josh DeFrates	Robert Mehl	Raul Fonda	
11/18/2008	Tuesday	323	AP	Land 8	Land8_1	20-29	Lars Lofgren	John Olson	Josh DeFrates	Robert Mehl	Raul Fonda	
11/18/2008	Tuesday	323	AQ	Land 8	Land8_1	30-40	Lars Lofgren	John Olson	Josh DeFrates	Robert Mehl	Raul Fonda	
11/18/2008	Tuesday	323	AR	Land 8	Land8_1	41-50	Lars Lofgren	John Olson	Josh DeFrates	Robert Mehl	Raul Fonda	
11/18/2008	Tuesday	323	AS	Land 8	Land8_3	22-35	Raul Fonda	John Olson	Josh DeFrates	Robert Mehl	Raul Fonda	
11/18/2008	Tuesday	323	AT	Noise	IVSA	1	Raul Fonda	John Olson	Josh DeFrates	Robert Mehl	Raul Fonda	
11/18/2008	Tuesday	323	AU	Validation Lane	IVSA	1-2	Raul Fonda	John Olson	Josh DeFrates	Robert Mehl	Raul Fonda	
11/18/2008	Tuesday	323	AV	Land 8	land8_1	36-49	Raul Fonda	John Olson	Josh DeFrates	Robert Mehl	Raul Fonda	
11/19/2008	Wednesday	324	AA	Static	IVSA	1	Lars Lofgren	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	
11/19/2008	Wednesday	324	AB	Validation Lane	IVSA	1-2	Lars Lofgren	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	
11/19/2008	Wednesday	324	AC	Noise	IVSA	1	Lars Lofgren	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	
11/19/2008	Wednesday	324	AD	Water 9	Water9_3	1-21	Lars Lofgren	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	
11/19/2008	Wednesday	324	AE	Water 9	Water9_3	22-35	Lars Lofgren	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	
11/19/2008	Wednesday	324	AF	Water 9	Water9_3	36-50	Lars Lofgren	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	

APPENDIX B – DATA PROCESSING LOG (EXAMPLE)

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Field Notes

Date	Day of Week	Day of Year	Sortie	Site	Line File	Lines	Sensor Operator	Pilot	Gound Support	Data Processor	Project Geophysicist	Comments
11/14/2008	Friday	319	AA	Validation Lane	IVSA	1-2	Raul Fonda	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	1m
11/14/2008	Friday	319	AB	Validation Lane		1-2	Raul Fonda	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	2m
11/14/2008	Friday	319	AC	Validation Lane		1-2	Raul Fonda	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	3m
11/14/2008	Friday	319	AD	Validation Lane		1-2	Raul Fonda	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	4m
11/14/2008	Friday	319	AE	Validation Lane		1-2	Raul Fonda	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	5m
11/14/2008	Friday	319	AF	Validation Lane	IVSB	1-2	Raul Fonda	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	1m
11/14/2008	Friday	319	AG	Validation Lane		1-2	Raul Fonda	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	2m
11/14/2008	Friday	319	AH	Validation Lane		1-2	Raul Fonda	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	3m
11/14/2008	Friday	319	AI	Validation Lane		1-2	Raul Fonda	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	4m
11/14/2008	Friday	319	AJ	Validation Lane		1-2	Raul Fonda	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	5m
11/14/2008	Friday	319	AK	Validation Lane		1-2	Raul Fonda	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	6m
11/14/2008	Friday	319	AL	Validation Lane		1-2	Raul Fonda	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	7m
11/14/2008	Friday	319	AM	Validation Lane		1-2	Raul Fonda	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	8m
11/14/2008	Friday	319	AN	Validation Lane		1-2	Raul Fonda	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	8m
11/14/2008	Friday	319	AO	Validation Lane		1-2	Raul Fonda	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	8m
11/14/2008	Friday	319	AP	Validation Lane		1-2	Raul Fonda	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	9m
11/14/2008	Friday	319	AQ	Validation Lane		1-2	Raul Fonda	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	10m
11/14/2008	Friday	319	AR	Validation Lane	IVSA	1-2	Raul Fonda	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	6m
11/14/2008	Friday	319	AS	Validation Lane		1-2	Raul Fonda	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	7m
11/14/2008	Friday	319	AT	Validation Lane		1-2	Raul Fonda	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	8m
11/14/2008	Friday	319	AU	Validation Lane		1-2	Raul Fonda	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	9m
11/14/2008	Friday	319	AV	Validation Lane		1-2	Raul Fonda	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	10m
11/14/2008	Friday	319	AW	Land 8	Land8_3	1-5	Raul Fonda	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	
11/14/2008	Friday	319	AX	Land 8	Land8_3	6-7	Raul Fonda	John Olson	Josh DeFrates	Robert Mehl	Raul Fonda	
11/14/2008	Friday	319	AY	Land 8	Land8_3	6-12	Raul Fonda	John Olson	Josh DeFrates	Robert Mehl	Raul Fonda	
11/14/2008	Friday	319	AZ	Land 8	Land8_3	13-14	Raul Fonda	John Olson	Josh DeFrates	Robert Mehl	Raul Fonda	
11/14/2008	Friday	319	BA	Land 8	Land8_3	15-21	Raul Fonda	John Olson	Josh DeFrates	Robert Mehl	Raul Fonda	
11/14/2008	Friday	319	BB	Static	IVSA	1-2	Raul Fonda	John Olson	Josh DeFrates	Robert Mehl	Raul Fonda	Static
11/15/2008	Saturday	320	AA	Static	IVSA	1	Lars Lofgren	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	
11/15/2008	Saturday	320	AB	Noise	IVSA	1	Lars Lofgren	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	
11/15/2008	Saturday	320	AC	IVSA	IVSA	1-2	Lars Lofgren	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	
11/15/2008	Saturday	320	AD	Land 8	Land8_2	1-12	Lars Lofgren	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	
11/15/2008	Saturday	320	AE	Land 8	Land8_2	13-15	Raul Fonda	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	
11/15/2008	Saturday	320	AF	Land 8	Land8_2	15-31	Raul Fonda	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	
11/15/2008	Saturday	320	AG	Land 8	Land8_2	32-39	Lars Lofgren	John Olson	Josh DeFrates	Robert Mehl	Raul Fonda	
11/15/2008	Saturday	320	AH	Land 8	Land8_2	40-47	Lars Lofgren	John Olson	Josh DeFrates	Robert Mehl	Raul Fonda	
11/15/2008	Saturday	320	AI	Land 8	Land8_2	48	Lars Lofgren	John Olson	Josh DeFrates	Robert Mehl	Raul Fonda	
11/15/2008	Saturday	320	AJ	Land 8	Land8_2	49-50	Lars Lofgren	John Olson	Josh DeFrates	Robert Mehl	Raul Fonda	
11/15/2008	Saturday	320	AK	Land 8	Land8_1	1-8	Lars Lofgren	John Olson	Josh DeFrates	Robert Mehl	Raul Fonda	
11/15/2008	Saturday	320	AL	Land 8	Land8_1	9-15	Lars Lofgren	John Olson	Josh DeFrates	Robert Mehl	Raul Fonda	
11/15/2008	Saturday	320	AM	IVSA	IVSA	1-2	Lars Lofgren	John Olson	Josh DeFrates	Robert Mehl	Raul Fonda	bad RTK
11/15/2008	Saturday	320	AN	IVSA	IVSA	1-2	Lars Lofgren	John Olson	Josh DeFrates	Robert Mehl	Raul Fonda	
11/15/2008	Saturday	320	AO	IVSB	IVSB	1	Lars Lofgren	John Olson	Josh DeFrates	Robert Mehl	Raul Fonda	5m
11/15/2008	Saturday	320	AP	IVSB	IVSB	1	Lars Lofgren	John Olson	Josh DeFrates	Robert Mehl	Raul Fonda	6m
11/15/2008	Saturday	320	AQ	IVSB	IVSB	1	Lars Lofgren	John Olson	Josh DeFrates	Robert Mehl	Raul Fonda	7m
11/15/2008	Saturday	320	AR	IVSB	IVSB	1	Lars Lofgren	John Olson	Josh DeFrates	Robert Mehl	Raul Fonda	8m
11/15/2008	Saturday	320	AS	IVSB	IVSB	1	Lars Lofgren	John Olson	Josh DeFrates	Robert Mehl	Raul Fonda	9m
11/15/2008	Saturday	320	AT	IVSB	IVSB	1	Lars Lofgren	John Olson	Josh DeFrates	Robert Mehl	Raul Fonda	10m
11/15/2008	Saturday	320	AU	IVSB	IVSB	1	Lars Lofgren	John Olson	Josh DeFrates	Robert Mehl	Raul Fonda	11m
11/15/2008	Saturday	320	AV	IVSB	IVSB	1	Lars Lofgren	John Olson	Josh DeFrates	Robert Mehl	Raul Fonda	12m
11/15/2008	Saturday	320	AW	IVSB	IVSB	1	Lars Lofgren	John Olson	Josh DeFrates	Robert Mehl	Raul Fonda	13m
11/15/2008	Saturday	320	AX	IVSB	IVSB	1	Lars Lofgren	John Olson	Josh DeFrates	Robert Mehl	Raul Fonda	14m

Data Processing Notes

Date	Day of Week	Day of Year	Sortie	Demedian Window	Low Pass Window	Aeromag.Comp.	Site Database	Grid name	Archive name	Gaps >0.4
11/14/2008	Friday	319	AA	15 pt	20 pt	n				
11/14/2008	Friday	319	AB	15 pt	20 pt	n				
11/14/2008	Friday	319	AC	15 pt	20 pt	n				
11/14/2008	Friday	319	AD	15 pt	20 pt	n				
11/14/2008	Friday	319	AE	15 pt	20 pt	n				
11/14/2008	Friday	319	AF	15 pt	20 pt	n				
11/14/2008	Friday	319	AG	15 pt	20 pt	n				
11/14/2008	Friday	319	AH	15 pt	20 pt	n				
11/14/2008	Friday	319	AI	15 pt	20 pt	n				
11/14/2008	Friday	319	AJ	15 pt	20 pt	n				
11/14/2008	Friday	319	AK	15 pt	20 pt	n				
11/14/2008	Friday	319	AL	15 pt	20 pt	n				
11/14/2008	Friday	319	AM	15 pt	20 pt	n				
11/14/2008	Friday	319	AN	15 pt	20 pt	n				
11/14/2008	Friday	319	AO	15 pt	20 pt	n				
11/14/2008	Friday	319	AP	15 pt	20 pt	n				
11/14/2008	Friday	319	AQ	15 pt	20 pt	n				
11/14/2008	Friday	319	AR	15 pt	20 pt	n				
11/14/2008	Friday	319	AS	15 pt	20 pt	n				
11/14/2008	Friday	319	AT	15 pt	20 pt	n				
11/14/2008	Friday	319	AU	15 pt	20 pt	n				
11/14/2008	Friday	319	AV	15 pt	20 pt	n				
11/14/2008	Friday	319	AW	15 pt	20 pt	n	VNTR_Land8.GDB	VNTR_Land8.GRD	VNTR_Land8.XYZ	<0.1%
11/14/2008	Friday	319	AX	15 pt	20 pt	n	VNTR_Land8.GDB	VNTR_Land8.GRD	VNTR_Land8.XYZ	<0.1%
11/14/2008	Friday	319	AY	15 pt	20 pt	n	VNTR_Land8.GDB	VNTR_Land8.GRD	VNTR_Land8.XYZ	<0.1%
11/14/2008	Friday	319	AZ	15 pt	20 pt	n	VNTR_Land8.GDB	VNTR_Land8.GRD	VNTR_Land8.XYZ	<0.1%
11/14/2008	Friday	319	BA	15 pt	20 pt	n	VNTR_Land8.GDB	VNTR_Land8.GRD	VNTR_Land8.XYZ	<0.1%
11/14/2008	Friday	319	BB	15 pt	20 pt	n				
11/15/2008	Saturday	320	AA	15 pt	20 pt	n				
11/15/2008	Saturday	320	AB	15 pt	20 pt	n				
11/15/2008	Saturday	320	AC	15 pt	20 pt	n				
11/15/2008	Saturday	320	AD	15 pt	20 pt	n	VNTR_Land8.GDB	VNTR_Land8.GRD	VNTR_Land8.XYZ	<0.1%
11/15/2008	Saturday	320	AE	15 pt	20 pt	n	VNTR_Land8.GDB	VNTR_Land8.GRD	VNTR_Land8.XYZ	<0.1%
11/15/2008	Saturday	320	AF	15 pt	20 pt	n	VNTR_Land8.GDB	VNTR_Land8.GRD	VNTR_Land8.XYZ	<0.1%
11/15/2008	Saturday	320	AG	15 pt	20 pt	n	VNTR_Land8.GDB	VNTR_Land8.GRD	VNTR_Land8.XYZ	<0.1%
11/15/2008	Saturday	320	AH	15 pt	20 pt	n	VNTR_Land8.GDB	VNTR_Land8.GRD	VNTR_Land8.XYZ	<0.1%
11/15/2008	Saturday	320	AI	15 pt	20 pt	n	VNTR_Land8.GDB	VNTR_Land8.GRD	VNTR_Land8.XYZ	<0.1%
11/15/2008	Saturday	320	AJ	15 pt	20 pt	n	VNTR_Land8.GDB	VNTR_Land8.GRD	VNTR_Land8.XYZ	<0.1%
11/15/2008	Saturday	320	AK	15 pt	20 pt	n	VNTR_Land8.GDB	VNTR_Land8.GRD	VNTR_Land8.XYZ	<0.1%
11/15/2008	Saturday	320	AL	15 pt	20 pt	n	VNTR_Land8.GDB	VNTR_Land8.GRD	VNTR_Land8.XYZ	<0.1%
11/15/2008	Saturday	320	AM	15 pt	20 pt	n				
11/15/2008	Saturday	320	AN	15 pt	20 pt	n				
11/15/2008	Saturday	320	AO	15 pt	20 pt	n				
11/15/2008	Saturday	320	AP	15 pt	20 pt	n				
11/15/2008	Saturday	320	AQ	15 pt	20 pt	n				
11/15/2008	Saturday	320	AR	15 pt	20 pt	n				
11/15/2008	Saturday	320	AS	15 pt	20 pt	n				
11/15/2008	Saturday	320	AT	15 pt	20 pt	n				
11/15/2008	Saturday	320	AU	15 pt	20 pt	n				
11/15/2008	Saturday	320	AV	15 pt	20 pt	n				
11/15/2008	Saturday	320	AW	15 pt	20 pt	n				
11/15/2008	Saturday	320	AX	15 pt	20 pt	n				

Field Notes

Date	Day of Week	Day of Year	Sortie	Site	Line File	Lines	Sensor Operator	Pilot	Gound Support	Data Processor	Project Geophysicist	Comments
11/15/2008	Saturday	320	AY	IVSB	IVSB	1	Lars Lofgren	John Olson	Josh DeFrates	Robert Mehl	Raul Fonda	15m
11/16/2008	Sunday	321	AA	Static	IVSA	1	Raul Fonda	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	
11/16/2008	Sunday	321	AB	Noise	IVSA	1	Raul Fonda	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	
11/16/2008	Sunday	321	AC	IVSA	IVSA	1-2	Raul Fonda	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	
11/16/2008	Sunday	321	AD	Water 6	Water6_4	1	Raul Fonda	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	
11/16/2008	Sunday	321	AE	Water 6	Water6_4	2-12	Raul Fonda	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	
11/16/2008	Sunday	321	AF	Water 6	Water6_4	13-18	Raul Fonda	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	
11/16/2008	Sunday	321	AG	Water 6	Water6_4	19-32	Raul Fonda	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	
11/16/2008	Sunday	321	AH	Water 6	Water6_4	33-40	Raul Fonda	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	
11/16/2008	Sunday	321	AI	Water 6	Water6_4	41-50	Raul Fonda	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	
11/16/2008	Sunday	321	AJ	Water 6	Water6_5	1-10	Raul Fonda	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	
11/16/2008	Sunday	321	AK	Water 6	Water6_5	11-19	Lars Lofgren	John Olson	Josh DeFrates	Robert Mehl	Raul Fonda	
11/16/2008	Sunday	321	AL	Water 6	Water6_5	20-24	Lars Lofgren	John Olson	Josh DeFrates	Robert Mehl	Raul Fonda	
11/16/2008	Sunday	321	AM	Water 6	Water6_5	25-32	Lars Lofgren	John Olson	Josh DeFrates	Robert Mehl	Raul Fonda	
11/16/2008	Sunday	321	AN	Water 6	Water6_5	33-42	Lars Lofgren	John Olson	Josh DeFrates	Robert Mehl	Raul Fonda	
11/16/2008	Sunday	321	AO	Water 6	Water6_5	43-50	Lars Lofgren	John Olson	Josh DeFrates	Robert Mehl	Raul Fonda	
11/16/2008	Sunday	321	AP	Water 6	Water6_6	1-10	Lars Lofgren	John Olson	Josh DeFrates	Robert Mehl	Raul Fonda	
11/16/2008	Sunday	321	AQ	Water 6	Water6_6	11-19	Lars Lofgren	John Olson	Josh DeFrates	Robert Mehl	Raul Fonda	
11/16/2008	Sunday	321	AR	IVSA	IVSA	1-2	Lars Lofgren	John Olson	Josh DeFrates	Robert Mehl	Raul Fonda	
11/16/2008	Sunday	321	AS	Noise	IVSA	1	Lars Lofgren	John Olson	Josh DeFrates	Robert Mehl	Raul Fonda	
11/17/2008	Monday	322	AA	Static	IVSA	1	Raul Fonda	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	
11/17/2008	Monday	322	AB	Jeep	IVSA	1	Raul Fonda	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	
11/17/2008	Monday	322	AC	Jeep	IVSA	1	Raul Fonda	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	**Bad File**
11/17/2008	Monday	322	AD	Jeep	IVSA	1	Raul Fonda	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	8m
11/17/2008	Monday	322	AE	Jeep	IVSA	1	Raul Fonda	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	9m
11/17/2008	Monday	322	AF	Jeep	IVSA	1	Raul Fonda	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	10m
11/17/2008	Monday	322	AG	Jeep	IVSA	1	Raul Fonda	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	11m
11/17/2008	Monday	322	AH	Jeep	IVSA	1	Raul Fonda	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	12m
11/17/2008	Monday	322	AI	Jeep	IVSA	1	Raul Fonda	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	13m
11/17/2008	Monday	322	AJ	Jeep	IVSA	1	Raul Fonda	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	14m
11/17/2008	Monday	322	AK	Noise	IVSA	1	Raul Fonda	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	15m
11/17/2008	Monday	322	AL	Validation Lane	IVSA	1	Raul Fonda	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	16m
11/17/2008	Monday	322	AM	Water 9	Water9_5	1-13	Raul Fonda	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	
11/17/2008	Monday	322	AN	Water 9	Water9_5	14-21	Lars Lofgren	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	
11/17/2008	Monday	322	AO	Water 9	Water9_5	22-32	Lars Lofgren	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	
11/17/2008	Monday	322	AP	Water 9	Water9_5	33-47	Lars Lofgren	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	
11/17/2008	Monday	322	AQ	Water 9	Water9_5	48-50	Lars Lofgren	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	
11/17/2008	Monday	322	AR	Water 9	Water9_6	1-9	Lars Lofgren	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	
11/17/2008	Monday	322	AS	Water 9	Water9_6	10-26	Lars Lofgren	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	
11/17/2008	Monday	322	AT	Water 9	Water9_6	27-40	Raul Fonda	John Olson	Josh DeFrates	Robert Mehl	Raul Fonda	
11/17/2008	Monday	322	AU	Water 9	Water9_6	41-50	Raul Fonda	John Olson	Josh DeFrates	Robert Mehl	Raul Fonda	
11/17/2008	Monday	322	AV	Water 9	Water9_7	1-21	Raul Fonda	John Olson	Josh DeFrates	Robert Mehl	Raul Fonda	
11/17/2008	Monday	322	AW	Water 9	Water9_7	22-50	Lars Lofgren	John Olson	Josh DeFrates	Robert Mehl	Raul Fonda	
11/17/2008	Monday	322	AX	Water 9	Water9-4	1-17	Lars Lofgren	John Olson	Josh DeFrates	Robert Mehl	Raul Fonda	
11/17/2008	Monday	322	AY	IVSA	IVSA	1-2	Lars Lofgren	John Olson	Josh DeFrates	Robert Mehl	Raul Fonda	
11/17/2008	Monday	322	AZ	Noise	IVSA	1	Lars Lofgren	John Olson	Josh DeFrates	Robert Mehl	Raul Fonda	
11/18/2008	Tuesday	323	AA	Static	IVSA	1	Lars Lofgren	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	
11/18/2008	Tuesday	323	AB	Noise	IVSA	1	Lars Lofgren	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	
11/18/2008	Tuesday	323	AC	Validation Lane	IVSA	1-2	Lars Lofgren	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	
11/18/2008	Tuesday	323	AD	Water 9	Water9_4	18-29	Lars Lofgren	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	
11/18/2008	Tuesday	323	AE	Water 9	Water9_4	30-48	Lars Lofgren	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	
11/18/2008	Tuesday	323	AF	Water 9	Water9_4	49-50	Lars Lofgren	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	
11/18/2008	Tuesday	323	AG	Water 9	Water9_3	1-25	Lars Lofgren	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	
11/18/2008	Tuesday	323	AH	Water 9	Water9_3	26-50	Lars Lofgren	Bob Rogers	Josh DeFrates	Robert Mehl	Raul Fonda	

Data Processing Notes

Date	Day of Week	Day of Year	Sortie	Demedian Window	Low Pass Window	Aeromag.Comp.	Site Database	Grid name	Archive name	Gaps >0.4
11/15/2008	Saturday	320	AY	15 pt	20 pt	n				
11/16/2008	Sunday	321	AA	15 pt	20 pt	n				
11/16/2008	Sunday	321	AB	15 pt	20 pt	n				
11/16/2008	Sunday	321	AC	15 pt	20 pt	n				
11/16/2008	Sunday	321	AD	15 pt	20 pt	n	VNTR_Water6.GDB	VNTR_Water6.GRD	VNTR_Water6.XYZ	<0.1%
11/16/2008	Sunday	321	AE	15 pt	20 pt	n	VNTR_Water6.GDB	VNTR_Water6.GRD	VNTR_Water6.XYZ	<0.1%
11/16/2008	Sunday	321	AF	15 pt	20 pt	n	VNTR_Water6.GDB	VNTR_Water6.GRD	VNTR_Water6.XYZ	<0.1%
11/16/2008	Sunday	321	AG	15 pt	20 pt	n	VNTR_Water6.GDB	VNTR_Water6.GRD	VNTR_Water6.XYZ	<0.1%
11/16/2008	Sunday	321	AH	15 pt	20 pt	n	VNTR_Water6.GDB	VNTR_Water6.GRD	VNTR_Water6.XYZ	<0.1%
11/16/2008	Sunday	321	AI	15 pt	20 pt	n	VNTR_Water6.GDB	VNTR_Water6.GRD	VNTR_Water6.XYZ	<0.1%
11/16/2008	Sunday	321	AJ	15 pt	20 pt	n	VNTR_Water6.GDB	VNTR_Water6.GRD	VNTR_Water6.XYZ	<0.1%
11/16/2008	Sunday	321	AK	15 pt	20 pt	n	VNTR_Water6.GDB	VNTR_Water6.GRD	VNTR_Water6.XYZ	<0.1%
11/16/2008	Sunday	321	AL	15 pt	20 pt	n	VNTR_Water6.GDB	VNTR_Water6.GRD	VNTR_Water6.XYZ	<0.1%
11/16/2008	Sunday	321	AM	15 pt	20 pt	n	VNTR_Water6.GDB	VNTR_Water6.GRD	VNTR_Water6.XYZ	<0.1%
11/16/2008	Sunday	321	AN	15 pt	20 pt	n	VNTR_Water6.GDB	VNTR_Water6.GRD	VNTR_Water6.XYZ	<0.1%
11/16/2008	Sunday	321	AO	15 pt	20 pt	n	VNTR_Water6.GDB	VNTR_Water6.GRD	VNTR_Water6.XYZ	<0.1%
11/16/2008	Sunday	321	AP	15 pt	20 pt	n	VNTR_Water6.GDB	VNTR_Water6.GRD	VNTR_Water6.XYZ	<0.1%
11/16/2008	Sunday	321	AQ	15 pt	20 pt	n	VNTR_Water6.GDB	VNTR_Water6.GRD	VNTR_Water6.XYZ	<0.1%
11/16/2008	Sunday	321	AR	15 pt	20 pt	n				
11/16/2008	Sunday	321	AS	15 pt	20 pt	n				
11/17/2008	Monday	322	AA	15 pt	20 pt	n				
11/17/2008	Monday	322	AB	15 pt	20 pt	n				
11/17/2008	Monday	322	AC	15 pt	20 pt	n				
11/17/2008	Monday	322	AD	15 pt	20 pt	n				
11/17/2008	Monday	322	AE	15 pt	20 pt	n				
11/17/2008	Monday	322	AF	15 pt	20 pt	n				
11/17/2008	Monday	322	AG	15 pt	20 pt	n				
11/17/2008	Monday	322	AH	15 pt	20 pt	n				
11/17/2008	Monday	322	AI	15 pt	20 pt	n				
11/17/2008	Monday	322	AJ	15 pt	20 pt	n				
11/17/2008	Monday	322	AK	15 pt	20 pt	n				
11/17/2008	Monday	322	AL	15 pt	20 pt	n				
11/17/2008	Monday	322	AM	15 pt	20 pt	n	VNTR_Water9.GDB	VNTR_Water9.GRD	VNTR_Water9.XYZ	<0.1%
11/17/2008	Monday	322	AN	15 pt	20 pt	n	VNTR_Water9.GDB	VNTR_Water9.GRD	VNTR_Water9.XYZ	<0.1%
11/17/2008	Monday	322	AO	15 pt	20 pt	n	VNTR_Water9.GDB	VNTR_Water9.GRD	VNTR_Water9.XYZ	<0.1%
11/17/2008	Monday	322	AP	15 pt	20 pt	n	VNTR_Water9.GDB	VNTR_Water9.GRD	VNTR_Water9.XYZ	<0.1%
11/17/2008	Monday	322	AQ	15 pt	20 pt	n	VNTR_Water9.GDB	VNTR_Water9.GRD	VNTR_Water9.XYZ	<0.1%
11/17/2008	Monday	322	AR	15 pt	20 pt	n	VNTR_Water9.GDB	VNTR_Water9.GRD	VNTR_Water9.XYZ	<0.1%
11/17/2008	Monday	322	AS	15 pt	20 pt	n	VNTR_Water9.GDB	VNTR_Water9.GRD	VNTR_Water9.XYZ	<0.1%
11/17/2008	Monday	322	AT	15 pt	20 pt	n	VNTR_Water9.GDB	VNTR_Water9.GRD	VNTR_Water9.XYZ	<0.1%
11/17/2008	Monday	322	AU	15 pt	20 pt	n	VNTR_Water9.GDB	VNTR_Water9.GRD	VNTR_Water9.XYZ	<0.1%
11/17/2008	Monday	322	AV	15 pt	20 pt	n	VNTR_Water9.GDB	VNTR_Water9.GRD	VNTR_Water9.XYZ	<0.1%
11/17/2008	Monday	322	AW	15 pt	20 pt	n	VNTR_Water9.GDB	VNTR_Water9.GRD	VNTR_Water9.XYZ	<0.1%
11/17/2008	Monday	322	AX	15 pt	20 pt	n	VNTR_Water9.GDB	VNTR_Water9.GRD	VNTR_Water9.XYZ	<0.1%
11/17/2008	Monday	322	AY	15 pt	20 pt	n				
11/17/2008	Monday	322	AZ	15 pt	20 pt	n				
11/18/2008	Tuesday	323	AA	15 pt	20 pt	n				
11/18/2008	Tuesday	323	AB	15 pt	20 pt	n				
11/18/2008	Tuesday	323	AC	15 pt	20 pt	n				
11/18/2008	Tuesday	323	AD	15 pt	20 pt	n	VNTR_Water9.GDB	VNTR_Water9.GRD	VNTR_Water9.XYZ	<0.1%
11/18/2008	Tuesday	323	AE	15 pt	20 pt	n	VNTR_Water9.GDB	VNTR_Water9.GRD	VNTR_Water9.XYZ	<0.1%
11/18/2008	Tuesday	323	AF	15 pt	20 pt	n	VNTR_Water9.GDB	VNTR_Water9.GRD	VNTR_Water9.XYZ	<0.1%
11/18/2008	Tuesday	323	AG	15 pt	20 pt	n	VNTR_Water9.GDB	VNTR_Water9.GRD	VNTR_Water9.XYZ	<0.1%
11/18/2008	Tuesday	323	AH	15 pt	20 pt	n	VNTR_Water9.GDB	VNTR_Water9.GRD	VNTR_Water9.XYZ	<0.1%

APPENDIX C – VALIDATION LANE AND POSITIONING STANDARDIZATION REPORT

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Validation Lane and Positioning Standardization Report

