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WORK PLAN
for
MTADS GEOPHYSICAL MAPPING AT THE PORTSMOUTH NAVAL SHIPYARD
Kittery, ME

FINAL, 28 September 1998

The U.S. Naval Research Laboratory
Washington, DC

July, 1998

CONTENTS

1.0 Introduction 1

1.1 Objectives of the *MTADS* Survey 1
1.2 Tasks Included in the *MTADS* Survey 2
1.3 Typical Geophysical Mapping Techniques 2
1.4 Applying UXO Technologies 3

2.0 *MTADS* Technology Description 5

2.1 Background and Applications 5

3.0 Site/Facility Description 7

3.1 General Site Background. 7
3.1.1 Site Location and Description 7
3.1.2 Physiography 8
3.1.3 Surface Water 9
3.1.4 Geology and Stratigraphy 9
3.1.5 Hydrogeology 10
3.1.6 Climatology 10
3.2 Operational Unit 3, Description and History 11
3.2.1 Site 8 - The JILF 13
3.2.2 Site 9 - The Mercury Burial Sites I and II (MB I and MB II) 16
3.2.3 Site 11 - Former Waste Oil Tanks Nos. 6 and 7 18

3.3 Previous Geophysical Investigations at OU 3 19

3.4 The Topeka Pier Site 20

4.0 *MTADS* Demonstration Approach 22

4.1 Performance Objectives and Site Specific Work Plan 22
4.2 Site Survey Plan 23
4.2.1 Mobilization 23
4.2.2 Site Preparation 23
4.2.3 Site Boundaries 24
4.2.4 Land Marking 24
4.2.5 Geophysical Investigations and Mapping 24
4.2.6 Demobilization 25
4.3 Deliverables 25

CONTENTS, Continued

5.0 References 26

Appendix B. Reviewers Comments and Responses 28

Comments from U.S. EPA 28
Comments from the Maine Department of Environmental Protection 29
Comments from Lepage Environmental Services 31

FIGURES

1. The *MTADS* Tow Vehicle with the magnetometer array 7
2. The *MTADS* survey system deployed with the pulsed induction array 7
3. The *MTADS* data analysis system showing the site view and target analysis windows 7
4. Recent aerial photograph of the Portsmouth Naval Shipyard. Operational Unit 3, including the Jamaica Island Landfill, is highlighted in yellow in the upper left corner 8
5. USGS aerial photograph of the PNS. The approximate boundary of OU 3 is outlined in yellow 11
6. Map of the PNS and Seavey Island. Site 8 (OU-3) and Site 32 (The Topeka Pier Site) are outlined in black 12
7. Map of the PNS showing the JILF. The OU-3 boundaries are given by the dark line labeled as Site 8 13
8. Locations of ground water monitoring wells and soil test borings on the JILF 17
9. Map of Site 32 (The Topeka Pier Site). The dark shaded area is designated for *MTADS* survey 21

TABLES

1. Estimates of the quantities of waste disposed in the JILF 15

MTADS GEOPHYSICAL MAPPING AT THE PORTSMOUTH NAVAL SHIPYARD KITTERY, ME

5-14 Oct 1998

The Naval Research Laboratory
Washington, DC

1.0 INTRODUCTION

1.1 Objectives of the *MTADS* Survey

The Naval Research Laboratory (NRL) as requested by the Northern Division, Naval Facilities Engineering Command (NAVFAC/ND) will conduct magnetometer and pulsed induction electromagnetic system surveys on two sites at the Portsmouth Naval Shipyard (PNS) totaling about 28 acres in size. The primary purpose of the surveys is establish geophysical maps of two sites (defined later) to locate and characterize large buried ferrous or steel-reinforced objects. The Multi-sensor Towed Array Detection System (*MTADS)* is the latest development in underground imaging of metallic objects with particular emphasis on Unexploded Ordnance (UXO). In earlier applications of this technology NRL has had extensive experience in the characterization of landfills having conducted geophysical studies of chemical and biological burial sites, materials disposal sites, municipal landfills and construction (concrete and rubble) landfills. These sites are characterized by the burials in ferrous containers (barrels), burial of high metal-content materials, or fills with high ferrous content (reinforced concrete and rubble).

