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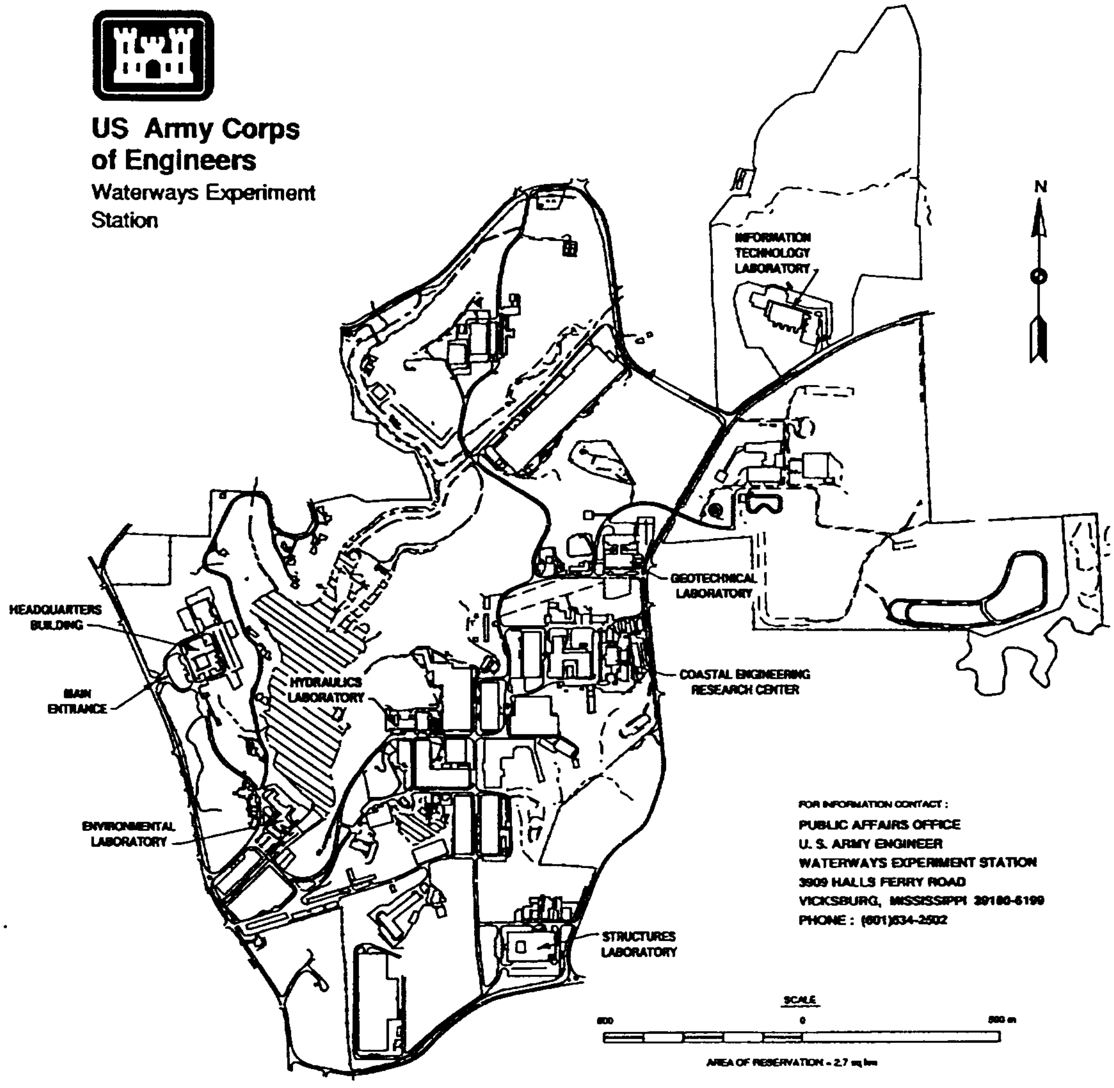
Pilot Study to Characterize Ordnance Contamination Within the Sea Bright, New Jersey, Sand Borrow Site

by Joan Pope, Richard Lewis,
Andrew Morang, Timothy Welp

WES

Prepared for Headquarters, U.S. Army Corps of Engineers

US Army Corps of Engineers
Waterways Experiment Station



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Preface

The field study and analysis described in this report were performed by the U.S. Army Engineer Waterways Experiment Station's (WES's) Coastal Engineering Research Center (CERC) and Geotechnical Laboratory (GL) for the U.S. Army Engineer (USAE) District, New York. A Pilot Study was designed and conducted off the north New Jersey shore at the approved sand borrow site for the Sea Bright Beach Erosion Control Project during September 1995 to test and evaluate various technologies for characterizing ordnance contamination. USAE Division, Huntsville, reviewed and approved the pilot study safety plan. USAE District, New York, provided survey vessel support. The U.S. Coast Guard Station at Sandy Hook provided dockage, logistical support, and an operation base. Rangers at the Fort Hancock National Park and Explosive Ordnance Disposal (EOD) team members at Fort Monmouth and Earle Naval Air Station provided valuable input on the nature and history of ordnance use and finds in the study area. CERC coordinated the overall study, analysis, and reporting. GL coordinated the magnetometer data collection and data analysis. CR Environmental provided the research vessel with Global Positioning System (GPS) position controls used for the magnetometer survey, Edgetech conducted the side-scan sonar and X-star surveys, and Geometrics furnished and operated the magnetometer. Additional magnetic data processing was conducted by Messrs. Douglas DeProspo, Erick Cleary, and Thomas Bell of Arete Engineeering Technologies Corporation (AETC). USAE District, New York, personnel responsible for project oversight include Mr. Joseph Zaraszczak and Ms. Lynn Bocamazo.

WES participants in the field study were Messrs. Timothy Welp, Michael Tubman, Douglas Lee, and William Kucharski from CERC's Prototype and Analysis Branch (PMAB); Ms. Joan Pope, Chief of CERC's Coastal Structures and Evaluation Branch; and Dr. Richard D. Lewis of GL's Engineering Geophysics Branch. Contract personnel contributing to the field effort were Messrs. Alfred Ackerknecht and Lynn Edwards (Geometrics), Mr. John H. Ryther, Jr. (CR Environmental), and Mr. William Charbonneau (Edgetech). Participants in the field investigations from USAE District, New York, were Messrs. Joseph Mayers, Ronald Burns, Douglas Wilson, Joseph Zaraszczak, Daniel Petrie, and Frank Santangelo Mr. Timothy LaFontaine of USAE District, New York, coordinated the support of the U.S. Army Corps of Engineers Survey

Vessel "Sentry" and crew. Mr. Wayne Galloway, USAE Division, Huntsville, reviewed and coordinated the safety plan. The project Geographic Information System (GIS), including reference maps, survey controls, and spacial database, was developed by Dr. Andrew Morang of CERC.

A number of individuals from the study area provided immeasurable assistance in coordinating logistical support, assisting with operational safety and security, and providing insight into the history of Fort Hancock and the occurrence of ordnance contamination. In particular, the authors wish to acknowledge the assistance of Mr. Thomas Hoffman, U.S National Park Service (Fort Hancock); Messrs. James Mullins and Douglas Wilson, USAE District, New York (Sea Bright Project Office); LT Amos Gallagher and Chief Warren, Earle Naval Air Station (Explosive Ordnance Disposal Team (EODT)); LT William Downer; Fort Monmouth (EODT); and LT Londratowiz, MK3 Daniel Newman, and BM1 Fred Squirini, U.S. Coast Guard (Sandy Hook).

Work in CERC was performed under the general administrative supervision of Mr. William Preslan, Chief, PMAB; Mr. Thomas W. Richardson, Chief, Engineering Development Division; Mr. Charles C. Calhoun, Jr., Assistant Director, CERC, and Dr. James R. Houston, Director, CERC. GL general administrative supervision was provided by Mr. Joseph Curro, Chief, Engineering Geophysics Branch; Dr. Arley G. Franklin, Chief, Earthquake Engineering and Geophysics Division; and Dr. William F. Marcuson, Director, GL. Ms. Pope of CERC was the Principal Investigator for this study. Dr. Lewis coordinated the magnetometer data collection and conducted the analysis of the magnetic data. Mr. Welp of CERC coordinated the field logistics. Mr. Tubman coordinated the acoustical systems, and Mr. Lee operated the remotely operated vehicle. Dr. Morang coordinated the development of the project GIS. Ms. Pope, Drs. Lewis and Morang, and Mr. Welp are the authors of this report.

Mses. Mary Claire Allison and Robin Hoban (CERC) and Dr. Cary Cox (WES Information Technology Laboratory) assisted in developing the GIS and in the post-processing of magnetometer data. Ms. Janie Daughtry assisted in text preparation.

Director of WES during publication of this report was Dr. Robert W. Whalin. Commander was COL Bruce K. Howard, EN.

Conversion Factors, Non-SI to SI Units of Measurement

Non-SI units of measurement used in this report can be converted to SI (metric) units as follows:

Multiply	By	To Obtain
cubic yards	0.7645549	cubic meters
feet	0.3048	meters
inches	2.54	centimeters
miles (U.S. statute)	1.609347	kilometers
knots (international)	0.5144444	m/sec
square miles	2.590	square kilometers
pounds (mass)	0.4536	kilograms
nautical miles	1.853	kilometers

1 Introduction

The U.S. Army Corps of Engineers (USACE) and the state of New Jersey are constructing the largest beach restoration project ever undertaken in the United States, known as the "Atlantic Coast of New Jersey, Sandy Hook to Barnegat Inlet, Section I, Sea Bright to Ocean Township." Its purpose is to protect 12 miles[1] of heavily eroded and highly developed north New Jersey shore from coastal storm damages. The total initial project cost is estimated at $165 million (Federal and non-Federal costs). The primary source for the beach quality sediment is a 3-square-mile area located 1 to 3 miles offshore of the southern end of Sandy Hook (Figure 1). Ocean-going hopper or cutterhead dredges excavate sediment (initial project construction total of 18.5 million cu yd) from the authorized borrow area and, with the assistance of nearshore pump-out facilities, transport the material onto the beaches. The project is scheduled to be constructed in four phases as individual contracts are awarded per section of beach and designated area within the authorized borrow area (i.e., contracts 1A, 1B, 2, and 3). Construction started in 1994 with the award of contract 1A and contract 1B was awarded in 1995. Fifty years of periodic beach renourishment are programmed into this project.

Within a very short period after initiation of Contract 1A, ordnance were discovered on the newly constructed beaches. Expensive cleanup operations were required to locate and remove the ordnance from the beach. The source of this material was determined to be ordnance mined along with the borrow, although there had been no preproject data suggesting the presence of this contamination. To eliminate further risk of ordnance ingestion, the project dredges where fitted with 1.5-in. square grates over the dragheads. These grates prohibit excavation of the ordnance, thus protecting the dredge and the resultant beach area from unexploded ordnance (UXO) contamination. However, the grates also reduced the efficiency of the dredging operation by an estimated 20 percent. Over the 50-year project life, the presence of these grates and the reduced dredging efficiency could cost hundreds of millions of dollars in lost productivity.

The U.S. Army Engineer District, New York (NAN) asked the U.S. Army Engineer Waterways Experiment Station (WES) to evaluate and make recommendations on a means of characterizing the ordnance contamination in the

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[1] A table of factors for converting non-SI units of measurement to SI units is presented on page ix.

conventional manner (i.e., without the grates on the dragheads) or to design a practical and safe predredging cleanup operation. Of particular interest would be data which may confirm that certain sections of the borrow area are not contaminated or that the ordnance is confined to the surface or near surface.

WES conducted a review of several technologies and recommended a "pilot study" to test oceanographic/geophysical systems for their suitability in detecting ordnance at the Sea Bright site. NAN concurred with this recommendation and requested that WES proceed with the pilot study, which is reported here.

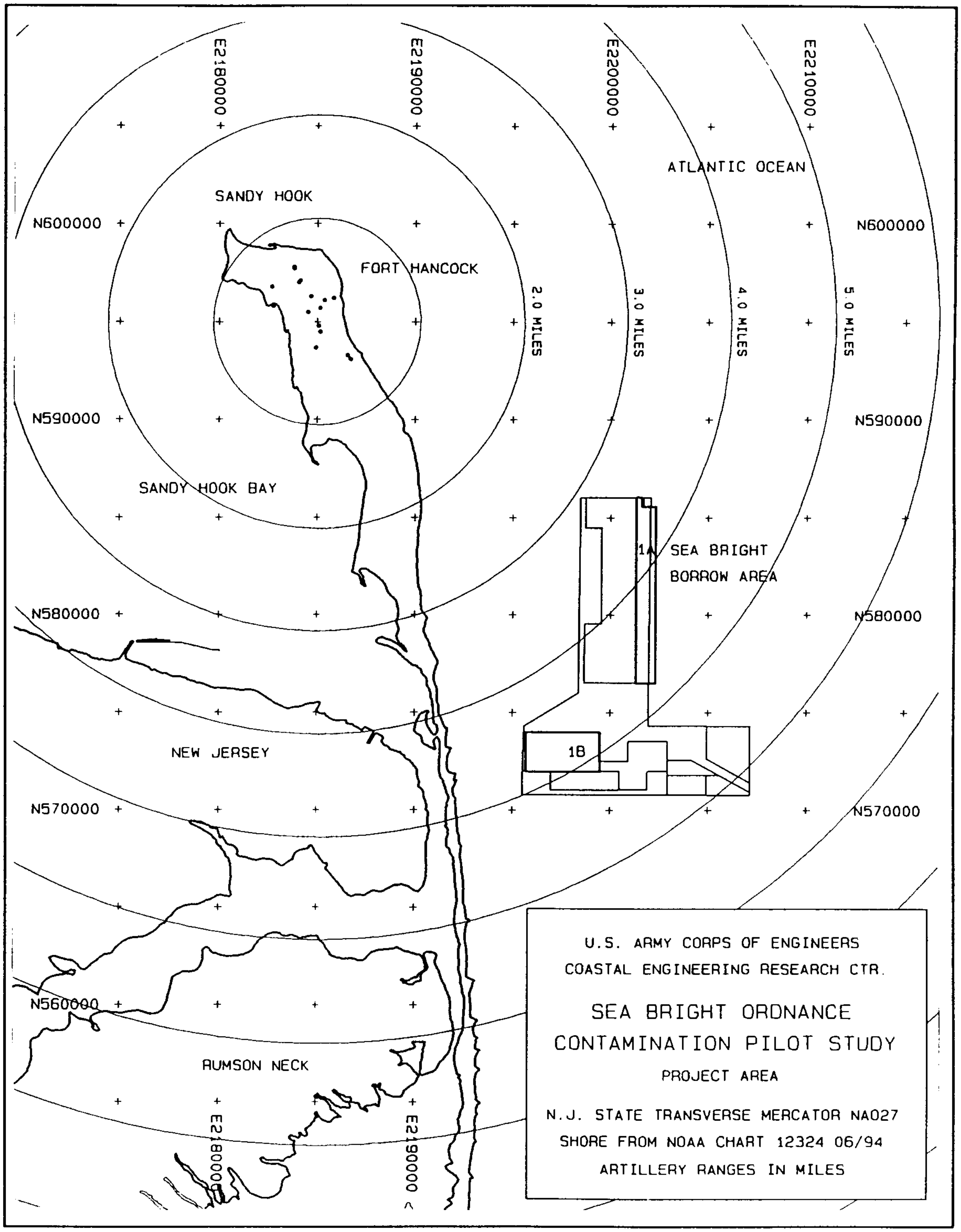

Figure 1. Location map of Sea Bright borrow area relative to Fort Hancock

2 Background on Fort Hancock, Sandy Hook

Coastal fortifications and military posts have been located at the northern end of Sandy Hook, NJ, since the mid 1700's. This strategic location guards the major navigation routes into New York Harbor. Construction of Fort Hancock began in 1857, and by 1874 Sandy Hook was designated as the Army's first proving grounds for munition and weapon testing. Consequently, various generations of large shore-based artillery and mortar batteries were built at Fort Hancock at the north end of this sand spit (Figure 2). Remnants of the fortifications constructed from the 1890's until the 1940's are still in place at this formerly used defense site and maintained by the National Park Service. From 1874 until World War I, a 4-mile stretch of beach and coastal dunes extending to the south and the offshore in several directions were used as target areas for the nation's primary artillery proving ground. Various naval and army artillery and experimental rounds were tested along with proof firing of barrels for government acceptance. This long-term use of Sandy Hook for military training and artillery proofing has resulted in ordnance contamination of large sections of Sandy Hook proper and the nearshore (U.S. Army Engineer (USAE) District, St Louis 1993). A wide variety of ordnance (light artillery to 15-in. cannonballs), dating from the Civil War through World War II, have been and are currently being recovered from Sandy Hook and adjacent areas.

During the pilot study reported here, each remnant battery and proving station at Fort Hancock was located and its position determined using a hand-held Global Positioning System (GPS) receiver. These positions were entered into the project Geographic Information System (GIS) database and are plotted in Figure 2. This mapping analysis was conducted to locate the Sea Bright borrow relative to Fort Hancock and its documented firing ranges to ascertain the potential for Fort Hancock to be the source of the observed ordnance contamination. In addition, an historical summary of the various batteries (caliber, range, firing zones, etc.) was developed (Table 1) based on information available through the Fort Hancock National Park.[1] It is known that the coastal batteries trained on targets that were towed in the Atlantic. Firing fans tended to cover the hemisphere from the north through the eastern quadrants to the south-southeast (directly down the line of the

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[1] Personal Communication, Thomas Hoffman, National Park Service, Fort Hancock, Sandy Hook, N.J.

spit) with ranges generally on the order of 7-9 miles (maximum of 20 miles). The borrow area in relation to the battery positions is presented in Figure 1. Note that the entire borrow area is within the quoted firing fans and range potential for most classes of artillery tested at Fort Hancock.

Discussions with Explosive Ordnance Disposal (EOD) team members at Fort Monmouth (Army) and Earle Naval Air Station (NAS) confirmed that the age and caliber of recovered ordnance from the general vicinity suggest that Fort Hancock is a likely source for the bulk of this material. They referenced finding Civil War-era cannonballs, parrot rounds, and a common array of 3-in. hollow rounds and 10-in. rounds filled with ball bearings which were known to have been tested at Fort Hancock from 1875-1919. However, they also pointed out that 90 percent of the World War II ordnance shipped to Europe went out of New York Harbor. Some of these vessels were sunk by German U-boats just outside the harbor. In addition, some ordnance cargo may have been lost or dumped off ships outside the harbor entrance. Thus, there is potentially a more modern source of ordnance contamination to the area, and more modern (circa WWII) pieces have been found in the offshore.

It was not the intent of the subject study or this cursory review of potential ordnance sources to conduct a complete historical assessment. However, the information presented here does indicate the potential for a wide variety of ordnance types and sizes to exist throughout the borrow area. A more in-depth archival review would be needed to better characterize the caliber, vintage, location, and volume of expected ordnance contamination.

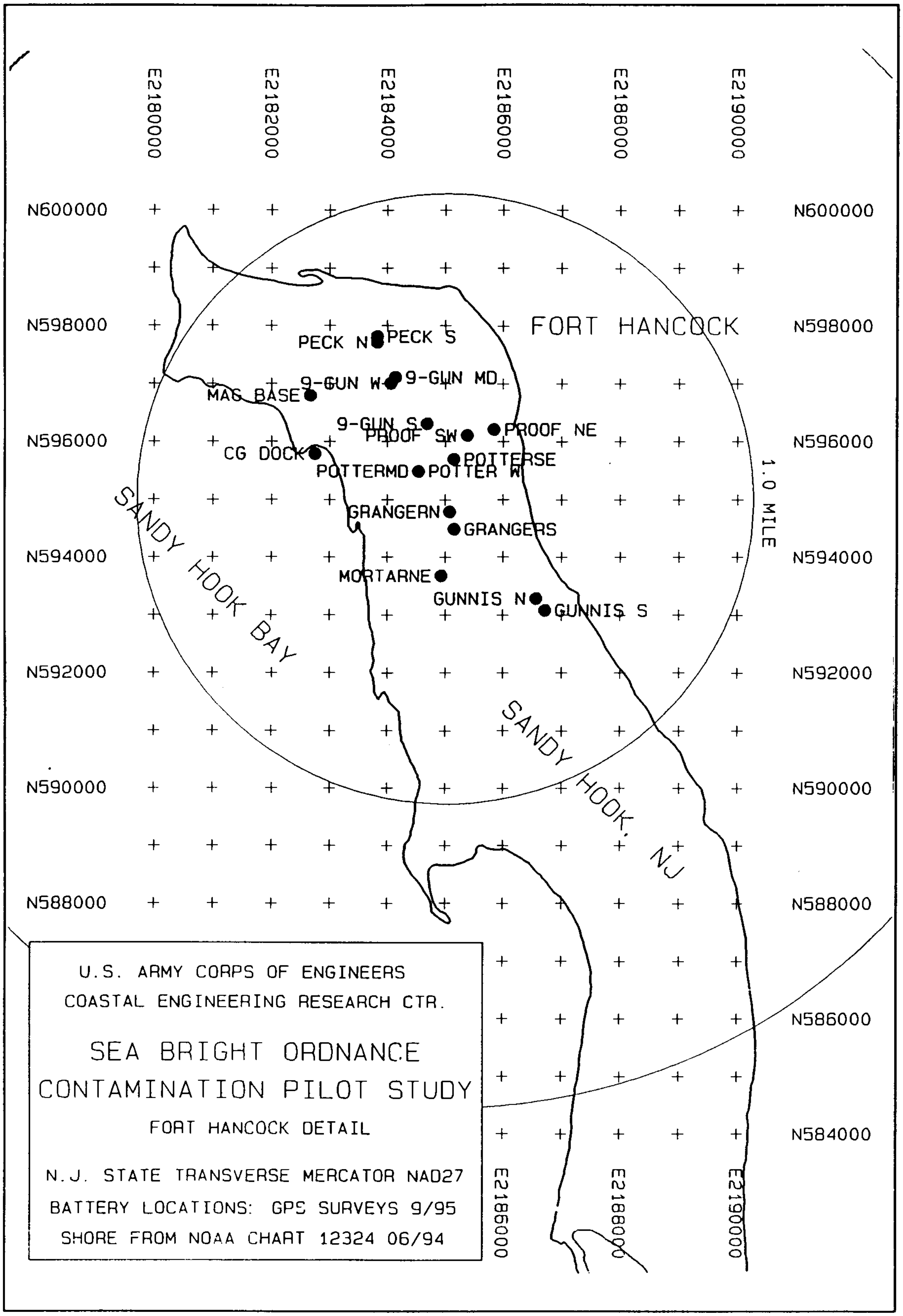

Figure 2. Fort Hancock batteries

Table 1
Fort Hancock, Sandy Hook, NJ, Battery Statistics

Battery	Active Period	Number Guns	Armorment	Weight	Range (miles)	Primary Direction of Fire	Comments
Morris	1903-1942	4	3"	15 lb for projectile + cartridge case was about 15 more pounds 30 lb per fixed round	6-8	North end of Sandy Hook toward NYC	360 deg field of fire guns mounted on Barbette carriages
Urmston	1903-1942	6	3"	15 lb for projectile + cartridge case was about 15 more pounds 30 lb per fixed round	6-8	Could fire 360 deg but mainly north toward NYC	360 deg swivel Barbette carriages
Engle	1898-1918	1	5"	50-60 lb	7-9	North end of Sandy Hook toward NYC could train to the east	Constructed 1898 disarmed 1918 fires north to east
Peck	Constructed 1903	2	6"	108 lb 18" long	15	360 deg	Barbette carriage 360 deg swivel
9-gun battery	1898-1902	3 6	10" 12"	700-1,080 lb	8-9	Northeast to southeast	"Pop up" guns disappearing carriages 140-145 deg swivel
Potter	Completed 1894, first fired 1892	2	12"	700-1,000 lb 700-1,080 lb	7-8	360 deg	2.5 to 4 or 5 ft long "torpedo" shell elevator platform guns
Granger	Built in 1896 Armed in 1897-98 Fired 1898 to 1943	2	10"	900-1,000	8-9	Northeast to southeast	Counterweight disappearing carriage
Sandy Hook Mortar Battery	1894	16	12"	700 lb	Maximum range was up to 9 miles, but accurate up to 6 miles	360 deg	Mortar pits 360 deg swivel. Four concrete firing pits, four mortars/pit

(Sheet 1 of 3)

Table 1 (Continued)

Battery	Active Period	Number Guns	Armorment	Weight	Range (miles)	Primary Direction of Fire	Comments
Gunnison	1904	2	6"			Northeast to southeast	Disappearing guns converted in 1943 to 2-6" Barbette carriages from battery Peck
	Converted in 1943 to Barbette carriages	2	6" from battery peck			360 deg	360 deg swivel
Old Proof	1874-1900 1874-1886 converted rifled Rodman guns were test fired	Small arms machine guns field, siege, and Navy artillery 1 to 16"			3.5+ mile range	Southeast over ocean and south down oceanside beach and sand dunes of Sandy Hook	All American ordnance and also foreign ordnance were test fired at the Sandy Hook Proving Ground
New Proof	1901-1919	Small arms machine guns field, siege, and Navy artillery 1 to 16"			3.5+ mile range	Southeast over ocean and south down oceanside beach and sand dunes of Sandy Hook	
Battery Kingman	WWI	2	12"	975 lb	20	From 1919 to 1941, 360 deg field of fire. Casemating in 1941 limited guns to about 145 deg northeast to southeast	Barbette carriage 360 deg swivel

(Sheet 2 of 3)

Table 1 (Concluded)[1]

Battery	Active Period	Number Guns	Armorment	Weight	Range (miles)	Primary Direction of Fire	Comments
Arrow-smith	1909-1919	3	8"	260 lb	8	Southwest to north	Disappearing guns - battery was located on bayside of Sandy Hook - could cover Sandy Hook Bay and lower New York Harbor
Mills	WWI to WWII	2	12"	975 lb	20	360 deg from 1919 to 1942 - guns were casemated in 1942, limiting field of fire to northeast to southeast	Barbette carriage 360 deg swivel roofed over in WWII which limited traverse
52nd Coast Artillery Hdq battery C battery - 12' mortar E battery - 8" rifles	1930-1941		8" rifles 12" mortars on railway flat cars	Moved 1917 260 lb moved 1938 260 lb moved 1917 700 lb	14 20 9 Maximum range	360 deg 360 deg 360 deg	Several rail spurs in the sand dunes on the ocean side of Sandy Hook
Anti-Aircraft 90mm	WWII 1942-1946	8	90mm	Projectile 21 lb 23.4 lb 24 lb	Horizontal range 11-12		Antiaircraft batteries active in WWII 4 guns at and near battery Peck, and 4 guns in sand dunes overlooking ocean - north of battery Gunnison
AAA Guns	1922-1945	10		Projectiles weighed 12.8 lb 15.5 lb 24.3 lb and 26.2 lb	Horizontal range 8-9		
Other .30 cal .50 cal .30 cal .50 cal 20mm 37mm 40mm	WWI WWII						

[1] Per Thomas Hoffman, National Park Service, personal communication, 1995.