Client: CH2M Hill		Data Quality Objectives											
Site: Vieques		Dipole Fit Results											
		Target Positioning		Target Size		Dipole angle		Lag test		Intrinsic Noise			
Date	File	Average Error (m)	< 0.5m ?	Average Variation (%)	<20% ?	Average Variation (degrees)	<20 degrees ?	Complete / Incomplete	Reference Image (.pdf)	20 sec Stdev	<1.0 nT ?	xyz Data Files	notes
14-Nov-08	V319AA	0.16	Pass	14%	Pass	2.47	Pass	Complete	V319AA_dipole_report				poor weather before noise tests could be flown
15-Nov-08	V320AC	0.21	Pass	10%	Pass	13.58	Pass	Complete	V320AC_dipole_report	0.14	Pass	N320AB	
15-Nov-08	V320AN	0.33	Pass	8%	Pass	3.88	Pass	Complete	V320AN_dipole_report	0.31	Pass	N320AY	
16-Nov-08	V321AC	0.10	Pass	9%	Pass	4.77	Pass	Complete	V321AC_dipole_report	0.24	Pass	N321AB	
16-Nov-08	V321AR	0.12	Pass	14%	Pass	2.55	Pass	Complete	V321AR_dipole_report	0.19	Pass	N321AS	
17-Nov-08	V322AL	0.17	Pass	7%	Pass	2.66	Pass	Complete	V322AL_dipole_report	0.48	Pass	N322AK	
17-Nov-08	V322AY	0.45	Pass	16%	Pass	8.53	Pass	Complete	V322AY_dipole_report	0.45	Pass	N322AZ	
18-Nov-08	V323AC	0.11	Pass	9%	Pass	2.76	Pass	Complete	V323AC_dipole_report	0.69	Pass	N323AB	
18-Nov-08	V323AU	0.40	Pass	18%	Pass	7.19	Pass	Complete	V323AU_dipole_report	0.18	Pass	N323AT	
19-Nov-08	V324AB	0.09	Pass	10%	Pass	5.39	Pass	Complete	V324AB_dipole_report	0.17	Pass	N324AC	
19-Nov-08	V324AV	Bad GPS						Incomplete	V324AV_dipole_report	0.11	Pass	N324AT	
20-Nov-08	V325AC	0.21	Pass	9%	Pass	7.01	Pass	Complete	V325AC_dipole_report	0.17	Pass	N325AB	
20-Nov-08	V325AU	0.28	Pass	19%	Pass	6.24	Pass	Complete	V325AU_dipole_report	0.17	Pass	N325AT	
21-Nov-08	V326AC	0.19	Pass	18%	Pass	6.00	Pass	Complete	V326AC_dipole_report	0.22	Pass	N326AB	
21-Nov-08	V326AU	0.41	Pass	12%	Pass	10.46	Pass	Complete	V326AU_dipole_report	0.25	Pass	N326AT	
22-Nov-08	V327AC	0.17	Pass	10%	Pass	4.16	Pass	Complete	V327AC_dipole_report	0.15	Pass	N327AB	
22-Nov-08	V327AS	0.35	Pass	13%	Pass	13.91	Pass	Complete	V327AS_dipole_report	0.22	Pass	N327AR	
23-Nov-08	V327AC	0.11	Pass	4%	Pass	3.71	Pass	Complete	V327AC_dipole_report	0.18	Pass	N327AB	
23-Nov-08	n/a	No end of day QC data (unscheduled maintenance)											
30-Nov-08	V335AC	0.10	Pass	7%	Pass	3.86	Pass	Complete	V335AC_dipole_report	0.26	Pass	N335AB	
30-Nov-08	V335AS	0.26	Pass	19%	Pass	4.92	Pass	Complete	V335AS_dipole_report	0.13	Pass	N335AR	
1-Dec-08	V336AC	0.15	Pass	10%	Pass	2.13	Pass	Complete	V336AC_dipole_report	0.19	Pass	N336AB	
1-Dec-08	V336AU	0.15	Pass	18%	Pass	3.66	Pass	Complete	V336AU_dipole_report	0.22	Pass	N336AT	
2-Dec-08	V337AC	0.16	Pass	15%	Pass	1.31	Pass	Complete	V337AC_dipole_report	0.29	Pass	N336AB	
2-Dec-08	V337AR	0.14	Pass	15%	Pass	2.37	Pass	Complete	V337AR_dipole_report	0.21	Pass	N337AS	
3-Dec-08	V338AD	0.16	Pass	15%	Pass	1.31	Pass	Complete	V338AD_dipole_report	0.29	Pass	N338AC	
3-Dec-08	V338AX	0.14	Pass	15%	Pass	2.37	Pass	Complete	V338AX_dipole_report	0.21	Pass	N338AW	
4-Dec-08	V339AC	0.11	Pass	8%	Pass	1.57	Pass	Complete	V339AC_dipole_report	0.25	Pass	N339AB	
4-Dec-08	V339AU	0.14	Pass	19%	Pass	2.88	Pass	Complete	V339AU_dipole_report	0.16	Pass	N339AT	
5-Dec-08	V340AC	0.07	Pass	7%	Pass	2.61	Pass	Complete	V340AC_dipole_report	0.32	Pass	N340AB	
5-Dec-08	V340BA	0.25	Pass	45%	Fail	7.01	Pass	Complete	V340BA_dipole_report	0.19	Pass	N340BB	poor coverage - lines flown offset from Validation line
6-Dec-08	V341AD	0.12	Pass	7%	Pass	1.68	Pass	Complete	V341AD_dipole_report	0.24	Pass	N341AC	
6-Dec-08	V341BC	0.16	Pass	9%	Pass	4.07	Pass	Complete	V341BC_dipole_report	0.15	Pass	N341BD	
7-Dec-08	V342AD	0.09	Pass	10%	Pass	1.86	Pass	Complete	V342AD_dipole_report	0.23	Pass	N342AC	
7-Dec-08	V342BC	0.20	Pass	16%	Pass	6.75	Pass	Complete	V342BC_dipole_report	0.17	Pass	N342BB	
8-Dec-08	V343AD	0.07	Pass	10%	Pass	2.75	Pass	Complete	V343AD_dipole_report	0.28	Pass	N343AC	
8-Dec-08	V343BA	0.14	Pass	6%	Pass	1.99	Pass	Complete	V343BA_dipole_report	0.23	Pass	N343BB	
10-Dec-08	V345AD	0.09	Pass	9%	Pass	2.90	Pass	Complete	V345AD_dipole_report	0.29	Pass	N345AB	
10-Dec-08	V345AY	0.10	Pass	9%	Pass	1.46	Pass	Complete	V345AY_dipole_report	0.3	Pass	N345AX	
11-Dec-08	V346AD	0.09	Pass	4%	Pass	2.58	Pass	Complete	V346AD_dipole_report	0.16	Pass	N346AC	
11-Dec-08		No end of day QC data (no access due to demolition activities)								0.22	Pass	N346BB	
12-Dec-08	V347AD	0.09	Pass	5%	Pass	1.80	Pass	Complete	V347AD_dipole_report	0.29	Pass	N347AC	
12-Dec-08	V347BF	0.10	Pass	12%	Pass	0.90	Pass	Complete	V347BF_dipole_report	0.2	Pass	N347BE	
13-Dec-08	V348AC	0.06	Pass	9%	Pass	1.89	Pass	Complete	V348AC_dipole_report	0.27	Pass	N348AB	
13-Dec-08	V348BV	0.21	Pass	5%	Pass	2.14	Pass	Complete	V348BV_dipole_report	0.11	Pass	N348BU	
14-Dec-08	V349AD	0.11	Pass	9%	Pass	2.93	Pass	Complete	V349AD_dipole_report	0.33	Pass	N348AC	
14-Dec-08	V349BP	0.17	Pass	12%	Pass	1.98	Pass	Complete	V349BP_dipole_report	0.17	Pass	N348BO	
15-Dec-08	V350AD	0.09	Pass	12%	Pass	2.25	Pass	Complete	V350AD_dipole_report	0.26	Pass	N350AC	
15-Dec-08	V350AR	0.18	Pass	9%	Pass	2.55	Pass	Complete	V350AR_dipole_report	0.16	Pass	N350AQ	
16-Dec-08	V351AD	0.13	Pass	15%	Pass	2.15	Pass	Complete	V351AD_dipole_report	0.25	Pass	N351AC	
16-Dec-08		No end of day QC data (unscheduled maintenance)											
17-Dec-08	V352AD	0.09	Pass	9%	Pass	2.47	Pass	Complete	V352AD_dipole_report	0.27	Pass	N352AC	
17-Dec-08	V352BF	0.17	Pass	10%	Pass	1.70	Pass	Complete	V352BF_dipole_report	0.14	Pass	N352BE	
18-Dec-08	V3535AD	0.09	Pass	6%	Pass	2.29	Pass	Complete	V3535AD_dipole_report	0.32	Pass	N353AC	
18-Dec-08	V353BM	0.13	Pass	14%	Pass	1.23	Pass	Complete	V353BM_dipole_report	0.13	Pass	N353BL	
19-Dec-08	V354AD	0.10	Pass	9%	Pass	2.02	Pass	Complete	V354AD_dipole_report	0.25	Pass	N354AC	
19-Dec-08	V354BC	0.09	Pass	10%	Pass	1.66	Pass	Complete	V354BC_dipole_report	0.21	Pass	N354BE	
20-Dec-08	V355AC	0.08	Pass	9%	Pass	2.82	Pass	Complete	V355AC_dipole_report	0.28	Pass	N355AB	
20-Dec-08	V355AF	0.15	Pass	13%	Pass	3.48	Pass	Complete	V355AF_dipole_report	0.32	Pass	N355AE	

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APPENDIX D – DATA ANALYSIS LOG (EXAMPLE)

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VNTR Analysis Log

Total Magnetic Field Data			Target Selections							Dipole Fit Analysis		
Site	Grid (*.grd)	Archive (*.xyz)	Method	Analytic Signal Grid (*.grd)	AS Threshold (nT/m^2)	Manual Selection Analyst	Prelim. List Name (*.csv)	Target Selection QC	Final List Name (*.csv)	Dipole Fit Analyst	Dipole Fit QC	Output file (*.xls)
Water1	VNTR_Water1_mag	VNTR_Water1_mag_archive	AS pk/manual	VNTR_Water1_AS	3	RMehl	VNTR_Water_Targets_all	DWright	VNTR_Water_Targets_QC	SMcNamara	SBillings	Combined Target Analysis Results
Water2	VNTR_Water2_mag	VNTR_Water2_mag_archive	AS pk/manual	VNTR_Water2_AS	3	RMehl	VNTR_Water_Targets_all	DWright	VNTR_Water_Targets_QC	SMcNamara	SBillings	Combined Target Analysis Results
Water3	VNTR_Water3_mag	VNTR_Water3_mag_archive	AS pk/manual	VNTR_Water3_AS	3	RMehl	VNTR_Water_Targets_all	DWright	VNTR_Water_Targets_QC	SMcNamara	SBillings	Combined Target Analysis Results
Water4	VNTR_Water4_mag	VNTR_Water4_mag_archive	AS pk/manual	VNTR_Water4_AS	3	RMehl	VNTR_Water_Targets_all	DWright	VNTR_Water_Targets_QC	SMcNamara	SBillings	Combined Target Analysis Results
Water5	VNTR_Water5_mag	VNTR_Water5_mag_archive	AS pk/manual	VNTR_Water5_AS	3	RMehl	VNTR_Water_Targets_all	DWright	VNTR_Water_Targets_QC	SMcNamara	SBillings	Combined Target Analysis Results
Water6	VNTR_Water6_mag	VNTR_Water6_mag_archive	AS pk/manual	VNTR_Water6_AS	3	RMehl	VNTR_Water_Targets_all	DWright	VNTR_Water_Targets_QC	SMcNamara	SBillings	Combined Target Analysis Results
Water7	VNTR_Water7_mag	VNTR_Water7_mag_archive	AS pk/manual	VNTR_Water7_AS	3	RMehl	VNTR_Water_Targets_all	DWright	VNTR_Water_Targets_QC	SMcNamara	SBillings	Combined Target Analysis Results
Water8	VNTR_Water8_mag	VNTR_Water8_mag_archive	AS pk/manual	VNTR_Water8_AS	3	RMehl	VNTR_Water_Targets_all	DWright	VNTR_Water_Targets_QC	SMcNamara	SBillings	Combined Target Analysis Results
Water9	VNTR_Water9_mag	VNTR_Water9_mag_archive	AS pk/manual	VNTR_Water9_AS	3	RMehl	VNTR_Water_Targets_all	DWright	VNTR_Water_Targets_QC	SMcNamara	SBillings	Combined Target Analysis Results
Water10	VNTR_Water10_mag	VNTR_Water10_mag_archive	AS pk/manual	VNTR_Water10_AS	3	RMehl	VNTR_Water_Targets_all	DWright	VNTR_Water_Targets_QC	SMcNamara	SBillings	Combined Target Analysis Results
Land1	VNTR_Land1_mag	VNTR_Land1_mag_archive	AS pk/manual	VNTR_Land1_AS	3	RMehl	VNTR_Land_Targets_all	DWright	VNTR_Land_Targets_QC	SMcNamara	SBillings	Combined Target Analysis Results
Land2	VNTR_Land2_mag	VNTR_Land2_mag_archive	AS pk/manual	VNTR_Land2_AS	3	RMehl	VNTR_Land_Targets_all	DWright	VNTR_Land_Targets_QC	SMcNamara	SBillings	Combined Target Analysis Results
Land3	VNTR_Land3_mag	VNTR_Land3_mag_archive	AS pk/manual	VNTR_Land3_AS	3	RMehl	VNTR_Land_Targets_all	DWright	VNTR_Land_Targets_QC	SMcNamara	SBillings	Combined Target Analysis Results
Land4	VNTR_Land4_mag	VNTR_Land4_mag_archive	AS pk/manual	VNTR_Land4_AS	3	RMehl	VNTR_Land_Targets_all	DWright	VNTR_Land_Targets_QC	SMcNamara	SBillings	Combined Target Analysis Results
Land5	VNTR_Land5_mag	VNTR_Land5_mag_archive	AS pk/manual	VNTR_Land5_AS	3	RMehl	VNTR_Land_Targets_all	DWright	VNTR_Land_Targets_QC	SMcNamara	SBillings	Combined Target Analysis Results
Land6	VNTR_Land6_mag	VNTR_Land6_mag_archive	AS pk/manual	VNTR_Land6_AS	3	RMehl	VNTR_Land_Targets_all	DWright	VNTR_Land_Targets_QC	SMcNamara	SBillings	Combined Target Analysis Results
Land7	VNTR_Land7_mag	VNTR_Land7_mag_archive	AS pk/manual	VNTR_Land7_AS	3	RMehl	VNTR_Land_Targets_all	DWright	VNTR_Land_Targets_QC	SMcNamara	SBillings	Combined Target Analysis Results
Land8	VNTR_Land8_mag	VNTR_Land8_mag_archive	AS pk/manual	VNTR_Land8_AS	3	RMehl	VNTR_Land_Targets_all	DWright	VNTR_Land_Targets_QC	SMcNamara	SBillings	Combined Target Analysis Results

GIS Mapping		
Map Products	GIS Production	GIS QC
Combined DEM/Bathymetry	PHille	DWright
Survey Altitude	PHille	DWright
Orth-photo, CH2 grid	PHille	DWright
Full Total Magnetic Field	PHille	DWright
De-median Filtered TMF	PHille	DWright
Anomaly Density	PHille	DWright
Dipole Angle Distribution	PHille	DWright

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APPENDIX E –DAILY FIELD NOTES: DAILY AIRBORNE GEOPHYSICAL SURVEY REPORT

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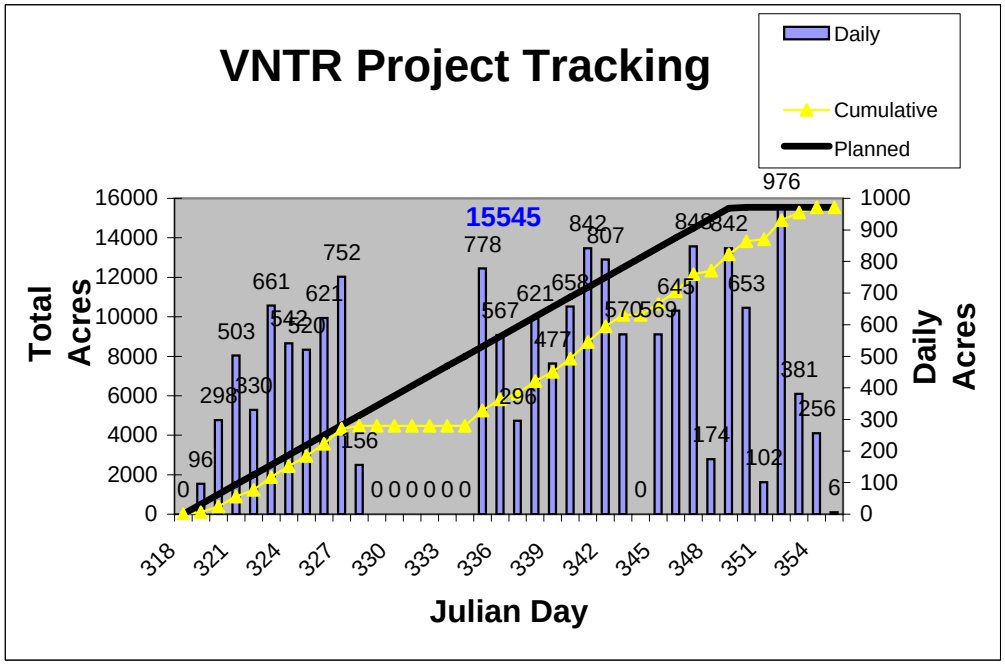
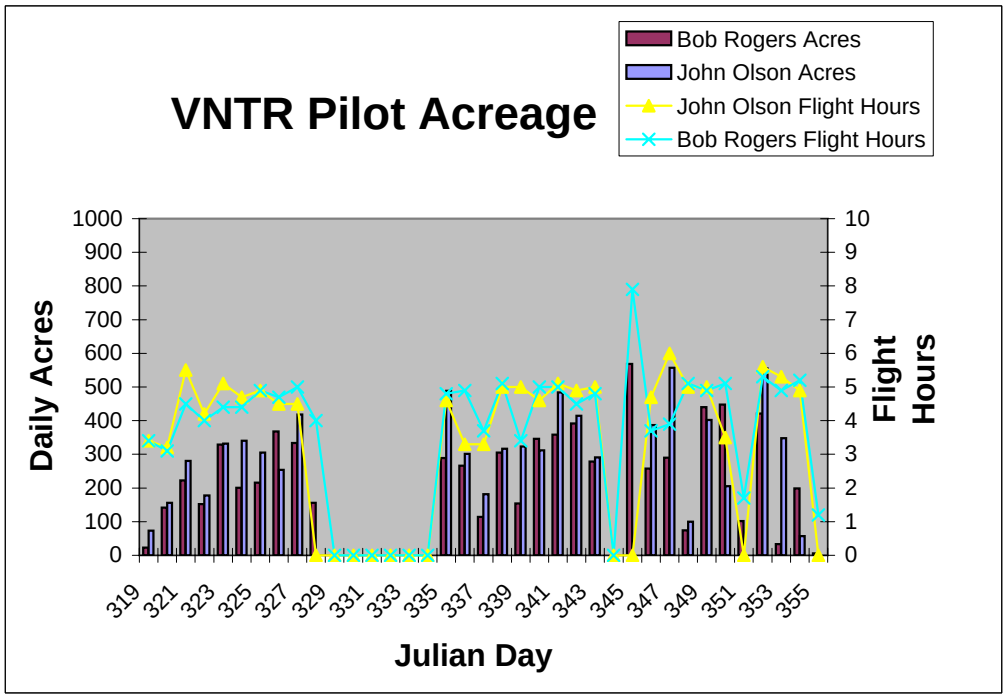
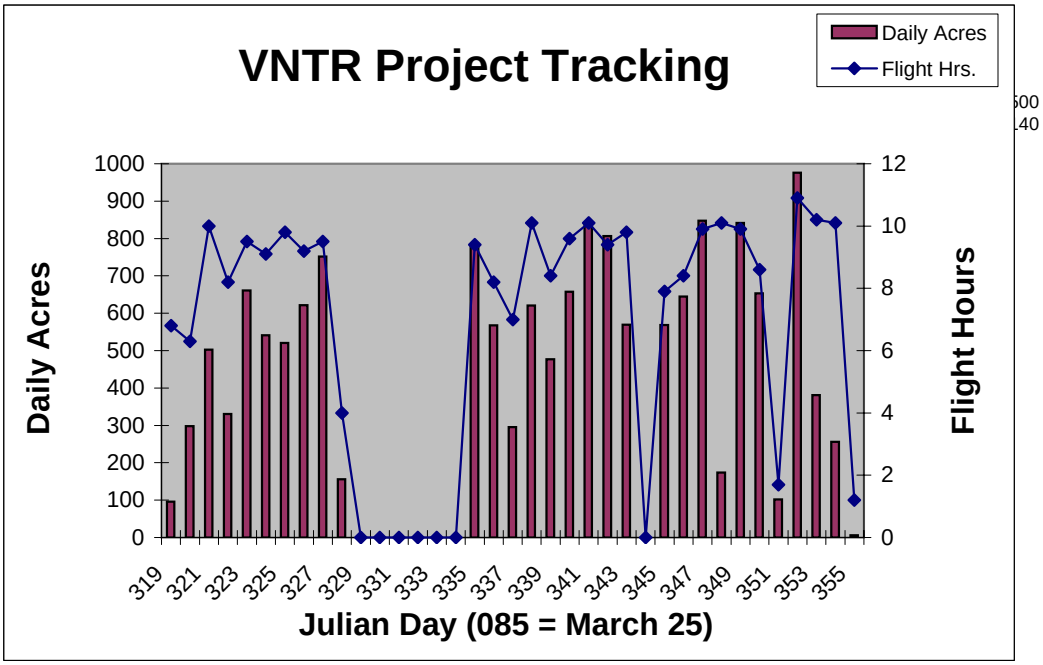

VNTR Project Tracking
Daily
Cumulative
Planned
Total Acres
Daily Acres
Julian Day
15545
976
0
96
298
503
330
661
542
520
621
752
156
0 0 0 0 0 0
778
567
296
621
477
658
842
807
570
0
569
645
848
842
653
174
102
381
256
6


VNTR Pilot Acreage
Bob Rogers Acres
John Olson Acres
John Olson Flight Hours
Bob Rogers Flight Hours
Daily Acres
Flight Hours
Julian Day


VNTR Project Tracking
Daily Acres
Flight Hrs.
Daily Acres
Flight Hours
1000
900
800
700
600
500
400
300
200
100
0
12
10
8
6
4
2
0
319
321
323
325
327
329
331
333
335
337
339
341
343
345
347
349
351
353
355
Julian Day (085 = March 25)

Day	Date	# of Days	Julian Day	Actual Daily	Actual Cumulative	Actual	Planned	Fuel	Pilots RR Hrs	Pilots JO Hrs	Total Hours	Total Acres
Thursday	13-Nov-08	0	318	0	0	0	0					0
Friday	14-Nov-08	1	319	96	96	500	500		3.4	3.4	6.8	96
Saturday	15-Nov-08	2	320	298	394	1000	1000		3.1	3.2	6.3	298
Sunday	16-Nov-08	3	321	503	897	1500	1500		4.5	5.5	10.0	503
Monday	17-Nov-08	4	322	330	1227	2000	2000		4.0	4.2	8.2	330
Tuesday	18-Nov-08	5	323	661	1888	2500	2500		4.4	5.1	9.5	661
Wednesday	19-Nov-08	6	324	542	2430	3000	3000		4.4	4.7	9.1	542
Thursday	20-Nov-08	7	325	520	2950	3500	3500		4.9	4.9	9.8	520
Friday	21-Nov-08	8	326	621	3571	4000	4000	377	4.7	4.5	9.2	621
Saturday	22-Nov-08	9	327	752	4323	4500	4500	330	5.0	4.5	9.5	752
Sunday	23-Nov-08	10	328	156	4479	5000	5000	65	4.0	0.0	4.0	156
Monday	24-Nov-08	11	329	0	4479	5000	5500	0	0.0	0.0	0.0	0
Tuesday	25-Nov-08	12	330	0	4479	5000	6000	0	0.0	0.0	0.0	0
Wednesday	26-Nov-08	13	331	0	4479	5000	6500	0	0.0	0.0	0.0	0
Thursday	27-Nov-08	14	332	0	4479	5000	7000	0	0.0	0.0	0.0	0
Friday	28-Nov-08	15	333	0	4479	5000	7500	0	0.0	0.0	0.0	0
Saturday	29-Nov-08	16	334	0	4479	5000	8000	0	0.0	0.0	0.0	0
Sunday	30-Nov-08	17	335	778	5257	5500	8500	295	4.8	4.6	9.4	778
Monday	1-Dec-08	18	336	567	5824	6000	9000	250	4.9	3.3	8.2	567
Tuesday	2-Dec-08	19	337	296	6119	6500	9500	217	3.7	3.3	7.0	296
Wednesday	3-Dec-08	20	338	621	6740	7000	10000	358	5.1	5.0	10.1	621
Thursday	4-Dec-08	21	339	477	7217	7500	10500	190	3.4	5.0	8.4	477
Friday	5-Dec-08	22	340	658	7875	8000	11000	297	5.0	4.6	9.6	658
Saturday	6-Dec-08	23	341	842	8717	8500	11500	287	5.0	5.1	10.1	842
Sunday	7-Dec-08	24	342	807	9524	9000	12000	257	4.5	4.9	9.4	807
Monday	8-Dec-08	25	343	570	10093	9500	12500	304	4.8	5.0	9.8	570
Tuesday	9-Dec-08	26	344	0	10093	9500	13000		0.0	0.0	0.0	0
Wednesday	10-Dec-08	27	345	569	10662	10000	13500	203	7.9	0.0	7.9	569
Thursday	11-Dec-08	28	346	645	11307	10500	14000	245	3.7	4.7	8.4	645
Friday	12-Dec-08	29	347	848	12155	11000	14500	263	3.9	6.0	9.9	848
Saturday	13-Dec-08	30	348	174	12329	11500	15000	296	5.1	5.0	10.1	174
Sunday	14-Dec-08	31	349	842	13171	12000	15500	315	4.9	5.0	9.9	842
Monday	15-Dec-08	32	350	653	13824	12500	15545	225	5.1	3.5	8.6	653
Tuesday	16-Dec-08	33	351	102	13925	12500	15545	52	1.7	0.0	1.7	102
Wednesday	17-Dec-08	34	352	976	14901	13000	15545	316	5.3	5.6	10.9	976
Thursday	18-Dec-08	35	353	381	15283	13500	15545	296	4.9	5.3	10.2	381
Friday	19-Dec-08	36	354	256	15539	14000	15545	292	5.2	4.9	10.1	256
Saturday	20-Dec-08	37	355	6	15545	14500	15545	32	1.2	0.0	1.2	6
Total								**2332**	**133**	**120.8**	**253.3**	**15545**

Pilots: JO John Olsen
RR Robert Rogers

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APPENDIX F – MAP PRODUCTS

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APPENDIX G: ANOMALY POSITIONS AND DIPOLE FIT RESULTS (EXAMPLE)

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Final Target List/Analysis Spreadsheet Description

Column Name	Units	Description
ID		Final unique target ID number
SITE		Original site (e.g. 'Water 1')
TARGET		Original ID Number - (reset for each site)
X	meters	Dipole fit easting position estimate (WGS84 UTM Zone 19)
Y	meters	Dipole fit northing position estimate (WGS84 UTM Zone 19)
DX	meters	Dipole fit easting position estimate offset from original target position
DY	meters	Dipole fit northing position estimate offset from original target position
Elevation (HAE m)	meters	Dipole fit vertical position estimate relative to WGS84 Ellipsoid
DEM (HAE m)	meters	Digital Elevation Model - combined terrestrial and sea floor elevations relative to WGS84 Ellipsoid
DEPTH	meters	Target Depth below DEM (m)
MAGMIN	nanoTesla	Minimum de-median filtered total magnetic field value (nT)
MAGMAX	nanoTesla	Maximum de-median filtered total magnetic field value (nT)
MAGAMP	nanoTesla	Net anomaly amplitude (nT)
MOMENT	ampere-meter^2	Dipole fit magnetic moment estimate
AZIMUTH	degrees	Dipole fit horizontal angle relative to magnetic north
DIP	degrees	Dipole fit vertical angle relative to magnetic north
ANGLE	degrees	Dipole fit angle relative to magnetic north (aka 'solid angle')
CORRCOEFF		Correlation coefficient of observed data vs 'best fit' dipole model
FIT Result		Declaration of successful or unsuccessful fit of observed data to a dipole model
CLASS		Classification category based upon dipole fit results
Description		Description of classification category

Target Identification			Dipole Position							Dipole Size				Dipole Orientation		
ID	SITE	TARGET	X	Y	DX	DY	Elevation (HAE m)	DEM (HAE m)	DEPTH	MAGMIN	MAGMAX	MAGAMP	MOMENT	AZIMUTH	DIP	ANGLE
1	LAND1	1	249838.86	2009162.80	8.26	-10.00	0.84	1.79	0.95	-109.9	11.3	121.1	789.2	-65	-2	62
2	LAND1	2	251242.85	2008439.04	-1.74	1.74	9.58	14.68	5.09	-7.1	4.7	11.8	57.5	-29	13	59
3	LAND1	3	250187.95	2008478.45	-3.64	-3.44	18.71	26.66	7.95	-17.2	13.6	30.8	647.4	104	-4	106
4	LAND1	4	247737.32	2009274.93	1.22	-0.56	8.08	7.75	-0.32	-16.9	28.2	45.1	232.6	-24	-16	30
5	LAND1	5	253378.26	2008144.96	-4.43	-0.83	-1.90	-1.27	0.63	-102.3	142.7	245.0	251.9	-13	-20	24
6	LAND1	6	249119.67	2009213.04	1.77	0.84	-0.21	2.25	2.46	-2.8	2.7	5.5	27.3	108	9	118
7	LAND1	7	245453.63	2009227.53	-0.26	-0.26	21.72	26.11	4.39	-3.7	3.7	7.4	126.7	-77	-13	62
8	LAND1	8	248423.46	2009289.40	0.56	1.40	3.79	4.54	0.75	-2.8	3.1	5.9	11.2	22	-20	38
9	LAND1	9	245453.58	2009227.49	0.78	-1.30	22.89	25.48	2.58	-3.7	3.7	7.4	79.6	-77	-11	64
10	LAND1	10	245697.31	2009349.04	-0.38	-1.15	36.21	39.11	2.90	-4.6	2.9	7.5	35.3	110	-1	112
11	LAND1	11	248964.44	2009204.95	-3.05	-1.04	-1.89	2.34	4.23	-1.1	3.7	4.8	11.7	-107	-8	87
12	LAND1	12	252630.07	2008252.59	-0.52	0.00	-8.20	3.68	11.89	-3.4	3.9	7.3	1212.0	-56	-9	51
13	LAND1	13	246115.10	2009270.35	2.50	2.15	25.44	27.29	1.84	-6.2	2.2	8.4	75.0	-44	-22	34
14	LAND1	14	247395.80	2009377.53	-5.29	2.43	56.81	61.03	4.21	-15.0	5.4	20.5	167.3	-34	18	65
15	LAND1	15	247436.94	2009268.28	-0.45	0.08	43.84	44.24	0.40	-0.3	4.1	4.4	24.6	172	-59	76
16	LAND1	16	247800.50	2009000.60	N/A	N/A	N/A	44.16	N/A	-8.6	6.1	14.7	N/A	N/A	N/A	N/A
17	LAND1	17	248147.60	2008969.14	10.00	-1.35	6.35	5.00	-1.35	-12.6	3.7	16.4	65.1	159	15	150
18	LAND1	18	250941.70	2008797.30	N/A	N/A	N/A	16.89	N/A	-7.1	3.5	10.6	N/A	N/A	N/A	N/A
19	LAND1	19	245916.95	2009197.90	-4.74	5.40	22.16	26.69	4.52	-11.3	11.2	22.5	263.1	80	-34	69
20	LAND1	20	246607.79	2009727.60	1.39	-2.29	14.64	22.96	8.32	-7.2	10.0	17.2	378.6	-20	-36	10
21	LAND1	21	254047.09	2007962.25	-1.60	4.25	8.56	18.96	10.39	-32.7	7.7	40.4	2693.8	-33	11	58
22	LAND1	22	246263.44	2009558.54	-6.85	-4.35	34.24	38.26	4.01	-32.8	10.5	43.3	208.7	-48	47	96
23	LAND1	23	249081.56	2009038.54	1.96	1.64	-2.56	9.64	12.21	-24.8	7.0	31.8	4084.2	45	-6	63
24	LAND1	24	247644.75	2009007.60	-2.14	8.00	43.21	48.31	5.10	-15.1	14.5	29.6	353.7	-120	10	109
25	LAND1	25	247509.22	2009598.84	5.42	-8.65	10.16	11.53	1.37	-13.2	13.5	26.6	100.1	-21	-40	7
26	LAND1	26	248102.22	2009425.33	3.02	-1.66	3.54	4.64	1.10	-15.3	3.9	19.2	20.1	-138	-47	77
27	LAND1	27	246434.07	2009235.80	-1.12	2.80	39.31	42.09	2.77	-12.3	3.8	16.0	64.1	-60	19	77
28	LAND1	28	252592.74	2008218.01	-0.45	3.81	7.45	14.58	7.13	-25.6	4.5	30.1	244.7	-58	10	68
29	LAND1	29	252244.28	2008209.17	-1.41	7.37	1.26	14.53	13.27	-10.2	26.3	36.5	3868.4	-134	-4	108
30	LAND1	30	249901.98	2008589.89	8.08	1.19	3.28	5.21	1.92	-52.0	-1.9	50.0	393.6	39	14	76
31	LAND1	31	252479.00	2008234.21	-7.39	1.31	19.23	20.23	1.00	-15.7	10.2	25.9	31.2	90	39	124
32	LAND1	32	246560.26	2009726.51	1.56	0.81	30.63	30.12	-0.51	-18.1	9.9	28.1	43.2	92	3	103
33	LAND1	33	247012.14	2009574.11	5.34	0.91	24.59	27.72	3.12	-8.9	30.7	39.6	225.8	-129	-9	102
34	LAND1	34	248257.98	2009439.13	5.18	-2.36	-4.97	-0.50	4.46	-51.7	13.7	65.4	277.5	50	13	81
35	LAND1	35	251894.51	2008277.33	-5.68	-1.26	6.78	9.49	2.71	-13.8	12.9	26.6	77.9	-144	53	147
36	LAND1	36	249525.94	2008997.88	-3.85	3.48	25.64	25.12	-0.52	-11.5	22.6	34.1	86.5	52	17	85
37	LAND1	37	249747.65	2008644.55	0.05	3.95	10.68	13.06	2.37	-15.2	6.8	22.0	58.5	60	20	92
38	LAND1	38	251874.66	2008294.79	9.66	9.99	5.41	11.36	5.94	-40.4	32.6	73.0	638.8	-68	-44	39
39	LAND1	39	252546.91	2008121.61	-5.88	-0.28	11.04	23.04	11.99	-7.6	28.7	36.3	1356.5	-47	-44	24
40	LAND1	40	245832.72	2009362.31	-1.87	5.91	29.12	36.89	7.76	-11.1	39.9	51.1	762.7	-140	-30	91

Target Identification			Dipole Fit Quality		Classification	
ID	SITE	TARGET	CORRCOEFF	FIT Result	CLASS	Description
1	LAND1	1	0.990	Success	4	Depth < 3m, Angle < 75°
2	LAND1	2	0.970	Success	2	Depth > 3m
3	LAND1	3	0.990	Success	2	Depth > 3m
4	LAND1	4	0.990	Success	4	Depth < 3m, Angle < 75°
5	LAND1	5	0.990	Success	4	Depth < 3m, Angle < 75°
6	LAND1	6	0.980	Success	3	Depth < 3m, Angle > 75°
7	LAND1	7	0.990	Success	4	Depth < 3m, Angle < 75°
8	LAND1	8	0.890	Success	4	Depth < 3m, Angle < 75°
9	LAND1	9	0.990	Success	4	Depth < 3m, Angle < 75°
10	LAND1	10	0.970	Success	3	Depth < 3m, Angle > 75°
11	LAND1	11	0.870	Success	2	Depth > 3m
12	LAND1	12	0.940	Success	2	Depth > 3m
13	LAND1	13	0.970	Success	4	Depth < 3m, Angle < 75°
14	LAND1	14	0.980	Success	4	Depth < 3m, Angle < 75°
15	LAND1	15	0.930	Success	3	Depth < 3m, Angle > 75°
16	LAND1	16	N/A	Failure	1	no fit
17	LAND1	17	0.920	Success	3	Depth < 3m, Angle > 75°
18	LAND1	18	N/A	Failure	1	no fit
19	LAND1	19	0.970	Success	4	Depth < 3m, Angle < 75°
20	LAND1	20	0.990	Success	2	Depth > 3m
21	LAND1	21	0.990	Success	2	Depth > 3m
22	LAND1	22	0.960	Success	3	Depth < 3m, Angle > 75°
23	LAND1	23	0.930	Success	2	Depth > 3m
24	LAND1	24	0.990	Success	3	Depth < 3m, Angle > 75°
25	LAND1	25	0.840	Success	4	Depth < 3m, Angle < 75°
26	LAND1	26	0.810	Success	3	Depth < 3m, Angle > 75°
27	LAND1	27	0.910	Success	3	Depth < 3m, Angle > 75°
28	LAND1	28	0.980	Success	2	Depth > 3m
29	LAND1	29	0.960	Success	2	Depth > 3m
30	LAND1	30	0.990	Success	3	Depth < 3m, Angle > 75°
31	LAND1	31	0.900	Success	3	Depth < 3m, Angle > 75°
32	LAND1	32	0.920	Success	3	Depth < 3m, Angle > 75°
33	LAND1	33	0.950	Success	2	Depth > 3m
34	LAND1	34	0.930	Success	2	Depth > 3m
35	LAND1	35	0.930	Success	3	Depth < 3m, Angle > 75°
36	LAND1	36	0.910	Success	3	Depth < 3m, Angle > 75°
37	LAND1	37	0.950	Success	3	Depth < 3m, Angle > 75°
38	LAND1	38	0.900	Success	2	Depth > 3m
39	LAND1	39	0.980	Success	2	Depth > 3m
40	LAND1	40	0.970	Success	2	Depth > 3m

Appendix F
NOAA Report—Underwater AUV

Vieques UXO Demonstration Project
AUV Activities Report

November 5-11, 2006

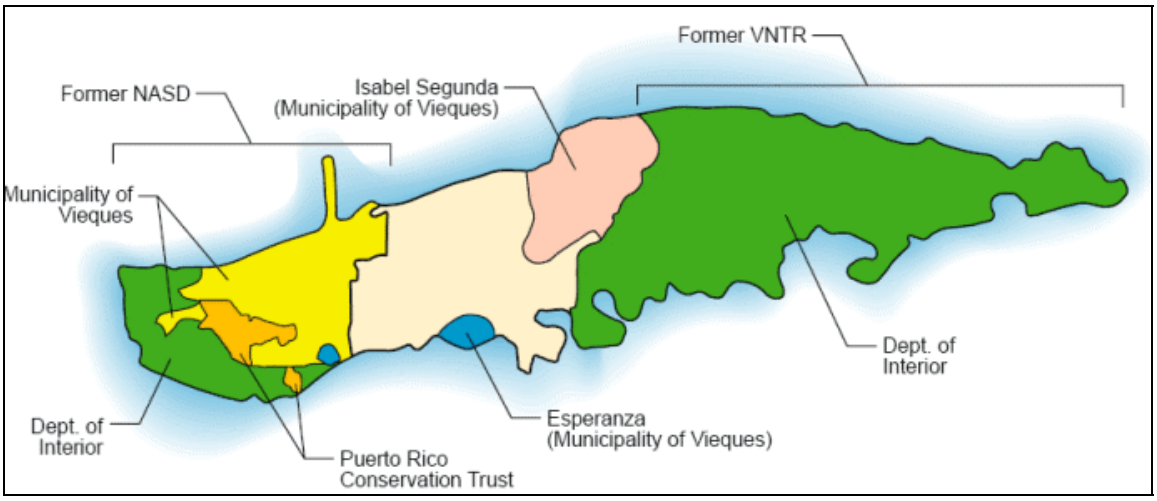
Prepared by:
NOAA Coast Survey Development Laboratory
Hydrographic Systems and Technology Programs

BACKGROUND

The Coast Survey Development Laboratory (CSDL) Hydrographic Systems and Technology Programs (HSTP) was invited to participate in a project led by NOAA's Office of Response and Restoration (OR&R) to determine the feasibility of using modern seafloor mapping technology as an effective and efficient means to evaluate underwater unexploded ordnance (UXO) and munitions debris. HSTP was asked to provide personnel and equipment to demonstrate the use of an Autonomous Underwater Vehicle (AUV) and Remotely Operated Vehicle (ROV). Additionally, HSTP personnel would be available to provide data processing assistance and technical support for the Navigation Response Team 7 vessel that would also be participating in the project.