At times one can discriminate and evaluate individual targets within a landfill. For instance, in a relatively clean background the *MTADS* can detect and characterize an individual barrel at depths up to 15 feet. Ongoing refinements in the target fitting algorithms and the development of a data fusion capability for magnetometer and pulsed induction data may prove valuable for application at this site. Target maps and reports will be generated as a result of this site characterization. Where possible, individual target positions will be provided identifying x (North), y (South), depth and size.

1.2 Tasks included in the *MTADS* Survey

- Establish highly accurate (first order survey) points:

  If no first-order control points can be identified that are suitable to support the two survey setups, in coordination with PNS, we will contract with a professional surveyor, using Global Positioning System (GPS) technology to establish control points for the survey.

- Land Marking Site #1and 3:

  Physical land marks such as fences, roads, buildings, structures, telephone poles, etc., will be geographically-located with the GPS for inclusion in the magnetic anomaly maps providing target-to-site relationships.

- Magnetometer Survey of Site #1:

  MTADS will survey the 25 acre, Site #1, the JILF (Jamaica Island Land Fill). The data will be transferred to the *MTADS* Data Analysis System (DAS), preprocessed, and visually analyzed for quality (spurious sensor data, missed survey areas, etc).

- Magnetometer Survey Site #2:

  MTADS will survey Site #2, the Parking Lot near the Topeka Pier Site. The data will be transferred to the *MTADS* DAS, preprocessed, and checked for quality.

- EM Survey Site #1:

  MTADS will survey Site #1, the JILF. The data will be transferred to the *MTADS* DAS, preprocessed and checked for quality (spurious sensor data, missed survey areas, etc).

- EM Survey Site #2:

  MTADS will survey Site #2, the parking lot near the Topeka Pier Site. The data will be transferred to the *MTADS* DAS, preprocessed, and checked for quality, missed areas, etc.

1.3 Typical Geophysical Mapping Techniques

Current techniques used for geophysical mapping of landfill areas, as opposed to UXO surveys, commonly involve magnetic measurements using magnetometers or gradiometers. Sites are typically characterized by making individual point measurements on a grid. The grid spacing determines the value of the information collected, but also strongly influences the cost of the survey. Measurements on a five meter grid may be useful for characterizing geological features or, perhaps locating large pit or trench burials. Locating individual targets on this scale, however, is unlikely. Measurements on a 2-meter grid, while requiring more than 6 times more measurements, can define

the boundaries of large pits or trenches and will likely record a hit on a large isolated target. Point sampling measurements are seldom done on a finer grid than this because of cost limitations.

Other techniques employed in geophysical mapping include ground penetrating radar (GPR), soil conductivity measurements, and acoustical mapping. The value of GPR is highly soil dependent and moisture sensitive. GPR is sometimes used in conjunction with other techniques that have previously been used to locate targets of potential interest. Soil conductivity measurements are sometimes useful for locating large pits and trench burials, particularly if the type of materials in the burial have a conductivity far different than the indigenous soil. Acoustic (seismic refraction) measurements are typically used to characterize local geological features such as faults, water tables, and bedrock.

1.4 Applying UXO Technologies

Modern automated techniques for UXO detection and site characterization, are directly applicable to geophysical mapping. The *MTADS* vehicular towed sensor arrays are highly efficient in mapping large areas, often covering more than 20 acres per day in favorable conditions. Using the magnetometer array with a 0.25 meter horizontal spacing the *MTADS* collects over a million individual magnetic measurements per acre. The pulsed induction array, with a 0.5 meter horizontal spacing collects over 300,000 data points per acre. Measurements on this very fine grid, not only map out large scale features such as pits and trenches, but can precisely locate and characterize individual targets. The ability to characterize an individual item may be limited either by geological interferences (highly magnetic soils) or the nearby presence of other larger targets or dense clutter fields of ferrous objects. These interferences in magnetometry surveys can sometimes be mitigated by redeploying the magnetometers in a gradiometer mode. The pulsed induction sensor array is essentially not affected by geological interferences.

