APPENDIX A
SUPPLEMENTAL STUDIES

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South Beach 26 Aug 2008
41 21’ 00’’N 070 31’ 36.9’’W

South Beach 26 Aug 2008

- Item one
  - 41.5” x 3.125”

- Item Two
  - 38.5” x 3.125”

South Beach 26 Aug 2008

- Item Three
  - 25.5” x 2.75”

- Item Four
  - 24.5” x 2.75”

South Beach 26 Aug 2008

- Item Five
  - 22.5" x 2.75"

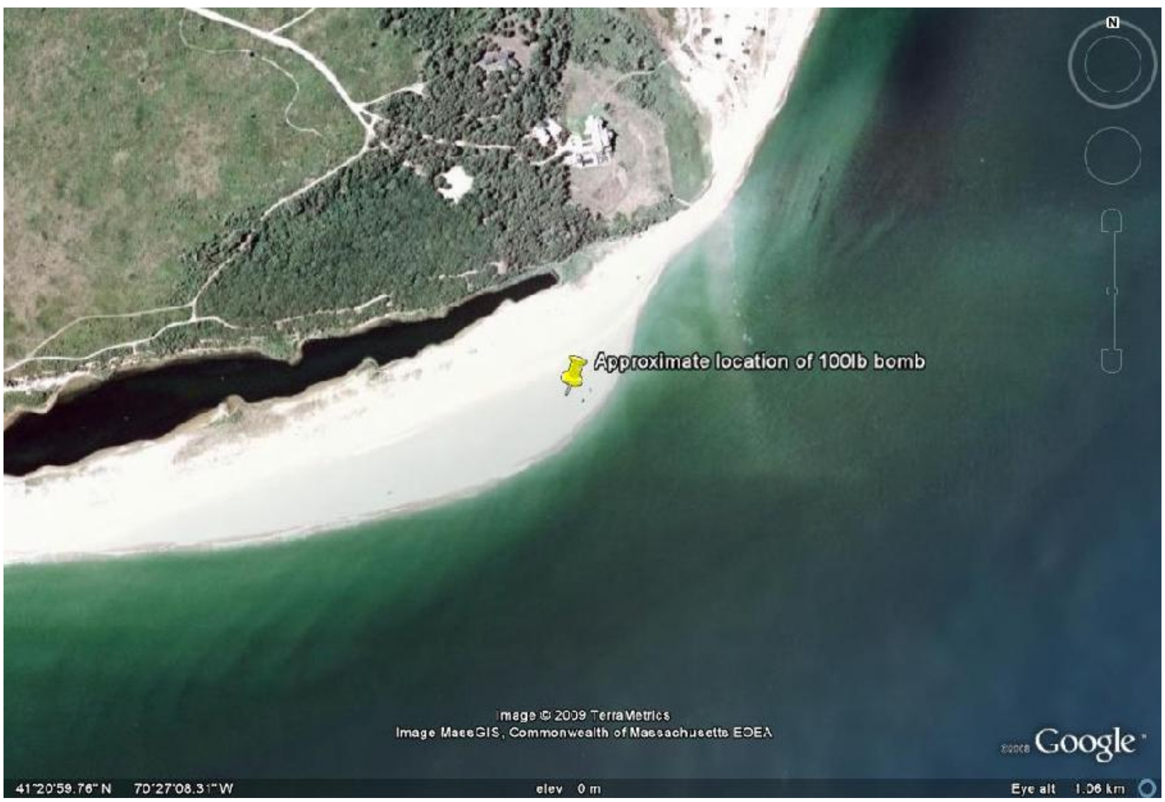
- Item Six
  - 24.75" x 2.75"

South Beach 26 Aug 2008

- Item Seven
  - 26” x 2.75”

- Item Eight
  - 6” x 2.75”

VRHabilis
Veteran-run work



One Person Response to Potential Ordnance Item

13 February 2009

Wasque Point, Chappaquiddick Island

15 February 2009
P.O. Box 150
West Tisbury, Ma 02575

TRC
650 Suffolk Street
Lowell, Massachusetts, 01854

Mr. Biolsi:

The attached report was completed following a requested one person response to a suspected ordnance item found on Chappaquiddick Island. This response was conducted in accordance/ compliance with Task Two of the SARSS_VRHabilis contract agreement.

The enclosed report is certified accurate. If you have any questions please feel free to call (508) 410-1306 or email me at rancich@vrhabilis.com.

We thank you for your business.

Sincerely,

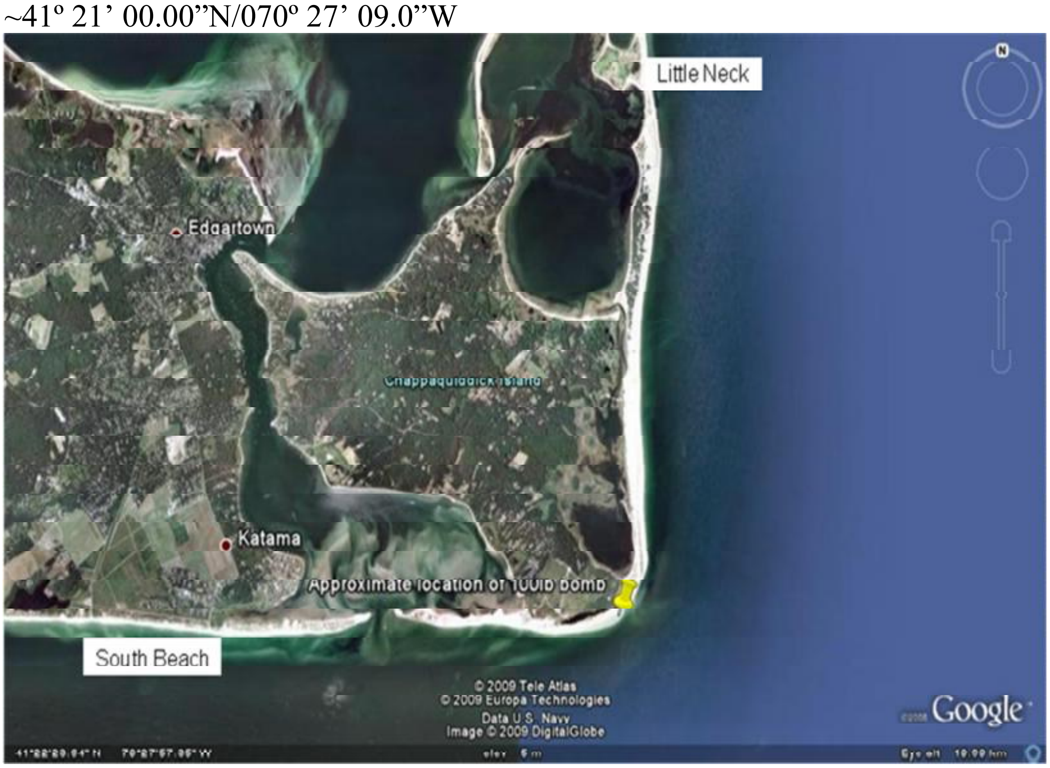
Tom Rancich
CEO
VRHabilis LLC
Veteran Run Work!!

Summary:

VRHabilis (VHR) received calls from the Trustees of the Reservation (TToR) and Edgartown Police (EP) that an item suspected of being ordnance was found on Wasque point by a TToR; each organization requesting that VRH respond to the scene. VRH responded to the scene within 90 minutes of the original calls. The suspected item was immediately identified as ordnance. VRH made sure that there were no conditions that would pose an imminent threat of explosion, secured the immediate area, insured that the beach had appropriate security and conducted an initial reconnaissance of the item and confirmed that it was an old style 100lb bomb. The Massachusetts State Police Bomb Squad had been notified of the incident and had notified Navy EOD in Newport, RI and had begun to respond to the scene. EP passed VRH’s assessment of the item to the responders. At approximately 5:15 State police bomb squad and two members of the Newport Navy EOD detachment arrived and took control of the scene. After briefing them and leading them to the 100 bomb, VRH concluded the one person response. Navy EOD made the determination to explosively detonate the device. After building protective berms, the bomb was detonated with 3 blocks of C4. The resulting explosion indicated the bomb had likely been filled with an incendiary compound. Nothing remained f the bomb with the exception of some minor fragmentation.

Incident Location:

Wasque Point, Chappaquiddick Island, Martha’s Vineyard, Massachusetts
~41º 21’ 00.00”N/070º 27’ 09.0”W



Weather:

Temperature: 34ºF and falling
Ceiling: Unlimited
Wind: 15-20Knts SW
Precipitation: None
Tide: Low

Responding Organizations:

Edgartown Police
Edgartown Fire and Rescue
Massachusetts State Police Bomb Squad
Navy Explosive Ordnance Disposal Detachment Newport
Trustees of the Reservation
VRHabilis, LLC

Timeline (some times approximate):

1314: Receive messages from TToR and EP of a possible ordnance item on beach
1316: Return calls to TToR and EP. Confirm VRH is responding
1350: Confirm gear load-out complete
1355: Notify TRC and MassDEP one person response underway
1425: Meet TToR personnel at site
1430: Confirm item is ordnance
1435: Site marked and secured
1437: Conduct reconnaissance on item, determine it to be an old style 100lb bomb
1445: Pass information to EP, confirm that bomb squad/EOD is responding
1615: Meet fire and emergency personnel near site
1713: Navy EOD and State Police Arrive on Site
1735: Navy EOD and State Police Bomb Squad brought to 100lb bomb
1807: VRH secures

Final Determination of Item:

100lb Old Style Bomb
Based on the scattering of flames during/following detonation it was likely filled with an incendiary compound, though it is possible it was degraded high explosive.

Final Disposition of Item:

Detonated in place utilizing three 1.25lb blocks of C-4

Damage:

None

Injuries:

None

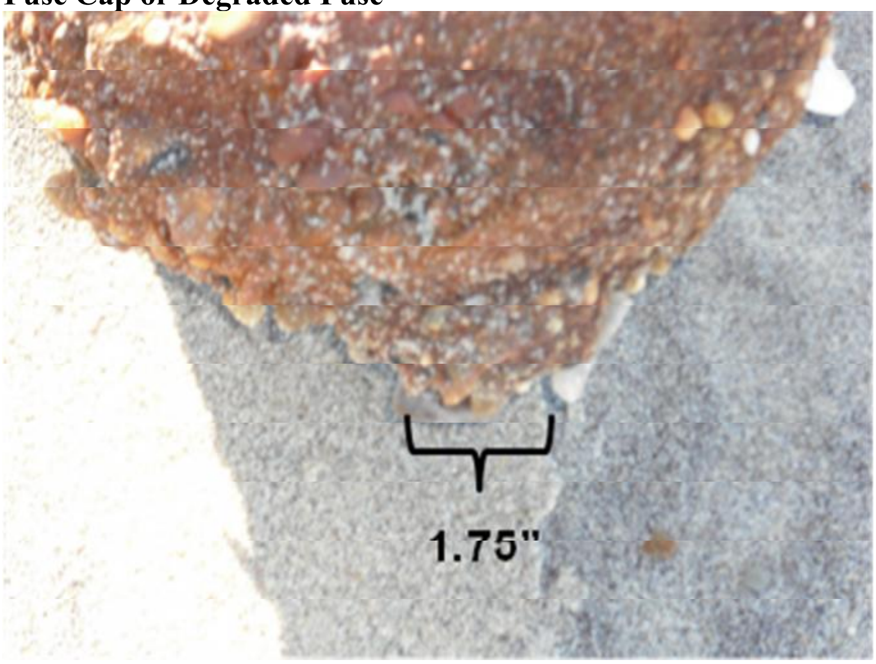
Reconnaissance:

Side View Distant

Side View Close

Top View

Fuse Cap or Degraded Fuse



Subject: 1 Aug 2011 Emergency Response

Location: Norton Point, Edgartown Massachusetts

Time: 1635

Narrative: VRHabilis received a call at 1635 from the Edgartown Police Department and the Trustees of the Reservation that potential ordnance items had been found on Norton Point. VRH responded to the scene 1750 and was directed to the suspect item which was now in the wave wash on a rising tide. The item was determined to be an expended 2.25” rocket motor (photo 1).

Photo 1-Expended 2.25” Rocket Motor

The item’s location was 41° 20.915’N, 070° 29.575W (see image 1, page 2). The rocket was determined to be free of hazardous/energetic material and was removed to the secure container at 1820. VRH personnel RTB and secured at 1847.


Katama Bay
1 Aug 2011, 2.25" Rocket Motor
41 20.915n070 29.575w
Image 1
Google
Imagery Date: 5/21/2010
1991
41°20'52.13" N 70°29'31.19" W elev 0 m
Eye alt 2.40 km

Daily Report

UXB International, Inc.

Date: 2-17-12 Contract Number: **107807**

Delivery Order Number: ____________________ Location: Martha's Vineyard

Weather Conditions 46F Wind WSW 5-10 Cloudy, rain

I. Work Summary: Checked beach conditions. Disposed of 5" rocket warhead (see attached). It was plaster filled. Checked Wasque, took photos and GPS coordinates.

a. Work Planned: Work as above

b. Work Accomplished: As above.

c. Explanation of Discrepancy: N\A

d. Inspection Results: Work met requirements,

II. Instructions Received from Customer Representative (s)

III. Safety Comments: All operations were conducted safely.

IV. UXO Summary

a. UXO Destroyed:

Type	Quantity	U/I	Disposition
5" rocket	1		ETPD

b. Demolition Supplies Used:			
Type	Quantity	U/I	Disposition
Perforator	2		expended
Detonation Cord	20’		expended
Caps, Blasting	2		expended
c.			
V. Personnel/Equipment Utilization:			
a. Personnel On-site			

Description	Number	Man-Hours
Oceanographic Engineer		0
First Aid Specialist		
Heavy Equipment Operator (Local)		0
Helper		
Magnetometer Operator		
Project Manager	1	0
Quality Control Specialist	1	0
Senior UXO Supervisor	1	8
Site Safety Officer	1	8
Geo	1	0
UXO Assistant		

UXO Specialist	1	0
UXO Supervisor		
Unskilled Labor		
Other Personnel (Woods Hole)	2	0
Trimble Operators	1	0
Diving Supervisor	0	0
Sub Contractor Personnel (List by Category)		
Rancich	Supervisor VRH	0
Alogna	PM/Dive Supervisor VRH	0
Shaw	Diver VRH	0
Bigos	Dive Supervisor /Diver VRH	3
Doctor	Diver VRH	0
VanDruff	Diver VRH	0
Kettle	Diver VRH	0
Hale	Diver VRH	0
Nettelson	Diver VRH	0
Armstrong	PM	3
		0
		0
		0
		0
		0
		0
b. Equipment Utilization		
Description	Number	Hours

Boat	1	0
Backhoe, Tracked	0	0
SUV (POV)	0	0
Pickup (1/2 ton)	1	8
Pickup (3/4 ton)	1	0
Radio, Handheld	3	3
Trash Pump	0	0
EM-61	0	0
Trimble	1	0
Minelab F3	0	0
Schonstedt	1	3
Fischer	1	0
Other Equipment (List)		
Diving Helmets and suits	3	0
Air Supply Tanks/compressor	1	0
Trailer	1	0
Generator	1	0
Explosive Magazine	1	8
Camera	1	3
Water Jet	1	0
VI. Comments/Concerns:		
VII. Signature(s)/Date 2-17-12 Project Manager	Senior UXO Supervisor	


N41°21'11.52"
5 In
W 70°31'39.36"
W 70°31'13.44"
W 70°30'47.52"
W 70°30'21.6"
N41°20'45.6"
Google earth
010
1991
41°20'57.88" N 70°31'03.54" W elev 2 m
Eye alt 2.47 km

BLASTER'S REPORT DATA SHEET

DATE
February 17, 2012
TIME
11:50
NUMBER
RR 3
LOCATION
SO. BEACH @ entrance to Norton pt.

DEMOLITION ITEMS/MATERIAL

5" MK 6 Practice warhead

WEATHER
CLEAR CLOUDY FOG RAIN SNOW
WIND SPEED & DIRECTION
NW 1 mph
DISTANCE & DIRECTION TO NEAREST STRUCTURE
NW 732'
EXPLOSIVES USED - 2 Jet perforators 19.5 gr each 2 elec blasting caps 0ms delay 12' 80 grain det cord

SHOT TYPE - UXO

INITIATION
ELECTRIC FUSE & CAP OTHER NON-ELECTRIC
NUMBER OF SERIES
2
CAPS/SERIES
2
OHMS/SERIES
5
TOTAL OHMS
5
BLASTING MACHINE ROE 450J

FACE HEIGHT

HOLE DIAMETER

NUMBER OF HOLES

SPACING

BURDEN

STEMMING

MAXIMUM lbs./DELAY PERIOD

HOLES/DELAYS

POWDER FACTOR

PRIMER USED

TOTAL EXPLOSIVES USED < 1 lb.

SEISMIC DATA

MATS USED sand bags
YES NO

SEISMOGRAPH LOCATION

BLASTER'S NAME

ID NUMBER BL 7200

SIGNATURE

DATE
February 17, 2012

HELPERS NAMES
P. Fogleson, C. Armstrong VRH, J. Bigos VRH

COMMENTS

Final Report
on
Airborne Geophysical Survey
at

Martha's Vineyard, MA

February, 2011

Prepared for

UXB International Inc.

Prepared by

Battelle Oak Ridge Operations

Executive Summary

Between February 6th and 18th 2011, a low-altitude airborne vertical magnetic gradient geophysical survey was conducted over 1301 acres distributed into three separate areas on Martha's Vineyard Island, Massachusetts. The objective of the survey was to collect high-resolution airborne magnetometer data to detect groupings and clusters of MEC and MD items. The project involved the application of Battelle's VG-22 airborne vertical gradient system,

This system consists of 11 vertical magnetic gradiometers, each consisting of a pair of cesium magnetometers, vertically offset by 0.5 meters. Lateral separation is 1m between seven gradiometers that compose the forward array and 1.7m between gradiometers in the side arrays.

A geophysical prove-out (GPO) line of ten representative target items was established at Martha's Vineyard airport and used to verify positioning and system operation. The target items were laid on the surface and the line was flown at 1-2m altitude during each day of project operations. Data were also acquired at a suite of altitudes ranging from 1-5 meters for sensitivity assessment.

The survey was comprised of 590 acres of Tisbury Great Pond, 364 acres of South Beach, and 347 acres of Cape Poge. Mean sensor altitude for the three sites ranged from 2.0 to 2.5m. The magnetic data were processed and picked for target locations using a dipole inversion method. The RMS noise value for the survey was 0.1nT. The picking threshold was then set at 0.5nT, 5 times the RMS value. A complete listing of the analytic signal anomalies equal to or above the threshold of 0.5nT is presented for each area. Cape Poge contains 2,447 anomalies above the threshold, Tisbury Great Pond contains 3,608 anomalies, and South Beach contains 4,349 anomalies.

Several QC parameters, including survey speed, GPS quality, data noise, data drops, and flight altitudes were monitored throughout the survey and are summarized in Appendix A. Final data deliverables include geophysical maps and databases. Final deliverables will also include anomaly pick lists for each of the three areas.

Area	Total Area Surveyed	Total Potential MEC	Group 1 Priority	Group 2 Priority	Group 3 Priority
Tisbury Great Pond	590 acres	3608	1386	722	1500
Cape Poge	347 acres	2447	782	550	1115
South Beach	364 acres	4349	2254	776	1319

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List of Acronyms

AGL	Above Ground Level
ASCII	American Standard Code for Information Interchange
DGM	Digital Geophysical Mapping
EM	Electromagnetic
GIS	Geographic Information System
GPO	Geophysical prove-out
GPS, DGPS	(Differential) Global Positioning System
HAE	Height above ellipsoid
HDOP	Horizontal Dilution of Precision
IMU	Inertial Measurement Unit
MD	Munitions Debris
MEC	Munitions and Explosives of Concern
MRP	Munitions Response Program
NAD83	North American Datum 1983
OE	Ordnance and ExplosivesQA/QC Quality Assurance/Quality Control
SI	Site Investigation
TEM	Transient Electromagnetic
TIF, GeoTIF	(Geographically referenced) Tagged Information FileUTM Universal Transverse Mercator
UXO	Unexploded Ordnance
VG-22	Battelle'sVertical magnetic Gradient airborne system with 22 total sensors
WGS84	World Geographic System 1984

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1. Introduction

1.1 Background

This report describes the methodology and results of a low-altitude vertical magnetic gradient helicopter geophysical survey carried out by Battelle for the purpose of detecting and mapping surface and buried munitions and explosives of concern (MEC) and munitions debris (MD) located over 1301 acres on Martha's Vineyard Island, MA. The survey used the state-of-the-art Battelle airborne high-resolution vertical magnetic gradient system (VG-22). This airborne system has previously been deployed at several sites in the U.S., including Twentynine Palms in California, Former Kirtland Precision Bombing Range in New Mexico, El Centro Naval air Facility in California, and Fort Wingate Army Depot in New Mexico. The Martha's Vineyard data will be used to guide ordnance remediation decisions for the site.

The objective of the airborne geophysical survey was to acquire vertical magnetic gradient data to provide an indication of the level of UXO contamination and to localize potential sources with sufficient positional accuracy (a few 10s of cm) to permit ground-based reacquisition of targets. It is important for potential users of these data to recognize that the airborne data should not be used to declare an area free of ordnance contamination. A lack of anomalies may indicate ordnance that is too small or deep to be detected or data that are insensitive to larger ordnance due to high survey altitudes.

1.2 Project Site Description

The survey site was composed of three areas: 1) Tisbury Great Pond, a 590-acre area where 100-lb M-38 ordnance occur at depths of 0-12 ft; 2) Poge Sound, a 347-acre area where 3-lb are found at up to 20 ft depth, and 3) a 364-acre portion of the South Beach and surf zone with mixed ordnance types. The locations of survey areas are shown in Figure 1.

Figure 1-1: Map of Martha's Vineyard

1.3 Site Geology

Martha's Vineyard Island's geologic origin dates back to the last ice age. This island is composed of deposited materials that were carried by the glaciers. Martha's shares its history with Cape Cod, Nantucket, Long Island, and Staten Island. They are all part of a large terminal moraine, unconsolidated material, which formed around 10,000 years ago at the end of the last ice age. As the glaciers melted at the end of the ice age the sea levels rose and only the areas of thickest sediments were left. The sea continues to erode and rework these islands giving them their distinct shapes.

1.4 Weather, Topography and Vegetation

The climate of Martha's Vineyard features generally milder winters and cooler weather in the summer compared to mainland cities such as New Bedford, Duxbury, and Boston. Average temperatures in the summer are in the 70s with the hottest month being July. Average temperatures in the winter are in the 40s, January being the coolest month of the year. The airborne survey took place during February when the temperature was relatively cold. The temperature fluctuated from the 20s and low 30s at night to the high 40s and 50s during the day.

The terrain of Martha's Vineyard is relatively flat. Each of the three survey areas, particularly Tisbury Great Pond and Cape Poge, had portions which were over water. As a safety measure, a rescue boat was mobilized and ready at these sites whenever data were being acquired. However, no incidents occurred which required activation of the boat.

1.5 Airborne Vertical Magnetic Gradient System

The airborne magnetic data at Martha's Vineyard were acquired with the VG-22 system, developed and operated by Battelle. This system, shown in Figure 1.2, consists of 11 vertical magnetic gradiometers, each consisting of a pair of cesium magnetometers, vertically offset by 0.5 meters. This arrangement provides a substantial increase in detection capability compared to total field airborne systems because the gradient arrangement serves to reject much of the magnetic noise caused by large or deep geologic features and the moving magnetized components of the helicopter. In addition, the sensors mounted in the forward boom of the VG-22 are more closely spaced (laterally) than in the Battelle VG-16 system, (1.0 m vs. 1.7 m horizontal separation), thus providing greater sensitivity to smaller ordnance and greater positional accuracy for detected items.

Figure 1-2: Battelle VG-22 vertical magnetic gradiometer system.

Fourteen magnetometers are located in the seven gradiometer pods with 1.0 meter lateral spacing on the forward boom (Figure 1-2) and four magnetometers are located in each of the lateral booms (two gradient pods on either side) at 1.7m lateral spacing. The VG-22 system is mounted on a Bell 206 Long Ranger helicopter and flown as low to the earth's surface as safety permits, typically 1-2 meters above ground level, in pre-programmed traverses over the survey areas. Survey speeds averaged 13m/s. Data are processed at 120 Hz sample rate.

Flight lines were spaced 10m apart in all three areas. The flight line spacing is greater than the width of the front array, and smaller than the width of the full (forward plus lateral) array, leading to a cost-effective hybrid approach. This approach was designed to provide high density data over about 70% of each swath (1.0m line spacing) to improve sensitivity to small ordnance items. The remaining 30% of each swath was covered by the lateral magnetometers at slightly greater altitude and less regular spacing. In this outer portion of each swath, outboard magnetometers from adjacent swaths overlap to provide line density of less than 1.7m, but varying along the flight path; depending on how precisely the pilot was able to fly the pre-programmed course. Airborne magnetic data are acquired during daylight hours only.

The data positioning and system orientation (pitch, roll, and yaw) is based on an integrated Global Positioning System (GPS) / Inertial Measurement Unit (IMU), The GPS antenna is mounted in the center of the forward array, and the IMU is mounted inside the aircraft near the center of gravity. A laser altimeter is mounted beneath the helicopter to monitor sensor height above the ground. Data are recorded digitally on a console inside the helicopter in a binary format. The magnetometers are sampled at a 1200 Hz sample rate and desampled to 120Hz before processing.

Figure 1-3: Rack-mount components inside the helicopter for the VG-22 system. These include the recording console, an extendable flat screen monitor, extendable keyboard and mouse shelf for navigation system, and the navigation system with CRT display and the GPS positioning console.

2. Survey Parameters and Procedures

2.1 Survey Parameters and Procedures

The airborne survey was completed during the 13 day period (on-site) between February 6, 2011 and February 18, 2011 with flight activity from February 8-17. A comprehensive Operational Emergency Response Plan was developed and issued previously to address issues related to flight operations, safety, and emergency response. This plan was incorporated into an overall Mission Plan that was developed and used to manage field survey operations.

The geophysical survey crew included William Doll (Project Manager), Jeffrey Gamey (Project Geophysicist) and Jeannie Norton (Project Geophysicist) from Battelle. The flight crew consisted of Doug Christie (pilot), Marcus Watson (system operator), and Darcy McPhee (engineer) from National Helicopters.

Operations were based out of Martha's Vineyard Airport. Equipment was installed there and the aircraft was parked there overnight. A local GPS base station was established at a known monument, MVY B, at the airport (NAD83 70° 36' 19.45872" West, 41° 23' 49.23710" North, NAVD 88 17.24m above ellipsoid) and was used throughout the survey. All computer operations and data processing were conducted at the hotel.

2.2 Magnetic Data Acquisition

Upon arrival in Martha's Vineyard, Battelle personnel set up a geophysical prove-out (GPO) line at the airport for quality control and calibration. The GPO line contained a 105 mm mortar round, an M38 practice bomb, two 81 mortars, a rocket venturi, two 3lb practice bombs, a 2.25 rocket, two 3-inch" rockets, a 2.75-inch rocket, and a 105 projectile (**Error! Reference source not found.**). These targets were considered representative of the types of MEC expected on site. Prior to placement of the calibration targets, the area was swept with a man-portable magnetometer to determine the presence of pre-existing subsurface anomalies. A post-seed ground-based magnetometer survey was conducted for comparison to the airborne data.

The helicopter arrived on-site on February 6th and equipment installation was conducted on February 7th. The GPO preseed survey, seed emplacement, and postseed survey were performed on February 8th, with airborne data acquisition starting on February 9th. The VG-22 data were desampled from 1200Hz to a 120 Hz recording rate. All other raw data were interpolated to a 120 Hz rate. This results in a down-line sample density of approximately 10cm at average survey speeds. Data were converted to an ASCII format and imported into a Geosoft format database for processing. With the exception of the differential GPS post-processing and the calculation of compensation coefficients, all data processing was conducted using the Geosoft Oasis Montaj software suite.

A variety of Quality Control checks were performed throughout the survey. The test line was flown at the beginning or end of each survey day. A "bed of nails" test was also run periodically, where a plywood sheet with a grid of roofing nails was pulled underneath each magnetometer to check noise levels, anomaly response, etc.

2.3 Positioning

The pilot was guided during flight by an onboard navigation system. This provided sufficient accuracy for data collection (approximately 1m), but was inadequate for final data positioning. To increase the accuracy of the final data positioning, a GPS base station was established at a monument, MVY B, located at the airport (NAD83 70° 36' 19.45872" West, 41° 23' 49.23710" North, NAVD 88 17.24m above ellipsoid). Raw GPS data were collected in the aircraft and on the ground for differential corrections. These were applied in post-processing to provide better accuracy in the antenna positioning. The final latitude/longitude data were projected onto an orthogonal grid using the North American Datum 1983, UTM Zone 19N, meters.

The locations of each magnetometer sensor and the GPS antenna have been precisely measured relative to the helicopter tow hook by a civil surveyor. In-flight locations are determined by using the GPS antenna location and the aircraft orientation, as measured by an inertial navigation unit that samples at a 100Hz rate. This system outputs pitch, roll and azimuth. These data are combined with the physical geometry of the array to calculate the position and relative height of each magnetometer sensor.

Height above ground was monitored by a laser altimeter with an accuracy of about 2cm.

3. Magnetic Data Processing

The magnetic data were processed in several stages. This included correction for time lags, removal of sensor spikes and dropouts, compensation for dynamic helicopter effects, correction for sensor heading error, array balancing, and removal of helicopter rotor noise. The vertical magnetic gradient was calculated by subtracting readings from pairs of total field magnetometers. The magnetic analytic signal (total gradient) was derived from the vertical gradient through an FFT integral algorithm.

3.1 Quality Control

The data were examined in the field to ensure sufficient data quality for final processing, as discussed in Appendix A. Each of the processing steps listed above were evaluated and tested. The adequacy of the compensation data, heading corrections, time lags, orientation calibration, overall performance and noise levels, and data format compatibility were all confirmed during data processing. During survey operations, flight line locations were plotted to verify full coverage of the area. Missing lines or areas where data were not captured were rejected and reacquired. Data were also examined for high noise levels and data drop-outs. Lines deemed to be unacceptable were re-flown. Occasional lines deviated from a straight flight path due to local vegetation, infrastructure, or topography. In instances where the pilot intentionally slid sideways down the hill in order to maintain uniform sensor clearance, the sensor altitude was given priority over uniform coverage.

3.2 Time Lag Correction

There is a lag between the time the sensor makes a measurement and when it is time-stamped and recorded. This applies to both the magnetometer and the GPS data. Accurate positioning requires a correction for this lag. Time lags between the magnetometers, fluxgate and GPS signals were measured by a proprietary utility. This utility sends a single EM pulse that is visible in the data streams of all three instruments. In order to save space in the database, the lag correction is applied to the timestamp data rather than all of the geophysical responses. All positioning data are referenced to this timestamp when they are imported into the database. No additional lag correction is required.

3.3 Sensor Drop-outs

Cesium vapor magnetometers have a preferred orientation to the Earth's magnetic field. As a result of the motion of the aircraft, the sensor dead zones will occasionally align with the Earth's field. In this event, the readings drop out, usually from a local average of over 50,000 nT to 0 nT. This usually occurs only during turns between lines, and rarely during on-line surveying (<1sec of data loss per day). All dropouts were removed manually during processing.

3.4 Aircraft Compensation

The close proximity of the helicopter to the sensors causes considerable deviation in the readings, which requires compensation. The orientation of the aircraft with respect to the sensors and the motion of the aircraft through the earth's magnetic field are contributing factors. A calibration flight is flown to record the information necessary to remove these effects. The maneuver consists of flying a square-shaped flight path at high altitude to gain information in each of the cardinal directions. During this procedure, the pitch, roll and yaw of the aircraft are varied. This provides a complete picture of the effects of the aircraft at all headings in all orientations. The entire maneuver was conducted twice for comparison. The information was used to calculate coefficients for a 19-term polynomial for each sensor. The fluxgate data were used as the baseline reference channel for orientation. The polynomial is applied post flight to the raw data, and the results are referred to as the compensated data.

3.5 Rotor Noise

The aircraft rotor spins at a constant rate of about 400rpm. This introduces noise to the magnetic readings at a frequency of approximately 6.6 Hz. Harmonics at multiples of this base are also observable, but have much smaller amplitudes. This frequency is usually higher than the spatial frequency created by near-surface metallic objects and is removed with a frequency filter.

3.6 Heading Corrections

Cesium vapor magnetometers are susceptible to heading errors. The result is that one sensor will give different readings when rotated about a stationary point. This error is usually less than 0.2 nT. Heading corrections are applied to adjust readings for this effect.

3.7 Vertical Magnetic Gradient

The vertical magnetic gradient is measured as the difference between measured values in each gradiometer pod (bottom magnetometer minus top). This is a distinction from total magnetic field surveys in which vertical magnetic gradient is calculated, rather than measured. In addition to reducing the effects of aircraft and rotor noise, this technique removes the necessity of monitoring and subtracting diurnal variations in the Earth's field. These data were gridded using a 0.5m interval.

3.8 Analytic Signal

The analytic signal is calculated from the gridded vertical magnetic gradient data as the square root of the sum of the squares of three orthogonal magnetic gradients. It represents the maximum rate of change of the magnetic field in three-dimensional space – a measure of how much the magnetic field would change by moving a small amount in the direction of maximum change.

There are several advantages to using the analytic signal. It is generally easier to interpret than total field or vertical gradient data for small object detection because it has a simple positive response above a zero background. The amplitude of the analytic signal response depends on the strength of the magnetic anomaly. In contrast, total field and vertical gradient maps typically display a dipolar response to small, compact sources (having both a positive and negative deviation from the background). The actual source location is at a point between the two peaks that is dependent upon the magnetic latitude of the site and the properties of the source itself. Analytic signal is essentially symmetric about the target, is always a positive value and is less dependent on magnetic latitude. More generally, the analytic signal highlights the corners of source objects, but for small targets at the latitude of this survey, these corners converge into a single peak almost directly over the target.

The dominant noise source in analytic signal is residual line-to-line inconsistencies in the gridded data which impact the horizontal gradients. These may be caused by residual heading error, altitude variation or uncompensated aircraft effects. The minimum anomaly threshold was set above the analytic signal noise floor at 0.2nT/m for single peaks. This represents the 10:1 signal-noise ratio based on a measured noise floor of 0.02nT/m.

3.9 Inversion

An automated dipole inversion routine was applied to the data to calculate the location, moment, dipole inclination/declination and RMS fit error. The angle between the Earth's field and the dipole vector was also calculated, as was the final forward model and residual after removal of the forward model. The inversion results of the GPO were sorted by each of the inversion parameters, but no single parameter showed a positive correlation with the ground truth at the GPO as well as the analytic signal. Where the inversion failed to resolve a target, the original analytic signal peak location was used. Anomalies were then examined manually to adjust their priority based on the appearance of the gridded data. The peakedness picking of the GPO resulted in a mean locational accuracy of 0.74m and a standard deviation of 0.38m. Locational accuracy, based on dipole inversion of anomalies for the VG-22 system at 1.5m altitude, had a mean of 0.3m and a standard deviation of 0.2m, proving that the inversion greatly improved the accuracy of the target locations.

3.10 Altitude Effect on Sensitivity

As mentioned previously, magnetometer system sensitivity is strongly limited by survey altitude and burial depth. The magnetic response amplitude from a single UXO target drops with $1/r^3$, where r is the distance between the sensor and target. This is illustrated in Figure 3-1 which shows the size of target (moment) required to generate a minimum magnetic response (1.5nT) at a range of altitudes.