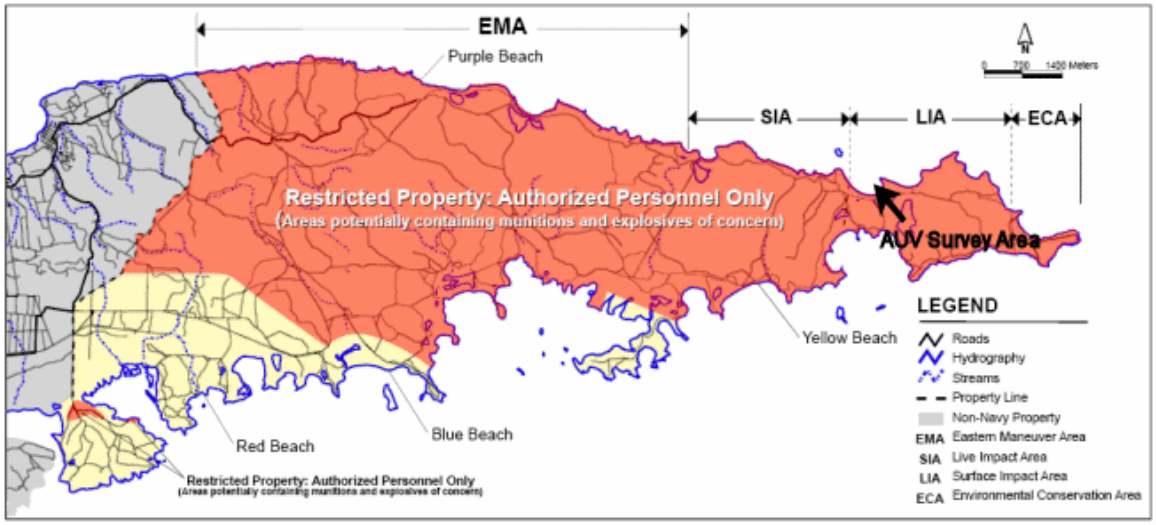
The project area is in the waters around the former U.S. Navy Vieques Naval Training Range (VNTR), now designated as the Vieques National Wildlife Refuge. Portions of the refuge are open to the public; however the majority of the area remains closed due to the presence of unexploded ordnance. According to a flyer[1] published by NAVFAC Atlantic (Naval Facilities Engineering Command Atlantic), as of June 2006 over 99,500 munitions related items have been removed from 165 acres. Of those items, 2,466 were detonated in place, and 1,139 contained high exlosive. (The eastern portion of the Vieques National Wildlife Refuge covers 14,573 acres.[2])

Access to the AUV survey areas is restricted and was coordinated with the on-site Navy representative and ordnance disposal contractors. The AUV team was provided with a radio and was required to contact on-site safety prior to moving locations within the restricted area. In an effort to maintain a good working relationship with the on-site personnel, the AUV survey schedule was modified so that the AUV team could depart the restricted area with the contractor work crews and not require a special escort.



Map of Vieques (source http://public.lantops-ir.org/sites/public/vieques)

[1] Navy Flyer July 2006 (http://public.lantops-ir.org/sites/public/vieques/Public%20Files/library.aspx)
[2] Fact Sheet of Viegues National Wildlife Refuge (http://www.fws.gov/southeast/pubs/facts/vieques.pdf)



Map of the Restricted Area (source http://public.lantops-ir.org/sites/public/vieques)

HSTP PERSONNEL
Rob Downs – AUV Lead
Steve Brodet – ROV Lead
Mike Annis – AUV Data Processing and ROV Support

SCHEDULE *(Sunday, November 5 to Sunday, November 12)*
Sunday –Travel Day
Monday – Equipment Prep
Tuesday – AUV Survey
Wednesday – AUV Survey
Thursday – No survey activities due to ordnance detonation activities.
Friday – Final Day of AUV Survey
Saturday-Sunday–ROV operations

ACTIVITIES
November 6, 2006 – Equipment Preparation - HSTP personnel prepared the equipment necessary for the AUV survey work, including charging the AUV batteries and programming the initial missions. Additionally, Mike Annis assisted the NRT7 crew with readying that vessel for survey operations.

Steve Brodet programming the REMUS-100 AUV

November 7, 2006 – Survey Day 1
Launch Point: Boat ramp at North Beach
Survey Area: Bahia Icacos

Mission 1 – Reconnaissance Box
Start Time: 0937
End Time: 1006

This mission consisted of a box survey plan around the perimeter of the western half of the bay to collect bathymetry data and evaluate side scan sonar settings to be used to program subsequent missions.

The AUV did not return to the programmed end point off the beach at the boat ramp when scheduled and did not respond to acoustic range interrogations with the hand-held Ranger. When a visual search of the survey area was also negative, Steve Brodet entered the bay on the kayak to deploy the Ranger in deeper water to interrogate the AUV. During his transit across the survey area Steve located the AUV on the beach at the western edge of the bay. Permission was obtained from the range safety coordinator to retrieve the AUV from the beach and it was towed back to the launch area with the kayak.

Playback of the mission file revealed the AUV had made an emergency ascent due to shallow water while transiting on the southbound western leg of the survey box. Once on the surface the AUV was overcome by wave action and washed ashore. However, the survey plan was based on existing NOAA nautical charts and no point was planned to be closer than 30 meters to the shore or shoal areas. After recovering the AUV, Mike Annis walked the shoreline while recording points on a handheld GPS receiver. The points were plotted on the nautical chart and the charted shoreline was up to 72 meters off.

The decision was made to conduct subsequent surveys with lines running east to west to take advantage of an AUV programming feature that allows the vehicle to end shoreward survey lines at a user-specified minimum depth to prevent groundings.

Western, Northern, and Eastern Views of Bahia Icacos

AUV Deployment from North Beach Boat Ramp in Bahia Icacos
(Western limit of the bay can be seen in the background)

Mission 2 – Survey of Western Portion of Bahia Icacos
Start Time: 1242
End Time: 1332

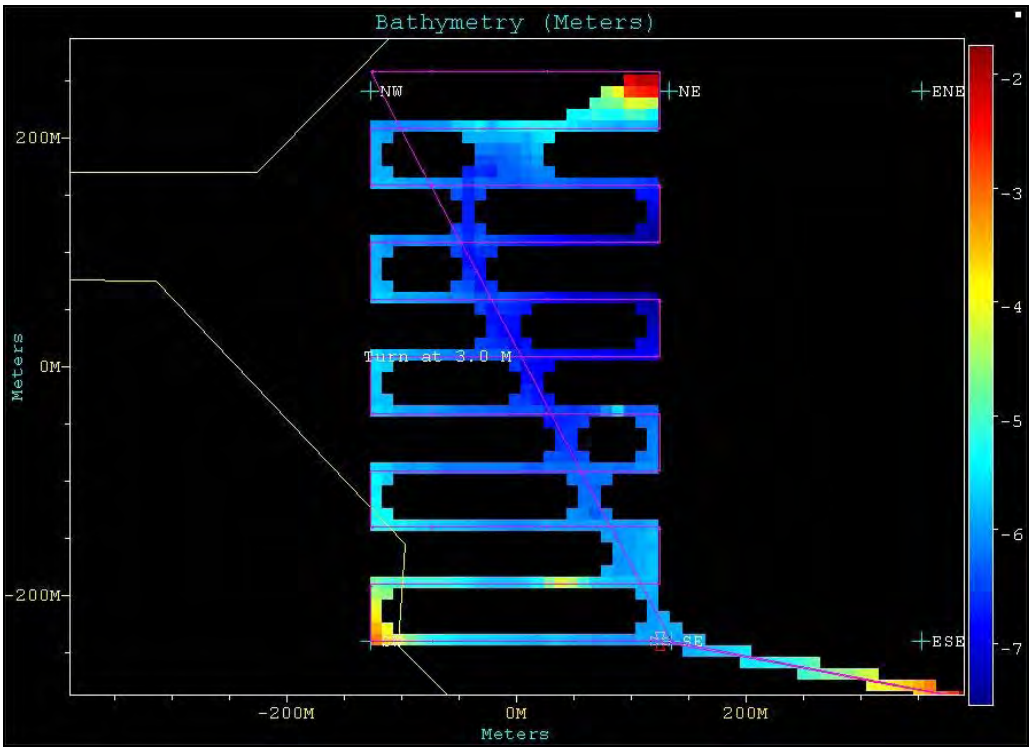
Mission 2 consisted of 11 east-west survey lines in the western portion of the bay. The bathymetry information collected during Mission 1 showed depths between 1 and 5 meters, which confirmed the only charted sounding in the bay (1.6 fathoms). Based on that information the AUV was programmed to run at an altitude of 2 meters and minimum depth of 1 meter. The sonar range was set to 30 meters and the shoreward leg minimum depth was set to 3 meters.

The mission ran without errors, but we were unable to examine the side scan sonar imagery onsite due to lack of an inverter necessary to power the Ethernet connection to the AUV. Later examination of the sonar data revealed poor image quality due to the low vehicle altitude relative to the range scale.

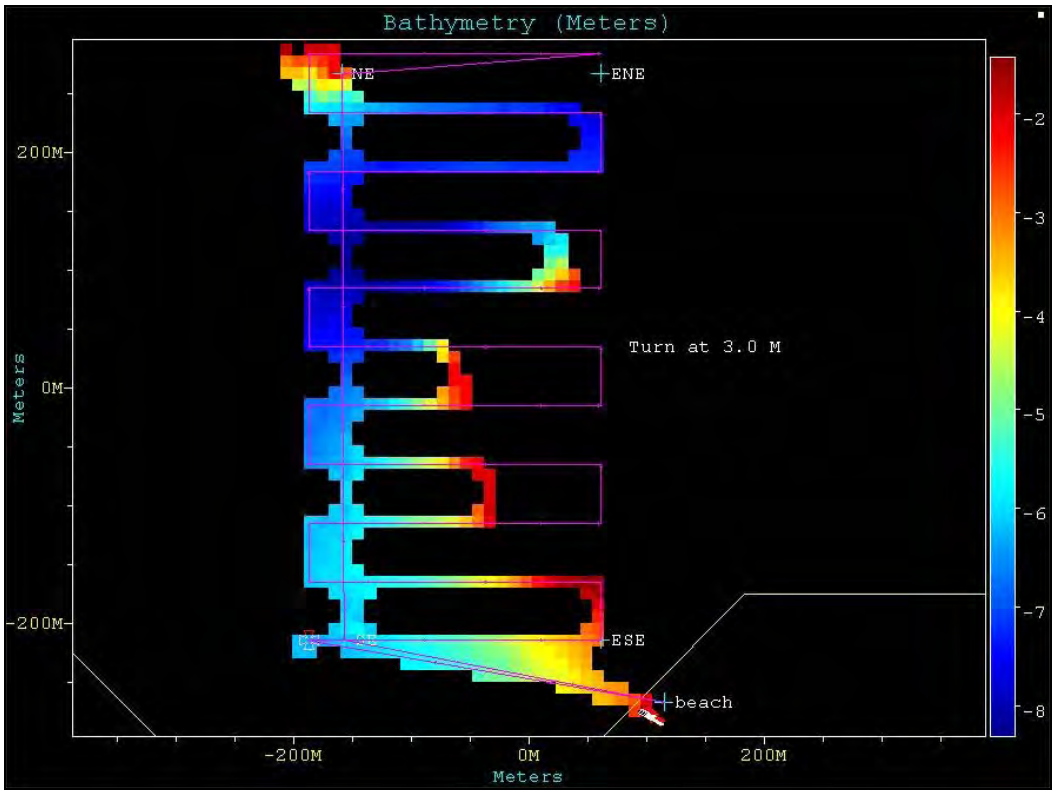
AUV Recovery in Bahia Icacos

Mission 3 – Survey of Eastern Portion of Bahia Icacos
Start Time: 1358
End Time: 1437

Mission 3 was similar to Mission 2, but 11 east-west survey lines were run in the eastern portion of the bay. The sonar imagery quality was also poor. However, the bathymetry data collected during both missions showed more depth than expected (up to 7 meters), which would allow the AUV to run at a higher altitude on subsequent missions.



AUV Bathymetery of the Western Portion of Bahia Icacos



AUV Bathymetry of Eastern Portion of Bahia Icacos

November 8, 2006 – Survey Day 2
Launch Point: Boat ramp at North Beach
Survey Area: Bahia Icacos

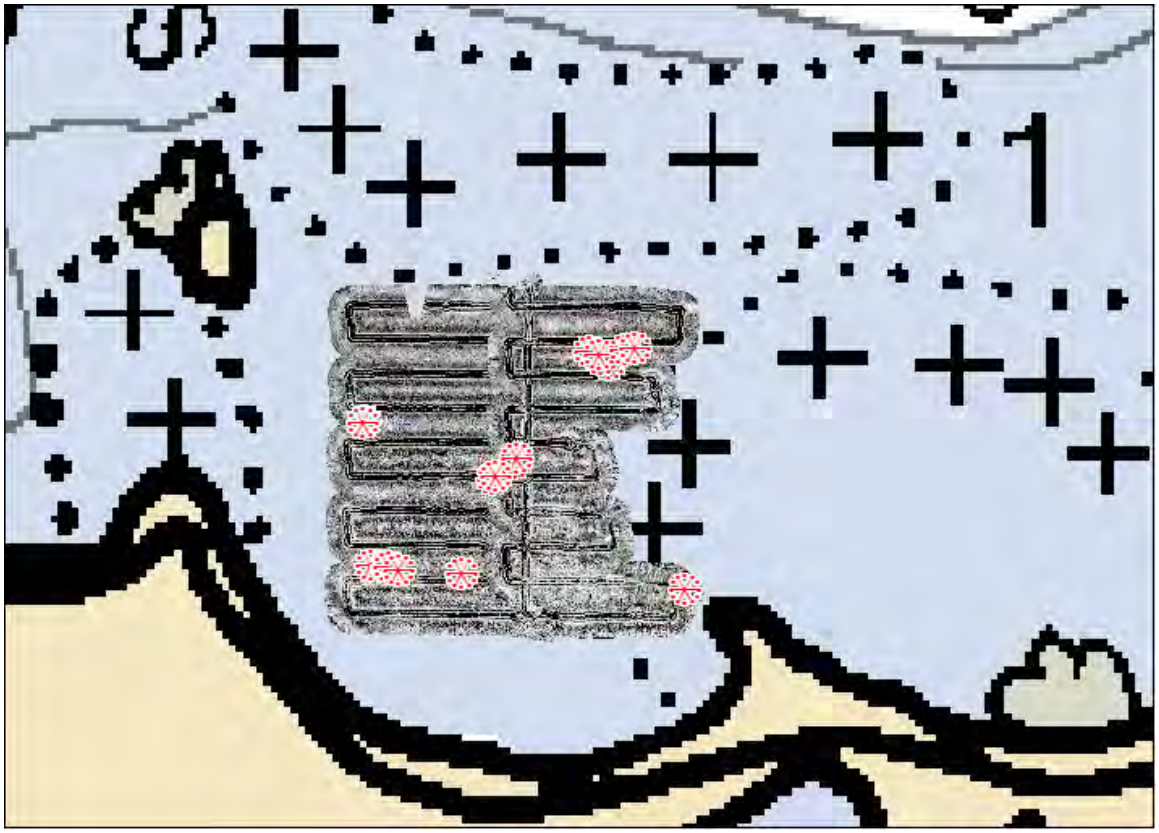
Mission 4 – Survey of Western Portion of Bahia Icacos
Start Time: 0830
End Time: 0916

Mission 4 was a repeat of the previous day survey of the western portion of the bay with the AUV altitude reset to 3 meters. The resulting sonar imagery was good quality in deeper water and adequate in shallower areas. Areas of vegetation and soft coral in the bay also negatively affected sonar image quality.

Several contacts were identified and positions recorded for further investigation with the AUV.

Mission 5 – Survey of Eastern Portion of Bahia Icacos
Start Time: 0951
End Time: 1031

Mission 5 was a repeat of the previous day's survey of the eastern portion of the bay with the AUV altitude reset to 3 meters. The results were the same as Mission 4 with additional contacts identified for further investigation.



AUV Sonar Mosaic and Contacts in Bahia Icacos

Mission 6 – Contact Investigation in Bahia Icacos
Start Time: 1203
End Time: 1230

Mission 6 was reacquisition of eight groupings of previously identified targets. The AUV sonar range scale was set to 20 meters and the AUV operated at an altitude of 3 meters.

Some of the targets were reacquired, however at the 20 meter range scale many were not ensonified.

Mission 7 – Contact Investigation and Survey of Southern Portion in Bahia Icacos
Start Time: 1311
End Time: 1343

Mission 7 was a repeat of Mission 6 with the sonar range scale set at 30 meters and additional north-south lines added to include initial coverage of the southern portion of the bay. As with Mission 6, some of the targets were reacquired, but the overall image quality was not substantially better than during initial surveys.

For the survey of the southern portion of the bay, the AUV was programmed to run north-south lines set with a shoreward leg minimum depth of 3 meters, which should have resulted in the AUV ending the southbound legs in deep enough water to turn onto the northbound legs. However, on the initial southbound leg the AUV made an emergency ascent too near the shore and was beached by the shore break. The

bathymetry data collected indicates that the bottom rose too steeply for the AUV to maneuver.

The AUV was quickly recovered without suffering any damage. No further missions were completed or planned for Bahia Icacos as it is determined that areas near shore and along the shoal at the bay's entrance are too shallow for successful AUV missions.

November 9 2006
On Thursday, November 9 the AUV Team and NRT7 were not allowed access to the Live Impact Area due to ordnance detonation activities. Project members worked on data processing, reporting, and planning. Additionally, HSTP personnel (Mike and Steve) assisted the NRT crew with configuration of the magnetometer and correcting a vessel generator problem.

November 10, 2006 – Survey Day 3
Launch Point: Fossil Beach
Survey Area: Bahia Salinas

Pre-Survey Reconnaissance
Upon arrival at Fossil Beach the AUV Team decided it would be prudent to conduct some reconnaissance of the shore and expected depths prior to deploying the AUV. One team member walked the beach with handheld GPS receiver to measure shoreline, while another member used a handheld GPS receiver and weighted meter tape aboard the kayak to take soundings in the bay.

The charted shoreline around the bay was up to 120 meters off. Fourteen soundings were taken and the deepest portion of the bay (6-7 meters) was a narrow channel between two shoal areas. The central portion of the bay averaged approximately 5 meters.

Mission 1 – Bathymetry Reconnaissance in Bahia Salinas
Start Time: 1037
End Time: 1101

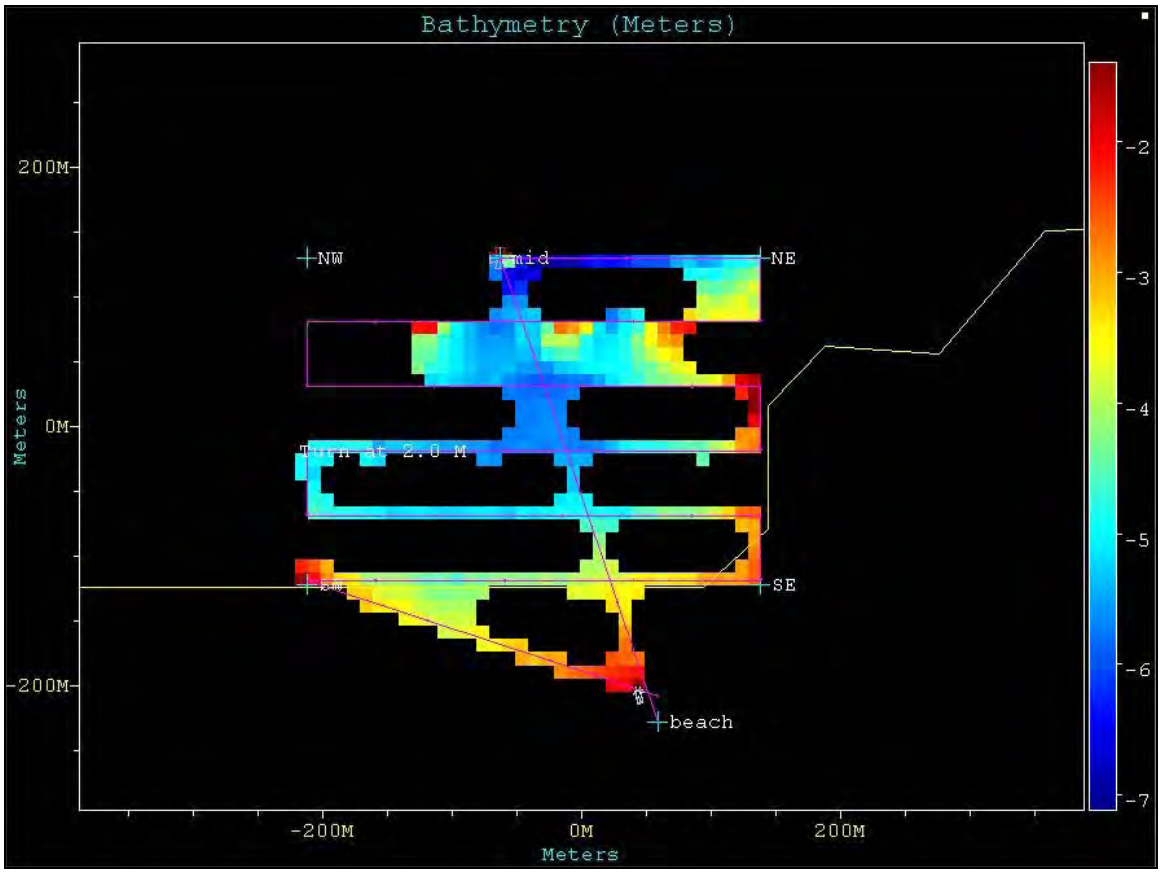
Based on the pre-survey reconnaissance it was decided to run a mission with the AUV programmed to operate at a shallow depth (1 meter) along east-west survey lines to collect bathymetry data to be used to plan subsequent side scan sonar survey missions. One team member entered the bay aboard the kayak with the Ranger so that the AUV's status could be monitored throughout the mission.

The northern most survey line was closer to the shoal areas than anticipated and the vehicle's mission was momentarily paused on the first eastbound leg. During the westbound leg the AUV team member aboard the kayak saw the AUV surfing the waves over the shoal and transmitted a "Go to End" command from the Ranger. The AUV received the command, immediately proceeded to the end point, and was safely recovered.

The AUV mission file showed that the vehicle had been tossed by the surf, but had recovered and was attempting to turn to the next survey line when the command was sent to end the mission.

Mission 2- Bathymetry Reconnaissance in Bahia Salinas
Start Time: 1150
End Time: 1226

Mission 2 was a repeat of the first bathymetry reconnaissance mission with the northern and eastern boundaries adjusted to maintain more distance from the shoal areas. The mission was successful and showed that the AUV survey area in the Bahia Salinas would be severely limited by shallow depths.



AUV Bathymetry from Bahia Salinas

Mission 3 – Side Scan Sonar Survey of Bahia Salinas

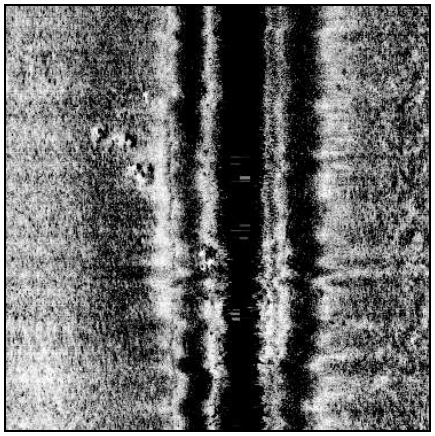
Mission 3 was never run to AUV equipment issues and the request for our early departure from the restricted area.

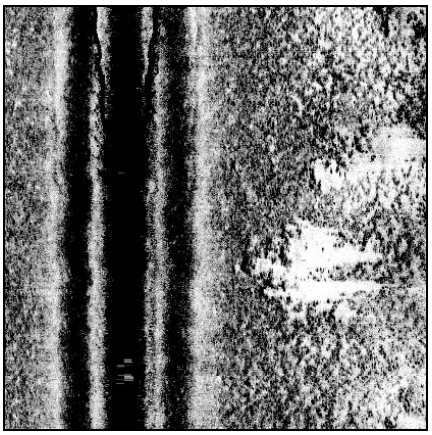
The equipment issues were likely caused by high internal temperature in the AUV. Initially communications with the AUV from the mission programming computer were interrupted and the mission program was lost. Once programmed, the Inertial Navigation System (INS) would not initialize despite efforts to cool the vehicle by floating it in the bay while powered off. If there were additional time available it is likely the AUV temperature would have reduced enough to correct the errors, however it is unlikely that the side scan sonar imagery in Bahia Salinas would have been of high quality due to the shallow depths.

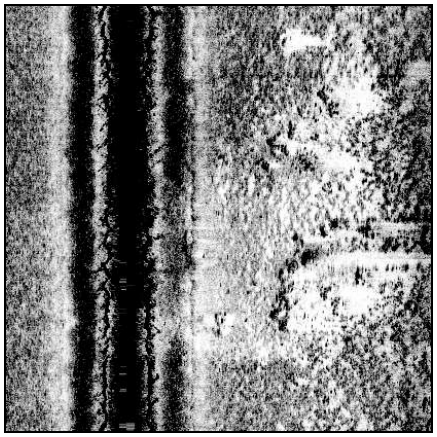
AUV Side Scan Sonar Imagery

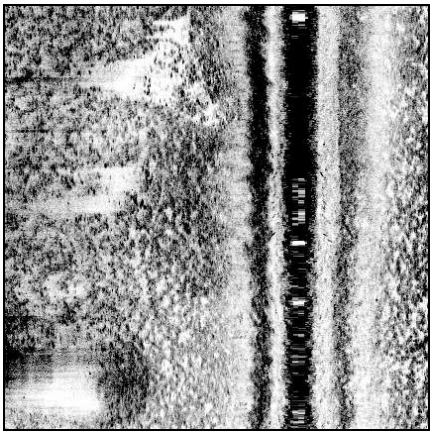
Many of the contacts that were identified in the side scan sonar records are actually clusters that are not clearly distinguishable as ordnance, coral, or rock without additional investigation with a Remotely Operated Vehicle (ROV) or diver. However, the success of the AUV survey is that the results can be used to direct manned resources to areas where some anomaly exists. (The contacts identified with the AUV are comparable to the contacts identified by NRT7 using a pole-mounted Klein 5000 sonar.)

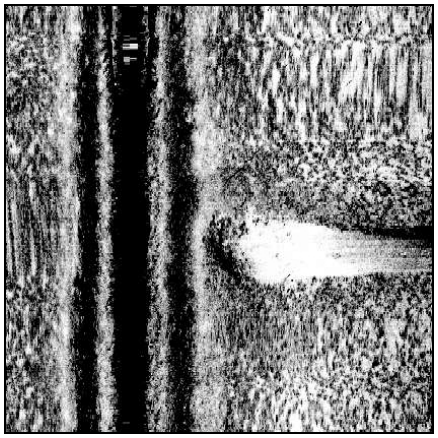
Target Clusters – The following images are representative of the target clusters that were seen in the AUV sonar data.



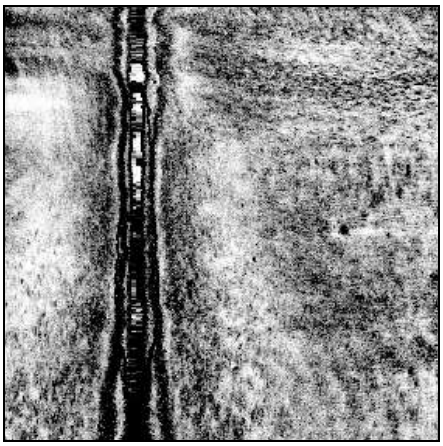


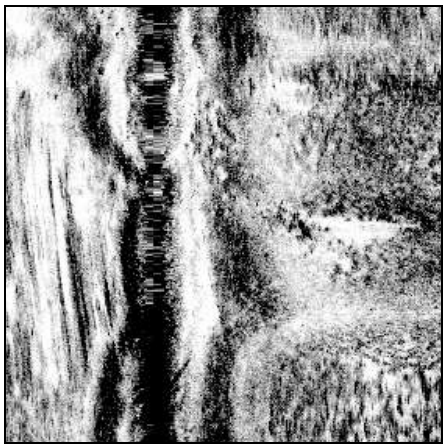






Discrete Targets – The following images are examples of discrete targets that were identified in the AUV sonar data.