Using hand-held magnetometers, UXO surveys are slow and expensive and are inefficient in locating buried targets.[1] Based upon demonstrated successes with our earlier towed-array survey systems,[2] The Environmental Security Technology Certification Program (ESTCP) provided funds to NRL for the development and demonstration of a multi-sensor vehicular towed array system.[3] The *MTADS* incorporates both cesium (Cs) vapor, full-field magnetometers and active, pulsed induction sensors.[4-6] The sensors are mounted as linear arrays on low-signature platforms that are

towed over survey sites by an all-terrain vehicle. The position-over-ground is plotted using state-of-the-art Real-Time Kinematic (RTK, or on-the-fly) technology that also provides vehicle guidance during the survey. Using mature sensor technologies, NRL has focused on the development and integration of a Data Analysis System to locate, identify and categorize all military ordnance at its maximum probable self-burial depths. The DAS is efficient and simple to operate by relatively untrained personnel.

The performance characteristics of the *MTADS* system have been evaluated through three previous technology demonstrations.[7] The first of these was a "TECHEVAL" demonstration at NRL's Chesapeake Bay Division (NRL/CBD) to measure system performance against the system requirements and performance specifications, and to generate a data base of sensor responses to diverse ordnance items at multiple depths and orientations.[8] The second demonstration was conducted at the Magnetic Test Range at The Marine Corps Air Ground Combat Test Center (MCAGCC) in Twentynine Palms, CA in December 1996.[9] In January 1997, the *MTADS* was demonstrated at the Jefferson Proving Grounds test site, following the completion of JPG III demonstrations by commercial vendors.[10]

In July and August of 1997, the *MTADS* was used to conduct a live-site survey and remediation of selected areas located on the Badlands Bombing Range, within the Pine Ridge Sioux Reservation, SD. Based upon the results of this survey conducted with the *MTADS*, approximately 1400 targets were identified. Of these, approximately 400 were selected for further investigation, reacquired using GPS (way pointed), and subsequently remediated under NRL's direction by Army Corps of Engineers personnel and a commercial ordnance remediation contractor.[11]

The *MTADS* will now be used for geophysical mapping of sites at the Portsmouth Naval Shipyard. A main objective of this survey is to locate ferrous, or steel reinforced concrete, containers that have been used to dispose of materials in landfill burials. Studies will be carried out on two sites. Site #1, an area of approximately 25 acres, is located between what was originally Jamaica and Seavey Islands. The area lies within the boundaries of Site #8. Of particular interest on this site is an individual target referred to as the Mercury Burial Vault II. This target is further described below. Site #2 is a 3-acre area contained within the Topeka Pier Site. Much of the surveyable area in Site #2 is a parking lot that will need to be roped off or surveyed during non-work hours. This geophysical mapping project is being done for the Northern Division, Naval Facilities Engineering Command, Lester, PA.

Based on historical information, it is documented that the Jamaica Island Landfill was filled in with various industrial waste materials, some possibly in drums. *MTADS* surveys are non-intrusive, no excavations will be done during the site characterization phase of this task. The surveys will be performed in a manner consistent with the Conprehensive Environmental Response, Compensation, and Liability Act (CERCLA) Section 104, and in compliance with NCP Sections 300.12(a) and 300.x00(e). Contractor personnel brought on site by NRL will be subject to the provisions of our Work Plan.

2.0 *MTADS* Technology Description

2.1 Background and Applications

The *MTADS* technology has been described in detail previously.[3,5,6,9] Briefly, the system hardware includes a low magnetic signature vehicle that is used to tow linear arrays of magnetic and electromagnetic (EM) sensors to conduct surveys of large-areas to detect buried metal targets. The *MTADS* Tow Vehicle, manufactured by Chenowth Racing Vehicles, is a custom-built off-road vehicle, specifically modified to have an extremely low magnetic self-signature. Most ferrous components have been removed from the body, drive train and engine and replaced by nonferrous alloys. The vehicle is powered by an modified Volkswagen aluminum engine.