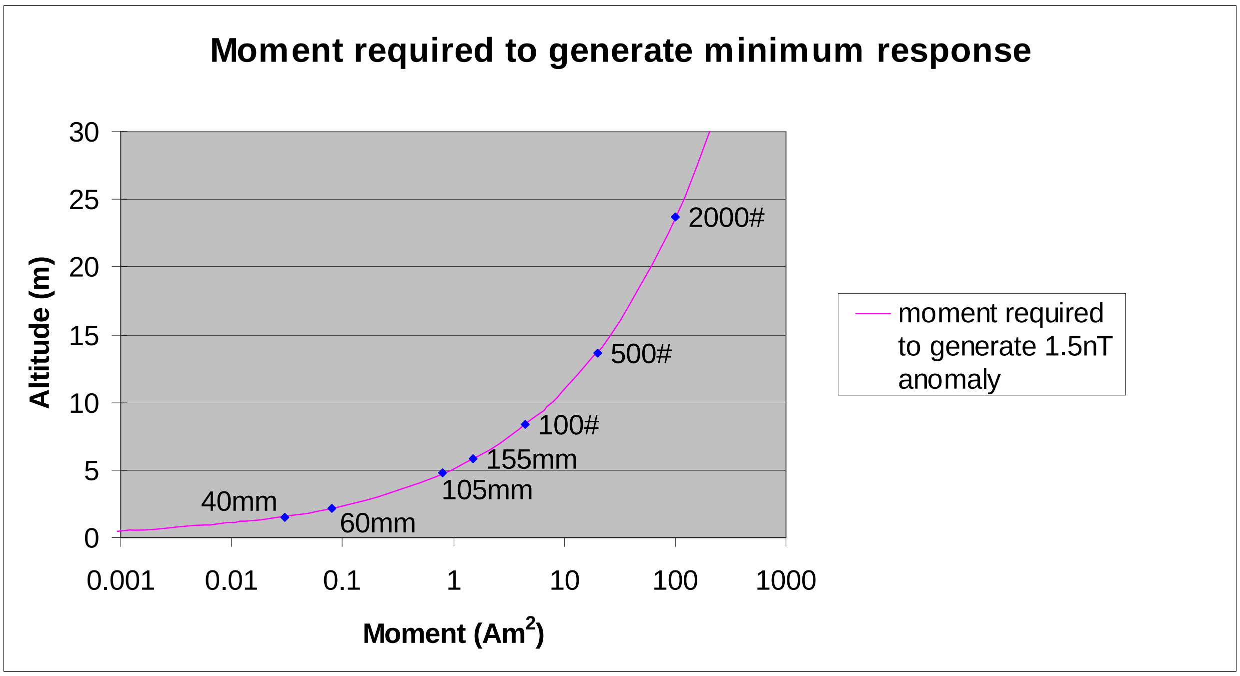


Figure 3-1: Magnetic moment required to generate a 1.5nT response at a range of altitudes. Moments shown here represent an average for each ordnance type and will vary with orientation. 40mm projectiles represent the smallest targets that have been detected by airborne systems. However, combinations of items in close proximity can create a cumulative anomaly, so that concentrations of small ordnance can be detected at greater altitudes than individual anomalies.

4. Calibration and Verification

4.1 Geophysical Prove Out Line

A calibration site was used to support QC of field operations and to verify target response against the local geologic background. The site consisted of 12 ordnance items in a line running approximately N-S. A pre-seed ground survey was conducted at the test line site to check for any preexisting anomalies. Several anomalies were present on the test line as seen in the vertical gradient map, Figure 4-1. The items (**Error! Reference source not found.**) were placed in areas where pre-existing anomalies were not present, approximately 10m apart on the surface as shown in **Error! Reference source not found.**. Figure 4-2 shows the vertical gradient data from the February 11th flight over the test line once the items were in place; this flight was flown at 1m altitude. Figure 4-3 shows the analytic signal of this same flight. This map shows the target positions collected from five different flights with flight altitudes of 1-2m. QC flights were flown over the calibration line throughout the survey, see Appendix A.

The percent of detection measured from the GPO low altitude test data are shown in **Error! Reference source not found.**. Lower detection rates are expected in the data from survey sites where flight heights were usually greater, and ordnance were buried at a range of depths, and are deformed and/or fragmented. Initial anomaly picks were based on the Geosoft peakedness utility, and final picks were based on dipole inversion. The peakedness picking resulted in a mean location accuracy of 0.74m and a standard deviation of 0.38m. Locational accuracy, based on dipole inversion of anomalies for the VG-22 system at 1.5m altitude, had a mean of 0.3m and a standard deviation of 0.2m.

Table 4-1: Geophysical Prove-Out Line detection probabilities for each emplaced target. A target was detected based up a 1m radial offset.

Description of item (North to South)	**Detection probability from low altitude test data**
5” projectile	100%
105 projectile	100%
3lb practice bomb	62.5%
3” rocket	87.5%
2.75” rocket	75%
81 mortar	100%
3” rocket	100%
2.25” rocket	75%
3lb practice bomb	87.5%
81 mortar	87.5%
VENT	87.5%
M38	75%

Table 4-2: Geophysical Prove-Out Line Table of radial offsets for each target for each survey day. Radial offsets are based upon inversion results and are reported in meters.

Target	2/8/2011 Radial offset in meters	2/9/2011 Radial offset in meters	2/10/2011 Radial offset in meters	2/11/2011 Radial offset in meters	2/12/2011 Radial offset in meters	2/13/2011 Radial offset in meters	2/14/2011 Radial offset in meters	2/17/2011 Radial offset in meters
5” projectile	0.237	0.112	0.134	0.166	0.274	0.104	0.834	0.137
105 projectile	0.213	0.787	0.787	0.301	0.703	0.06	0.707	0.787
3lb practice bomb	0.708	1.054	0.708	0.708	x	1.49	1.435	0.652
3” rocket	0.143	0.116	x	0.196	0.572	0.168	0.158	0.519
2.75” rocket	0.122	0.424	0.066	0.037	1.397	0.038	0.618	1.011
81 mortar	0.442	0.086	0.236	0.201	0.831	0.204	0.319	0.747
3” rocket	0.081	0.081	0.139	0.049	1.336	0.182	0.518	0.962
2.25” rocket	0.255	0.315	0.066	0.093	1.096	0.303	0.523	1.189
3lb practice bomb	0.646	0.311	0.418	0.384	0.646	0.485	0.646	1.006
81 mortar	0.246	0.231	0.154	0.332	0.405	0.105	0.125	1.347
Venturi	0.177	0.177	0.177	0.177	0.177	0.177	0.177	1.114
M38	0.359	1.333	0.199	0.33	0.429	0.2	0.429	1.059

Table 4-3: Geophysical Prove-Out Line Table of the analytic signal for each target for each survey day.

Target	2/8/2011 Analytic Signal (nT/m)	2/9/2011 Analytic Signal (nT/m)	2/10/2011 Analytic Signal (nT/m)	2/11/2011 Analytic Signal (nT/m)	2/12/2011 Analytic Signal (nT/m)	2/13/2011 Analytic Signal (nT/m)	2/14/2011 Analytic Signal (nT/m)	2/14/2011 Analytic Signal (nT/m)
5” projectile	40.1	49.84	191.78	62.38	36.26	102.77	82.37	146.89
105 projectile	962.92	2964.92	4544.32	2191.14	1658.16	1133.12	993.77	2262.55
3lb practice bomb	1.81	0.56	0.29	0.66	x	1.03	1.18	0.55
3” rocket	11.1	21.26	x	13.31	31.01	37.46	41.93	30.91
2.75” rocket	166.02	162.39	63.79	160.2	447.07	154.62	301.25	292.06
81 mortar	6.41	31.99	27.68	24.29	12.25	35.04	10.34	18.77
3” rocket	58.36	44.15	118.88	151.01	230.9	233.55	83.4	81.48
2.25” rocket	43.65	26.94	60.23	84.39	90.34	142.97	58.39	43.77
3lb practice bomb	0.68	2.88	2.45	2.95	4.26	2.67	2.34	4.06
81 mortar	94.78	22.72	15.41	76.47	51.92	77.67	72.13	12.56
Venturi	0.56	0.72	1.52	0.74	1.35	1.35	0.55	0.92
M38	282.32	52.19	2.86	135.94	107.81	137.02	258.97	35.48

The Geophysical Prove Out line was flown on February 11th at 5 different altitudes; 1m, 2m, 3m, 5m, and 7m heights (Figure 4-4, Figure 4-5, and Figure 4-6). Using a picking threshold of 0.5nT, Table 4-2 shows the analytic signal for each target that was detected at each of the heights. A picking radius of 1.5m was used for the target detections for the 5 separate flight altitudes.

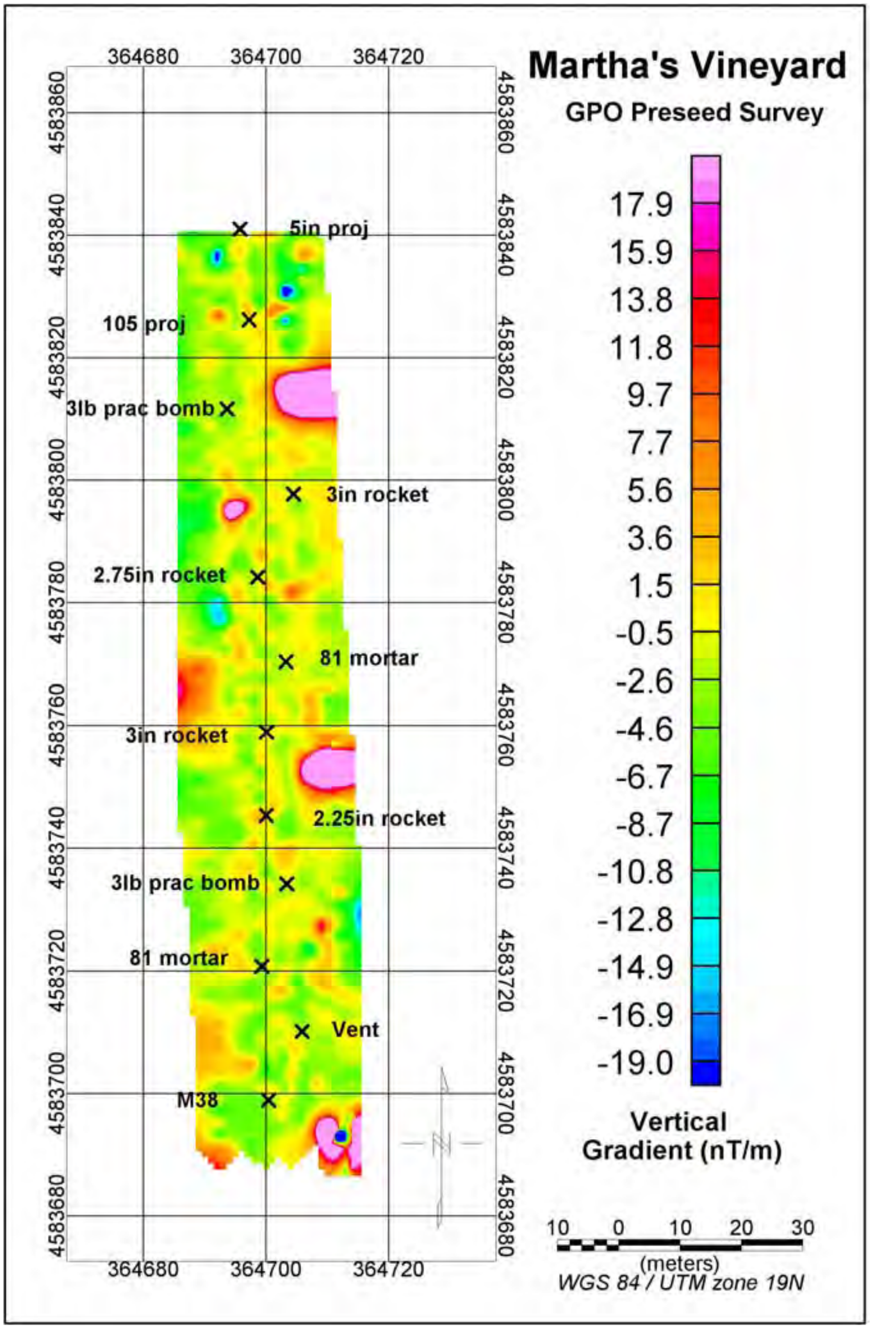


Figure 4-1: Vertical Gradient of the Geophysical Prove Out area before any items were emplaced. The scale used is -20 to 20 nanoTesla/meter. A large anomaly is present about halfway down the line.

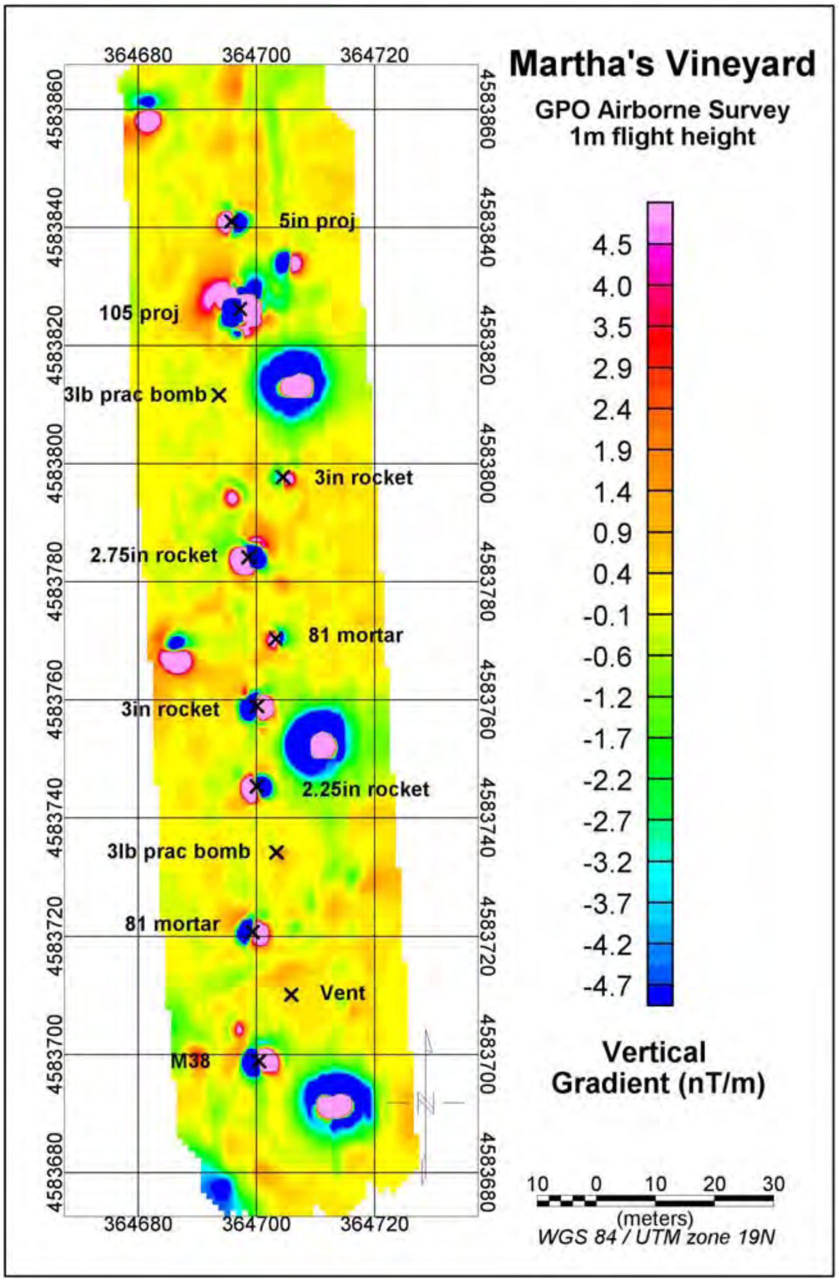


Figure 4-2: Vertical Gradient of Ground Prove Out line with target labels and locations. The scale of the vertical gradient is -5 to 5 nanoTesla/meter.

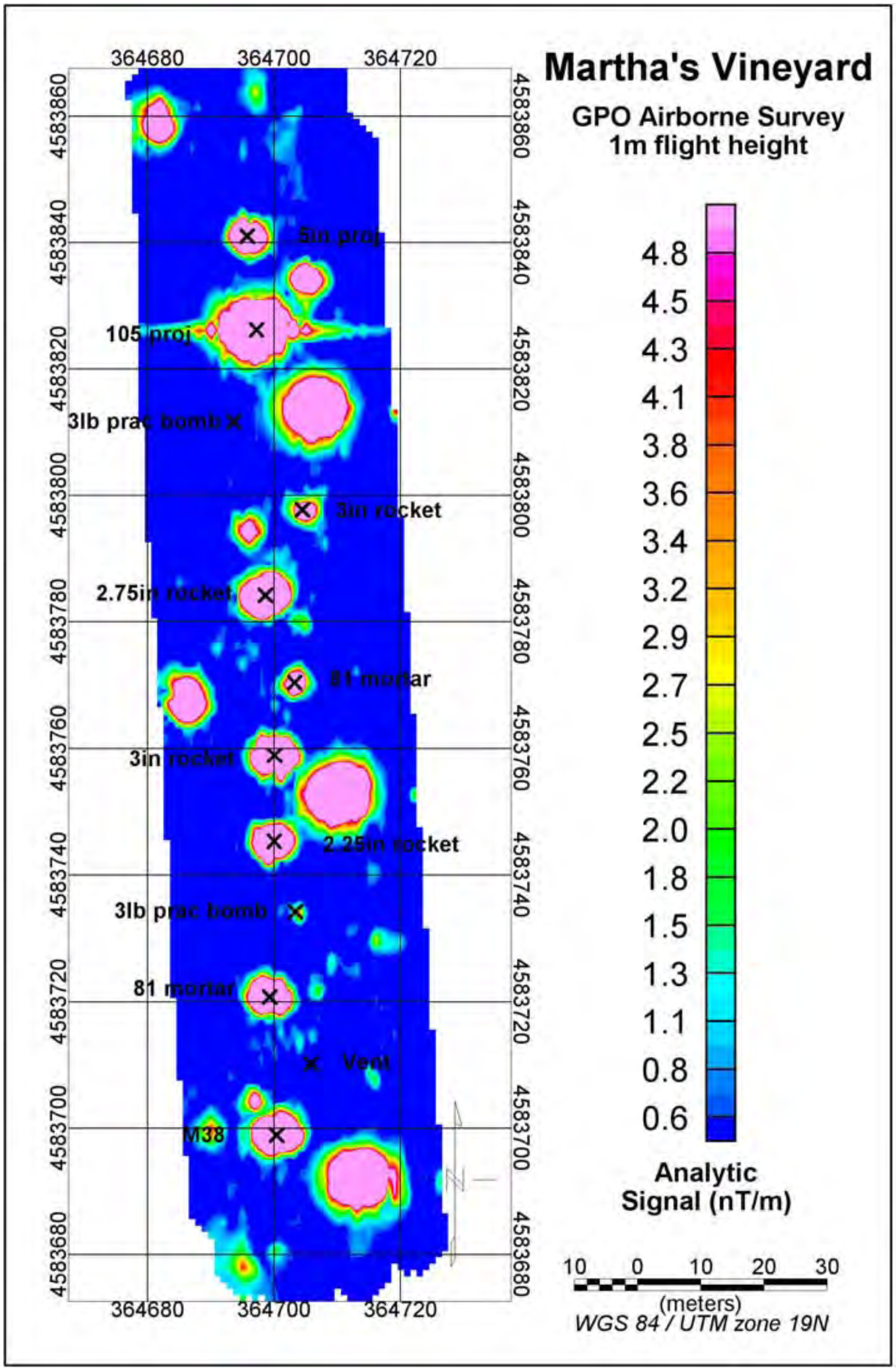


Figure 4-3: Analytic signal of Geophysical Prove Out line for 1m flight height. The scale of the analytical signal map is 0.5 to 5 nanoTesla/meter.

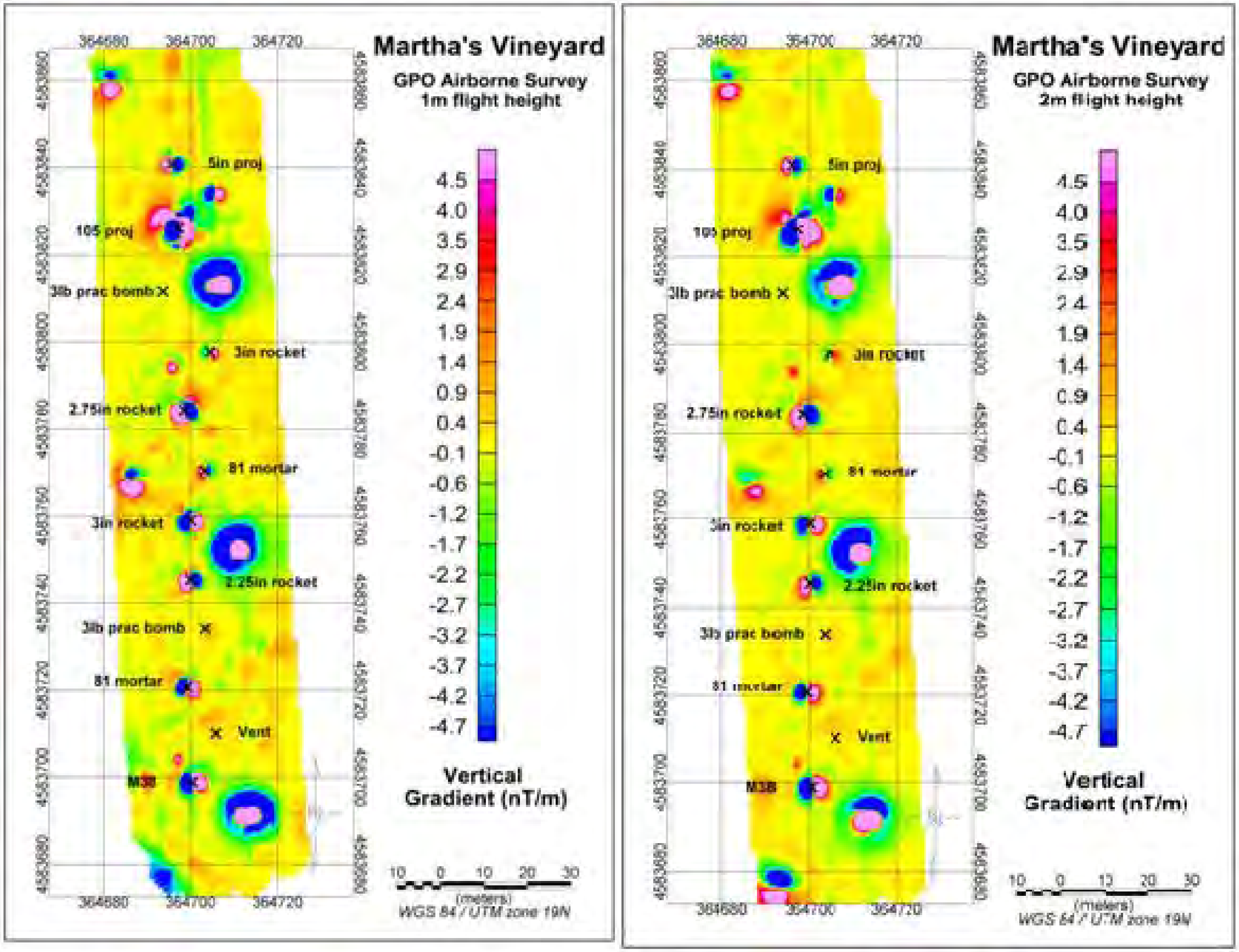


Figure 4-4: Vertical Gradient of Geophysical Prove Out line for 1m and 2m flight height. The scale of the vertical gradient maps is -5 to 5 nanoTesla/meter.

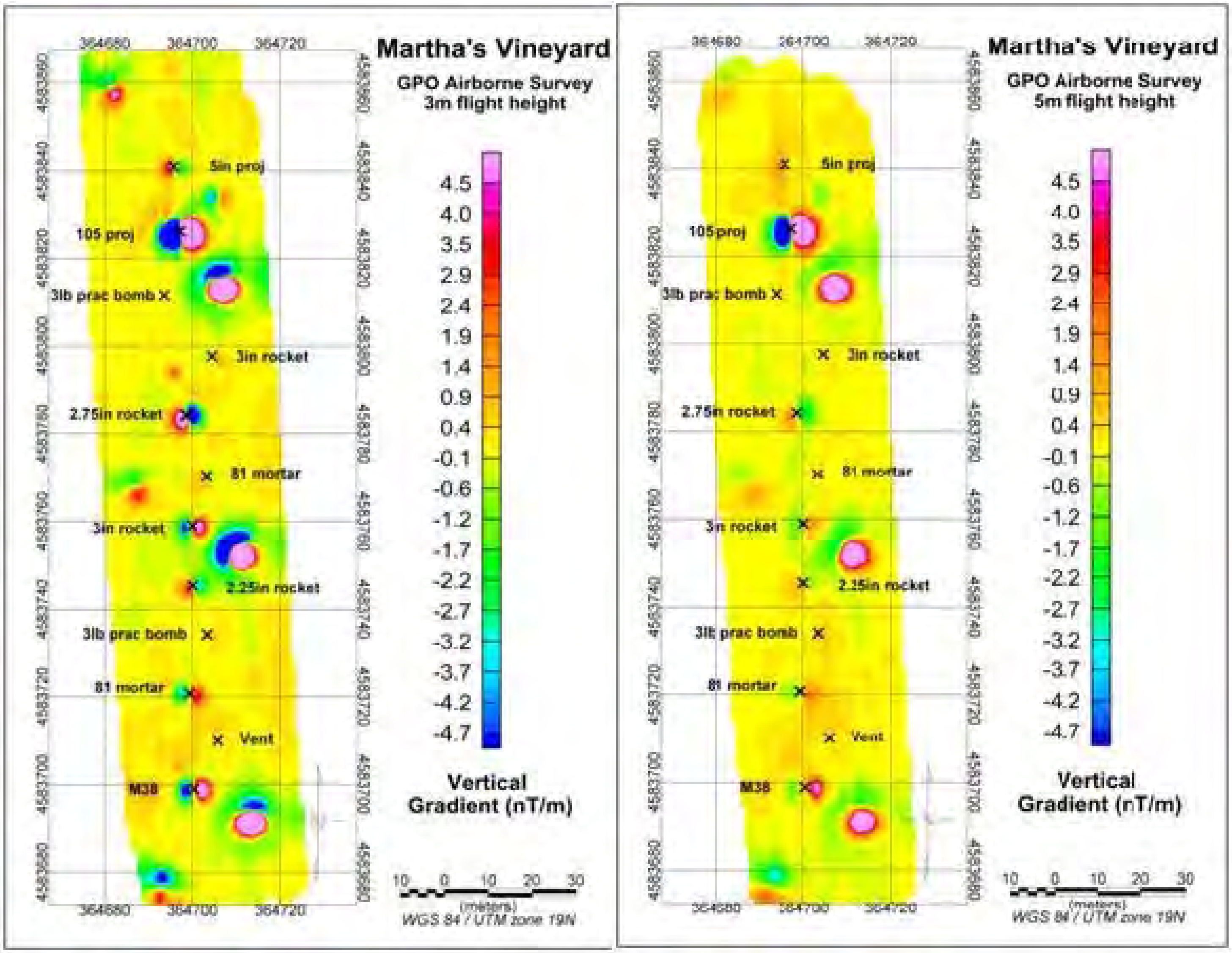


Figure 4-5: Vertical Gradient of Geophysical Prove Out line for 3m and 4m flight height. The scale of the vertical gradient maps is -5 to 5 nanoTesla/meter.

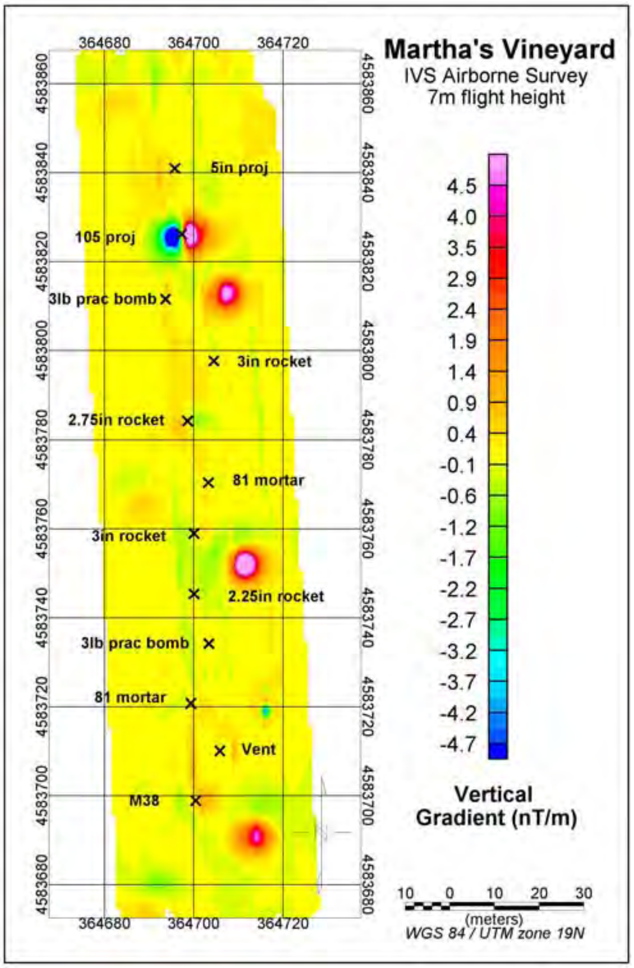


Figure 4-6: Vertical Gradient of Geophysical Prove Out line for 7m flight height. The scale of the vertical gradient map is -5 to 5 nanoTesla/meter.

Table 4-4: Geophysical Test Line results for five separate flight altitudes; 1m, 2m, 3m, 4m, and 5m. Table documents the amplitude of the analytic signal for each of the twelve targets.

	1m height (analytic signal)	2m height (analytic signal)	3m height (analytic signal)	5m height (analytic signal)	7m height (analytic signal)
5” projectile	40.1	33.14	7.28	1.04	x
105 projectile	962.89	589.34	129.19	23.99	7.27
3lb practice bomb	2.59	x	x	x	x
3” rocket	11.1	x	x	x	x
2.75” rocket	166.01	74.92	14.31	2.44	0.64
81 mortar	6.41	5.84	1.14	x	x
3” rocket	62.55	33.51	10.18	1.45	x
2.25” rocket	43.65	15.32	5.54	0.88	x
3lb practice bomb	0.68	1.25	x	x	x
81 mortar	94.78	29.35	4.13	x	x
Venturi	0.56	x	x	x	x
M38	282.31	54.97	8.02	x	x

5. Data Interpretation

5.1 Great Tisbury Pond Vertical Gradient, Analytic Signal, and Altitude Maps

Error! Reference source not found. shows a map of the vertical magnetic gradient anomalies at Tisbury Great Pond. **Error! Reference source not found.** shows a map of the analytical signal computed from the vertical magnetic gradient data. An altitude map is shown in **Error! Reference source not found.**. The average laser altimeter altitude over the area was 1.96 m. A vertical gradient map with the anomaly picks is shown in Figure 5.1-4. This map shows the location of the 3,608 picks for Tisbury Great Pond. The data for this area were collected over February 9, 10, and 14 with reflights on February 17th. Geologic features appear to be scattered throughout this area, with some long linear geologic anomalies in the central region of the map. Other linear features on the beach (southeastern are of the map) indicate possible manmade structures. A few anomalies that may be related to crab traps also appear to be present in the survey area. These anomalies appear similar to plus signs or like the 5 dots on one side of dice and are approximately 35m x 35m.

A total of 3,608 anomalies were selected and divided into three priority groups as shown in Table 5-1. Priority 1 group included 1386 anomalies. These had analytic signal amplitudes greater or equal to 2 nT. The Priority 2 group included 722 anomalies. These had analytic signal amplitudes less than 2 nT and greater than 1 nT. The Priority 3 group included 1500 anomalies. These anomalies had analytic signal amplitudes less than or equal to 1 nT and greater than or equal to 0.5 nT. The prioritization scheme was chosen based upon the GPO results.

Table 5-1: Geophysical Test Line results for five separate flight altitudes; 1m, 2m, 3m, 4m, and 5m.

Great Tisbury Pond - 3608 total anomalies		
Priority 1 group	Priority 2 group	Priority 3 group
1386	722	1500

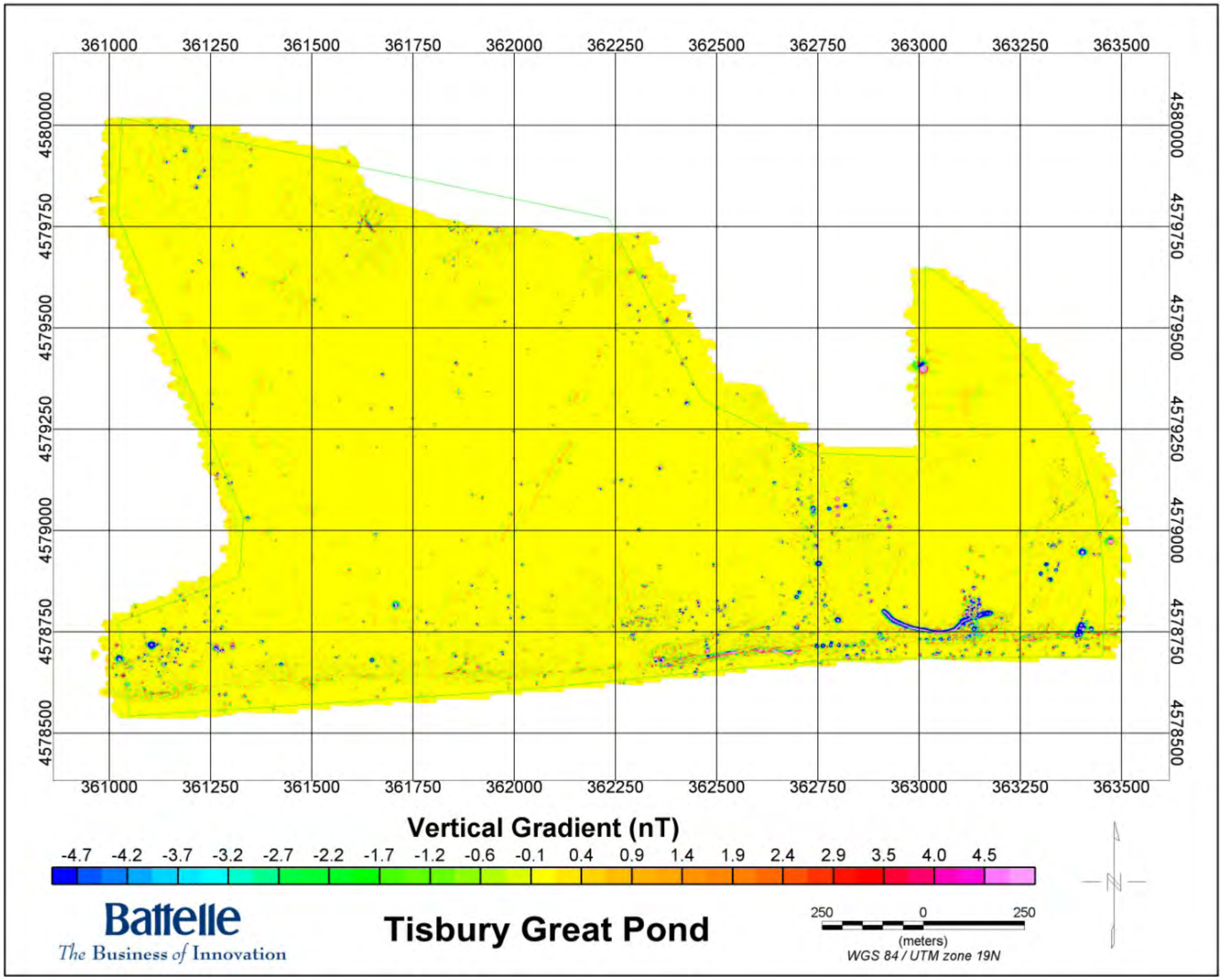


Figure 5-1: Vertical gradient map of the Tisbury Great Pond. The scale of the vertical gradient is -5 to 5 nanoTesla/meter.