Observations and Recommendations

- Deployment and recovery of the REMUS-100 AUV from a sandy beach is easily accomplished.
    - The end position for each mission was programmed to be approximately 15 meters off the beach and the vehicle's momentum practically swam the vehicle into the team's hands.
- Additional work in Bahia Icacos and Bahia Salinas could have been accomplished with better bathymetry data.
    - Existing charts had only one sounding (1.5 fathoms) and grossly inaccurate shoreline (up to 120 meters error determined by handheld GPS)
- The shallow bays in Vieques are excellent candidates for airborne LIDAR bathymetry as the water clarity is excellent and the bottom appears to be sandy, soft coral, or covered with low grass.
- A motorized AUV recovery vessel would have increased the team's confidence in operating the AUV near the shoal areas at the northern limits of Bahia Icacos.
- An AUV equipped with higher frequency (600-900 kHz) side scan sonar may be more effective in the shallow water.
- The logistical support and planning provided by Jason Rolfe (OR&R) was essential to the success of the project and is greatly appreciated.

Appendix G
Geomarine Report—Underwater Surveys

PRELIMINARY UNDERWATER SURVEY OF MUNITIONS RELATED ITEMS AND NON-MUNITIONS DEBRIS, VIEQUES ISLAND, PUERTO RICO

FINAL REPORT

PREPARED BY:
GEO-MARINE, INC., MARINE SCIENCES GROUP, PLANO, TEXAS

JULY 2007

PRELIMINARY UNDERWATER SURVEY OF MUNITIONS RELATED ITEMS AND NON-MUNITIONS DEBRIS, VIEQUES ISLAND, PUERTO RICO

FINAL REPORT – JULY 2007

CONTRACT NUMBER: CH2M HILL #918383 VIEQUES

NAVFAC
Naval Facilities Engineering Command

PREPARED BY:
GEO-MARINE, INC., MARINE SCIENCES GROUP, PLANO, TEXAS

GMI
GEO-MARINE INCORPORATED

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LIST OF ACRONYMS AND ABBREVIATIONS

°	Degree(s)
%	Percent
BSS	Bahia Salina del Sur
CCA	Crustose Coralline Algae
cm	Centimeter(s)
DGPS	Differential Global Positioning System
EMA	Eastern Maneuver Area
ESRI	Environmental Systems Research Institute
GMI	Geo-Marine, Inc
GPS	Global Positioning System
in	Inch
lb	Pound
LDGP	Low Drag General Purpose
LIA	Live Impact Area
m	Meter
m^2	Square Meters
MA	Macroalgae
MK	Mark
mm	Millimeter
NOAA	National Oceanic and Atmospheric Administration
QA/QC	Quality Assurance/Quality Control
SAV	Submerged Aquatic Vegetation
sp	Species
sp(p)	Species
TA	Turf Algae
UXO	Unexploded Ordnance

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1.0 INTRODUCTION

From November 12 to 19, 2006 the Geo-Marine, Inc. (GMI) team conducted an underwater survey of munitions related items and non-munitions debris at Vieques Island in conjunction with National Oceanic and Atmospheric Administration (NOAA) Office of Response and Restoration remote sensing effort at Bahia Salina del Sur (BSS) (**Figure 1**). The GMI team that conducted this underwater survey was composed of GMI marine scientists and qualified unexploded ordnance (UXO) technicians which were former U.S. Navy Explosive Ordnance Disposal personnel.

Surveys were conducted within BSS (**Figure 1**), a general area in the vicinity of former shoreline military targets located within the former Live Impact Area (LIA). Other surveys were conducted along the northern side of the former Eastern Maneuver Area (EMA) and former LIA (**Figure 1**). The team conducted two main tasks:

(1) NOAA verification survey: Groundtruthing of underwater side scan sonar, magnetic, and multibeam contacts generated by NOAA Office of Response and Restoration in BSS during November 2006 (**Figure 1**).
(2) Independent military munitions survey: Independent visual survey of munitions related items in the nearshore area of BSS between former military targets T1 and T6 (**Figure 1**). Two additional tasks were conducted: Qualitative underwater video transects of the seafloor off former military targets T1 through T6 (**Figure 1**); and the survey of future reference points within Bahia Icacos, around Roca Alcatraz (Bahia Salina del Sur), and the easternmost point of BSS (**Figure 1**).

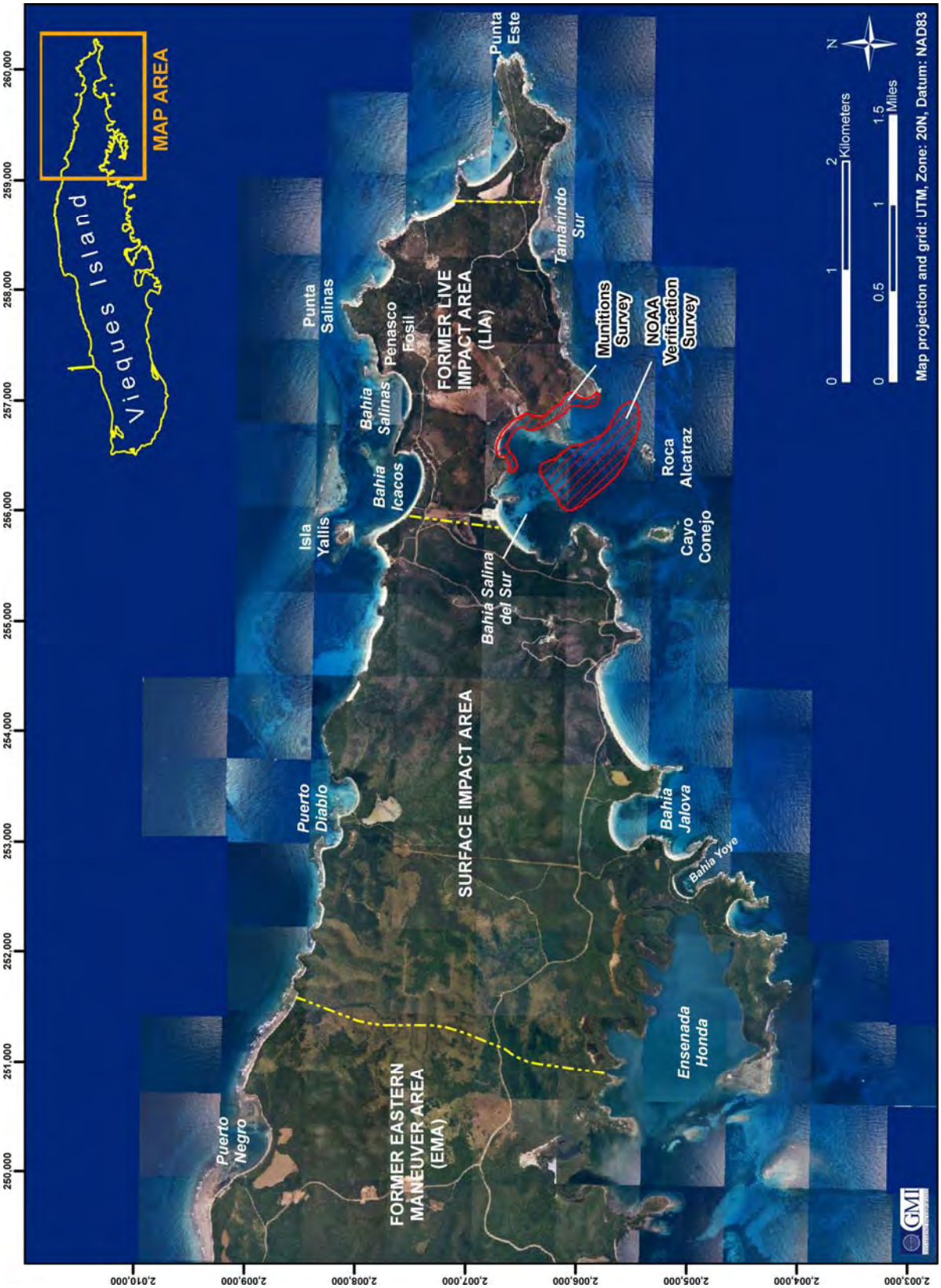


Figure 1. Location map of Vieques Island, Puerto Rico and survey locations used in November 2006 at the former Eastern Maneuver Area, Surface Impact Area, and Live Impact Area

2.0 METHODS

2.1 NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION VERIFICATION SURVEY

While onsite at Vieques Island, the NOAA Office of Response and Restoration provided GMI the geographical coordinates of 109 survey anomalies they acquired in BSS (center of the bay). These points indicated the potential presence of munitions related items. NOAA voluntarily included positive and false-positive anomalies for GMI to document. False-positive anomalies may have included hard substrate such as a coral head that generated a sand halo which was characteristic of several exposed (versus buried) positive anomalies. For the first survey day, NOAA assigned the locations of five anomalies in BSS. Geo-Marine, Inc. (GMI) surveyed these points and found nine others nearby consisting of munitions related items and non-munitions debris. For the second survey day, NOAA provided the geographical coordinates of 104 points in BSS, many of which were spatially distributed in clusters. From this list, GMI selected 23 points scattered throughout the bay and found five others located nearby the designated locations. In total, the GMI team verified 42 locations: 28 NOAA-provided points and 14 additional points (**Appendix 1**).

As requested by NOAA, groundtruthed locations that included visible munitions related items and non-munitions debris or topographic relief were photographed facing north and facing west. Underwater photographs were taken using a digital camera (4 megapixel resolution). Locations that did not include visible munitions related items, non-munitions debris or topographic relief were searched within a 10 meter (m) radius of the NOAA-designated point using a metal detector (White's Surf PI Pro Metal Detector using pulse induction). At some of these locations, a metal signature of buried items was found.

Digital images of the surveyed objects included a slate on which we recorded the item number, location, date, and what direction the camera lens was facing. Additional notes were taken on underwater paper (substrate, type of debris [munitions related items or non-munitions], and identification of munitions related items).

Geographical coordinates of each of these groundtruthed locations were collected using a Trimble® ProXRS differential global positioning system (DGPS) unit (Trimble Navigation Ltd., Sunnyvale, California) running Asset Surveyor 4.0. The OmniSTAR (Caribbean/South American Service) real-time DGPS correction service was used to obtain accuracies of ± 1.0 m (OmniSTAR, Inc. 2003). The DGPS positioning data were downloaded using Pathfinder Office 3.10, quality assurance/quality controlled for positional accuracy, and exported to Environmental Systems Research Institute (ESRI) shapefile format. It is important to note that for the aim of this part of the GMI survey was to find and groundtruth anomalies on NOAA's list, document what item was found, and then record the position of the described item. The accuracy of the NOAA positioning was less than 10 centimeters (cm). The GMI survey was to document items NOAA detected and not verify/corroborate the positioning of the items.

Notes collected underwater and geographical positioning data were transcribed onto an electronic spreadsheet. Notes while viewing photographs and video were also transcribed onto an electronic spreadsheet. These data were used to summarize findings and for mapping purposes.

2.2 INDEPENDENT MILITARY MUNITIONS SURVEY

An underwater visual survey of munitions related items and non-munitions debris was conducted in the nearshore area (within 30 m of the shoreline; water depth ranged from >1 m to approximately 4 m) along the eastern shoreline of BSS, between targets T1 and T6.

Each item surveyed was assigned a survey number (e.g., the first item found off T1 was assigned "GMI-BSS-T1-1"). Munitions related items and non-munitions debris were characterized by a UXO technician and additional notes and photographs were taken by a marine scientist. The geographical coordinates of

each surveyed item were acquired using a Trimble® ProXRS DGPS unit running Asset Surveyor 4.0. The OmniSTAR (Caribbean/South American Service) real-time DGPS correction service was used to ensure accuracies of ± 1.0 m (OmniSTAR, Inc. 2003). The DGPS positioning data were downloaded using Pathfinder Office 3.10, quality assured/quality controlled (QA/QC'ed) for positional accuracy and exported to ESRI shapefile format.

In addition to the visual survey of munitions related items and non-munitions debris, qualitative underwater video transects were acquired off each former military target (T1 through T6) to typify the nearshore environment, munitions related items, and non-munitions debris. Three underwater video transects (25 to 30 m in length) were recorded perpendicular to the shoreline off each former shoreline target. The video transects were taken at a 45 degree (°) angle relative to the seafloor. The transect length and direction were established using a weighted measuring tape stretched over the seafloor. The first video transect was taken directly over the measuring tape and the two other transects parallel to and at 5 m on either side from the first transect. At each former target, the geographical coordinates of the first transect's origin were recorded using the DGPS unit. The video transects were done by a marine scientist and a UXO technician.

As part of the munitions survey a marine scientist and a UXO technician also assessed the presence/absence of munitions related items and non-munitions debris at four additional underwater locations: three in BSS and one in Bahia Icacos. The visual assessments within BSS were done in the general vicinity of a wreck located in the northwestern corner of the bay, off the easternmost point of the bay (off former military target 6), and around Roca Alcatraz (fringing reef surrounding the island [0 to 10 m]) (**Figure 1**). In Bahia Icacos, a 150 m by 3 m swatch of the seafloor was surveyed (**Figure 1**). While only visual surveys were done in the additional surveys in BSS and around Roca Alcatraz, a metal detection survey was conducted in Bahia Icacos with a White's Surf PI Pro Metal Detector using pulse induction. The geographical coordinates of the center of the swath surveyed in Bahia Icacos was recorded using the DGPS unit. All data recorded while underwater or after reviewing photographs were transcribed to an electronic spreadsheet.

3.0 RESULTS AND DISCUSSION

3.1 MUNITIONS RELATED ITEMS

The recognizable munitions related items found during the survey efforts are listed in **Table 1**. Ten types of munitions were found including bombs, mines, and projectiles as well as 12 types of munitions debris. More details on where and how much of these munitions related items were found are presented in **Sections 3.2** and **3.3**. To illustrate the types of munitions found here, photographs were taken underwater. The underwater images are presented in **Sections 3.2** and **3.3**. The illustrations and on land images of some of the munitions related items found here are presented in **Figures 2** to **8**.

Table 1. List of munitions and munitions debris found in the nearshore area (less than 4 m water depth) off former military targets T1 through T6 at Bahia Salina del Sur, Vieques Island in November 2006. [in = inch; lb = pound; LDGP = Low Drag General Purpose; MK = Mark; mm = millimeter; "Old Style" = pre 1950s]

Munitions	Munitions Debris
3 in Projectile	5 in/54 Projectile Debris
5 in/54 Projectile	Base of a 5 in/54 Projectile
MK 82 LDGP Bomb	Base plate from MK 82 LDGP Bomb
MK 83 Bomb	Nose section MK 82
500 lb Old Style General Purpose Bomb	MK 82 LDGP Bomb (spotting charges expended)
750 lb Old Style Bomb	32 in MK 6 mine
Bomb Dummy Unit 33 Practice Bomb	81 mm Mortar Illumination Tail Assembly
British MK 7	Fragment
Tube from inside of a 5 in Puff Round	Metal debris
Snake Eye Fins (bomb possibly attached)	Rockeye Half Shell Submunition Canister
	Snake Eye Fin
	Old Style Fin Assembly

a

b

Figure 2. Illustration of a 5 in/54 projectile (a) and a 5 in/54 projectile being fired from a U.S. Navy vessel (b).

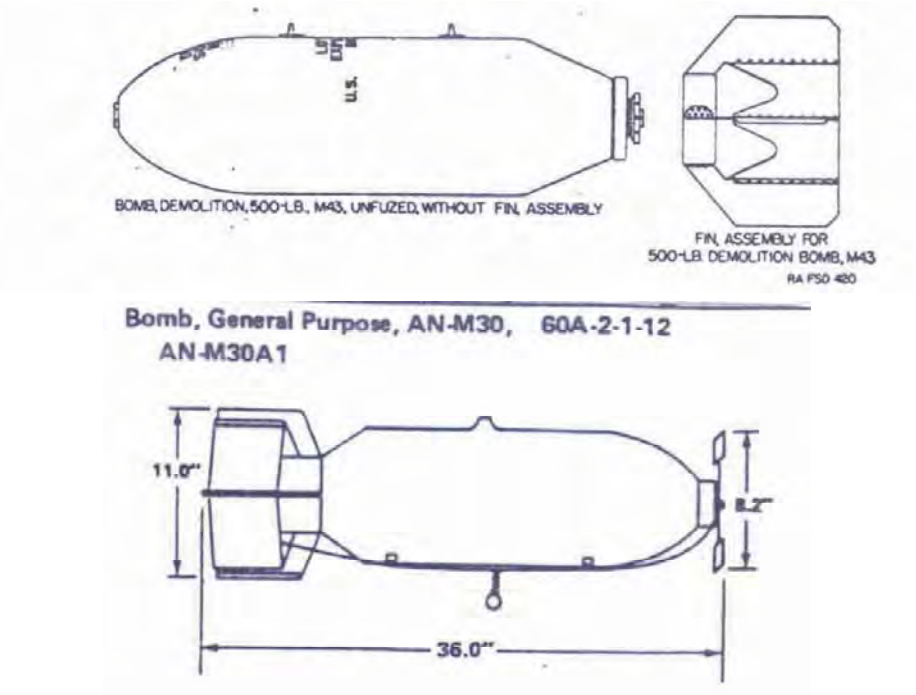


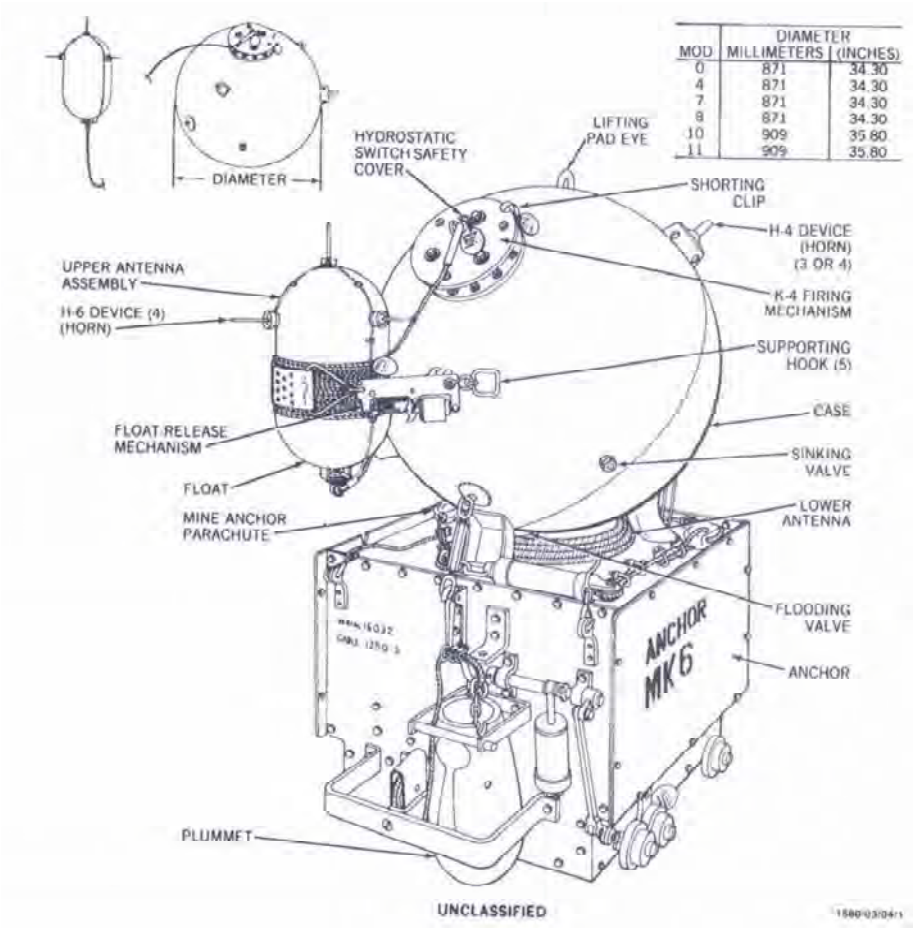
Figure 3. Drawings of 500 lb and 750 lb old style (pre 1950s) bombs.

Figure 4. Illustration of a Bomb Dummy Unit 33.

Figure 5. Illustration of MK 80 bombs including the MK 82 and MK 83 bombs found in Bahia Salina del Sur, Vieques Island.

Figure 6. Example of snake eye fins attached to a bomb.

Figure 7. Rockeye submunition dispenser.



MOD	DIAMETER MILLIMETERS	DIAMETER (INCHES)
0	871	34.30
4	871	34.30
7	871	34.30
8	871	34.30
10	909	35.80
11	909	35.80

Figure 8. Drawings of a 32 inch MK 6 mine.

3.2 NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION VERIFICATION SURVEY

During the NOAA verification survey, a total of 42 points were documented, 26 of which were NOAA-provided points. The remaining points were acquired in the near vicinity of the NOAA-provided locations. **Table 2** lists the surveyed locations. The surveyed items were generally found within the central part of BSS (**Figure 9**).

Six general types of items were found during the NOAA verification survey: Munitions, munitions debris, non-munitions debris, reef rocks, patch reefs, and carbonate nodules (**Appendices 1** and **2**). Eleven locations surveyed here had no apparent munitions related items or non-munitions debris. Even though metal was detected at each of these locations, the source of the signal was unknown. Each of these locations was labeled as "unknown." In six of these locations, the metallic object was buried under submerged aquatic vegetation (SAV), in four locations the object was buried in sand, and in one location we detected a weak signal for metal among protruding rocks on hardbottom. At five locations, munitions related items or non-munitions debris were not observed nor was any metal detected. These locations were labeled as "not found" (**Appendices 1** and **2**).

The confirmed presence of munitions were all Mark-(MK) 82 Low Drag General Purpose (LDGP) bombs (e.g., NOAA-BSS-12, NOAA-BSS-6_3BIS, NOAA-BSS-10, NOAA-BSS-11, NOAA-BSS-201, NOAA-BSS-13). These bombs were in some cases associated with snake eye fins and/or a parachute (**Figure 10**). Munitions debris included a detonated 32-inch (in) MK 6 mine (NOAA-BSS-94; **Figure 11**), bomb fragments, tail fin boom of an MK-82 LDGP bomb, snake eye fins, and one "old style" (pre-1950s) fin assembly. Non-munitions debris included a large piece of aluminum (**Figure 12**), an open 55 gallon drum, a possible drive shaft (**Figure 13**), and some metal scrap. Other NOAA-assigned geographical coordinates led the survey team to objects that were neither munitions related items or non-munitions debris: a patch reef (NOAA-BSS-121; **Figure 14**), and five areas of reef rock (**Figures 15** and **16**). Carbonate nodules were found in one location: they had overgrown a metallic core and yielded a loud metal detection signal (NOAA-BSS-60; **Figure 17**).

Table 2. Locations GMI groundtruthed within Bahia Salina del Sur, Vieques Island in November 2006. NOAA locations correspond to those provided by NOAA Office of Response and Restoration to GMI. The additional locations correspond to locations found in the near vicinity of the NOAA locations and added to the data collection.

Date	Surveyed Locations	NOAA Locations	Additional Locations
12 Nov	15	1, 6, 7, 9, 10	6_bis, 6_2bis, 6_3bis, 7_bis, 9_bis, 9_3bis, 11, 12, 13
13 Nov	17	20, 21, 22, 22_bis, 22_2bis, 88, 91, 92, 92_bis, 93, 94, 95, 97, 98, 99, 108	
14 Nov	12	31, 32, 58, 59, 60, 70, 100, 110, 120, 121	32_bis, 201

All the munitions related items and non-munitions debris that were exposed (i.e., on the seafloor or partially buried) are accessible (**Appendices 1** and **2**). Those items detected but not seen are not accessible and in most cases buried under sand and/or SAV. Substrates within which the exposed munitions related items and non-munitions were found included sand, coral rubble, coral gravel, and SAV. Biological growth on munitions related items and non-munitions debris included hard corals, soft corals, encrusting hard corals, fire coral, encrusting fire coral (*Millepora alcicornis*), hydroids, sponges, crustose coralline algae (CCA), turf algae (TA), and macroalgae (MA). No live specimens of the threatened elkhorn

(*Acropora palmata*) or staghorn (*Acropora cervicornis*) corals were seen growing on munitions related items and non-munitions debris, reef rock, or patch reefs surveyed during the NOAA verification.

3.3 INDEPENDENT MILITARY MUNITIONS SURVEY

3.3.1 Nearshore Survey at Bahia Salina del Sur

This survey was conducted in the nearshore area off the former military targets T1 through T6. Any visible munitions related items encountered were documented. Two teams of two divers (one marine scientist and one UXO technician) surveyed each of these areas. In 2001, one of the field participants (Deslarzes) reconnoitered this general area (from the northwestern corner of BSS to T5). During this early survey, in addition to observing munitions related items, Deslarzes encountered the remains of two sunken vessels off former military targets T1 and T2. The sunken vessels (landing barges; Rogers et al. 1978) were also seen during this survey and were labeled Barge T1 and Barge T2. The 2006 survey included a search for munitions related items around and within these sunken vessels.

The 2001 reconnoitering of BSS included underwater photography, coarse Global Positioning System (GPS) of items seen, and note taking. The GPS positioning provided an accuracy that was possibly in the order of 2 to 10 m which is not compatible with the excellent mapping grade accuracy obtained during the 2006 survey. The 2001 survey was useful in revealing the presence of munitions related items, nearshore hazards (wreckages, reefs), and the condition of the nearshore habitats which facilitated the 2006 survey. In 2001, the largest amount of munitions related items was observed off T1 and T4. Most commonly encountered munitions related items included MK 82 bombs and projectiles. Commonly seen non-munitions debris included illumination flare canisters. Fractured reef substrate was mainly observed off T4. Biological growth was observed on Barge T1 and Barge T2 and on many of the munitions related items and non-munitions debris. Images of munitions related items and non-munitions debris observed in the 2001 survey are shown in **Appendix 3**.

In general, all exposed munitions related items and non-munitions debris observed in 2006 are accessible. Those items that were labeled as “munitions” probably still contain a charge. Those labeled as munitions debris and non-munitions debris did not contain a charge. The identification of the munitions related items and non-munitions debris was done by the UXO technicians. Relocating these items will be facilitated by the ± 1.0 m accuracy of the geographical coordinates provided here (**Appendix 4**). Of the 168 munitions related items and non-munitions debris found in 2006 off former military targets T1 through T6 (**Figure 18**), 120 were munitions, 32 were munitions debris, and 16 were non-munitions debris (**Appendix 4**). Ten general of types of munitions were found (**Table 3**), mostly consisting of 5 in/54 projectiles (64 percent [%]). The greatest concentration of these munitions was found off former military targets T4 and T6 (**Table 3**; **Figure 18**; **Appendix 4**). Images of the munitions related items and non-munitions debris observed in 2006 are presented in **Appendix 5**.

The seafloor substrate is rocky off T1, T4, T5, and T6. Off T2 and T3, the seafloor consists mainly of SAV and soft sediments. Most of the munitions related items and non-munitions debris are lodged into the seafloor substrate (soft sediments, rock), partially sedimented over, and covered by TA. Some of the munitions related items and non-munitions debris have additional live cover including juvenile corals (e.g., *Siderastrea* species [sp(p).]), mature corals (e.g., symmetrical brain coral, *Diploria strigosa*; branched finger coral, *Porites furcata*), and white scroll algae, (*Padina jamaicensis*). Depictions of live cover on the munitions related items and non-munitions debris are shown in the images in **Appendix 5**.

The visual survey of munitions related items and non-munitions debris included observations made at two sunken vessels, Barge T1 and Barge T2. The outlines of the barges shown in **Figure 18** were obtained by mapping the geographical coordinates of weighted floats placed along the edges of the wreckages. The UXO technicians examined both barges for the presence of munitions related items. The Barge T1

Figure 9. Locations of anomalies NOAA Office of Response and Restoration recorded in Bahia Salina del Sur, Vieques Island in November 2006 and locations of groundtruthed items.

Figure 10. MK-82 Low Drag General Purpose (LDGP) bomb (NOAA-BSS-10) in Bahia Salina del Sur, Vieques Island in November 2006.

Figure 11. 32 inch MK 6 mine (NOAA-BSS-94) in Bahia Salina del Sur, Vieques Island in November 2006.

Figure 12. Large piece of aluminum (NOAA-BSS-6) in Bahia Salina del Sur, Vieques Island in November 2006.

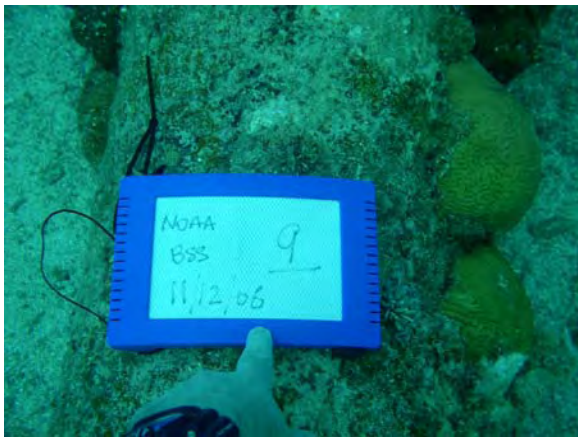


Figure 13. Machinery (NOAA-BSS-9) in Bahia Salina del Sur, Vieques Island in November 2006.

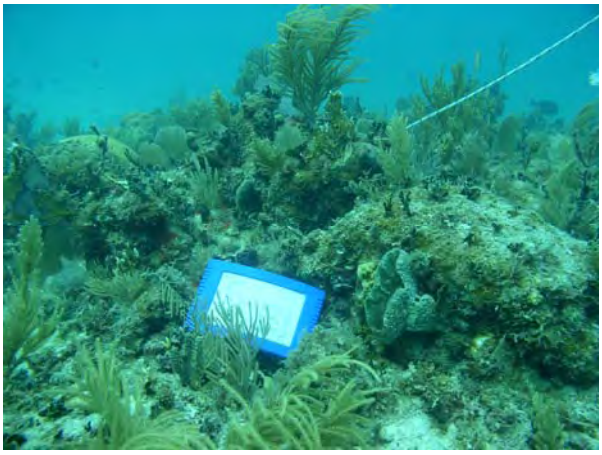


Figure 14. Patch reef (NOAA-BSS-121) in Bahia Salina del Sur, Vieques Island in November 2006.

Figure 15. Reef rock (NOAA-BSS-22-2BIS) in Bahia Salina del Sur, Vieques Island in November 2006.

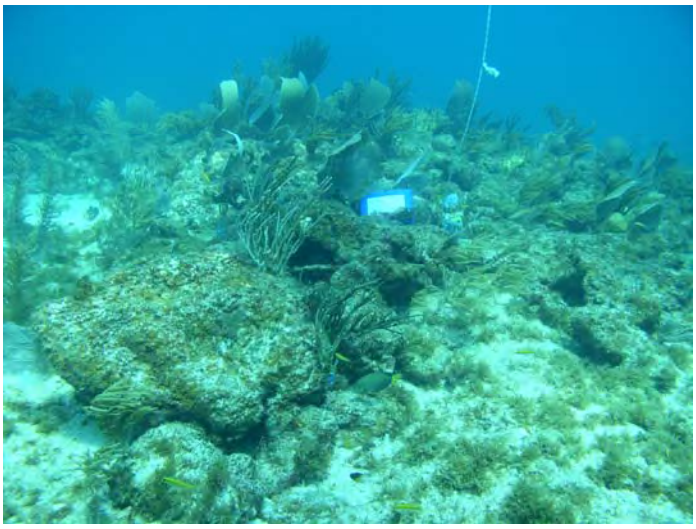


Figure 16. Reef rock (NOAA-BSS-21) and *Acropora palmata* (elkhorn coral) skeleton in Bahia Salina del Sur, Vieques Island in November 2006.

Figure 17. Carbonate nodules with metallic cores (NOAA-BSS-60) in Bahia Salina del Sur, Vieques Island in November 2006.

site (**Figure 18**) contained one snake eye fins assembly, one 155 millimeter (mm) projectile, four MK 82 LDGP bombs, and two 5 in/54 projectiles. The Barge T2 site did not contain any munitions related items. Both barges are navigational hazards since they lie in less than 2 m of water depth and parts of the wreckages reach the sea surface.

3.3.2 Qualitative Videographic Survey

The qualitative videographic surveys off the former military targets T1 through T6 show general aspects of the marine habitats and the occurrence of munitions related items and non-munitions debris. The videographic footage is particularly useful as a reference on the types of environments, munitions related items, and non-munitions debris that occur at these locations.