The *MTADS* magnetic sensors are cesium (Cs) vapor full-field magnetometers is a variant of the Geometrics Model 822 selected for low noise, a small dead zone and high sensitivity. It is designated as the Model 822ROV). An array of eight sensors, Figure 1, is deployed either as a magnetometer array or as a four-unit gradiometer array measuring the vertical component of the Earth's total field. The time-dependence of the Earth's background field is measured by a ninth sensor deployed at a static site during survey operations. The magnetometers were acceptance tested at the manufacturer's facility to verify sensitivity, sensor noise, heading error, dead zones, inter-sensor compatibility, and performance with the multisensor interface modules.[7] The EM sensors (a variant of the Geonics EM-61 instrument) are deployed as an array of three pulsed induction sensors, see Figure 2. These sensors, configured as an overlapping horizontal array, transmit a tailored electromagnetic pulse into the Earth. Metallic objects absorb the transmitted energy, inducing eddy currents that re-radiate electromagnetic energy. This secondary signal is time-

sampled by six detection coils that are collocated with and above the three transmission coils. The EM sensors on the *MTADS* platform differ in several ways from the commercial Geonics EM-61 units. The *MTADS* sensors synchronously transmit a much higher power signal at a higher repetition rate. The amplifier gain has been increased and the damping time-constant of the interface filter has been lowered. The position and width of the detection sampling window has also been changed to allow detection of smaller objects while still suppressing signals from typical soils.

The sensor positions on the surface of the Earth (latitude, longitude, and height above the surface) are determined using GPS navigation equipment, employing the latest Real Time Kinematic (RTK) technology which provide position updates at 5 Hz with a real-time accuracy of about 5 cm. GPS satellite clock time is used to time-stamp both position and sensor data information for later correlation. In addition, an electronic compass, attitude sensors (that detect pitch, roll and yaw of the sensor platform), and tick wheel sensors provide navigation back-up and dead reckoning capability. All navigation and sensor data are provided through electronic interfaces to the Data Acquisition Computer (DAQ) in the Tow Vehicle. The DAQ computer also functions as a survey set-up tool and provides real-time guidance displays and information for the driver.

Perimeter surveys and/or point landmarks are used to define the survey site bounds. The DAQ develops a survey track grid that is presented to the vehicle operator on a touch screen display located beside the steering wheel. The survey course-over-ground is plotted in real time on the display, as are presentations of the course heading error and distance-off-track information. This allows the operator to respond to both visual cues on the ground and to the survey guidance display. Following a survey, the operator can return to survey any missed areas before leaving the field.

Survey data in the DAQ computer is downloaded by tape or serial port connection to a notebook computer for transfer to the DAS computer. The DAS software was developed specifically for this program as a stand-alone suite of programs written using IDL development tools, and graphics user interfaces (GUI's) working in a UNIX-based workstation environment. The DAS is written in multiple levels for both sophisticated and novice users. Even the novice user can perform a complete data analysis using menu-driven tools and the background default analysis settings. An extensive range of (advanced) options are also available to facilitate the cleanup of navigation data, sensor nulling and leveling, noise filtering, and other electronic data preprocessing options as may be desired.

The DAS uses resident independent physics-based algorithms to analyze target signatures interactively using magnetometry, gradiometry, and EM data. Extensive training data sets (using inert ordnance) have been taken and used to refine the algorithms to improve target analysis. In addition to position, depth, and size solutions, magnetic analyses provide estimates of the target orientation.

Figure 1. The *MTADS* Tow Vehicle with the magnetometer array.

Figure 2. The *MTADS* survey system deployed with the pulsed induction array.