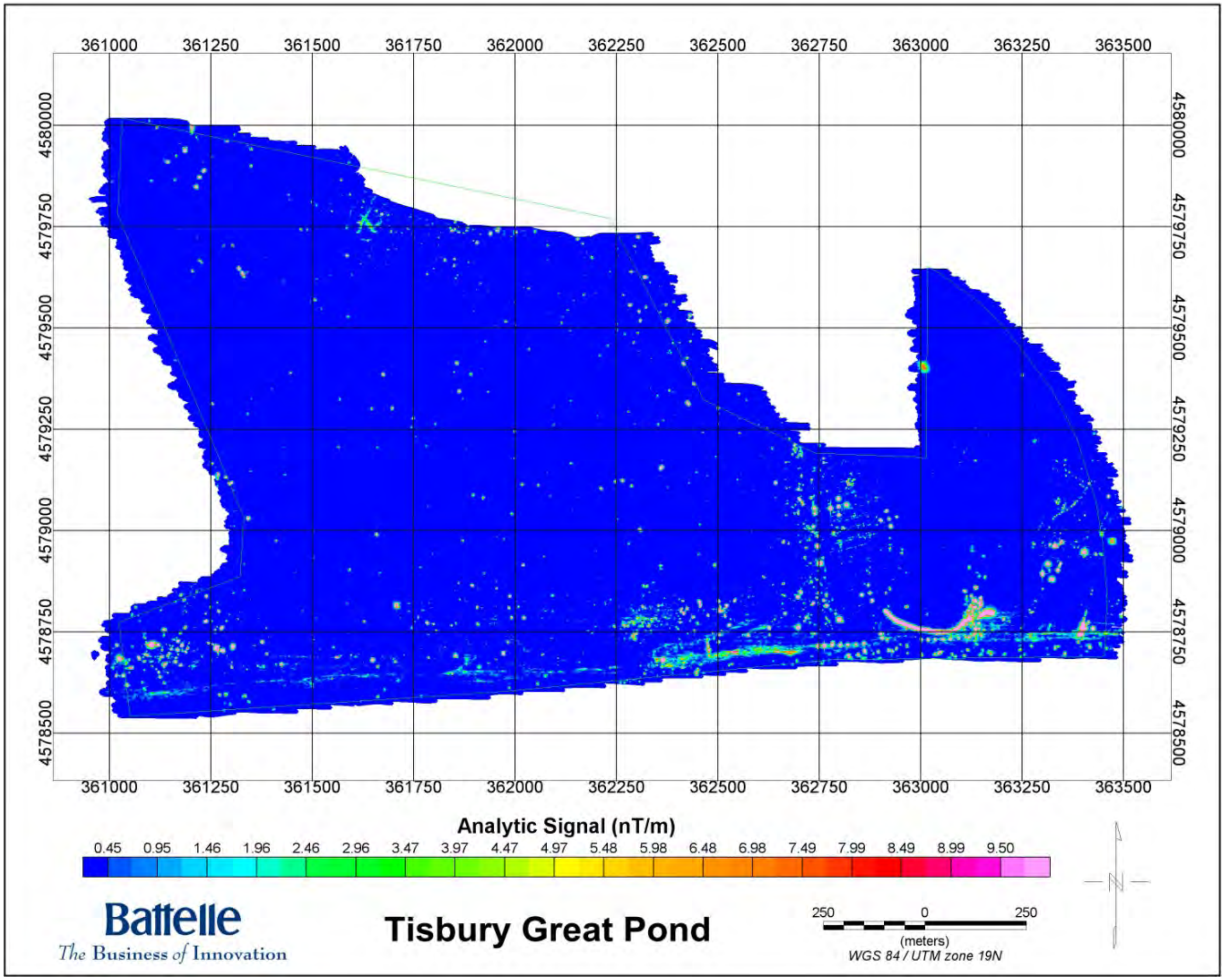


Figure 5-2: Analytic Signal map of the Tisbury Great Pond. The scale of the analytic signal is 0.5 to 10 nanoTesla/meter.

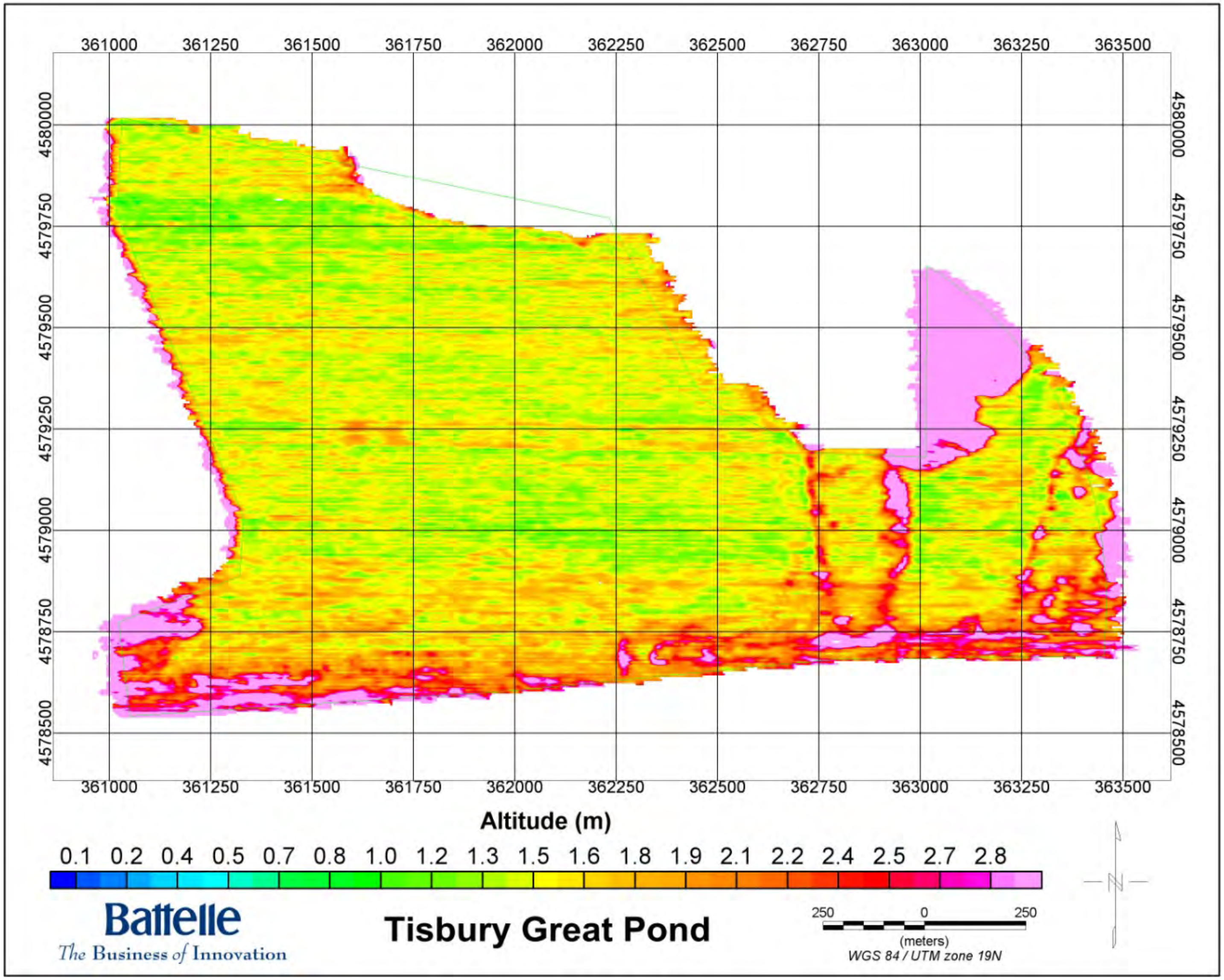


Figure 5-3: Altitude map for the Tisbury Great Pond.

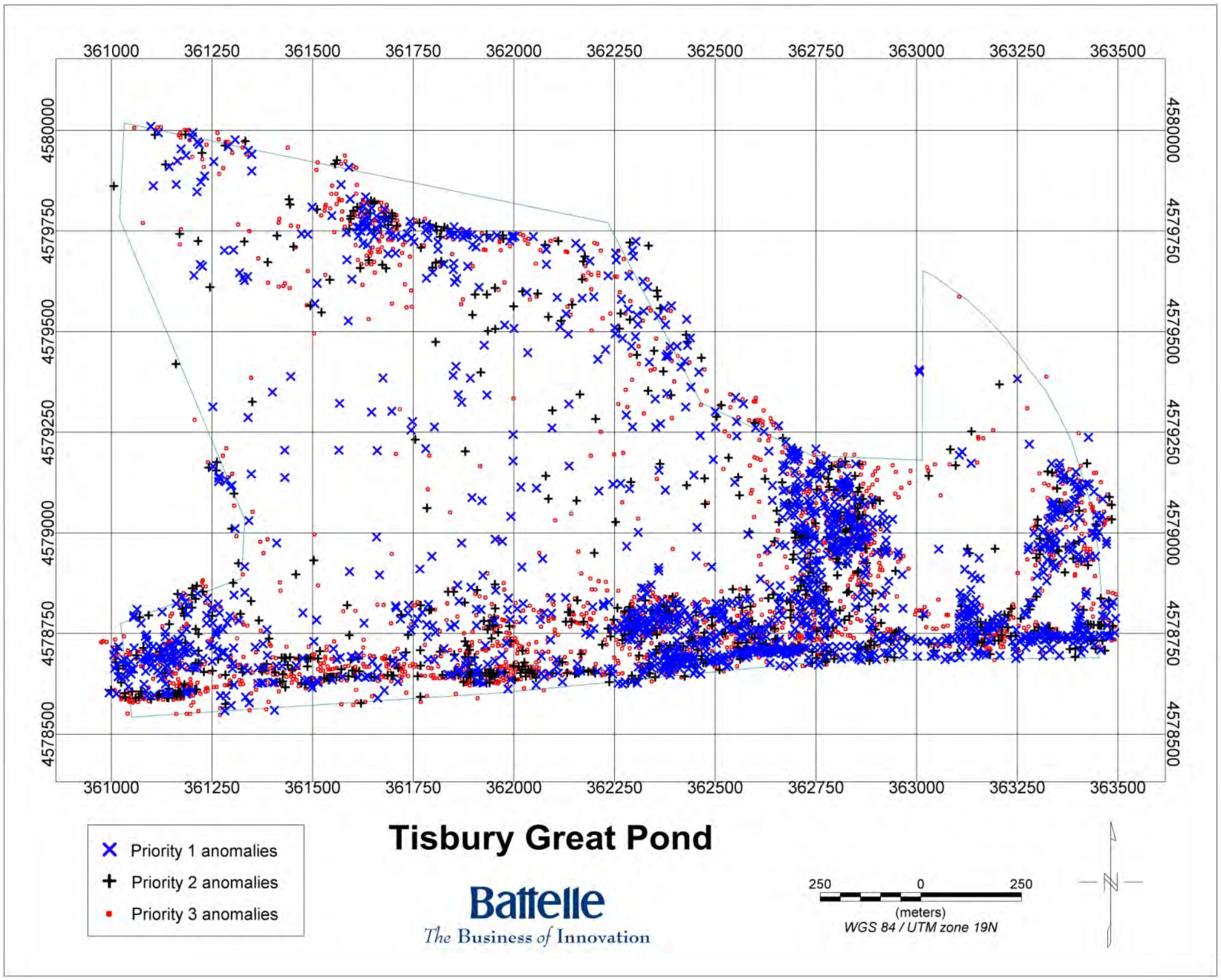


Figure 5-4: Anomaly map for the Tisbury Great Pond

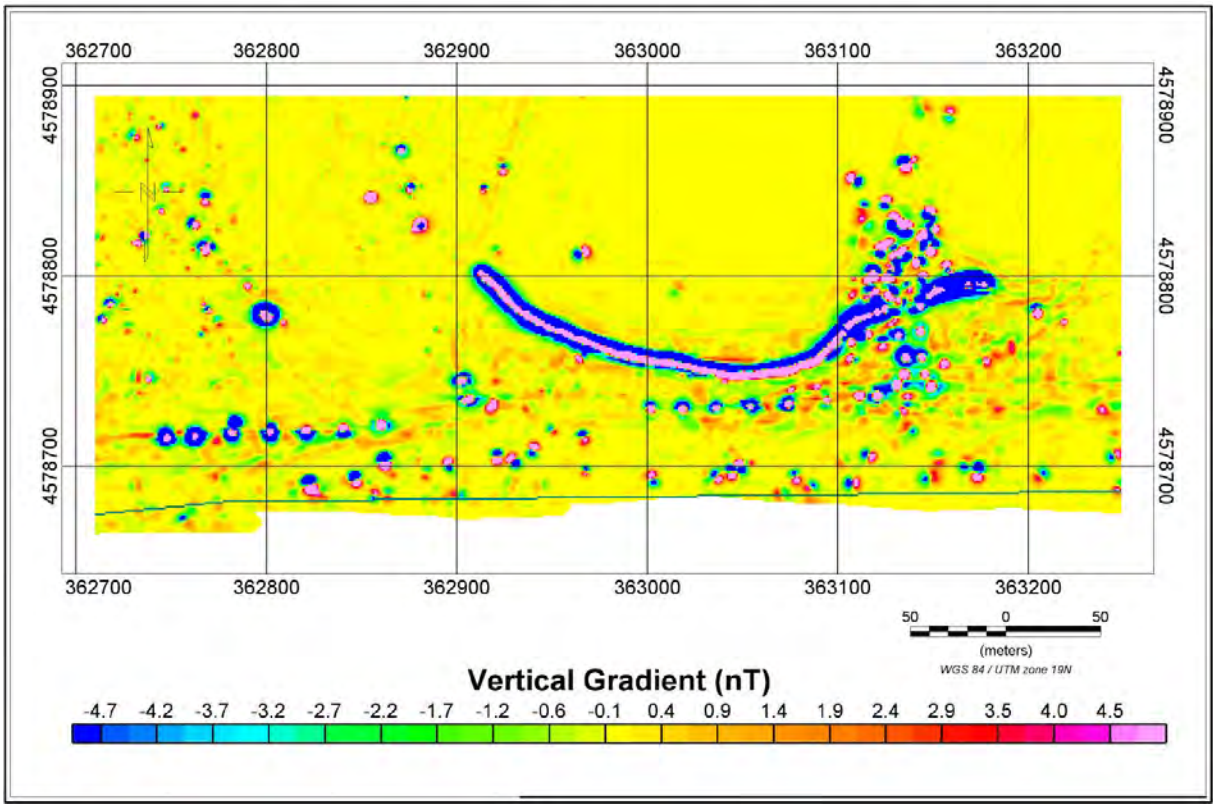


Figure 5-5: Manmade structures on the beach found in the southern portion of the Tisbury Great Pond survey area.

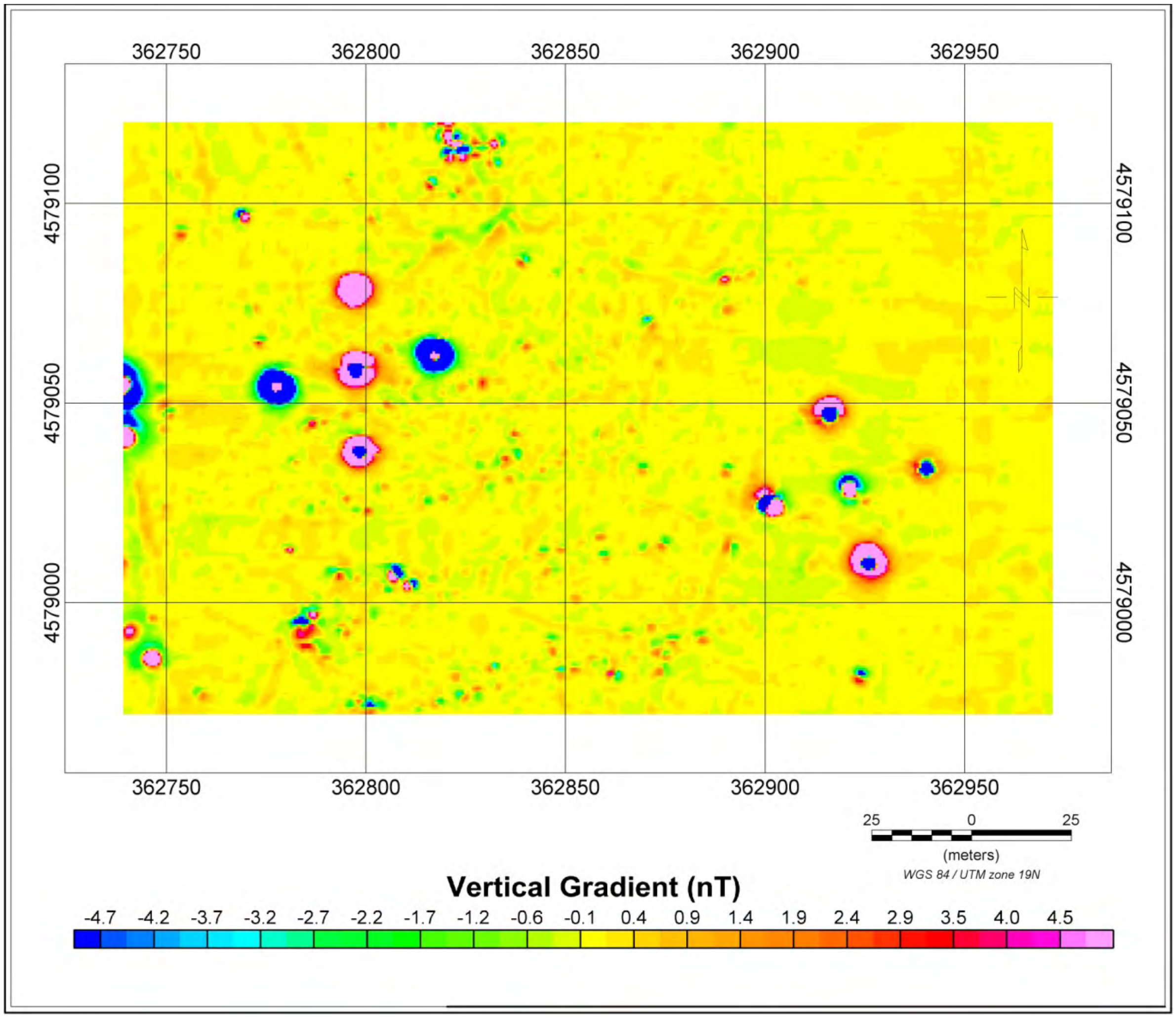


Figure 5-6: Interesting anomalies of possible crab traps.

5.2 Cape Poge Vertical Gradient, Analytic Signal, and Altitude Maps

Error! Reference source not found. shows a map of the vertical magnetic gradient anomalies at the Cape Poge survey area. **Error! Reference source not found.** shows a map of the analytical signal computed from the vertical magnetic gradient data. **Error! Reference source not found.** shows an altitude map of the Cape Poge survey area. The average laser altimeter altitude over the area was 2.5 m. A vertical gradient map with the anomaly picks is shown in Figure 5.1-10. This anomaly maps shows the location of the 2,447 picks for Cape Poge. Data for Cape Poge were collected on February 11th, 16th, and 17th. Three lines for Cape Poge were flown on the 11th. The Cape Poge site was completely reflown on February 17th. There were no required reflights for the area Figure 5.1-11 shows an example of the geology present at the Cape Poge site.

A total of 2,447 anomalies were selected and divided into three priority groups as shown in Table 5-2. Priority 1 group included 782 anomalies. These had analytic signal amplitudes greater or equal to 2 nT. The Priority 2 group included 550 anomalies. These had analytic signal amplitudes less than 2 nT and greater than 1 nT. The Priority 3 group included 1115 anomalies. These anomalies had analytic signal amplitudes less than or equal to 1 nT and greater than or equal to 0.5 nT. The prioritization scheme was chosen based upon the GPO results.

Table 5-2: Geophysical Test Line results for five separate flight altitudes; 1m, 2m, 3m, 4m, and 5m.

Cape Poge -2447 total anomalies		
Priority 1 group	Priority 2 group	Priority 3 group
782	550	1115

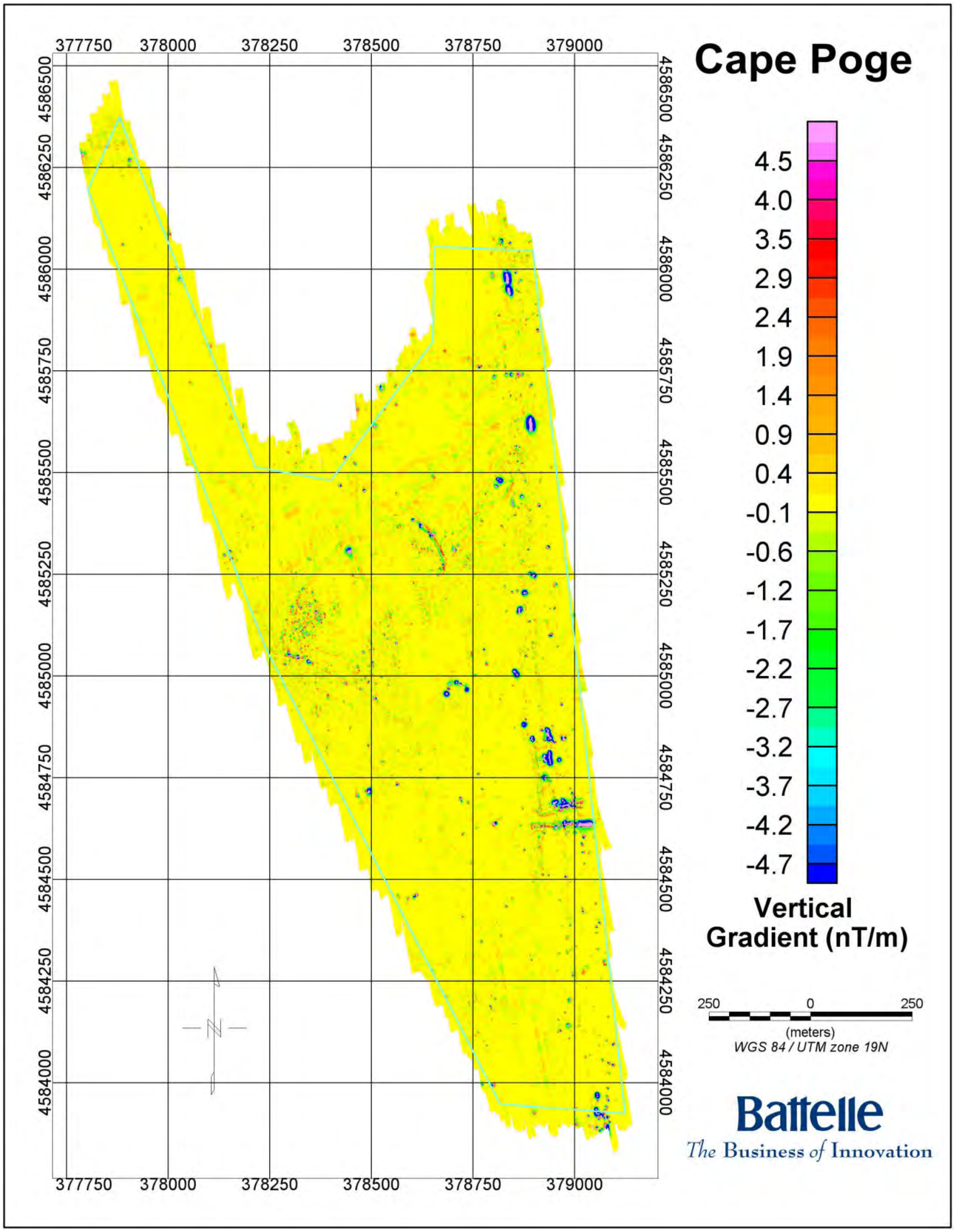


Figure 5-7: Vertical gradient map of Cape Poge. The scale of the vertical gradient is -5 to 5 nanoTesla/meter.

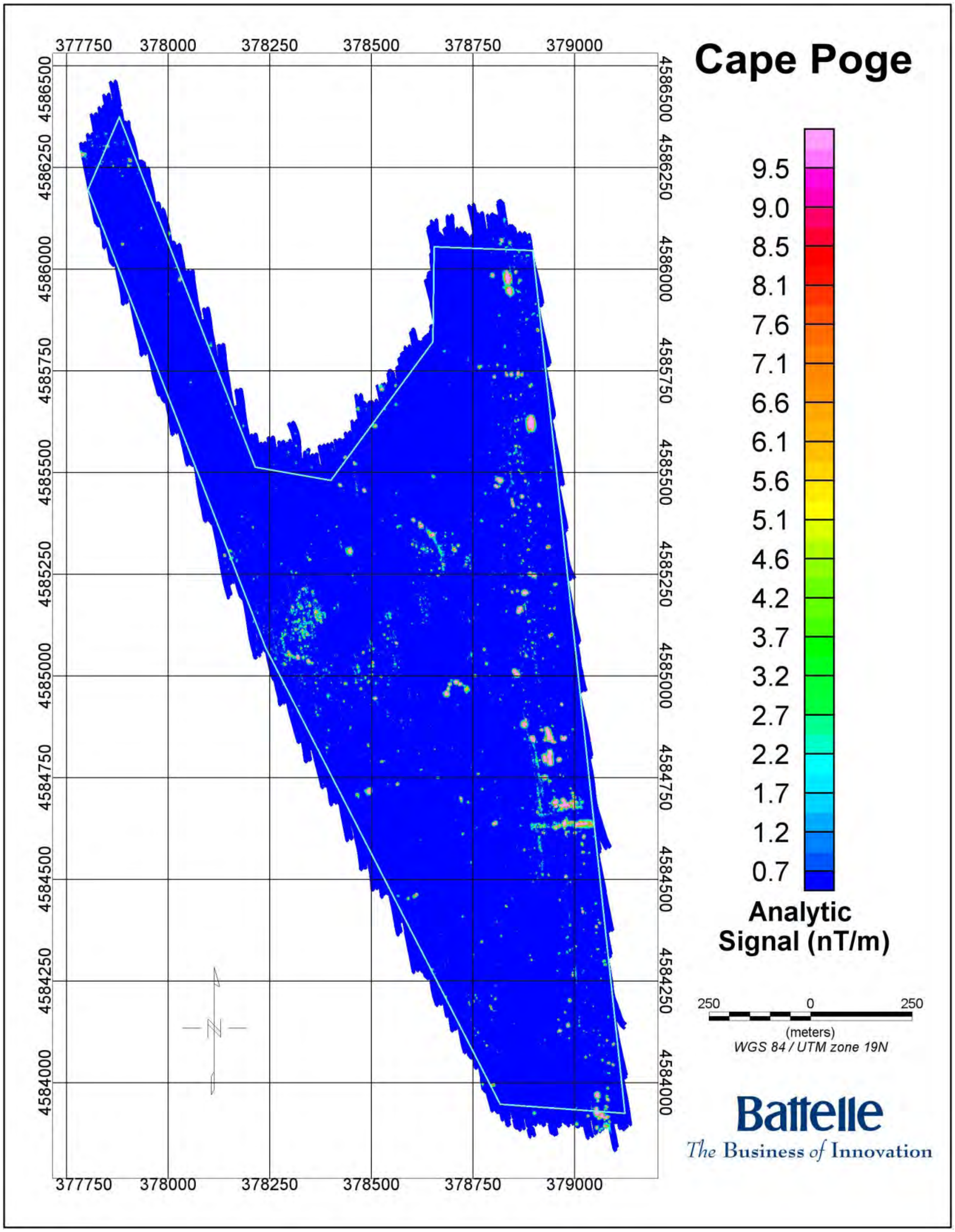


Figure 5-8: Analytic Signal map of the Cape Poge. The scale of the analytic signal is 0.5 to 10 nanoTesla/meter.

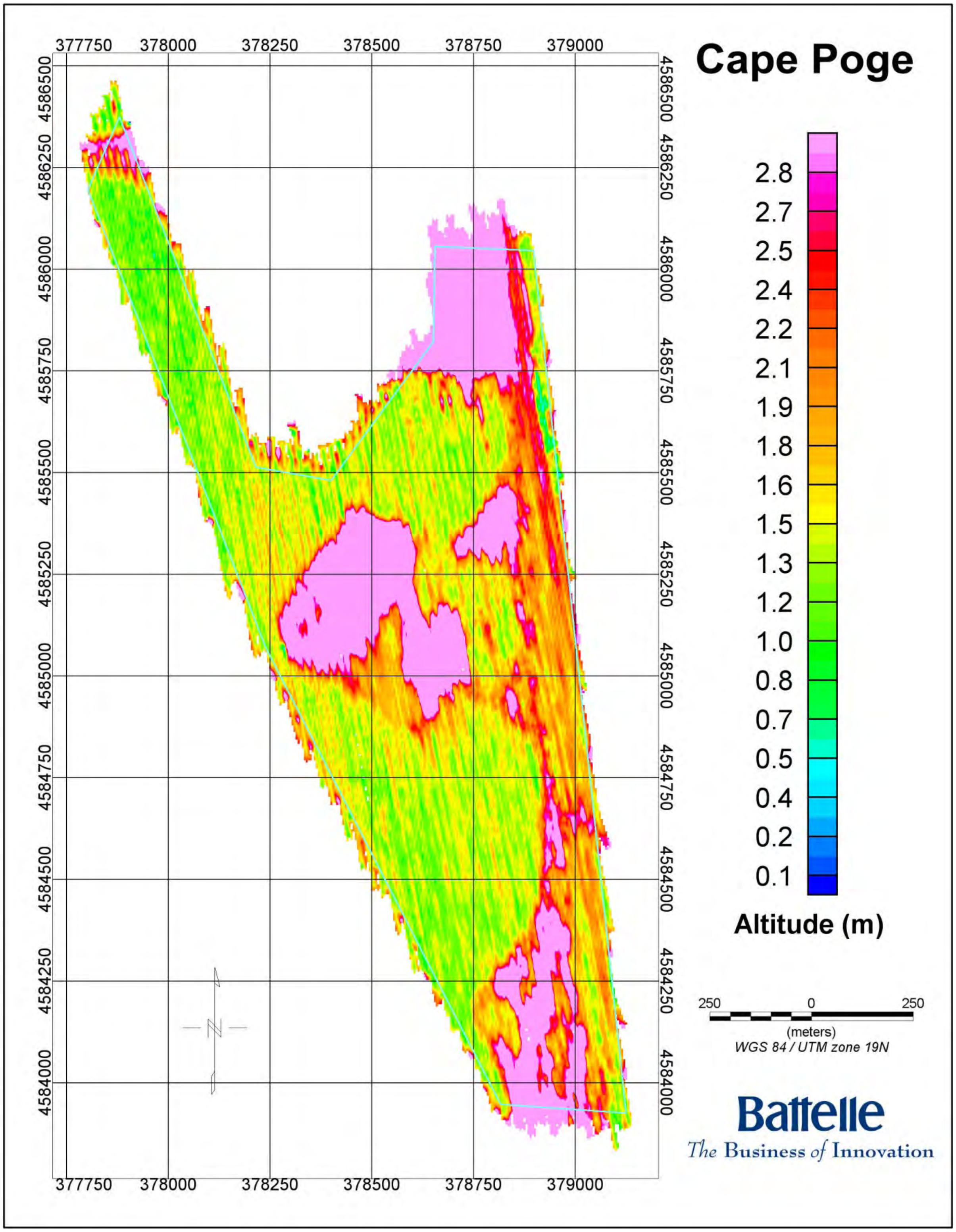


Figure 5-9: Altitude map for the Cape Poge.

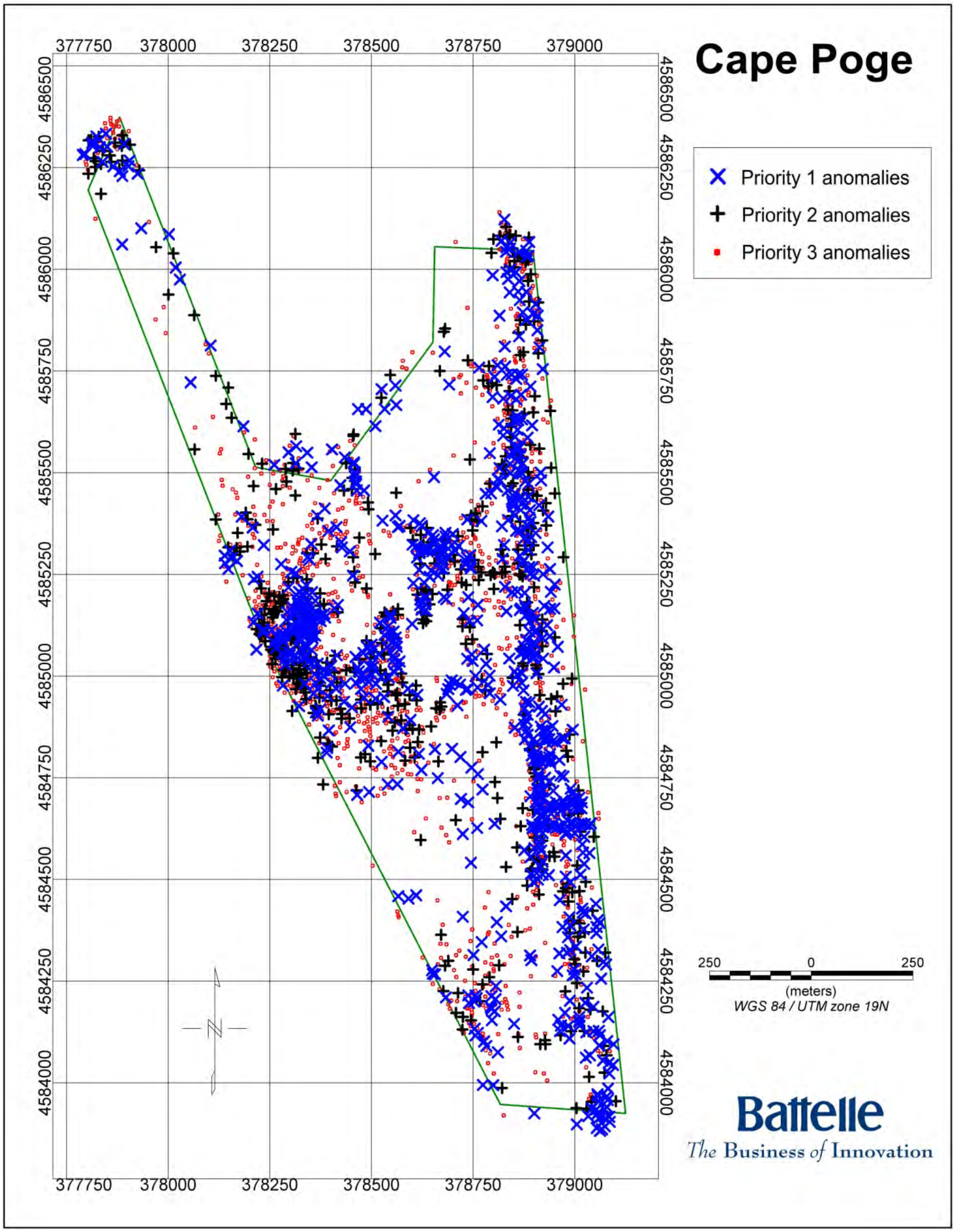


Figure 5-10: Anomaly map for the Cape Poge.

