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SURVEY WORK PLAN FOR DEPLETED URANIUM (DU) PENETRATORS VIEQUES NAVAL
TARGET RANGE, LIVE IMPACT AREA REVISION 1 VIEQUES PUERTO RICO
5/1/2000
NAVAL SEA SYSTEMS COMMAND DETACHMENT RADIOLOGICAL AFFAIRS SUPPORT
OFFICE

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VIEQUES, PR

SURVEY WORK PLAN

For

**Depleted Uranium (DU) Penetrators
Vieques Naval Target Range, Live Impact Area
Vieques, Puerto Rico**



Prepared By

**NAVAL SEA SYSTEMS COMMAND DETACHMENT
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GLOSSARY OF ACRONYMS, ABBREVIATIONS AND SYMBOLS

AFWTF	Atlantic Fleet Weapons Training Facility
cpm	counts per minute
DC	direct current
DCGL	Derived Concentration Guideline Level
DGPS	Differential Global Positioning System
DU	depleted uranium
E-600	Eberline Model E-600 Survey Meter
EOD	Explosive Ordnance Disposal
EPM	Environmental Project Manager
HV	high voltage
keV	kiloelectron volt
L _D	detection limit
LIA	Live Impact Area
MDA	minimum detectable activity
MeV	megaelectron volt
mm	millimeter
mrem	millirem
NaI(Tl)	sodium iodide with thallium (crystal)
NAVSEADET RASO	Naval Sea Systems Command Detachment, Radiological Affairs Support Office
NIST	National Institute of Standards and Technology
Pa	protactinium
PCB	polychlorinated biphenyl
pCi	picocurie
pCi/g	picocurie per gram
POC	point of contact
RF	radiofrequency
TEDE	total effective dose equivalent
Th	thorium
U	uranium
UXO	unexploded ordnance
V	volt

1.0 EXECUTIVE SUMMARY

On February 19, 1999, two U.S. Marine Corps A/V-8 Harrier aircraft fired 263 rounds of 25 mm depleted uranium (DU) ammunition on the Live Impact Area (LIA), Atlantic Fleet Weapons Training Facility (AFWTF) on the island of Vieques, Puerto Rico. The LIA is approximately a 2.5 square mile live-fire training range used by the Navy and Marine Corps for aircraft, ship and amphibious assault fire exercises. The affected area was isolated to a portion of the LIA called the North Convoy Site. A team lead by Navy health physicists was dispatched to Vieques (North Convoy Site) between 10 and 19 March 1999, to locate and recover as many DU rounds as possible. The team recovered 57 rounds during this period, then had to leave due to logistic constraints.

Navy health physicists will return to the affected site and recover all detectable DU penetrators. The team will conduct a 100% high-density scan of the affected area using sodium iodide detectors. All areas that are distinguishable from background, above the minimal detectable count rate (MDCR) will be investigated. At a 95% true positive rate and 60% false positive rate, the scanning detection system can detect a 25 mm DU round, consisting of 148 grams of DU at a depth of 9 inches in soil.

The Navy must contend with several challenges before and during surveys of the North Convoy Site. Most importantly, the Navy must carefully weight the risk to survey/cleanup personnel with the risk to an average member of the critical group. Typically, dose modeling is used to estimate the total effective dose equivalent (TEDE) to an average member of the critical group from residual radioactivity. The critical group means the group of individuals reasonably expected to receive the greatest exposure to residual radioactivity for any applicable set of circumstances. Ultimately, the TEDE corresponds to an acceptable risk factor for the critical group. This acceptable TEDE is 25 mrem per year. The concentration of residual radioactivity distinguishable from background that if distributed uniformly throughout a survey unit would result in a TEDE of 25 mrem per year is called the derived concentration guideline (DCGL). Ideally, the objective of the Navy would be to perform a final status survey to demonstrate compliance with a DCGL. Unfortunately, current computer dose/risk models, even using site specific parameters, can not derive a DCGL for the situation on Vieques. But, since there are no exposure pathways (internal or external from the DU penetrators), the Navy concludes that the TEDE to the average member of the critical group (range personnel who periodically refurbish the Site) is 0 mrem per year. This equates to a risk factor of less than 10^{-6} . However, this Site does contain unexploded ordnance (UXO) that does present a greater risk to members of the critical group and to survey/cleanup personnel. Generally, UXO risk evaluations take a conservative approach and assume that the consequences of UXO detonation are serious injury or death. The exact risk from UXO at the North Convoy Site is being assessed and will continue to be assessed during the survey. This assessment must be considered and balanced against the potential risk and the degree of risk reduction that could be achieved by removing the DU penetrators. Furthermore, all brush in the survey area will have to be removed or cut to a height not to exceed four inches prior to the survey to allow survey teams full access.

This Radiological Survey Work Plan describes the methods and activities to be performed during the survey of the North Convoy Site, LIA, Vieques.

2.0 PURPOSE

Conduct a 100% survey of the affected area and remove all detectable DU penetrators. The survey equipment combines a commercial Differential Global Positioning System (DGPS) and high-density data collection/management system with commercial radiation detection equipment.

3.0 HISTORY

On February 19, 1999, during a training exercise on the Live Impact Area of the Vieques Inner Range on Vieques, Puerto Rico, two U.S. Marine Corps Harrier aircraft expended 263 depleted uranium (DU) 25-mm rounds. Each 25-mm round contains 148 grams of DU in the form of a pencil shaped penetrator. The Live Impact Area is located on the eastern tip of the island of Vieques and covers approximately 2.5 square miles (see Figure 1). Interviews with the Marine pilots isolated the affected area to a small portion of the LIA called the North Convoy Site (see Figure 2).

The Harrier aircraft approached the North Convoy Site from the south, firing on targets in a northern direction. Each Harrier was loaded with 200 rounds. The Harriers made one pass over the Site. One Harrier expended all 200 rounds; the other Harrier expended only 63 round due to a gun jam. The pilots stated that their line-of-fire extended past the northern edge of the North Convoy Site into the brush area between the Site and the edge of the island. One pilot stated that his line-of-fire could have extended into the sea (see Figure 3).

4.0 DESCRIPTION OF THE SITE

The Live Impact Area is located on the East End of Vieques. The North Convoy Site is on the northeast side of the LIA. As shown in Figure 3, the Site is completely clear of vegetation and the soil is a mixture of sand and small rocks. Targets (a convoy of armored vehicles) are located on a hill, approximately centered on the Site. The hill slopes steeply downward toward the south, east and west, and slopes gradually in north direction. The area north of the North Convoy Site extends from the Site's north edge to the edge of the island (or to the sea). This area is covered with patches of mesquite vegetation and the soil is also composed of a mixture of sand and small rocks. Both these areas are littered with metal debris, some unexploded ordinance, and contain several large craters.

For brevity, both these sites will be referred to collective as the North Convoy Site. Accounts of the incident and a previous site investigation indicate that only a limited section of the North Convoy Site was actually affected. Penetrators were located along two distinct paths radiating from the targets in a northern direction. This pattern corresponded to the direction of fire employed by both Harrier pilots. This narrows the actual affected area to approximately

9.5 acres (see Figure 3). It is optimistic that the actual lines-of-fire can be identified and then the actual affected area could be reduced to approximately 1.5 acres.

5.0 PREVIOUS RADIOLOGICAL INVESTIGATIONS

A team lead by Navy health physicists was dispatched to Vieques between 10 and 19 March 1999, to locate and recover as many DU penetrators as possible. Visual searches and radiological surveys of the North Convoy site confirmed the location of penetrators along two distinct paths radiating from the targets (starting at two armored tanks) in a northern direction (see Figure 3). Buried penetrators were visually located by the presence of a depression, hole, or divot in the soil and confirmed radiologically using a 2 inch by 2 inch sodium iodide and pancake G-M detectors.

The team recovered a total of 57 DU penetrators, most of them completely intact. Due to the low trajectory of the Harriers, although several penetrators were located near the targets, the majority of penetrators were located north of the targets within the brush. Penetrators were located approximately 10 to 20 feet apart. About 20% of the penetrators recovered were located on the surface, the rest were buried in the soil at an average depth of 6-8 inches (see Figures 4). One penetrator was buried up to 18 inches in very loose soil. Only a few holes exhibited residual contamination after the penetrator was removed. In each of these cases, part of the penetrator had fractured into smaller pieces.

The soil covering the North Convey Site can be classified as sandy. It is dry, has a coarse texture and consists of large particles with uneven surfaces and large pore spaces. This makes the soil loose and easy to work. Background radiation readings of the soil ranged from 2,000-4,000 cpm.