During WWII (1942-43) some field artillery was probably employed, probably 75-mm and/or 105-mm guns.

(Sheet 3 of 3)

3 Pilot Study Overview

Background

Previous to this investigation, the ordnance contamination characteristics of the offshore borrow area were unknown. Data were lacking on the ordnance density per sector and ordnance distribution, and it was not known if the ordnance were proud (i.e. located on the surface), shallow-buried, or situated deep in the sediments. In order to investigate the possibility that more efficient dredging can be conducted in certain areas or if the ordnance fields may be suitable for efficient clean-up operations, it is necessary to characterize the degree of contamination. The challenges of mapping an underwater ordnance contamination field are significant and have received recent attention at other USACE projects (Pope, Lewis, and Welp 1996; Welp et al. 1994) and within the Military Research and Development Program. A review of available and emerging technologies was made and a pilot offshore geophysical survey designed with the intent of testing geophysical and oceanographic techniques which might be suitable for use at Sea Bright. The results of this pilot study would be used to determine the potential for application as part of a large-scale survey and to identify the appropriate development and equipment integration needed for an efficient operational-scale survey. The ultimate goal of the pilot study was to develop a recommendation and reasonable cost estimate for a full-scale study.

Equipment adapted and mobilized to the project site included a research vessel with GPS positioning, two underwater video cameras, two acoustical systems, and a magnetic gradiometer. In addition, a number of inert pieces of ordnance were used on site calibration testing of the equipment. The underwater video system and two acoustical systems were "off-the-shelf" items which required no further development for their use at this site. The two acoustical systems included a high-frequency side-scan sonar and sweep frequency subbottom profiler (i.e., X-star). Some field experimentation was conducted to improve system deployment and evaluate the performance of each system in detecting ordnance-like objects. Most of the effort during this pilot study was expended in adapting a state-of-the-technology cesium-vapor magnetic gradiometer for underwater deployment and towing. This involved the design and fabrication of a water-tight tow containing two magnetometers, integration with an altimeter for controlling elevation, and adaptation of data processing software. A sea trial of the fabricated system was conducted in California prior to shipment to Sandy Hook.

The pilot study was conducted during 8-15 September 1995, and included the following sequence of activities:

a. Mobilized equipment and personnel to study site (8-9 September).

b. Assembled magnetometer and conducted deployment tests (10 September).

c. Constructed equipment calibration range using inert ordnance in shallow water (10 September).

d. Conducted tests of magnetometer over the calibration range and deepwater deployment tests (11 September).

e. Assembled subbottom and conducted tests over calibration range (11 September).

f. Conducted side-scan sonar survey of northwest corner of borrow area 1A from NAN vessel (12 September).

g. Conducted magnetometer survey along long lines adjacent to borrow area 1A (12 September).

h. Conducted dense magnetometer survey of northwest corner of borrow area 1A (13 September).

I. Conducted video camera drift surveys along long lines adjacent to borrow area 1A from NAN vessel (13 September).

j. Conducted subbottom (X-star) surveys of northwest corner of borrow area 1A and long lines adjacent to 1A (14 September).

k. Obtained video footage of northwest corner of borrow area 1A using towed video and Remotely Operated Vehicle (ROV) (14 September).

l. Briefed NAN staff during onsite visit (14 September).

m. Removed equipment calibration range (14 September).

n. Conducted magnetometer and side-scan sonar surveys in northwest corner of 1A and long lines adjacent to 1A (15 September).

o. Coordinated background information with EOD detachments at Fort Monmouth and Earle NAS and determined position of historical batteries (15 September).

p. Packed equipment and demobilized from site (15 September).

After completion of the pilot study, the survey tracklines were captured and entered into a GIS database, and the individual data sets were processed. The surveys were conducted in water depths of 30-50 ft (Figure 3). The survey coverage obtained per system (i.e., video camera track lines, X-star track lines, and magnetometer track lines) is illustrated in Figures 4-7.

Inert Ordnance Test Bed

An ordnance calibration and test field was temporarily installed in a protected cove adjacent to the Sandy Hook Coast Guard (CG) Station (near CG dock shown on Figure 2). A jet pump was used during low tide to bury (approximately 0.7 m below the sand surface) a cluster of several pieces of inert ordnance. This created a buried target approximately 0.5 by 0.5 m^2. In addition, nine pieces of inert ordnance of various calibers (generally ranging from 75 mm to 105 mm, including a 155-mm piece) were placed 3 m apart in a line parallel to shore at a location where approximately 2 to 2.3 m of water would exist during high tide. The single inert ordnance piece closest to the cluster was buried approximately 0.3 m below the sand surface. Each ordnance target was marked with a witness buoy. Prior to the installation of the ordnance test bed, the area had been "swept" with a hand-held magnetometer to confirm that no other ferrous metal objects were present. There were, however, a number of pieces of wood and stone in the test bed area. The magnetic gradiometer and the X-star were towed over this test bed several times during high tide in an attempt to evaluate the performance of these two instruments in a controlled test. After completion of these tests, the inert ordnance was removed and the site was returned to its pretest condition.

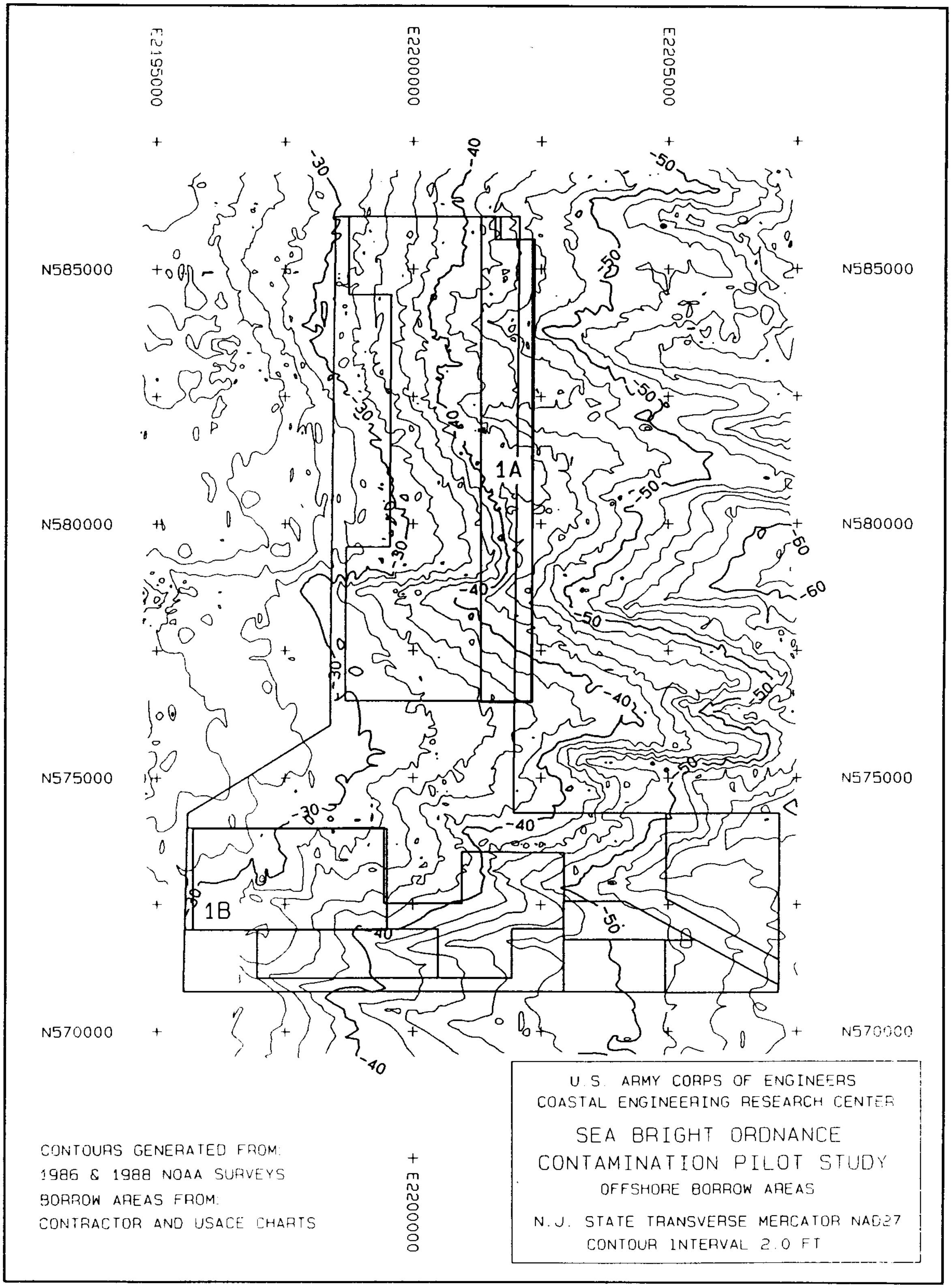

Figure 3. Borrow area and bathymetry

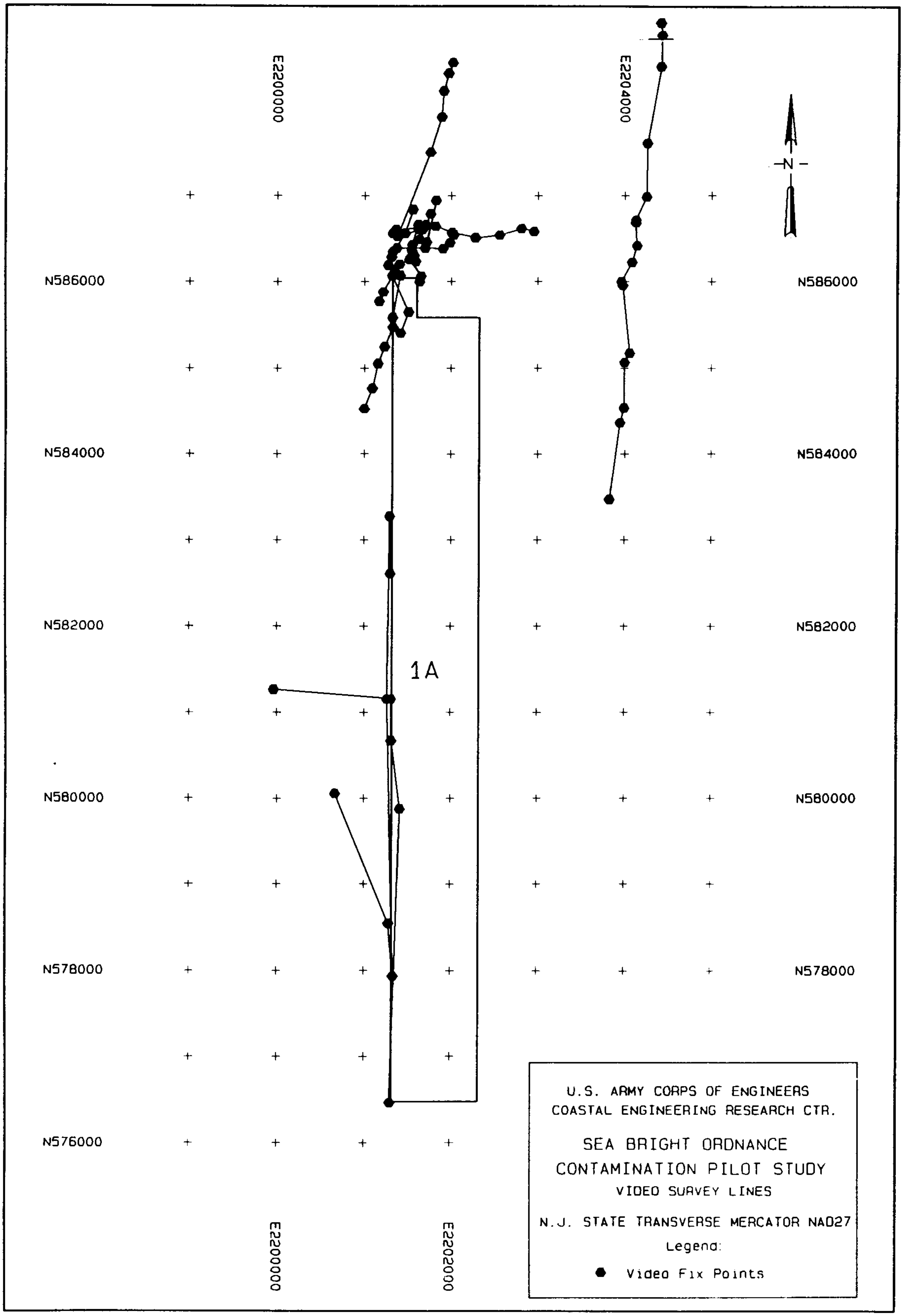

Figure 4. Underwater video survey lines. Borrow area 1A shown for reference

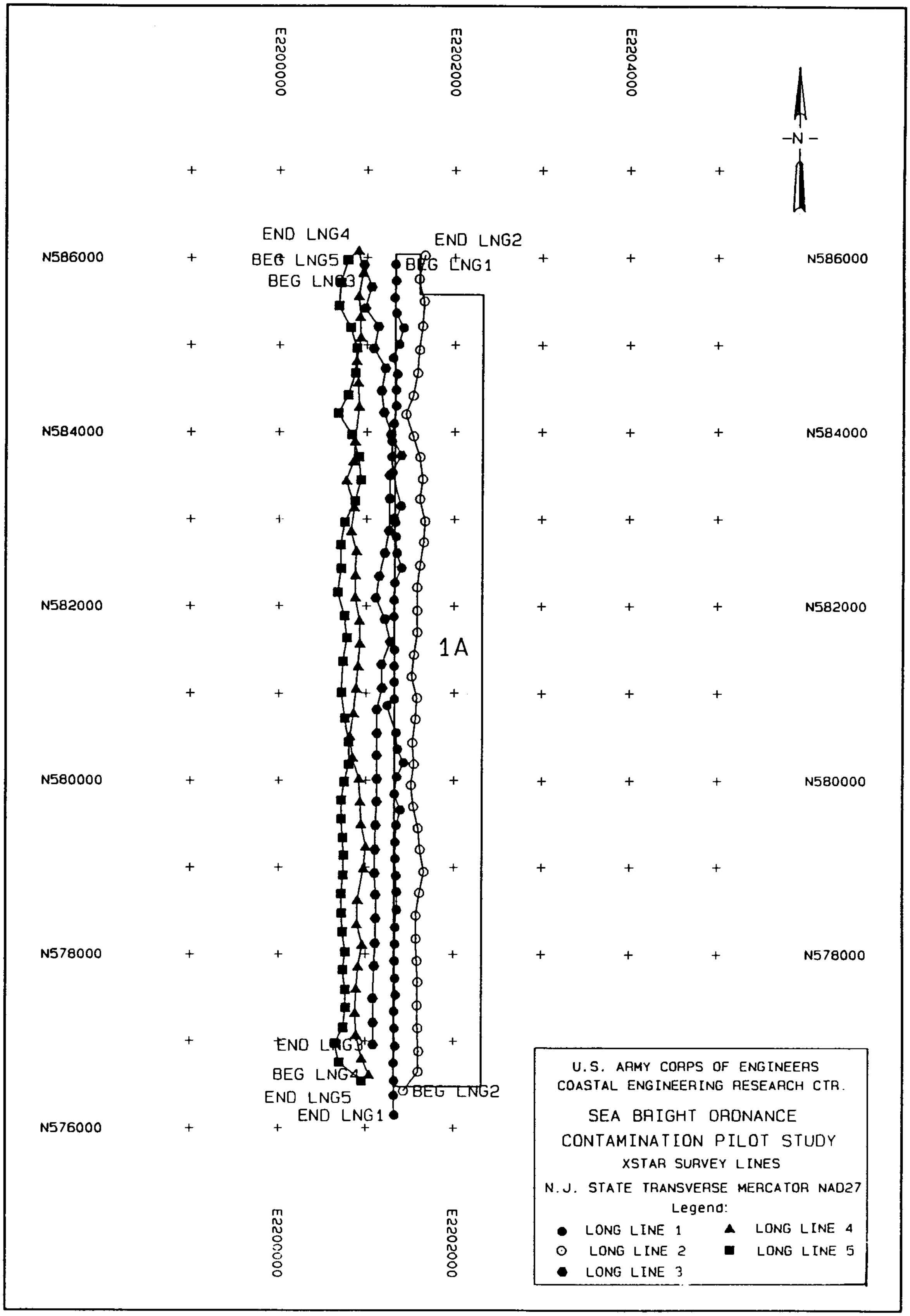

Figure 5. X-star subbottom profiler survey lines. Borrow area 1A shown for reference

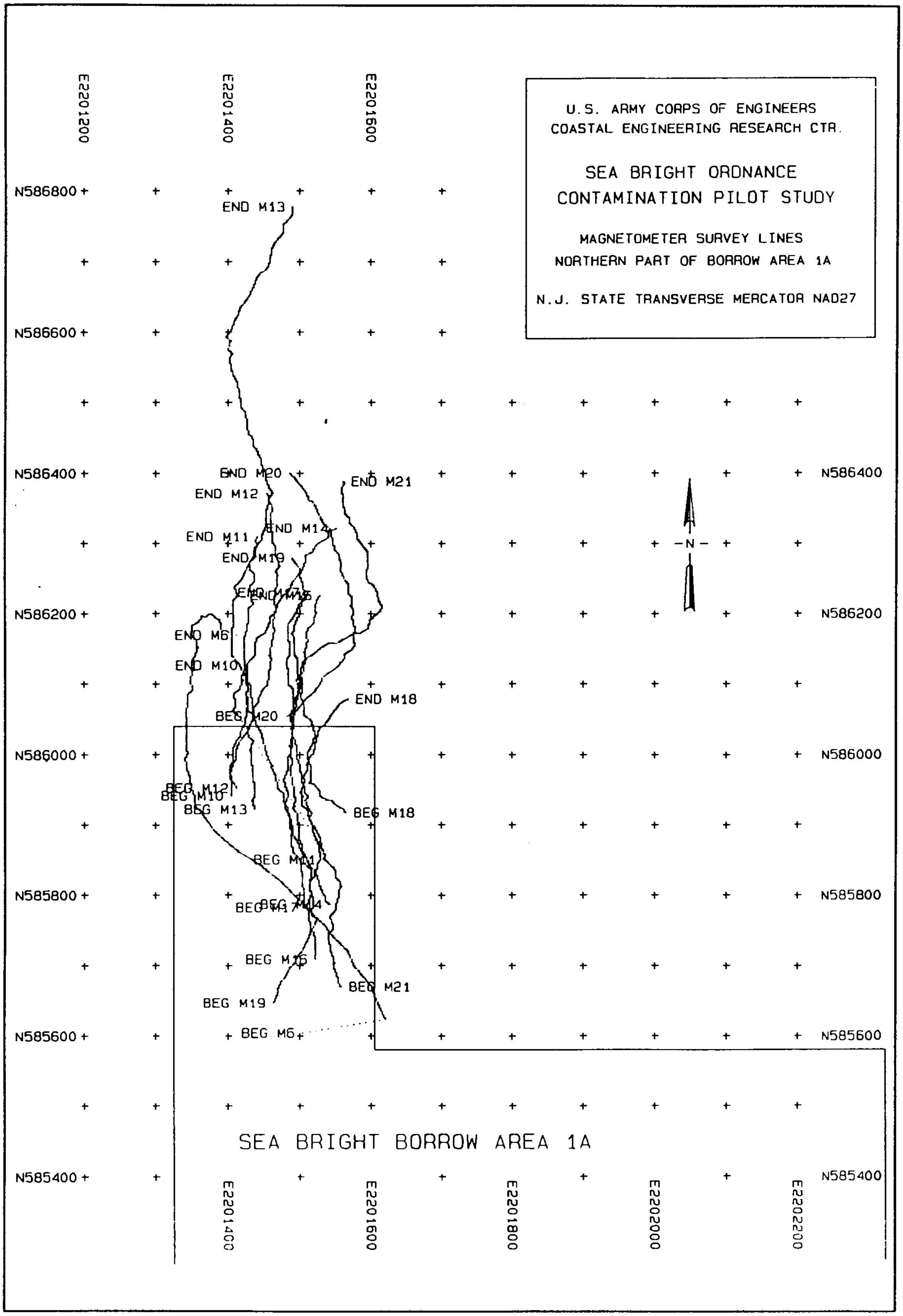

Figure 6. Magnetometer survey lines, northern portion of borrow area 1A

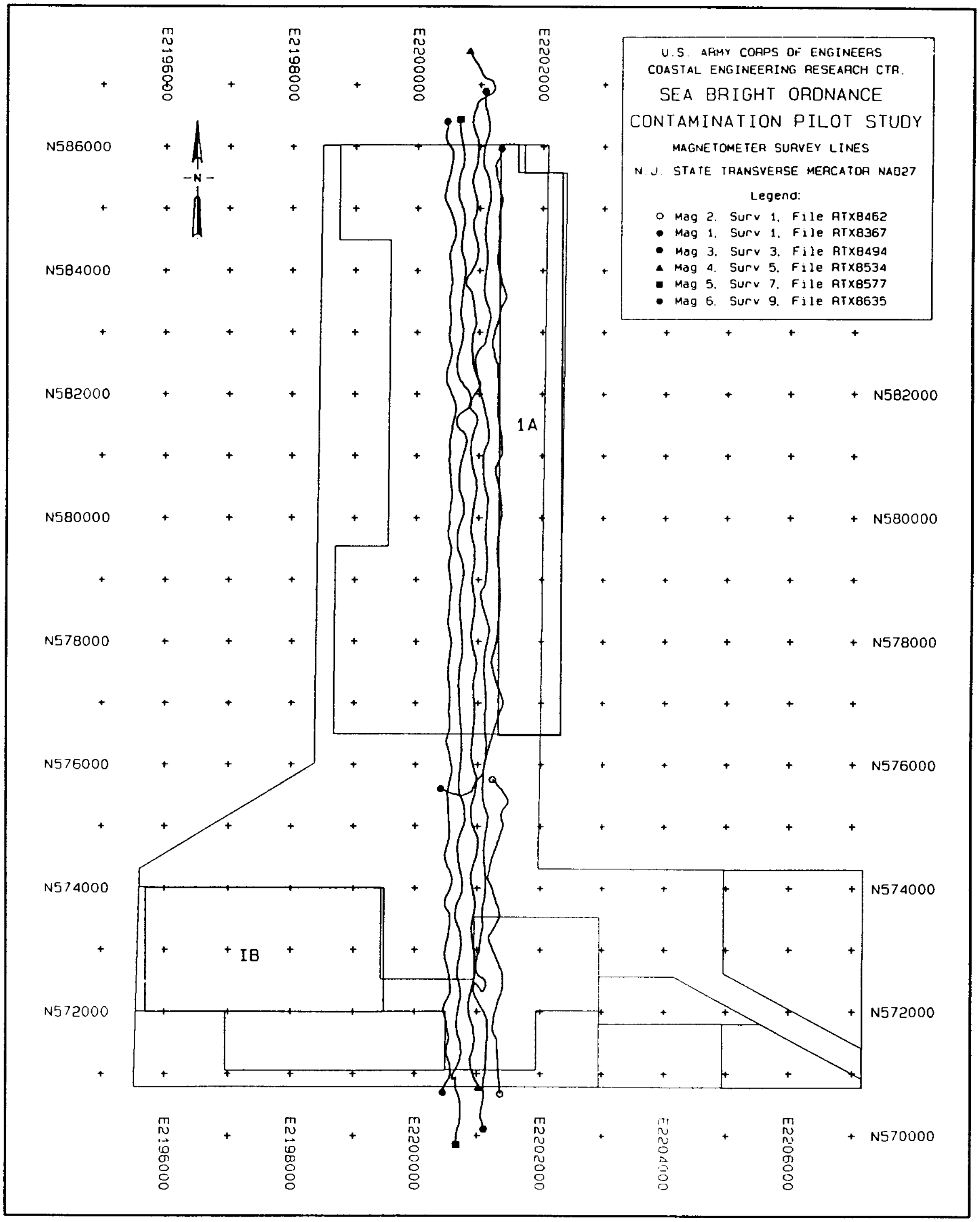

Figure 7. Long magnetometer survey lines. Overall Sea Bright borrow area shown for reference

4 Acoustical Systems

Side-Scan Sonar

Side-scan sonar was used during the pilot study for several purposes: to provide a general "picture" of the site including bed forms, to note large obstructions which may need to be avoided, and to test the capability to detect small (ordnance-type) objects on the bottom. The latter goal would require identifying a pattern of returns in a specific area that was more likely to be a cluster of hard, cylindrical objects than normal returns from bottom roughness elements. Throughout the survey area there were hard, dark targets that appeared on the sonographs as 0.25-m-long, relatively strong backscatter signals. Because these areas were observed throughout the survey area and appeared with no particular pattern, their source may be accredited to a natural effect of bottom roughness. Without additional ground-truthing, it is not appropriate to identify these returns as pieces of ordnance. Larger objects with patterns that were likely of man-made origin were observed in the study area. These included what appeared to be a small sunken boat partially buried and a subsurface buoy. In the case of the subsurface buoy, the magnetometer detected the presence of metal in approximately the same area. Sand waves were prevalent over several sections of the study area (Figure 8), which tended to dominate the acoustical signal in these areas, obliterating any smaller returns. To the north of borrow area 1A, the bottom had a mottled appearance which suggests the presence of circular zones containing a different (finer-grained) material than the surrounding sandy bottom (verified by video camera crossings of the same area). The side-scan sonar did a satisfactory job in locating larger objects and illustrating changes in bottom texture, but it is not appropriate as an instrument for independently detecting the classes of ordnance present at this site. As with all applications of side-scan sonar, a full-survey use of this instrument would need to include a "ground-truthing" phase where divers or other forms of bottom imaging would be collected and used to verify record interpretation.