Following are summaries of what was observed in the qualitative video transects taken off former military targets T1 through T6. While the starting points of the actual video transects alternated between a point near the shoreline and a point approximately 25 m from the shoreline (25 m was generally the length of a transect), the analysis of each video transect was done from shoreline to the seaward most point of the transect. The video transects provided three replicate views of the habitat and the presence of munitions related items and non-munitions debris off each target. Transects were taken perpendicularly to the shoreline (**Figure 18**). Video footage of the transects is included in the electronic deliverable (CD-ROM) of this summary report.

Target T1 (Main features: Soft bottom and Barge T1 wreckage) – *Transect 1* included coral rubble overgrown by abundant white scroll algae and Y branched algae (*Dictyota* species [sp.]). Further along the transect, there was turtle grass (*Thalassia testudinum*), and more macroalgal cover consisting of

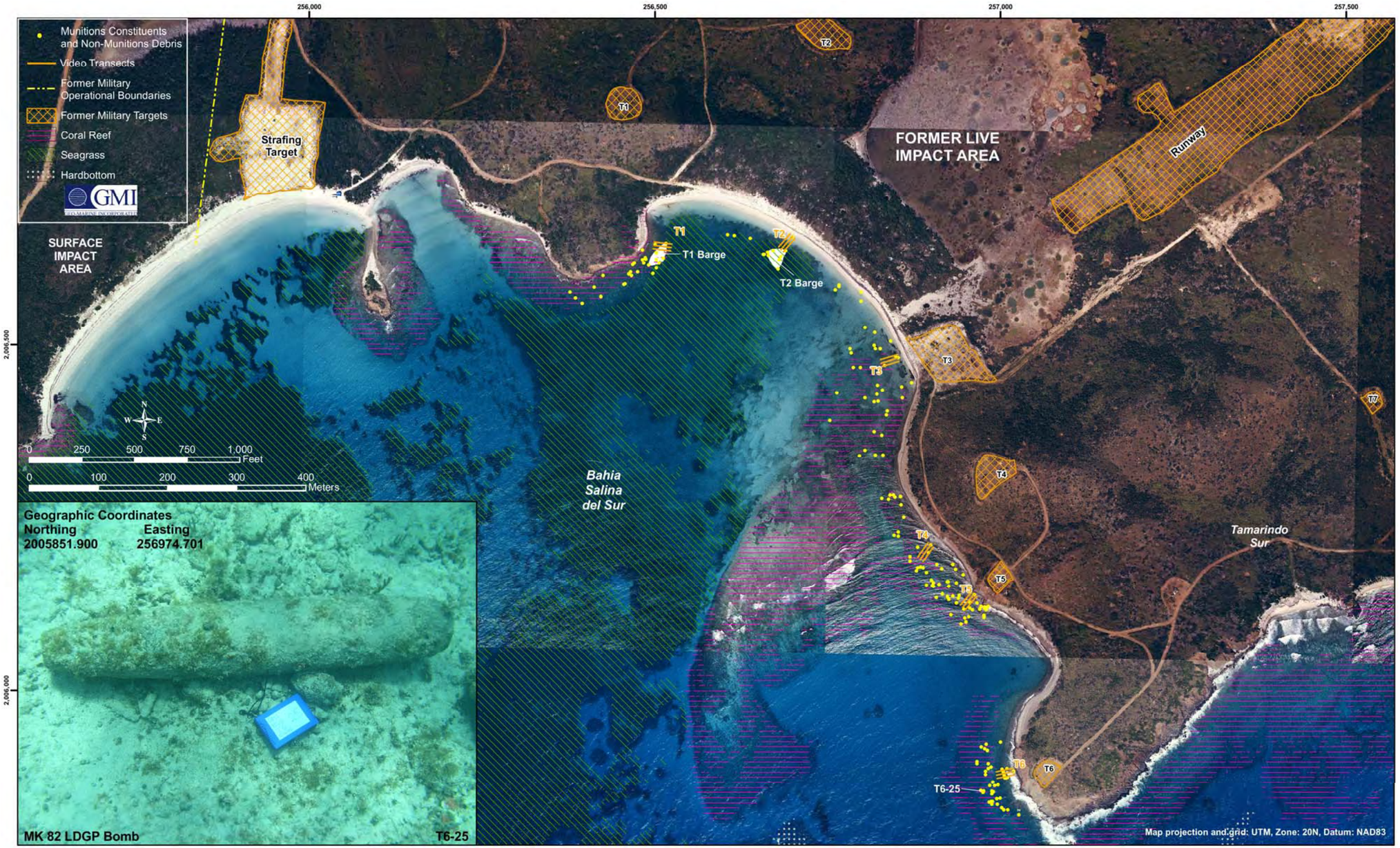


Figure 18. Location of munitions related items and non-munitions debris observed off former military targets T1 through T6 in the nearshore environment (water depth less than 4 m; less than 30 m distance from shore) at Bahia Salina del Sur, Vieques Island in November 2006.

Table 3. Summary of the types and quantities of munitions, munitions debris, and non-munitions debris found in the nearshore area (less than 4 m water depth) off former military targets T1 through T6 at Bahia Salina del Sur, Vieques Island in November 2006. [in = inch; lb = pound; LDGP = Low Drag General Purpose; MK = Mark; mm = millimeter; "Old Style" = pre 1950s]

Munitions	**T1**	**T2**	**T3**	**T4**	**T5**	**T6**	**Total**
3 in Projectile				1		1	**2**
5 in/54 Projectile	10			24	13	34	**82**
500 lb Old Style General Purpose Bomb				1			**1**
Bomb Dummy Unit 33 Practice Bomb	1				7	2	**10**
British MK 7				1			**1**
MK 82 LDGP Bomb	12	3	2	4	2	1	**24**
MK 83 Bomb					1		**1**
Tube from inside of a 5 in Puff Round						1	**1**
Snake Eye Fins (bomb possibly attached)		1	2	2			**5**
Cylindrical Object (partially buried mine or bomb)				1			**1**
Munitions Debris	**T1**	**T2**	**T3**	**T4**	**T5**	**T6**	
5 in/54 Projectile Debris					1		
81 mm Mortar Illumination Tail Assembly				1			**1**
Base of a 5 in/54 Projectile						1	**1**
Base plate from MK 82 LDGP Bomb	1						**1**
Nose section MK 82 LDGP Bomb	1						**1**
MK 82 LDGP Bomb (spotting charges expended)				1			**1**
Fragment						1	**1**
Metal Debris			2	1			
Rockeye Half Shell Submunition Canister			1	3			**3**
Snake Eye Fins		1	6	11			**18**
Non-Munitions Debris	**T1**	**T2**	**T3**	**T4**	**T5**	**T6**	
Target debris					2	2	**4**
Tank track				2			**2**
Expended MK 24 Flare Canister		1					**1**
Metal debris		2	2	5			**12**
Metal mesh grate				1			**1**
Metal pipe				1			**1**
Total	**25**	**8**	**15**	**60**	**26**	**43**	**177**

white scroll algae and Y branched algae. The branched finger coral was seen in front of the wreckage of a barge (Barge T1). The transect continued onto Barge T1 wreckage that was covered by a thin layer of fine sediments. Fish were seen swimming among the wreckage. Abundant white scroll algae and Y branched algae were growing on the wreck.

Transect 2 showed soft sediments colonized by MA including Y branched algae and turtle seagrass. Abundant coral rubble was present and colonized by MA. The seafloor in this area was mostly covered by white scroll algae and Y branched algae. The transect continued onto the wreckage of the Barge T1 that supported high MA cover. The wreckage was covered by a thin layer of fine sediments. Fish were seen swimming about the wreckage. The transect continued onto a segment of soft bottom that supported white scroll algae and Y branched algae. The transect ended with more of the Barge T1 wreckage.

Transect 3 began with views of wreckage supporting branched finger coral, white scroll algae, and Y branched algae. The transect continued onto an area of coral and rock rubble that supported abundant MA (white scroll algae and Y branched algae). The transect continued onto Barge T1 wreckage where fine sediments covered portions of the wreckage that were occupied by coral (branched finger coral) or MA (white scroll algae and Y branched algae). Fish were seen swimming on the wreckage. The video footage showed where parts of the wreckage reach the sea surface. A barrel sponge was seen on the wreckage toward the end of the transect. The transect ended with more wreckage and a segment of seafloor consisting of soft sediments.

Target T2 (Soft bottom, submerged aquatic vegetation, and the wreckage of Barge T2) – *Transect 1* contained manatee grass (*Syringodium filiforme*) and MA growing on a sandy seafloor where mounds of sand made by burrowing sea cucumbers were present. Such mounds are common occurrence in soft sediments of turtle grass beds (Kaplan 1988). The transect continued over the wreckage of Barge T2. The steel wreckage was covered by a fine sediment deposit and abundant MA consisting mainly of white scroll algae and Y branched alga. Colonies of branched finger coral were seen growing on the wreckage.

Transect 2 in the nearshore included manatee grass, MA, and mounds formed by burrowing sea cucumbers. The transect continued onto some steel wreckage (probably from Barge T2) that supported a sponge. Further along, the transect included soft sediments supporting turtle grass and MA. Barge 2 wreckage was covered by fine sediments and supported branched finger coral, fish, and abundant MA (white scroll alga and Y branched alga). The transect ended on Barge 2 wreckage.

Transect 3 began with soft sediments, mounds formed by burrowing sea cucumbers, and MA growing on the seafloor. The transect continued onto Barge 2 wreckage that supported abundant macroalgal growth (white scroll alga and Y branched alga). Fine sediments covered the wreckage. Fish were seen swimming within the wreckage. Further along the transect were colonies of branched finger coral and more macroalgal growth on the wreck. Toward the end of the transect were soft sediments and sea cucumber mounds, and more of the wreckage.

Target T3 (Submerged aquatic vegetation, soft bottom, and mounds) – *Transect 1* nearshore seafloor consisted of SAV) with abundant turtle grass growing on soft sediments. Sea cucumber mounds were found along the transect. The SAV further along the transect also included manatee grass and MA.

Transect 2 nearshore contained turtle grass and MA, and some mounds made by burrowing sea cucumbers. Further along the transect were MA, more turtle seagrass, and manatee grass.. Toward the end of the transect, turtle grass and MA were abundant.

Transect 3 contained turtle grass and many sea cucumber mounds. Additionally, manatee grass and MA were present toward the end of the transect.

Target T4 (Rubble, rocks, hardbottom, and sand pockets) – *Transect 1* contained rocks, rock rubble, and sedimented (fine sediments) hard bottom colonized by MA and Y branched algae in the nearshore area. Further along the transect was hardbottom colonized by MA along with small sand pockets followed by rock rubble covered with fine sediments and supporting MA. Toward the end of the transect, the sand pockets were relatively large and supported some MA and a few soft corals. Boulder-sized rocks supporting some MA were at the end of the transect.

Transect 2 contained large rocks supporting CCA and MA. Further along the transect, the seafloor included hard bottom and scattered rocks. The hard substrates were covered by fine sediments and supported some MA. One piece of ordnance was found. More scattered rocks and rubble were found further down the transect. Fine sediments covered the hard substrates. Toward the end of the transect, a fairly large rock supported fire coral (*Millepora alcicornis*), MA (Y branched alga), and a few soft corals.

Transect 3 in the nearshore contained scattered rocks and hard bottom, as well as Y branched algae, fine sediments covering hard substrates, and a few soft corals. Further down the transect, sand pockets were seen among scattered rocks that supported MA. Toward the end of the transect, hard bottom supporting MA, some sand pockets, and one piece ordnance were found.

Target T5 (**Rubble, rocks, hardbottom, sand pockets, and long-spined urchins**) – *Transect 1* nearshore area included hard bottom, rocks, rock rubble, evidence of sedimentation (fine sediments), and the presence of MA. Further down the transect, the rocks had rough edges. Rock rubble, sedimentation (fine sediments), fire coral, and long-spined urchins (*Diadema antillarum*) were also present. Toward the end of the transect were rocks and small sand pockets.

Transect 2 included hard bottom, rubble and sedimentation (fine sediments) in the nearshore area. Further along the transect were small sand pockets, hard bottom, one MK 82, Y branched algae, and TA. Toward the end of the transect were sand, hard bottom, coarse rocks, rock rubble, TA, and MA.

Transect 3 in the nearshore contained hard bottom, rock rubble, and loose rocks colonized in places by MA. Some fish were seen swimming in this nearshore area. Further into the transect, the seafloor was characterized by large fragments of recent fractured rock. Fish and long-spined urchins were seen amongst these rocks. This area made of fractured rocks was succeeded by hard bottom that was sedimented over by fine sediments that supported MA, some fire coral, and small gorgonians. Toward the end of the transect, the seafloor included rubble and small sand pockets.

Target T6 (**Rubble, rocks, hardbottom, sand pockets, and long-spined urchins)** – *Transect 1* contained hard substrate including rubble, boulders, rock, and pavement. Toward the end of the transect, the transect contained few soft corals (gorgonians) and some long-spined urchins.

Transect 2 showed a hard bottom area with some topographic relief. The seafloor was sedimented over. Hard substrate was colonized in places by CCA. Further along the transect was same general type of substrate that supported sparse and small soft coral colonies. Toward the seaward end of the transect was hard bottom with more topographic relief, rock rubble, soft corals (including sea fans), fire coral, CCA, and long-spined urchins.

Transect 3 began with hard bottom including boulders and rock rubble. Some long-spined urchins and small fish were seen in this nearshore area. Further along the transect were soft corals (sea fans) and more long-spined urchins, followed by soft corals on hard bottom. Long-spined urchins and one piece of ordnance were seen in a hard bottom area (pavement and large rocks). Toward the end of the transect were soft corals and MA growing of pavement.

3.2.3 Potential Survey Sites

In an effort to identify potential survey sites for the future, the presence of munitions related items was assessed at additional locations within BSS, around Roca Alcatraz, and at Bahia Icacos (**Figure 1**). This survey was by no means exhaustive and is not representative of additional sites needing to be surveyed for munitions at the eastern end of Vieques Island. Sites other than BSS and Roca Alcatraz (this study; Rogers et al. 1978; Antonius and Weiner 1982; DoN 2003) that are known to contain ordnance include an area near Cayo Conejo (previously No Name Key; Rogers et al. 1978), Tamarindo Sur coastline (southside of the LIA) between T6 and T7 (Antonius and Weiner 1982; DoN 2003; Ken Deslarzes pers. obs.), Isla Yallis (Antonius and Weiner 1982), Bahia Icacos (Rogers et al. 1978), Punta Icacos (Antonius and Weiner 1982), Bahia Salinas (between Punta Icacos and Peñasco Fossil; Rogers et al. 1978; Antonius and Weiner 1982; DoN 2003; Ken Deslarzes pers. obs.), seaward of the barrier reef off Bahia Icacos and Bahia Salinas (DoN 2003; Ken Deslarzes, pers. obs.), and two bays east of Punta Salinas (Playa Banco, Playa Brava; Clifton Anclelet, pers. obs.). Rogers et al. (1978) found munitions related

items on the south side of Vieques Island as far west as the Jalova Peninsula and as far east as the eastern end of the island.

In the northwestern corner of BSS close to the shoreline is an emergent wreckage of a vessel. The wreckage lies in shallow water (less than 2 m water depth) and on a seagrass bed dominated by turtle grass. The UXO technicians found no munitions related items amongst this wreckage. A rapid survey off the eastern tip of BSS, revealed the presence of munitions related items within a 3 to 10 m depth range: one MK 82 with a nose fuse and nine 5 in/54 projectiles. During a rapid survey around Roca Alcatraz, one MK 82 LDGP bomb and two 5 in/54 projectiles were found on the leeward side of the island, and one 5 in/54 projectile, one 750 pound (lb) old style bomb, two 3 in projectiles, and two MK 82 LDGP bombs were found on the windward side. At Bahia Icacos, a metal detection survey was conducted along a 150 m east to west belt transect (3 m wide) over a soft bottom substrate. No munitions related items were visually apparent but were suspected to occur considering the proximity of the land targets on the north side of the LIA (including SAM East, Convoy, and Railroad Tunnel). Within these belt transects at Bahia Icacos, 13 metallic objects were detected with the metal detector, 10 of which emitted a strong signal. The average signal density was approximately 3 per 100 square meters (m^2). In the first 50 m (using the east end of the belt transect as a starting point), there were two strong signals and one weak signal. From the 50 to the 100 m mark, there two strong signals, and from the 100 to the 150 m mark there were six strong signals and two weak signals.

In summary, based on this survey, other documentation (including Rogers et al. 1978, Antonius and Wiener 1982, and DoN 2003), and personal observations (Ken Deslarzes and Clifton Ancelet), munitions related items are found in a broad area to the south and north of the LIA and to the east and west of the LIA on the south side of Vieques Island. Further documentation of submerged munitions related items and non-munitions debris, particularly in the nearshore shallow environment, is needed at Vieques Island to evaluate the density and distribution of munitions related items and non-munitions debris.

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APPENDIX 1

MUNITIONS RELATED ITEMS, NON-MUNITIONS DEBRIS, AND REEF SUBSTRATES ENCOUNTERED IN NOVEMBER 2006 IN BAHIA SALINA DEL SUR, VIEQUES ISLAND, AS PART OF A GROUNDTRUTHING EFFORT OF ANOMALIES REMOTELY-SENSED BY THE NOAA OFFICE OF RESPONSE AND RESTORATION

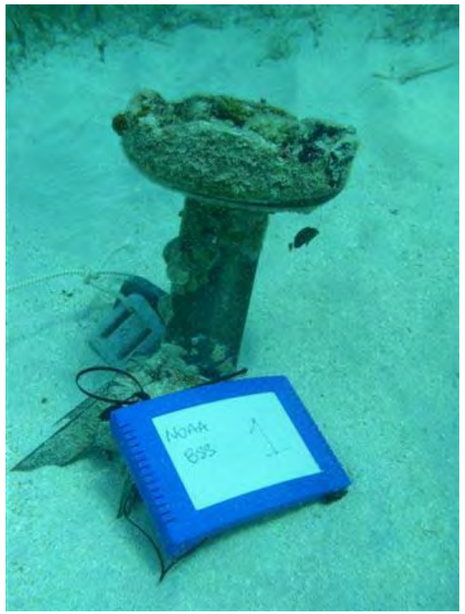
LDGP = Low Drag General Purpose; MK = Mark; CCA = Crustose Coralline Algae; MA = macroalgae; TA = Turf Algae; SAV = Submerged Aquatic Vegetation; NA = Not Available; min = minute; cm = centimeter; m = meter; in = inch

Item Label	NOAA/ Additional Item	Item Type	Positive / False-Positive	Item Description	Biological Growth	Substrate	Accessibility	Northing	Easting
NOAA BSS 1	NOAA	Munitions debris	Positive	Snake eye fins (no bomb attached)	CCA, Sponge, TA, Encrusting coral	Sand	Yes	2006145.960	256223.5
NOAA BSS 6	NOAA	Non-munitions debris	Positive	Large piece of aluminum debris, 69 cm by 290 cm.	TA	Coral rubble	Yes	2005586.7	256683.3
NOAA BSS 6 BIS	Additional Item	Munitions debris	Positive	Snake eye fins (no bomb)	Fire coral, Soft coral, MA, Sponge, TA	Sand/Coral rubble	Yes	2005577.492	256669.841
NOAA BSS 6 2BIS	Additional Item	Munitions debris	Positive	Small piece of snake eye fin (one arm and base)	CCA, TA, Sponge, MA	Sand/Coral rubble	Yes	2005580.810	256683.702
NOAA BSS 6 3BIS	Additional Item	Munition	Positive	MK-82 LDGP bomb, no nose fuse	Hard coral, Soft coral, MA, CCA, TA	Sand/Coral rubble	Yes	2005555.087	256669.153
NOAA BSS 7	NOAA	Munitions debris	Positive	Snake eye fins (no bomb attached)	Fire coral, CCA, TA	SAV	Yes	2005679.625	256446.837
NOAA BSS 7 BIS	Additional Item	Munitions debris	Positive	Old style fin assembly	CCA, TA	SAV	Yes	2005670.270	256448.193
NOAA BSS 9	NOAA	Non-munitions debris	Positive	Piece of machinery	Hard corals, TA, CCA	Coral gravel	Yes	2005662.791	256347.881
NOAA BSS 9 BIS	Additional Item	Non-munitions debris	Positive	Open 55 gallon drum	Hard coral, CCA, TA	SAV	Yes	2005680.758	256349.400
NOAA BSS 9 3BIS	Additional Item	Non-munitions debris	Positive	Metal scrap	Hard corals, Fire coral, CCA, TA	Coral gravel	Yes	2005669.883	256379.188
NOAA BSS 10	NOAA	Munition	Positive	MK-82 LDGP bomb, nose 3/4 in, snake eye fins	CCA, Sponge, TA, Fire coral	Sand	Yes	2006153.7	256322
NOAA BSS 11	Additional Item	Munition	Positive	MK-82 LDGP bomb, snake eye fin, parachute	TA	Sand	Yes	2006151.4	256332.5
NOAA BSS 12	Additional Item	Munition	Positive	MK-82 LDGP bomb fin assembly, no fins, parachute	TA, Fire coral, Hydroids	Sand	Yes	2006150.536	256318.103
NOAA BSS 13	Additional Item	Munition	Positive	Possible MK-82 LDGP bomb, surface of bomb visible	NA	SAV	Yes	2006158.442	256357.245
NOAA BSS 20	NOAA	Reef rock	False Positive	Reef rock	Hard coral, Hydroids	Reef rock	No	2005518.778	256950.917
NOAA BSS 21	NOAA	Reef rock	False Positive	Prominent patch reef, *A. palmata* skeleton	Soft corals, Hard corals, Fire coral, CCA, TA, MA	Patch Reef	No	2005481.766	256766.132
NOAA BSS 22	NOAA	Reef rock	False Positive	Reef rock	Soft coral, Fire coral, TA, CCA,	Reef rock	No	2005568.348	256696.032
NOAA BSS 22 BIS	Additional Item	Munitions debris	Positive	Snake eye fin assembly, no bomb attached	CCA, MA, Fire coral	Sand and dead hard coral fragments	Yes	2005544.725	256688.874
NOAA BSS 22 2BIS	Additional Item	Reef rock	False Positive	Reef rock	Sponge, CCA, TA, Hard coral	Reef rock	No	2005571.741	256689.545
NOAA BSS 31	NOAA	Munitions debris	Positive	Fragments of a bomb	NA	Sand	Yes	2006013.030	256496.815
NOAA BSS 32	NOAA	Unknown	Unknown	Metal, 13 cm by 4 cm size object buried in sand at the edge of a seagrass bed.	NA	Sand	Yes	2006028.252	256514.531
NOAA BSS 32 BIS	Additional Item	Unknown	Unknown	Metal, 64 cm length, buried under seagrass, 6 m water depth.	NA	SAV	No	2006033.528	256517.532
NOAA BSS 58	NOAA	Reef rock	False Positive	Isolated rock on flat submerged aquatic vegetation surface, coarse carbonate sediments. Found several shell casings near isolated rock.	NA	Shell hash	Yes	2005844.992	256531.766
NOAA BSS 59	NOAA	Unknown	Unknown	Weak contacts. Fringing reef hardbottom with protrudings rocks. 7 m water depth.	Fire coral, Soft coral, Sponge, CCA, TA, MA	Reef rock	No	2005885.233	256573.246
NOAA BSS 60	NOAA	Carbonate nodules (hot rocks)	False Positive	Nodules consisting of small metal fragments overgrown by carbonate accretion.	NA	Sand	Yes	2005942.721	256536.435
NOAA BSS 70	NOAA	Not found	Not found	If present, it is buried under a *Thalassia* seagrass bed	NA	SAV	No	2005839.973	256318.059
NOAA BSS 88	NOAA	Not found	Not found	No metal detector signature. *Thalassia* seagrass bed.	NA	SAV	No	2006044.790	256038.502
NOAA BSS 91	NOAA	Unknown	Unknown	Contact buried under *Thalassia* seagrass bed. Metal detector gave a strong signal. The contact was 40 cm in diameter Water depth was 8 m.	NA	SAV	No	2005938.499	256132.022
NOAA BSS 92	NOAA	Unknown	Unknown	Drogue chute, small signature within a 5 m radius	NA	Sand	No	2005976.622	256118.112
NOAA BSS 92 BIS	Additional Item	Munitions debris	Positive	MK-82 LDGP bomb tail fin boom sticking out of the seafloor	Sponge, Hydroids, TA	Sand	Yes	2006020.808	256101.592
NOAA BSS 93	NOAA	Unknown	Unknown	Contact buried under *Thalassia* seagrass bed. Metal detector gave a strong signal. The contact was about 1 m by 40 cm in size. Water depth was 8 m.	NA	SAV	No	2005929.942	256182.148
NOAA BSS 94	NOAA	Munitions debris	Positive	32 in MK 6 mine. Case break in one side.	Fire coral, Hard coral, Sponge, MA, TA	SAV	Yes	2006035.336	256169.426
NOAA BSS 95	NOAA	Unknown	Unknown	Contact buried under *Thalassia* seagrass bed. Metal detector gave a strong signal. The contact was about 2 m in radius.	NA	SAV	No	2005989.081	256153.808
NOAA BSS 97	NOAA	Unknown	Unknown	Contact buried under *Thalassia/Halodule* seagrass bed. Metal detector gave a strong signal. The contact was about 4 m in diameter.	NA	SAV	No	2006124.159	256138.561

Item Label	NOAA/ Additional Item	Item Type	Positive / False-Positive	Item Description	Biological Growth	Substrate	Accessibility	Northing	Easting
NOAA BSS 98	NOAA	Not found	Not found	We did not find anything at this location. There was no metal detector signature. Halodule seagrass bed. Anything in the immediate vicinity would defintely buried. Flat seagrass bed.	NA	SAV	No	2006191.320	256266.835
NOAA BSS 99	NOAA	Unknown	Unknown	Contact buried under *Thalassia* seagrass bed. Metal detector gave a strong signal. The contact was about 1.5 m long and approximately 30 cm wide. Water depth was 6 m.	NA	SAV	No	2006283.616	256353.274
NOAA BSS 100	NOAA	Not found	Not found	Did a 15 min search, obtained small metal detection signals for shell casings. If present, it is buried under a *Thalassia* seagarss bed. Depth was 8 m.	NA	SAV	No	2005901.951	256328.484
NOAA BSS 108	NOAA	Unknown	Unknown	Contact buried under *Thalassia* seagrass bed. Metal detector gave a strong signal. The contact had a radius of about 4 m radius. Water depth was 5 m.	NA	SAV	No	2006209.221	256377.436
NOAA BSS 110	NOAA	Not found	Not found	If present, it is buried under a *Thalassia* seagrass bed	NA	SAV	No	2006059.674	256481.279
NOAA BSS 120	NOAA	Unknown	Unknown	Weak contacts in the sand. If there was anything else (other than the weak contacts) it was buried in the sand.	NA	Sand	No	2005826.226	256582.840
NOAA BSS 121	NOAA	Patch reef	False Positive	Topographic prominence	Soft corals, Hard corals, Encrusting coral, Fire coral, Sponges, CCA, TA, MA	Patch Reef	No	2005884.671	256503.337
NOAA BSS 201	Additional Item	Munition	Positive	MK-82 LDGP bomb. Nose-up 1/4 proud. 7 m water depth. Edge of the edge seagrass.	Fire coral, TA, CCA	Sand/SAV	Yes	2005981.216	256412.228

APPENDIX 2

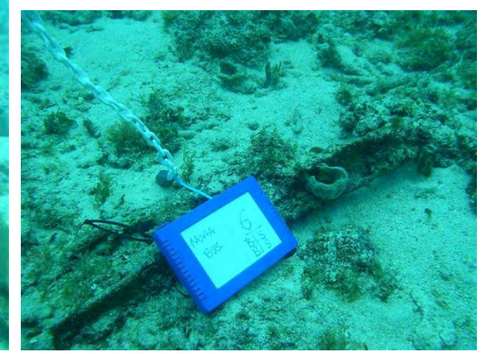
PHOTOGRAPHIC ILLUSTRATIONS ACQUIRED IN NOVEMBER 2006 OF THE MUNITIONS RELATED ITEMS, NON-MUNITIONS DEBRIS, AND REEF SUBSTRATES ENCOUNTERED IN BAHIA SALINA DEL SUR, VIEQUES ISLAND, AS PART OF A GROUNDTRUTHING EFFORT OF ANOMALIES REMOTELY-SENSED BY THE NOAA OFFICE OF RESPONSE & RESTORATION



NOAA BSS 1

NOAA BSS 6

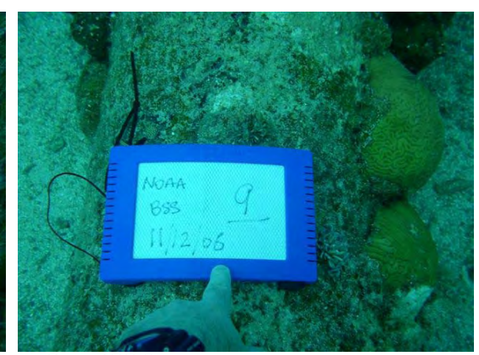
NOAA BSS 6 BIS


NOAA BSS 6 2BIS

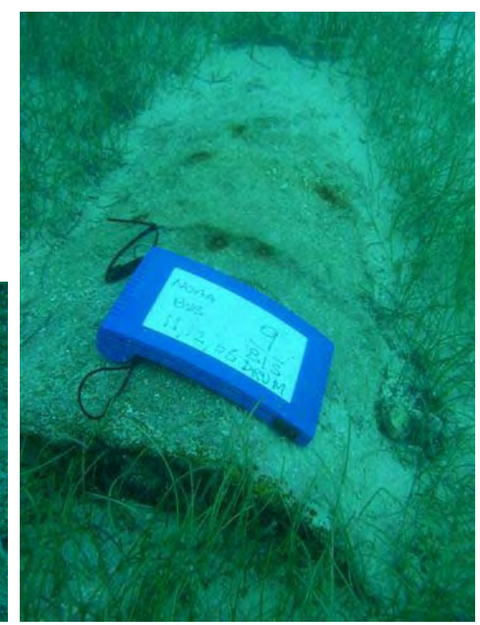
NOAA BSS 6 3BIS

NOAA BSS 7

NOAA BSS 7 BIS



NOAA BSS 9


NOAA BSS 9 BIS

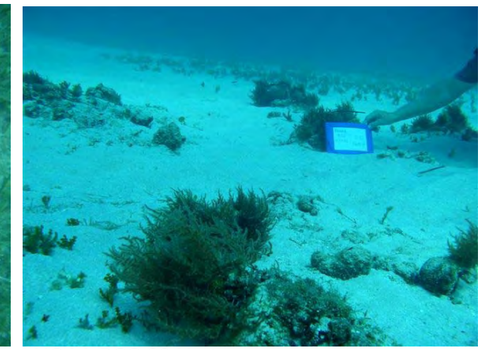
NOAA BSS 9 3BIS

NOAA BSS 10

NOAA BSS 11

NOAA BSS 12

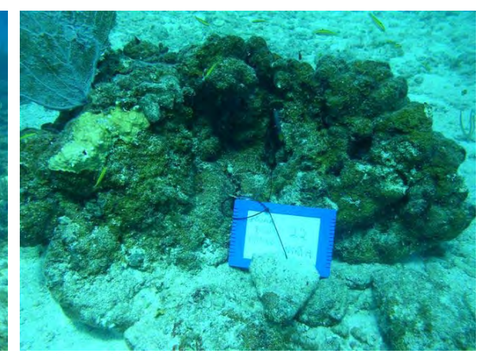
NOAA BSS 13


NOAA BSS 20 North

NOAA BSS 20 West

NOAA BSS 21 North

NOAA BSS 21 West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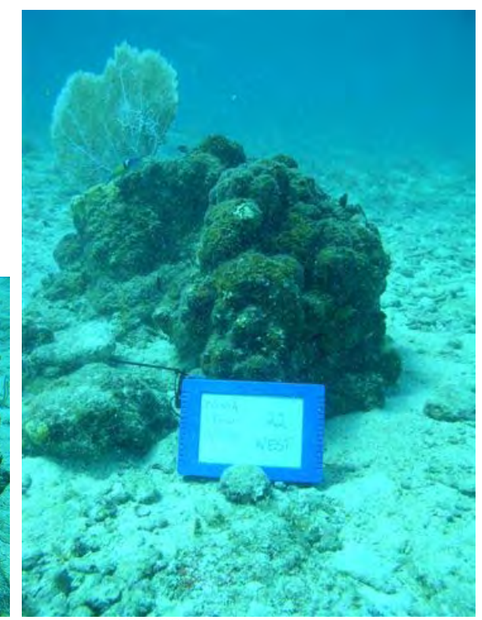
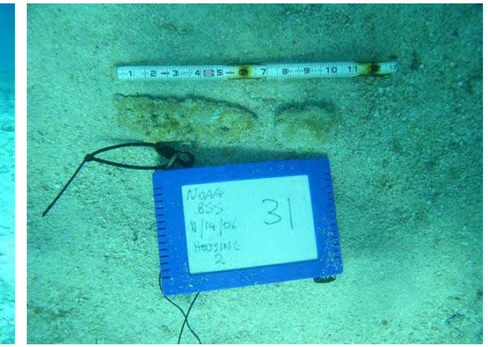