A radiological scan survey of the North Convoy Site, out to the perimeter of the brush, was conducted using a 2 inch by 2 inch sodium iodide detector following the recovery of all penetrators. No additional penetrators or residual contamination were noted as a result of the radiological survey. Due to the dense vegetation and the possibility of hidden unexploded ordnance (UXO), detailed surveys were limited to the immediate vicinity of the cleared area of the North Convoy Site.

6.0 RADIOLOGICAL CONTAMINANT

The radiological contaminant of concern is depleted uranium. Depleted uranium is uranium metal that is the by-product of the uranium enrichment process. It is called depleted uranium because the amounts of the more radioactive forms of uranium have been reduced (depleted). This means its radioactive hazard has also been lessened. DU is almost entirely U-238 (99.8% U-238), and is 40% less radioactive than natural uranium found in air, water and soil. Because of its high density and strength, DU is used by the U.S. military in ammunition for armored shore vehicles, aircraft, and ships; as armored shielding for tanks; as counterweights in aircraft; and as radiation shielding in hospital nuclear medicine and radiation therapy clinics.

7.0 HEALTH EFFECTS REGARDING EXPOSURE TO DEPLETED URANIUM

The health risks associated with using DU in the peacetime military are minimal because DU is shielded and or intact. If the integrity of DU materials is compromised, such as when munitions are fired or armor is pierced, uranium can then react with other elements in the environment. This can create chemical reactions that may yield compounds with various chemical toxicities. Toxicologically, DU poses a health risk to the kidneys when internalized by ingestion or inhalation. The risk to the kidneys is similar to that from any other heavy metal such as lead, cadmium, or nickel. The toxicological health threat far out weights any radiological threat posed by DU.

The Navy has assessed the health consequences of the Vieques incident and has determined that the depleted uranium penetrators and minimal soil contamination do not pose an immediate safety concern to range workers or the trespassers occupying the Live Impact Area (LIA)¹. Although civilian trespassers have unimpeded access to the entire Atlantic Fleet Weapons Training Facility on Vieques, they have seldom been observed for extended periods on the LIA but have been seen transiting the access perimeter road.

The risk from incidental exposure to a depleted uranium penetrator does not pose a significant radiological hazard due to the low radioactivity of depleted uranium and the low energy photons emitted. Although many reports addresses health effects occurring from excessive ingestion or inhalation of depleted uranium, an individual on the range is very unlikely to receive such an intake. The depleted uranium penetrators already recovered were intact or in large fragments that are not respirable or easily ingested. External radiation exposure may also occur from contact with the bare skin. The current dose limit for skin would only be exceeded if unshielded DU remains in direct contact with the skin for more than 270 hours¹. This type of exposure to the DU penetrators is very unlikely.

During the radiological survey conducted in March 1999, depleted uranium penetrators were removed from the area bounded in Figure 5. The balance of the penetrators are located in an area that is fairly inaccessible to people.

8.0 NON-RADIOLOGICAL CONTAMINANTS

The Atlantic Fleet Weapons Training Facility does support live-fire training operations. It does contain unexploded ordnance and explosive residues. A complete analysis of the range has not been performed, but it can be expected to contain contaminants typical of this type of range. These contaminants can include UXO, lead, mercury, beryllium, chromium, nickel, PCBs, oils and other petroleum products, antifreeze, and other organic compounds. The range is littered with scrap metal ranging in size from small pieces, which are a fraction of an inch in length to the remains of tanks, trucks, airplanes, and other target vehicles.

¹ Chief of Naval Operations (N455), Naval Radiation Safety Committee letter, Serial N455/9U595729 of 22 July 1999 to Nuclear Regulatory Commission, Region II (Ms. Anne Boland, Enforcement Officer).

9.0 SITE PREPARATION, EQUIPMENT AND PERSONNEL

9.1 Accessibility

All brush in the survey area will have to be removed or cut to a height not to exceed 4 inches prior to the 100% scan survey to allow survey teams full access. Because of the unexploded ordnance, access to the range requires an Explosive Ordnance Disposal (EOD) team escort. Access to the site will be limited to only those personnel engaged in the survey.

9.2 Electrical Power

There is no electrical power available at the range. A portable gasoline generator will supply electrical power.

9.3 Personnel

At a minimum the technical assist team will consist of a Team Leader (Navy health physicist), a Radiological Environmental Project Manager (EPM) from NAVSEADET RASO, two explosive ordnance disposal (EOD) personnel, and two AFWTF Inner Range personnel. Commanding Officer AFWTF, will provide local logistical support, NAVSEADET RASO is the technical point of contact (POC) for the team, and Chief of Naval Operations (N455) is the Naval Radiation Safety Committee's POC for the team.

10.0 RADIOLOGICAL SCAN SURVEY EQUIPMENT

10.1 Introduction

As shown in Figure 6, the survey equipment combines a commercial Differential Global Positioning System (DGPS) and data management system with commercial radiation detection equipment. The system records a detector's physical location to the data acquired during scan surveys. The system produces real-time positioning for the survey data that is collected every second. The system manages all the data and provides posting plots of the area surveyed.

10.2 Geographic Positioning

The positioning system is based on a commercial Differential Global Positioning System. The software with the system identifies the location of the data collection point and assigns relative coordinates to the data for later analysis. The positioning system is accurate to within 6 to 18 inches.

10.3 Data Collection

The NAVTRACK 2200 system is able to transmit data from up to six detectors every second. The NAVTRACK data pack receives detector input and transmits the data via radiofrequency modem to a receiver connected to a microcomputer, which records the data and its position. The system records 3600 data points per hour per detector.

10.4 Detectors

Eberline SPA-3, 2-inch by 2-inch sodium iodide detectors will be used for the survey. The detector will be calibrated specifically for DU. The detector's field of view was mapped by measuring penetrators on the surface and buried in soil. In the field, the measurement system was capable of detecting the MDCR, net counts above background, as defined in Section 11.3.

When terrain features permit, multiple detectors will be mounted on a pushcart, similar to the one shown in Figure 6 to survey a wider area at one time.

10.5 Multi-Purpose Digital Survey Instrument

The sodium iodide detectors are connected to the Eberline E-600 multi-purpose digital survey instrument. The E-600 is operated in the Gross count mode for photon energies between 60 and 2000 keV. Operating in this mode enhances the signal from DU to signal from background radiation ratio because it records primarily DU specific photon energies. The count rate from each detector is exported to the NAVTRACK system.

11.0 **RADIOLOGICAL SCAN SURVEYS**

11.1 Radiological Surveys

Using the survey system described in Section 10 above and a forward scanning speed of 18 inches per second, with the detector(s) 4 inches from the surface, the Navy is prepared to conduct a high density scan survey over the area identified in Figure 3. This area covers approximately 10 acres. However, the Navy is optimistic that the survey area can be further reduced in size if the exact lines-of-fire can be identified. The survey would then be concentrated on precise paths and potentially reduce the survey area from 10 acres to approximately 1.5 acres.

Initial scoping surveys will be conducted with hand-held Eberline E-600s with SPA-3 detectors. Based on the location of previously recovered penetrator, the Harrier pilots accounts, and any remaining visual divots caused by the penetrators, the line(s)-of-fire will be established and surveyed. Detected penetrators will be recovered. Unless all the penetrators are recovered during the scoping surveys, the brush covering the line(s)-of-fire will be cleared and a 100 % high-density scan conducted.

11.2 Background Determination

The background radiation level(s) will be established on-site from an unaffected area or from readings in the actual survey area. Since the contamination is not uniformly dispersed over the survey area but consists of discreet sources, the survey area itself can be used as the background. Potentially contaminated areas will be identified relative to the local area background.

11.3 Scanning Minimal Detectable Count Rate (MDCR)

The minimum detectable number of net source counts in the scan interval required for a specified level of performance will be derived using the following equation.

$$\text{MDCR} = d' \sqrt{b_i} C$$

Where :

d' = index of sensitivity (α and β error)

b_i = number of bkgd counts in scan time interval

i = integrated scan interval (seconds)

C = 60/ i used to convert to cpm

For example, if the background count rate on Vieques is 4,000 cpm for a one second observation interval and using an index of sensitivity of 1.38 (95% true positive rate and 60% false positive rate); the MDCR is 676 cpm (or 4676 cpm gross).

11.4 The Detectability of DU

DU consists of 99.8% U-238 and 0.2% U-235. Also present are the short-lived progeny of these radionuclides, considered in secular equilibrium with their parents (i.e., having the same activity). U-238's short-lived progeny are Th-234 and Pa-234m, and U-235's daughter is Th-231.