X-star

The purpose of testing the X-star was to determine the ability of this instrument to detect hard return objects buried within the upper (say, 2-m) portion of a sandy bottom. The potential value of X-star in characterizing the ordnance contamination at Sea Bright would be realized if it was able to document whether or not suspected ordnance was buried beneath the sand surface which would complicate any prospective site clean-up activities. As the first step in testing the X-star, it was towed several times approximately 1 to 2 m above the inert ordnance test bed. Targets were detected which may be interpreted as representing the ordnance located on the bottom (Figure 9); however, nothing could be detected at the location of the single buried piece or at the buried cluster. Since a return from the buried ordnance could not be detected, we conclude that the scattering of the acoustical signal by the sandy sediment prohibits the use of X-star to identify buried ordnance targets in this setting. The X-star was towed along a number of lines in the survey area and throughout the record there were target returns from the bottom surface similar to those observed in the test bed at the Coast Guard Station. There were some subsurface targets noted in the tows from the borrow area, but the nature of these returns could not be used to verify if they were or were not ordnance. The acoustical return from the X-star cannot be used to discriminate between objects of different composition. Thus, the observed returns could be stones, wood, or ordnance. The conclusion of the pilot study is that X-star would be of limited use during the conduct of a full-scale survey.

In summary, both acoustical systems did provide information on the bottom texture and indicated the presence of hard target returns. However, interpretation of these targets as ordnance is not appropriate without verification via ground-truthing or the magnetometer. The X-star did not provide the additional information on buried targets which was its primary aim. In addition, the footprint (i.e., width of field of view) of the X-star is much more limited than that of a magnetometer. It is not (under presently available operational configurations) appropriate to use the X-star for conducting the broad survey operations. The side-scan sonar, however, is appropriate as a reconnaissance tool to document bottom conditions and obstructions prior to conducting a magnetometer survey/sweep of an area.

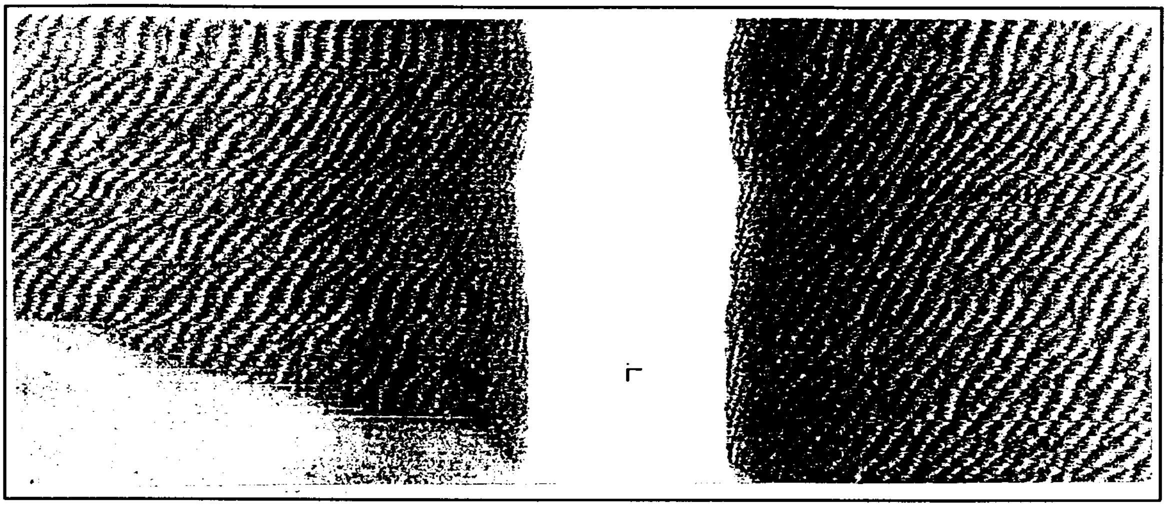

Figure 8. Side-scan sonar record showing sand waves

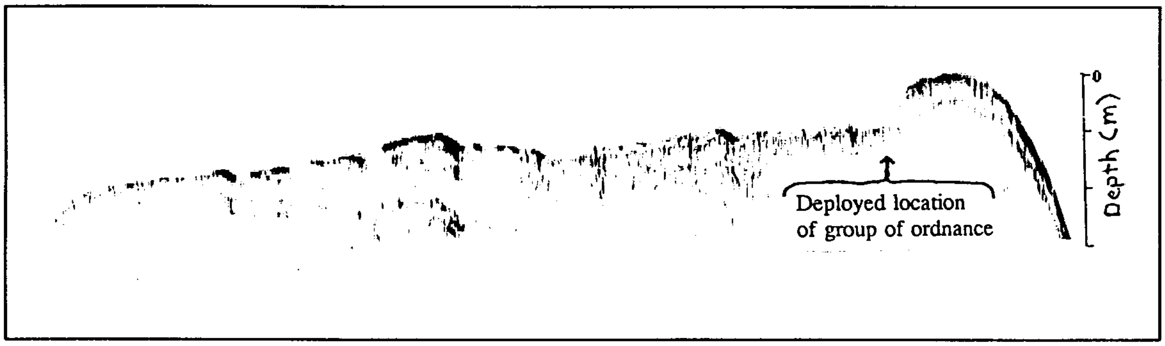

Figure 9. X-star record from along line of ordnance placed for test of system

5 Video Camera

Two types of underwater video camera deployments were tested. The Coastal Engineering Research Center ROV is maneuverable and contains an underwater video camera. In addition, a higher resolution, low-light camera was brought onsite for testing. The original intent was to mount the low-light camera on the magnetometer sled to allow filming and real-time visual monitoring of the bottom as the magnetometer surveys were being conducted. Although the low-light camera was specified as non-metallic, onsite testing revealed that there were enough metal parts in the camera to contaminate the highly sensitive magnetometer signal. This prohibited its use on the magnetometer mount. Thus, the low-light camera was deployed as an independent sensor via mounting on the ROV and on a towable v-fin.

Ideally, remotely operated underwater cameras are controlled from a motionless vessel. However, the project safety plan prohibited anchoring of manned vessels, and strong tidal currents and wave action at this site caused significant vessel drift. Thus, both the ROV and the low-light camera were towed over the bottom in the same areas but independent of the other instruments. Areas viewed during the video tows are shown in Figure 4.

Video image observations revealed the bottom borrow areas to be sandy with some rhythmic topography (sand ripples) and occasional coarser sand/gravel streaks (usually in the troughs between the sand waves/ripples). Several pieces of suspected ordnance were observed. The video tows included several drifts to the north of borrow area 1A. Here, the camera passed over a bottom which changed from clean sand to hummocky-clay zones. The clay was scarred with current marks. Bottom debris (plastic, ceramics, metal, and suspected ordnance) were observed in these clay zones.

6 Magnetometer

Introduction

To detect the presence of ferrous dipole targets of finite length, a marine cesium vapor magnetic gradiometer was developed, deployed, and tested. The instrument noise level was about 0.015 nanoTeslas/meter (nT/m) or 5 times less than the magnetic gradients generated by relatively quiet coastal waves. Numerous clusters were identified which contained responses typical of the anticipated ordnance items. The magnetic gradiometer demonstrated a high degree of ferrous object sensitivity, thus providing a large detection range and target location capability. Potentially the gradient data can be used for basic classification and discrimination of ordnance size. Underwater magnetic investigations to detect ordnance were conducted in the Sandy Hook area at a constructed test site, an ordnance disposal site, and at the Sea Bright designated borrow area.

Theoretical Background

The principle of magnetic detection and location of ordnance originates from the localized magnetic field variations that these objects produce. These deviations from normal magnetic field conditions are the result of specific characteristics of the ferrous material (iron and steel) contained in the manufactured ordnance. Two physical features are present in ferrous material which, in turn, cause a change in the local magnetic field. These properties are as follows:

a. Induced magnetism. This is the phenomenon that makes most ferrous metal ordnance detection and classification possible with magnetic surveys. The Earth's magnetic field establishes a secondary magnetic field in the ordnance item. This disturbance is measurable when a sensor is within the area of the ordnance's magnetic signature. The intensity and range of the local magnetic field alteration is based on the magnetic susceptibility of the iron or steel and the size and shape of the shell. If this value is known, the mass (weight) of the ordnance can be estimated and the caliber roughly approximated.

b. Remnant magnetism. This is the natural magnetic field that the ordnance material contains. It is a function of the properties of the metal and the casting procedure. Both of the above properties form the basis whereby various sizes and types of ordnance may be detected. Currently, few measurements have been made to determine what these values are for WWII and earlier ordnance items.

Instrumentation

To accurately and rapidly detect the magnetic field variations produced by ordnance, a much more precise magnetic sensor is used than commonly employed in terrestrial and marine surveys. The instruments used for the Sandy Hook investigation were state-of-the-art cesium vapor marine magnetic sensors produced by Geometrics of Sunnyvale, CA. These were fabricated and configured expressly for this project in a development effort. The normal precision of a standard marine magnetometer is about ±4 nT. (As a reference, the Earth's magnetic field intensity is about 55,000 nT at this site.) For marine use, this sensitivity level has been satisfactory in the location of larger objects such as hulls, wrecks, etc. To pinpoint smaller items such as ordnance, it is necessary to use cesium-vapor magnetic sensors or some other extremely precise instrument which have a sensitivity of ±0.02 nT. This aids the discovery effort in two ways: (a) a much smaller object can be detected, and (b) it is possible to measure the local field using two or more closely spaced sensors and achieving the gradient of the anomalous magnetic field. This measurement can be used to effectively vector toward the object. From several locations, the target location can be established by triangulation. In addition, by using the magnetic gradient to detect the ordnance, a much more accurate and straightforward procedure is achieved. In this investigation, two cesium-vapor magnetometers were towed about 50 m behind a fiberglass-hulled research vessel at a height of 1 to 2 m off the ocean bottom (Figure 10). These instruments were mounted 2 m apart, transverse to the towed direction. The following data were collected every 2 sec: (a) time, (b) ship's position, (c) instrument setback, (d) instrument altitude from the sea bottom, (e) course over ground (COG), and (f) speed over ground (SOG). The following were recorded every 0.1 sec: (a) the magnetic field at both sensors, and (b) the horizontal magnetic field gradient. As a consequence of measuring the magnetic gradient, it was possible to immediately determine if an ordnance type signature originated from the port or starboard side of the track line.

Test Site

A test site was established offshore of the Sandy Hook Coast Guard Station. A magnetic sweep of the site for any foreign iron objects was first conducted at low tide confirming a magnetically clean test area. The magnetic gradiometer was then towed over this calibration site after the inert ordnance targets had been placed. In this test the magnetic sensors were approximately 1.3 m under water, or 1 m above the bottom and the inert ordnance items. The individual and the cluster inert ordnance targets were detected in various calibration passes over the test site, Figures 11 and 12. In most tests the signature of adjacent items overlapped, since the area of magnetic disturbance well exceeded 3 m. However, it was still possible to distinguish the individual presence of seven to nine items from the magnetic gradient data in every instrument pass through the test area.

Small Site

An offshore location near the northern part of borrow area 1A where previously recovered ordnance had been disposed was investigated[1] (Figure 6). Multiple traverses were made over this site. The water depth at the time of the investigation was nominally 10 to 12 m. This designated ordnance placement site was about 75 by 100 m in size. Multiple passes over this and the immediate adjacent area detected numerous ordnance-type magnetic signatures (Figures 13 to 17). During all of these short traverses, the cesium vapor magnetic sensors were "flown" 1 to 2 m above the seafloor. All of these detected responses are indicative of short magnetic dipole type targets, typical of the expected ordnance that had been placed at the location. However, the magnetic responses of many of the objects were suggestive of a dipole (i.e. an elongated object having a distinctive north and south pole) in a rather random orientation. This would be expected for ordnance items dropped on the site recently. In comparison, the magnetic investigation of the borrow site using rather long traverses revealed that for the most part, the ordnance items appear to have become aligned with the long axis parallel to the shore. This preferred orientation has been observed in other coastal environments (Pope, Lewis, and Welp 1996).

Long Lines

Five traverses, which stretched several miles in length, were collected in north-south directions at separations of 60 m. These lines were immediately west of borrow area 1A (Figure 7). Adjoining track lines ran in opposite directions, i.e, a north-to-south line was adjacent to a south-to-north line, etc. The instrument package was located at a 54-m setback behind the vessel and was flown at an elevation of 1 to 2 m above the seafloor.

Significant concentrations of ordnance-sized objects were encountered throughout these passes. The spatial distributions of magnetic responses along the traverses are shown in Figure 18. Areas along the line where a magnetic response was evident are darkened. This practice shows any two-dimensional distribution of ferrous objects in the investigated area and allows for discrimination of larger versus smaller objects. The transverse magnetic gradient of each of the long track lines is displayed in Figures 19 through 27. A positive gradient anomaly in these figures represents a magnetic object east of the line, while a negative response indicates an object west of the line. A larger object will have a longer segment of the line where a magnetic disturbance is recorded. Evidence suggests that the density of magnetic objects diminishes at the southern end of the surveyed area.

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[1] Personal Communication, James Mullens, USAE District, New York.

The magnetometer data were processed in the following manner: (a) the COG as collected by the Differential Global Positioning System (DGPS) was smoothed. This removed the pitching by the sea conditions of the research vessel from the navigation data which were collected every 2 sec. The SOG was smoothed for the same reason, to remove the variations due to the vessel moving from sea conditions. Subsequent measurements, collected every 2 m, were used to compute the magnetic gradient parallel to the traverse. This gave a very close approximation of the total horizonal magnetic gradient since the gradient was then both perpendicular and parallel to the track lines. This gradient, either negative (dashed lines) or positive (solid lines) was used to vector toward and triangulate upon the pole and dipole locations of various ferrous objects. Examples of these data are shown in Appendix A. Three figures are generated for each anomaly, the upper left is the total anomalous magnetic field (in nanoTeslas x 10^4) as measured by the two cesium vapor sensors separated by 2 m traverse to the track line of the vessel. Sensor "A" is to the left or port of the course, and sensor "B" is to the right or starboard of the track line. The right side of the figure is to the south or north as indicated by "S" or "N" in the caption. With only a few exceptions, the majority of the detected magnetic objects have a magnetic "low" response to the north of the magnetic "positive" response. In the northern latitudes such as New Jersey, this is indicative of anomalous magnetic effects originating from mainly the induced magnetic field effect, and only a smaller portion is from remnant magnetization. Ultimately, if physical measurements on some recovered items demonstrate that this is correct, the data can be processed using more straightforward and simpler assumptions. The horizontal magnetic field gradients are displayed in the lower left figure. These are "G" "east-west" gradients (perpendicular to the track line) and "H" north-south" magnetic gradients (parallel to the track line). Both measurements are in nanoTeslas/meter. The right figure on each page displays the smoothed track line. The portion of the track line which is inclusive of the detected anomaly is plotted in relative northing and easting locations (units in feet). The intensity and horizontal direction of the resultant magnetic gradient are then plotted in reference to the smoothed COG. In these plots, the length of the magnetic gradient vector is proportional to the strength of the gradient. Since the target objects generally respond as dipoles (each generates a positive [south end] and negative [north end] magnetic anomaly) the gradient vector from the track line is dashed in its decreasing direction and solid in its increasing direction. This is necessary since a magnetic low anomaly on one side of the track line can have the same gradient as a magnetic high on the opposite side. However, as the sensors pass by the anomaly, the gradients will converge on the source location. From this method, ordnance-type dipole objects can be even further identified by the location of a magnetic negative gradient (dashed lines) being generally immediately northward of a magnetic positive gradient (solid lines).

Almost all of the detected magnetic responses were locatable within distances of about 3 m on each side and beneath the cesium vapor magnetic sensors. This gives a detection and location swath width of about 8 m for survey purposes. Over 95 percent of the detected anomalies were determined to X-Y locations of a meter. The major exception to plotting an object's location were circumstances where it was located in a debris field and thus in a complicated magnetic gradient environment. Many of the objects are most likely elongated dipole objects (much like a 3- to 4-ft-long, 10-in.-diam shell would be). These type of items could very easily be situated so that a convergence of negative magnetic gradients would be immediately (2 to 3 m) north of the convergence of magnetic positive gradients.

Target Location and Analysis by Maximum Likelihood Estimation Method

Areté Engineering Technologies Corporation (AETC) of Arlington, VA, examined and conducted additional post-processing of about 60 percent of the magnetometer data from Sea Bright. AETC used a target characterization procedure based on matching measured magnetic anomalies to magnetic dipole fields using Maximum Likelihood Estimation techniques. They inferred the object size from the dipole moment using an empirical relationship (Bell, DeProspo, and Prouty 1996).

Areté Engineering pointed out that there was a significant range of magnetic response from the UXO, even for items of fixed caliber, and the standard deviation about the mean correlation for similar-sized targets was about 25 percent. Some of the variability in apparent size for specific ordnance items was due to remnant magnetization, but the primary factor was the shape and orientation of objects on their magnetic signatures. When the long axis is aligned with the earth's field, the induced dipole moment of such an object is much larger than, for example, the dipole moment that is induced when the object is lying transverse to the earth's field. This indicates that future calibration field tests of the cesium magnetometers must be conducted with test objects lying both parallel with and perpendicular to the earth's magnetic field.

One hundred magnetic anomalies were selected from the survey data for detailed analysis to demonstrate the target characterization procedures. The data were taken from the six long north-south lines. A histogram of the distribution of anomaly strengths is shown in Figure 28. With few exceptions, the apparent dipoles were oriented more or less to the north, suggesting that ordnance in this area is lying on the seafloor approximately parallel to the New Jersey shore. Distribution of the estimated cross-track locations of the 100 anomalies is shown in Figure 29. Positive values are to the right of the survey track line, and the shaded area shows the detection swath width for the magnetometer array used during this survey. With the magnetic sensor array flying at about 1.7 m above the seafloor, the system detected objects at a range slightly over 4 m to either side. Sensitivity studies based on dipole anomalies embedded in uncorrelated Gaussian noise demonstrated that for these ranges, typical ordnance can be located with 10- to 20-cm accuracy using the survey data.

The distribution in depth for the test anomalies is shown in Figure 30. Most objects were lying on the seafloor, but a small minority appeared to be hovering 50 to 100 cm above the bottom. It is not clear if these peculiar results were due to faults with the altitude sensor, raised seafloor areas, or some other undetected problems. Possibly they represent long or irregular-shaped marine debris that are sticking out of the bottom (proud objects). Most likely, these are errors induced by the sensor platform traversing at a slightly tilted angle from horizontal.

Finally, Figure 31 shows the distribution of apparent sizes of the anomalies. The apparent size of an object is its equivalent radius, which is the radius of a steel ball having the same dipole moment. Bell, DeProspo, and Prouty (1996) found that ordnance caliber is almost equal to the measured dipole radius. Figure 31 also shows that objects range from 5 to 50 cm, with the most common clustering between 10 and 35 cm (4 to 14 in.). These sizes are consistent with the caliber of ordnance recovered in the test raking operation by the *Miss Kathy*, but the distribution is different. The distribution of the raked ordnance was dominated by smaller pieces (*i.e.*, 8- to 13-cm range), and the raking operation only recovered 24 objects, a sample size too small to use to evaluate the distribution of size classes (Figure 32).

A total of 240 anomalies were counted by AETC during their analyses. Assuming that all the anomalies correspond to targets and that the detection swath is 4 m to either side of the track, this amounts to an ordnance density of about 15.4 objects per hectare. The raking operation recovered ordnance at only one tenth of this density, about 1.3 objects per hectare. The discrepancy may be due to three factors. First, not all anomalies may be caused by actual ordnance but rather by other sorts of metallic debris. This, however, is not likely to be significant due to the average precision of fit which exceeded 0.98 of the measured magnetic anomalies to simple dipole models. Most marine debris would not be representative of simple dipole magnetic sources. Second, the raking operation may have failed to recover many ordnance items on the seafloor. Preliminary tests in other locations have shown that many shells fall out of the rakes before they can be retrieved onto the deck of the vessel. Also, a factor due to the raking activity occurred in Borrow area 1A, which is seaward of the area evaluated by AETC. Most likely the difference is from the shallow depth (10 cm) that the *Miss Kathy* was able to reach. Analysis of the depth of the ordnance, Figure 29, shows that most of the ordnance is below 10 cm in the sand, but buried shallower than 1.5 m.

In summary, the AETC sensitivity analyses indicate that out to a range of 3 or 4 m from the survey track, a large piece of ordnance (*e.g.*, greater than a 4-in. caliber shell) can be located within 10 - 20 cm accuracy (x, y, and z) relative to the array using the survey data. Using a statistical sample of 100 magnetic anomalies from the surveys, the distribution of apparent dipole orientations indicates that the magnetic moments are largely induced and that the objects tend to be lying flat, parallel to the bottom, rather than upright. Most objects appear to be on the bottom or at fairly shallow depths. The computed target density was about 16 items per hectare, over ten times greater than was computed from the *Miss Kathy* raking operation.

Magnetic Location Conclusions

The cesium-vapor gradient magnetometer proved to be highly successful in detecting and resolving the presence and location of ordnance-like objects in the borrow area. Magnetic signatures obtained during the pilot study indicated the presence of numerous dipole objects corresponding to ordnance signatures in the areas surveyed. The occurrence of these characteristic signatures diminished toward the south. The most common detected dipole objects were: (a) comparable in size to 6- to 12-in. shells, (b) located at or near the sand surface, and (c) oriented generally parallel to the shoreline (north-south). This information has implications concerning the mobility of the ordnance and methods to be used in any potential site cleanup operations. Other specific magnetic signatures have been identified as representing metal spheres (such as a cannonball), marine clutter (such as a zone of odd-shaped metal fragments), and larger objects (drums and possibly shipboard jetsum). Further post-processing of the magnetic data would give additional information concerning individual objects and the orientation, approximate size, and three-dimensional location of these defined targets.