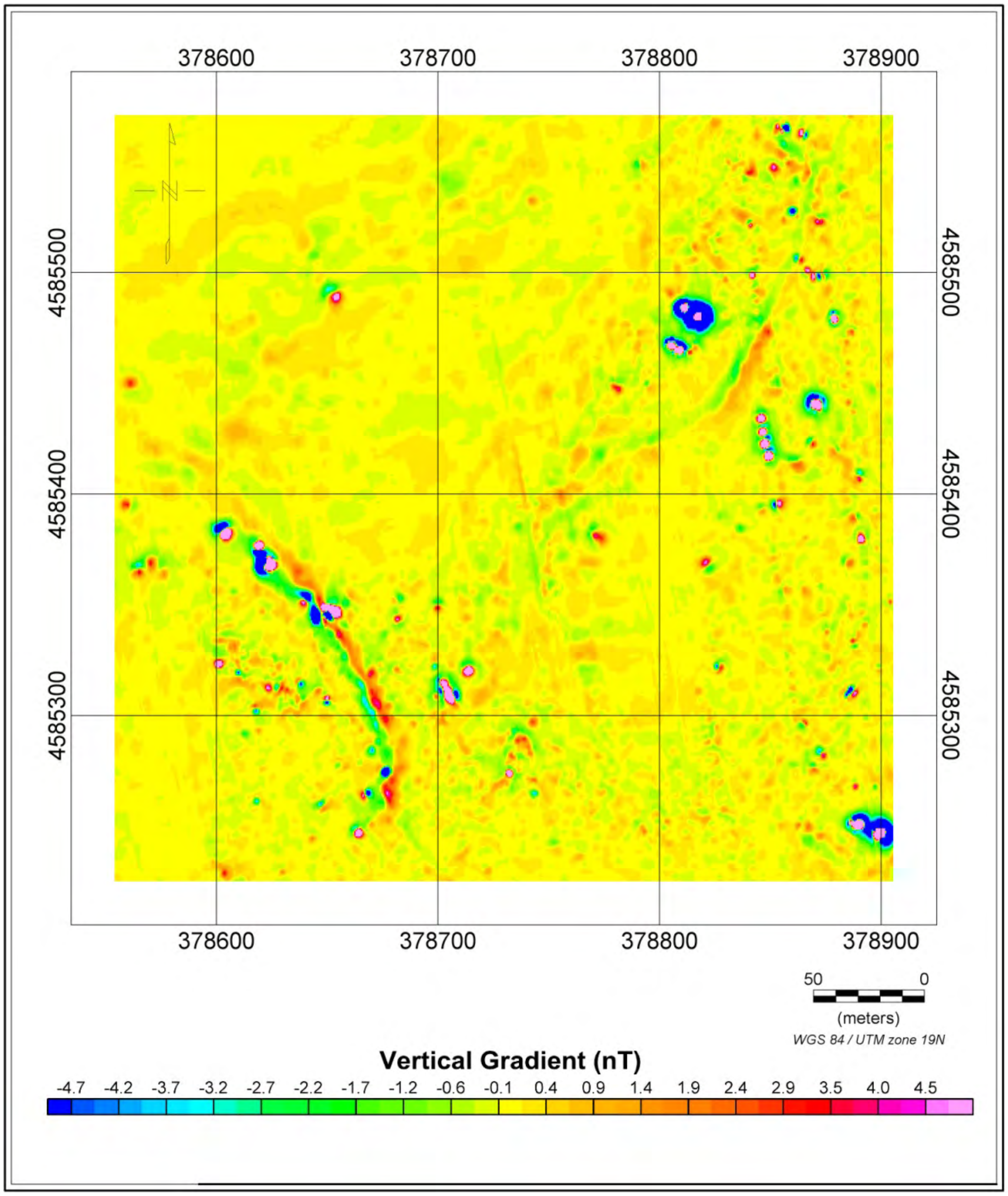


Figure 5-11: Example of geologic anomalies intermingled with others that are presumably associated with man-made items in Cape Poge vertical gradient map.

5.3 South Beach Vertical Gradient, Analytic Signal, and Altitude Maps

Error! Reference source not found. shows a map of the vertical magnetic gradient anomalies at the South Beach site. **Error! Reference source not found.** shows a map of the analytical signal computed from the vertical magnetic gradient data. An altitude map is shown in **Error! Reference source not found.**; the average laser altimeter altitude over the area was 2.34 m. A vertical gradient map with the anomaly picks is shown in Figure 5.1-14. This anomaly maps shows the location of the 4,349 picks for South Beach. Data for the South Beach survey were collected over February 10th and 11th with the a few reflights due to data gaps on February17th.

A total of 4,349 anomalies were selected and divided into three priority groups as shown in Table 5-3 . Priority 1 group included 2254 anomalies. These had analytic signal amplitudes greater or equal to 2 nT. The Priority 2 group included 776 anomalies. These had analytic signal amplitudes less than 2 nT and greater than 1 nT. The Priority 3 group included 1319 anomalies. These anomalies had analytic signal amplitudes less than or equal to 1 nT and greater than or equal to 0.5 nT. The prioritization scheme was chosen based upon the GPO results.

Table 5-3: Geophysical Test Line results for five separate flight altitudes; 1m, 2m, 3m, 4m, and 5m.

South Beach - 4349 total anomalies		
Priority 1 group	Priority 2 group	Priority 3 group
2254	776	4349

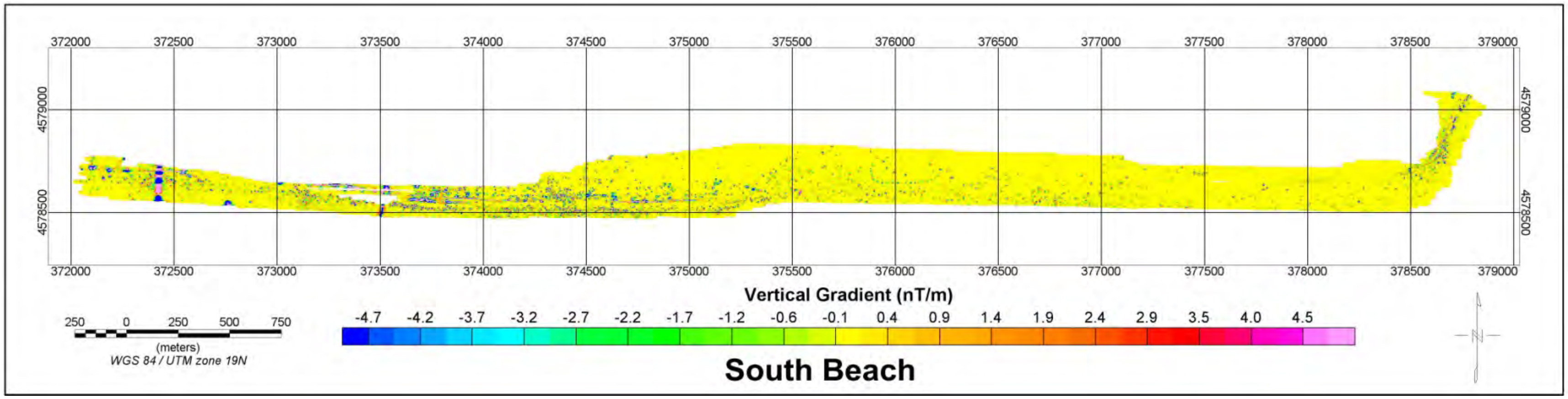


Figure 5-12: Vertical magnetic gradient map of South Beach. The scale of the vertical gradient is -3 to 3 nanoTesla/meter.

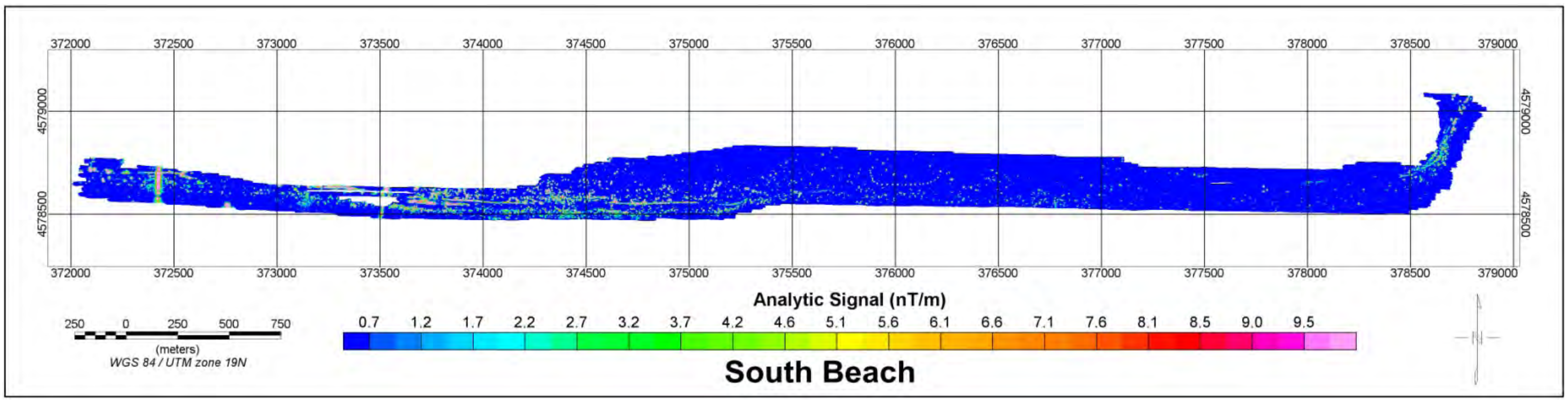


Figure 5-13: Analytic Signal map of South Beach. The scale of the analytic signal is 0.5 to 5 nanoTesla/meter.

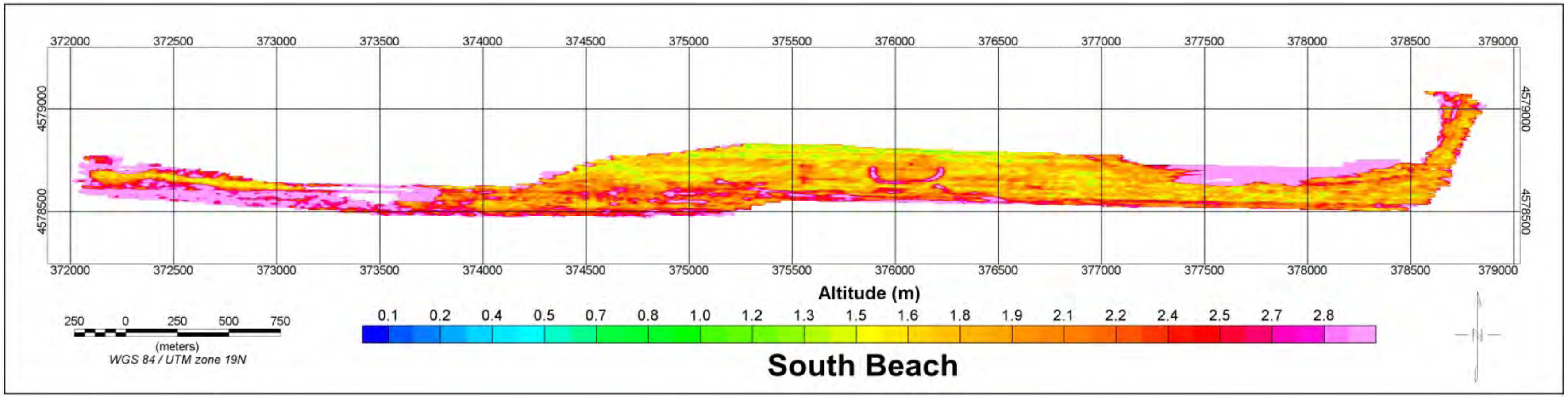


Figure 5-14: Altitude map of South Beach.

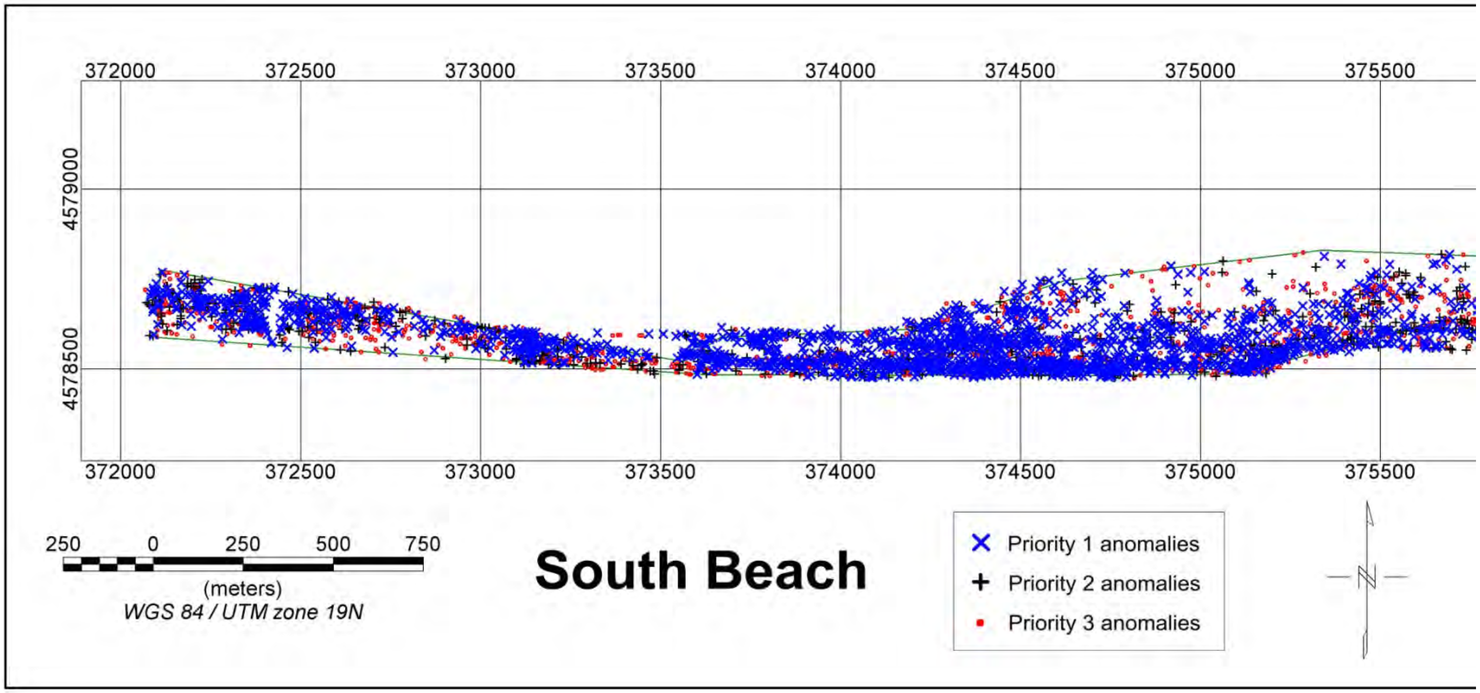


Figure 5-15: Anomaly map for the eastern portion of South Beach.

5.4

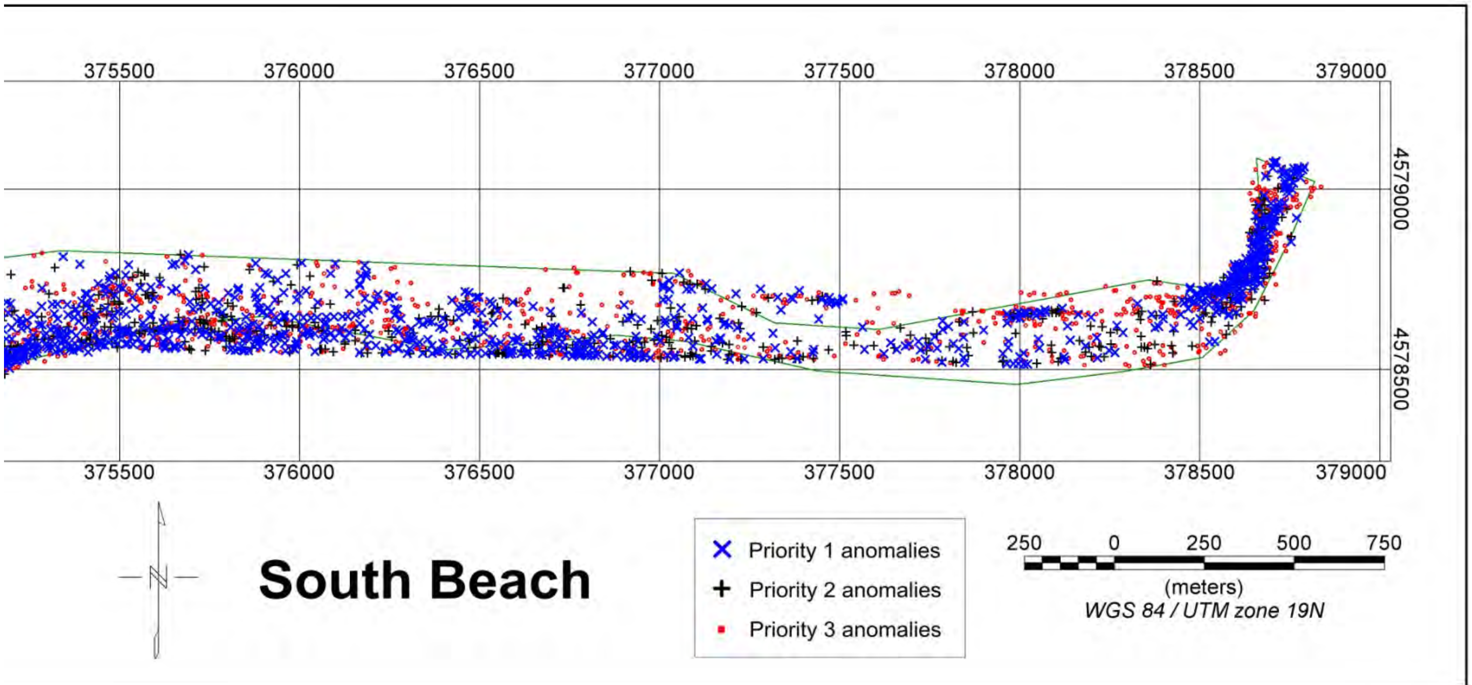


Figure 5-16: Anomaly map for the western portion of South Beach.

5.5 Anomaly Lists

Anomalies are picked from the peaks in the analytic signal map. An inversion was then run on the pick lists for each of the areas. The actual target location is usually within 75cm, of this peak/inversion location. The inversion results of the GPO test line were analyzed and sorted using different inversion results; amplitude, orientation, RMS fit, etc. Sorting with the analytic signal provided the most effective prioritization. The targets were then broken up into three separate groupings; Priority 1, Priority 2, and Priority 3. The thresholds used to select the thresholds between the different groups were based up the GPO results. Priority 1 group had analytic signal amplitudes greater or equal to 2 nT. The Priority 2 group included anomalies with analytic signal amplitudes less than 2 nT and greater than 1 nT. The Priority 3 group anomalies had analytic signal amplitudes less than or equal to 1 nT and greater than or equal to 0.5 nT. The prioritization scheme was chosen based upon the GPO results. For the Priority 1 Group the threshold of 2 nT encompassed the analytic signal results for the majority of the target items on the test grid. The 3lb practice bomb and the Venturi had analytic signals below the 2nT threshold of Group 1, however both of these two targets gave responses higher than 1nT for most of the GPO flights. Geology was present at all three of the Martha's Vineyard sites and the associated anomalies generally fell into the Priority 3 Group.

Table 5-4: Summary table for the anomaly picks for all three areas.

Area	Total Area Surveyed	Total Potential MEC	Group 1 Priority	Group 2 Priority	Group 3 Priority
Tisbury Great Pond	590 acres	3608	1386	722	1500
Cape Poge	347 acres	2447	782	550	1115
South Beach	364 acres	4349	2254	776	1319

6. Data and Image Archive

Geosoft gridded data files were provided to UXB International upon completion of the field component of the project. Although these were preliminary files, they were considered to be sufficiently similar to the anticipated final products that UXB and USAESCH would be able to use them for preliminary assessment of ordnance density in the three areas so that follow-on activities could be planned.

Several files in final form accompany this report. Original Geosoft format files are provided as the principal digital format. This includes database files with georeferenced point data (GDB), and interpolated grid files (GRD). A free data viewer is included with the digital data or is available online at www.geosoft.com (Oasis Montaj Viewer). Map data are provided as image files in GeoTiff format in addition to the smaller reproductions included in this report. These maps are provided with a digital resolution of 300 dpi. GeoTiff format files of the geophysical data alone are provided for quick inclusion into other GIS platforms, but the resolution is not as high as the original Geosoft GRD files. Image files are named as follows;

MV_*area* vg.tif	Vertical gradient map
MV _*area* vg.grd	Vertical gradient grid (Geosoft format)
MV _*area* vg only.tif	Vertical gradient map with data only (for GIS import)
MV _*area* as.tif	Analytic signal map
MV _*area* as.grd	Analytic signal grid (Geosoft format)
MV _*area* as only.tif	Analytic signal map with data only (for GIS import)
MV _*area* alt.grd	Flight altitude grid (Geosoft format)
MV _*area* alt.tif	Flight altitude map
MV _IVS as.tif	Calibration line analytic signal with item locations
MV _IVSvg.tif	Calibration line vertical gradient with item locations

The Geosoft databases (GDB) are the primary data source. They represent the highest data resolution, but have no visual component. Lines in the vertical gradient survey database represent the trace of a single sensor as it travels down the line. Lines are numbered "L####.S", where #### is the survey line number and S is the sensor number (1-7 from left to right across the VG-22 front array). Data columns or channels in the vertical gradient databases are bulleted below.

- Xm Easting coordinate in UTM Zone 19N meters.
- Ym Northing coordinate in UTM Zone 19N meters.
- HAE Height above ellipsoid.
- alt Sensor altitude above ground level in meters.
- vg Total field magnetic values in nanoTesla per meter.
- line Flight line number

The final data type provided is the anomaly list file (also known as a dig list or pick file) in XYZ format. This file is named picks "MV_*area* picklist.XYZ" and contains the following four columns:

- ID number of the specific analytic signal anomaly
- x x coordinate in meters (UTM zone 19N)
- y y coordinate in meters (UTM zone 19N)
- AS magnitude of analytic signal anomaly

7. Conclusions

7.1 Summary

Airborne vertical magnetic data were acquired over 1301 acres at Martha's Vineyard Island. The sizes of the areas flown are as follows; 590 acres of Tisbury Great Pond, 364 acres of South Beach, and 347 acres of Cape Poge. The purpose of the survey was to use geophysical information derived from a low-flying helicopter system to precisely locate metallic items and ordnance. To this end, the VG-22 high-resolution vertical magnetic gradient system developed by Battelle was used. Table 7-1 summarizes the results of the survey.

Table 7-1: Summary Table

Site	Size	Mean altitude	Total number of anomalies	Number of anomalies picked	Collection Dates	Number of reflights lines
Tisbury Great Pond	590 acres	2.03m	3608	Priority 1 = 1386 Priority 2 = 722 Priority 3 = 1500	2/9/11, 2/10/11, 2/14/11, 2/17/11	3 reflight lines
Cape Poge	347 acres	2.49m	2447	Priority 1 = 782 Priority 2 = 550 Priority 3 = 1115	2/11/11, 2/16/11, 2/17/11	0 reflight lines
South Beach	364 acres	2.42m	4349	Priority 1 = 2254 Priority 2 = 776 Priority 3 = 1319	2/10/11, 2/11/11	6 reflight lines

7.2 Performance Evaluation

The results from the Geophysical Prove-Out (GPO) line demonstrate that the system performed well. These targets were considered representative of the range of the UXO expected on site. Prior to placement of the calibration targets, the area was swept with a man-portable magnetometer to determine the presence of pre-existing subsurface anomalies. The 5” projectile, 105 projectile, one of 81 mortars, and one of the 3” rockets were detected 100% of the time on the GPO line. The second 81 mortar the 3” rocket, the 3lb practice bomb, and the venturi were detected 87.5% of the time. The 2.75” rocket, 2.25” rocket, and the M38 were all detected 75% of the time while the second 3lb practice bomb was detected 62.5% of the flights over the GPO line (refer to Table 4.1). This gives an overall target detection of 86%. The location accuracy was calculated from the difference between item locations as recorded by post-processed GPS readings and airborne locations based on the analytic signal maps and inversion results, as determined by automated picking algorithms. Figure A-8 shows the distribution of airborne anomalies against the ground anomalies. The standard deviation of the radial offset is 38cm showing the consistency of the airborne data.

Appendix A **Battelle Quality Control Report**

A-1 **Introduction**

These tables, together with daily maps of various Quality Control (QC) parameters, constitute the final QC Report for the Martha's Vineyard Airborne Geophysical Survey Project. Each level of QC test corresponds to a different frequency of trigger event. Some tests are conducted only once per survey (Level A), while others are conducted on a point-by-point basis throughout the entire dataset (Level D). A description of the various parameters is provided in the QC Work Plan (see Appendix). Individual specifications may be modified by the Mission Plan or by special exception with the concurrence of the client.

Text notes and graphic examples are included for many of the QC items. Parameters which fail the QC test are flagged in red within the table. A note explaining either the exceptional circumstances or the resolution methods taken accompany each QC failure.

A-2 **Level A (Installation)**

These tests are conducted only once at the start of each survey, usually immediately after equipment installation on the helicopter. Some tests were repeated if the magnetometer sensors were altered or replaced during the course of the survey. All results for the following six Level A tests are recorded in Table A-3.

a) Rotor susceptibility

- Trigger: Prior to mob or on new equipment installation.
- Description: The rotor head is the source of 6.5Hz magnetic noise in the data. Its parts should be measured with a Gaussmeter prior to mobilization if possible. This allows the helicopter company to de-Gauss the head if necessary. If the aircraft has not been tested within the last 6 months this test must be done prior to mobilization. If the aircraft has been in continuous use, or if it has been tested within the last six months then it will be tested prior to each installation. If the specs approach failure limits at any time, then plans should be made to de-Gauss at a convenient maintenance break.
- Pass criteria: <20 if in the field, <10 if in the hangar prior to mob (if >6mo since last test).
- Failure resolution: Remove rotor mast and send for de-Gaussing until it passes.

b) GPS base station

- Trigger: New GPS base station setup.
- Description: The GPS base station should be located at a known survey benchmark (minimum 3rd order to meet DID, preferably 1st order or better). These coordinates are available on-line at http://www.ngs.noaa.gov/cgi-bin/ds_radius.prl. Errors in identifying the monument or typing in the coordinates to the post-processing software will result in an offset to the survey data. The location of a second monument should be measured with a hand-held GPS and differentially corrected. The location error between the measured and published monument positions should be minimal.

- Pass criteria: Maximum location error 20cm.
- Failure resolution: Determine source of error (identification, typo etc) and resolve. This may involved acquiring data from third party GPS stations and recalculating the base station location. Any data collected during this period should be reprocessed after the correct location is determined. Failure of this criteria is not necessarily sufficient reason to fail survey data QC since it can be recovered with additional post-processing.

c) Impulse test for lag

- Trigger: On installation or change of system configuration file in firmware.
- Description: The Battelle airborne system incorporates a small EM coil between the cesium magnetometer and the fluxgate magnetometer. It is triggered manually by the operator and synchronized to the next GPS pulse-per-second. The response from this coil can be seen in the magnetometers and is used to determine the electronic latency or lag between the GPS time and the magnetometers. This number is used in subsequent processing routines. It has no pass/fail criteria but is critical to data positioning.
- Pass criteria: N/A
- Failure resolution: N/A

d) Static noise with heli off

- Trigger: On installation or change of magnetometer.
- Description: A brief data file is collected with the helicopter turned off. The 4^{th} difference noise parameter is automatically output, and the standard deviation is calculated. This test may require relocating the helicopter to a lower noise environment away from the concrete runway.
- Pass criteria: Standard deviation of 4^{th} difference channel over 1s <0.2 nT/m/(sample)^4.
- Failure resolution: Replace sensor and retest until pass.

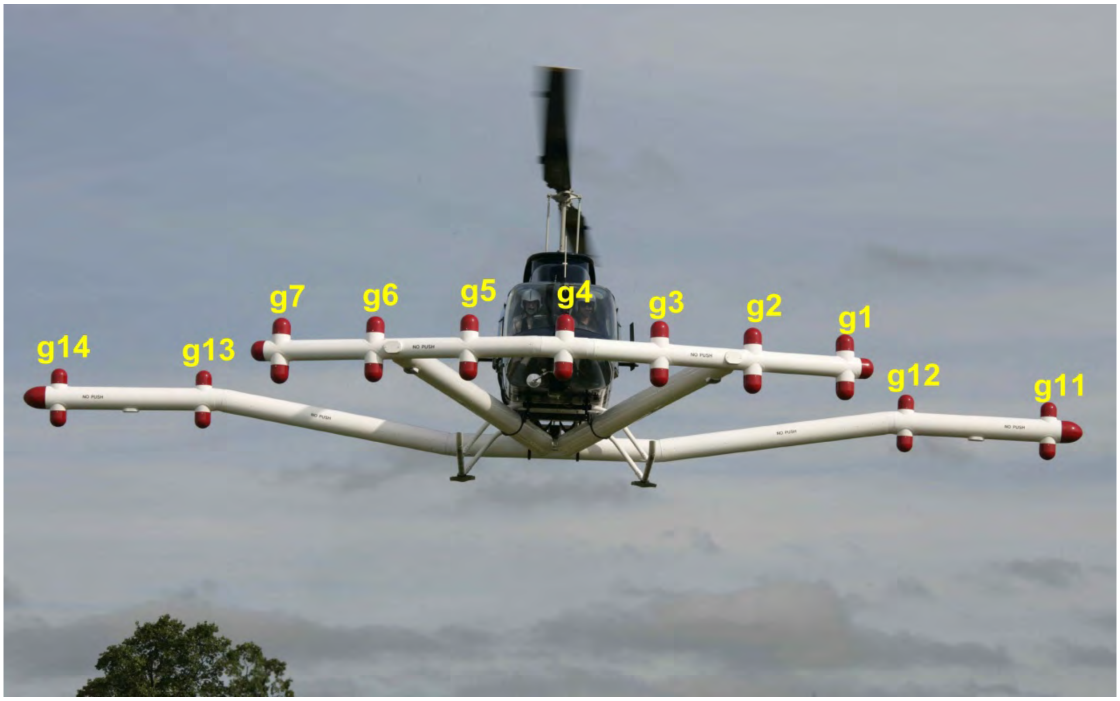


Figure A-1: Diagram showing the locations of each of the 11 gradients. Gradients 1-7 are located in the front array, while gradients 11-14 are located in the back lateral array.

Table A-1: Table of gradient calculations. Gradients equal the lower magnetometer minus the upper magnetometer divided by the magnetometer's separation distance (0.5 meters). Lm stands for Lateral magnetometers (see Figure A-1).

Gradient	Gradient Calculation
grad1	(mag1 -mag2) / 0.5m
grad2	(mag3 -mag4) / 0.5m
grad3	(mag5 -mag6) / 0.5m
grad4	(mag7 -mag8) / 0.5m
grad5	(mag9 -mag10) / 0.5m
grad6	(mag11 -mag12) / 0.5m
grad7	(mag13 -mag14) / 0.5m
grad11	(Lm1 -Lm2) / 0.5m
grad12	(Lm3 -Lm4) / 0.5m
grad13	(Lm5 -Lm6) / 0.5m
grad14	(Lm7 -Lm8) / 0.5m

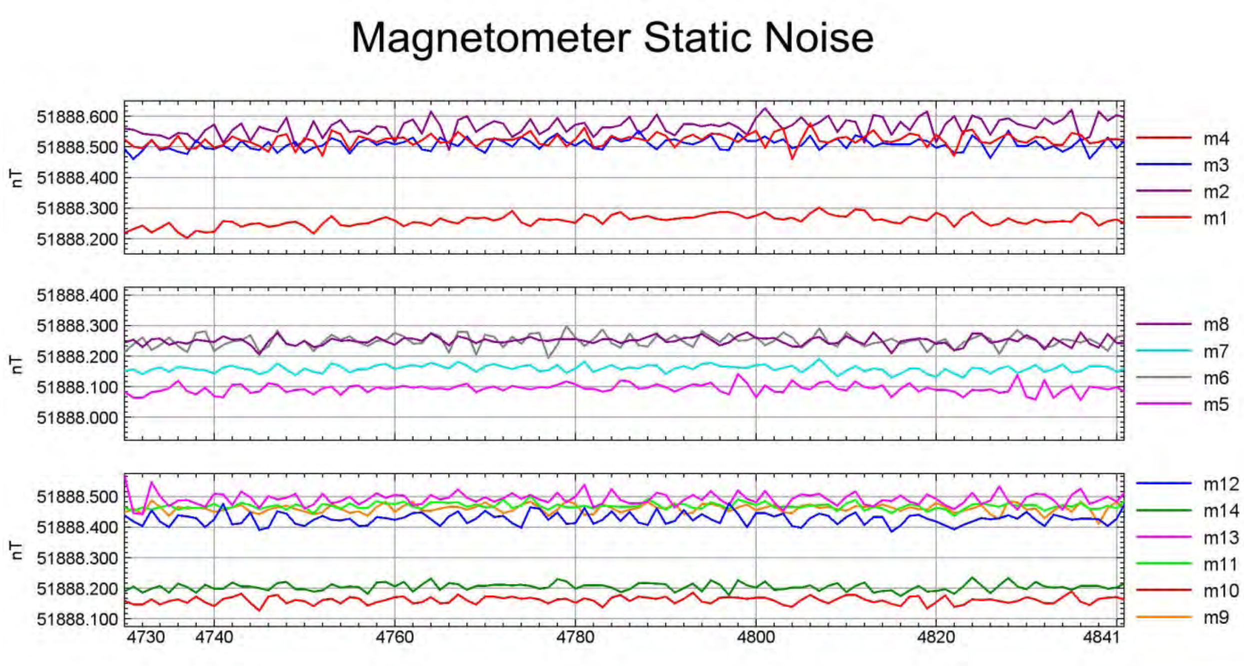


Figure A-2: Profiles show the front 14 magnetometers (for gradients 1-7) static noise levels while the helicopter is shut off.

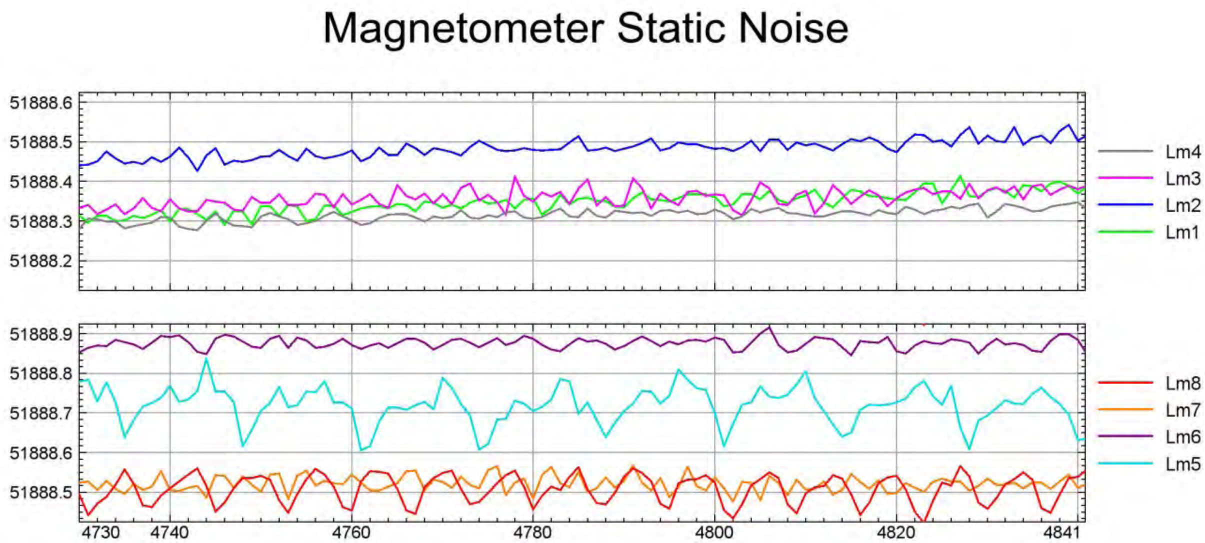


Figure A-3: Profiles show the lateral 8 magnetometers (for gradients 11-14) static noise levels while the helicopter is shut off.