The mass of a 25 mm DU penetrator is 148 g and therefore contains 147.7 g of U-238 and 0.3 g of U-235. Using a specific activity of 3.33×10^{-7} Ci g⁻¹ for U-238 and a specific activity of 2.14×10^{-5} Ci g for U-235, the total activity of a penetrator is approximately 5×10^{-5} Ci. The photon emissions from DU are of most concern for detection purposes. DU's photon spectrum is shown in Table 1. Most of the photons emitted by DU have energies below 150 keV.

Both theoretical and empirical data were used to evaluate the ability of an Eberline E-600 with a SPA-3 probe to detect a DU penetrator. Using the computer program MicroShield and actual physical measurements in the field, the response of the detection system was evaluated. Using MicroShield, dose rates were calculated for a DU round on the surface and buried in sand (1.5 g cm⁻³) at depths of 3, 6, 9, and 12 inches. A measured conversion factor was used to convert mR h⁻¹ to cpm (this conversion factor is not depth specific). The estimated count rate at each depth was then compared to the MDCR. As shown in Table 1, a 148 g penetrator buried in sand can be detected (i.e., exceeds the MDCR) at a depth up to 9 inches.

Table 1. DU Photon Emission Spectra

Nuclide	Energy (MeV)	Fraction	Nuclide	Energy (MeV)	Fraction	Nuclide	Energy (MeV)	Fraction
U-238	0.013	0.088	U-235	0.013	0.309	Th-231	0.013	0.708
	0.066	0.001		0.073	0.001		0.017	0.002
Th-234	0.013	0.096		0.090	0.027		0.026	0.147
	0.063	0.038		0.093	0.045		0.059	0.005
	0.092	0.027		0.105	0.021		0.073	0.002
	0.093	0.027		0.109	0.015		0.081	0.009
	0.113	0.002		0.120	0.002		0.082	0.004
	0.077	0.001		0.141	0.002		0.084	0.064
Pa-234m	0.013	0.001		0.144	0.105		0.090	0.009
	0.074	0.000		0.163	0.047		0.092	0.004
	0.014	0.004		0.183	0.004		0.096	0.006
	0.095	0.001		0.184	0.540		0.099	0.001
	0.098	0.002		0.195	0.006		0.102	0.004
	0.111	0.001		0.202	0.010		0.108	0.003
	0.766	0.002		0.205	0.047		0.163	0.002
	1.001	0.006		0.221	0.001		0.114	0.006
	0.926	0.004		0.190	0.009			

Table 2. Detectability of DU in Sand – Exceeding the MDCR

Depth in Sand (in)	Exposure Rate $\mu\text{R h}^{-1}$	Conversion Factor $\text{cpm} / \mu\text{R h}^{-1}$	Net Detector Response (cpm)	Net MDCR (cpm)
0	24	1315	31568	676
3	6	1315	7892	676
6	2	1315	2631	676
9	0.8	1315	1052	676
12	0.3	1315	395	676

With the detector located 4 inches above ground.

To validate the calculations in Table 2, NAVSEADET RASO performed a field study of the detection system's ability to detect a 148 g and 70 g penetrator in sand. The experimental design is shown in Figure 7. The detection system's response was evaluated with a penetrator on the surface and buried at depths of 3, 6, 9, and 12 inches. The system was also evaluated with the position of the penetrator, centerline, at the beginning and middle of the scan interval. Additionally, the detector was offset at 2-inch increments up to 12 inches from centerline to determine the detector field of view.

This study verified that a 148 g penetrator buried in sand can be detected (exceeds the MDCR) at a depth up to 9 inches. The 70 g penetrator could be detected at a depth to 6 inches. The offset, or detector's field of view, was determined to be 2 inches. Therefore, if an array of multiple detectors is used on a pushcart, they will be mounted no more than 4 inches apart (center to center).

This study will be repeated on Vieques to determine the detection systems true capability onsite.

11.5 Potentially Contaminated Areas

Areas that exhibit readings above background (net counts that exceed the MDCR) and areas have been remediated will be re-surveyed with either a hand-held E-600/SP-3 survey instrument or the NAVTRACK system. The minimum number of source counts required to support a detection decision for this scan stage can be estimated using the same methodology described in Section 11.3. The required rate of true positives remains high (95%), but fewer false positives (20%) can be tolerated, such that d' is now 2.45. If the survey interval is now increased to 4 seconds, the MDCR equals 600 cpm. Fixed surveys can also be conducted to further reduce the MDC.

11.6 Data Analysis

The data analysis software can provide real time screen displays and printouts in real time of the data being collected. The data can be color coded to different thresholds specified by the operator. Statistical information (high, low, mean, and standard deviation) can be calculated for the entire survey file or operator specified blocks. The software can also apply gridding and calculate the average values for each grid and display them by operator specified thresholds. Figure 8 shows a track map of a small scanned area. This area has several different surface media (asphalt, clay soil, grass over clay soil, and sand) and three DU penetrators located on the surface. The track map has color-coded thresholds based on the count rate. The red dots show the locations of the DU penetrators. Figure 9 shows a stack map (combined contour and surface maps) of the same scan data. These types of graphical representations of the scan data, in conjunction with statistical tests will be used to detect the location of DU penetrators on Vieques.

All areas that exhibit readings above background (net counts above the MDCR) will be investigated.

12.0 QUALITY ASSURANCE PLAN

12.1 Project Description

To identify areas of elevated radioactivity on the North Convoy Site, LIA, Vieques, and determine whether these areas are due to DU penetrators.

12.2 Project Organization

The Team Leader will ensure that personnel involved in this project meet the necessary training requirements. An environmental project manager (EPM) from NAVSEADET RASO will control data collection and with the Team Leader analyze the data.

12.3 Training

Personnel authorized access to the North Convoy Site will receive appropriate explosive safety training and general training on hazards associated with conducting operations on an ordnance range.

Personnel operating the NAVTRACK 2200 system will have either completed training by CHEMRAD, the manufacturer of the system, or be under the supervision of someone that has completed the CHEMRAD training.

Personnel operating the survey detection equipment will have either completed training by NAVSEADET RASO or be under the supervision of someone that has completed the training.

Personnel recovering DU penetrators will have either completed training by NAVSEADET RASO or be under the supervision of someone that has completed the training.

NAVSEADET RASO personnel are trained radiation workers and are familiar with the handling and storage of radioactive materials, contamination controls, and the use of radiation survey equipment.

12.4 Design of Data Collection Operations

12.4.1 Equipment

The SPA-3 and E-600 systems will be calibrated using the manufacturer's calibration protocol to a National Institute of Standards and Technology (NIST) traceable source at the Radiological Affairs Support Office. The E-600/SPA-3 is calibrated to detect gamma radiation within the approximate energy range of 60 keV to 2000 keV with an accuracy of $\pm 10\%$. Daily source checks will be performed to verify proper operation of the detectors and E-600s. In addition, as part of the NAVTRACK 2200 operation, a Quality Control Point (DGPS point) is taken at the start of each survey and a second point is taken at the same location at the end of the survey to verify proper operation of the tracking equipment.

12.4.2 Data Collection

Data collection will be performed in accordance with CHEMRAD specifications. CHEMRAD is the manufacturer of the NAVTRACK equipment.

12.4.3 Database Security

The NAVTRACK 2200 system is designed to produce tamper-resistant survey files (*.sva). These files cannot be used for data analysis and data reduction. The system also produces correlated data files (*.cdf) that can be used for data analysis and reduction. All of the raw data collected during the survey will be copied to floppy discs and safeguarded by the EPM. Upon return to NAVSEADET RASO, the files will be transferred to an access-controlled computer.

12.4.4 Data Review

The Team Leader will review data at the end of each survey to determine the validity of the results and adequate coverage of the survey area.

12.5 Data Assessment

Basic statistical quantities will be calculated for the data in order to identify patterns, relationships and any type anomaly. Graphical review of the data will be performed using posting plots/maps and frequency plots/maps. This will identify any small heterogeneities in the survey unit and will serve as a visual representation of the symmetry in the data.

13.0 **HEALTH AND SAFETY PLAN**

13.1 Introduction

Federal laws, as well as Navy policy, make the safety and health of our members the first consideration in operations. Good safety and health practices must be a part of our operation, and every member's responsibility. Work conditions will be reviewed to identify hazards. Appropriate actions will be taken to ensure a safe workplace. No member will be required to work at a job known to be unsafe or dangerous to his or her health.

13.2 Safety First Priority

The personal safety and health of each member is of primary importance. Prevention of occupationally induced injuries and illnesses will be given precedence over operating productivity. The Team Leader will provide all mechanical and physical protection required for personal safety and health. Workers bear primary responsibility for working safely.