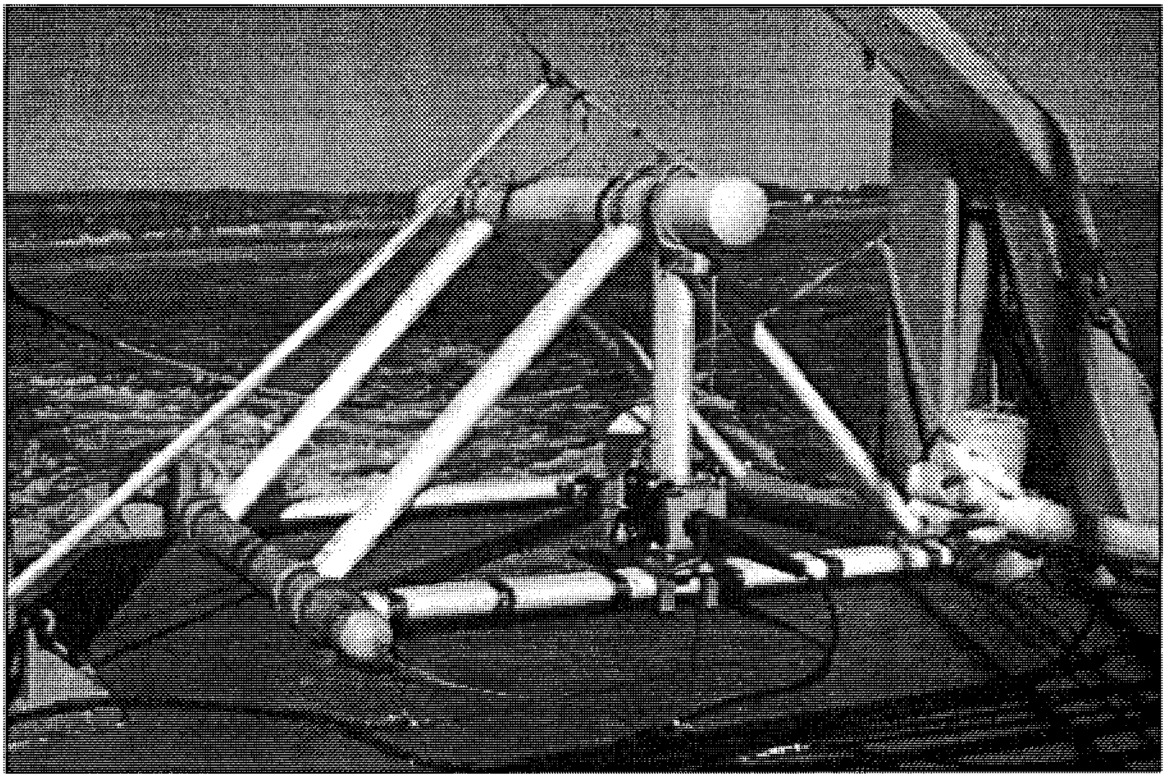

Figure 10. Custom-fabricated mount for cesium-vapor sensors

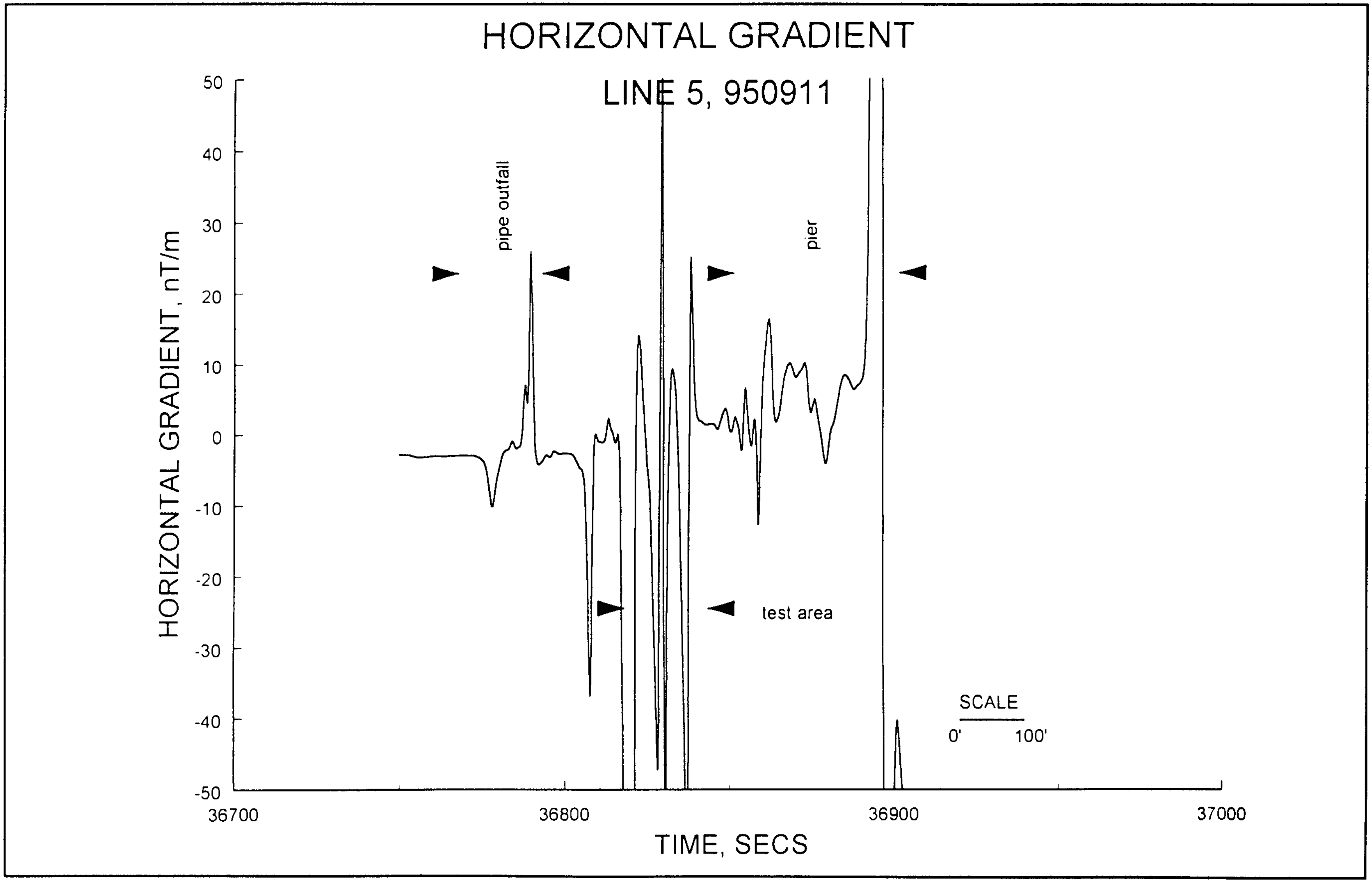

Figure 11. Example of horizontal magnetic gradient recorded during calibration tests with inert ordnance test targets, pass number 5

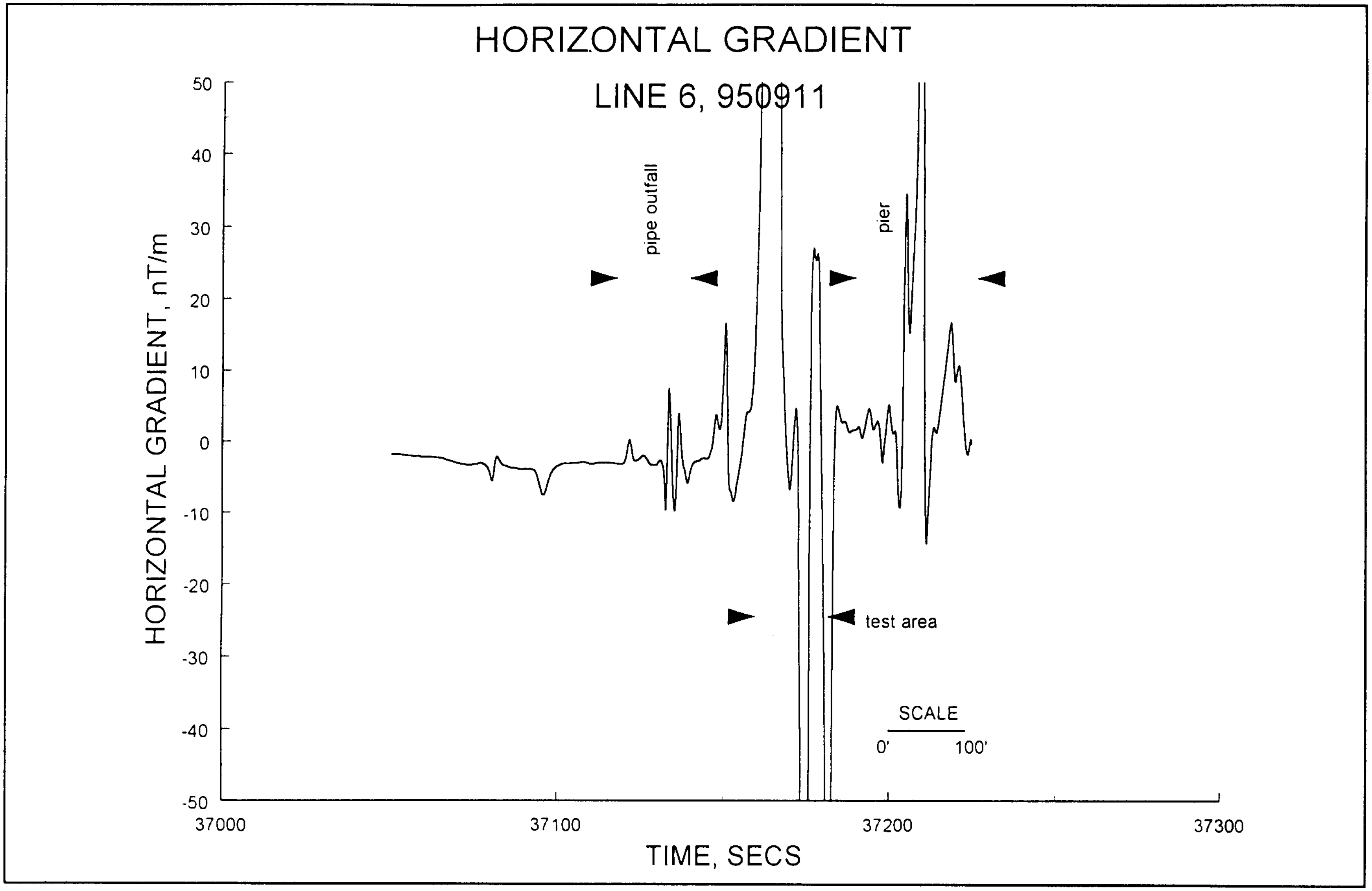

Figure 12. Example of horizontal magnetic gradient recorded during calibration tests with inert ordnance test targets, pass number 6

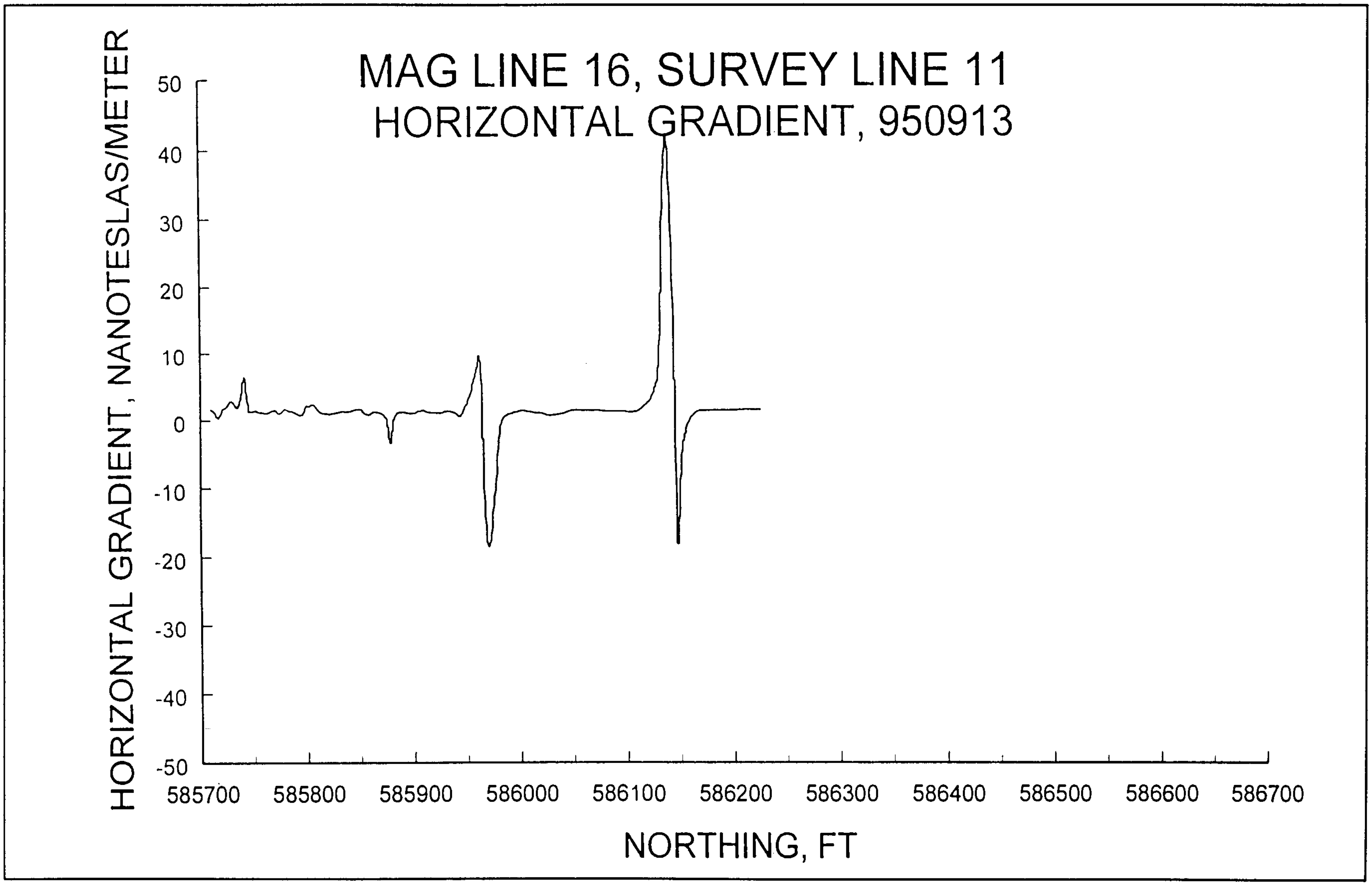

Figure 13. Horizontal magnetic gradient recorded in ordnance disposal area, magnetic line 16 (reference Figure 6)

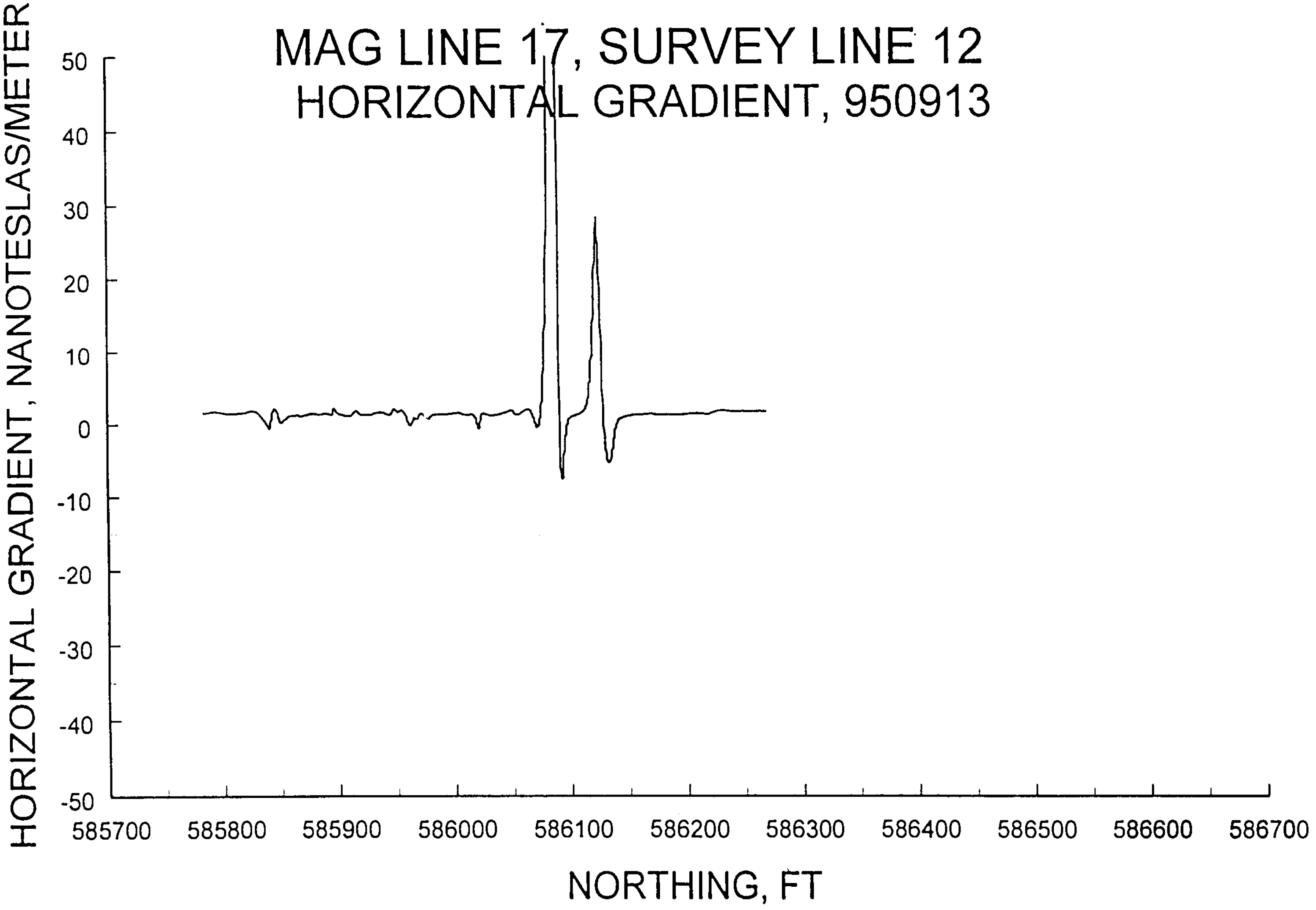

Figure 14. Horizontal magnetic gradient recorded in ordnance disposal area, magnetic line 17

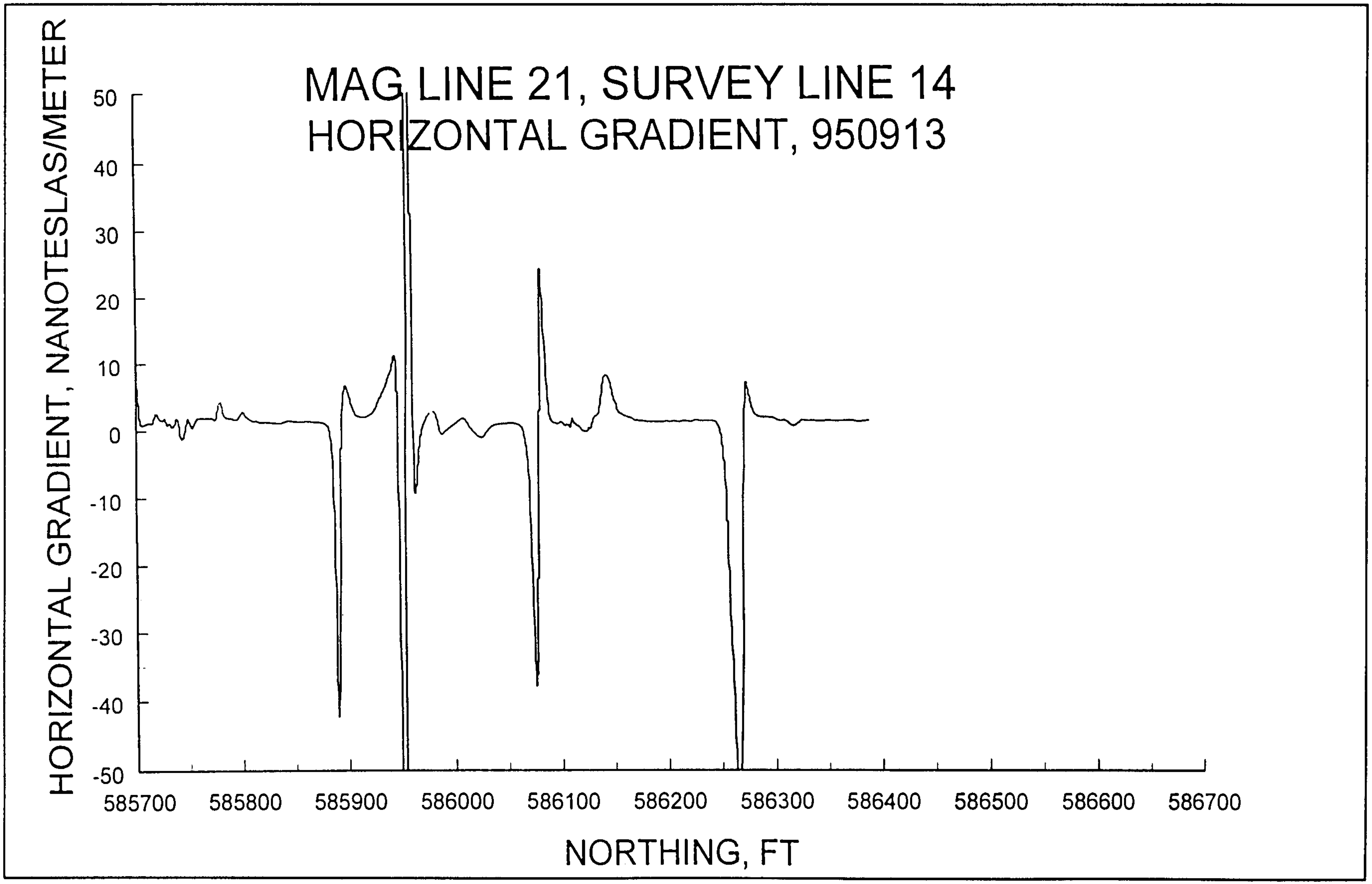

Figure 15. Horizontal magnetic gradient recorded in ordnance disposal area, magnetic line 21

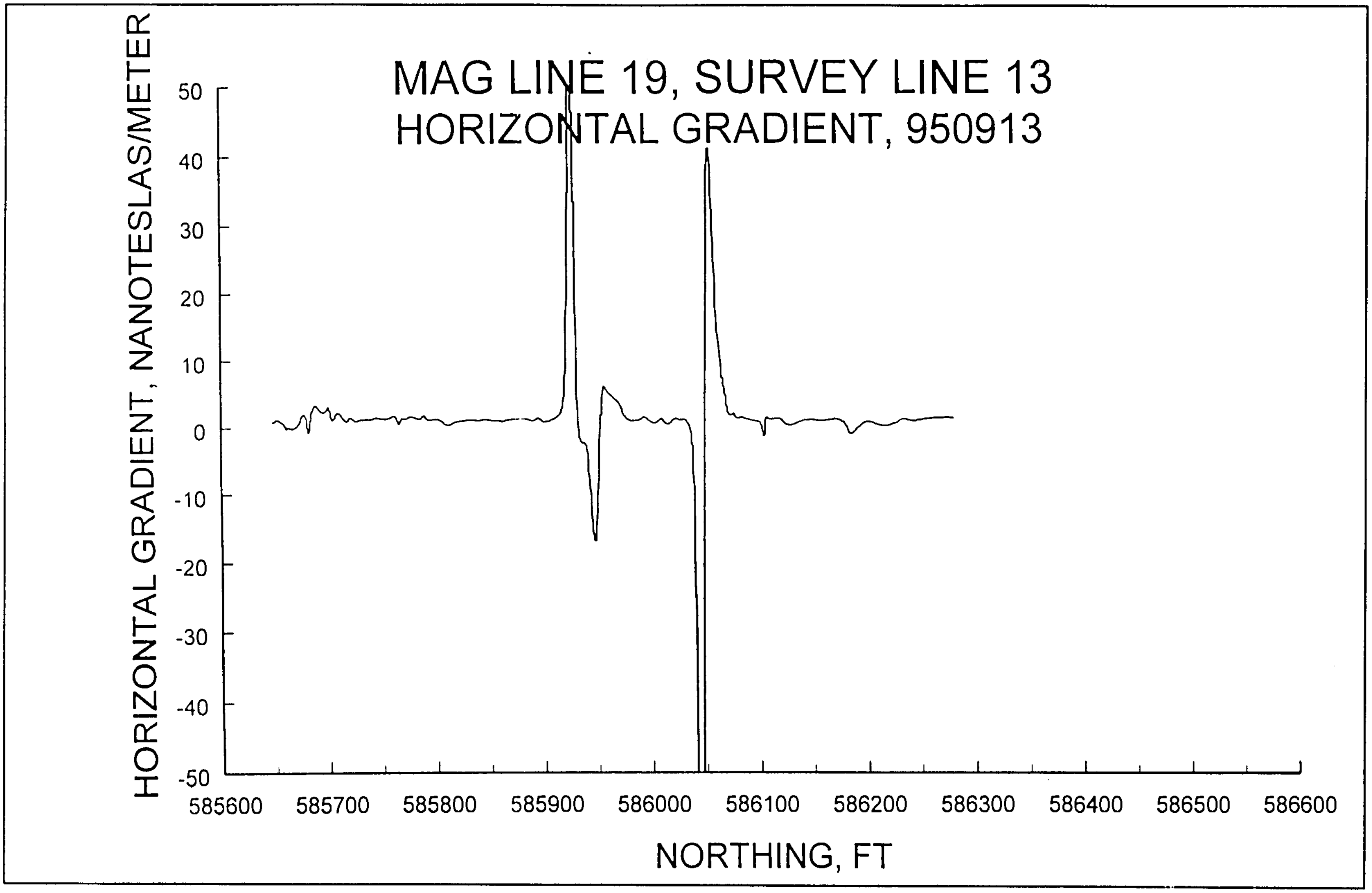

Figure 16. Horizontal magnetic gradient recorded in ordnance disposal area, magnetic line 19