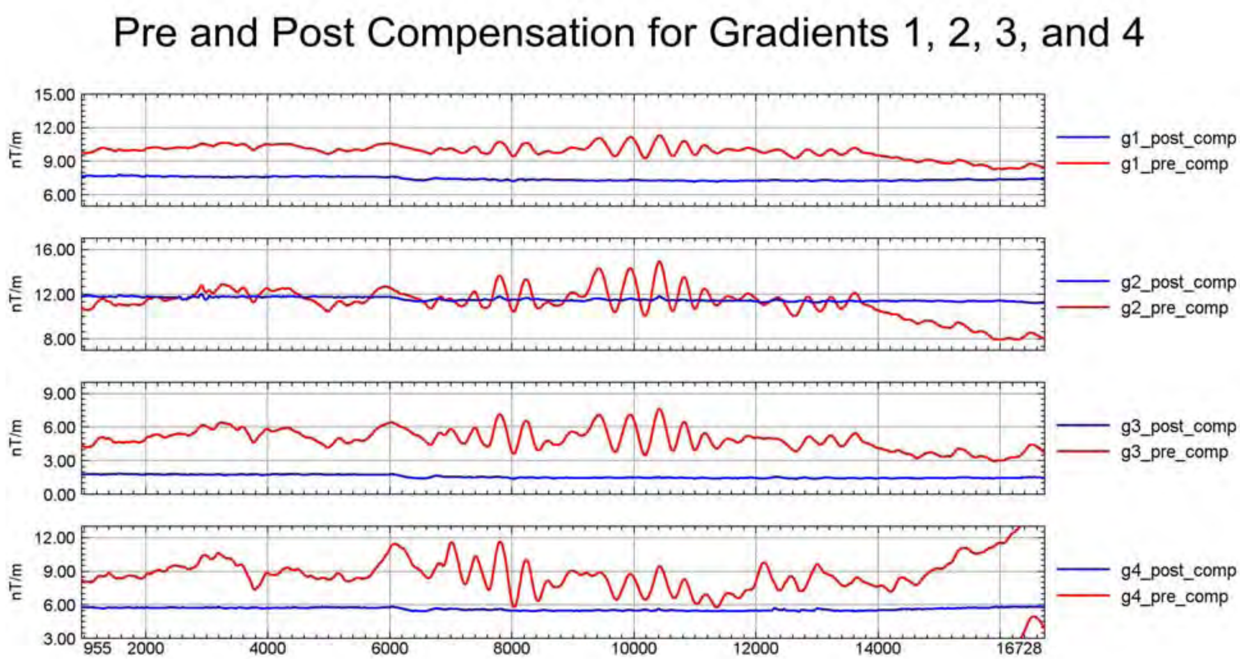


Figure A-4: Profiles show gradiometers 1-4 static noise levels while the helicopter is shut off. The pre comp values represent the static noise levels before compensation was applied, post comp values represent the static noise levels once compensation has been applied.

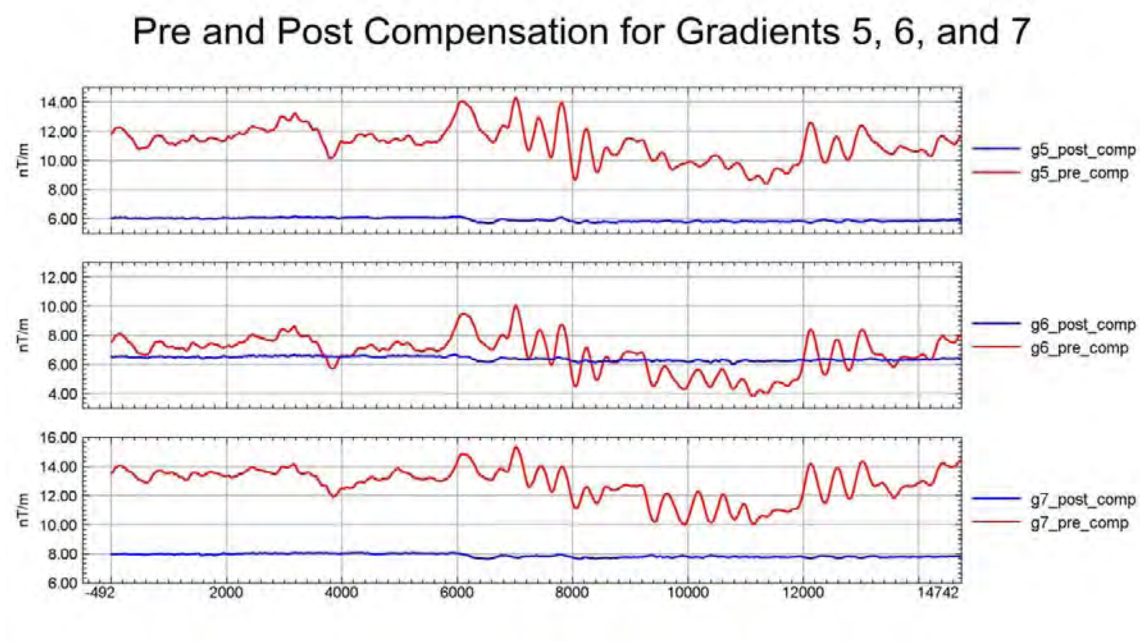


Figure A-5: Profiles show gradiometers 5-7 static noise levels while the helicopter is shut off. The pre comp values represent the static noise levels before compensation was applied, post comp values represent the static noise levels once compensation has been applied.

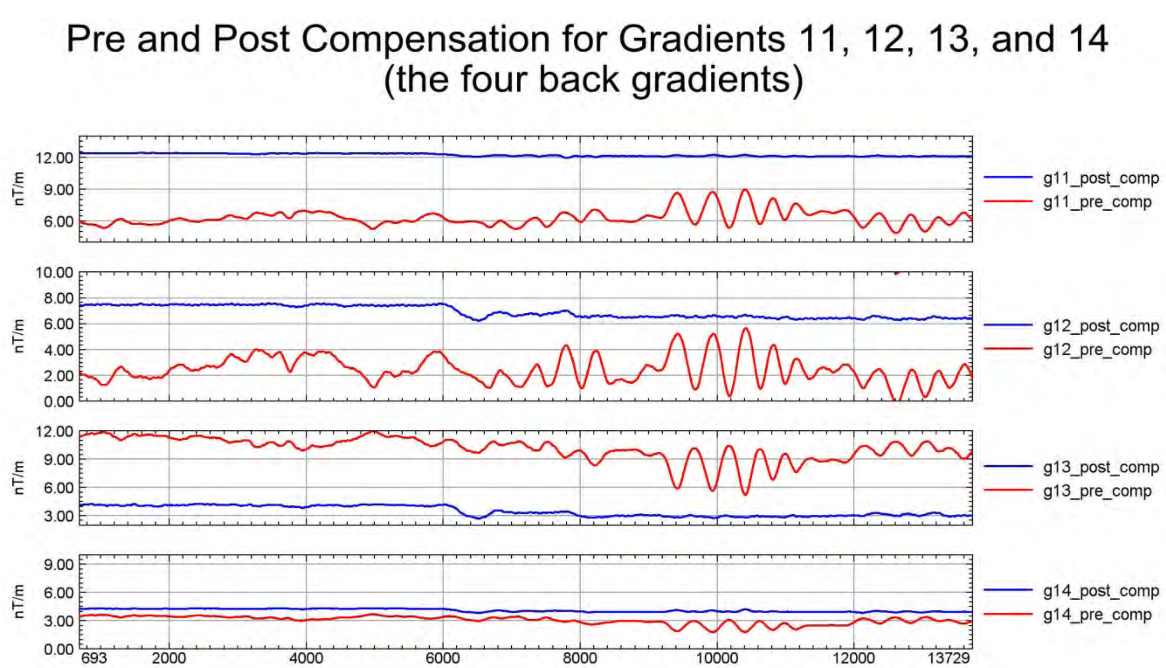


Figure A-6: Profiles show gradiometers 1-4 static noise levels while the helicopter is shut off. The pre comp values represent the static noise levels before compensation was applied, post comp values represent the static noise levels once compensation has been applied.

e) Standard target response

- Trigger: Equipment installation or mag sensor replacement
- Description: A single target will be dragged on the ground beneath the sensor pods without the helicopter running, and the response amplitude will be compared for consistency across the array.
- Pass criteria: Maximum +/-20% of average gradient amplitude.
- Failure resolution: Replace faulty sensor and repeat until pass. Faulty sensors will be returned to the manufacturer for servicing.

Table A-2 shows the target responses for each of the survey days. The responses on February 14th and 17th were lost due to a noise source which masked the data. The helicopter was more than likely parked over or near a significant noise for these two days. Gradient 13 and Gradient 14 were inconsistent and this may also be due to where the helicopter was parked during the testing. If the helicopter was not positioned in the exact same position as the day before, where the previous test was performed, then the responses will vary.

Table A-2: Standard target response table showing the vertical gradient responses for each gradient.

	Gradient 1	Gradient 2	Gradient 3	Gradient 4	Gradient 5	Gradient 6	Gradient 7	Gradient 11	Gradient 12	Gradient 13	Gradient 14
Vertical Gradient on 2/9/2011	*	64.4	64.1	65.3	67.8	71.5	73.0	33.7	36.6	26.2	36.3
Vertical Gradient on 2/11/2011	66.3	64.3	64.7	61.5	62.7	64.6	66.8	40.9	34.0	28.1	33.7
Vertical Gradient on 2/12/2011	56.9	61.4	66.6	65.3	73.8	82.8	92.0	35.1	27.8	69.9	81.7
Vertical Gradient on 2/13/2011	54.7	59.0	60.4	59.3	69.6	79.2	90.0	32.9	30.0	59.8	76.8

f) Aeromagnetic compensation FOM/IR

- Trigger: Equipment installation or mag sensor replacement.
- Description: The Figure of Merit (FOM) and Improvement Ratio (IR) is a measure of the absolute and relative effectiveness of the compensation coefficients. The FOM is measured as the sum of the average peak-peak deflection which remains in the calibration flight data after compensation. The calibration flight consists of twelve distinct movements in a continuous data stream. These movements include pitch, roll and yaw in each of the four cardinal directions (N,S,E,W). After application of the compensation correction, the average peak-peak residual is measured for each movement and the sum is the FOM. With perfect compensation, the FOM will equal 12x the noise floor. The IR is defined as the ratio of the standard deviation of the calibration flight data before and after compensation correction.
- Pass criteria: FOM 10nT/m, IR 10:1
- Failure resolution: Recalculate the coefficients based on a different subset of the original data, or refly the calibration flight until it passes.

g) Summary of Level A Tests

Table A-3: Level A Test Results (Installation)

Test	Pass/Fail	Measurement	made by
rotor susceptibility	Max 1 nT	Max 0.25 nT	J. Gamey
GPS base accuracy	Max 20cm	11cm	J. Norton
response latency	N/A	33pts	J.Norton
sensor noise (heli off)	Max $0.5nT/m/s^4$	Average $0.01nT/m/s^4$	J.Norton
target response -1 (gradient 1)	Max ±20%	8 %	J. Norton
target response -2 (gradient 2)	Max ±20%	3 %	J. Norton
target response -3 (gradient 3)	Max ±20%	3 %	J. Norton
target response -4 (gradient 4)	Max ±20%	4 %	J. Norton
target response -5 (gradient 5)	Max ±20%	5 %	J. Norton
target response -6 (gradient 6)	Max ±20%	9 %	J. Norton
target response -7 (gradient 7)	Max ±20%	1 %	J. Norton
target response -8 (gradient 11)	Max ±20%	7 %	J. Norton
target response -9 (gradient 12)	Max ±20%	10 %	J. Norton
target response -10 (gradient 13)	Max ±20%	25.9 %	J. Norton
target response -11 (gradient 14)	Max ±20%	21.5 %	J. Norton
compensation FOM	Max 10nT	1.46 nT	J. Norton
compensation IR	Min 10x	10.35x	J. Norton

A-3 **Level B (GPO)**

Depending on the project and local availability, the Geophysical Prove-out (GPO) grid may be an extant site, a custom airborne site, or a few target items laid out on the surface. For the GPO at the Martha's Vineyard Airport, 12 items of interest were laid out near one of the airport runways. This GPO was flown at the beginning and end of each day and also in each direction, north and south. The GPO was also flown at five different flight altitudes; 1m, 2m, 3m 5m , and 7m. See Table A-4 for the Level B test results. Figure A-7 is a vertical gradient map of a low altitude flight over the GPO. Items are labeled and the x's indicate the items position of the daily low altitude flights (1-2m). This figure visually shows the picked target locations and offsets.

a) In-flight lag

- Trigger: Over GPO grid
- Description: The GPO will be flown twice in opposite directions. Each direction will be gridded separately. Peak target locations from opposite directions will be used to verify that the latency calculated in the impulse test is accurate.
- Pass criteria: Average location differences not to exceed 50cm.
- Failure resolution: Adjust lag setting until pass. If no single lag is sufficient, double check positioning system accuracy. Repeat until pass.

b) Target detection

- Trigger: Over GPO grid
- Description: Targets of interest and the probability of detection will vary between sites and will be specified in the Work Plan. Anomalies will be selected by an automated picking procedure. Processing and picking parameters will be adjusted until the required detection probabilities are met. The corresponding false positive ratio will then be determined and reported. It is assumed that the false positive ratio is not part of the pass criteria, but is a qualifying parameter.
- Pass criteria: Detection of targets of interest will exceed specifications.
- Failure resolution: Repeat or reprocess until pass.

c) Target location

- Trigger: Over GPO grid
- Description: Having detected a target, this tests how accurately its position is known and represented in the gridded data.
- Pass criteria: Average location differences not to exceed 1m.
- Failure resolution:

d) Summary of Level B Tests

Table A- 4: Level B Test Results (GPO)

Test	Pass/Fail	Measurement	made by
positional lag	max50cm	33cm	J.Norton
target detection	80%	86%	J.Norton

probability			
target position error	max50cm	38cm radius	J.Norton

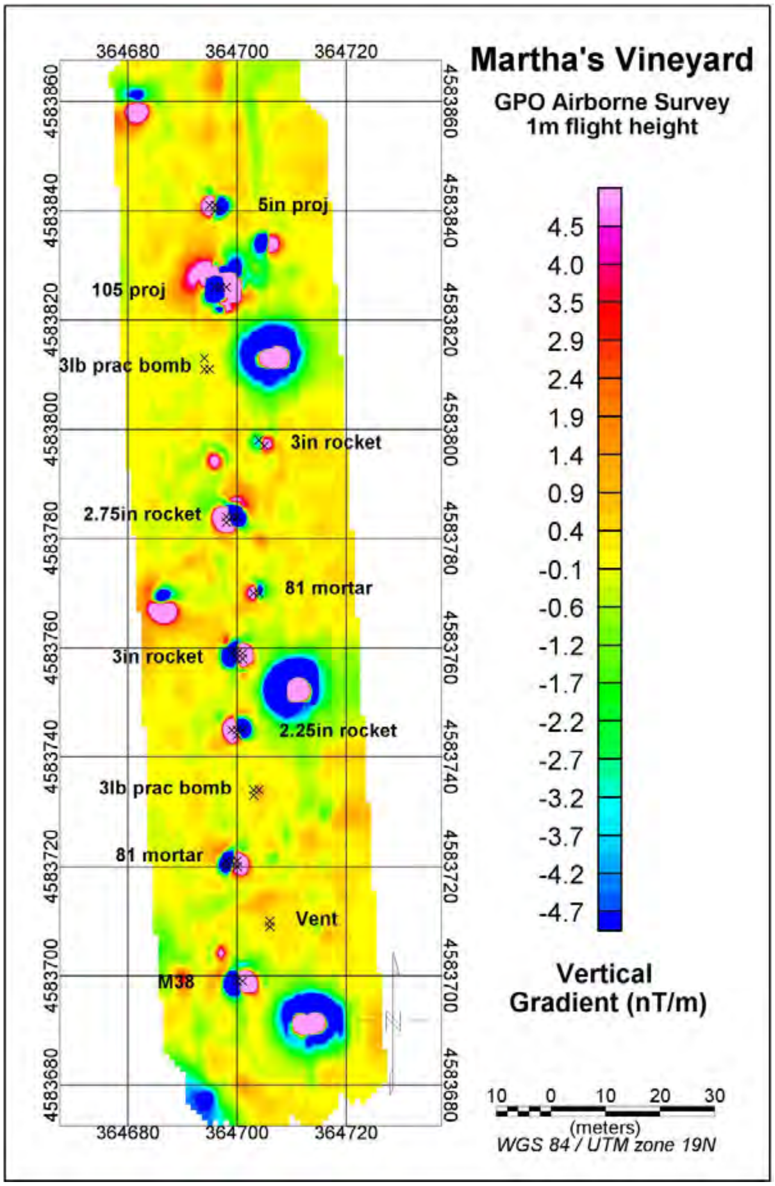


Figure A-7: Vertical Gradient map for GPO test line. Items are labeled and the x's indicate the items position of the daily low altitude flights (1-2m).

- Detection probability was measured from the GPO low altitude test data. All targets were considered detected when seen with automated anomaly picking procedures, see Table A-5. Detection Accuracy was calculated from the difference between item locations as recorded by post-processed GPS readings and airborne locations based on the analytic signal maps as determined by automated picking algorithms. Figure A-8 shows the distribution of airborne anomalies against the ground anomalies. The standard deviation of the radial offset is 38cm showing the consistency of the airborne data.

Table A-5: GPO items detection rates.

Description of item (North to South)	**Detection probability from low altitude test data**
5” projectile	100%
105 projectile	100%
3lb practice bomb	62.5%
3” rocket	87.5%
2.75” rocket	75%
81 mortar	100%
3” rocket	100%
2.25” rocket	75%
3lb practice bomb	87.5%
81 mortar	87.5%
VENT	87.5%
M38	75%

Table A-6: Mean offsets for the GPO test line.

	Mean Offsets
x_off mean	0.15
y_off mean	-0.07
rad_off mean	0.38

Table A-7: Standard deviation of the radial offset for the GPO test line target locations.

	Standard Deviation Offsets
x_off stdev	0.34
y_off stdev	0.30
rad_off stdev	0.33

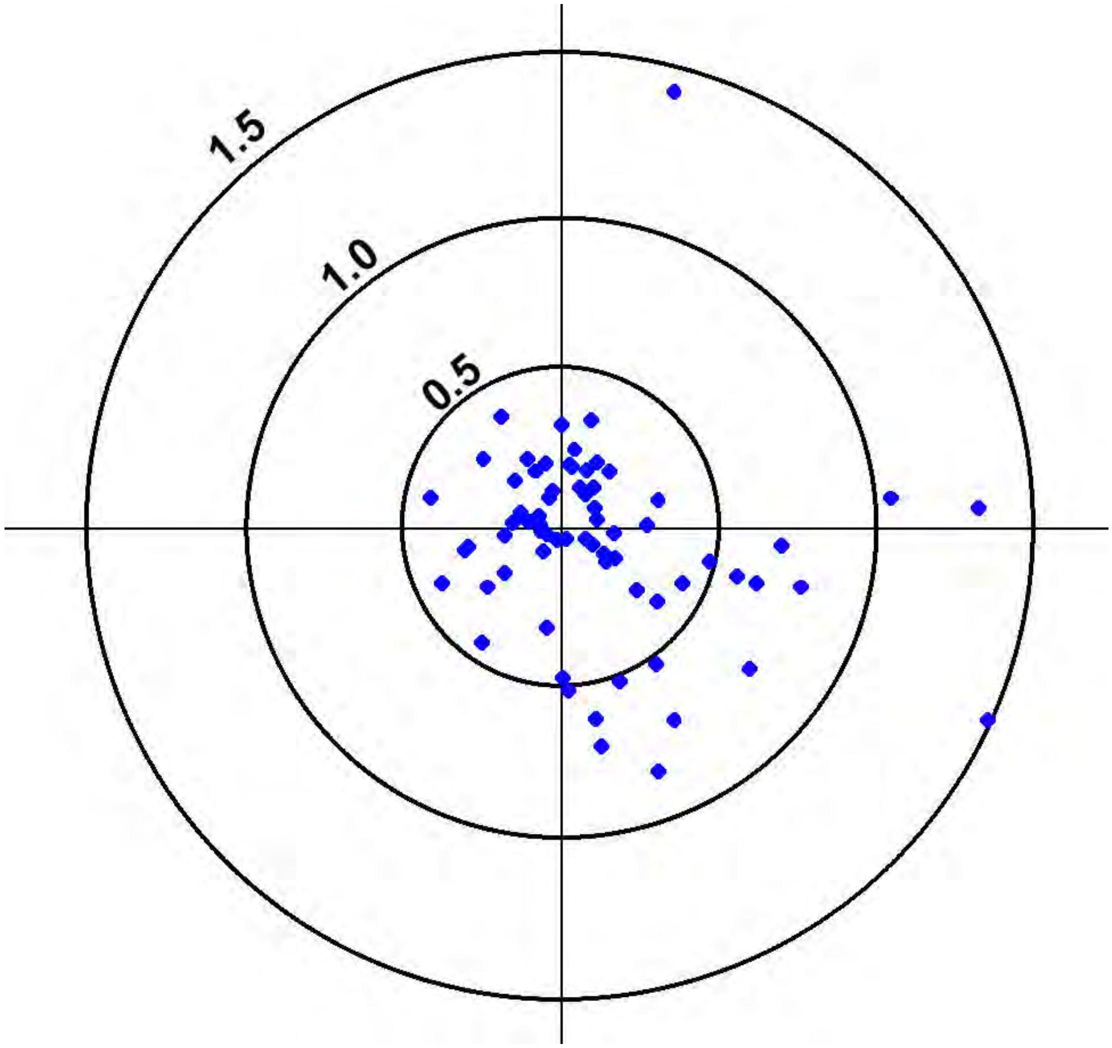


Figure A-8: Standard deviation radial offsets for each target item of each flight for the GPO test line.

A-4 **QC plots**

The results of each day's data collection were subjected to a series of QC tests. These were conducted at the end of each day and problems were reported to the crew by the following morning. Most of these procedures monitored the raw data quality of on-line data for elevated noise levels. A map of each parameter is included in Figures A-9 through A-24. The figures below contain the QC plots for the airborne survey of Martha's Vineyard for Tisbury Great Pond, Cape Poge, and South Beach. These figures include QC plots for altitude, data drops, GPS, noise, and speed. Figures A-9 through A-14 show QC plots for the Tisbury Pond site. The Cape Poge site QC plots are represented in Figures A-15 through A-19. The South Beach QC plots are represented in Figures A-20 through A-24.

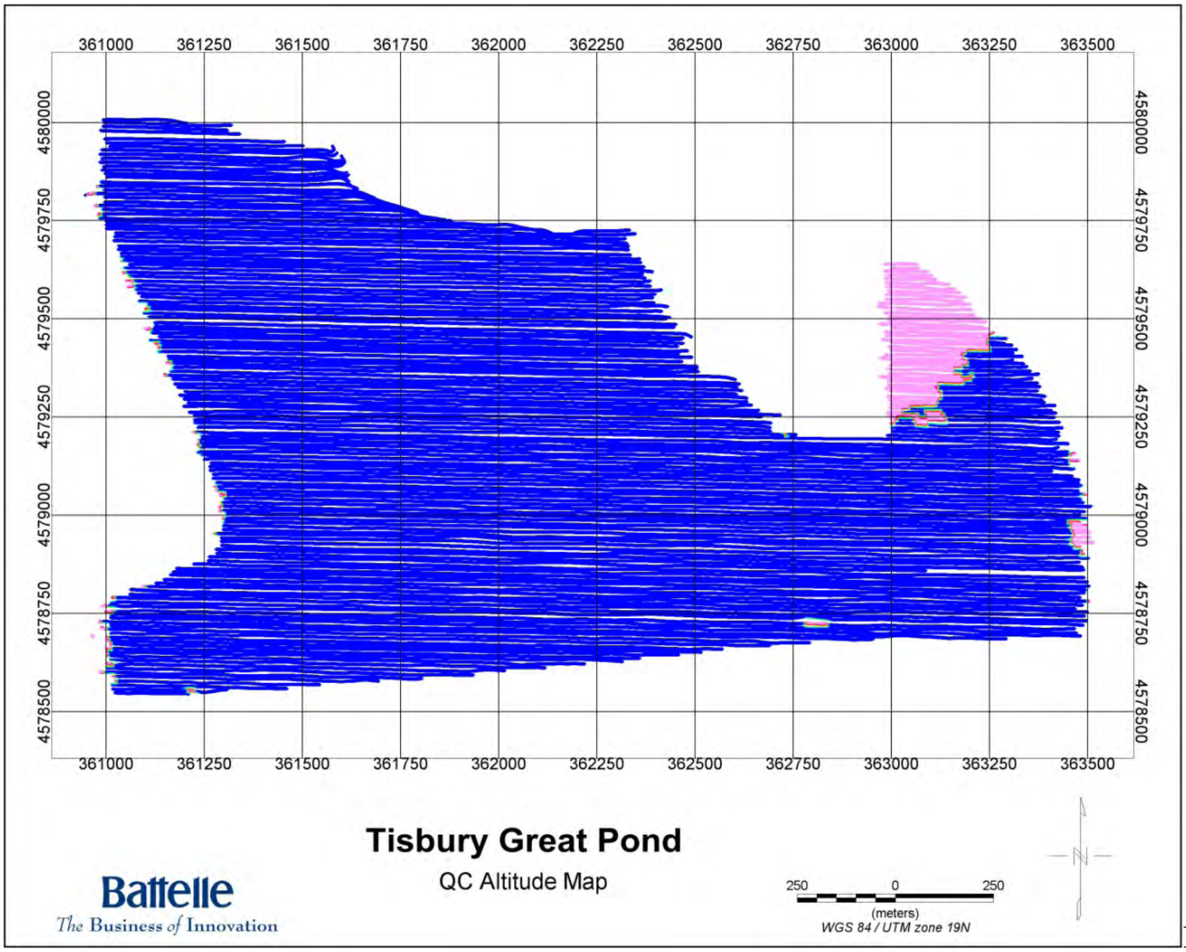


Figure A-9: QC Altitude Map for Tisbury Great Pond. The areas in pink are where the flight altitude reached 5m or more. The high alt sections are due to higher vegetation.

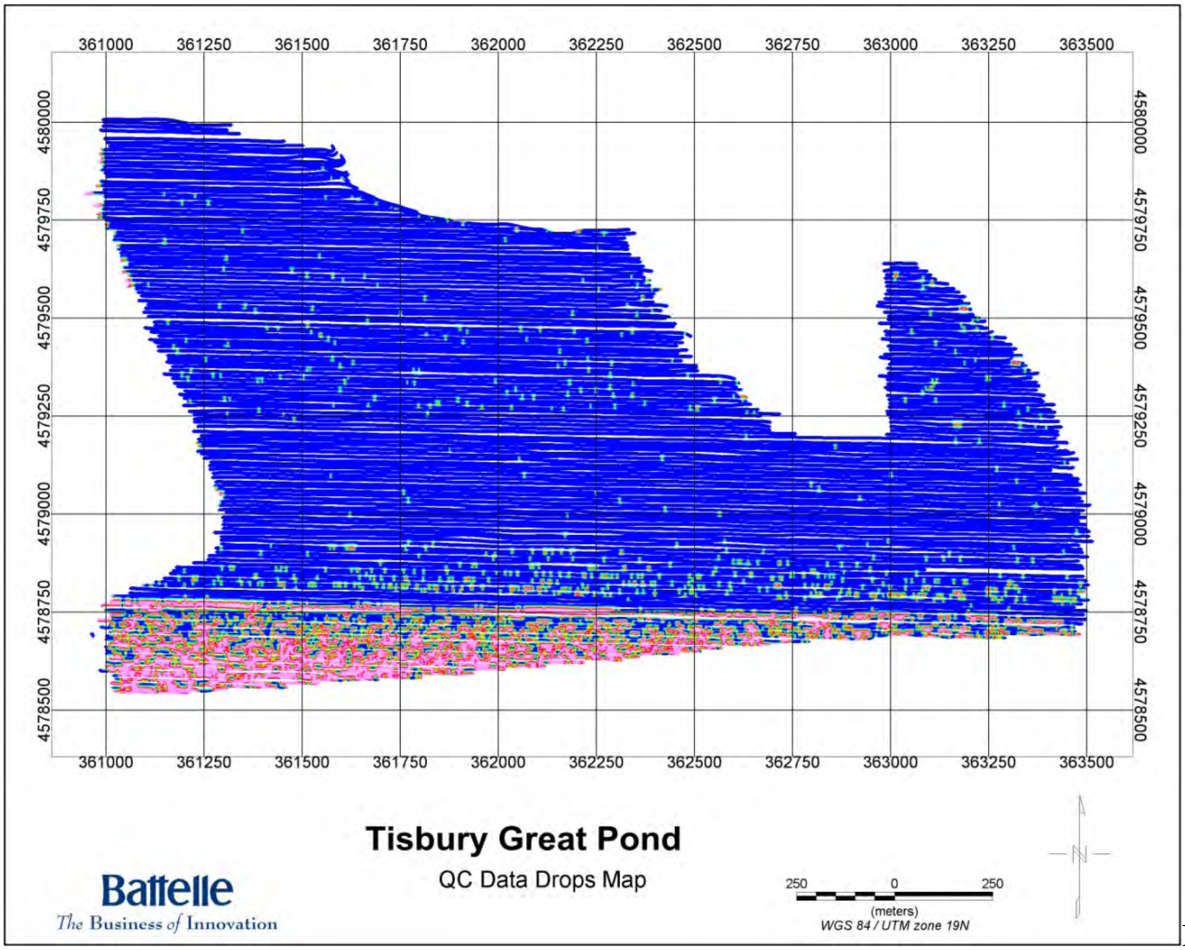


Figure A-10: QC Data Drops Map for Tisbury Great Pond. The pink areas are where there were data drops of more than 2 seconds. A single failing sensor caused the dropouts of some of the data in the southern region. Data were reviewed and it was determined that it was not a critical problem because the sensor was on the front, dense array where sensors have 1m lateral spacing. Therefore, no separation occurred on these data lines that were greater than 2m and hence no data gaps exceeded the threshold.

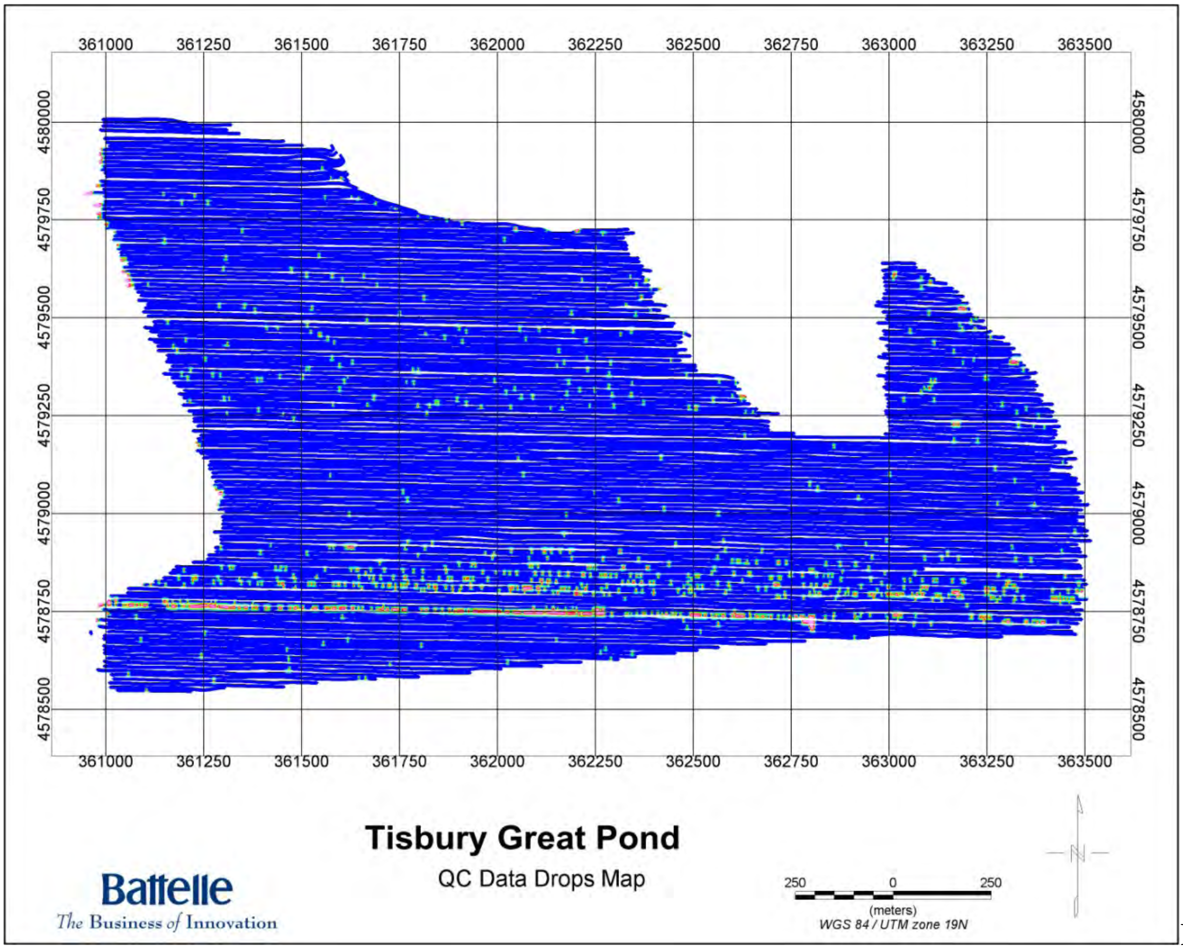


Figure A-11: QC Data Drops Map for Tisbury Great Pond once the failing sensor data were removed.