NOAA BSS 22 West

NOAA BSS 22 BIS North

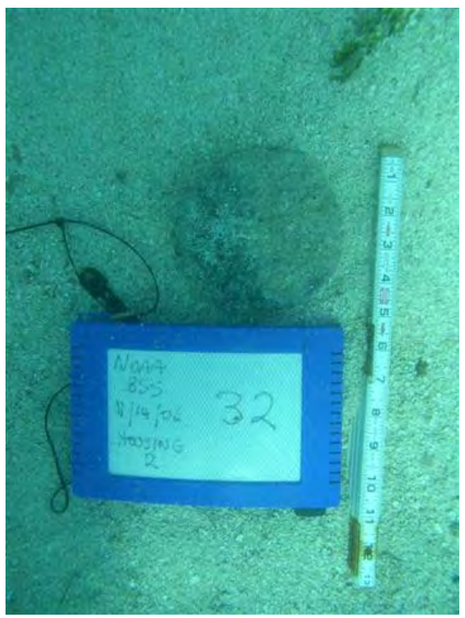
NOAA BSS 22 BIS West

NOAA BSS 22 2BIS North

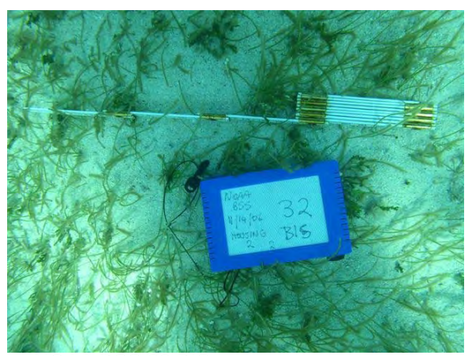
NOAA BSS 22 2BIS West



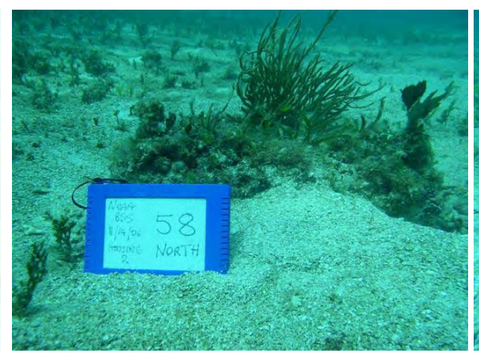
NOAA BSS 31



NOAA BSS 32



NOAA BSS 32 BIS



NOAA BSS 58 North

NOAA BSS 58 West

NOAA BSS 58

NOAA BSS 59 North

NOAA BSS 59 West

NOAA BSS 60

NOAA BSS 70

NOAA BSS 88

NOAA BSS 91

NOAA BSS 92 North

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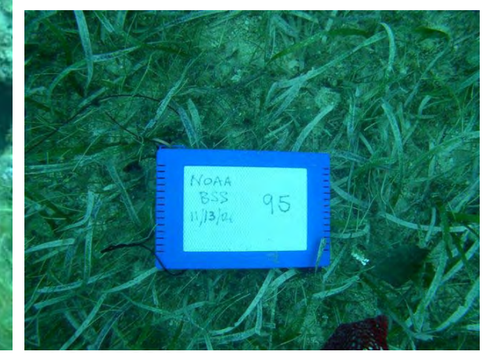
NOAA BSS 93

NOAA BSS 94 North

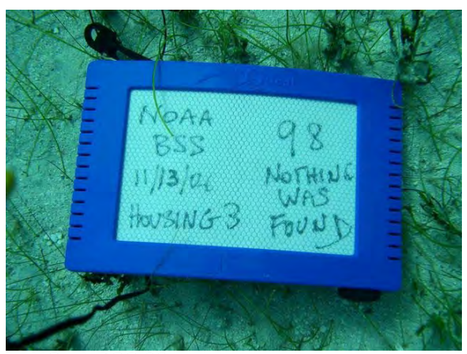
NOAA BSS 94 West

NOAA BSS 94



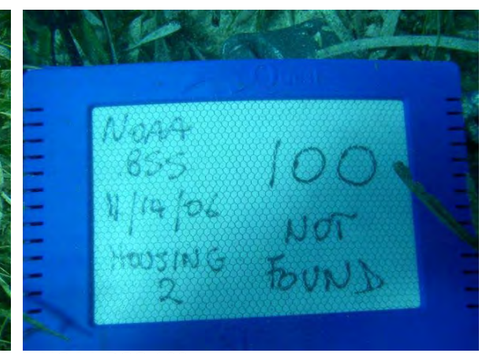
NOAA BSS 95

NOAA BSS 97



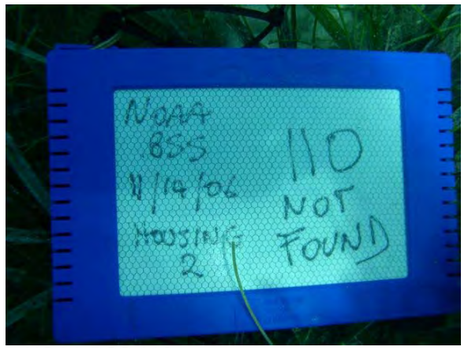
NOAA BSS 98

NOAA BSS 99



NOAA BSS 100

NOAA BSS 108



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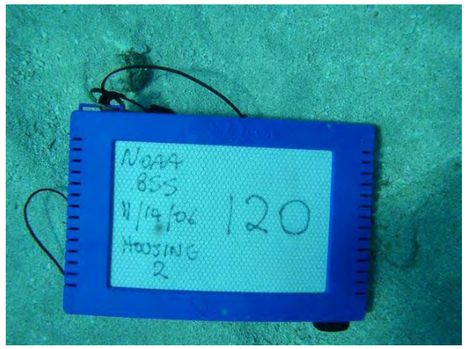
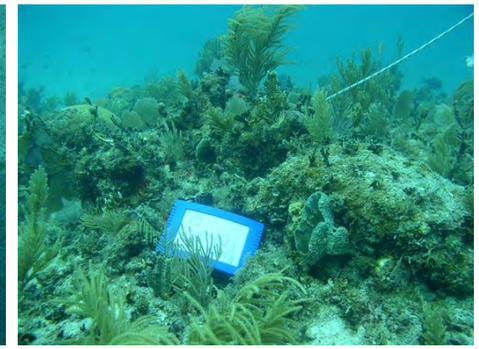
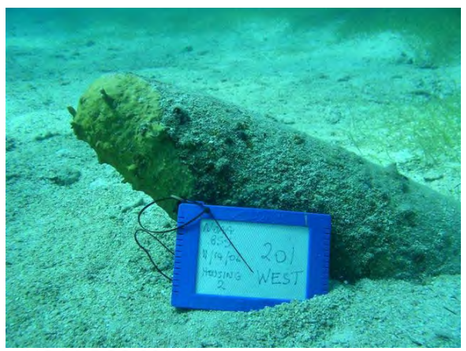


NOAA BSS 120


NOAA BSS 121 North

NOAA BSS 121 West

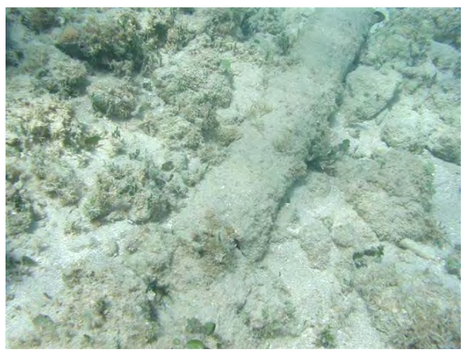
NOAA BSS 201 North

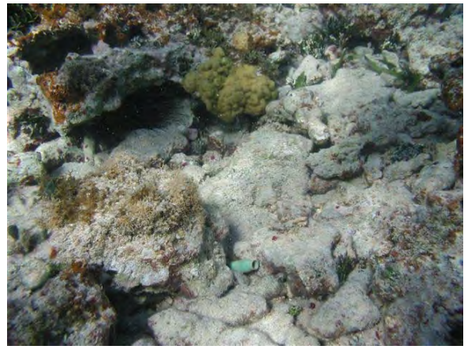


NOAA BSS 201 West

APPENDIX 3

PHOTOGRAPHIC ILLUSTRATIONS OF MUNITIONS RELATED ITEMS AND NON-MUNITIONS DEBRIS IN BAHIA SALINA DEL SUR, VIEQUES ISLAND, ACQUIRED DURING A PRELIMINARY UNDERWATER SURVEY CONDUCTED IN 2001. PHOTOGRAPHS WERE TAKEN FROM THE NORTHWESTERN CORNER OF THE BAY (SMALL BOAT RAMP) THROUGH MILITARY TARGET T5





APPENDIX 4

MUNITIONS RELATED ITEMS AND NON-MUNITIONS DEBRIS DOCUMENTED IN NOVEMBER 2006 IN BAHIA SALINA DEL SUR, VIEQUES ISLAND, OFF FORMER MILITARY TARGETS T1 THROUGH T6

[LDGP = Low Drag General Purpose; MK = Mark; BDU = Bomb Dummy Unit; in = inch; mm = millimeter; m = meter; lb = pound; ft = feet]

Item Label	Item Type	Item Description	Northing	Easting
GMI BSS T1 1	Munition	MK-82 LDGP Bomb	2006570.221	256421.704
GMI BSS T1 2	Munition	5 in/54 Projectile	2006582.968	256412.498
GMI BSS T1 2 BIS	Munition	5 in/54 Projectile	2006582.968	256412.498
GMI BSS T1 3	Munition	5 in/54 Projectile	2006559.606	256394.838
GMI BSS T1 3 BIS	Munition	5 in/54 Projectile	2006559.606	256394.838
GMI BSS T1 4	Munition	5 in/54 Projectile	2006567.940	256385.071
GMI BSS T1 5	Munition	MK-82 LDGP Bomb	2006576.457	256376.808
GMI BSS T1 6	Munition	MK-82 LDGP Bomb lying on top of a 5 in/54 projectile	2006600.313	256424.978
GMI BSS T1 7	Munition	BDU 33	2006588.321	256457.450
GMI BSS T1 8	Munitions debris	Base plate from MK-82 LDGP Bomb	2006587.151	256455.269
GMI BSS T1 9	Munitions debris	Nose section brocken off MK-82 LDGP Bomb	2006601.867	256462.222
GMI BSS T1 10	Munition	5 in/54 Projectile	2006600.373	256466.069
GMI BSS T1 11	Munition	MK-82 LDGP Bomb	2006604.588	256465.181
GMI BSS T1 12	Munition	MK-82 LDGP Bomb; tail section high ordered nose section remains	2006605.442	256474.524
GMI BSS T1 13	Munition	5 in/54 Projectile	2006618.162	256469.855
GMI BSS T1 14	Munition	5 in/54 Projectile	2006615.983	256467.575
GMI BSS T1 15	Munition	MK-82 LDGP Bomb	2006617.992	256483.946
GMI BSS T1 16	Munition	MK-82 LDGP Bomb	2006623.080	256482.423
GMI BSS T1 17	Munition	MK-82 LDGP Bomb	2006624.241	256486.704
GMI BSS T1 18	Munition	Two 5 in / 54 Projectiles	2006626.361	256486.347
GMI BSS T1 19	Munition	MK-82 LDGP Bomb	2006637.328	256481.997
GMI BSS T1 20	Munition	MK-82 LDGP Bomb	2006622.911	256501.632
GMI BSS T1 21	Munition	MK-82 LDGP Bomb and nose section	2006610.701	256501.853
GMI BSS T1 22	Munition	MK-82 LDGP Bomb	2006602.526	256497.045
GMI BSS T2 1	Munition	MK-82 LDGP Bomb with snake eye fins attached	2006658.886	256605.067
GMI BSS T2 2	Munition	Snake eye fins (unknown if bomb is attached)	2006657.703	256615.122
GMI BSS T2 3	Non-munitions debris	Large piece of metal, not ordnance related	2006653.678	256637.974
GMI BSS T2 4	Non-munitions debris	Large piece of metal, not ordnance related	2006631.164	256657.163
GMI BSS T2 4 BIS	Munition	MK-82 LDGP Bomb	2006630.617	256658.116
GMI BSS T2 5	Munition	MK-82 LDGP Bomb with fins	2006584.481	256766.219
GMI BSS T2 6	Munitions debris	Snake eye fins	2006578.906	256760.809
GMI BSS T2 7	Munitions debris	Empty/expended MK-24 Flare Canister	2006585.557	256765.805
GMI BSS T3 1	Munition	MK-82 LDGP Bomb	2006563.107	256797.951
GMI BSS T3 2	Munition	MK-82 LDGP Bomb	2006575.890	256797.530
GMI BSS T3 3	Munitions debris	Snake eye fins	2006493.516	256782.135
GMI BSS T3 4	Munitions debris	Snake eye fin debris	2006488.215	256784.332
GMI BSS T3 5	Munitions debris	Metal debris	2006525.252	256803.892
GMI BSS T3 6	Munitions debris	Metal debris	2006517.785	256817.637
GMI BSS T3 7	Munition	Snake eye fins (unkown if bomb is attached)	2006494.321	256825.997
GMI BSS T3 8	Munitions debris	Snake eye fins	2006499.363	256816.575
GMI BSS T3 9	Munitions debris	Snake eye fins	2006466.628	256797.368
GMI BSS T3 10	Munition	Snake eye fins (unkown is bomb is attached)	2006429.592	256762.832
GMI BSS T3 11	Munitions debris	Rockeye half shell submunition canister	2006467.014	256786.750
GMI BSS T3 12	Munitions debris	Snake eye fins	2006505.377	256840.505
GMI BSS T3 13	Munitions debris	Snake eye fins	2006494.109	256818.615
GMI BSS T3 14	Non-munitions debris	Metal debris, not ordnance related	2006470.206	256831.906
GMI BSS T3 14	Non-munitions debris	Metal debris, not ordnance related	2006470.206	256831.906
GMI BSS T3 15	Non-munitions debris	Metal debris, not ordnance related	2006483.048	256847.959
GMI BSS T4 1	Munitions debris	Snake eye fins	2006440.793	256821.647

Item Label	Item Type	Item Description	Northing	Easting
GMI BSS T4 2	Non-munitions debris	Metal debris	2006434.362	256828.757
GMI BSS T4 3	Munitions debris	Snake eye fin	2006428.170	256820.901
GMI BSS T4 4	Munitions debris	Snake eye fin	2006418.383	256823.111
GMI BSS T4 5	Munitions debris	Snake eye fins	2006417.097	256816.704
GMI BSS T4 6	Munitions debris	Snake eye fins	2006422.801	256803.966
GMI BSS T4 7	Non-munitions debris	Metal debris	2006438.906	256856.701
GMI BSS T4 8	Munition	MK-82 LDGP Bomb	2006444.670	256870.570
GMI BSS T4 9	Munitions debris	Snake eye fins metal debris	2006422.646	256857.788
GMI BSS T4 10	Munitions debris	Snake eye fins	2006404.069	256836.037
GMI BSS T4 11	Non-munitions debris	Metal mesh grate	2006397.827	256835.426
GMI BSS T4 12	Munitions debris	Snake eye fins metal debris	2006368.550	256827.901
GMI BSS T4 13	Munitions debris	Snake eye fins metal debris	2006373.940	256817.315
GMI BSS T4 14	Munitions debris	Rockeye half shell submunition canister	2006338.612	256796.480
GMI BSS T4 15	Non-munitions debris	Metal debris	2006347.087	256804.290
GMI BSS T4 16	Non-munitions debris	Metal debris	2006340.364	256818.569
GMI BSS T4 17	Munitions debris	Snake eye fins	2006339.735	256829.578
GMI BSS T4 18	Munition/Seamine	British MK-7? 13 in diameter by 6 ft; 13 in between lugs. Arming wires attached	2006276.549	256837.800
GMI BSS T4 19	Munitions debris	Rockeye half shell submunition canister	2006278.343	256828.300
GMI BSS T4 20	Munitions debris	Snake eye fins	2006282.958	256839.879
GMI BSS T4 21	Munitions debris	81 mm mortar illumination tail assembly	2006282.930	256845.485
GMI BSS T4 22	Munition	Large cylindrical object, partially buried object (mine or bomb?)	2006279.953	256846.561
GMI BSS T4 23	Munitions debris	Metal debris	2006281.251	256854.701
GMI BSS T4 24	Munition	5 in/54 Projectile	2006269.159	256855.552
GMI BSS T4 25	Munition	5 in/54 Projectile	2006251.141	256860.327
GMI BSS T4 26	Non-munitions debris	Metal pipe, non ordnance	2006223.805	256846.366
GMI BSS T4 27	Munition	3 in Projectile	2006223.144	256852.292
GMI BSS T4 28	Munition	MK-82 LDGP Bomb; Two 5 in/54 Projectiles	2006229.495	256851.741
GMI BSS T4 29	Munition	Two snake eye fins and one rock eye half clam shell	2006389.781	256753.017
GMI BSS T4 30	Munition	5 in/54 Projectile	2006207.023	256879.620
GMI BSS T4 31	Munition	5 in/54 Projectile	2006193.219	256868.855
GMI BSS T4 32	Munition	5 in/54 Projectile	2006186.731	256868.661
GMI BSS T4 33	Munition	5 in/54 Projectile	2006177.777	256884.231
GMI BSS T4 34	Munition	5 in/54 Projectile	2006177.483	256880.291
GMI BSS T4 35	Munition	5 in/54 Projectile	2006172.729	256878.416
GMI BSS T4 36	Munition	5 in/54 Projectile	2006177.408	256888.454
GMI BSS T4 37	Munition	MK-82 LDGP Bomb, no nose or tail fuse	2006198.913	256895.737
GMI BSS T4 38	Munition	5 in/54 Projectile	2006182.384	256908.102
GMI BSS T4 39	Non-munitions debris	Large piece of metal, target debris	2006170.320	256893.111
GMI BSS T4 40	Munition	5 in/54 Projectile	2006159.451	256900.355
GMI BSS T4 41	Munition	5 in/54 Projectile	2006155.431	256903.289
GMI BSS T4 42	Munition	Two 5 in/54 Projectiles, two inches apart	2006151.846	256892.699
GMI BSS T4 43	Munition	5 in/54 Projectile	2006150.649	256900.570
GMI BSS T4 44	Munition	5 in/54 Projectile	2006149.868	256903.019
GMI BSS T4 45	Munition	500 lb old style General Purpose Bomb	2006152.670	256911.188
GMI BSS T4 46	Munition	5 in/54 Projectile	2006176.071	256914.572
GMI BSS T4 47	Munitions debris	MK-82 LDGP Bomb spotting charges expended	2006181.724	256930.653
GMI BSS T4 49	Non-munitions debris	Tank track metal debris	2006174.964	256935.305
GMI BSS T4 50	Munition and non-munitions debris	Tank track metal debris, small arms 7.62 mm and small arms debris close by	2006166.912	256945.523
GMI BSS T4 51	Munition	MK-82 LDGP Bomb with tail boom assembly	2006156.874	256924.028

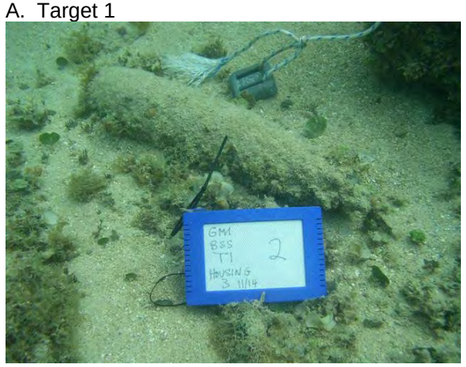
Item Label	Item Type	Item Description	Northing	Easting
GMI BSS T4 52	Munition	Two 5 in rounds	2006156.740	256923.448
GMI BSS T4 53	Munition	5 in/54 Projectile, no nose or tail fuse	2006150.244	256925.366
GMI BSS T4 54	Munition	5 in/54 Projectile	2006155.353	256936.034
GMI BSS T4 55	Munition	5 in/54 Projectile	2006134.312	256906.778
GMI BSS T4 56	Munition	5 in/54 Projectile	2006139.200	256916.392
GMI BSS T4 57	Munition	5 in/54 Projectile	2006134.695	256923.444
GMI BSS T5 1	Munition	Bomb Dummy Unit 33 Practice Bomb	2006131.039	256924.751
GMI BSS T5 2	Munition	Bomb Dummy Unit 33 Practice Bomb	2006135.769	256930.792
GMI BSS T5 3	Non-munitions debris	Target debris from tank	2006137.155	256939.631
GMI BSS T5 4	Munition	5 in/54 Projectile	2006132.863	256939.008
GMI BSS T5 5	Munition	MK-83 Bomb	2006125.760	256935.991
GMI BSS T5 6	Munitions debris	5 in/54 Debris	2006108.816	256928.446
GMI BSS T5 7	Munition	Bomb Dummy Unit 33 Practice Bomb	2006104.029	256947.562
GMI BSS T5 8	Munition	5 in/54 Projectile	2006099.208	256949.619
GMI BSS T5 8 BIS	Munition	Bomb Dummy Unit 33 Practice Bomb	2006099.208	256949.619
GMI BSS T5 9	Munition	5 in/54 Projectile	2006106.264	256954.382
GMI BSS T5 10	Munition	5 in/54 Projectile	2006116.946	256947.272
GMI BSS T5 11	Munition	MK-82 LDGP Bomb	2006127.226	256954.653
GMI BSS T5 12	Munition	Bomb Dummy Unit 33 Practice Bomb	2006126.315	256965.556
GMI BSS T5 13	Munition	5 in/54 Projectile	2006120.749	256972.286
GMI BSS T5 14	Munition	5 in/54 Projectile	2006118.737	256955.283
GMI BSS T5 15	Munition	Two 5 in/54 Projectiles partial case	2006116.308	256959.452
GMI BSS T5 16	Munition	5 in/54 Projectile	2006107.516	256975.642
GMI BSS T5 17	Munition	5 in/54 Projectile	2006117.276	256970.161
GMI BSS T5 18	Munition	MK-82 LDGP Bomb	2006121.287	256981.746
GMI BSS T5 19	Munition	Two 5 in/54 Projectiles, 1 broken in half	2006120.125	256977.340
GMI BSS T5 20	Munition	Bomb Dummy Unit 33 Practice Bomb	2006118.630	256977.366
GMI BSS T5 21	Non-munitions debris	Target debris	2006116.068	256979.282
GMI BSS T5 22	Munition	5 in/54 Projectile	2006105.316	256976.085
GMI BSS T5 23	Munition	Bomb Dummy Unit 33 Practice Bomb	2006096.342	256942.553
GMI BSS T6 1	Munition	5 in/54 Projectile half shell	2005925.330	257000.191
GMI BSS T6 1 BIS	Munition	5 in/54 Projectile half shell	2005925.330	257000.191
GMI BSS T6 2	Munition	5 in/54 Projectile	2005912.937	256980.625
GMI BSS T6 3	Munition	5 in/54 Projectile	2005918.419	256971.541
GMI BSS T6 4	Munition	5 in/54 Projectile	2005915.170	256976.525
GMI BSS T6 5	Munition	5 in/54 Projectile	2005921.785	256979.049
GMI BSS T6 6	Munition	5 in/54 Projectile	2005893.549	256982.360
GMI BSS T6 7	Munitions debris	Base of 5 in/54 Projectile	2005889.465	256985.898
GMI BSS T6 8	Munition	5 in/54 Projectile	2005894.256	256966.489
GMI BSS T6 9	Munition	5 in/54 Projectile	2005897.406	256966.150
GMI BSS T6 10	Munition	Half case of 5 in/54 projectile	2005887.341	256981.513
GMI BSS T6 11	Munitions debris	Large piece of fragment	2005883.128	256977.728
GMI BSS T6 12	Munition	5 in/54 Projectile	2005877.949	256978.133
GMI BSS T6 13	Munition	5 in/54 Projectile	2005885.525	257002.418
GMI BSS T6 14	Munition	5 in/54 Projectile broken in half	2005886.702	257009.243
GMI BSS T6 15	Munition	5 in/54 Projectile	2005882.069	257004.449
GMI BSS T6 16	Munition	Half shell of 5 in/54 projectile	2005877.435	257004.779
GMI BSS T6 17	Munition	5 in/54 Projectile	2005873.180	257006.379
GMI BSS T6 18	Munition	5 in/54 Projectile	2005873.830	257009.924
GMI BSS T6 19	Munition	5 in/54 Projectile	2005872.707	257008.348

Item Label	Item Type	Item Description	Northing	Easting
GMI BSS T6 20	Munition	5 in/54 Projectile	2005863.017	256997.324
GMI BSS T6 21	Munition	3 in Projectile	2005862.439	256992.372
GMI BSS T6 22	Non-munitions debris	Cylinder, target debris (tank track hub?)	2005862.114	256985.033
GMI BSS T6 23	Munition	Tube from inside 5 in puff round	2005866.556	256988.506
GMI BSS T6 24	Munition	5 in/54 Projectile	2005854.470	256976.243
GMI BSS T6 25	Munition	MK-82 LDGP Bomb	2005851.900	256974.701
GMI BSS T6 26	Munition	5 in/54 Projectile	2005855.432	256972.000
GMI BSS T6 27	Munition	5 in/54 Projectile	2005854.013	256988.021
GMI BSS T6 28	Munition	5 in/54 Projectile	2005853.007	256990.285
GMI BSS T6 29	Munition	5 in/54 Projectile half case and debris	2005849.651	256988.373
GMI BSS T6 30	Munition	5 in/54 Projectile	2005838.959	256989.212
GMI BSS T6 31	Munition	5 in/54 Projectile	2005838.719	256986.642
GMI BSS T6 32	Non-munitions debris	Cylindrical object, target debris	2005837.752	256984.090
GMI BSS T6 33	Munition	5 in/54 Projectile	2005835.202	256987.694
GMI BSS T6 34	Munition	5 in/54 Projectile	2005834.612	256995.819
GMI BSS T6 35	Munition	5 in/54 Projectile	2005843.248	256994.632
GMI BSS T6 36	Munition	5 in/54 Projectile	2005844.085	256999.582
GMI BSS T6 37	Munition	5 in/54 Projectile	2005829.956	257001.741
GMI BSS T6 38	Munition	Bomb Dummy Unit 33	2005826.906	257004.640
GMI BSS T6 39	Munition	two 5 in/54 projectile and BDU 33	2005826.811	257010.809
GMI BSS T6 40	Munition	5 in/54 Projectile	2005819.964	257026.608

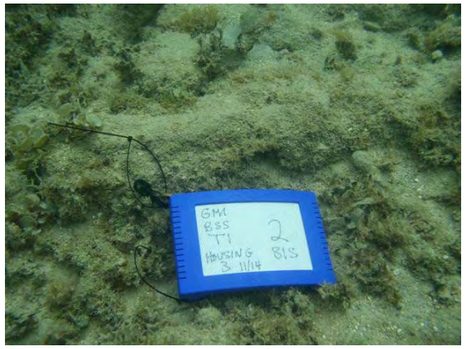
APPENDIX 5

PHOTOGRAPHIC ILLUSTRATIONS ACQUIRED IN NOVEMBER 2006 OF THE MUNITIONS RELATED ITEMS AND NON-MUNITIONS DEBRIS IN BAHIA SALINA DEL SUR, VIEQUES ISLAND, OFF FORMER MILITARY TARGETS T1 THROUGH T6

A. Target 1



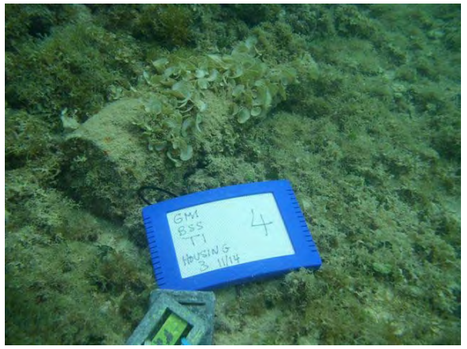
T1 2



T1 2 BIS

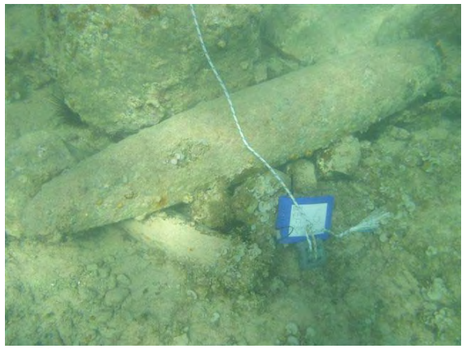
T1 3

T1 3 BIS



T1 4

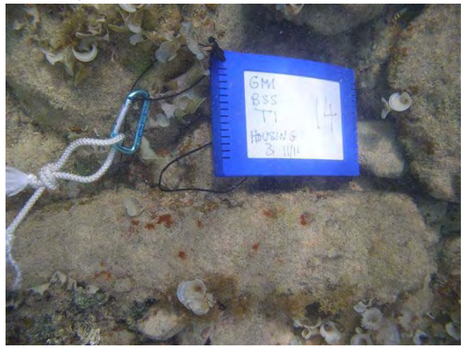
T1 5


T1 6

T1 7

T1 12

T1 13



T1 14

T1 15

T1 18

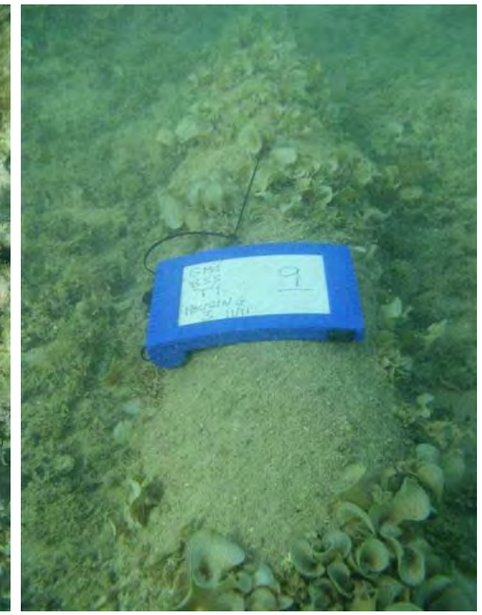
T1 18 BIS

T1 19

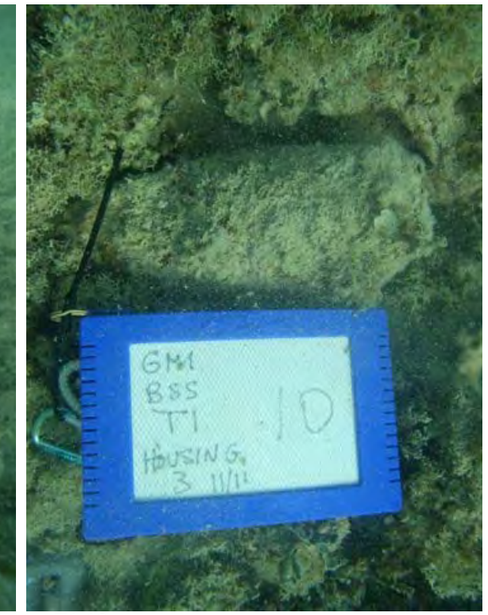
T1 20

T1 1

T1 8

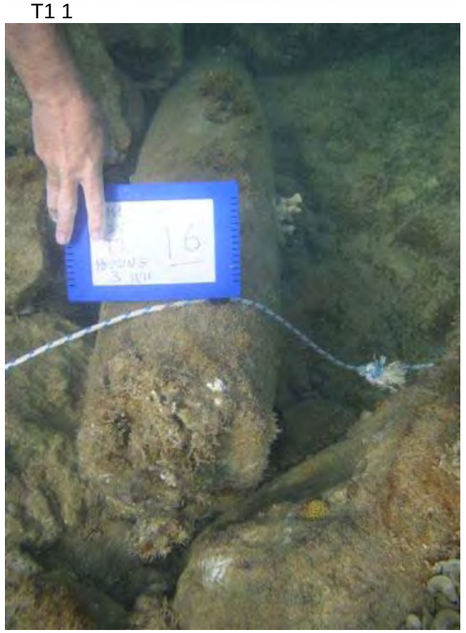


T1 9



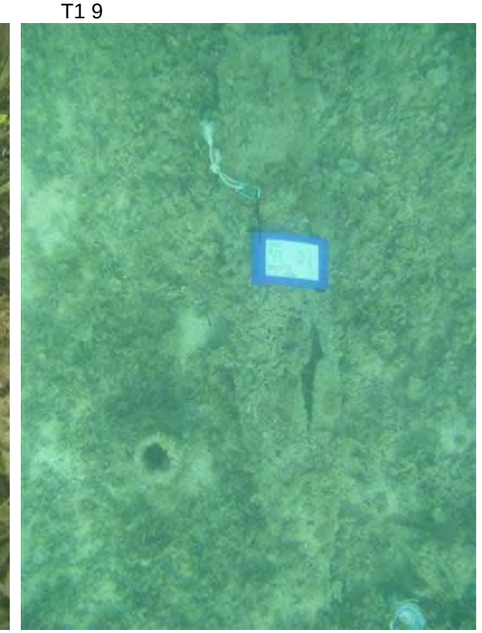
T1 10

T1 11



T1 16

T1 17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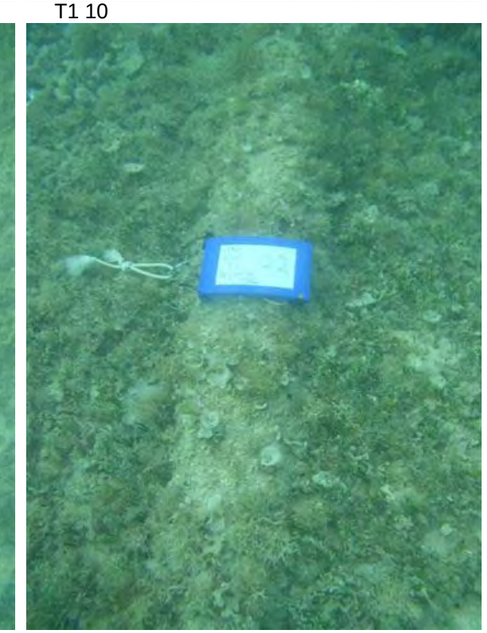