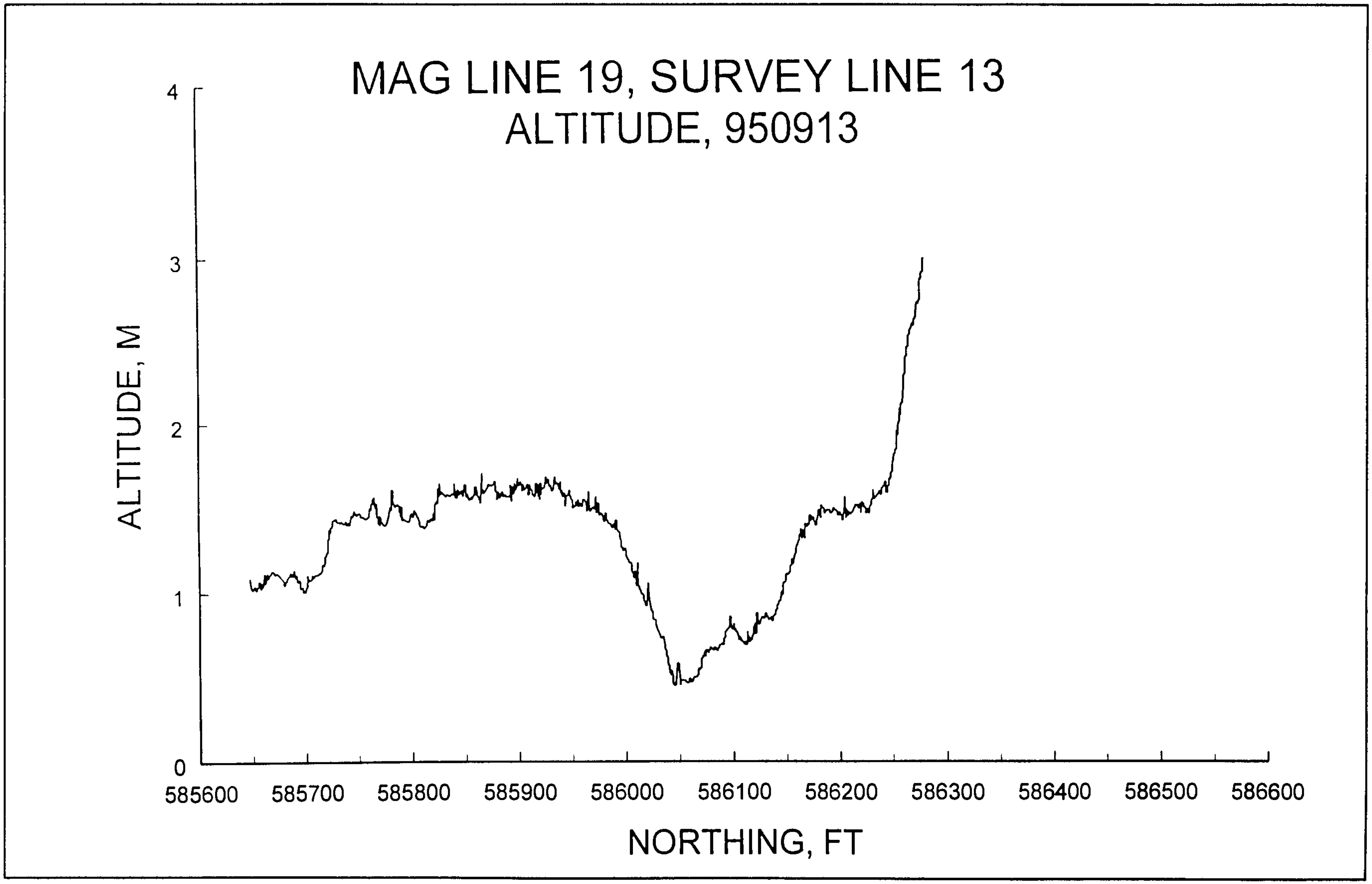

Figure 17. Altitude of V-fin and cesium-vapor magnetometers on magnetic line 19

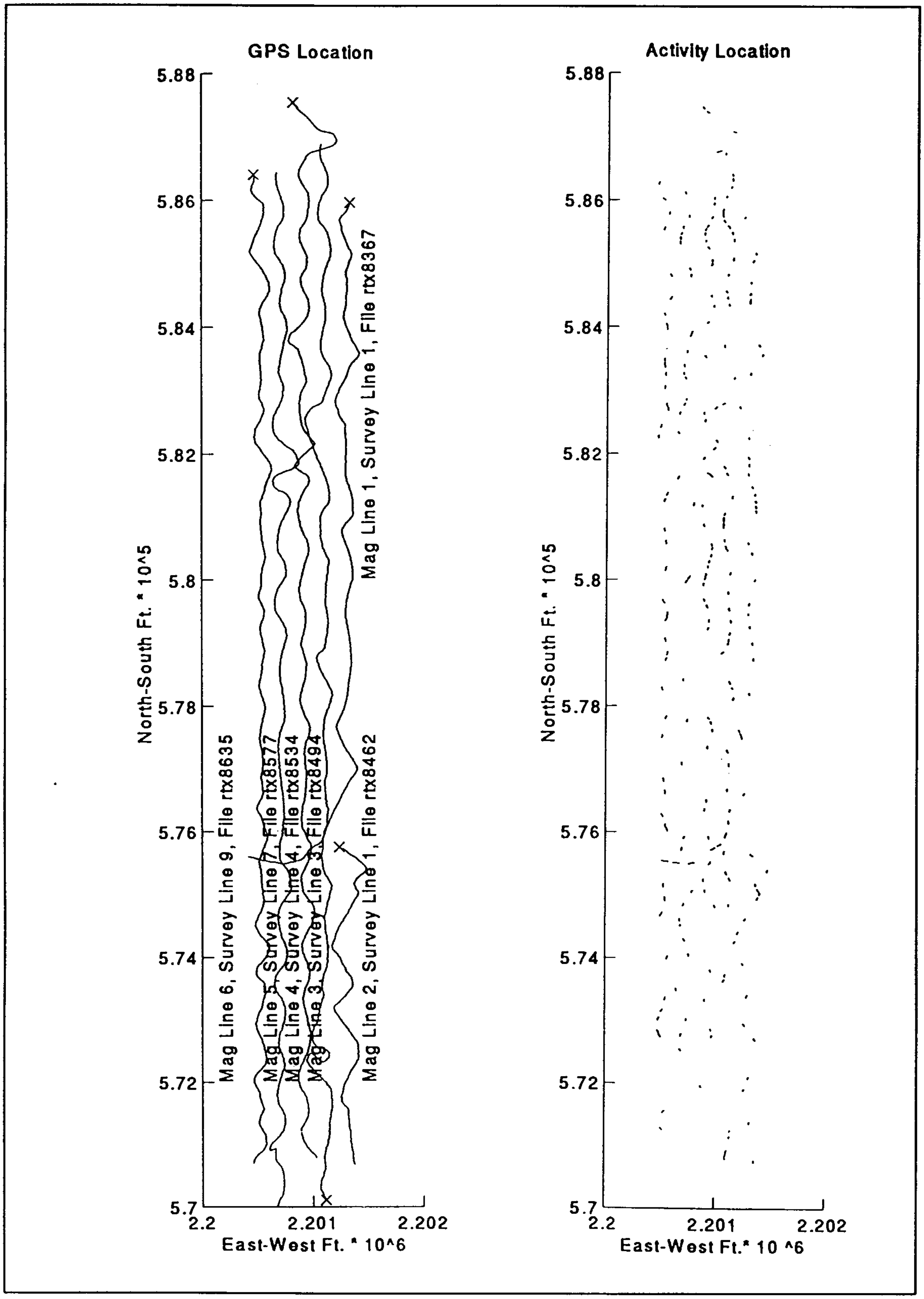

Figure 18. Plot of long magnetic traverses showing truck lines on left and zones of magnetic response on the right. Scales are in feet measured from arbitrary zero points - locations do not represent State Plane coordinates

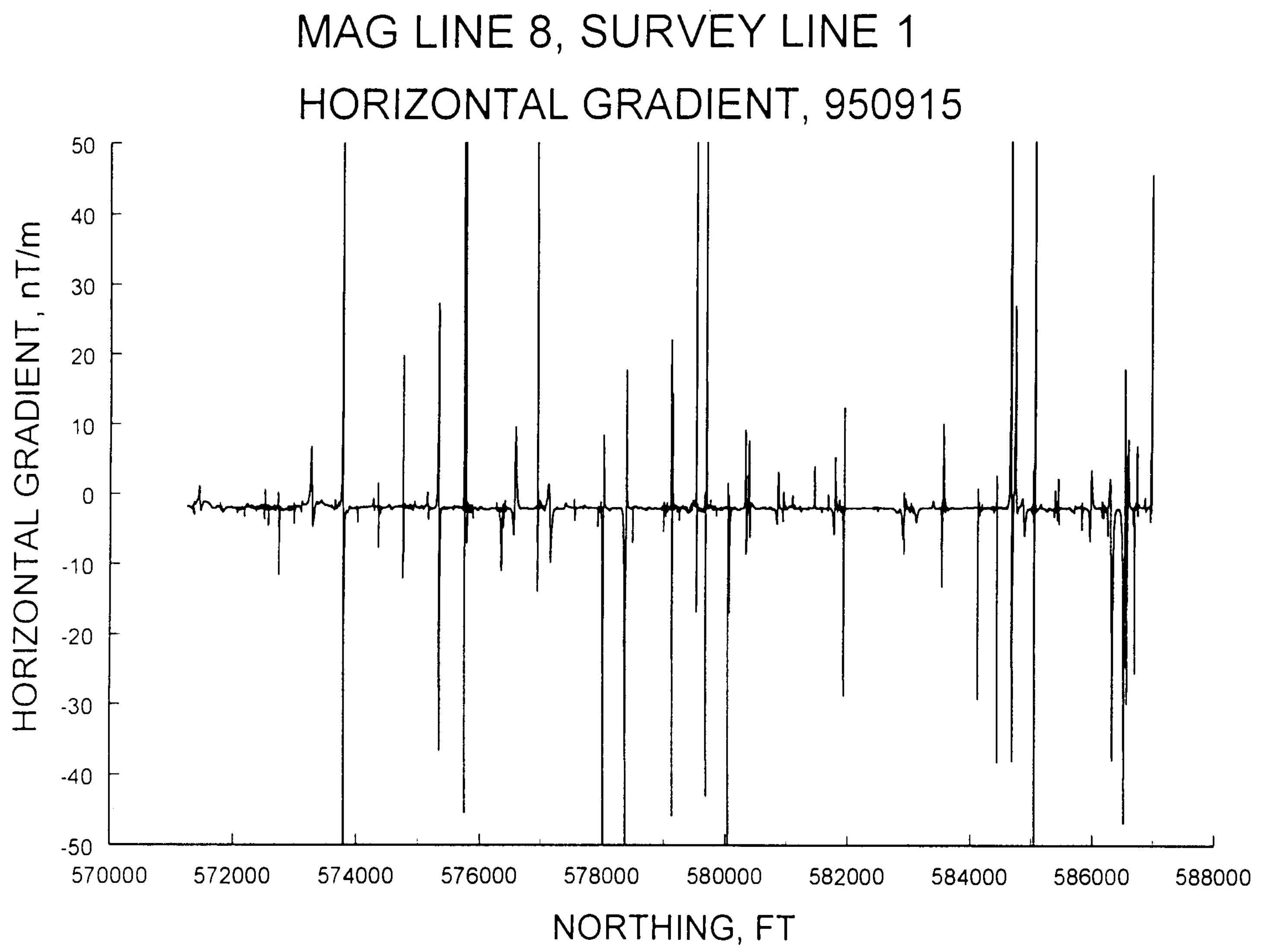

Figure 19. Horizontal gradient recorded on long magnetic traverse number 8. X-axis represents State Plane coordinate

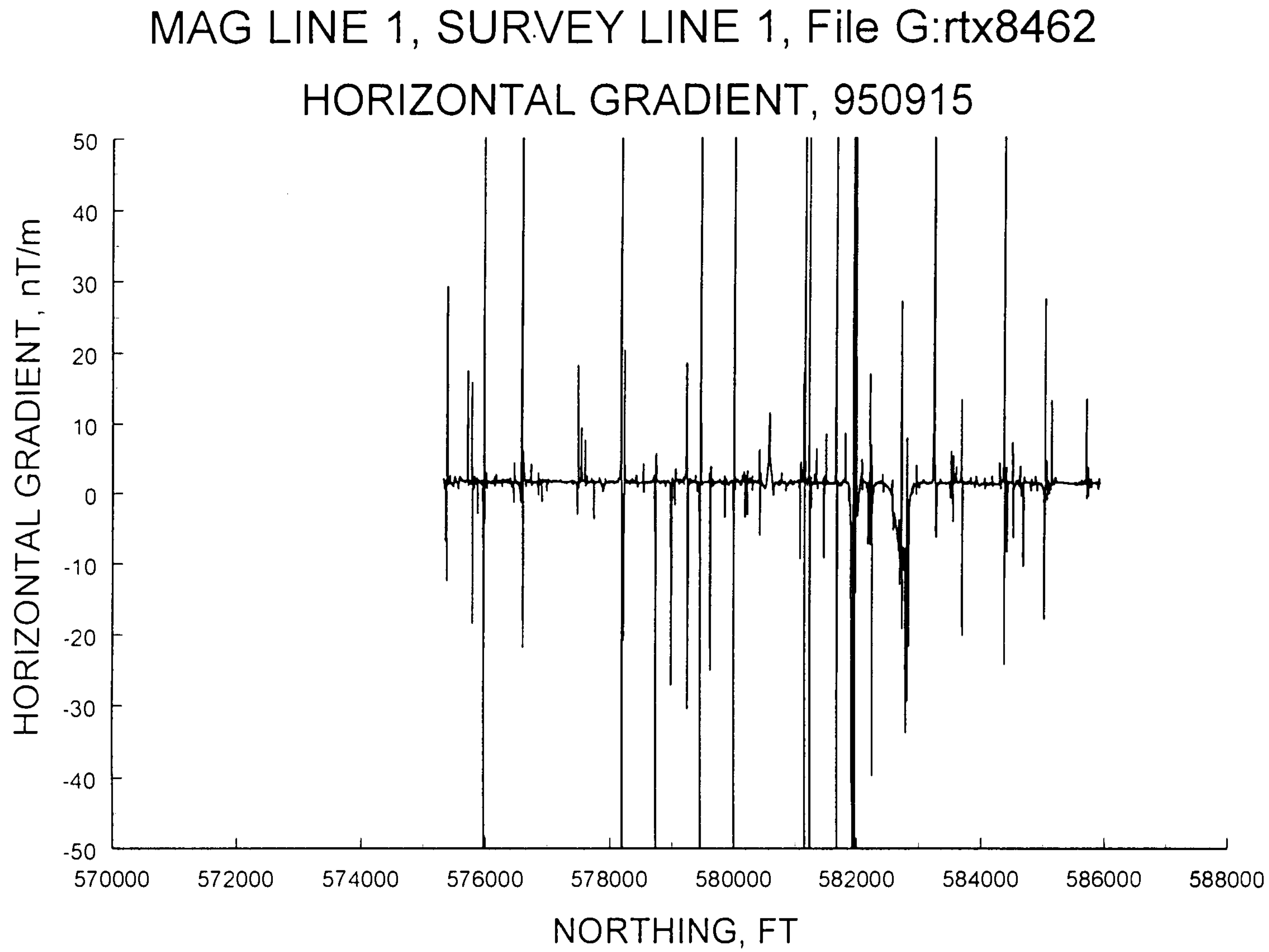

Figure 20. Horizontal gradient recorded on long magnetic line number 1. X-axis represents State Plane coordinate

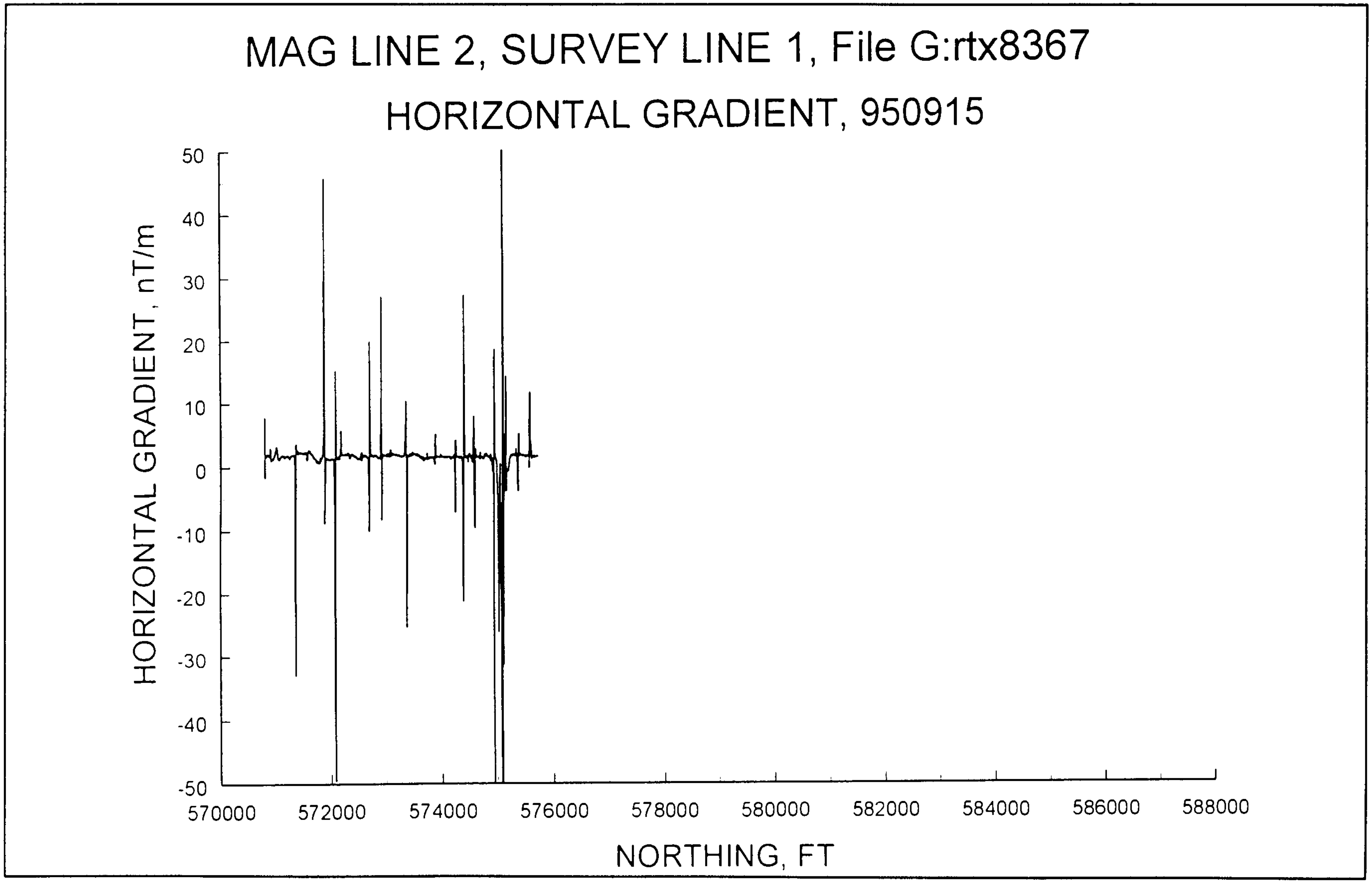

Figure 21. Horizontal gradient recorded on long magnetic line number 2. X-axis represents State Plane coordinate

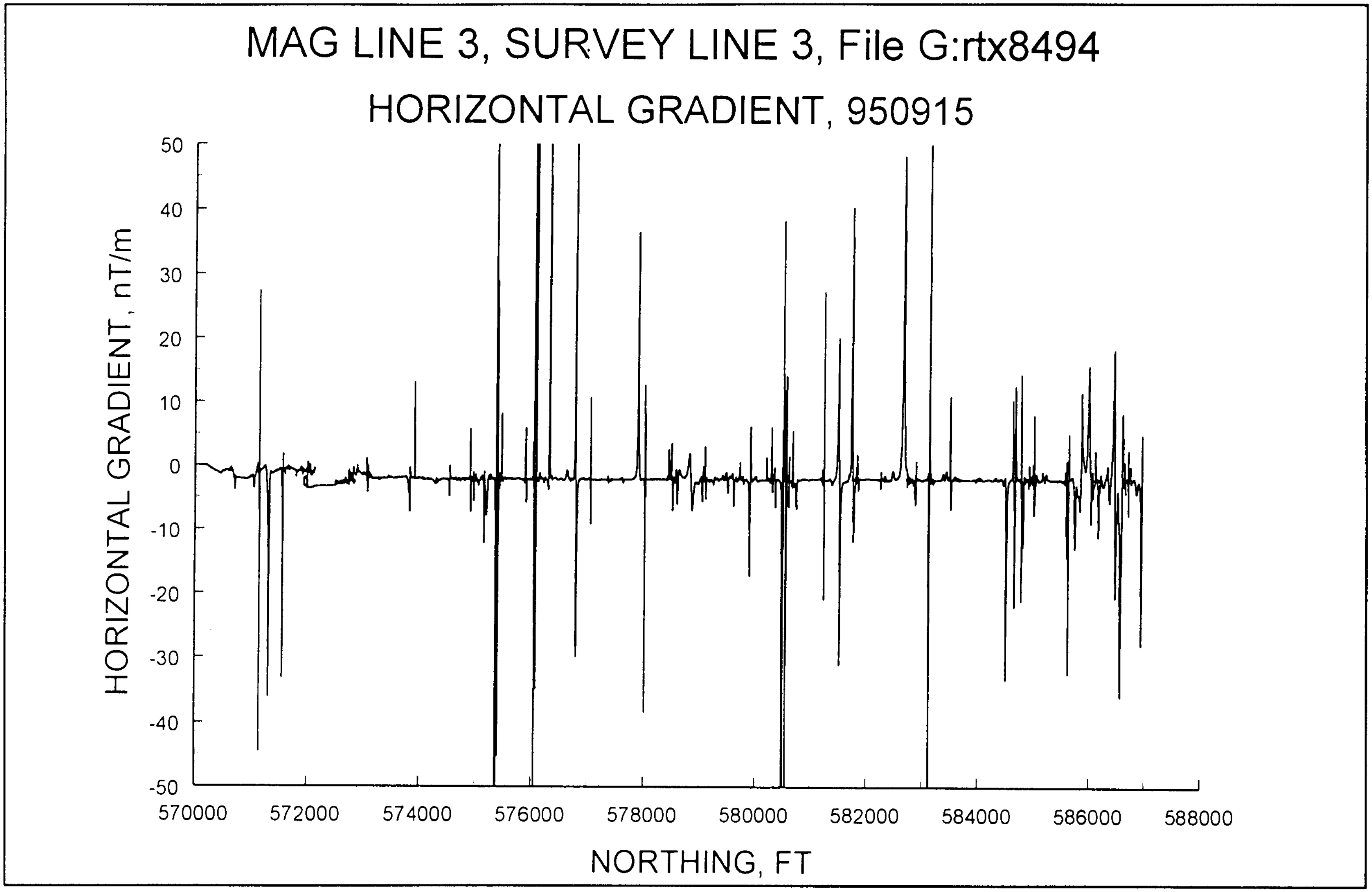

Figure 22. Horizontal gradient recorded on long magnetic line number 3. X-axis represents State Plane coordinate

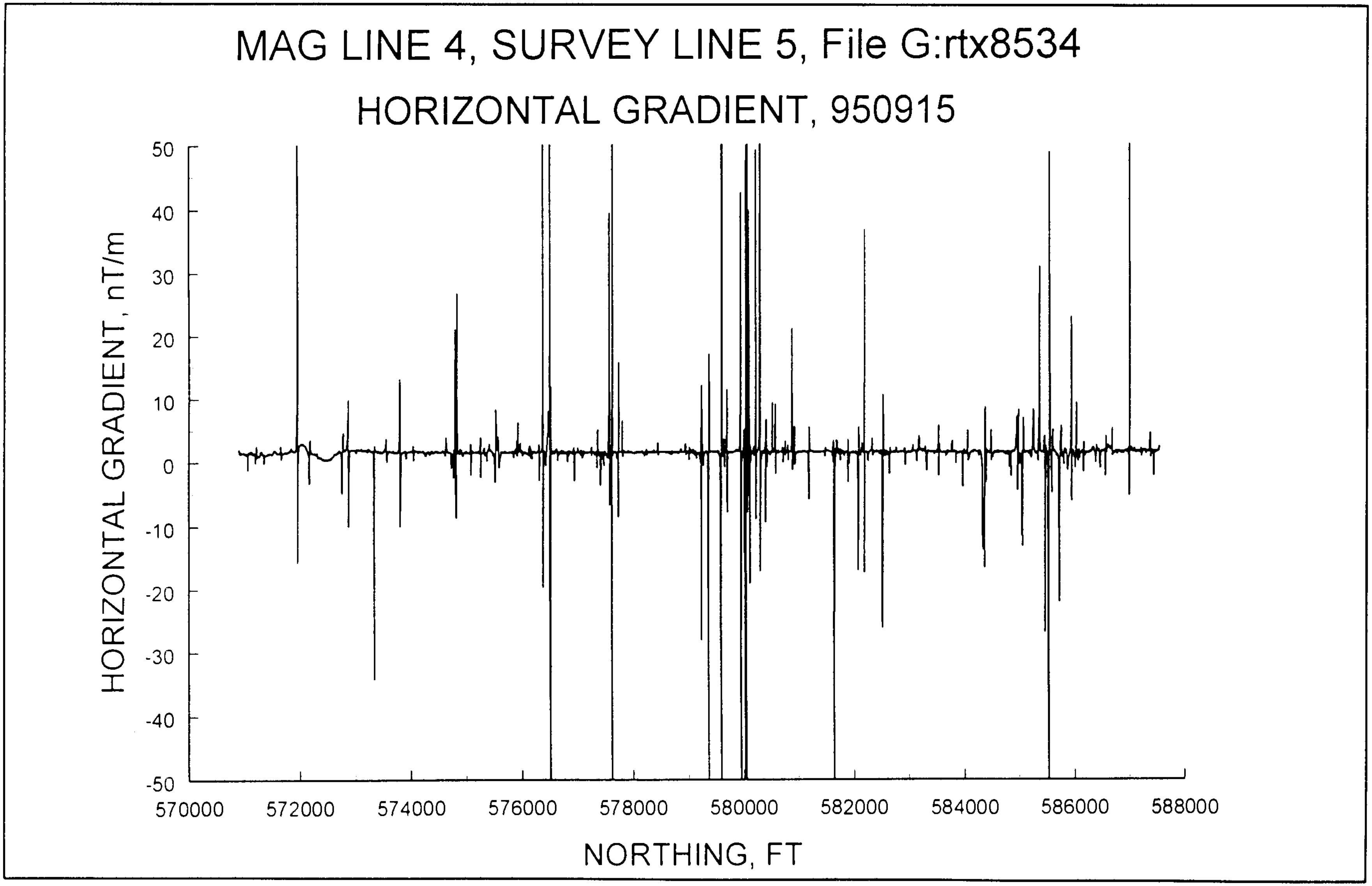

Figure 23. Horizontal gradient recorded on long magnetic line number 4. X-axis represents State Plane coordinate