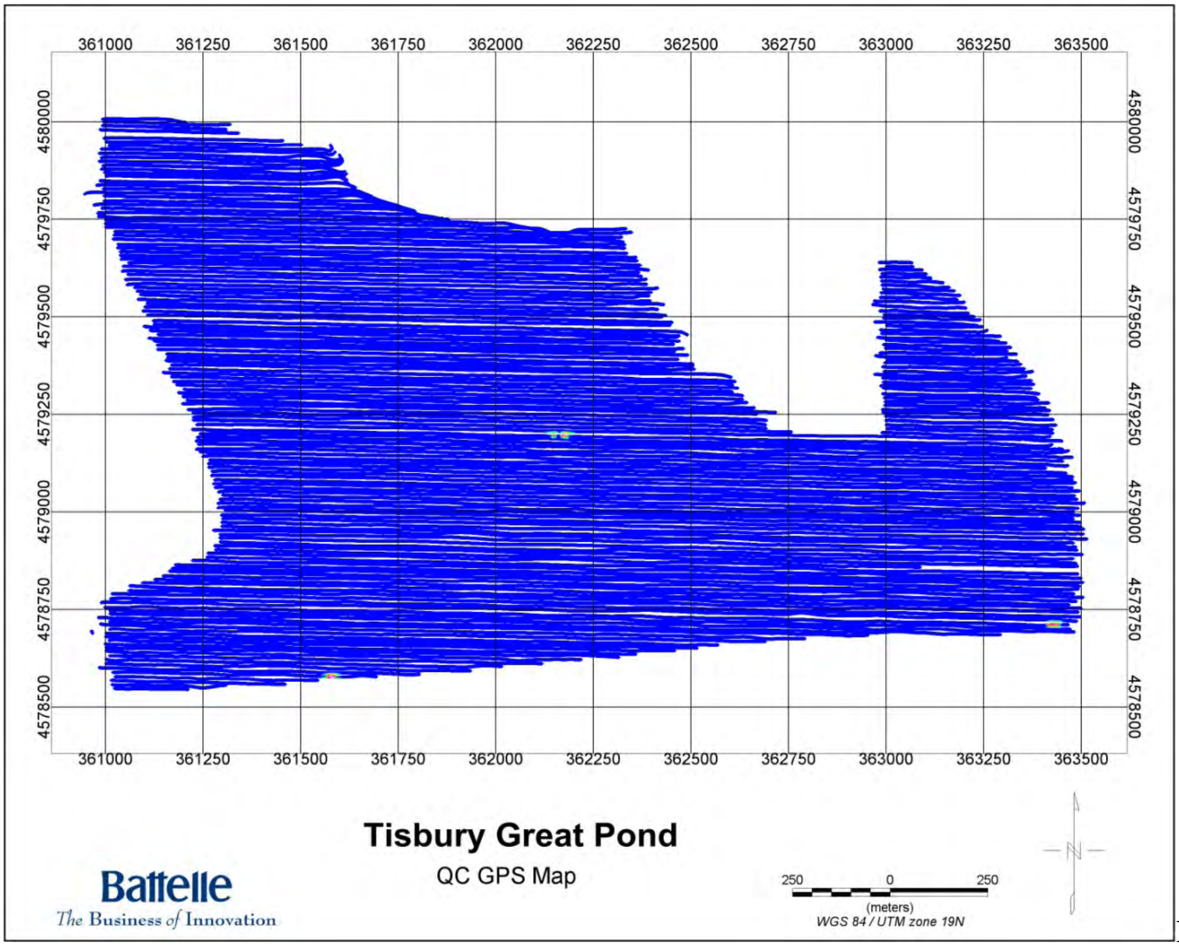


Figure A-12: QC GPS Map for Tisbury Great Pond. The blue areas show where the HDOP of the GPS is greater than 3.5.

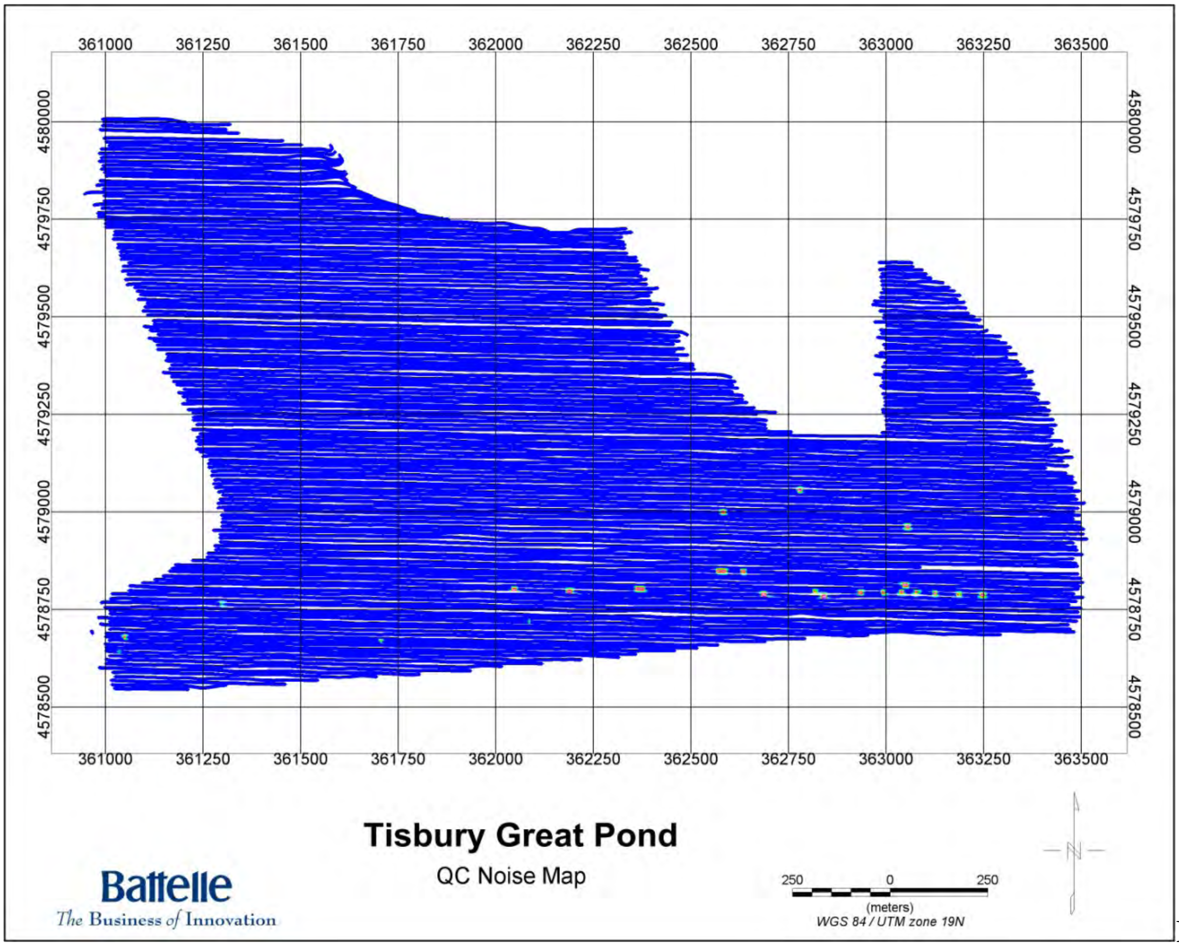


Figure A-13: QC Noise Map for Tisbury Great Pond. The blue represents where the noise was less than $0.5nT/m/s^4$.

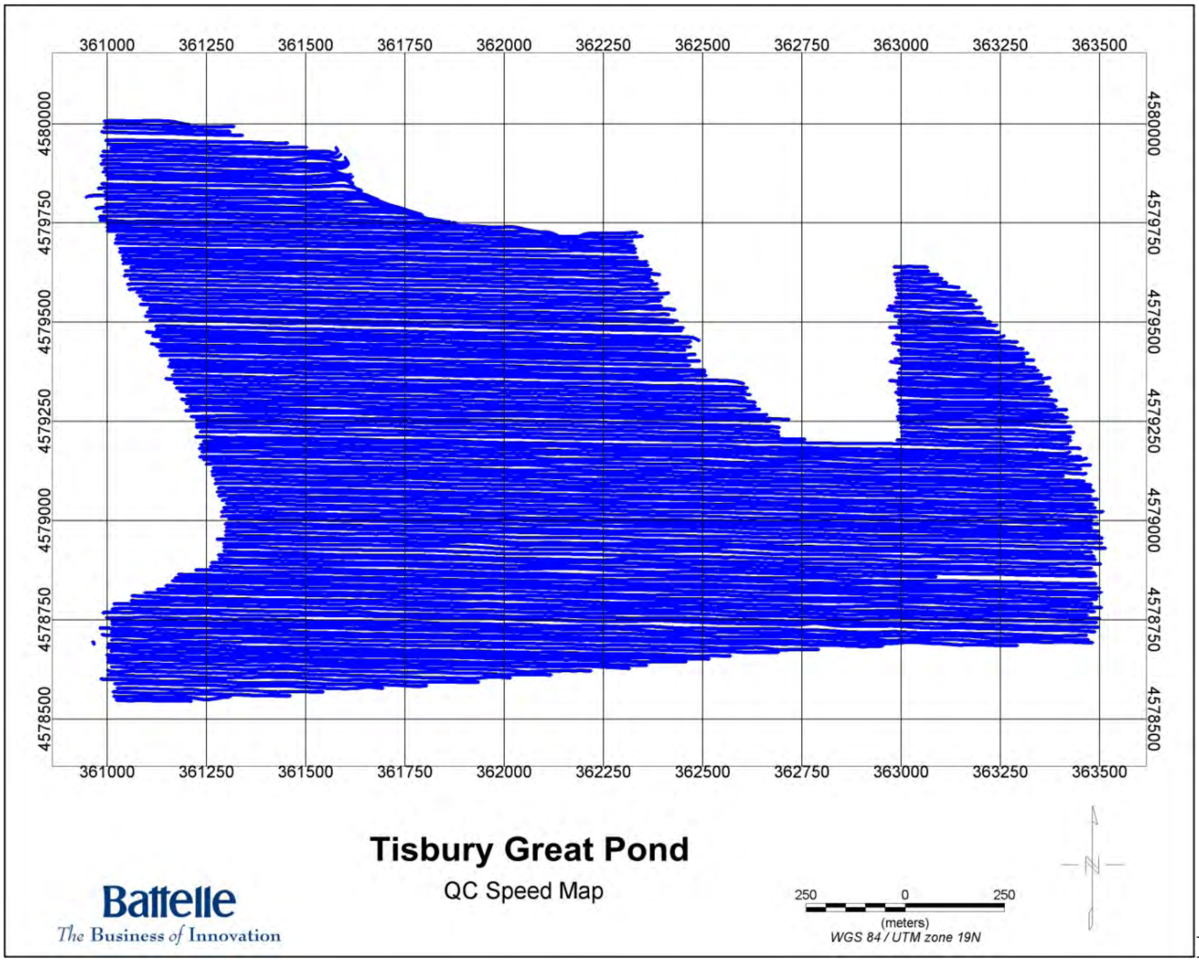


Figure A-14: QC Speed Map for Tisbury Great Pond. The blue represents where the speed of the aircraft is less than 60mph.

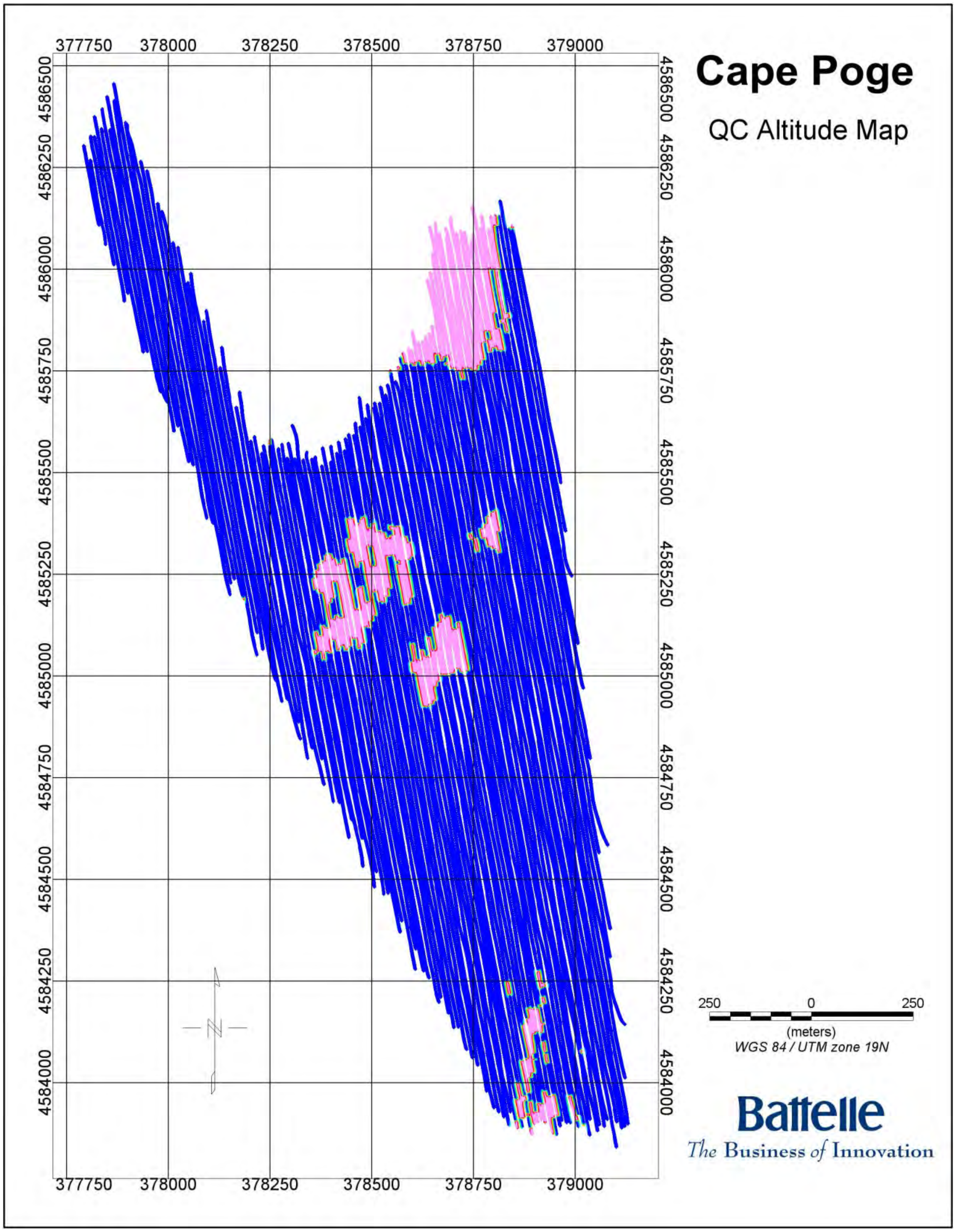


Figure A-15: QC Altitude Map for Cape Poge. The areas in pink are where the flight altitude reached 5m or more. The high alt sections are due to higher vegetation, birds, or manmade obstacles.

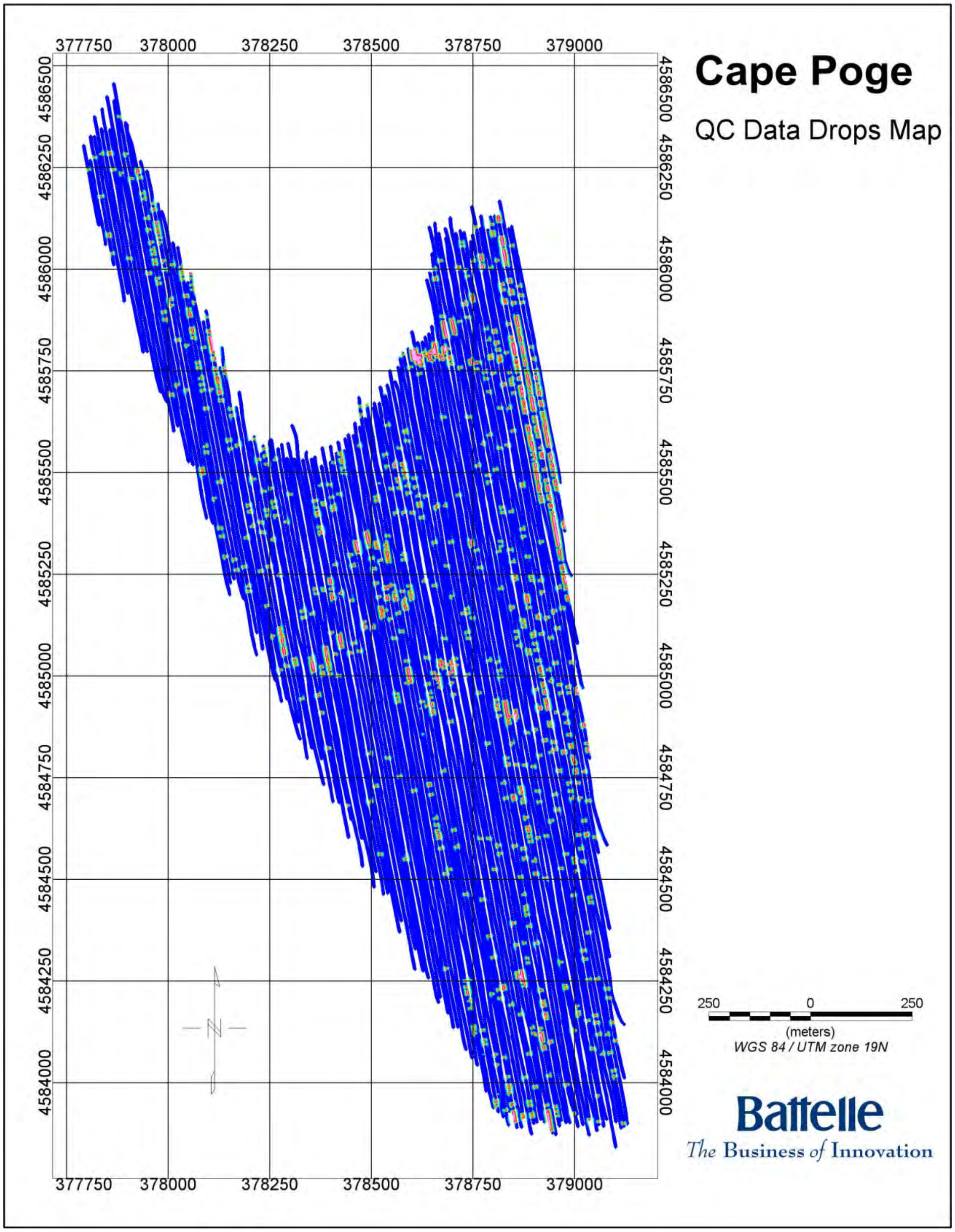


Figure A-16: QC Data Drops Map for Cape Poge. The pink areas represent where there are data drops of more than 2 seconds; however these 2 second drops only occurred over one sensor therefore not created any data gaps (5m x 5m) which would require reflights.

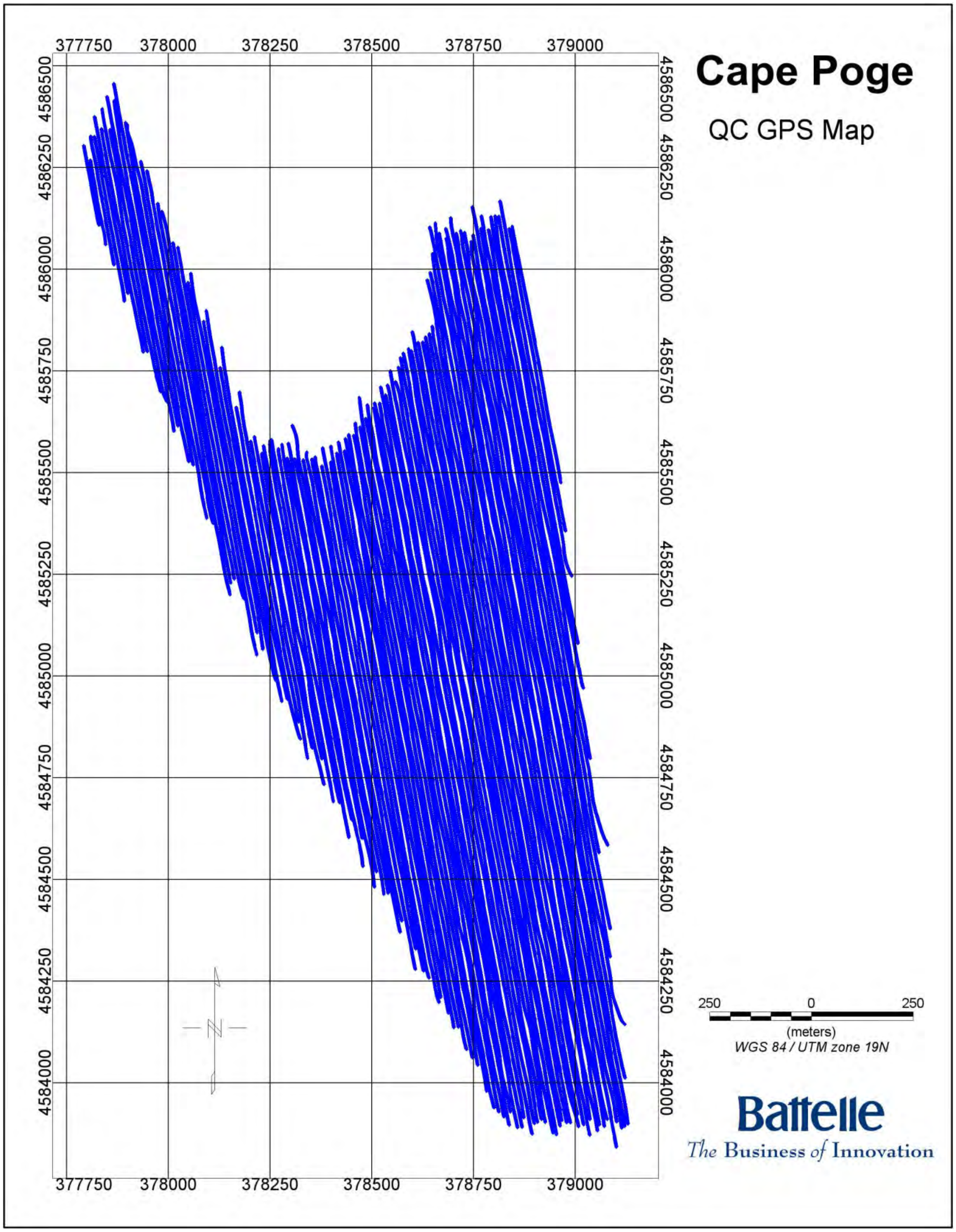


Figure A-17: QC GPS Map for Cape Poge. The blue areas show where the HDOP of the GPS is greater than 3.5.

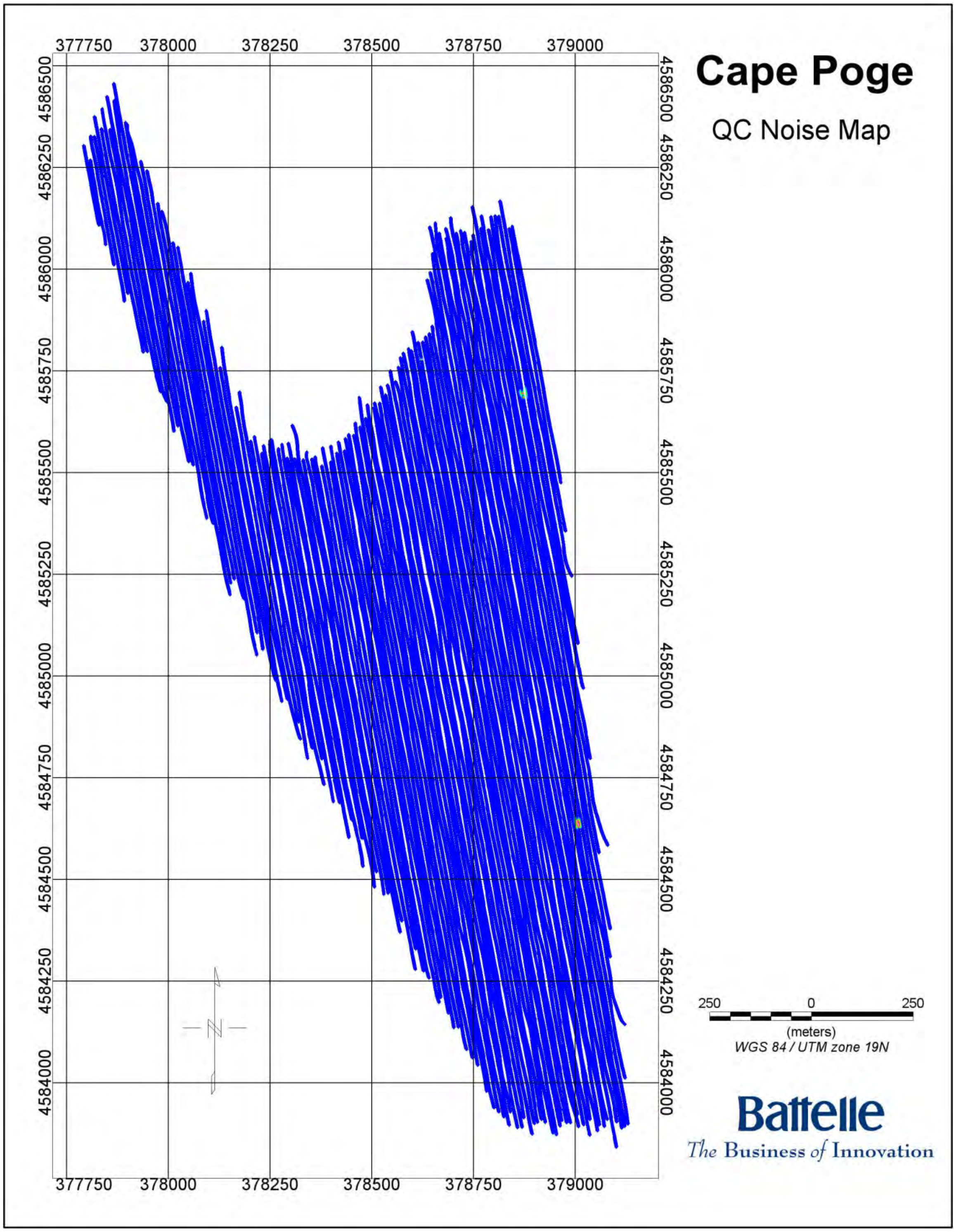


Figure A-18: QC GPS Map for Cape Poge. The blue represents where the noise was less than $0.5 nT/m/s^4$.

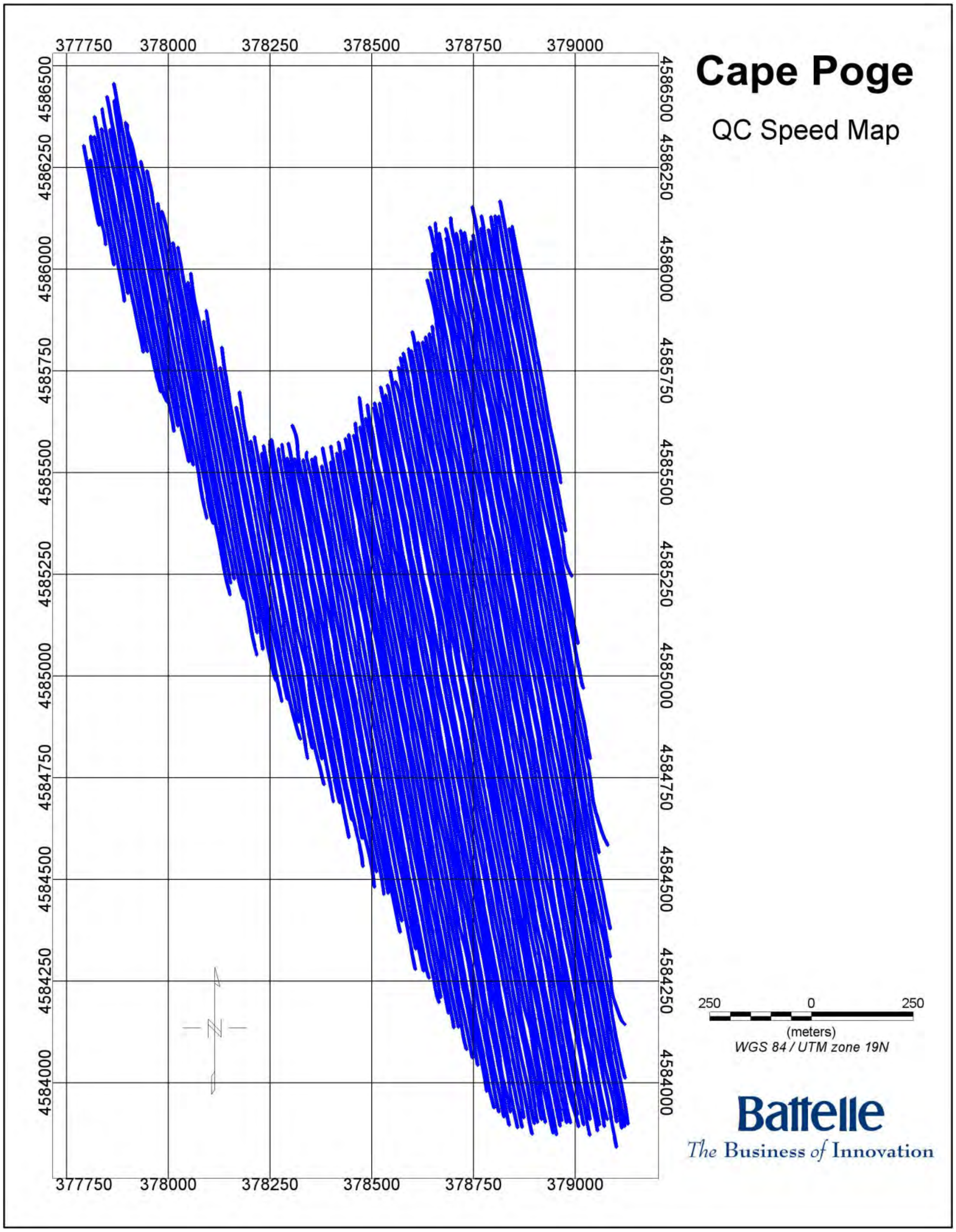


Figure A-19: QC Speed Map for Cape Poge. The blue represents where the speed of the aircraft is less than 60mph.

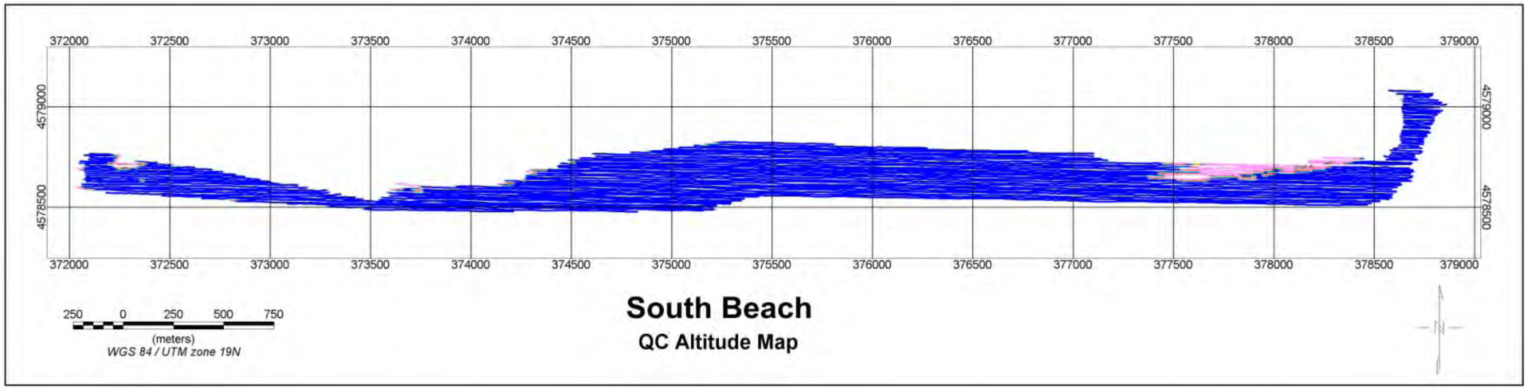


Figure A-20: QC Altitude Map for South Beach. The areas in pink are where the flight altitude reached 5m or more. The high altitude sections are due to higher vegetation or manmade obstacles.

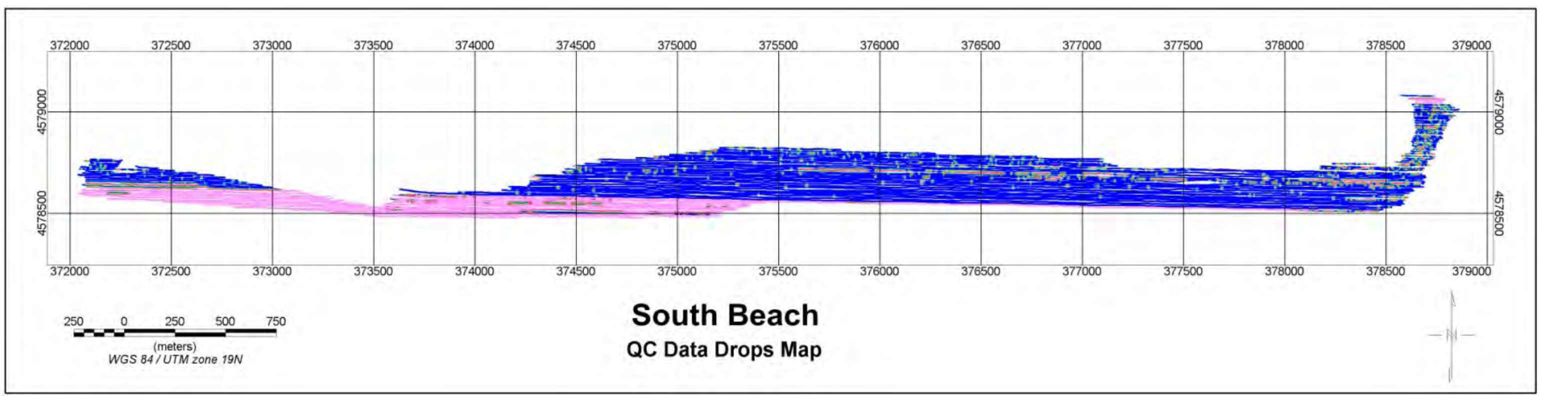


Figure A-21: QC Data Drops Map for South Beach. The pink areas represent where there are data drops of more than 2 seconds. A failing sensor caused the dropouts of the data in the southern region, as previously shown for Tisbury Great Pond, the data were reviewed and it was determined that it was not a critical problem because the sensor was on the front, dense array and hence does not leave data gaps.

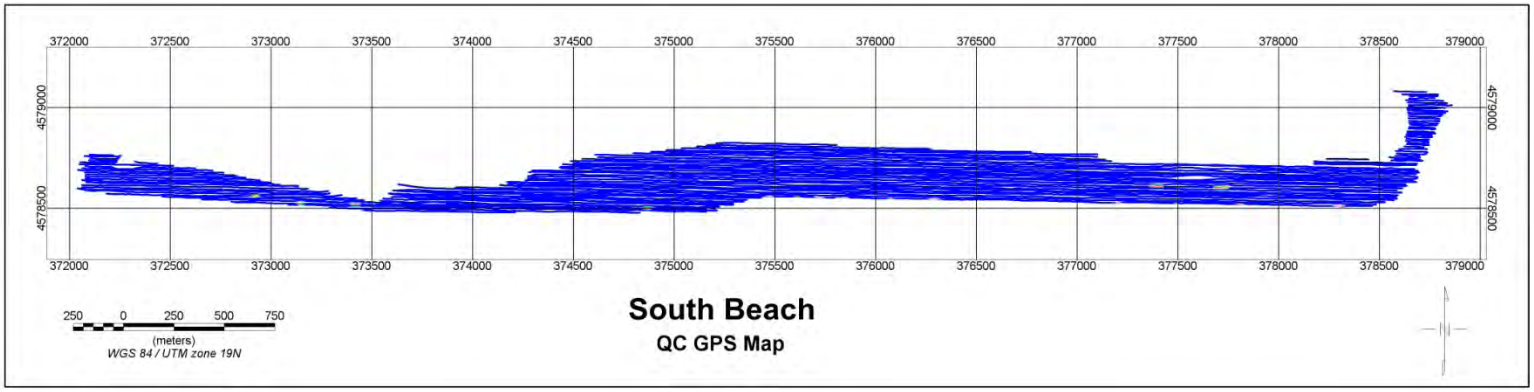


Figure A-22: QC GPS Map for South Beach. The blue areas show where the HDOP of the GPS is greater than 3.5.