13.3 Individual Cooperation Necessary

The Navy will maintain a safety and health program conforming to the best practices of our field. To be successful, such a program must embody proper attitudes towards injury and illness prevention on the part of supervisors and members. It requires the cooperation in all safety and health matters, not only of the employer and member, but between the member and all co-workers. Only through such a cooperative effort can a safety program in the best interest of all be established and preserved. Safety is no accident; think safety and the job will be safer.

13.4 Safety Rules for All Team Members

– All members shall follow the safe practices contained in this plan and communicated on the job. Members are responsible to report all unsafe conditions or practices to the proper authority, including the Team Leader. Safety considerations will be included in job pre-briefs. Members will observe safe practice rules and instructions relating to the efficient handling of the job. Know and obey safe practice rules. Know that disciplinary action may result from a violation of the safety rules.

- The Team Leader/supervisors shall be responsible for implementing these policies by insisting that members observe and obey all rules and regulations necessary to maintain a safe work place and safe work habits and practices.

- Suitable clothing and footwear must be worn at all times. Do not wear shoes with thin or torn soles. Equipment (hard-hats, respirators, and eye protection) will be worn whenever needed.

- There will be no consumption of liquor or beer on the job. Anyone under the influence of intoxicating liquor or drugs, including prescription drugs that might impair motor skills and judgment, shall not be allowed on the job.

- Horseplay, scuffling, and other acts which tend to have an adverse influence on safety or well being of other members are prohibited. Do not throw things, especially material and equipment. Caution fellow workers when they perform unsafe acts.

- Work shall be well planned and supervised to avoid injuries in the handling of heavy materials and while using equipment. When lifting heavy objects, use the large muscles of the leg instead of the smaller muscles of the back

- No one shall be permitted to work while the member's ability or alertness is so impaired by fatigue, illness, or other causes that might expose the member or others to injury. No one will be allowed to work when a person's physical condition, may impair judgment and safety.

- Good housekeeping must be practiced at all times in the work area. Dispose of all waste properly and carefully.

- Members should be alert to see that protective devices are in proper places and adjusted, and shall report deficiencies promptly to supervisors. Report all unsafe conditions or equipment to your supervisor immediately.

- Members shall not handle or tamper with any electrical equipment, machinery, or air or water lines in a manner not within the scope of their duties, unless they have received specific instructions. Don't tamper with anything you do not understand.

- All injuries will be reported to the supervisor so that arrangements can be made for medical or first aid treatment. Report all injuries immediately, no matter how slight the injury may be.

- Don't take chances. Ask questions when there is any doubt concerning safety.

- Fire hazards are to be minimized. Smoking is not allowed on the site, except in designated areas.

13.5 Safety and Health Training

Training is one of the most important elements of any injury and illness prevention program. Training is required for both supervisors and members alike. The content of each training session will vary, but each session will attempt to teach: (a) the individual responsibility to ensure a safe work place and illness prevention program depends on the actions of individual members; (b) when personal protective equipment is required or necessary and how to use and maintain the equipment in good condition; and (c) what to do in case of emergencies occurring in the workplace.

13.6 Communication

The Team Leader/Supervisors shall remind team members their obligation to safety and ensure that members are familiar with the elements of the safety program. A copy of this plan will be maintained in the work area. Concentrated efforts shall produce safe working conditions and result in efficient, productive operations. Safeguarding the health and welfare of our members cannot be stressed too strongly. Accident prevention is everyone's responsibility.

13.7 Hazard Identification & Abatement

EOD and Range personnel assigned to the team will review areas/sites prior to commencement of work and periodically. The review will identify any potential hazards and methods to abate.

13.8 Accident Investigation

Whenever there is an accident resulting in an injury a critique will be held to identify the root, contributing causes and corrective actions. Purpose of the critique is to identify root causes and corrective actions, and is independent of disciplinary actions.

13.9 Records

All training records and accident investigation will be maintained.

14.0 CALIBRATION OF DETECTORS FOR NAVTRACK OPERATION

14.1 Purpose

The purpose of this procedure is to ensure that the radiation detection equipment used with the NAVTRACK system is calibrated.

14.2 References

Eberline Model E-600 Portable Radiation Monitor Technical Manual

14.3 Materials

- E-600 survey meters
- Computer with Eberlines E-600 Interface program (ver 210) installed
- E-600 interface data cable
- E-600 probe cable
- Printer
- Eberline SPA-3, 2"x2" NaI(Tl) detectors
- Smart packs. One for each detector where they are not already an integral part of the detectors to be used
- NIST traceable DU calibration standard
- Ruler
- Tape, planchets or whatever else is required to hold the geometry constant between the detectors and the standard
- Calibration work sheet, one for each detector

14.4 Responsibility

NAVSEADET RASO is responsible for the proper calibration of the instruments.

14.5 Protocol

14.5.1 Preparation

a. Turn each of the E-600's on to the "check" position and observe the display face. The display should provide the following information:

- 1) Scale - across top
- 2) Probe Fail - lower left corner
- 3) Battery strength - lower right corner

b. Turn each E-600 off. Replace the batteries in any ratemeter which are at less than 70% for battery strength. Do this by removing cover on bottom of case to gain access to the batteries. The E-600 uses three "C" cells.

c. Hook-up

- 1) Connect the E-600 to the computer via the interface cable.
- 2) Connect the detector to the E-600 via the probe cable. Connect any required smart packs prior to this step.
- 3) Connect the printer to the computer.
- 4) Turn the computer and the printer ON.

- 5) Turn the E-600 switch to the CHECK position.

14.5.2 Calibration

- a. Double click on the E-600 icon.
- b. Double click on INSTRUMENT PARAMS.

- 1) Set instrument parameters to desired characteristics. Recommend setting the STAR KEY to start scaler.

- 2) After setting parameters, click on OK. At this time you will be asked for a password: Enter EBERLINE.

- c. Double click on SMART PROBE.

- 1) Using the manual confirm parameters for the detector being used.

- 2) Click on OK.

- d. Double click on SMART CHANNEL.

- 1) Confirm that the CHANNEL TYPE and UNITS are as desired for each channel. Confirm that all other parameters are set in accordance with the manual.

- 2) Click on OK.

- e. At the top of the E-600 window, click on CALIBRATE.

- 1) On the drop down menu, click on RUN PLATEAU.

- 2) On the VOLTAGE PLATEAU screen set the desired parameters. This will vary with type of detector and source to detector geometry. Name the graph and file.

- 3) Click on start. It will take 30 seconds for the HV to stabilize. Watch the plot develop, if the continuous discharge region is reached before the end of the selected voltage range, stop the plot by clicking on DONE and answering following messages.

- 4) Determine the proper HV for the detector by using the HV value that occurs halfway between the knee of the plateau and the start of the continuous discharge region.

- 5) Set the HV by click on the arrows on the graph until the vertical line is at the desired point. Click on the SET HV button.

14.5.3 Efficiency

(Matching of Survey Equipment: While it is allowable for most survey instruments to be calibrated to $\pm 20\%$, the precision between the instruments needs to be much

tighter. Otherwise problems are perceived where none exist, especially since one second counting times are used.)

- a. Select the appropriate geometry and NIST traceable standard for the detector being used. This will normally be:
- b. Gamma - Point source standard at a distance of eight inches from the face of the detector, centered.

14.6 Calibration Forms

14.6.1 Printing the Calibration Graph for each Detector

- a. Click on DISPLAY GRAPH.
- b. Double click on file to be displayed.
- c. Click on FILE.
- d. Click on PRINT GRAPH.

14.6.2 Printing the Calibration Report for each Detector

- a. Click on PRINT CALIBRATION REPORT in the CALIBRATE pull-down menu.
- b. Enter the isotope and activity of the source used to calibrate the detector on the calibration report.

15.0 **GAMMA SCINTILLATION OPERATION**

15.1 Purpose

This procedure describes the use of the Eberline E-600 and its associated gamma scintillation detectors.

15.2 Reference

Eberline Technical Manual. E -600 Portable Radiation Monitor

15.2.1 Figures

- a. E-600 and associated scintillometers (Figures 6 and 8)
- b. Survey Path (Figure 3)

15.2.2 Materials

- a. Eberline E-600
- b. Eberline Scintillation Probe SPA-3
- c. Probe Cable
- d. Computer Interface Cable
- e. Type C batteries

15.2.3 Responsibility

- a. TEAM LEADER: Is responsible to ensure that enough instruments are available for fieldwork and that they meet the calibration specifications.
- b. TEAM MEMBERS: Team members prevent loss of or damage to instruments and clean and decontaminate instruments after field use.
- c. NAVSEADET RASO: Is responsible for the proper calibration of the instruments.