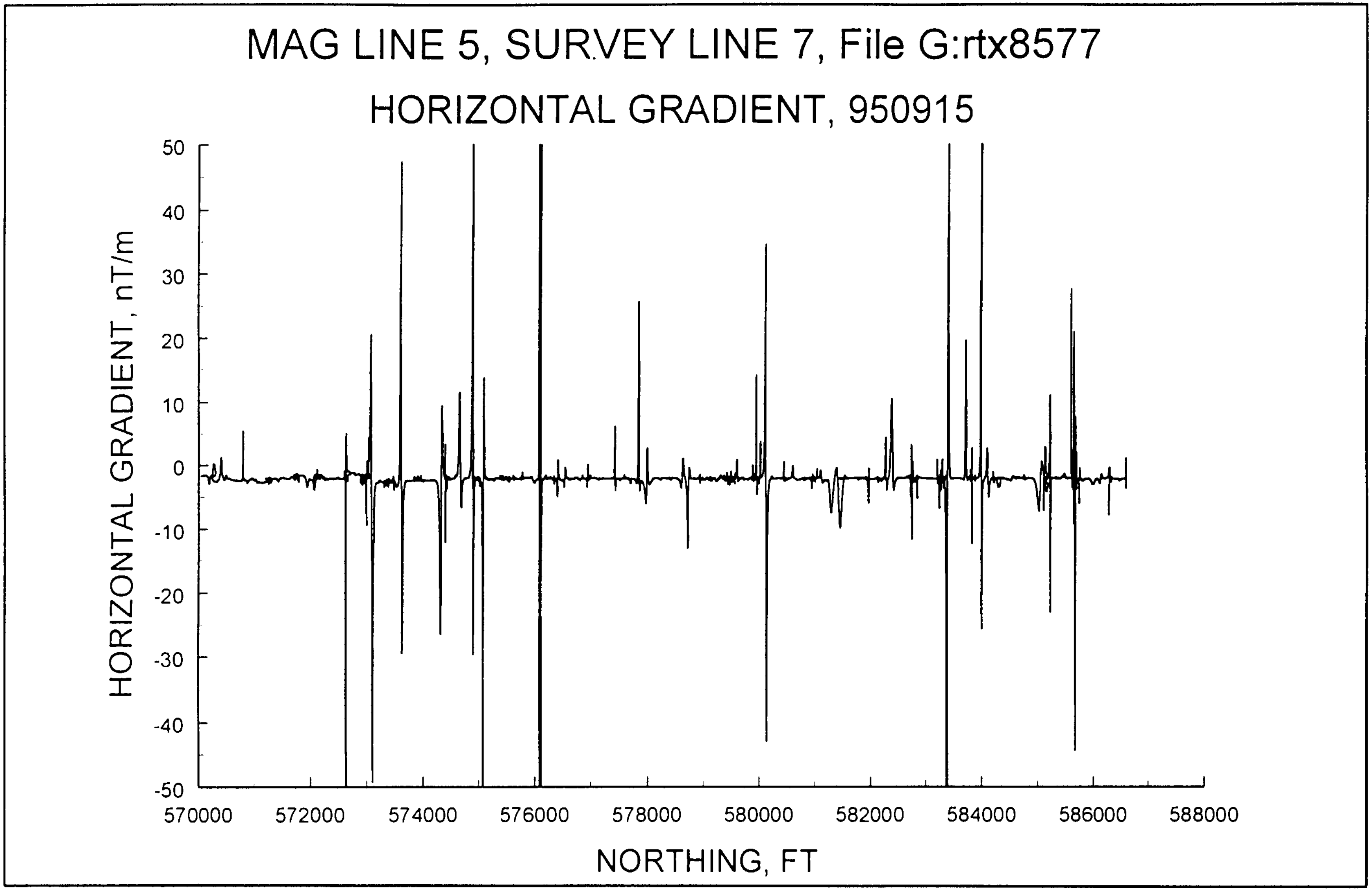

Figure 24. Horizontal gradient recorded on long magnetic line number 5. X-axis represents State Plane coordinate

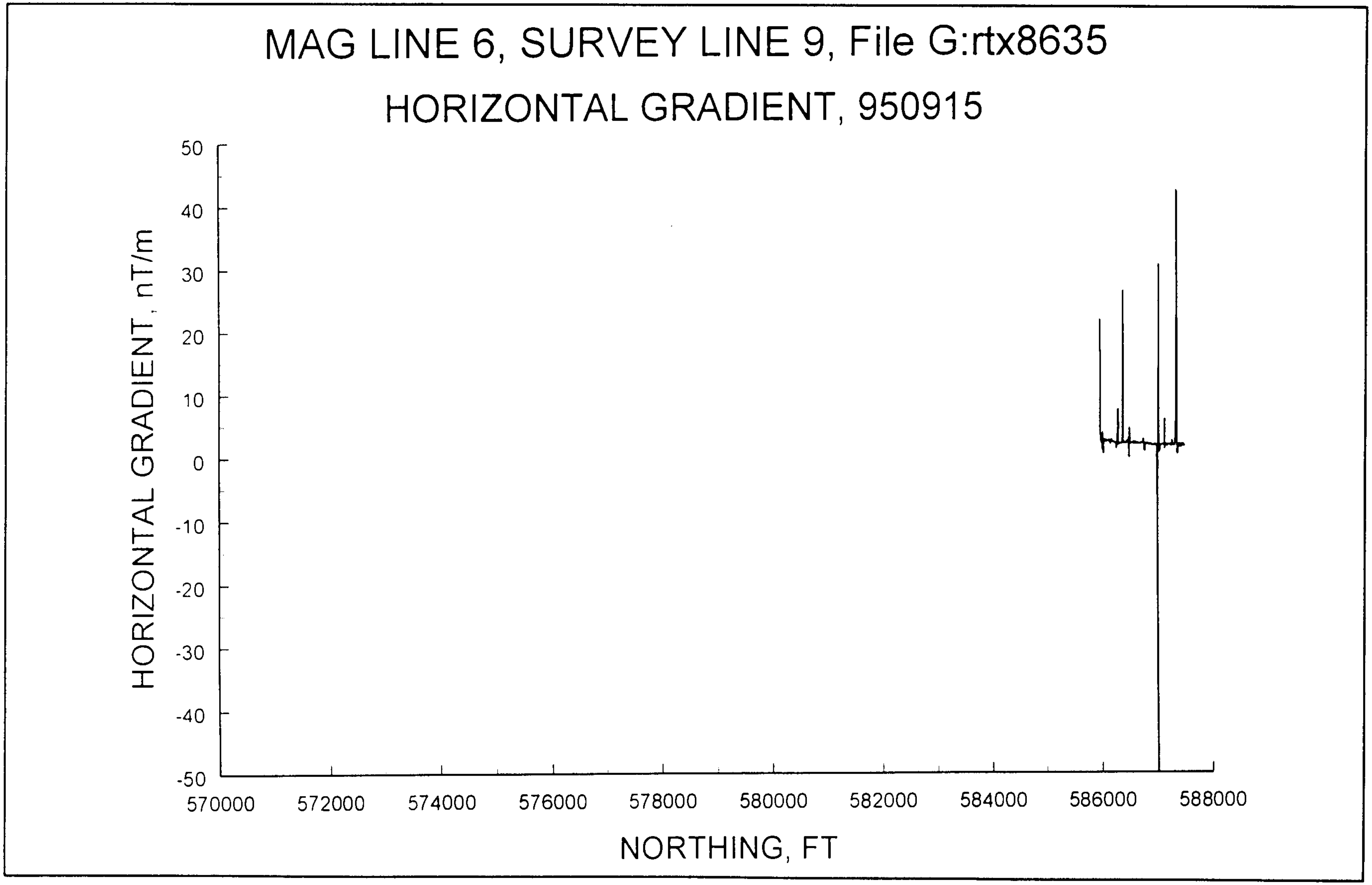

Figure 25. Horizontal gradient recorded on long magnetic traverse number 6. X-axis represents State Plane coordinate

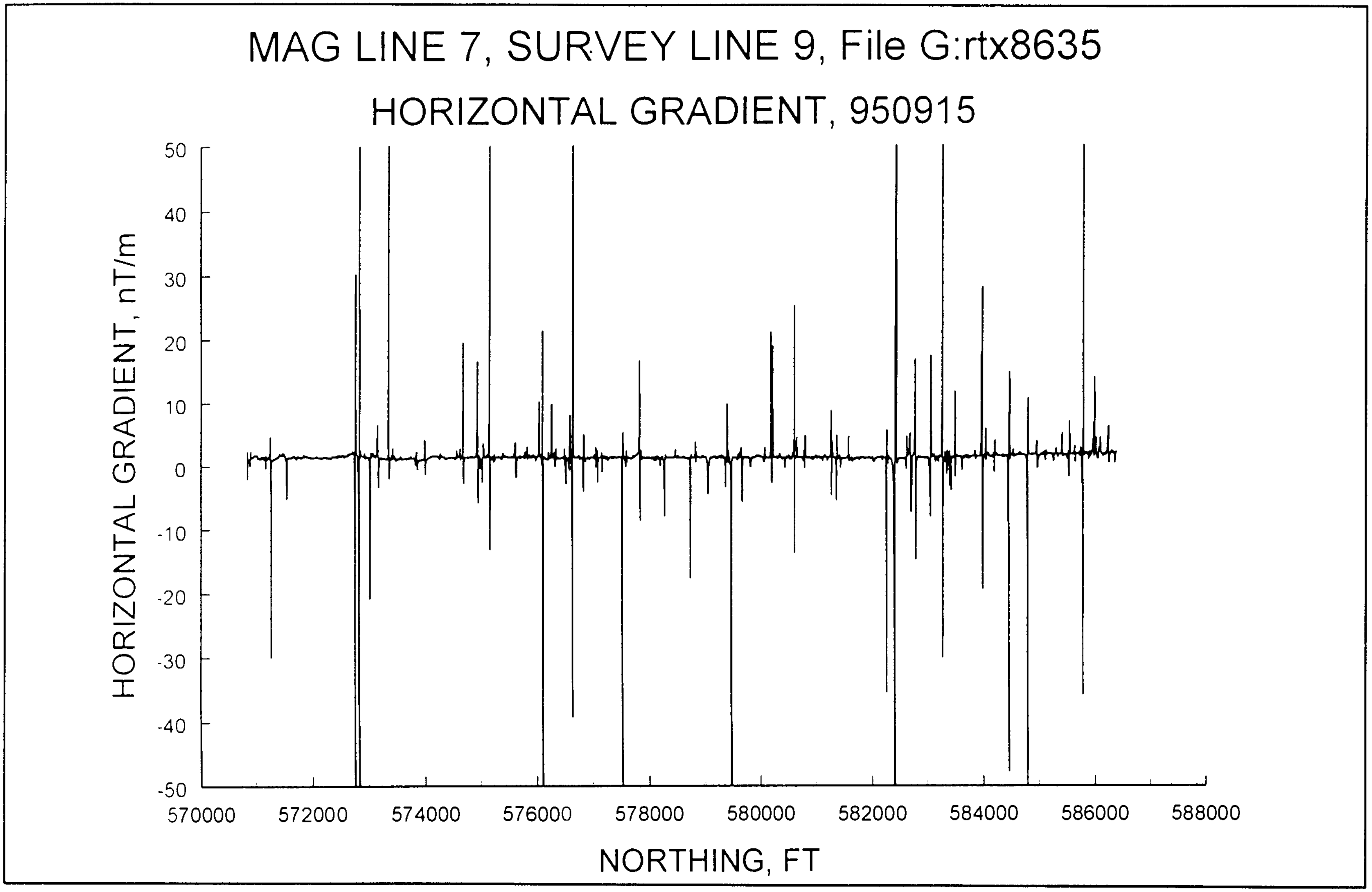

Figure 26. Horizontal gradient recorded on long magnetic traverse number 7. X-axis represents State Plane coordinate

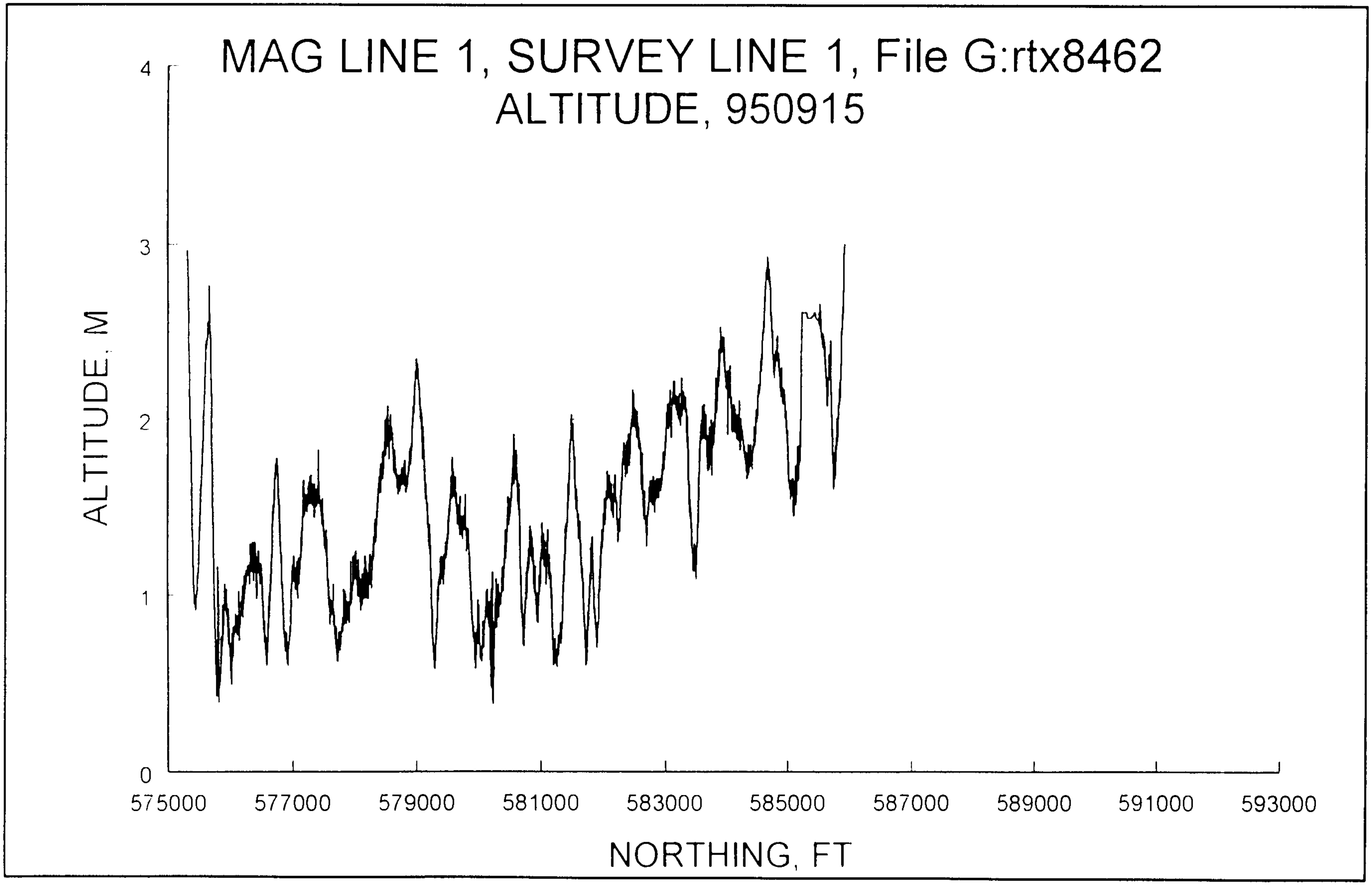

Figure 27. Altitude of V-fin and magnetometers on magnetic line 1, survey line 1

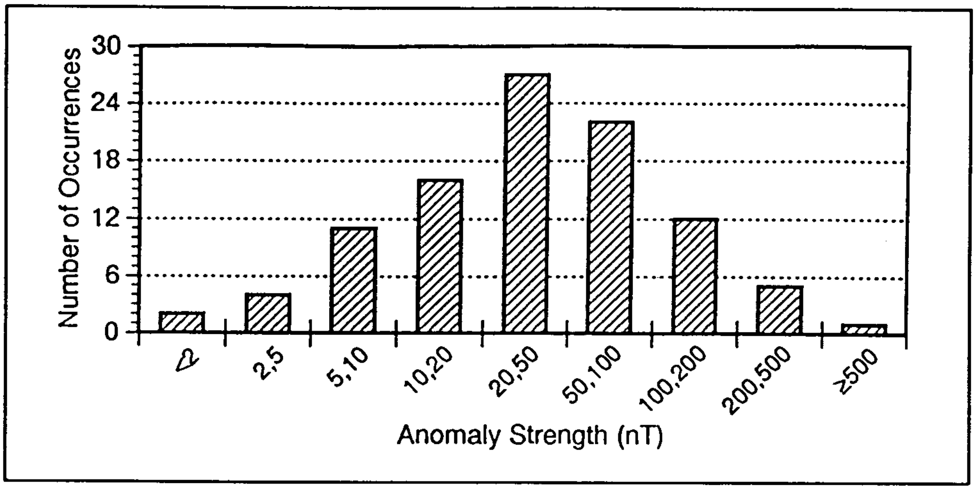

Figure 28. Anomaly strength (peak signal magnitude) of 100 samples selected from the north-south magnetometer lines. (Plot provided by AETC)

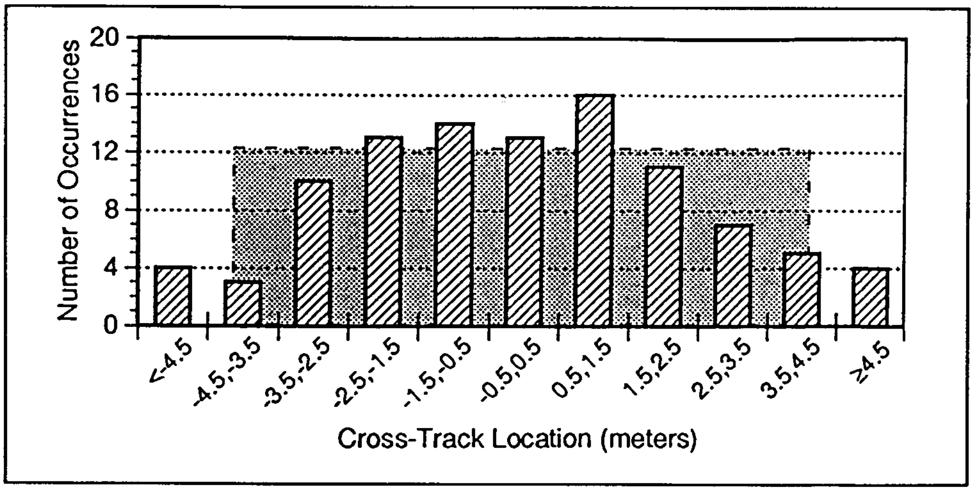

Figure 29. Cross-track locations, 100 analyzed samples. Shaded area indicates computed detection range of array used in the field. (Plot provided by AETC)

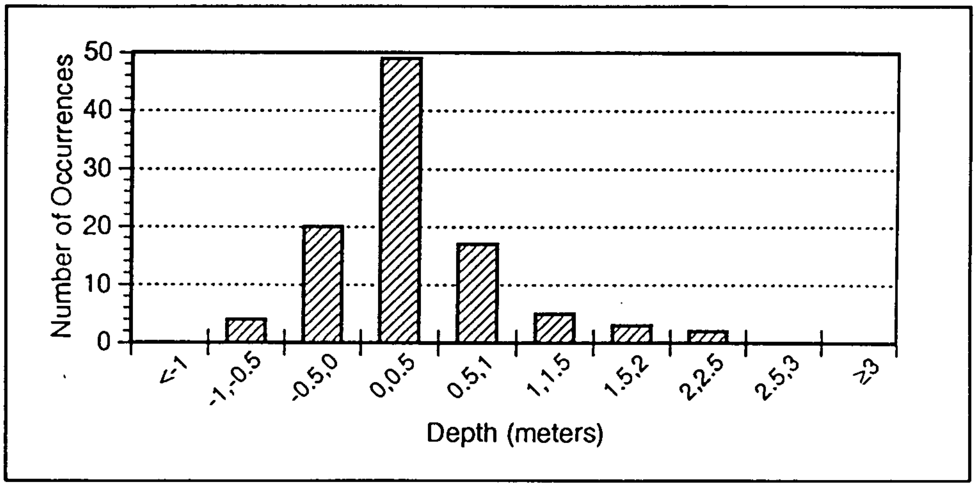

Figure 30. Computed depth from seafloor to center of objects. Negative values correspond to dipole fits where the center of object is above the bottom. Most objects are lying on the seafloor. (Plot provided by AETC)

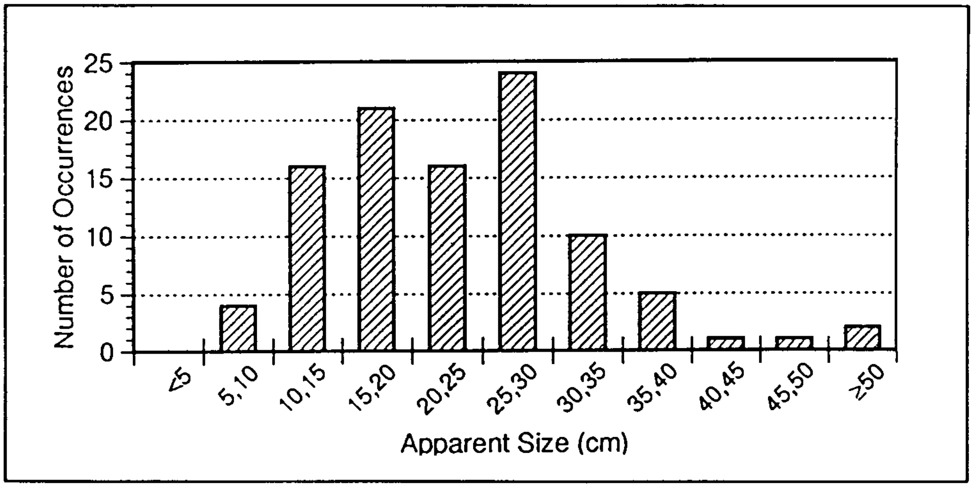

Figure 31. Distribution of apparent sizes of the 100 test objects. (Plot provided by AETC)

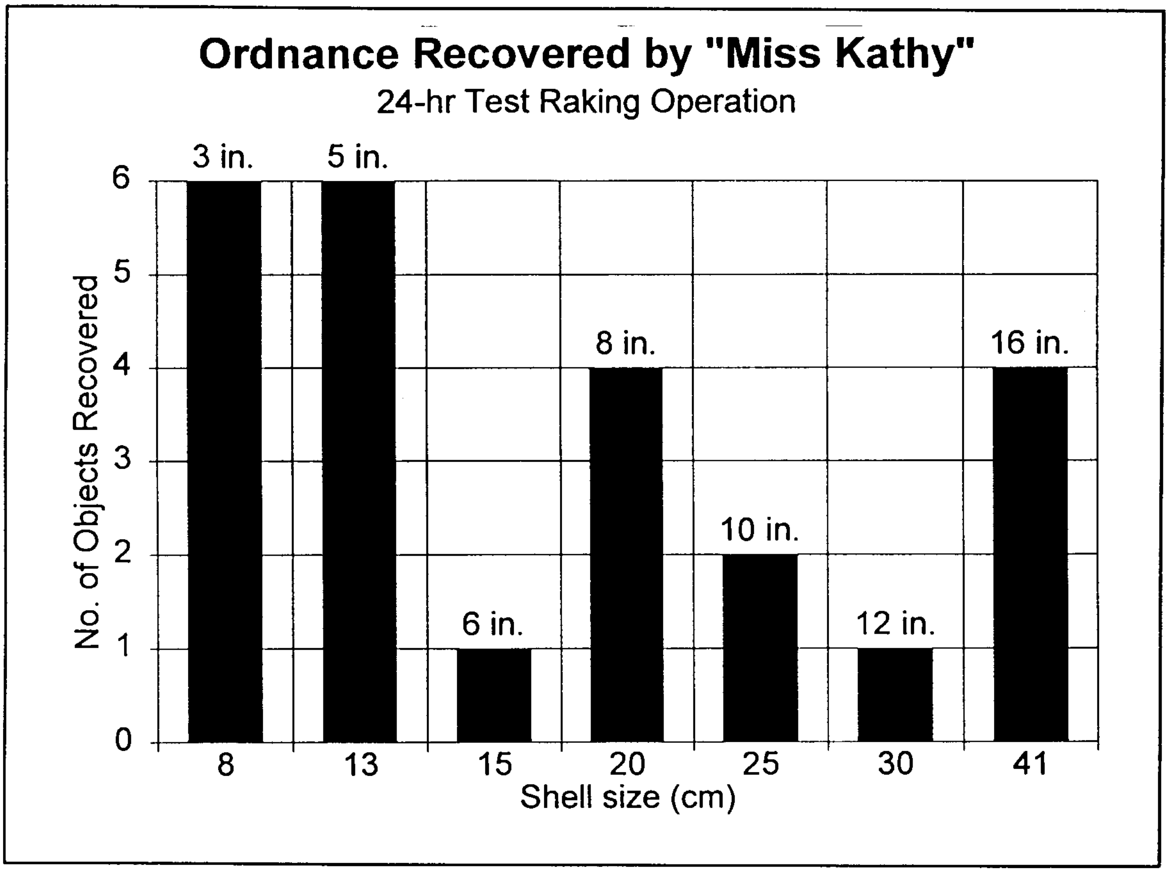

Figure 32. Distribution of sizes of ordnance recovered during 24-hr test raking operation

7 Cartographic Display and Data Summaries

Data used in the Sea Bright Pilot study were derived from several sources. This included magnetometer and acoustic geophysical information collected from survey boats in the field and hydrographic soundings provided by the National Oceanic and Atmospheric Administration. Table 2 lists sources and projections of the original navigation data provided with these data. For display in this report, all data were converted to a uniform projection and coordinate system: New Jersey Transverse Mercator, NAD27. Horizontal and vertical units of feet were used to maintain compatibility with historical maps and with the units currently used by USAE District, New York, project charts. Data display and projection conversion were performed with Terramodel software (Version 8.33 for DOS-based personal computers).