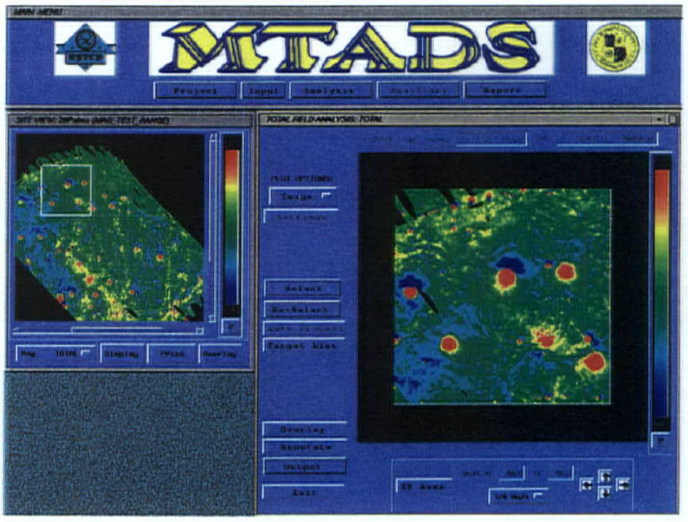

Figure 3. The *MTADS* data analysis system showing the site view and target analysis windows.

3.0 Site/Facility Description

3.1 GENERAL SITE BACKGROUND

The following sections provide background information about the PNS and the survey sites relevant to our planned geophysical surveys.

3.1.1 Site Location and Description

Situated within the town limits of Kittery, Maine, the PNS is located on an island (referred to on National Oceanic and Atmospheric Administration (NOAA) nautical charts as Seavey Island) in the Piscataqua River. The mouth of the Piscataqua River forms a tidal estuary which lies at the border between New Hampshire and Maine. The PNS is located at the mouth of the Great Bay estuary (commonly referred to as Portsmouth

Harbor). The PNS mission is the conversion, overhaul, and repair of submarines for the Navy. The site has been occupied since 1800 when the facility was established. The first government-built submarine was constructed at PNS during World War 1. A large number of submarines have been designed, constructed, and repaired at this facility since 1917.[12] Figure 4 shows the PNS and the survey test sites; the JILF is highlighted.

3.1.2 Physiography

The PNS is located on Seavey Island in the Piscataqua River immediately south of Kittery, Maine. The facility is built on an area comprised of Dennett's, Seavey, Jamaica, Pumpkin and Clark Islands, as well as man-made land created over time between these islands. The eastern tip is referred to as Jamaica Island. Clarks Island is a non-industrialized island connected to Seavey