T1 22

B. Target 2

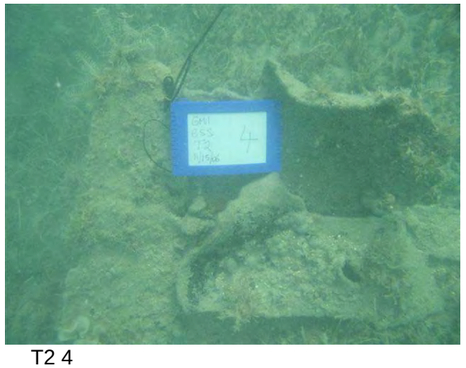
T2 1

T2 2

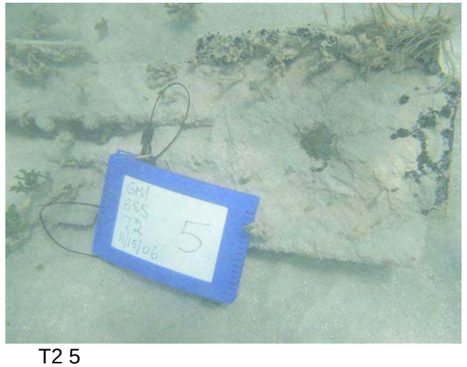
T2 3

T2 4 BIS (MISLABELED ON SLATE)

T2 7



T2 4



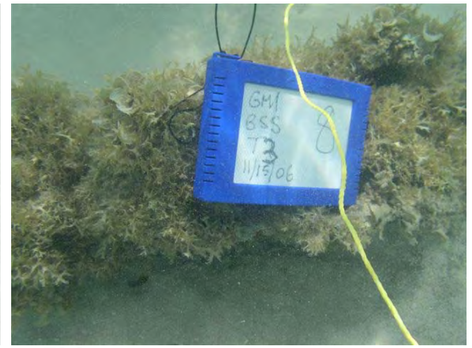
T2 5

T2 6

C. Target 3

T3 2

T3 7



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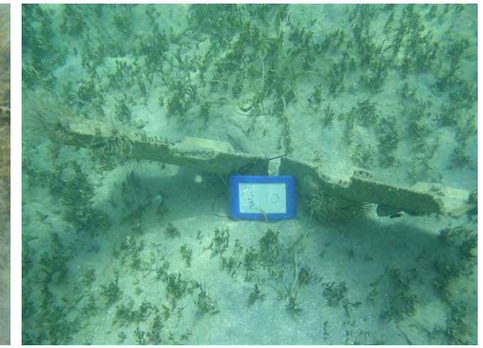
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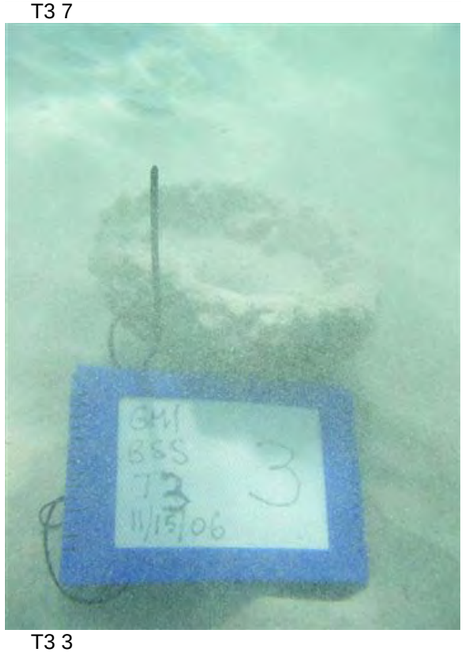
T3 1



T3 3

T3 4

T3 5

T3 6

T3 11

T3 12

T3 13

T3 14

T3 15

T3 9

D. Target 4

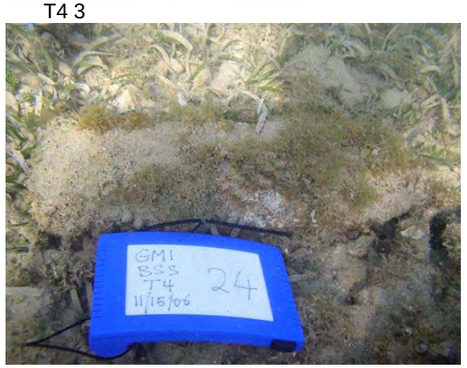
T4 3

T4 5

T4 7

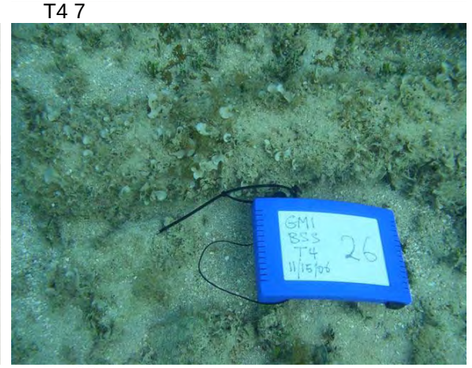
T4 11

T4 22



T4 24

T4 25



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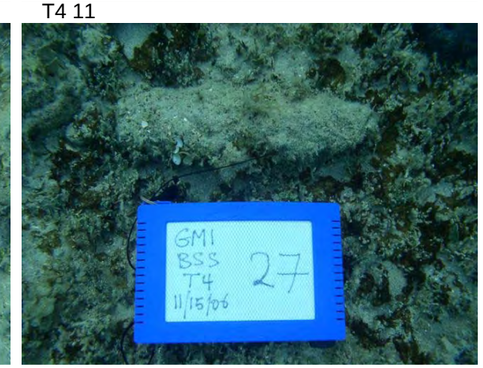

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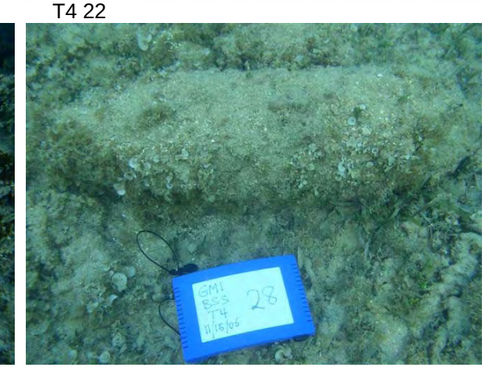

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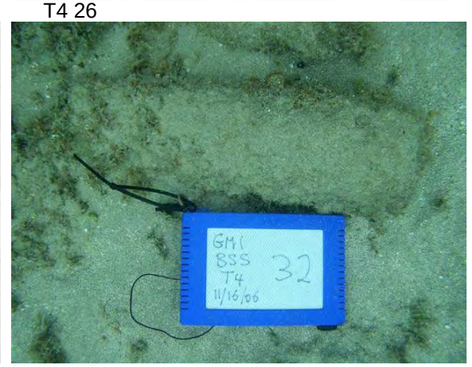
T4 30

T4 31



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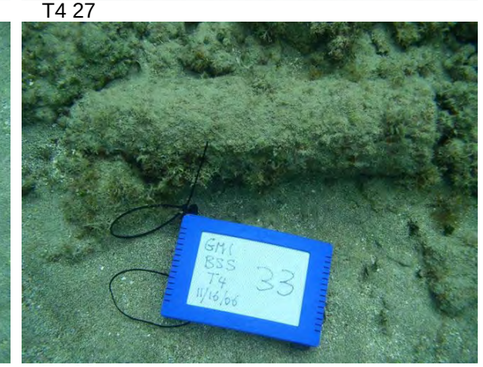

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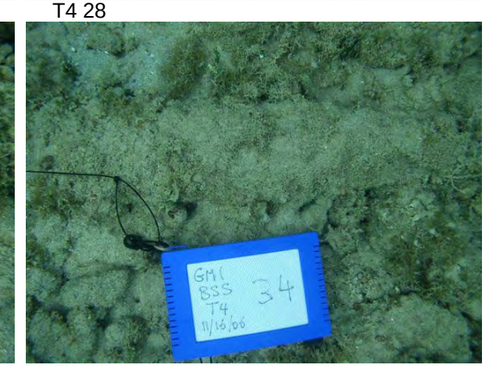

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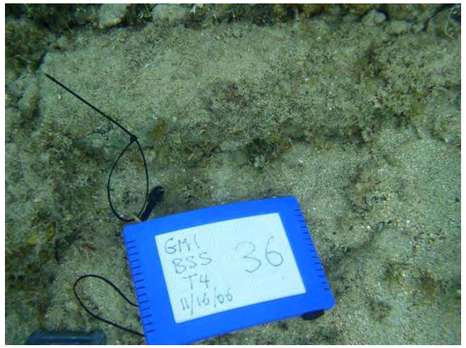
T4 35



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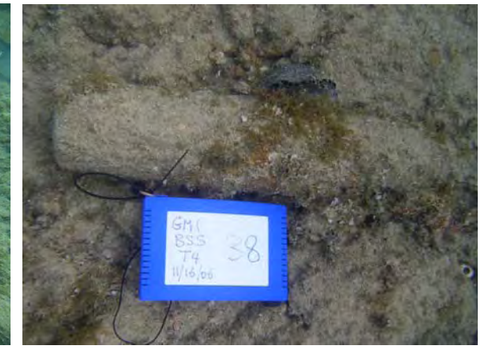
T4 37



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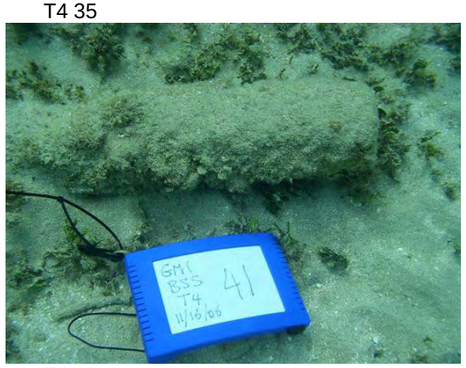
T4 40



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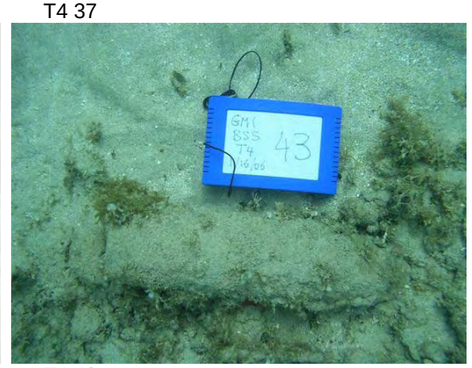

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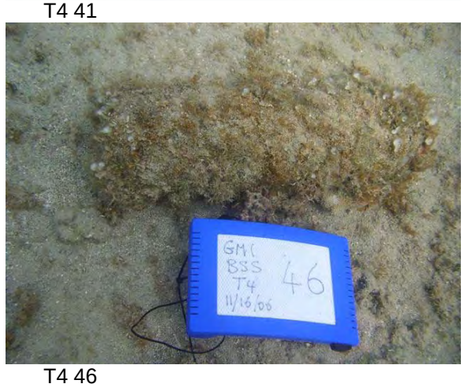
T4 45



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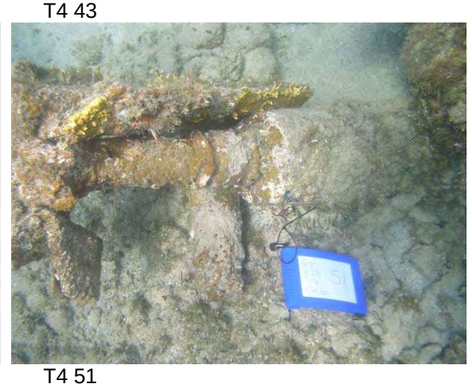
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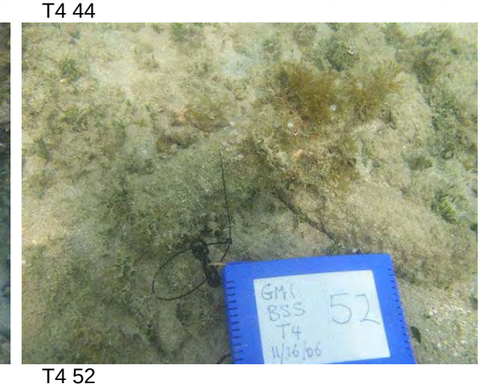

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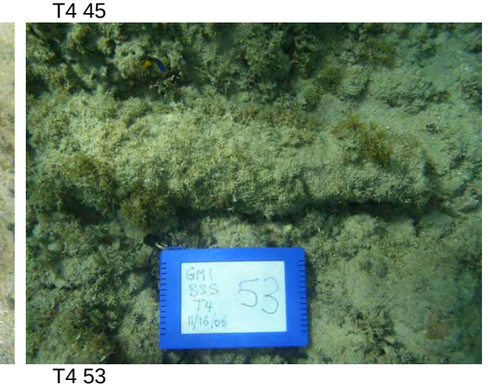

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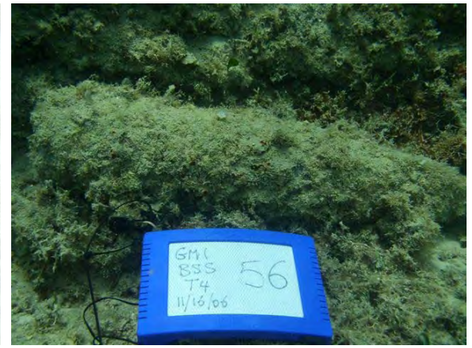
T4 54

T4 55



T4 56

T4 57

T4 1

T4 2

T4 4

T4 5

T4 8

T4 9

T4 10

T4 13

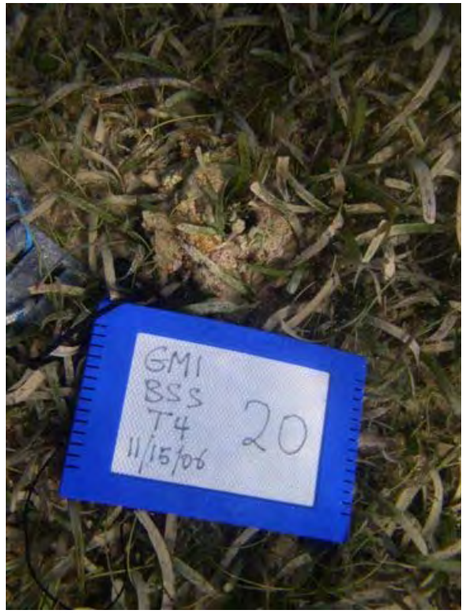
T4 14

T4 15

T4 17

T4 18

T4 19

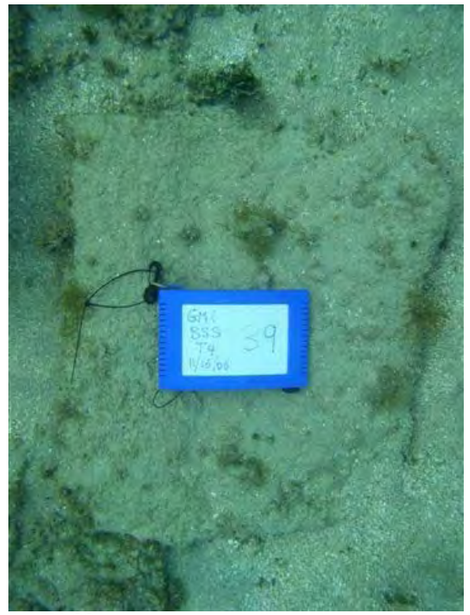


T4 20

T4 21

T4 23

T4 29

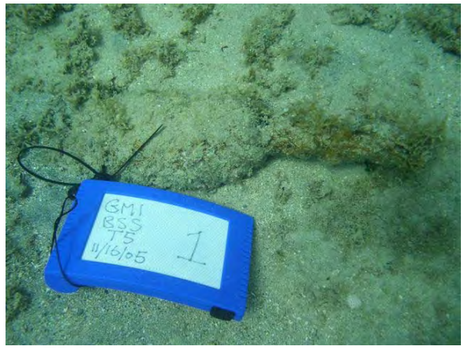


T4 39

T4 49

T4 50

D. Target 5



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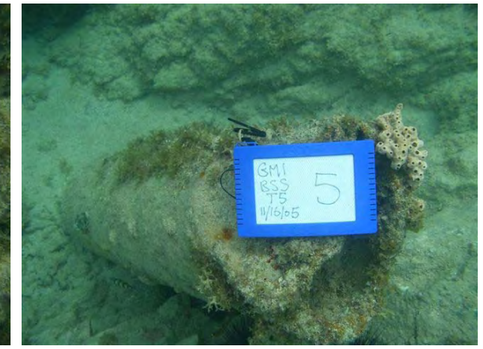

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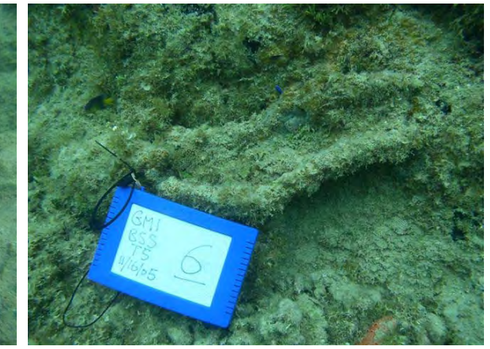

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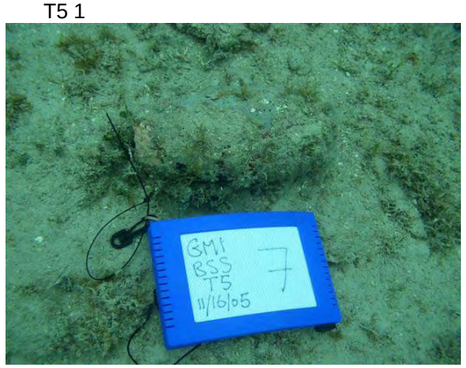

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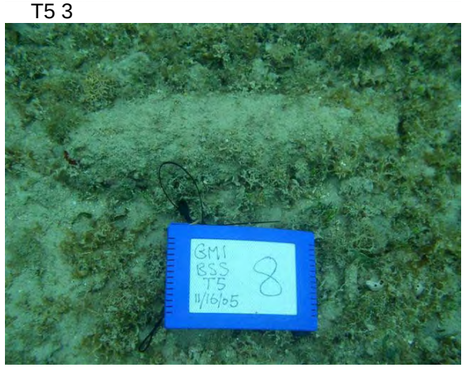

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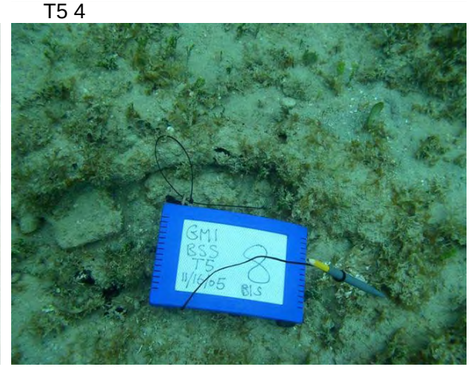

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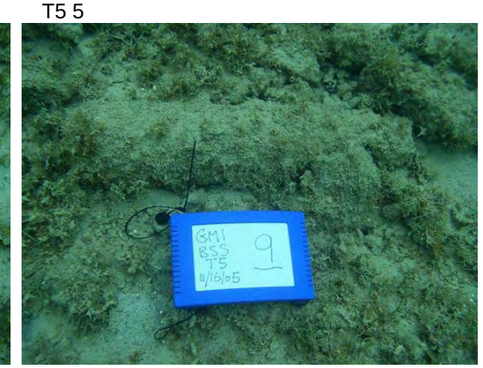

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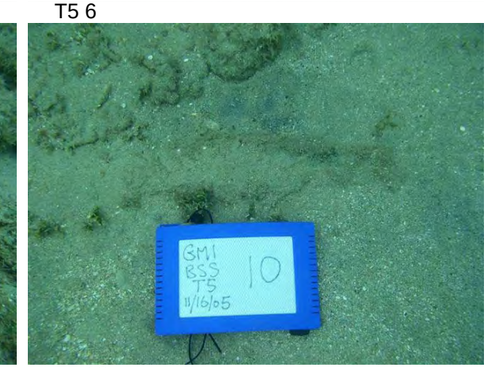

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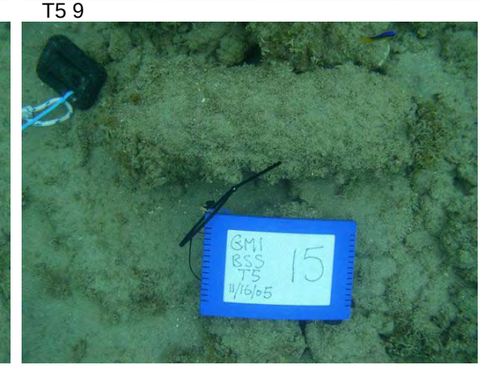

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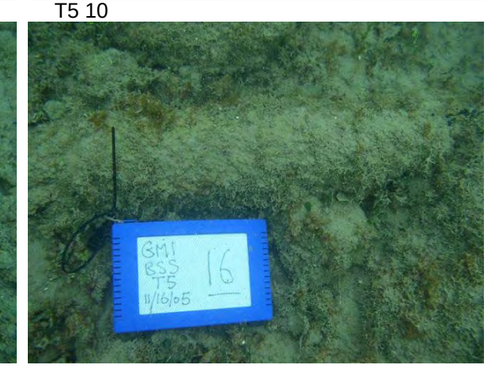

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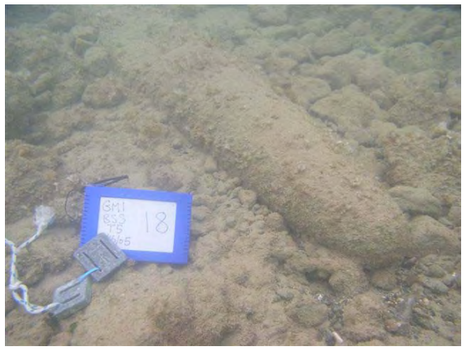

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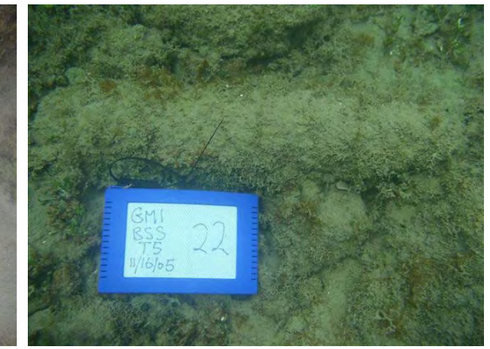

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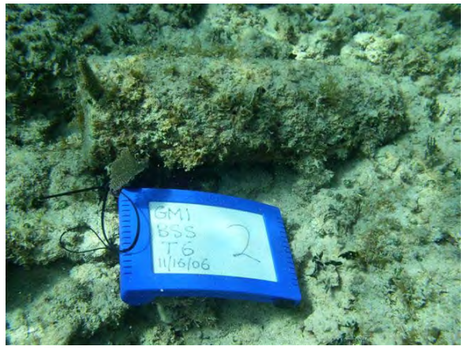

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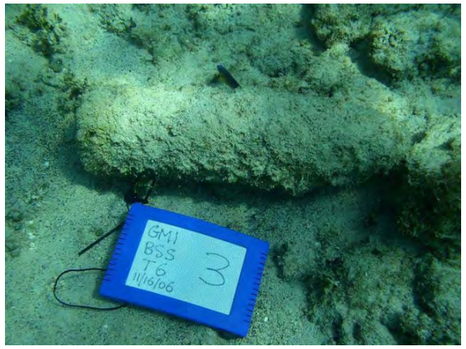

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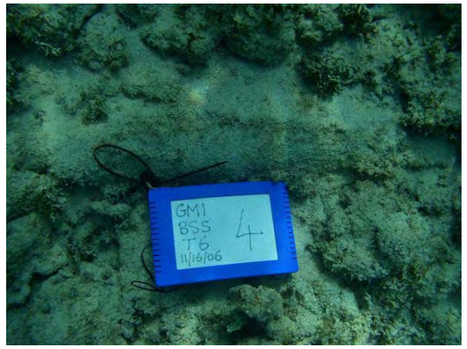

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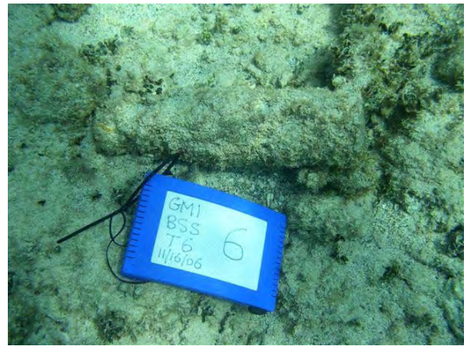

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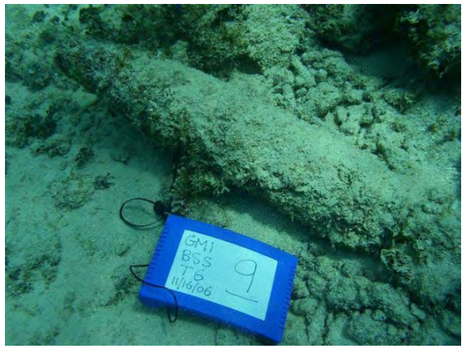

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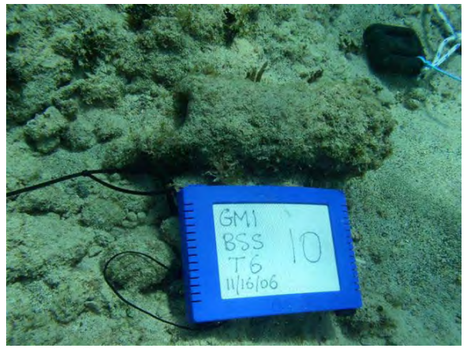

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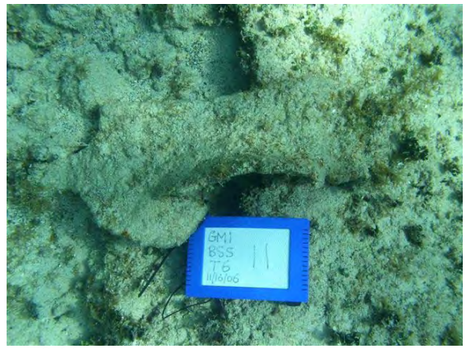

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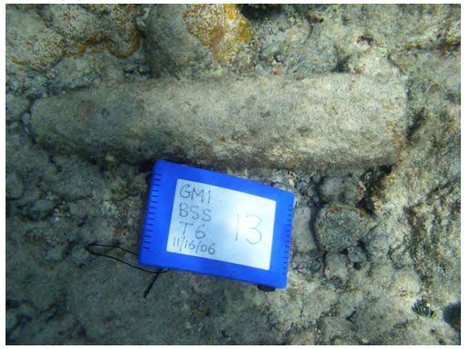

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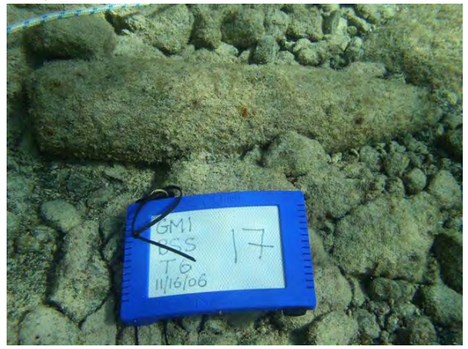

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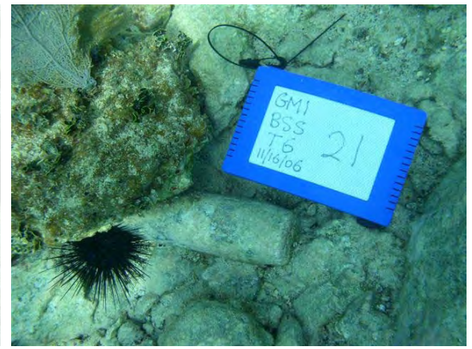

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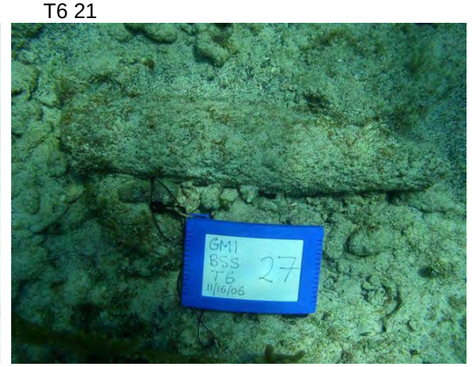

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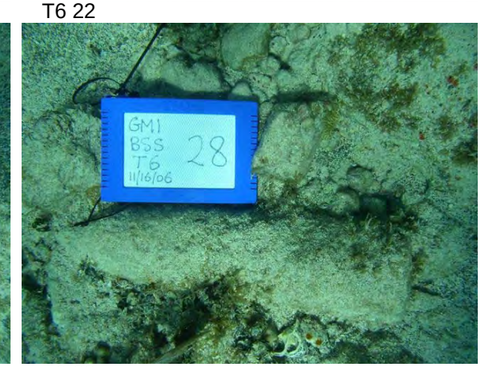

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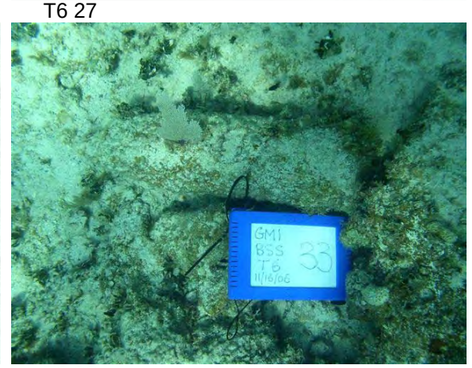

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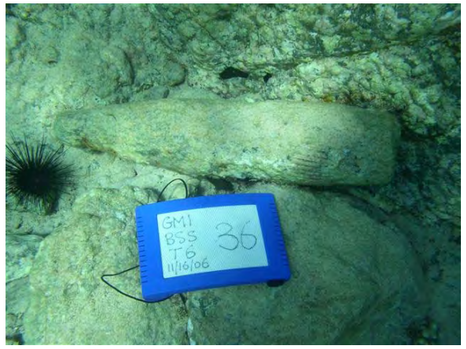

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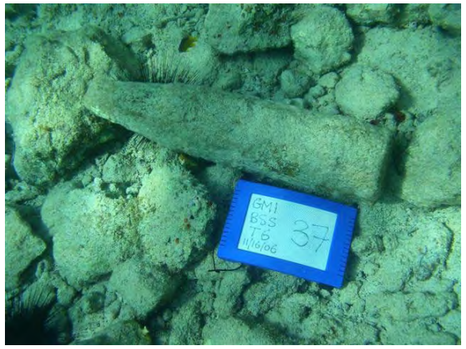

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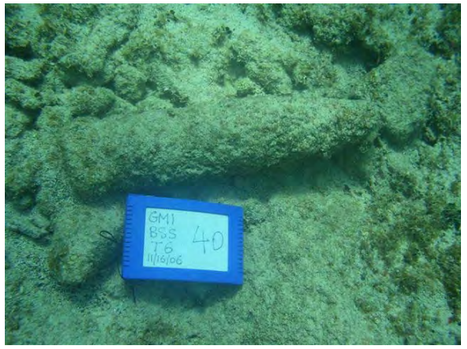

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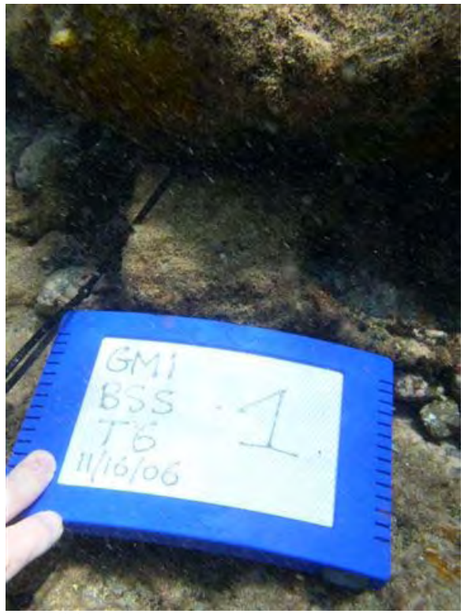

T6 1

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Appendix H
USA Environmental Report—Underwater ROV

AFTER ACTION REPORT

VIDEORAY MINIATURE REMOTELY OPERATED VEHICLE (ROV) DEMONSTRATION

FORMER VIEQUES NAVAL TRAINING RANGE
VIEQUES, PUERTO RICO

31 March 2009

USA Environmental, Inc.
720 Brooker Creek Boulevard
Suite 204
Oldsmar, FL 34677

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1.0 DEMONSTRATION OVERVIEW

USA Environmental, Inc. (USAE) conducted an operational demonstration of a VideoRay Miniature Remotely Operated Vehicle (ROV) within specific waterborne areas surrounding the Former Vieques Naval Training Range (VNTR) in Vieques, Puerto Rico. The demonstration was conducted with the concurrence of the Naval Facilities Engineering Command (NAVFAC) Atlantic.