Magnetometer data were processed using MATLAB software (Version 4.0 for personal computers running Microsoft Windows). Magnetometer plots in Appendix A were generated with MATLAB.

Table 2
Sources, Units, and Projections of Positioning Data

Data Type	Source	Original Units	Projection
Hydrographic soundings	NOAA - National Geophysical Data Center	Latitude, longitude, depths in ft below MLW	NAD27
Shoreline	NOAA chart 12324 (June 1994)	N.J. State Plane Grid - feet	NAD27
Sub-bottom profiler	DGPS collected via X-STAR survey system	Latitude, longitude	NAD27
Magnetometer	DGPS collected via SEAMAG system (Sandia Laboratories)	Latitude, longitude	NAD27
Fort Hancock battery locations	Magellan NAV 5000 hand-held DGPS receiver	Latitude, longitude	NAD83
Underwater video	North Star 800X	Latitude, longitude	NAD83

8 Summary of Findings

Findings of the pilot study are summarized as follows:

a. The entire Sea Bright borrow area is within the historical impact area for Fort Hancock and has the potential to be contaminated with ordnance.

b. Some evidence of a spatial concentration to the ordnance contamination could be determined within the context of this very limited pilot study. Preliminary evidence suggests that there may be a trend of decreasing magnetic returns toward the south and there may be limited zones which are clear of magnetic objects.

c. X-star has limited use in determining if there are hard object targets (could be ordnance, stones, or even wood) buried in the sediments. X-star does not add any substantial additional data capability.

d. Side-scan sonar could and should be used to provide a reconnaissance level assessment of obstructions/large objects and bottom texture.

e. The magnetometer adapted for and tested during this pilot study is superior to other commercially available systems and is the recommended work horse for a full-scale survey. It is extremely sensitive and is able to detect individual ferro-magnetic objects of the size of ordnance. It can also be used to sweep an 8-m-wide and 8-m-deep zone during a single tow and can be used to indicate relative size, shape, orientation, depth of burial, and location of metal targets.

f. However, the magnetometer would need some further development prior to use in a full-scale operating mode. Some laboratory and field calibration tests would be needed to better interpret the magnetic signature for different classes of ordnance versus other magnetic objects. Additional deployment and data acquisition improvements are needed.

g. The presence of extensive sand wave zones and other bottom texture evidence observed via the underwater video and the side-scan sonar suggest that the bottom sediments are quite mobile and it is likely that there will have been some scour and burial of bottom siting ordnance (particularly in the northern section of the borrow). However, the finite magnetometer data collected and analyzed during this study suggest that most of the ordnance-like targets are at or close to the sand surface and appear to be mobile, having oriented themselves parallel to the predominate wave crests.

9 Recommendations and Conclusions Relative to a Full-Scale Survey

The pilot study was successful in documenting the capability of the cesium-vapor gradient magnetometer to characterize ordnance contamination at the Sea Bright borrow area. This system can be used to document size, shape, orientation, depth of burial, and location relative to the tow of ordnance-like targets and other metallic objects. A full-scale, operational magnetometer survey which includes the use of side-scan sonar for reconnaissance, an underwater low-light video camera, DGPS, survey design and tracking software, and EOD trained divers for limited ground-truthing is feasible and appropriate for detecting the presence, density, approximate caliber, and location of ordnance at this site.

The potential value and application of the results of such a full-scale survey would be in locating any areas within the borrow which are not contaminated with ordnance (i.e., possibly to the south or further offshore Asbury Park borrow). Conversely, any areas which are so littered with large size ordnance that it would be appropriate to keep the dredging operations clear of these areas for safety reasons would also be documented. The data collected during a full-scale survey could be used to design a cleanup operation (for example, using a surface rake). A repeat survey after cleanup would determine the effectiveness of the cleanup. Finally, an operational survey of other proposed borrow areas in this vicinity may be appropriate prior to initiating other mining operations in order to ascertain the presence of ordnance contamination at these sites.

Several lessons learned from the pilot study should be incorporated into the design of any proposed full-scale operational survey:

a. An additional archival search (possibly by the St. Louis or Rock Island District) to document historical information, firing fans, ranges, caliber, etc. which may have impacted the offshore borrow would help in planning and interpreting the results of the survey.

b. A full-scale survey should include EOD-certified divers for select ground truthing of the data.

c. Integrating a non-magnetic signature low light or acoustical line scan camera with the magnetometer might provide real-time imaging of targets, providing additional ground-truthing.

d. Commercially available survey planning and tracking software would improve the efficiency of the survey and assist in determining the confidence limits for the survey coverage.

e. Positioning improvements to better control the magnetometer tow and document absolute position are also needed to be able to assign confidence limits on survey coverage.

f. Some improvement to the magnetometer system is warranted to ruggidize the tow for continuous operation and streamline signal post-processing. Processing of the magnetometer data should be continuous throughout the survey. The assembly of a magnetometer system tailored specifically for use on this project is recommended. Calibration of the magnetometer arrays must include field tests using ordnance with their long axes oriented both parallel and perpendicular to the earth's magnetic field.

g. Considering the size of the borrow and a line spacing of 8 m, a full-scale operational survey would require a large, non-magnetic research vessel to transit a total of 1,300 nautical miles. Such a survey would take 4-6 weeks of 24-hr data collection.

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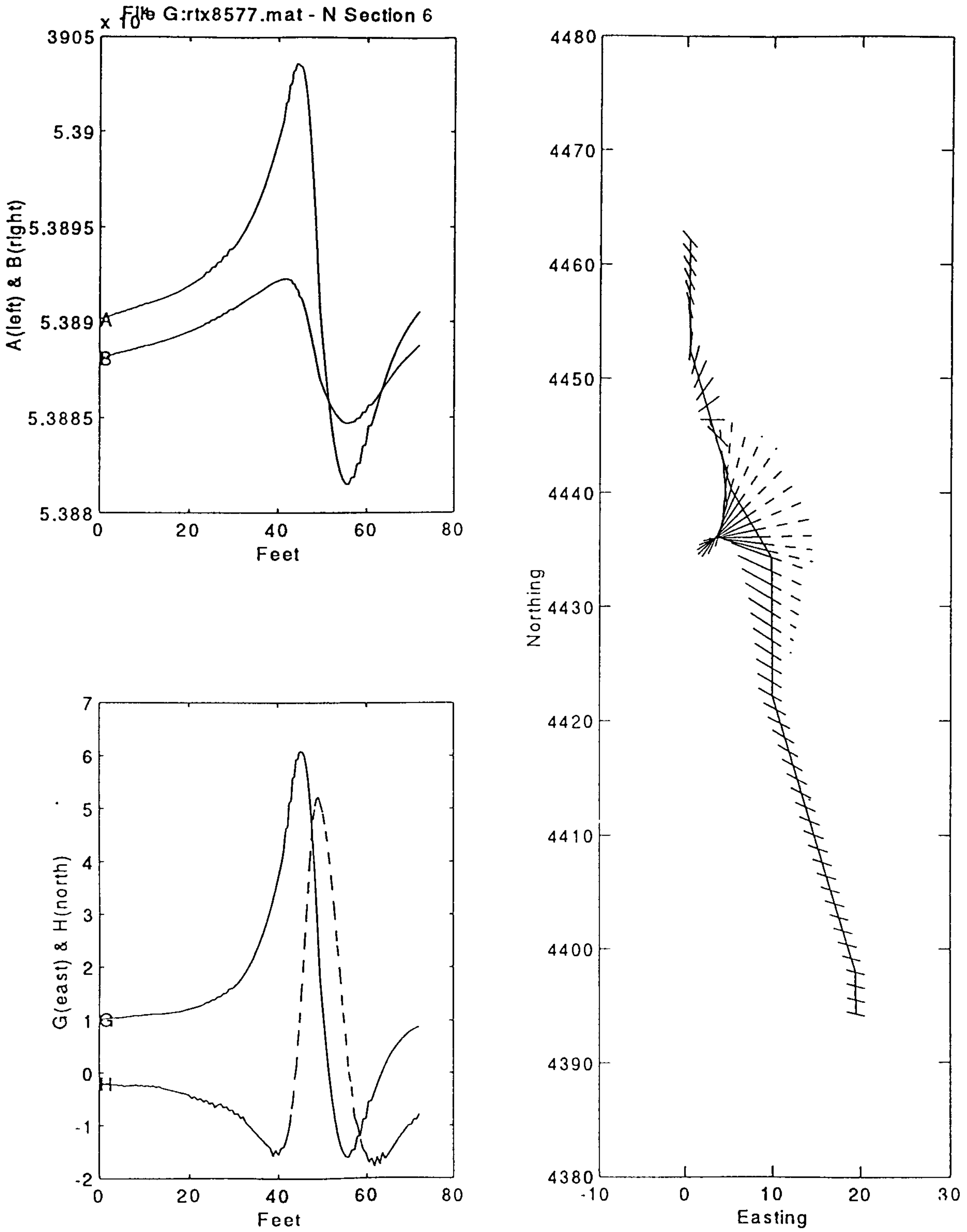
Appendix A
Analysis of Magnetometer Targets from Long Magnetometer Lines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5.39
5.3895
5.389
5.3885
5.388
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A
B
0
20
40
60
80
Feet
7
6
5
4
3
2
1
0
-1
-2
G(east) & H(north)
G
H
0
20
40
60
80
Feet
4480
4470
4460
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4410
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4390
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0
10
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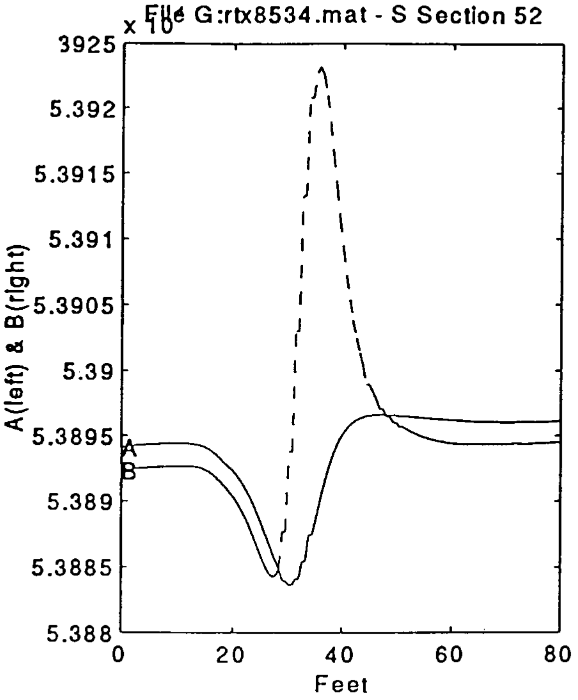
30
Easting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5.3885
5.388
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B
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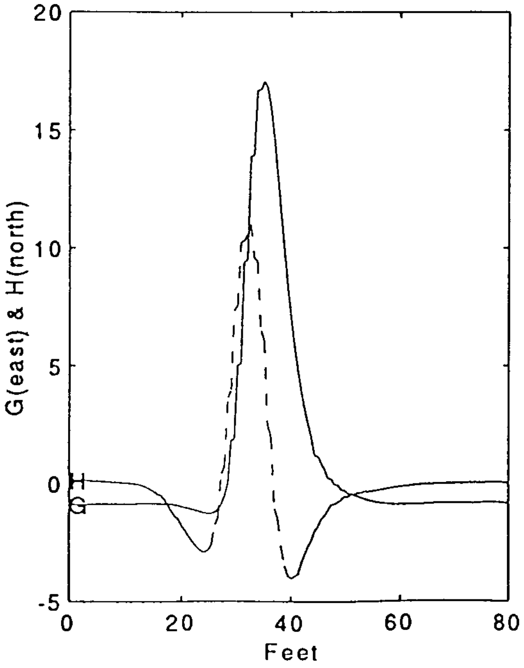
20
40
60
80
Feet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G
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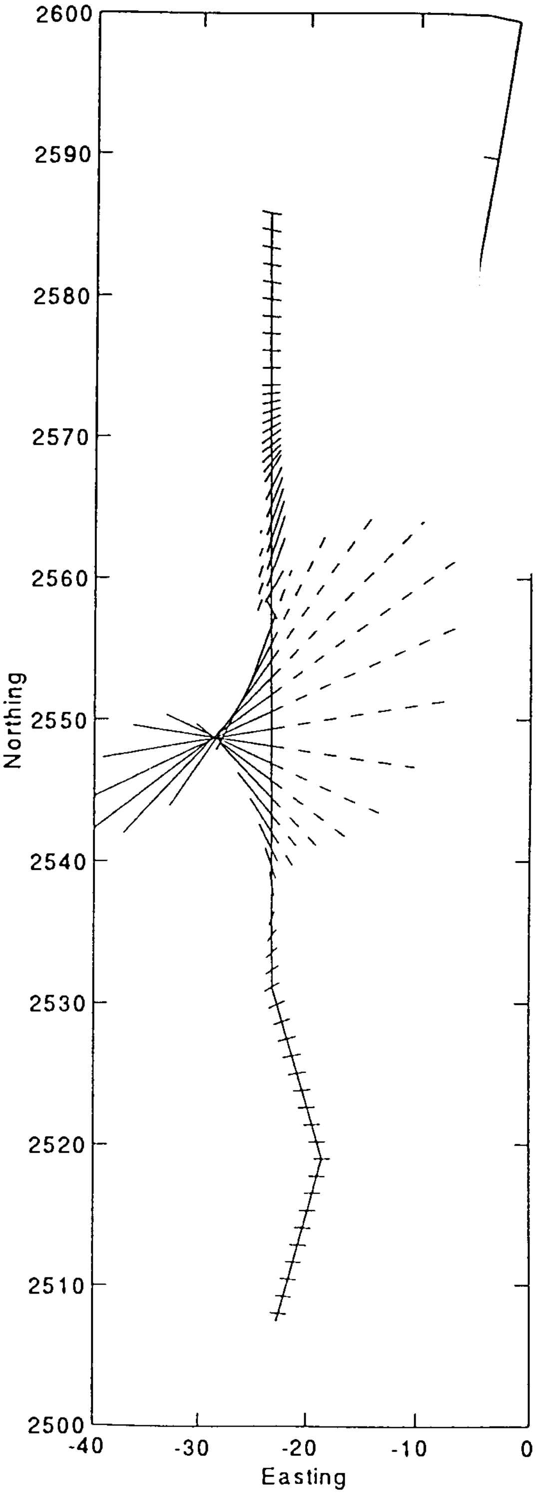
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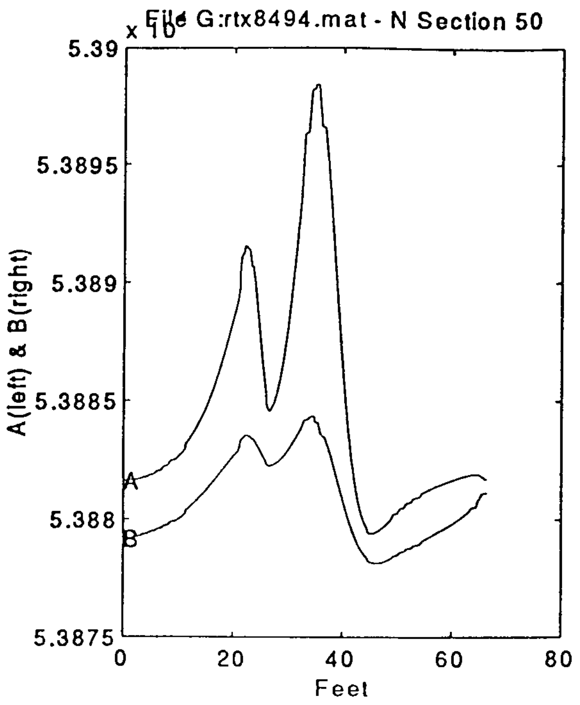

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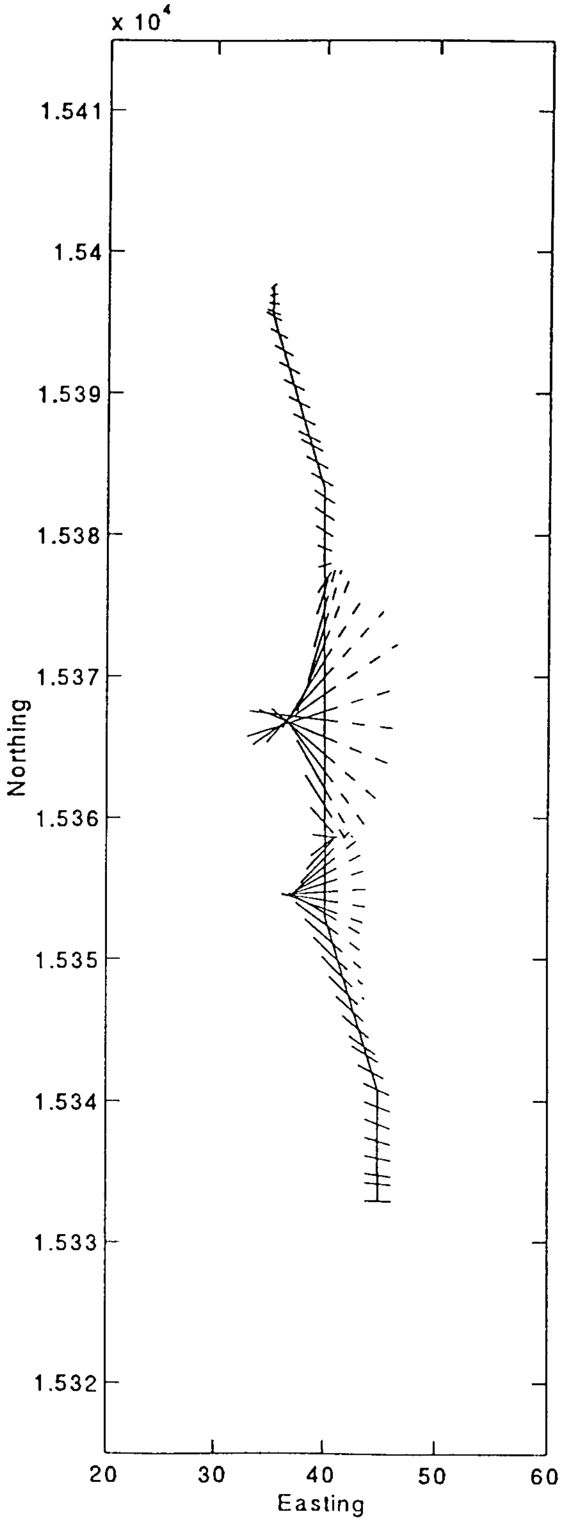