15.2.4 Frequency

- a. Calibration of the instruments will be performed on a yearly basis.
- b. Calibration checks will be performed, at a minimum, daily prior to use.

15.2.5 Protocol

- a. Remove the E-600 and corresponding probe, SPA-3, from storage in the survey vehicle and visually check for physical damage. If physically damaged, do not use.
- b. Connect probe to ratemeter. Annotate the serial numbers.
- c. Turn instrument selector switch to "Check"
- d. Insure that the display indicates that the instrument is set for "γ" and the serial number of the probe is correct. If the display indicates any anomaly replace the probe or the ratemeter.
- e. Insure that the batteries are over 70% charged. If not, replace.
- f. Connect the ratemeter via the computer interface cable to the NAVTRACK serial expansion or the data pack on the Radcart or the Backpack.

15.2.6 Calibration Check

- a. Perform a calibration check at the beginning of each survey day.
- b. After a quality check has been performed with the NAVTRACK software the calibration check is performed using the "Bias Point" command.
- c. Place the check source under the probe or between probes if using an array of probes. Allow for the collection of data.
- d. Print the "survey statistics" from the NAVTRACK survey program.
- e. Subtract the "Bias Point" readings from the "Quality Point" readings from the same coordinates. This will produce the net cpm necessary to confirm the calibration check.

15.2.7 Survey

- a. Traverse the property to be surveyed by following parallel paths, adjacent but slightly overlapping.
- b. The Audio response of the ratemeter may be used to identify areas of elevated readings as the survey progresses. However, the surveyor should concentrate on maintaining a straight path.
- c. When the survey is complete progress to an acceptable position to record a "Quality Point."
- d. When given the signal that data collection is complete, turn the instruments off.

16.0 **BACKPACK, RADCARD AND PC/MASTER CONTROLLER ASSEMBLY**

16.1 Purpose

To provide assembly instructions for the Backpack and Radcart for use with the NAVTRACK system.

16.2 Reference

NAVTRACK Users Manual, Chemrad Tennessee Corp, Oak Ridge, TN.

16.3 Materials

- 12 V Battery
- Backpack Frame

- Coaxial Cables
- Data Pack
- DGPS Rover Antenna
- Eberline E-600s
- Handheld Terminal
- Instrument Rack
- Masts
- NaI Detectors
- Radiofrequency (RF) Modems
- Serial Expansion Box
- Velcro Straps

16.4 Responsibility

It is the responsibility of the team leader to insure that the Backpack and Radcart reach their destination. It is the responsibility of the RASO EPM to assemble the Backpack and Radcart and ensure they are working properly.

16.5 Protocol

16.5.1 Backpack

- a. Assemble the Instrument Rack according to the instructions provided by the manufacturer. Attach the Instrument Rack to the backpack frame.
- b. Attach the Data Pack and Serial Expansion Box to the Instrument Rack.
- c. Attach the E-600s to the Instrument Rack. Secure with velcro straps.
- d. Attach the DGPS and Master Controller RF modems to their masts. Attach the masts to the backpack, ensuring one of the modems is at least 12 inches higher than the other.
- e. Connect the modem cables to the Data Pack. Connect the computer interface cables between the E-600s and the Serial Expansion Box. Connect the cable between the Serial Expansion Box and the Data Pack. Ensure the Data Pack power switch is OFF and connect the power cable to the 12-volt battery (on Radcart).

16.5.2 Radcart

- a. Assemble the Radcart frame (base, wheels, handle, and antenna post).
- b. Connect the antenna cable to the DGPS Rover antenna and attach the antenna to the antenna post.
- c. Install the NaI detectors in the holders. Place the end of the detector not more than 4 inches above the ground. Tighten the mounting set screws.

- d. Attach applicable coaxial cables.
- e. Connect the detector cable between the E-600s and the detectors on the Radcart.

16.5.3 PC/Master Controller

- a. Attach an antenna to the Master Controller.
- b. Connect the Master Controller to the computer with a serial cable.
- c. Connect the Master Controller to a 12 V DC power source.

Figure 1. Live Impact Area on Island of Vieques.

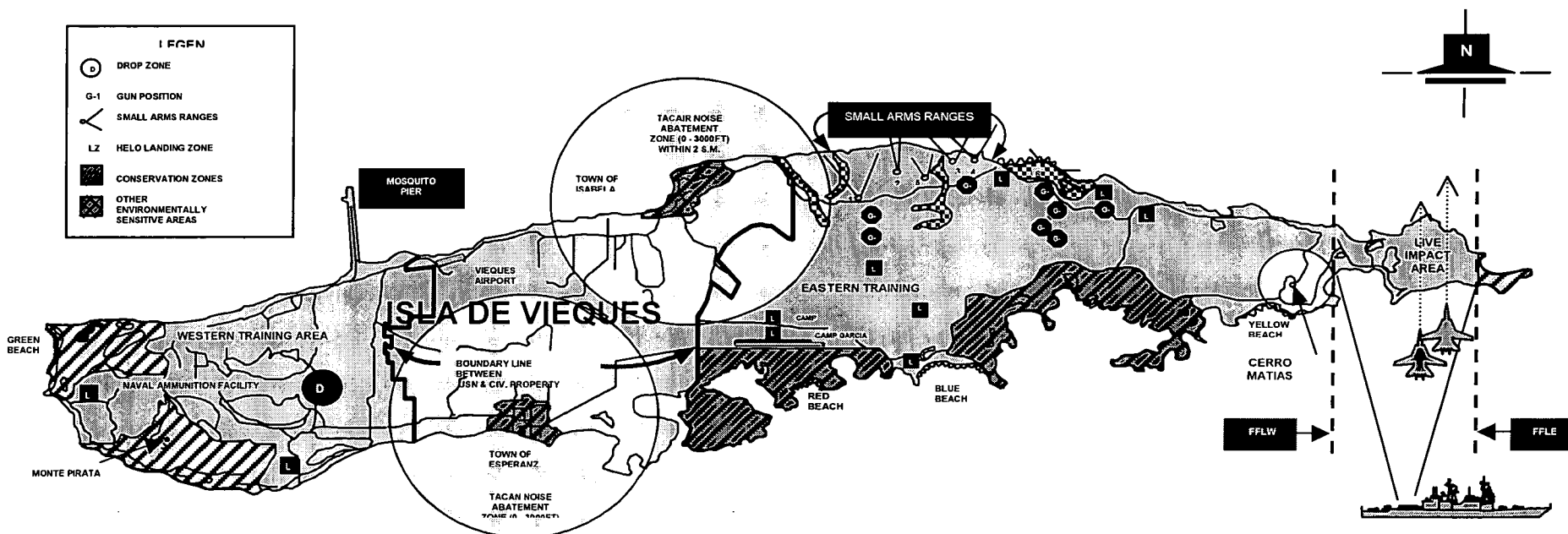


Figure 2. North Convoy Site.