The purpose of the demonstration was to determine if the ROV system was capable of efficiently performing a wide spectrum of munitions and explosives of concern (MEC)-related tasks, and also served as a practical test of the unit's navigation, positioning, sonar, and image capturing systems.

While the VideoRay ROV system is used extensively for military, emergency response, law enforcement, and industrial applications, this demonstration represented one of the first utilizations of the system to specifically conduct underwater MEC operations. The demonstration focused on development of the most effective procedures regarding search patterns, target relocation techniques, and the generation of post-survey data products and reports.

The demonstration was successful in proving the VideoRay ROV as an effective system for conducting underwater MEC operations, and this After Action Report is provided to both document the activities completed and provide an overall assessment of the VideoRay's capabilities and performance.

An additional collection of photographs and maps relating to the demonstration is contained in Enclosure 1 of this report.

2.0 DEMONSTRATION OBJECTIVES

In order to fully exercise the anticipated capabilities of the ROV unit, the following objectives were identified for completion:

1) Environmental assessment of seabed conditions at proposed mooring buoy points (access channels) within Bahia Icacos
2) Ground truthing to determine ROV positioning system accuracy
3) Reacquisition of selected targets within Bahia Salinas del Sur
4) Seabed surface survey of designated portions of Bahia Icacos
5) Assessment of the unit's ability to access and operate in shallow water/surf zones

These objectives were not listed by intended order of completion, and were pursued as the pace of satisfactory objective achievement, the length of the demonstration period, and local weather conditions allowed.

The locations of each of the demonstration areas are reflected in Enclosure 1.

The demonstration consisted of a 3-day on-water period, and the following is a summary of the overall demonstration schedule:

- 18 January 2009: Mobilization and Equipment Preparation
- 19 January 2009: Reacquisition of selected targets within Bahia Salinas Del Sur
- 20-21 January 2009: Seabed investigation and area search within Bahia Icacos
- 22 January 2009: Demobilization

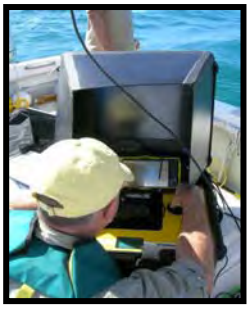
3.0 SYSTEM COMPONENTS AND CAPABILITIES

The unit utilized for the demonstration was a VideoRay Pro-3 Miniature ROV. This ROV unit contains a multiple thrust propulsion system, high-intensity halogen lights, and high-resolution forward/rear cameras.

Size of VideoRay ROV Unit

The following additional system components were provided:

- Smart Tether navigation and positioning system
- Detachable 900-kHz multibeam sonar.



Maneuvering the ROV is accomplished through use of a control console situated with the operator. The console also contains a display screen for viewing real time video images of the underwater environment. The console allows activation of a series of options, including depth control functions, magnetic heading and depth display, and video recording.

The size of the display screen, along with use of an additional laptop computer, allows multiple personnel to view the images and provide assessments regarding the identification of encountered items. The recorded video can be viewed following completion of underwater operations, and still images can be captured and inserted into associated reports and documents.

Optional sonar images can also be displayed on the console screen, and can be viewed concurrently with video images.

The operational depth range for the VideoRay System extends from 1 to 400 feet (ft), depending on the tether type and length. The system can be powered from a standard 110-volt receptacle, a small gasoline generator, or a 12-Volt vehicle/marine battery with 12VDC to 110VAC power inverter.

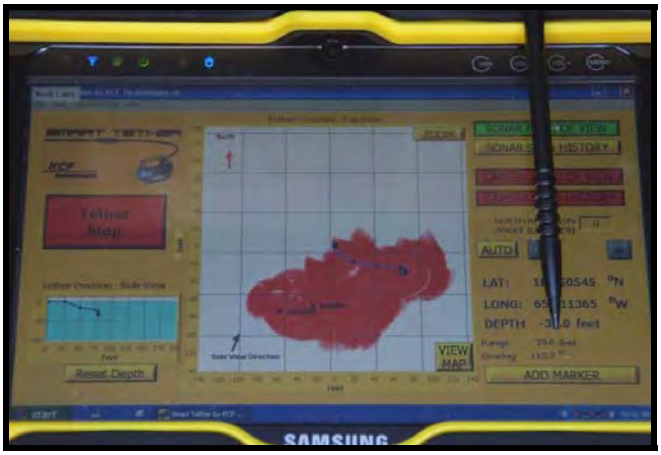
The complete VideoRay ROV system is contained within 2 to 3 Pelican cases, depending on the accessories and tether length. These cases can be checked onboard a commercial aircraft as luggage, resulting in a highly mobile ROV system requiring minimal pre-deployment lead time and logistic planning.

3.1 SMART TETHER

The Smart Tether system includes a series of sensor nodes embedded along the length of the ROV tether. These nodes use acceleration, magnetic, and rate-gyro sensors to measure the orientation and track the position of the ROV unit and tether. A commercially available Global Positioning System (GPS) receiver is utilized to provide the location input, with the data being processed in the system interface

control box. The combined ROV smart tether and GPS data is processed, and the ROV position data is then transmitted and displayed on the user interface screen in real time.

The Smart Tether system can be programmed to operate on a visual and sonar distance scale, depending on the water clarity and bottom composition. This distance is reflected as a colored swath on the Smart Tether user interface. Once surveyed, the area remains highlighted in order to ensure complete coverage.



Smart Tether User Interface
Reflects Real-Time ROV Position in Relation to Support Boat and Coverage Area

In order to facilitate ground truthing of the Smart Tether system, a Real Time Kinematic Differential Global Positioning System (RTK-D GPS) unit was positioned and activated at a known survey control point within the VNTR.

The initial ground truthing test of the Smart Tether indicated an accuracy to within 5 ft of a ground truthed point. Additional testing of the Smart Tether system is planned in the future, including an attempt to utilize the RTK-DGPS as the direct GPS source to provide location data for the system.

3.2 SONAR

The multibeam sonar is a detachable component of the ROV system. When installed and activated, it produces sonar images of items exposed on the seabed surface up to 60 ft from the ROV unit. The sonar is used extensively for a variety of underwater search operations conducted by the U.S. Navy, the commercial oil industry, and the Department of Homeland Security.

The sonar is an ideal tool in low visibility environments, and is used in conjunction with the ROV's video system. When an object is reflected on the sonar screen, the ROV can be initially navigated to the item through the sole use of the sonar image. As the ROV advances on the item, the video screen can be juxtaposed next to the sonar image in order for the operator to utilize both views for final navigation to within visual sight of the item.

The sonar system was not used during the demonstration due to a technical difficulty. While conducting pre-operation checks on the system in a hotel room, an electric service line providing power to the building exploded. The resulting power surge damaged the sonar converter box beyond repair. However, participants in this demonstration have witnessed the sonar's use during previous underwater operations.

This technical difficulty did highlight a unique advantage of the VideoRay system. Since the unit and accessory components are small in size and commercially available, replacement parts can be shipped from the manufacturer and received in 1 to 3 days, depending on the location of the operating site. In addition, many of the generic parts can be purchased if suitable electronic stores are present in the local

area. In this particular case, it was not feasible to order and ship the replacement converter box given the short duration of the demonstration scheduled.

4.0 OPERATIONS IN BAHIA SALINAS DEL SUR

The first demonstration day was focused on prosecution and reacquisition of bottom targets within Bahia Salinas Del Sur. The targets within this area were detected during previous sonar and magnetometer underwater surveys conducted in 2007. However, the specific identity of the chosen targets was not verified due to lack of visual identification capabilities of the varying systems that were utilized.

The following site conditions presented considerable challenges during execution of this effort:

- Wind speed (10 to 15 knots)
- 4- to 6-ft seas
- Swift surface and subsurface current (1 to 3 knots)
- Inability to anchor support boat in known MEC area.

The demonstration team worked to develop procedures to effectively prosecute underwater targets, and refined these procedures throughout the effort. Constant maneuvering of the support boat in order to maintain station for deployment and operation of the ROV proved a significant challenge, though this difficulty was successfully overcome through practice and effective communication between the ROV and boat operator.

The team also developed an effective procedure to utilize the Smart Tether system to quickly prosecute underwater targets. At the conclusion of this effort, the demonstration team was capable of deploying the ROV and prosecuting a single target in a 2 to 4-minute time period.

The ROV was maneuvered to the recorded position of the targets, and was then used to conduct a visual search of the immediate site and surrounding area. The visibility of the water allowed easy detection of surface targets, even those embedded in heavy sea grass beds. In reduced visibility situations, the accompanying sonar system would be used to achieve the initial detection and maneuvering to the target, followed by visual identification once in video range.

Reacquired Wreck Structure

Of the six targets chosen for investigation, three were successfully reacquired and identified.

The remaining three targets were not located at the indicated location. It is believed that the approximate 1.5 year time lapse since the targets were initially detected resulted in the items either being buried in the seabed or moved/rolled to other locations. Local residents indicated that Vieques had been subjected to several significant storms since the previous underwater survey were accomplished, with accompanying 10 to 15-ft waves moving through Bahia Salinas del Sur as a result of these storms.

It would be imperative to conduct prosecution of individual surface targets immediately following any preceding area DGM survey in order to achieve the best probability of completing positive visual identification of the target.

5.0 OPERATIONS IN BAHIA ICACOS

The remaining demonstration days were spent conducting an underwater investigation of several proposed mooring buoy anchoring points and a bottom survey of a large, shallow-water area.

As in the previous day's operations, the demonstration team focused on assessing the ROV system capabilities and developing best practices regarding the most efficient procedures to conduct this type of underwater task.

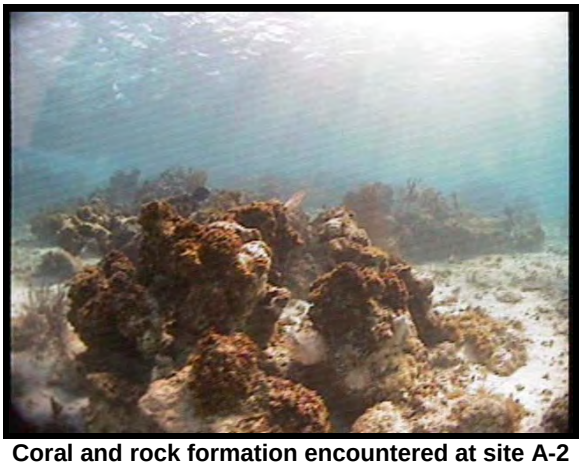
Once again, the following site conditions presented considerable challenges during the execution of this effort:

- Wind speed (10 to 12 knots)
- 1 to 4-ft seas
- Swift surface and subsurface current (1 to 4 knots)
- Inability to anchor support boat in known MEC area.

5.1 PROPOSED ANCHOR POINTS

The demonstration team was provided with coordinates of several sites proposed for installation of mooring buoy anchor systems. Once installed, the buoys are intended to warn boaters of the potential MEC danger within the area. A total of seven sites were successfully investigated within the demonstration time period.

The VideoRay system allowed the NAVFAC Atlantic Marine Biologist accompanying the demonstration team to view the underwater environment in real time, and assess whether the proposed site was suitable given the presence or absence of any sensitive underwater species.



Coral and rock formation encountered at site A-2

During the investigation of the anchoring points, significant currents of up to 4 knots were noted within the access channels to Bahia Icacos. While the VideoRay ROV was capable of operating in these currents and capturing usable data, the conditions would have negated the ability to utilize divers to perform the operation. The effort would have been canceled or postponed until suitable conditions were present.

5.2 SHALLOW-WATER AREA SURVEY

The demonstration team also conducted an underwater survey of a shallow-water surf zone area along the east beach of Bahia Icacos.

In order to prove the field mobility of the system, surveys were conducted from both land and water. The demonstration team positioned the support boat in shallow water close to shore, and hand carried all required equipment through waist deep water to the beach. This transition required only 25 minutes to relocate and configure the complete system for operation. Following surveying efforts from the beach, all equipment was transferred back to the support boat for continued operations.

Given the water clarity and resolution of the ROV cameras, the demonstration team could easily identify a wide range of items, consisting of small starfish and debris materials. Water depth of the survey area ranged from 1 to 7 ft, and the small size of the ROV allowed for accurate surveying in close proximity of the beach.

Images of starfish located and recorded in shallow water survey area

6.0 SAFETY AND COST ADVANTAGES

Compared to divers and larger ROV systems, the VideoRay maintains some significant advantages for a variety of underwater MEC operations.

The system can effectively survey level seabed surfaces, or maneuver through areas containing considerable obstructions or obstacles (coral heads, jetties, piers, and wreck structures). In addition to area surveys, the system is ideal for prosecution of individual targets to achieve positive identification.

The small size of the ROV also enables the unit to investigate the interior contents of underwater ship hulks and wrecks that may contain conventional or chemical-related ordnance, as well as very shallow water and surf zone regions that larger systems cannot access.

In addition, safety considerations and logistical planning for use of larger ROV systems or divers are considerably more complex than those associated with the VideoRay.

Utilizing MEC-qualified divers demands the development and implementation of extensive Work and Safety Plans, as well as requirements for locally available recompression chambers, larger support craft, and more expansive equipment load outs. Diving operations in remote locations may also be hampered by the availability of equipment sources and medical facilities for treatment of diving related injuries.

The depth profile and sea state/current conditions can also limit the ability of divers to safely and effectively operate. For example, a non-decompression dive for a single SCUBA diver to a depth of 60 ft is limited to 1 hour of bottom time. Diving regulations also prohibit SCUBA operations at depths deeper

than 100 ft and against currents exceeding 1 knot. In contrast, the VideoRay is not restricted to any bottom time limitation, while effectively operating at depths up to 400 ft and in currents of 3 to 4 knots.

In order to identify the associated cost effectiveness of the VideoRay ROV, the system was compared to deployment of a five-person MEC dive team to conduct similar underwater operations in Vieques. The following chart illustrates estimated cost differences:

System	Daily Rate
2-Person VideoRay Team	$2,697.00
5-Person SCUBA Dive Team	$4,684.00
Daily Cost Difference	**$1,987.00**
Cost Savings for 5-day Period	**$9,935.00**

Additional savings in using the VideoRay system would also be realized in cost reductions associated with mobilization and demobilization of a smaller personnel/equipment footprint, reduced effort in development of Work and Safety plans, smaller support boat, and minimized logistics coordination.

7.0 SYSTEM ASSESSMENT

Capable of being deployed while operating from a small boat or land based location, the VideoRay ROV proved to be a highly mobile, low cost, and effective platform to accurately capture location data and video documentation of underwater environments and bottom surface targets.

USAE intends to pursue continued use of the VideoRay system and development of enhanced capabilities, including an underwater magnetometer/metal detector as an additional accessory component.

8.0 POINT OF CONTACT

The following USAE representative can be contacted for any questions regarding this report, or the application of the VideoRay ROV system for underwater MEC operations:

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E-mail: bskubin@usatamapa.com

ROV DEMONSTRATION PHOTOGRAPHS AND MAPS

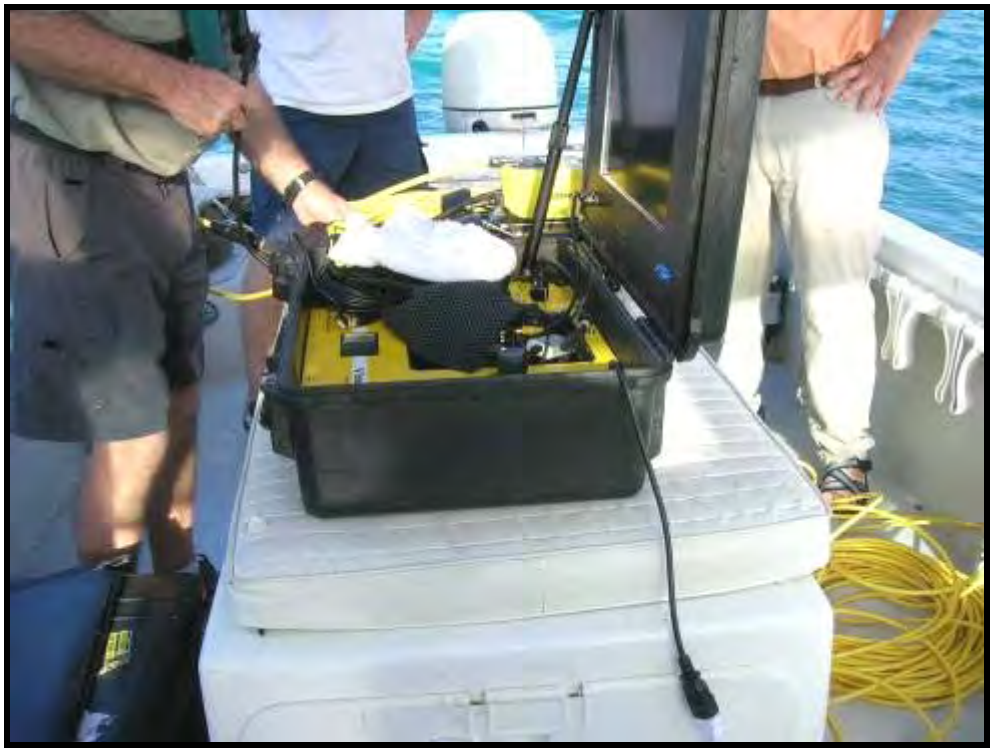
DEMONSTRATION AREAS

ROV Demonstration areas within the VNTR- Vieques, Puerto Rico

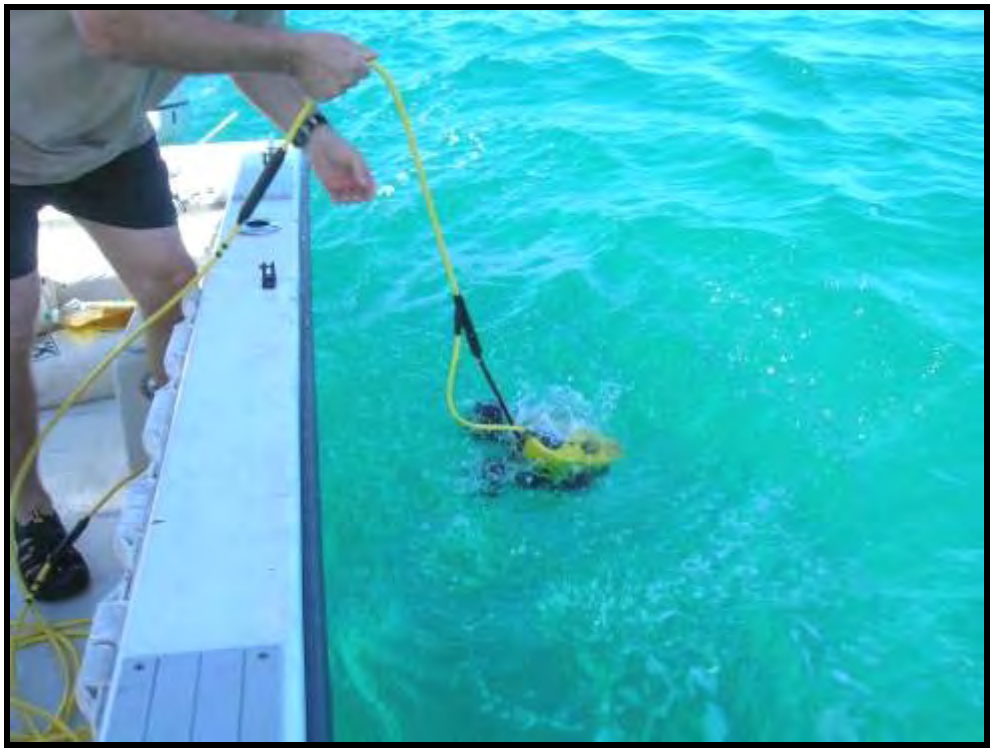
VIDEORAY ROV SYSTEM

Highly mobile ROV system components used during the demonstration
- (2) Pelican Cases
- 120-foot tether length
- ROV Unit
- Gasoline powered generator

ROV unit situated on support boat prior to deployment

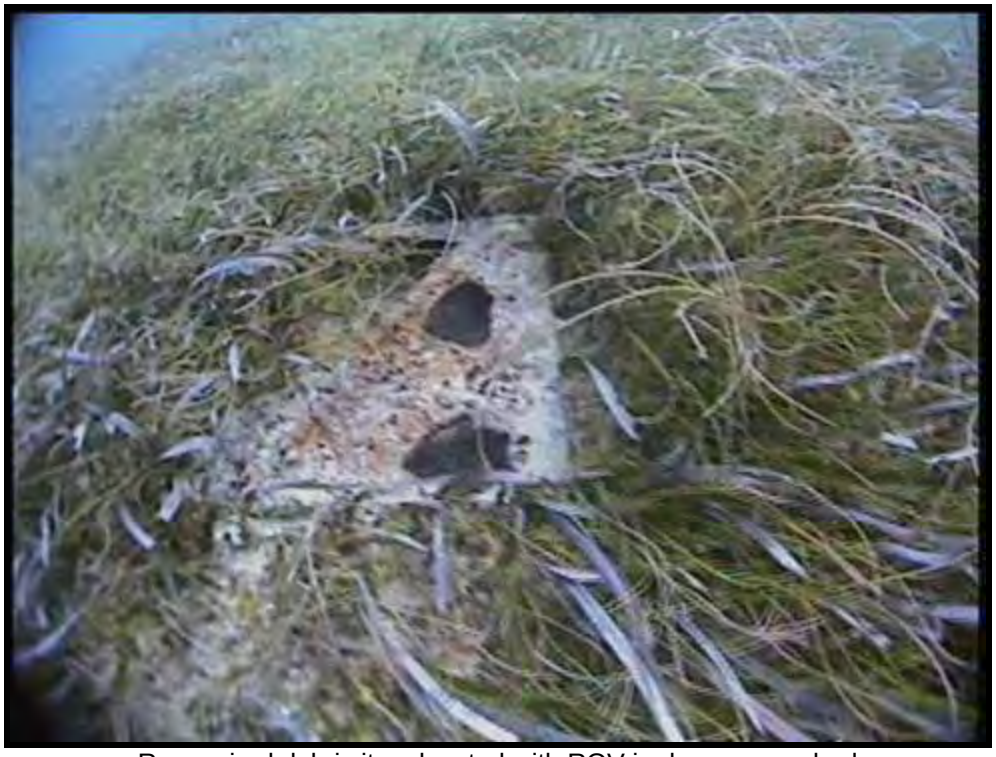


Control console footprint on support boat



Single person deployment of ROV from support boat

BAHIA SALINAS DEL SUR TARGET PROSECUTION



Reacquired debris item located with ROV in dense grass bed

Close proximity image of debris item showing quality of ROV cameras

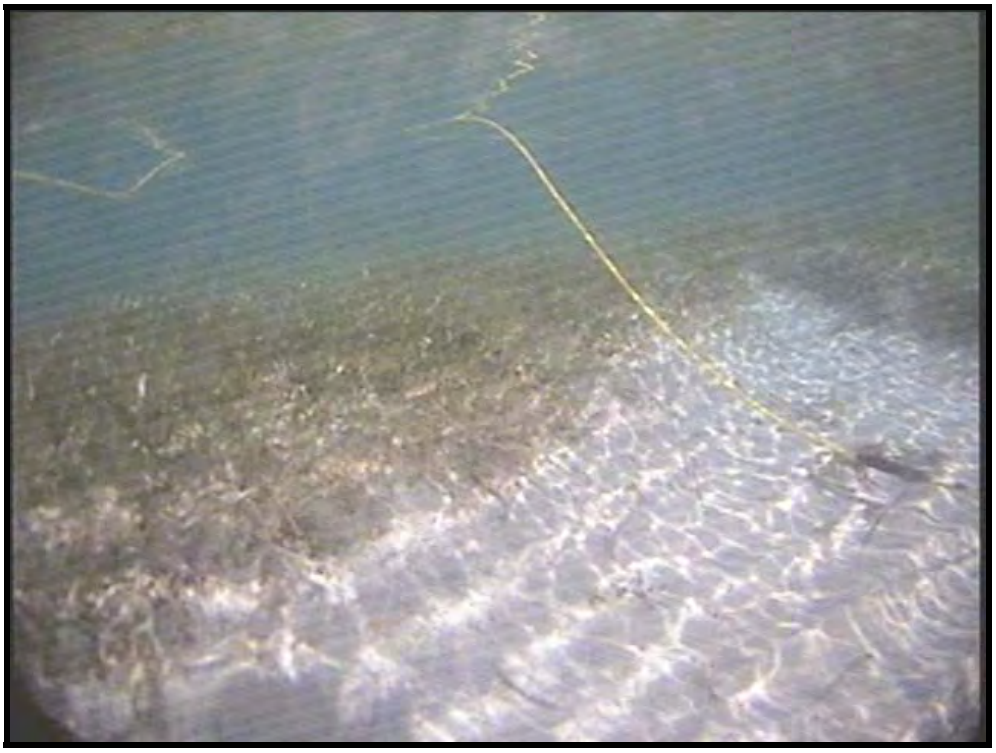
Storage drums located inside of wreck structure

Flare casing located under wreck debris

Partially buried storage drum located in grass bed

SHALLOW WATER BEACH SURVEY

ROV system control point established on beach for shallow water survey



View of tether length suspended in water column

ROV survey in close proximity to beach control point (Water depth estimated at 1.5 ft)
- Note shadows of personnel standing on beach

INVESTIGATION OF PROPOSED ANCHOR POINTS

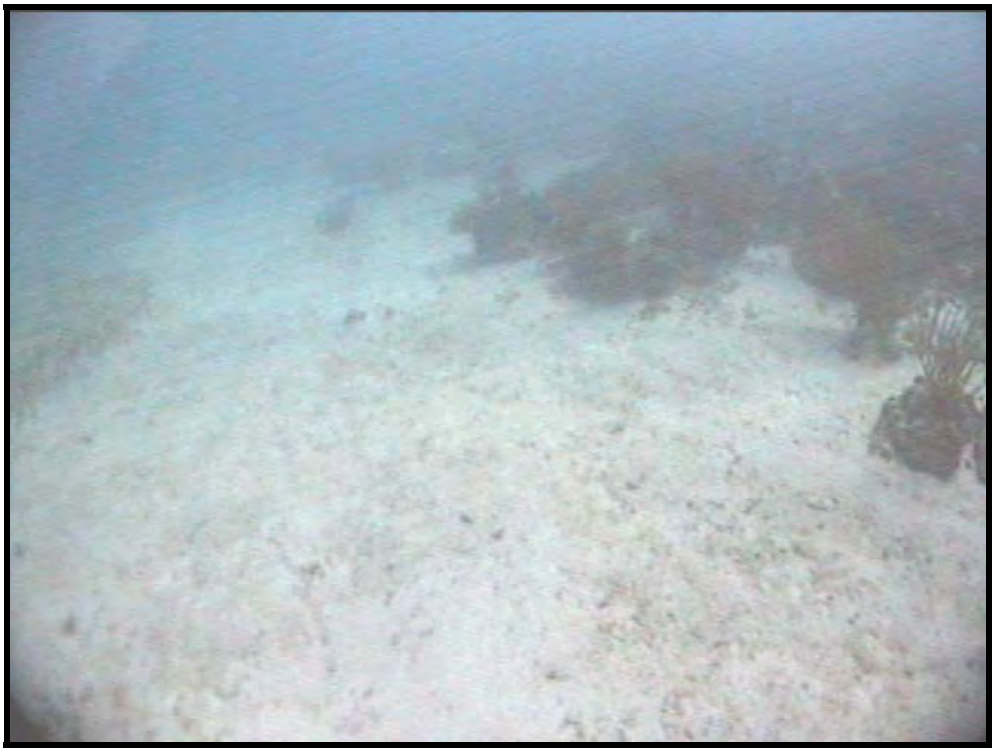
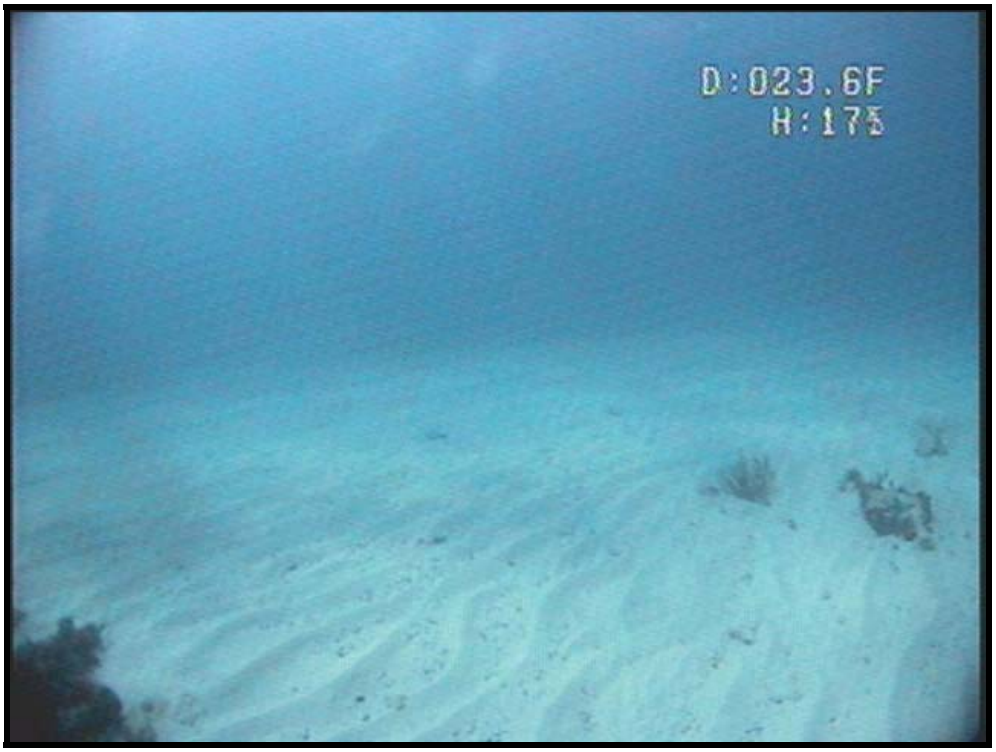


Image of sea floor at site A-1

Sand channel located at site D-1



Large open sea floor area at site Sand 2
- Note depth and heading indication on screen view

SMART TETHER GOOGLE EARTH IMAGES

ROV underwater navigation track recorded during target prosecution

ROV underwater navigation track recorded during shallow water survey

FINAL EXPANDED RANGE ASSESSMENT/ SITE INSPECTION REPORT
SEPTEMBER 2010

Appendix H

Underwater Videos

Appendix H contains underwater videos illustrating the sea floor conditions at the following locations within the vicinity of the former Live Impact Area:

- **Bahia Icacos**
- **Bahia Salinas del Sur**

Explanation: The webpage program does not support this video format.

To view the underwater videos, please contact:

Public Affairs Office
NAVFAC Atlantic
6506 Hampton Blvd.
Norfolk, VA 23508-1278

757-322-8005

email: NFECL PMO@navy.mil