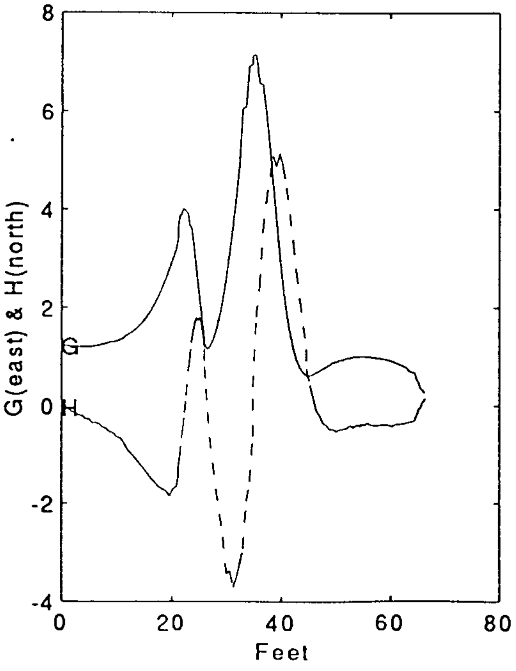

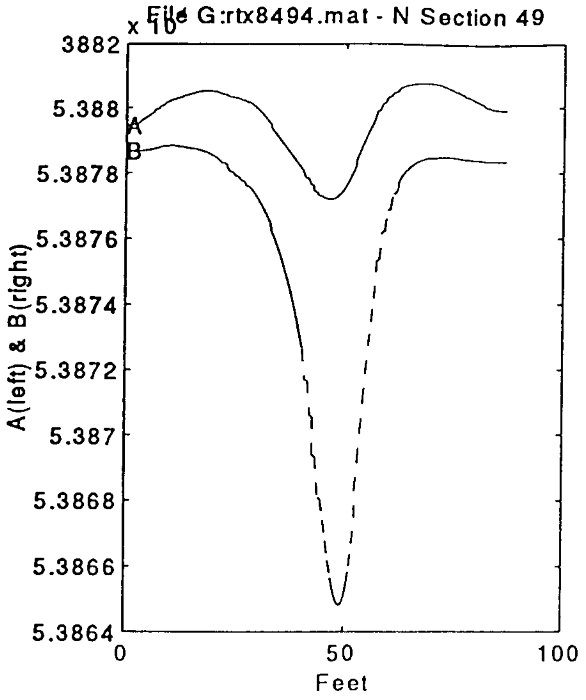
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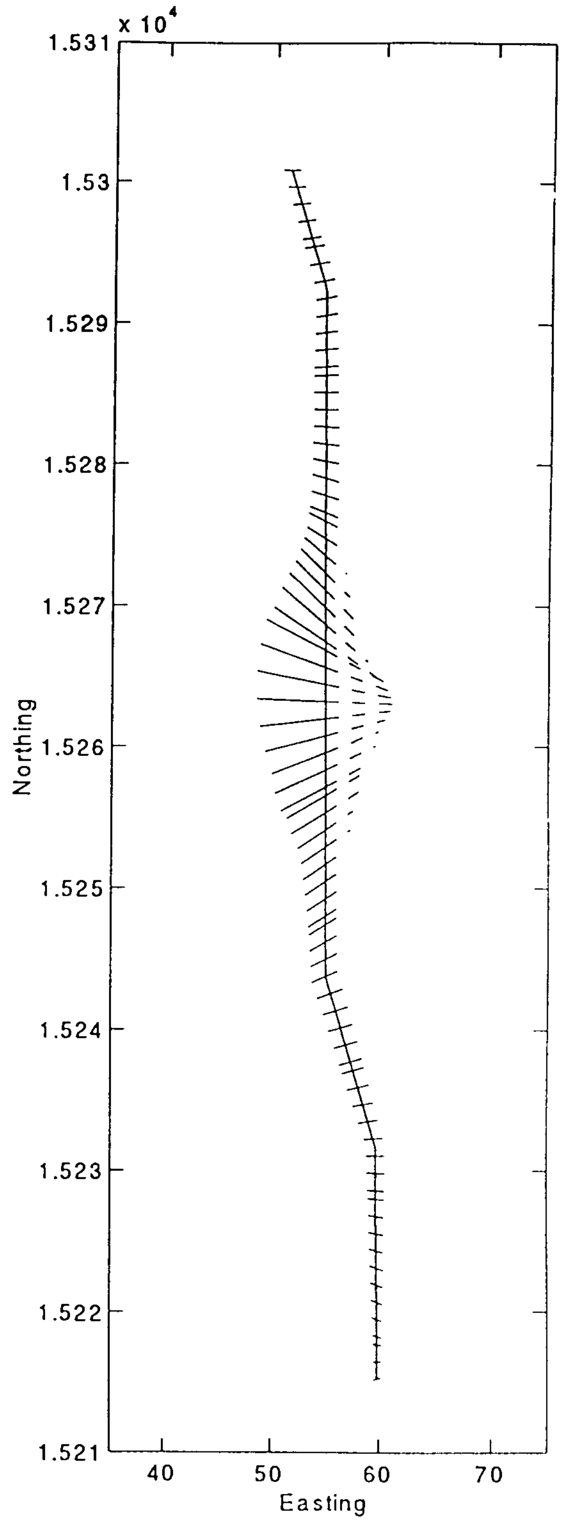
B
A(left) & B(right)
0
50
100
Feet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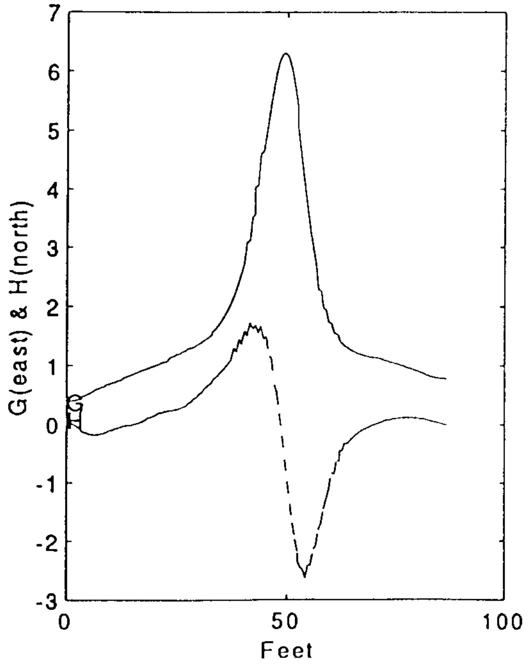
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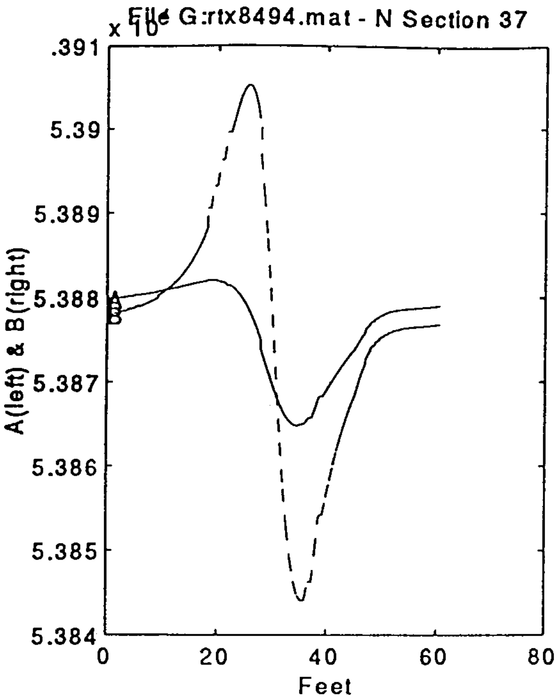
Feet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5.389
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B
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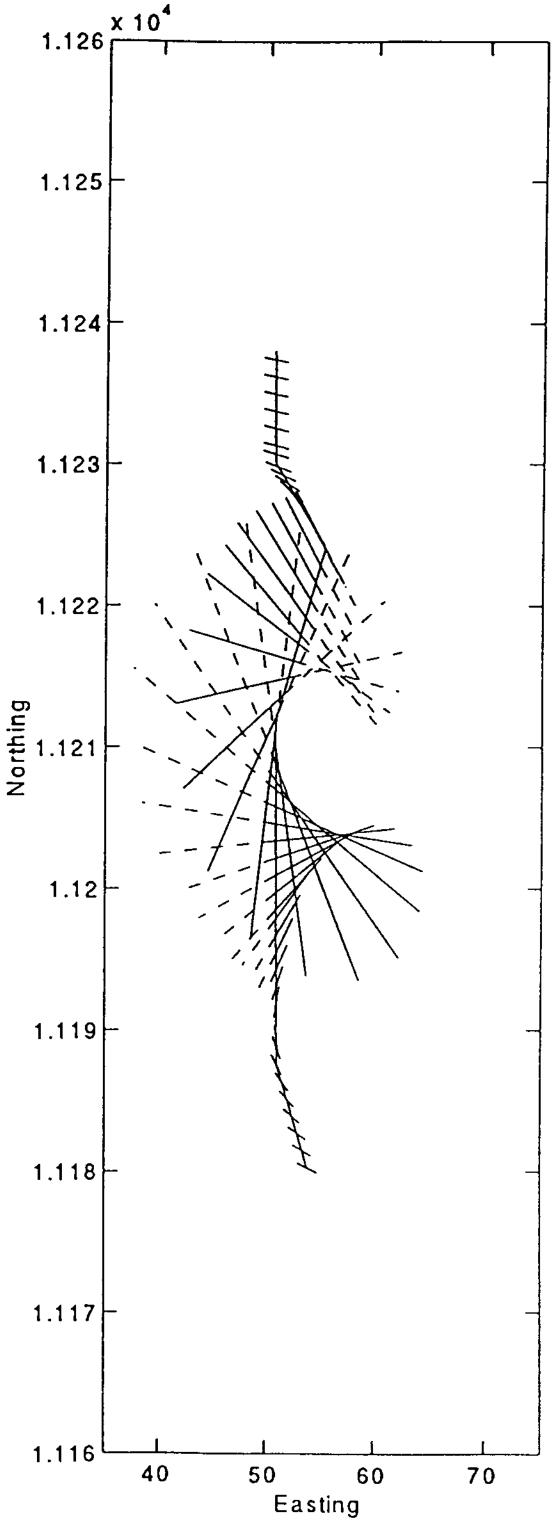
Feet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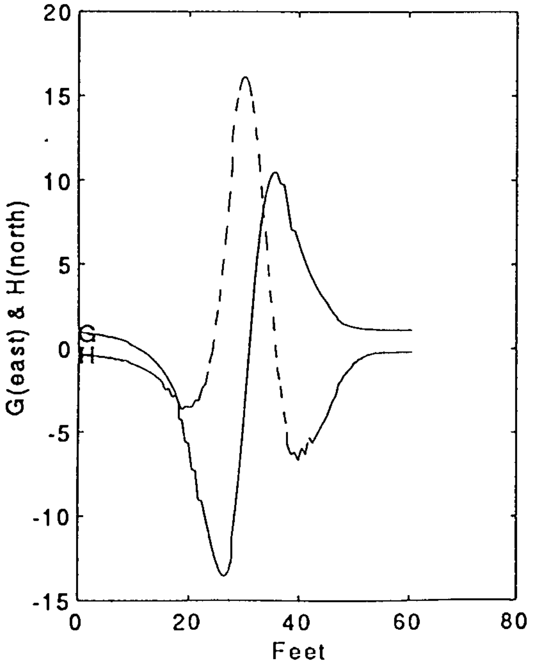
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20
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60
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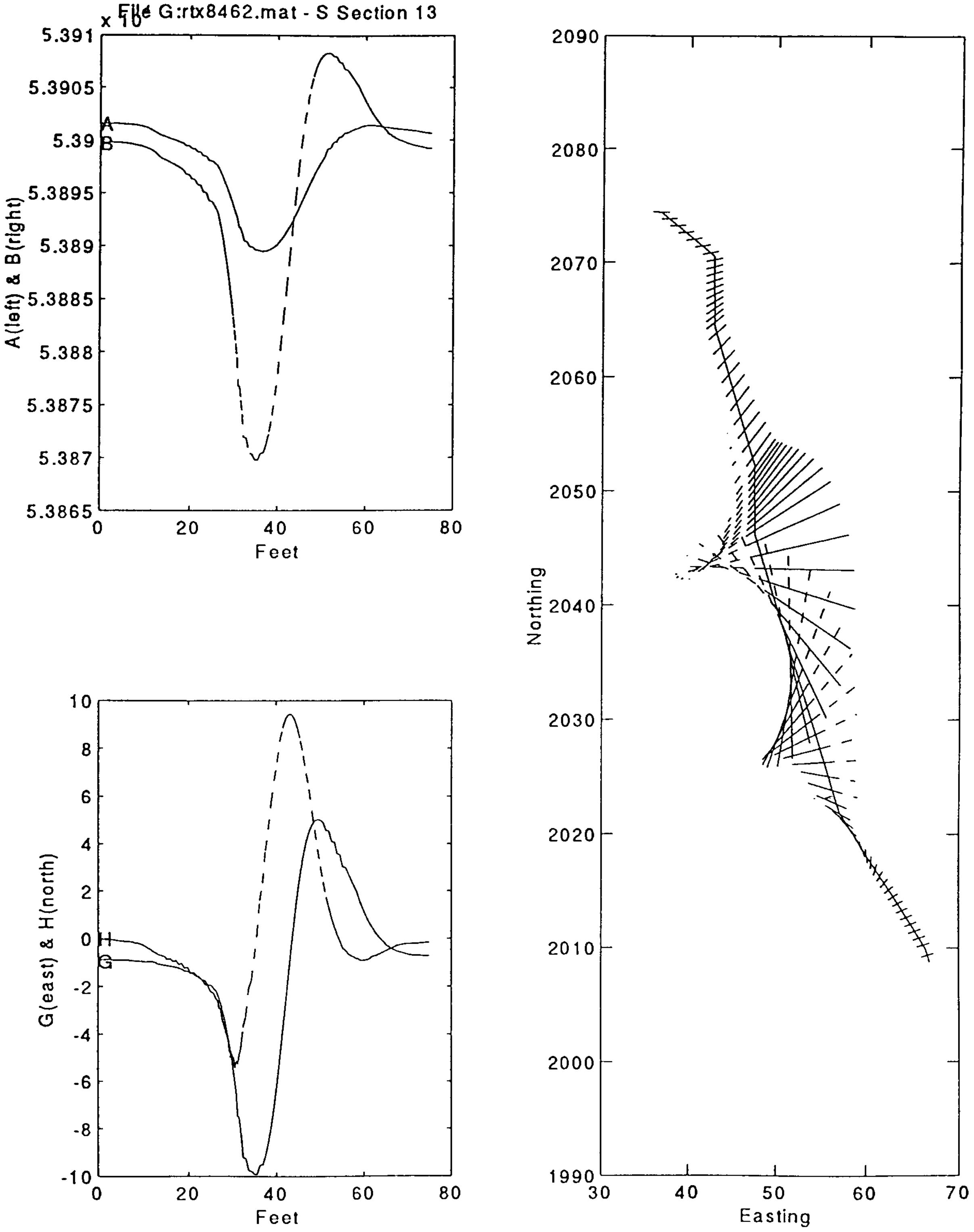
Feet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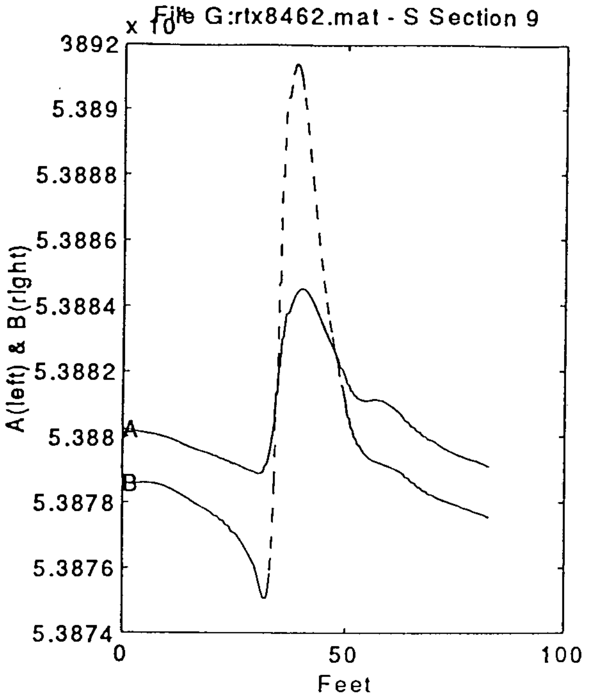
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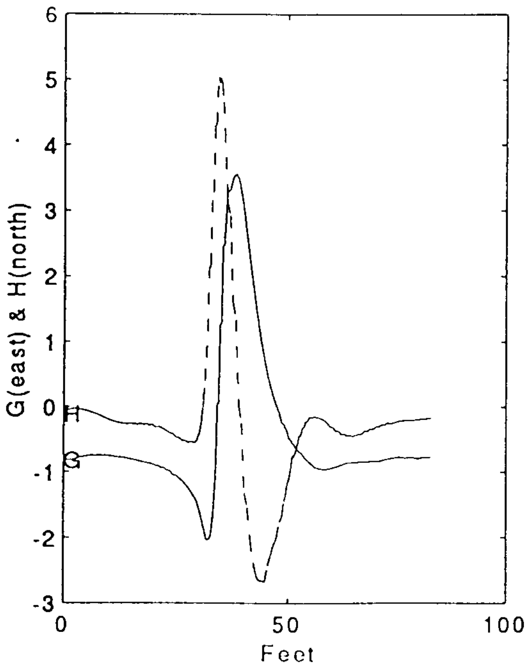
100
Feet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G
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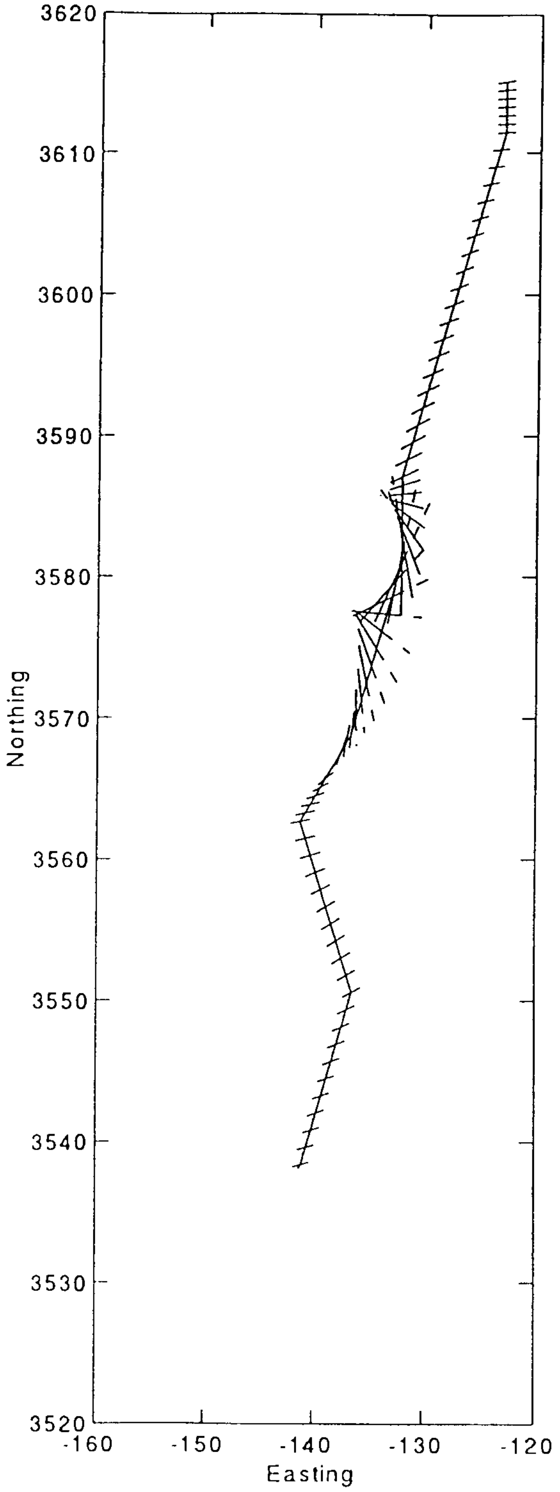
Feet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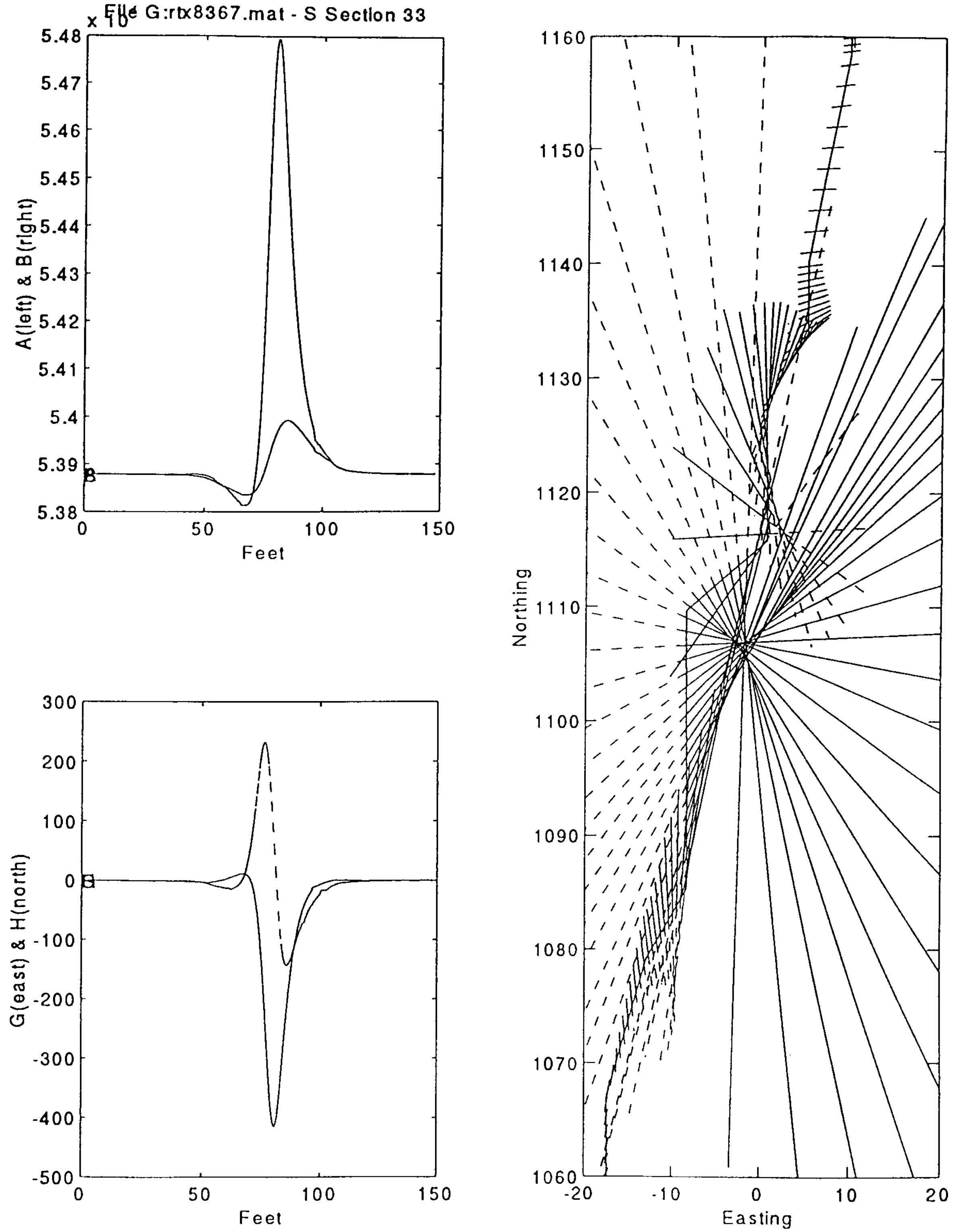
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5.38
A(left) & B(right)
B
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50
100
150
Feet
300
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100
0
-100
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-300
-400
-500
G(east) & H(north)
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50
100
150
Feet
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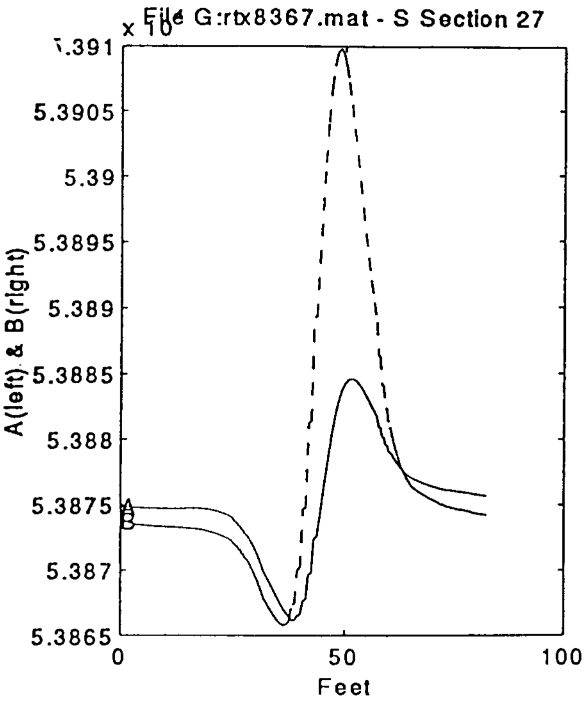
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B
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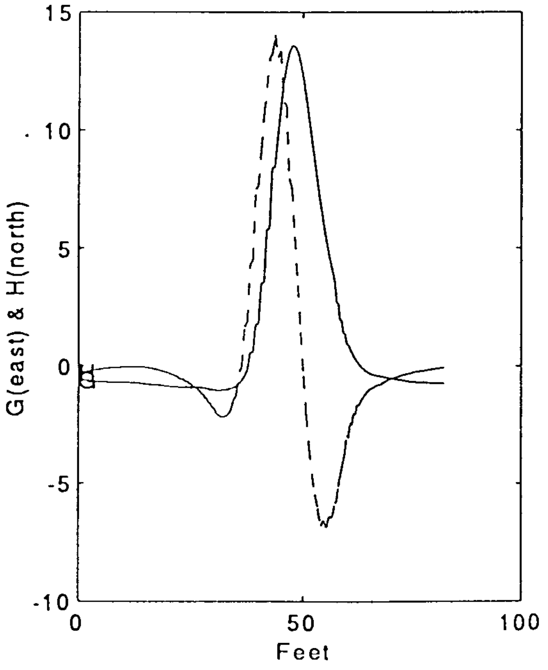
Feet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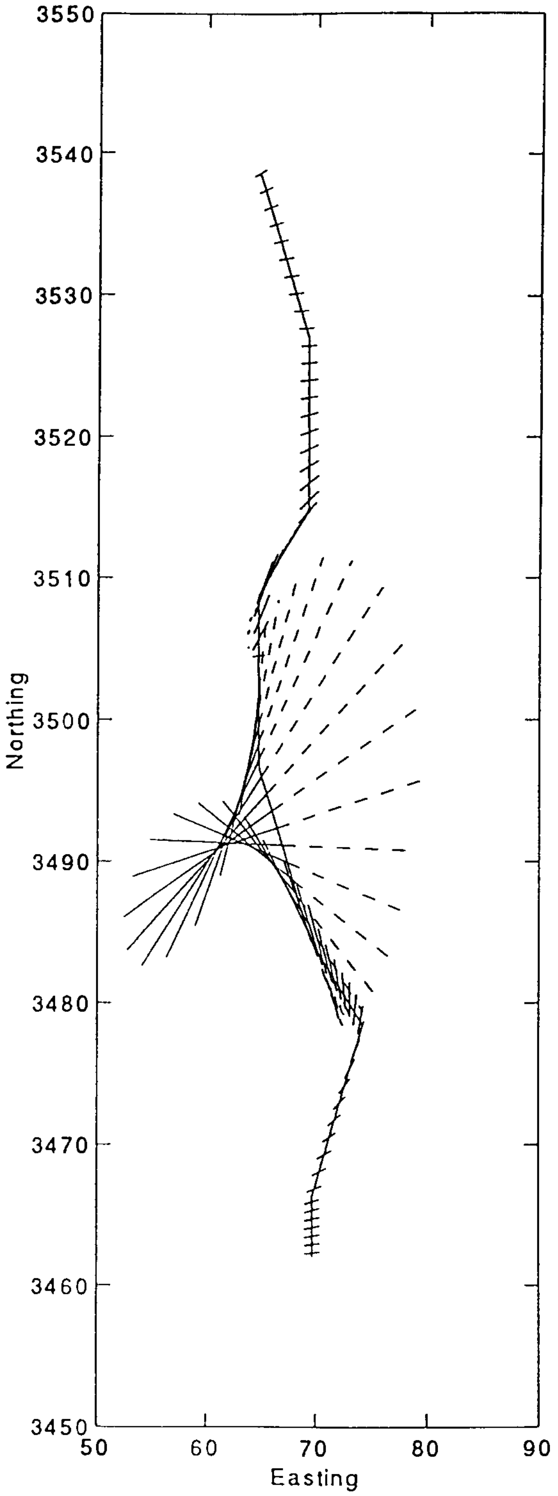
Feet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Easting

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13. ABSTRACT ***(Maximum 200 words)***

The U.S. Army Corps of Engineers and the state of New Jersey have undertaken the largest beach restoration project in U.S. history, known as the "Atlantic Coast of New Jersey, Sandy Hook to Barnegat Inlet, Section I, Sea Bright to Ocean Township." Within a very short period after the initiation of construction in 1994, ordnance were discovered on the newly constructed beaches. The expensive cleanup operations that were required to locate and remove the ordnance from the beach included fitting project dredges with 1.5-in. square grates over the dragheads. These grates prohibit excavation of the ordnance, thus, protecting the dredge and the resultant beach area from unexploded ordnance contamination. However, the grates also reduce the efficiency of the dredging operation by an estimated 20 percent. Over the 50-year life of the project, this could cost hundreds of millions of dollars in lost productivity.

The U.S. Army Engineer District, New York, asked the U.S. Army Engineer Waterways Experiment Station to evaluate and make recommendations on a means of characterizing the ordnance contamination in the borrow area. Once the coverage and extent of the contamination have been determined, it may be possible to identify sections that can be dredged in a conventional manner or to design a practical and safe predredging cleanup operation. WES conducted a review of several technologies and recommended a "pilot study" to test oceanographic/geophysical systems for their suitability in detecting ordnance at the Sea Bright site. The New York District concurred with this recommendation and the pilot study conducted by WES is reported herein.

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Ordnance contamination
Sea Bright, NJ

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