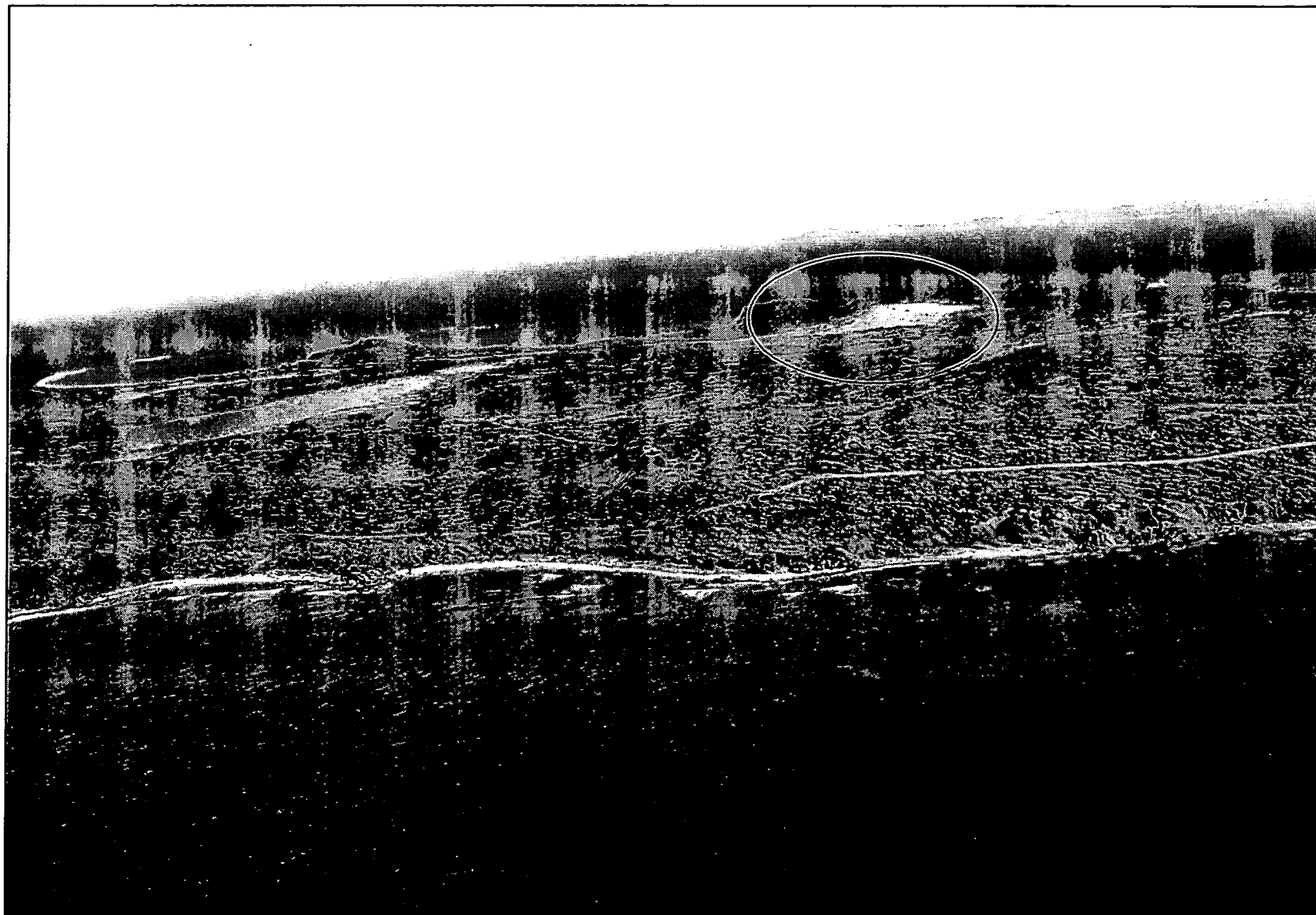


Figure 3. Affected Area of North Convoy Site and Harrier Aircraft Line-of-Fire.

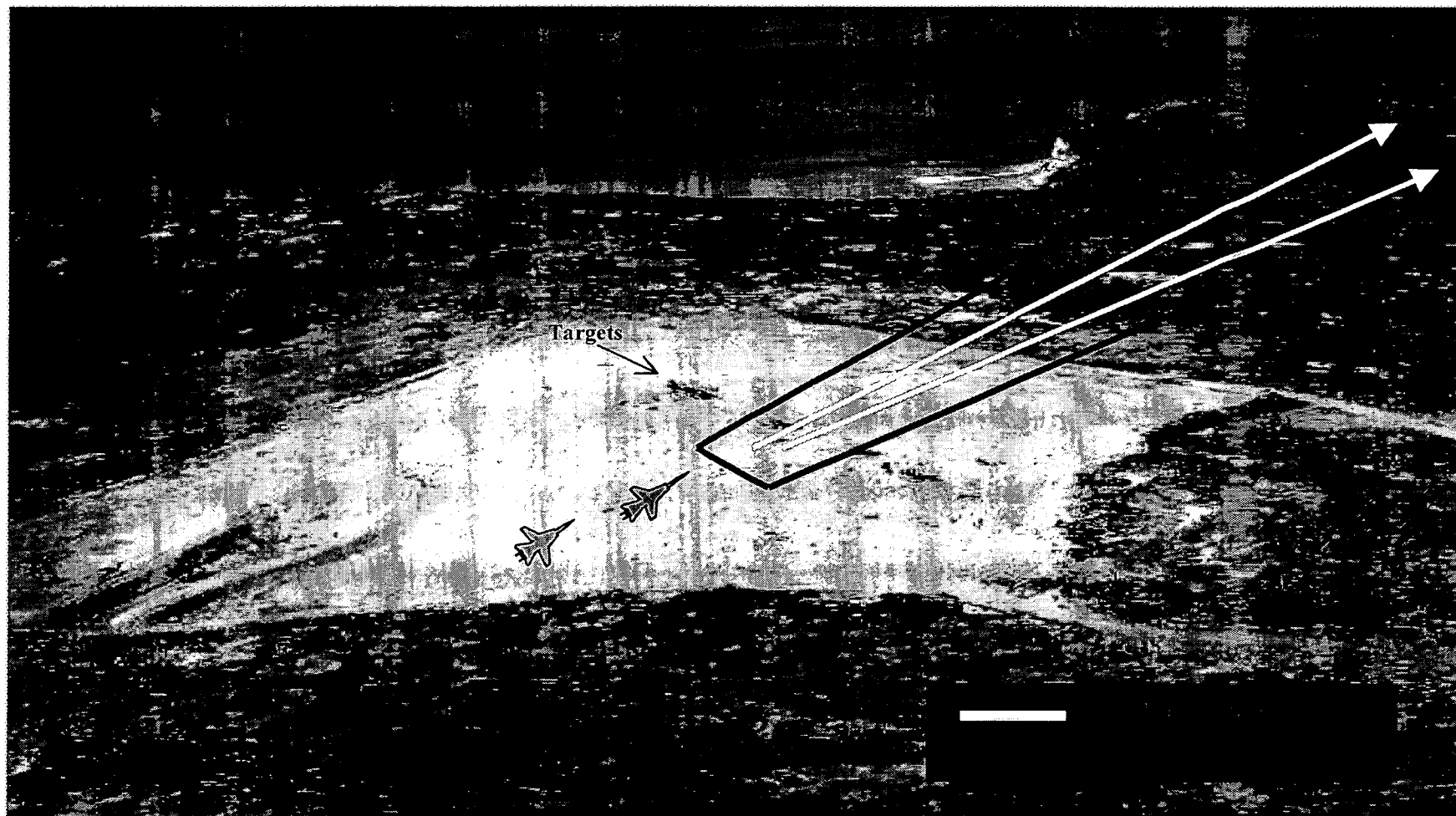
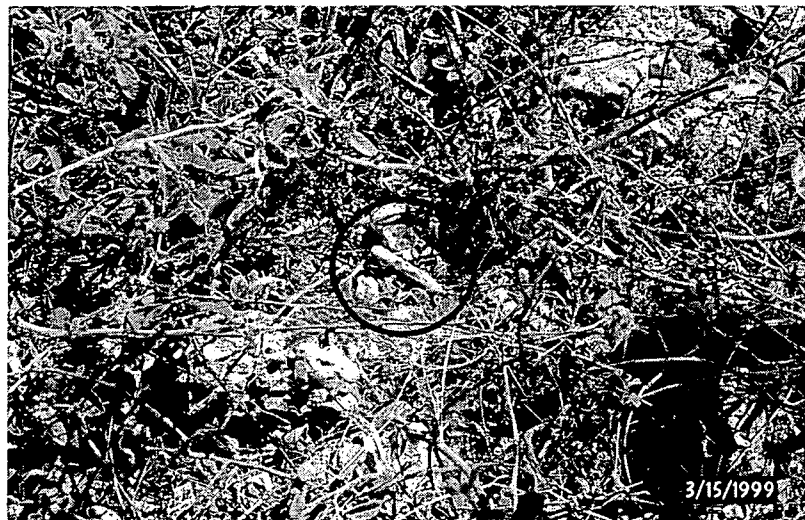


Figure 4. DU penetrators previously located on the North Convoy Site.

Penetrator located on the surface.



Penetrator located (buried) in soil.

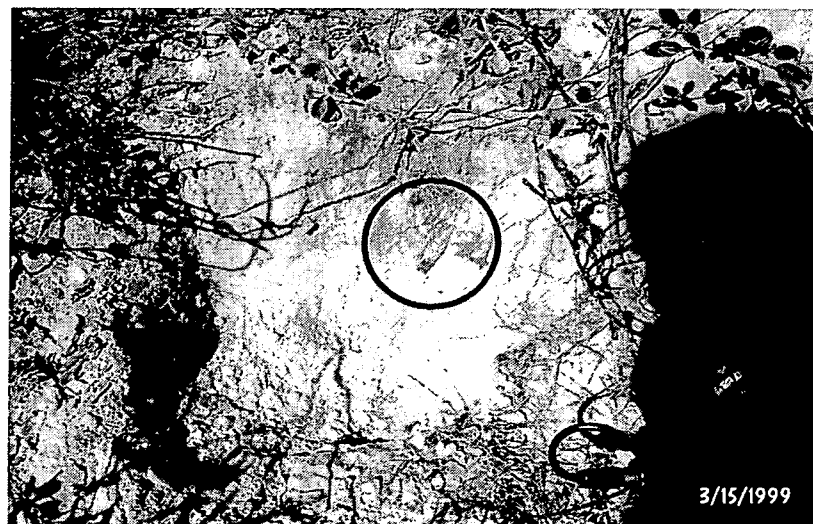


Figure 5. Area of North Convoy Site Previously Surveyed.