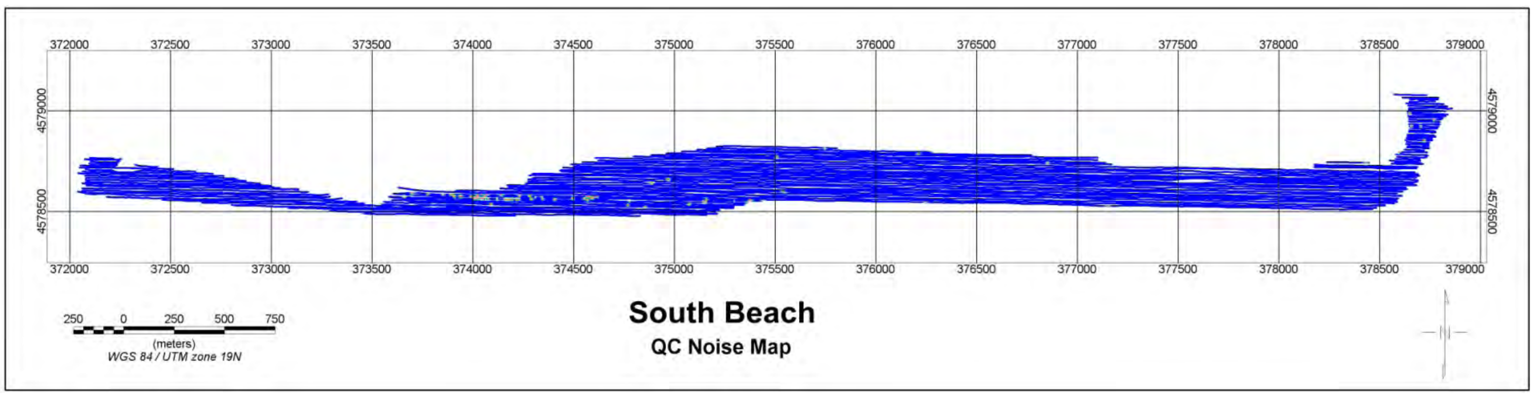


Figure A-23: QC GPS Map for South Beach. The blue represents where the noise was less than $0.5nT/m/s^4$.

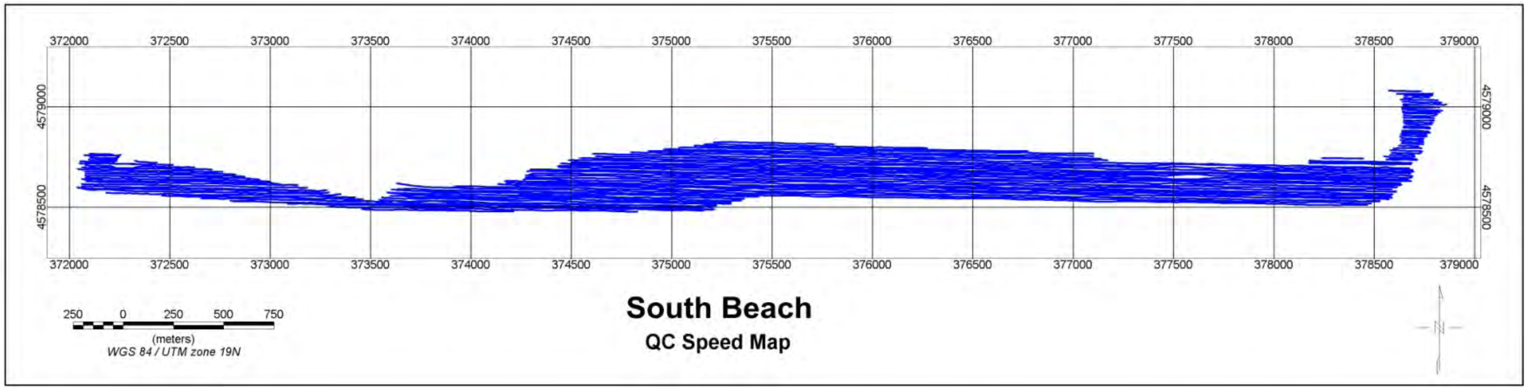


Figure A-24: QC Speed Map for South Beach. The blue represents where the speed of the aircraft is less than 60mph.

A-5 **Reflight Tables**

Table A-25: Lines for Tisbury Great Pond that required reflights. This table includes the coordinates of the data gaps that were greater than 2 seconds.

TISBURY GREAT POND - coordinates of data gaps

	Eastern		Western	
Line	X	Y	X	Y
127	362778.58	4578724.21	362809.54	4578722.93
73	362502.76	4579269.25	362509.01	4579268.87
23	361738.29	4579782.53	361743.69	4579780.78

Table A-26: Lines for South Beach that required reflights. This table includes the coordinates of the data gaps that were greater than 2 seconds.

SOUTH BEACH - coordinates of data gaps

	Eastern		Western	
Line	X	Y	X	Y
59	373969.28	4578580.09	373986.26	4578579.19
	374178.62	4578576.71	374193.25	4578576.64
	374223.43	4578576.50	374236.52	4578576.46
	374290.88	4578576.09	374307.17	4578576.13
	374647.16	4578579.30	374662.16	4578578.82
	374453.93	4578580.50	374472.67	4578580.37
	375068.89	4578571.85	375082.56	4578571.66
56	375130.22	4578603.48	375143.97	4578602.90
	377754.68	4578558.37	377766.34	4578558.03
45	376838.77	4578675.07	376845.99	4578675.00
40	378187.02	4578709.76	378666.92	4578701.39
39	378224.77	4578714.25	378669.16	4578709.19
36	378633.68	4578731.33	378686.64	4578730.69

A-6 **Daily Activity Logs**

This log summarizes project activities. Its primary purpose is to record survey progress and to flag events that may impact progress. Detailed notes of specific meetings or decisions are maintained elsewhere. Notes that have an impact on the billing or deliverables are indicated in red.

Down-days for weather or standby are defined as “one (1) hour or less of flight time during a standard survey project day”. Survey days do not include days for mobilization, installation, calibration or reflights. This provides sufficient time for one reconnaissance flight in marginal weather conditions to make an attempt at data collection, but is less than half a single production flight. Provision was also made in the contract for half days, which were defined as “more than one (1) but less than three (3) hours of flight time”.

Down-days may be the result of unsafe weather conditions (including rain, fog, high winds or glassy water conditions), maintenance (equipment failure or regularly scheduled helicopter maintenance) or client activities (limited or no site access due to client activities). The onus for each down-day has been attributed to either Battelle or UXB, depending on the circumstances. These are all included in the summary below.

Crew rotations have also been noted in the logs
Details of daily activities:

Date	03-Feb-2011	
Primary Activity	Mobilization	0.0 flt hrs
Survey Block	n/a	
Notes	Battelle field crew depart from Oak Ridge (William Doll, Jeff Gamey), arrive Pittsburgh, PA	
Flags	-	

Date	04-Feb-2011	
Primary Activity	Mobilization	0.0 flt hrs
Survey Block	n/a	
Notes	Battelle en route, arrive Hyannis.	
Flags	-	

Date	05-Feb-2011	
Primary Activity	Mobilization	2.8 flt hrs
Survey Block	n/a	
Notes	Battelle en route, arrive Martha’s Vineyard. Mag-flag survey of potential GPO site. National Helicopters crew (Doug Christie, Marcus Watson, Darcy McPhee) mobilize from Toronto, held up in New York due to weather.	
Flags	Half day during mob – Battelle	

Date	06-Feb-2011	
Primary Activity	Installation	2.5 flt hrs

Survey Block	n/a	
Notes	G858 pre-seed survey of GPO area. National Helicopter crew arrives MVY. Begin VG22 system installation on aircraft.	
Flags	Half day during mob – Battelle	

Date	07-Feb-2011	
Primary Activity	Installation	0.0 flt hrs
Survey Block	n/a	
Notes	Complete VG22 system installation on aircraft.	
Flags	-	

Date	08-Feb-2011	
Primary Activity	Survey	0.6 flt hrs
Survey Block	n/a	
Notes	Kick-off safety briefing. Airborne survey of GPO at multiple heights. No survey work due to weather (rain, ceiling, winds), ground support not yet set up.	
Flags	Full day standby – UXB	

Date	09-Feb-2011	
Primary Activity	Survey	2.7 flt hrs
Survey Block	Tisbury	
Notes	Airborne survey of TGP. Operations ceased due to high winds.	
Flags	Half day standby – UXB	

Date	10-Feb-2011	
Primary Activity	Survey	5.6 flt hrs
Survey Block	South Beach	
Notes	Airborne survey of South Beach.	
Flags	-	

Date	11-Feb-2011	
Primary Activity	Survey	3.8 flt hrs
Survey Block	South Beach/Poge	
Notes	Airborne survey of South Beach complete. Attempted Poge but aborted for cross-winds. Reflew compensation flight and GPO.	
Flags	-	

Date	12-Feb-2011	
Primary Activity	Survey	5.6 flt hrs

Survey Block	Tisbury	
Notes	Continued survey of Tisbury.	
Flags	-	

Date	13-Feb-2011	
Primary Activity	Survey	3.6 flt hrs
Survey Block	Tisbury	
Notes	Continued airborne survey of Tisbury. Battelle crew rotation, Jeannie Norton mob to Martha's Vineyard while Jeff Gamey mob back to Oak Ridge, TN.	
Flags	-	

Date	14-Feb-2011	
Primary Activity	Survey	1.0 flt hrs
Survey Block	Tisbury	
Notes	Completed airborne survey of Tisbury Great Pond. Only able to get in one flight before the wind picked up and was too strong to fly.	
Flags	Half day standby – UXB	

Date	15-Feb-2011	
Primary Activity	Survey	0 flt hrs
Survey Block	N/A	
Notes	Down for wind.	
Flags	Full day standby – UXB	

Date	16-Feb-2011	
Primary Activity	Survey	6.0 flt hrs
Survey Block	Cape Poge	
Notes	2 morning flights of Cape Poge flown leaving only 23 lines remaining. Base GPS station failure, the Cape Poge data was unrecoverable.	
Flags		

Date	17-Feb-2011	
Primary Activity	Survey	5.3 flt hrs
Survey Block	Cape Poge	
Notes	Flew all of Cape Poge and was able to finish reflights for both South Beach and Tisbury Great Pond	
Flags	-	

Date	18-Feb-2011	
Primary Activity	N/A	0.0 flt hrs
Survey Block	Deinstall /Mob	
Notes	Complete VG22 system deinstallation on aircraft in the morning. .Battelle field crew depart from Martha's Vineyard (William Doll, Jeannie Norton). National Helicopters crew (Doug Christie, Marcus Watson, Darcy McPhee) demobilize from Martha's Vineyard.	
Flags	-	

Summary of down-time attributable to Battelle

Date	Event	Flt hrs	Standby
02-05-11	Weather during mob (heli crew only)	2.8 flt hrs	Half day
02-06-11	Weather during mob (heli crew only)	2.5 flt hrs	Half-day

Summary of down-time attributable to UXB

Date	Event	Flt hrs	Standby
02-08-11	Weather	0.6	Full day
02-09-11	Weather	2.7	Half day
02-14-11	Weather	0.0	Half day
02-15-11	Weather	0.0	Full day

Standby 1: 2 full days
Standby 2: 2 half days

A-7 **Daily Data Tracking Logs**

Feb 08-2011

The data processing will be tracked on a daily basis. This sheet will track information on data processing as applied to each day's preliminary GDB. It will cover the following inputs (at a minimum). These will be provided along with each delivery of preliminary field data.

Item	Survey Project Team Input
Date of data collection	2/08/11
Sortie ID	1115-1116
Site ID	GPO
Survey Line File (Track File)	
Survey Lines Flown	GPO preseed/postseed
Pilot's Name	Doug Christie
System Operator's name	Marcus Watson
Ground Support Technician Name	Darcy
Data Processor's name	Jeff Gamey
Project Geophysicist's name	William Doll
Field notes (comments)	
All Filtering Information (e.g. Demedian, Lpass, etc.)	Std (see report)
Oasis Site Database	MVY020811.gdb
Grid name	Vg020811.grd, as020811.grd
Archive name	MVY_GPO

Feb 09-2011

The data processing will be tracked on a daily basis. This sheet will track information on data processing as applied to each day's preliminary GDB. It will cover the following inputs (at a minimum). These will be provided along with each delivery of preliminary field data.

Item	Survey Project Team Input
Date of data collection	2/09/11
Sortie ID	1117-1128
Site ID	Tisbury Great Pond
Survey Line File (Track File)	
Survey Lines Flown	122-148
Pilot's Name	Doug Christie
System Operator's name	Marcus Watson
Ground Support Technician Name	Darcy
Data Processor's name	Jeff Gamey
Project Geophysicist's name	William Doll
Field notes (comments)	
All Filtering Information (e.g. Demedian, Lpass, etc.)	Std (see report)
Oasis Site Database	MVY020911.gdb
Grid name	Vg020911.grd, as020911.grd
Archive name	MVY_Tisbury

Feb 10-2011

The data processing will be tracked on a daily basis. This sheet will track information on data processing as applied to each day's preliminary GDB. It will cover the following inputs (at a minimum). These will be provided along with each delivery of preliminary field data.

Item	**Survey Project Team Input**
Date of data collection	2/10/11
Sortie ID	1129-1145
Site ID	South Beach
Survey Line File (Track File)	
Survey Lines Flown	W44-69, E40-58, W2-5
Pilot's Name	Doug Christie
System Operator's name	Marcus Watson
Ground Support Technician Name	Darcy
Data Processor's name	Jeff Gamey
Project Geophysicist's name	William Doll
Field notes (comments)	
All Filtering Information (e.g. Demedian, Lpass, etc.)	Std (see report)
Oasis Site Database	MVY021011.gdb
Grid name	Vg021011.grd, as021011.grd
Archive name	MVY_South

Feb 11-2011

The data processing will be tracked on a daily basis. This sheet will track information on data processing as applied to each day's preliminary GDB. It will cover the following inputs (at a minimum). These will be provided along with each delivery of preliminary field data.

Item	Survey Project Team Input
Date of data collection	2/11/11
Sortie ID	1147-1159
Site ID	South Beach/Poge/GPO
Survey Line File (Track File)	
Survey Lines Flown	SB E6-39, C59-66 Poge 103-105
Pilot's Name	Doug Christie
System Operator's name	Marcus Watson
Ground Support Technician Name	Darcy
Data Processor's name	Jeff Gamey
Project Geophysicist's name	William Doll
Field notes (comments)	
All Filtering Information (e.g. Demedian, Lpass, etc.)	Std (see report)
Oasis Site Database	MVY021111.gdb
Grid name	Vg021111.grd, as021111.grd
Archive name	MVY_South MVY_Poge MVY_GPO

Feb 12-2011

The data processing will be tracked on a daily basis. This sheet will track information on data processing as applied to each day's preliminary GDB. It will cover the following inputs (at a minimum). These will be provided along with each delivery of preliminary field data.

Item	Survey Project Team Input
Date of data collection	2/12/11
Sortie ID	1160-1180
Site ID	Tisbury Great Pond
Survey Line File (Track File)	
Survey Lines Flown	TGP 35-121
Pilot's Name	Doug Christie
System Operator's name	Marcus Watson
Ground Support Technician Name	Darcy
Data Processor's name	Jeff Gamey
Project Geophysicist's name	William Doll
Field notes (comments)	
All Filtering Information (e.g. Demedian, Lpass, etc.)	Std (see report)
Oasis Site Database	MVY021211.gdb
Grid name	Vg021211.grd, as021211.grd
Archive name	MVY_Tisbury

Feb 13-2011

The data processing will be tracked on a daily basis. This sheet will track information on data processing as applied to each day's preliminary GDB. It will cover the following inputs (at a minimum). These will be provided along with each delivery of preliminary field data.

Item	Survey Project Team Input
Date of data collection	2/13/11
Sortie ID	1147-1159
Site ID	Tisbury Great Pond
Survey Line File (Track File)	
Survey Lines Flown	TGP 21-74
Pilot's Name	Doug Christie
System Operator's name	Marcus Watson
Ground Support Technician Name	Darcy
Data Processor's name	Jeannie Norton
Project Geophysicist's name	William Doll
Field notes (comments)	
All Filtering Information (e.g. Demedian, Lpass, etc.)	Std (see report)
Oasis Site Database	MVY021311.gdb
Grid name	Vg021311.grd, as021311.grd
Archive name	MVY_Tisbury

Feb 14-2011

The data processing will be tracked on a daily basis. This sheet will track information on data processing as applied to each day's preliminary GDB. It will cover the following inputs (at a minimum). These will be provided along with each delivery of preliminary field data.

Item	**Survey Project Team Input**
Date of data collection	2/14/11
Sortie ID	1196-1201
Site ID	Tisbury Great Pond
Survey Line File (Track File)	
Survey Lines Flown	TGP 2-20
Pilot's Name	Doug Christie
System Operator's name	Marcus Watson
Ground Support Technician Name	Darcy
Data Processor's name	Jeannie Norton
Project Geophysicist's name	William Doll
Field notes (comments)	
All Filtering Information (e.g. Demedian, Lpass, etc.)	Std (see report)
Oasis Site Database	MVY021411.gdb
Grid name	Vg021411.grd, as021411.grd
Archive name	MVY_Tisbury

Feb 16-2011

The data processing will be tracked on a daily basis. This sheet will track information on data processing as applied to each day's preliminary GDB. It will cover the following inputs (at a minimum). These will be provided along with each delivery of preliminary field data.

Item	Survey Project Team Input
Date of data collection	2/16/11
Sortie ID	1202-1222
Site ID	Cape Poge
Survey Line File (Track File)	
Survey Lines Flown	Poge 2-102
Pilot's Name	Doug Christie
System Operator's name	Marcus Watson
Ground Support Technician Name	Darcy
Data Processor's name	Jeannie Norton
Project Geophysicist's name	William Doll
Field notes (comments)	GPS failure, resulting in unusable data
All Filtering Information (e.g. Demedian, Lpass, etc.)	Std (see report)
Oasis Site Database	
Grid name	
Archive name	

Feb 17-2011

The data processing will be tracked on a daily basis. This sheet will track information on data processing as applied to each day's preliminary GDB. It will cover the following inputs (at a minimum). These will be provided along with each delivery of preliminary field data.

Item	**Survey Project Team Input**
Date of data collection	2/17/11
Sortie ID	1147-1159
Site ID	Cape Poge / South Beach / Tisbury
Survey Line File (Track File)	
Survey Lines Flown	Poge 2-102 SB 59, 56, 45, 40, 39, 37, 36 TGP 127
Pilot's Name	Doug Christie
System Operator's name	Marcus Watson
Ground Support Technician Name	Darcy
Data Processor's name	Jeannie Norton
Project Geophysicist's name	William Doll
Field notes (comments)	
All Filtering Information (e.g. Demedian, Lpass, etc.)	Std (see report)
Oasis Site Database	MVY021711.gdb
Grid name	Vg021711.grd, as021711.grd
Archive name	MVY_Tisbury MVY_Poge MBY_South

The data analysis will also be tracked on a site basis. The tracking sheet will document the various analysis steps as follows (at a minimum). Data analysis is not conducted until data collection is complete. This tracking report will be included in the Final Report and will cover the entire project.

Item	Survey Project Team Input
Site name	Tisbury Great Pond
Grid name	Tisbury_vg.grd, Tisbury_as.grd
Archive name	Vgcomb_Tisbury.gdb
Anomaly Selection method (manual/wavelet/AS peak detection)	AS peak detection
Anomaly selection analyst name	Jeannie Norton
Anomaly list file name	Tisbury_picklist.xyz
Anomaly QC analyst name	
Final QC-processed anomaly list name	
Dipole fit/classification analyst name	Jeannie Norton
Dipole fit analysis output file name	Tisbury_inversion.xyz
Anomaly classification output file name	
Dipole fit/Classification QC name	
GIS analyst name	
GIS density map output filename	
Density map QC name	

Item	Survey Project Team Input
Site name	South Beach
Grid name	South_vg.grd, South_as.grd
Archive name	Vgcomb_south.gdb
Anomaly Selection method (manual/wavelet/AS peak detection)	AS peak detection
Anomaly selection analyst name	Jeannie Norton
Anomaly list file name	South_picklist.xyz
Anomaly QC analyst name	
Final QC-processed anomaly list name	
Dipole fit/classification analyst name	Jeannie Norton
Dipole fit analysis output file name	South_inversion.xyz
Anomaly classification output file name	
Dipole fit/Classification QC name	
GIS analyst name	
GIS density map output filename	
Density map QC name	

Item	Survey Project Team Input
Site name	Cape Poge
Grid name	Poge_vg.grd, Poge_as.grd
Archive name	Vgcomb_poge.gdb
Anomaly Selection method (manual/wavelet/AS peak detection)	AS peak detection
Anomaly selection analyst name	Jeannie Norton
Anomaly list file name	Poge_picklist.xyz
Anomaly QC analyst name	
Final QC-processed anomaly list name	
Dipole fit/classification analyst name	Jeannie Norton
Dipole fit analysis output file name	Poge_inversion.xyz
Anomaly classification output file name	
Dipole fit/Classification QC name	
GIS analyst name	
GIS density map output filename	
Density map QC name	

1. INTRODUCTION

During World War II, the U.S. military utilized areas on or near various beaches on the Island of Martha's Vineyard, Massachusetts for training troops in air-to-ground combat. Since that time, various remnant munitions have been found either on shore or in nearby water bodies (marine waters and freshwater ponds) where they may potentially pose a risk to human health and the environment. Pursuant to the Department of Defense's (DoD's) Military Munitions Response Program (MMRP), the US Army Corps of Engineers (USACE) has completed a Remedial Investigation/Feasibility Study (RI/FS) in the areas known to have been impacted by remnant munitions.

1.1. OBJECTIVES

1. Determine whether MPPEH can be transported by ocean waves
2. Determine the area within the coastal surf zone where wave-driven MPPEH transport is most likely to occur
3. Determine whether prevailing wave-induced erosion is likely to continue exposing and transporting MPPEH if any remain buried under the existing beach; if so, determine the sections of beach that might be most vulnerable.

1.2. SOUTH BEACH MRS

Between 1943 and 1944 the Department of the Navy acquired the leases to the properties which comprised the former ranges studied during the RI/FS. The sites were used to provide training for the 1st Naval District, whose flight operations were based at Naval Air Station Quonset Point, Rhode Island, and the Naval Auxiliary Air Station Martha's Vineyard located on Martha's Vineyard, Massachusetts. The leases for the South Beach parcels were held until 1947.

The following section provides a brief description of the Former Moving Target Machine Gun Range at South Beach. For this investigation the following definitions will be used to describe the land and water environments:

Beach – Beach is defined as the land adjacent to either marine or fresh water;

Land – Land is defined as the land excluding beach and dunes;

Inland Water – Inland Water is defined as protected marine or fresh water environments, such as coves or ponds; and

Ocean – Ocean will be defined as those waters directly associated with the Atlantic Ocean, Vineyard Sound or Nantucket Sound.

1.3. THE FORMER MOVING TARGET MACHINE GUN RANGE

The Former Moving Target Machine Gun Range at South Beach is located within the town of Edgartown along the southern shore of Martha's Vineyard, Massachusetts. The South Beach area of investigation (AOI) as defined in the FUDSMIS database encompasses approximately 478 acres: 1) approximately 18.7 acres of land; 2) approximately 182.7 acres of beach; 3) approximately 7.7 acres of inland water; and 4) approximately 268.7 acres of ocean immediately adjacent to the beach (Figure 1). Due to extensive beach erosion that resulted in the low-water mark at South Beach moving northward, the area that once functioned on land as the former range is now thought to be approximately 150 yards off-shore in waters up to 35 feet deep. Military ordnance used at the former Moving Target Machine Gun Range Site included 30 mm and 50 mm ammunition, 100 lb high explosive bombs, MK 1 rockets and 2.25 inch to 6 inch rockets. Rockets, bombs and bomb fragments have been observed on the property. In 1988/89, the U.S. Army and Navy conducted clearance operations in dunes in the vicinity of the Former Moving Target Machine Gun Range; 1655 items were removed, of which 99 were warheads.

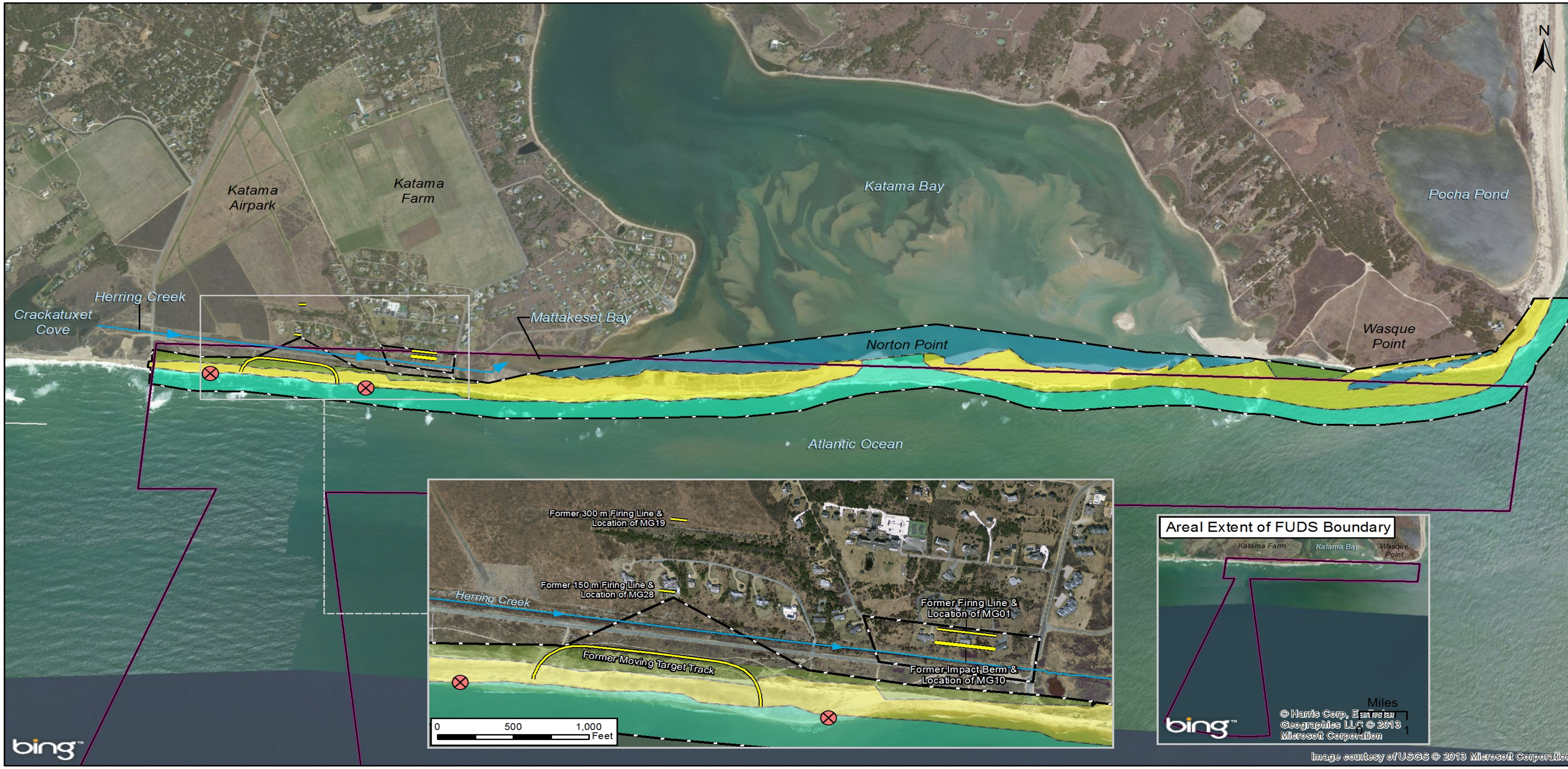
A subsequent surface and subsurface time critical removal action (TCRA) was conducted 2009 using hand held analog detectors and mag/dig approach; 617 munitions debris items recovered, with 42 inert items (2.25 to 5 inch sub-caliber aircraft rockets). MD items were recovered between 0 and 1 ft bgs. In addition an emergency response in 2008 (100 pound HE bomb) and 2009 (100 pound photoflash bomb) resulted when bombs washed ashore at Wasque Point , which were subsequently demolished by the Massachusetts State Police bomb squad and Navy EOD.

2. METHODS

2.1. MEC TRANSPORT GRID SURVEYS

UXB monitored migration of ordnance items currently in the environment by completing marine analog magnetometry surveys within the bounds of two "MEC Transport Grids" located in the near-shore environment at South Beach. Two one-acre grid areas were established in areas previously cleared as part of the 2009 TCRA. These MEC Transport Grids were planned to be surveyed multiple times to show changes in MEC/MD density/spatial distribution over time, as follows:

1. A **baseline survey** was planned to locate any anomalies existing within the grid prior to the beginning of the survey; all anomalies detected would be geospatially located, and documented for future reference and mapping.
2. A **storm-event follow-up survey** was planned to monitor the change in anomaly distribution and density after a storm wave action changed seafloor conditions. Again, all



Former Rocket Target
Moving Target and Machine Gun Range Features
Herring Creek
South Beach FUDS Boundary
South Beach Investigation Area

South Beach Investigation Areas Subdivisions
- Beach - 183 acres
- Inland Water - 269 acres
- Land - 19 acres
- Ocean - 173 acres

US Army Corps of Engineers

FIGURE 1
Site Map - Former Moving Target Machine Gun Range at South Beach Investigation Area, Martha's Vineyard, MA

0 150 300 600 900 1,200 Meters
0 700 1,400 2,800 4,200 Feet

UXB amec

NOTES:
2011 Aerial Data Source: Bing Maps, Microsoft Corp.

03/04/2013	Rev:	SBeach_Site_Loc_MEC_Trans_App.mxd
Drawn: JBO	Chk: DMS	PROJ: 562910000

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anomalies detected would be geospatially located, and documented for future reference and mapping.

3. A **close-out survey** was anticipated near the completion of field operations to further characterize variations in anomaly distribution and densities.

All dive operations associated with the Transport Study were performed in accordance with the approved Dive Plan. MD discovered as part of intrusive investigation during the Transport study was disposed of as described in the ESP.

2.2. MEC TRANSPORT ACOUSTIC TARGET TRANSPONDER ("PINGER") SURVEY

UXB, along with its marine EOD diving subcontractor VRHabilis, LLC, documented offshore marine transport at two locations by placing and monitoring the movement of 8 acoustic target transponders ("pingers") placed within the vicinity of the two South Beach MEC Transport Grids. As stated above, prior to establishing the MEC Transport Grids, a baseline survey was conducted to locate any existing anomalies.

Each South Beach Grid was seeded with 4 rocket simulants and each seed was fitted with a pinger. To maximize potential movement over a relatively short time, all of the items were laid proud on the bottom. All geophysical location data were acquired, recorded, geospatially located, and interpreted using the same quality protocols used to obtain the other marine analog magnetometry data. All relevant meta-data were recorded and archived in the geospatial database.

The plan was to interrogate the pinger locations on regular intervals during the conduct of dive operations, and recover the items during conduct of mag/dig ocean transect operations adjacent to the MEC transport grids.

3. FIELD OPERATIONS AND EXECUTION

3.1. MEC TRANSPORT GRID SURVEYS

At South Beach, the MEC transport grid locations were selected in the vicinity of TCRA Grids 5/6 and 18/19 as these areas were proximate to historic target locations and had the highest anomaly densities recorded during completion of the 2009 TCRA. The grids were located by establishing a known point on the beach in a position not affected by wind and tide, and measuring bearing and distance to establish the "virtual" limits of the grid. Baseline surveys of the two MEC Transport Grids were completed June 16-22, 2010 and the Storm Event follow-up surveys were completed October 4-20, 2010.

VRHabilis used the following geospatial location methodology for all field data acquisition during the MEC Transport Grid Surveys:

- Anomaly positions were recorded by measuring from the known point on the beach. A jackstay search line was then placed in the water. The diver began his search approximately 15 feet to seaward from the water's edge and continued out to sea another 240 feet.
- Upon discovery of each anomaly, a measurement was taken from the northwest corner stake measuring to the east (recorded as the "X" coordinate) and from that point on due south to the diver's position (recorded as the "Y" coordinate). Coordinates for the positions of the northwest and northeast corner stakes are expressed in Universal Transverse Mercator (UTM) using a Datum of NAD 83.
- The jackstay was advanced in five foot increments starting on the anchor positioned in the deep water. The diver search began in the shallow water approximately fifteen feet from the water's edge and continued to the deep-water anchor. When the diver arrives at the anchor, he shifted it five feet to the east and continued back to the shallow water.

The information derived from the South Beach MEC Transport Grid surveys was determined adequate to answer study objective number 1 (see Introduction), which was to determine whether MPPEH can be transported by ocean waves. Similarly, because the MEC Transport Grid surveys conducted at South Beach effectively met the program's intended objective, the planned revisits were shortened to include only the baseline and storm-event follow-up surveys. The Closeout survey revisit was determined unnecessary.

3.2. MEC TRANSPORT ACOUSTIC TARGET TRANSPONDER ("PINGER") SURVEY

UXB deployed two models of acoustic target transponders for this survey. The ATT-400 pinger is a small (8.5-inch long, 2.5-inch diameter), self-contained, battery-operated underwater acoustic target transponder weighing 1 pound (Figure 2), designed and manufactured by RJE International, Inc. of Irvine, CA that is part of the "Dive-Trak Pro" diver marking and relocation system.

Figure 2: ATT-400 Pinger

This transponder works with the RJE DTI-300 Diver Transponder Interrogator (Figures 3 and 4) to allow divers to mark underwater targets and relocate them at a distance of up to 2250 feet.

Figure 4: RJE DTI-300 Diver Transponder

Figure 3: RJE DTI-300 Diver Transponder Interrogator User Console

The Dive-Trak Pro system provides range and bearing information to the diver through the DTI-300 navigation system so that the target can be reacquired to a location accuracy of 3 feet. The ATT-400 activates upon submersion and remains active up to six months while it waits for an interrogation signal from the DTI-300. The Dive-Trak Pro has eight available channels for simultaneous tracking of a maximum of 8 ATT-400 pingers.

The ULB-364EL pinger (Figure 5) is a small (12.7-inch long, 2.5-inch diameter), self-contained, battery-operated underwater location beacon designed and manufactured for extended-life rigorous offshore use by RJE International, Inc. of Irvine, CA. The ULB-364EL extended-life pinger is part of the "Dive-Trak Pro" diver marking and relocation system and has an effective battery life of up to 11.5 months.

Figure 5: ULB-364EL (Extended-life) pinger

The seed items for the South Beach grids were designed to simulate rocket motors and were made of 18-inch lengths of 2-inch steel pipe capped at each end with a cable fixed pinger attached (Figure 6). Shortly after the first set of simulants was deployed, a pinger broke free and washed ashore because the attachment cable had twisted to the point of fatigue. The second set of pingers was deployed using swivels in the cable to prevent the twist problem.

Figure 6: A rocket motor simulant with attached pinger

Table 1 identifies dates and locations of deployment for the simulant seed items and their respective pingers.

Table 1. Deployment of Simulant Seed Items and Pingers

	Rocket Motor Simulant seed w/ DTT-400 pinger	Rocket Motor Simulant Seed w/ ULB-EL pinger	Rocket Motor Simulant Seed w/ DTT-400 pinger	Rocket Motor Simulant Seed w/ ULB-EL pinger
South Beach Grid 5/6	10/21/2010	11/02/2010	11/03/2010	11/09/2010
South Beach Grid 18	11/09/2010	11/09/2010	11/09/2010	11/09/2010

4. RESULTS

This section presents the results of the MEC Transport Grid surveys and the Acoustic Target Transponder ("Pinger") surveys at South Beach.