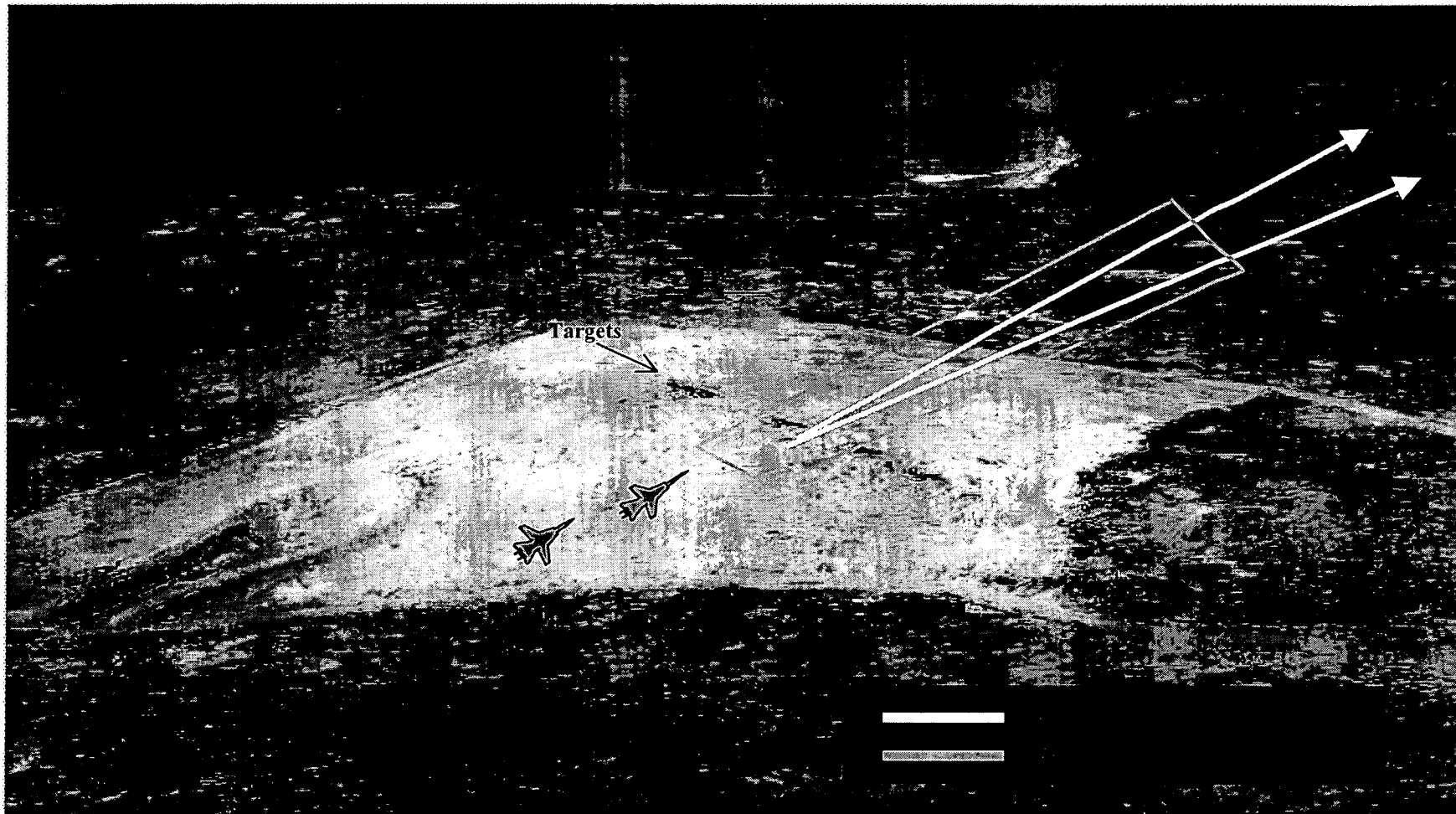


Figure 6. Radiological Scan Survey Equipment.

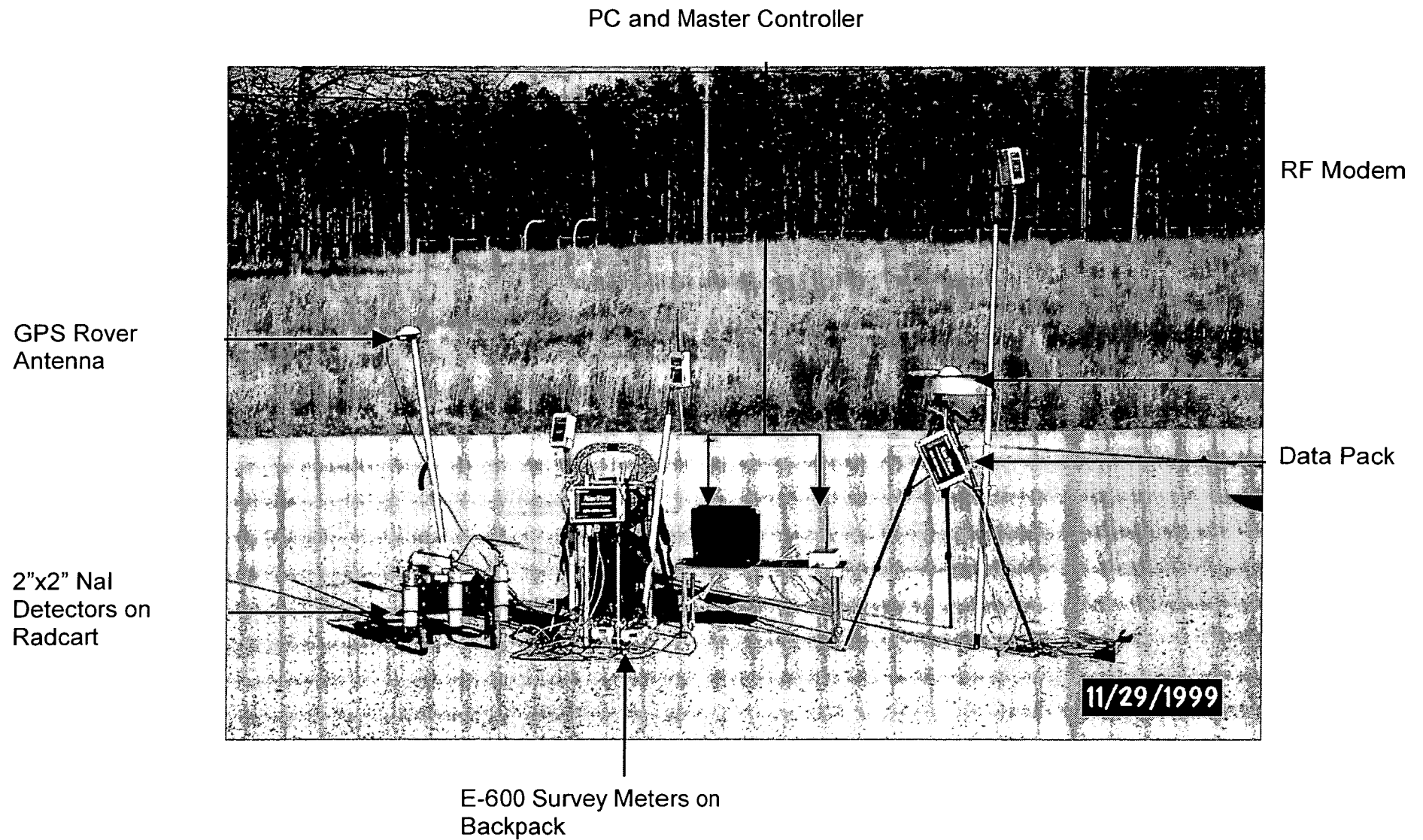


Figure 7. Field Study Design for Determining the Detectability of a DU Penetrator