4.1. MEC TRANSPORT GRID SURVEYS

The MEC Transport Grid baseline survey was completed June 16-22, 2010 and the Storm Event follow-up survey was completed October 4-20, 2010. During the baseline survey, 24 anomalies were detected at TCRA grids 5/6, and 155 anomalies were detected at TCRA grids 18/19. There were no items visible on the ocean bottom in either location. During the post-storm event survey, 22 anomalies were detected at TCRA grid 5/6, and 385 anomalies detected at TCRA Grid 18/19. In addition, there were MD items visible on the ocean bottom in both locations. These presence of anomalies found during the follow-up survey clearly demonstrates that ferrous items are moving in to these two grid areas over a period of five months, with a measurable change after storm events.

Figure 7 shows the locations of all anomalies found in the baseline survey (yellow) and the follow-up survey (red). These presence of anomalies found during the follow-up survey clearly demonstrates that ferrous items are moving in to these two grid areas over a period of five months. Field records document a series of bad weather days which may have added energy to the surf and enhanced the transport.

4.2. MEC TRANSPORT ACOUSTIC TARGET TRANSPONDER ("PINGER") SURVEY

During the post storm event dive, rocket motor simulants (steel pipe lengths) were instrumented with acoustic transponders, and placed in the MEC Transport Grids as noted in Table 2.

Table 2. Summary of Pinger Survey Results

	Rocket Motor Seed w/ DTT-400 pinger	Rocket Motor Seed w/ ULB-EL pinger	Rocket Motor Seed w/ DTT-400 pinger	Rocket Motor Seed w/ ULB-EL pinger
South Beach Grid 5/6	Interrogated but no return signal (migration status unknown – Battery life exceeded)	Interrogated but no return signal (migration status undetermined)	Interrogated but no return signal (migration status unknown – Battery life exceeded)	Interrogated but no return signal (migration status undetermined)
South Beach Grid 18	Interrogated but no return signal (migration status unknown – Battery life exceeded)	Interrogated but no return signal (migration status undetermined)	Interrogated but no return signal (migration status unknown – Battery life exceeded)	Interrogated but no return signal (migration status undetermined)

5. CONCLUSIONS

5.1. MEC TRANSPORT GRID SURVEYS

The results of the transport study indicate a continuing source of MD at both locations. Of particular note is the continued beach erosion not only reduces the width of the beach, but also results in deeper water at points in the surf-zone. This has the potential to expose buried items previously too deep to detect with analog hand-held sensors close enough to the surface that they are now detectable. The dynamic nature of the surf zone documented in the transport study resulted in a change in the Work Plan for the ocean transects from a survey/reacquire/intrusively investigate approach to a direct mag/dig approach.

5.2. MEC TRANSPORT ACOUSTIC TARGET TRANSPONDER ("PINGER") SURVEY

Extreme/unpredictable weather patterns over the winter months prohibited diver access to locate/track the items. Once diver access for ocean transects resumed, the items were interrogated by initiating an acoustic signal/listening for return signal, but none were located as noted below. One pinger did break free (cable fatigued) and washed ashore and was turned in to the Edgartown Police Department. While an exact location of the point it washed ashore is not known, it does confirm the general movement of items from the surf zone to the beach.

MARINE INVESTIGATION OVERVIEW

INTRODUCTION

During World War II, the U.S. military utilized areas on or near various beaches on the Island of Martha's Vineyard, Massachusetts for training troops in air-to-ground combat. Since that time, various remnant munitions have been found either on shore or in nearby water bodies (marine and freshwater ponds) where they may potentially pose a risk to human health and the environment. Pursuant to the Department of Defense's (DoD's) Military Munitions Response Program (MMRP), the US Army Corps of Engineers (USACE) has completed a Remedial Investigation/Feasibility Study (RI/FS) in the areas known to have been impacted by remnant munitions. In a complementary and coincident study, the Environmental Security Technology Certification Program (ESTCP), commensurate with its mission to develop standardized and effective data collection methods at munition contaminated sites, initiated a project to develop and demonstrate a Wide Area Assessment (WAA) technique for locating and delineating munition-like objects in marine condition environments. In a cooperative effort, the USACE and the ESTCP combined their resources with a plan wherein the data collected during the ESTCP WAA demonstration could be used to augment the information being collected for the RI/FS. The fundamentals of that plan would be that ESTCP would conduct its WAA study, demonstrating the technology and acquiring data in an area useful to the RI/FS and the USACE would include, as part of its RI field activities, a validation of the ESTCP findings. In this way, the two studies would gain valuable information not previously available to them separately. This summary report provides details of the USACE's validation of the ESTCP results, supporting the discussion with brief descriptions of relevant elements of the ESTCP study for context and technical background. A full and complete description of the ESTCP WAA study is available in the ESTCP Final Report (Tetra Tech EC, 2011).

OBJECTIVES FOR ESTCP DEMONSTRATION

The objective of the ESTCP WAA for Marine UXO demonstration was to address the lack of effective and proven approaches for conducting WAA at sites where munitions and explosives of concern (MEC) may be present underwater. This demonstration was performed offshore of "South Beach" on Martha's Vineyard, Massachusetts adjacent to the Formerly Used Defense Site (FUDS) "Former Moving Target Machine Gun Range" where the USACE was conducting the aforementioned RI/FS. The contractor performing the ESTCP demonstration, Tetra Tech EC, Inc, developed and implemented an approach that combined multiple customized geophysical detection and mapping technologies and processing methods, including marine-towed sonar systems (multibeam, sidescan, and sub-bottom profiling) plus a marine-towed magnetic gradiometer array. The portion of the final deliverable from the ESTCP WAA demonstration that was applicable to the USACE's RI/FS was a list of the locations of magnetic gradiometer anomalies that exhibited geophysical characteristics consistent with submerged remnant munitions. The USACE would conduct the final phase of the combined study by confirming whether the anomalies listed were produced by munitions or whether they were produced by non-munition-related objects.

OBJECTIVES FOR USACE FOLLOW-UP VALIDATION

The objective of the USACE RI/FS portion of the marine study was to provide divers trained and certified in Explosives, Ordnance and Disposal (EOD) related activities to conduct underwater investigations potentially involving Munitions and Explosives of Concern (MEC). The diver's objectives included two steps: 1) assist Tetra Tech EC, Inc with dive-related activities during the installation of an Instrument Verification Strip (IVS) that would be used to confirm functionality of the ESTCP WAA magnetic Gradiometer Array (MGA), and 2) complete the validation of the ESTCP WAA results to identify and dispose of any underwater MEC that may have been located during the ESTCP WAA demonstration. For each anomaly identified by ESTCP and confirmed by USACE for follow-up investigation, the USACE dive team maneuvered their support boat into position over the GPS location of the anomaly, dropped a "descent line" from the dive platform to the location of the anomaly, had a diver follow the descent line to the seafloor, and conducted a circular search around the area using a hand-held, water-proofed magnetometer to locate the anomaly. Once the anomaly was reacquired, intrusive excavation was conducted to identify the source of the anomaly, using either an airlift or a water jet to remove the seafloor sediments from around the source item to allow a visual examination of the item for markings and other identifying features such as shape, size, or, if present, external fittings. Depending upon what type of item proved to be the source of the geophysical anomaly, the dive team would then follow pre-established, USACE approved item documentation, reporting, and disposal protocols.

STUDY AREA AND THE FORMER MOVING TARGET MACHINE GUN RANGE

Between 1943 and 1944 the Department of the Nay acquired the leases to the properties which comprised the former ranges studied during the RI/FS. The sites were used to provide training for the 1st Naval District, whose flight operations were based at Naval Air Station Quonset Point, Rhode Island, and the Naval Auxiliary Air Station Martha's Vineyard located on Martha's Vineyard, Massachusetts. The leases for the South beach parcels were held until 1947.

The following section provides a brief description of the Former Moving Target Machine Gun Range at South Beach and the ESTCP Study area in the ocean area adjacent to it. For this investigation the following definitions will be used to describe the land and water environments:

- Beach – Beach is defined as the land adjacent to either marine or fresh water;
- Land – Land is defined as the land excluding beach and dunes;
- Inland Water – Inland Water is defined as protected marine or fresh water environments, such as coves or ponds; and
- Ocean – Ocean will be defined as those waters directly associated with the Atlantic Ocean, Vineyard Sound or Nantucket Sound.

The Former Moving Target Machine Gun Range at South Beach is located within the town of Edgartown along the southern shore of Martha's Vineyard, Massachusetts. The South Beach Munitions Response Site (MRS) as defined in the FUDSMIS database encompasses approximately 478 acres: 1) approximately 18.7 acres of land; 2) approximately 182.7 acres of beach; 3) approximately 7.7 acres of inland water; and 4) approximately 268.7 acres of ocean immediately adjacent to the beach (Figure 1). Due to extensive beach erosion that resulted in the low-water mark at South Beach moving northward, the area that once functioned on land as the former range is now thought to be approximately 150 yards off-shore in waters up to 35 feet deep. Military ordnance used at the former Moving Target Machine Gun Range Site included 30 mm and 50 mm ammunition, 100 lb high explosive bombs, MK 1 rockets and 2.25 inch to 6 inch rockets. Rockets, bombs and bomb fragments have been observed on the property. In 1988, the U.S. Army and Navy conducted clearance operations in the vicinity of the Former Moving Target Machine Gun Range. In excess of 1,650 potential MEC items were recovered from the area.

ESTCP completed their WAA demonstration over a rectangular area of the Atlantic Ocean approximately 12,500 feet long (~2.3 miles) in the long-shore direction and approximately 9,800 feet long (~1.8 miles) in the off-shore direction (Figure 2). TetraTech EC, Inc (TtEC) collected magnetic gradiometer array (MGA) along 29 parallel, east-west transects totaling 7.1 kilometers in length (23,294 feet).

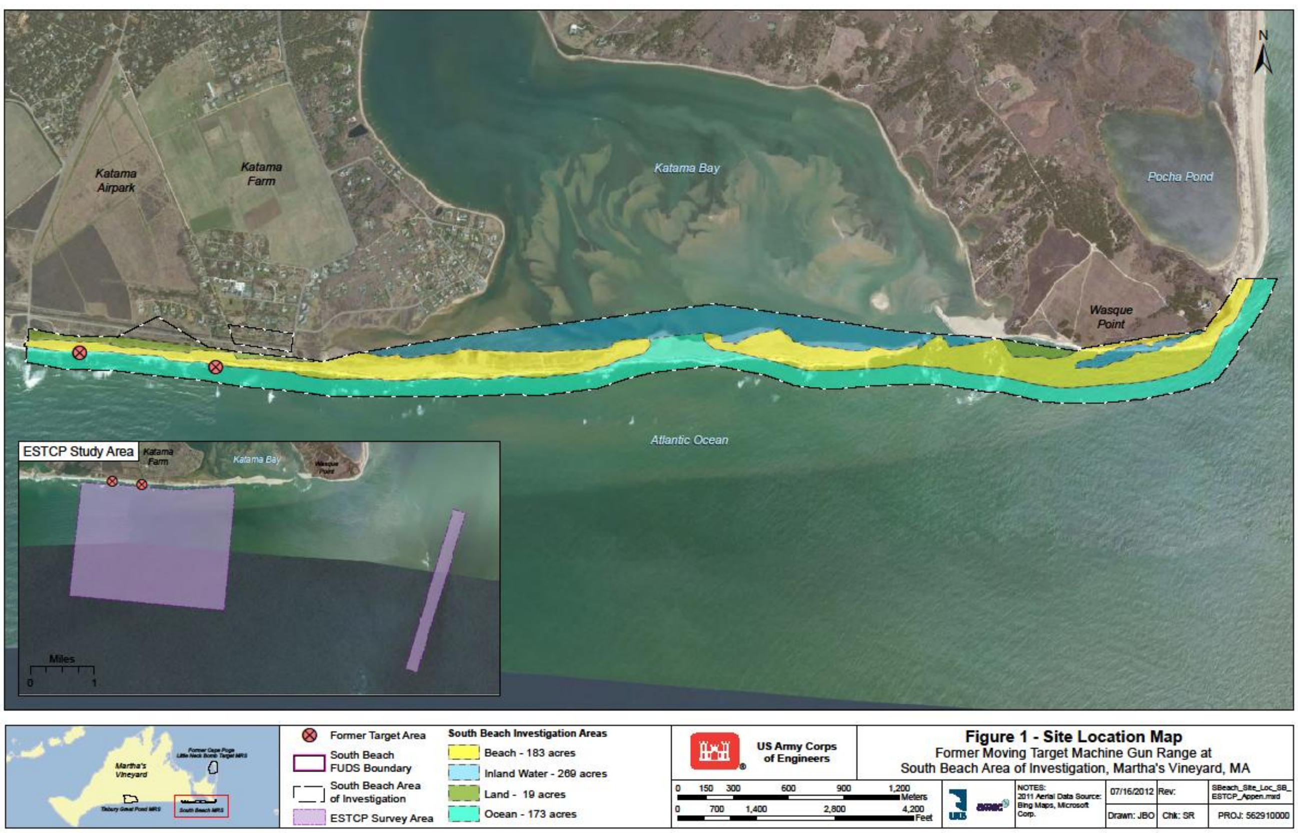


Figure 1: Site map of the South Beach MRS and associated landmarks and structures.

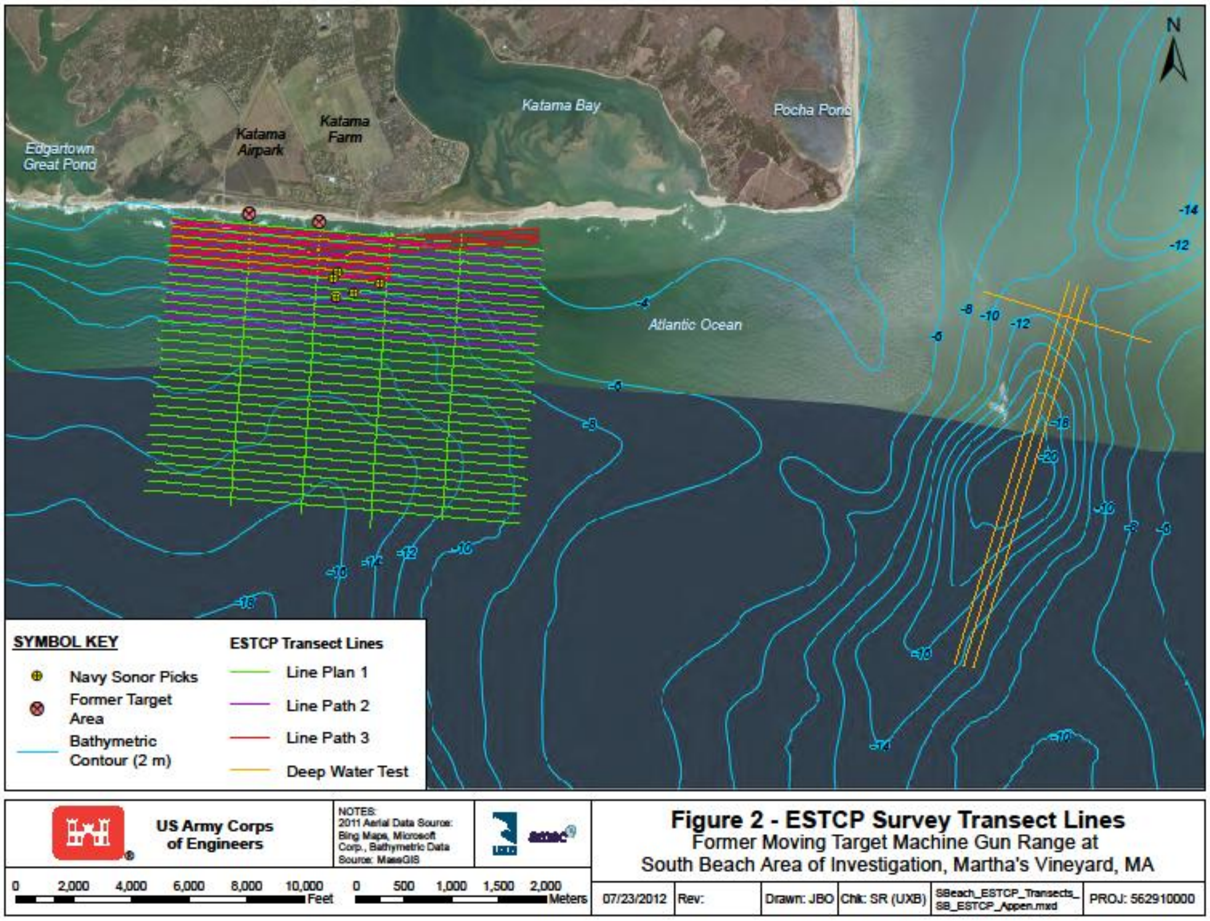


Figure 2: Location of ESTCP WAA marine gradiometry survey transects.

MARINE WIDE-AREA ASSESSMENT DEMONSTRATION

This section will provide a brief overview of the ESTCP WAA demonstration in order to provide context for discussion of the USACE's follow-up intrusive investigations of the ESTCP anomaly list.

WAA DEMONSTRATION TECHNOLOGY OVERVIEW

TtEC deployed four principal complementary technologies during the completion of is WAA demonstration project. Each technology was carefully selected to meet a specific need, as follows:

- **Mapping of water depth/seafloor topography (Bathymetry)**: for use in navigation and control of the towed equipment:
    - TtEC utilized Multibeam Echosounding (MBE) equipment to determine the depth of the water below the boat and towed equipment and to map the seafloor topography. The

MBE is a high resolution system that allows identification of items larger than approximately one-half meter square such as cultural debris and variations in the natural seafloor topography that may pose a risk of collision when the towed equipment is being "flown" above the seafloor at very low flight altitudes.

- **Mapping/locating potential items/obstacles on the seafloor**:
  - TtEC utilized Sidescan sonar (SSS) to identify smaller items projecting above the seafloor. This is possible with SSS because the sonar beams are projected away from the boat at a very low grazing angle to the seafloor, creating high-resolution shadows of any items present.
- **Locating iron-containing (ferrous) objects that may be munition related**:
  - TtEC utilized a Marine Magnetic Gradiometer Array to measure the strength of the earth's magnetic field (and the 3-dimensional gradients of that field) to search for the presence of ferrous objects below the array while it is towed along a transect. The strength of the magnetic field and its 3-D gradients can be used to determine various characteristics of a ferrous object that can potentially be used to discriminate MEC-like objects from non-MEC-like objects (dimensions and peak magnetic field strength, for example, would likely be very different for a submerged automobile than for a 100-pound practice bomb).

Each technology was integrated with high-resolution geographic positioning system (GPS) instrumentation such that all data was carefully located and the position of any anomalous findings could be communicated to the USACE dive team for further investigation.

ESTCP DEMONSTRATION FIELD EXECUTION SUMMARY

The ESTCP WAA demonstration project team notified the USACE that 761 magnetic gradiometer anomalies had been detected using the auto-picking algorithm available through the geophysical processing software called Geosoft Oasis Montaj. The auto-picking algorithm identified all anomalies with peak magnetic field strengths exceeding 3 nanoTeslas (nT) from all transects completed. This "auto-picked list" of anomalies constituted an all-inclusive baseline from which "anomalies of interest" would be selected for intrusive investigation. TtEC recommended that the USACE conduct intrusive investigations on thirty-six (36) anomalies selected from transects 5, 6, 7 and 8. No recommendations were received from TtEC for any of the remaining transects. A full and complete description of the ESTCP WAA field execution is available in the ESTCP Final Report (Tetra Tech EC, 2011).

USACE SUPPORT OF ESTCP WAA DEMONSTRATION ACTIVITIES

Prior to validation/intrusive investigation of the ESTCP WAA anomalies, the USACE completed two support activities. One was specifically planned while one was completed as complementary to the results delivered to USACE. The first activity was for the EOD dive team to assist with the installation of the Instrument Verification Strip (IVS). The second was to complete a more thorough review of the anomalies in the auto-picked list.

INSTALLATION OF THE INSTRUMENT VERIFICATION STRIP (IVS)

The VRHabilis, LLC EOD dive team, under contract to UXB, installed an IVS for use by TtEC in testing the functionality of their underwater Marine Gradiometer Array (MGA) prior to conducting underwater operations. The test strip was placed just outside of the Edgartown outer harbor in an area clear of metallic anomalies. Figure 3 identifies the IVS area. Test items included in the IVS were a 3-inch rocket with a 5-inch warhead affixed, a 3-in rocket motor, a 5-inch warhead, a 3.25-inch rocket motor, a Mark 23 practice bomb, an inert 3-inch full rocket, and a section of pipe (Figure 4). Additionally, TtEC also included a selection of smaller objects fixed to a flexible mat which was intended for field quality control of the MGA performance over clusters of smaller objects (Figure 4-- items 1 through 14). Figure 4 shows one of the TtEC daily report maps of the emplaced IVS strip showing the item types and associated magnetic gradient anomalies.

Figure 3: Location of ESTCP Instrument Verification Strip Installation.

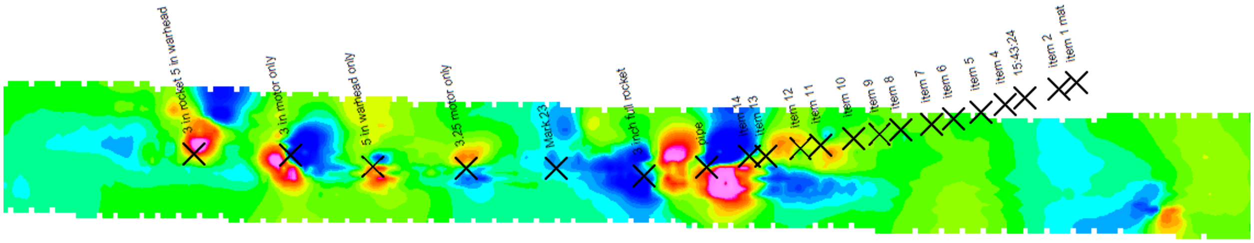


Figure 4: An example survey of the ESTCP MGA data from the IVS.

A full and complete description of the MGA over the IVS test strip for all field operation days is available in the ESTCP Final Report (Tetra Tech EC, 2011).

ADDITIONAL ANOMALY SELECTION FOR VALIDATION

The ESTCP WAA demonstration project team notified the USACE that 761 magnetic gradiometer anomalies had been identified by the Geosoft Oasis Montaj auto-picking algorithm and recommended intrusive investigations on 36 of those anomalies. UXB reanalyzed the 761 auto-picked anomalies looking for evidence that some of the auto-picked anomalies may have been associated with historically documented buried undersea pipelines or cables. UXB extracted from the auto-picked list all spatially correlated anomalies that followed long linear trends oriented perpendicular or sub-perpendicular to the shore. This resulted in a reduction of anomalies from 751 to 540 that were considered of potential interest. Of the 540 remaining anomalies, each organization (TtEC, USACE, and UXB) selected a number of anomalies for intrusive investigation based on the anomaly's magnetic characteristics; including but not necessarily limited to its vertical gradient and total field magnetic dipole and analytic signal strengths, the anomaly's analytic signal lateral dimensions, and the anomaly's magnetic moment. Also taken into consideration were: spatial sampling over the entire ESTCP study area, areas of non-linear spatial clustering, and areas as close to the surf zone as the TtEC equipment could be towed because remnant munitions had previously been recovered from this ocean area. The final list of anomalies-of-interest slated for intrusive investigation/validation was:

- TtEC selected: 36
- USACE selected: 19
- UXB selected: 45
- Additional locations: 5 (anomalies previously located during the 1988 Navy study)

Total anomalies selected: 95

MARINE INTRUSIVE VALIDATION

INTRUSIVE VALIDATION TECHNOLOGY OVERVIEW

All dive operations adhered strictly to the approved dive plan included as Appendix D to the Abbreviated Work Plan. Diving operations were conducted from a small craft with an available accessory safety craft, which was not used. The primary dive platform was a 29' Phoenix captained by a USCG 100 Ton Master.

Surface supplied diving was conducted using HP air and Kirby Morgan diving helmets. The primary diver's helmet was equipped with a video camera hard wired to a surface monitor to allow real time viewing of the diver's activities, identification confirmation of UXO, quality assurance and to ensure proper shot placement during underwater demolition operations (which was not used during the ESTCP validation effort). The diver has two way communications to allow topside to monitor and direct the diver. Surface supplied diving provides the greatest amount of control and safety for the diver. VRHabilis asserts that the real time video is essential to underwater UXO work as it allows topside UXO professionals to examine the UXO and determine its hazards. The diver does not have access to publications or computer software which the topside personnel have. This meets and exceeds the intents and purpose of the two man rule. Typically, surface supplied diving is always to be used in currents greater than 1 knots to allow the diver to work in the most efficient means possible. Surface supplied diving is also used when sea state exceeds 2 on the Buford scale and whenever the diver is excavating or conducting other arduous and primarily stationary work such as excavating to contacts. Surface supplied air is used in these circumstances due to the positive control of the diver, protection/safety of the diver (helmet, harness, umbilical), unlimited air supply (no need to switch out divers) and ability of diver to maintain position due to high negative buoyancy.

Video was recorded at all times while the diver was in the water regardless of task (search, anomaly reacquisition, excavation, demolition, post detonation surveys, sampling, etc.). This feature allowed direct observation of the diver performance allowing for enhanced Quality Control and Safety. As noted above, this technique also allows supervisory personnel to "direct" the activities of the diver.

The final list of 95 anomalies slated for validation included GPS coordinates that the dive team would use to reacquire each anomaly's location. For each anomaly on the final validation list, the UXO dive team maneuvered the boat into position over the TtEC GPS location of the anomaly. Sea state, tides, current, wind and diving method determined the type of moor used at any particular location, but generally a three point moor was preferred (two anchors forward and one anchor aft). A heavy clump of non-magnetic material was placed over the side with a descent line that is tensioned from the dive platform and attached to the clump, allowing the diver a means to accurately go from the surface to the search area and have a clear and distinct means of resurfacing next to the dive platform. For each anomaly the diver followed the descent line to the clump and conducted a spiral search pattern around the clump using a Schonstedt metal detector (in a custom designed and built pressure housing) to locate the anomaly. The spiral search produced a circular investigation area 40-foot radius.

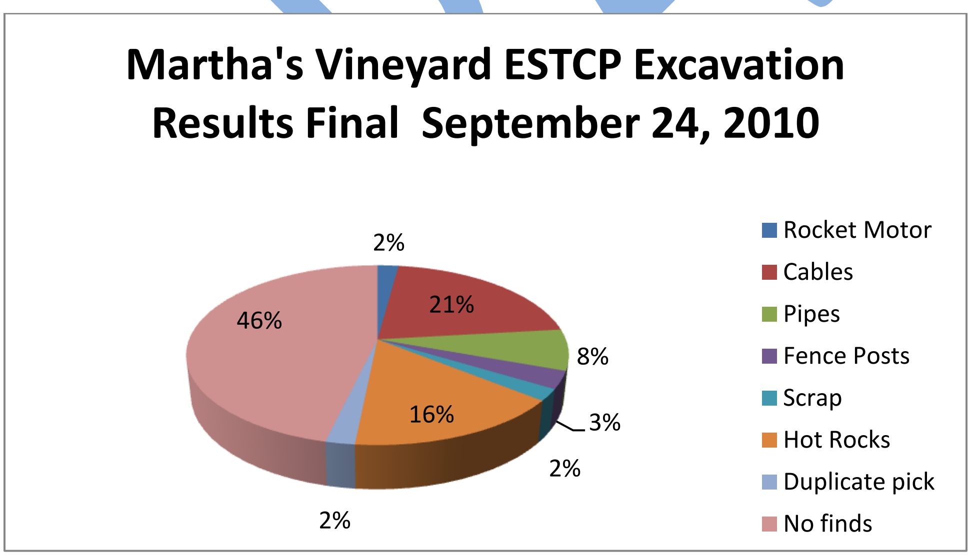
Once the anomalies were reacquired, excavation was conducted using either the previously mentioned airlift or the water jet. Due to the nature of the bottom (sandy, clay, mud) excavation will naturally have gently sloped sides so there is no danger of excavation collapse. Due to the dynamic nature of the ocean, these excavations are filled in through natural sea/current action and return to the steady state depth in a few hours.

USACE VALIDATION SUMMARY

The VRHabilis EOD dive team investigated a total of 95 ESTCP anomalies. Of those 95, Table 1 and Figures 5 and 6 describe the findings, as follows:

Table 1: Table and associated Pie Chart of the intrusive investigation findings resulting from the ESTCP WAA.

Description of item causal to the MGA anomaly	**Quantity**
Rocket Motor (Munitions Debris "MD" items)	2
Cables	20
Pipes	7
Fence Posts	3
Metal Scrap	2
Magnetic Rocks or Sand	15
Duplicate Anomalies Picked	2
No Find (no cause of a MGA anomaly found)	44
Total number of anomalies investigated/validated	**95**



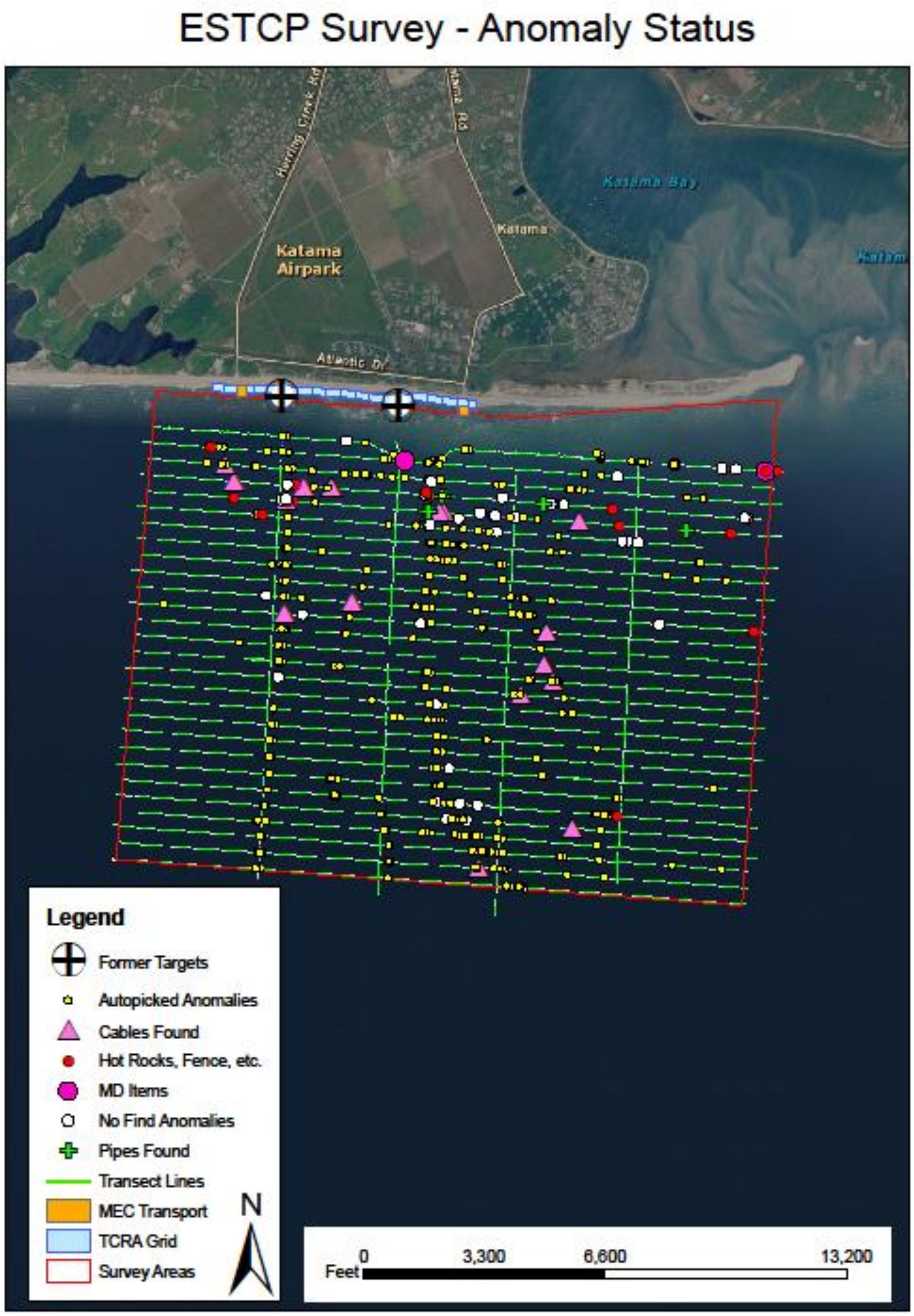


Figure 5: Anomaly location map from ESTCP WAA with intrusive investigation findings.

DISCUSSION AND CONCLUSIONS

Figure 6 shows one of the two expended rocket motors found during the validation phase of the ESTCP Wide Area Assessment project. While this find demonstrates that munition debris exists in locations beyond the current boundaries of the RI/FS Munitions Response Site as it currently is defined in FUDSMIS, an assessment of the information in Table 1 and Figure 5 suggest that there are a number of limitations to interpreting the results as they apply to the RI/FS.

Figure 6: Expended rocket motor retrieved from the ESTCP WAA survey area.

Most importantly is the issue of whether the technology demonstrated successfully discriminated between MEC and non-MEC related anomalies. Of the 95 anomalies slated for validation by the EOD dive team, only two were found to be items of interest relative to the RI/FS. This result is true despite the fact that the original auto-picked anomaly list and the anomalies selected from it were evaluated by three senior-level, qualified geophysicists specializing in MEC-related geophysics. Although the detection and spatial location capabilities of the ESTCP WAA technologies demonstrated may be accurate for ferrous objects, the ability to discriminate MEC from non-MEC items prior to validation and intrusive investigation appears unreliable.

Another important characteristic of the data set is that the geophysical analysts were unable to discern MEC items from naturally occurring magnetic rocks and/or sand lenses. Sixteen (16) percent of the anomalies investigated by the dive team appear to be associated with these naturally occurring sources.

A method for screening these types of anomalies from the data set would have been of considerable value in that it would have allowed more dive time to be assigned to other anomalies, perhaps increasing the rate of MEC finds.

Another finding in the data from Table 1 and Figure 5 is that approximately half (46%) of all anomalies investigated were found to be lacking any obvious source (a.k.a. "No Find"). Two possible explanations exist for this. One presents a concern as to whether the dive team consistently and accurately reacquired the listed anomaly's MGA GPS position. The other presents a concern as to whether currents and seafloor conditions may have moved the source object outside of the search radius. Because MEC items have proven to come ashore periodically, it can be concluded that MEC items cannot be consistently stationary in this particular ocean environment. Whether the movement occurs principally after storm events is yet to be determined. Regarding the potential for inaccuracies in geospatial positioning during reacquisition, the EOD dive team accounted for any potential inaccuracy in GPS positioning due to sea-surface dynamics, poor satellite coverage, or a difference in GPS instrumentation accuracy by conducting a very large search radius. The 40-foot search radius was determined to be sufficient to encompass any potential positioning error likely and suggests that the dynamic hydrologic conditions were likely sufficient to move the ferrous source items outside of the search radius between the date the WAA was completed at each location and the date the dive team completed the anomaly investigation. This conclusion is also supported by results of the MEC transport study where in it was demonstrated that seeded simulants of the same size and weight of the items of interest had moved considerable distances along the sea floor in the near-shore environment at South Beach. The MEC study results are presented as Appendix A of the Final South Beach MRS RI/FS report.

REFERENCES

Tetra Tech EC. 2011. Final Report: Wide Area Assessment (WAA) for Marine Munitions and Explosives of Concern. ESTCP Project MR-200808. Developed for ESTCP by Tetra Tech EC. August 2011. http://serdp.org/Program-Areas/Munitions-Response/Underwater-Environments/MR-200808