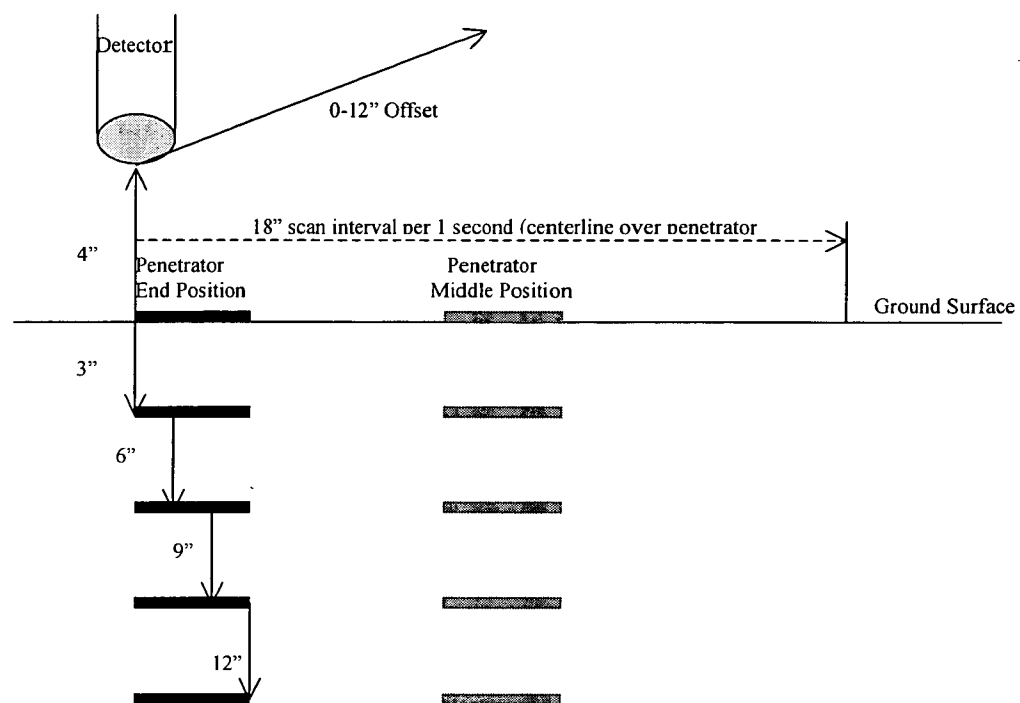
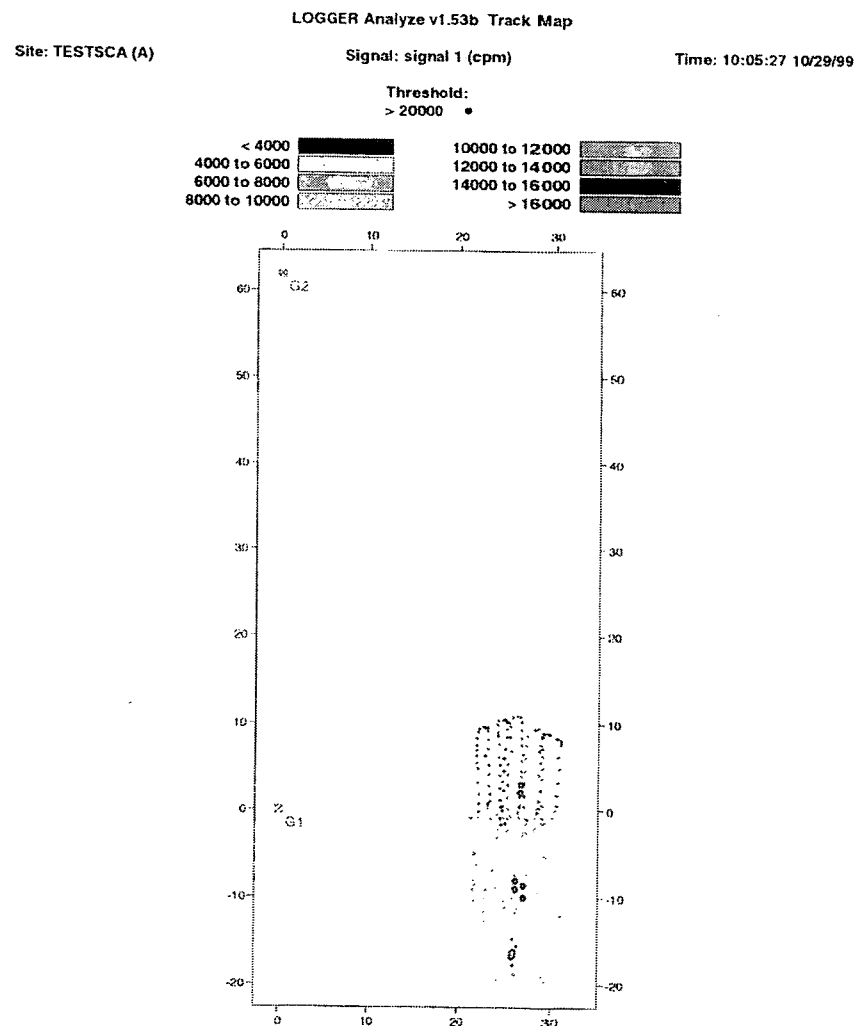
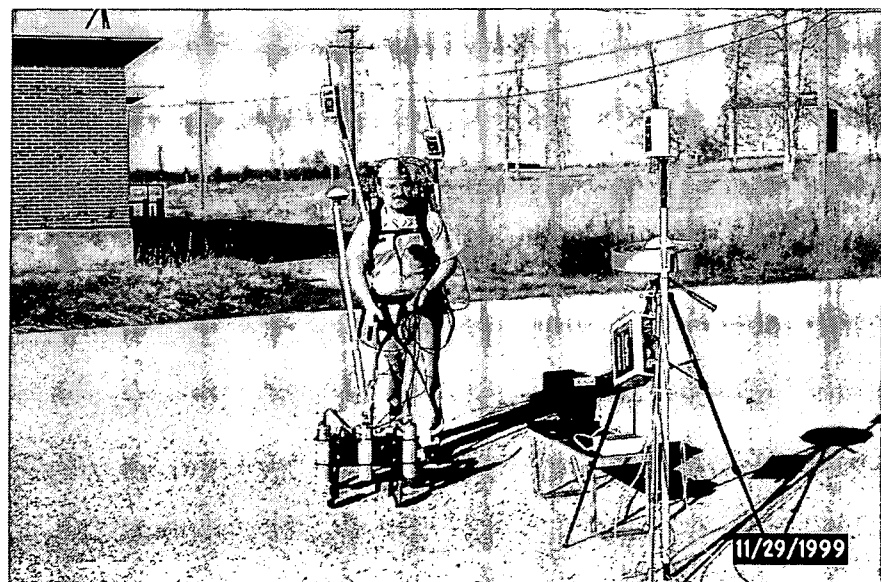
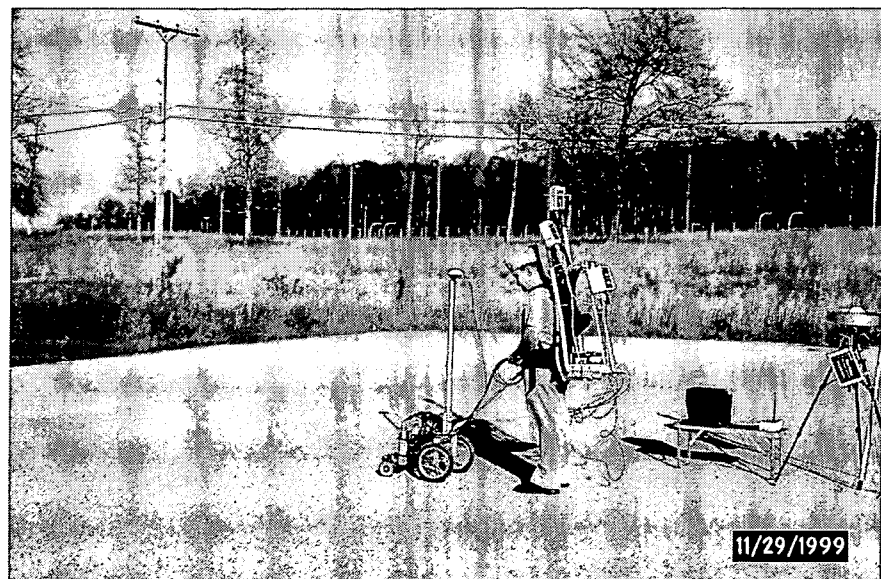


Figure 8. Radiological Scan Survey and Real Time Track Map of Area Surveyed.



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Figure 9. Stack Map Used to Analyze Scan Survey Data.

PENETRATORS ON THE SURFACE OF VARIOUS MEDIA