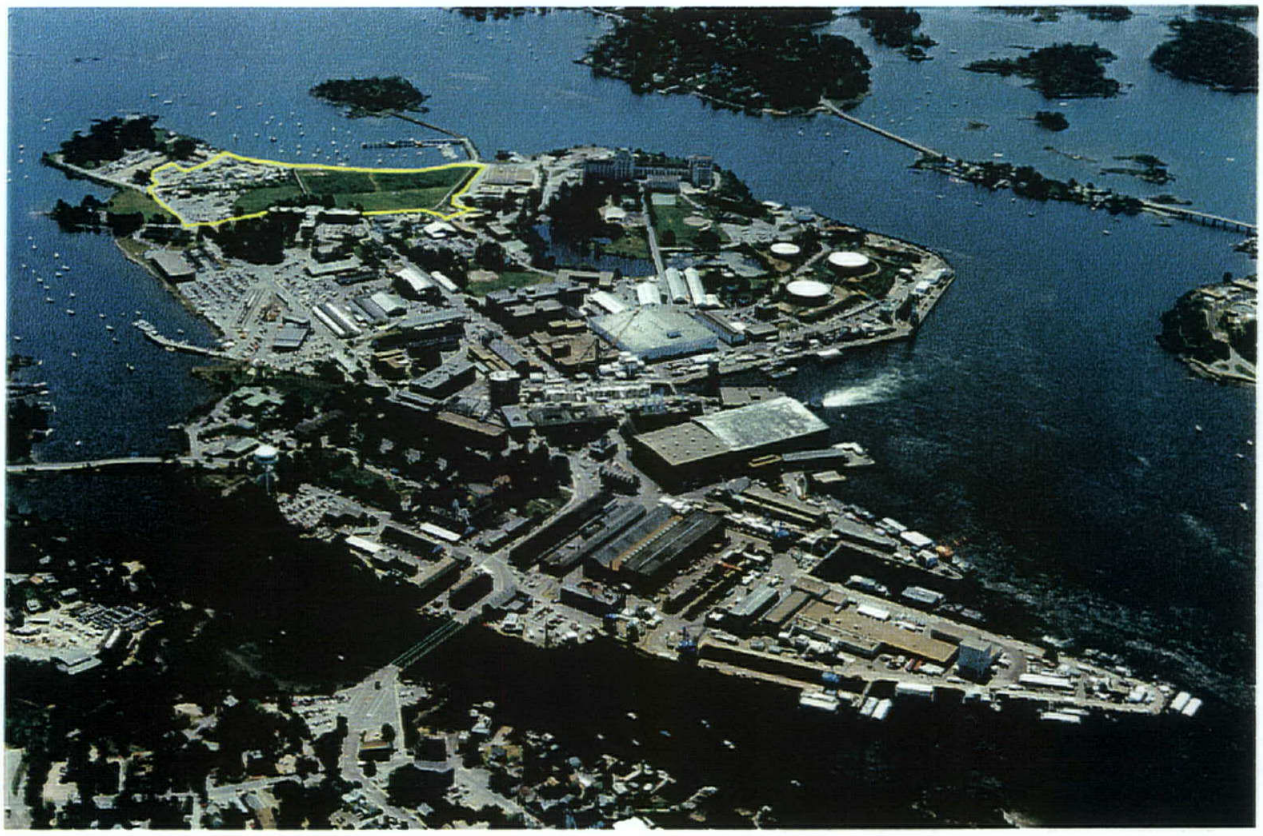

Figure 4. Recent aerial photograph of the Portsmouth Naval Shipyard. Operational Unit 3, including the Jamaica Island Landfill, is highlighted in yellow in the upper left corner.

Island by a rock causeway. Elevations range from sea level to 60 feet above mean sea level (MSL). Two-thirds of the site is a high-density industrial area containing about 330 buildings. The remaining area is generally flat to gently sloping, grass-covered fields. Minor wooded areas exist on the east side of Jamaica Island. The shoreline in the Portsmouth area is an embayed coast produced by partial submergence of a fluvially eroded land mass. This type of shoreline is closely associated with a drowned river-valley type estuary, such as the Great Bay Estuary. During past glacial periods, valleys were straightened and deepened by ice and lined with till deposits. Hilltops have been blunted by ice erosion.[13, 16, 17]

3.1.3 Surface Water

The Piscataqua River, Little Bay, Great Bay, and seven converging rivers and streams form the Great Bay Estuary referred to as the Portsmouth Harbor. Seavey Island is located in the mouth of the Great Bay Estuary. The harbor's main channel is approximately 75 feet deep at mean low water, and the back channel is approximately 20 feet deep in the vicinity of Seavey Island. Additional surface water information can be found in Reference 13.

3.1.4 Geology and Stratigraphy

The islands composing the PNS are formed on bedrock highs covered with thin veneers of glacial till, recent alluvium, and/or fill materials. The bedrock is tectonically deformed volcanic rocks and highly fractured, metamorphosed sandstones, shales, and siltstone of the Kittery Formation, ranging from Middle Ordovician to Precambrian in age.[14] Mesozoic dikes occupy fault traces, fracture zones, bed planes and fold hinges.[15] Metamorphism (biotite grade) has destroyed original interparticle porosity in the sedimentary rocks. Most groundwater flow is, therefore, controlled by fractures.

The bedrock of this area has undergone at least three periods of deformation: the Taconic Orogeny (440 million years before present [mybp]), Acadian (360 mybp), and the Appalachian (260 mybp), resulting in multiple rock cleavages, planes of foliation, faults of various ages and types, and varied fold orientations and geometries. Fold types observed in the vicinity of the PNS include post-depositional, soft-sediment folds; early recumbent folds; upright, tight asymmetrical folds; open

folds; kink folds related to faulting; and intrafolial folds near the Kittery/Rye contact.[16] Faults observed in outcrops along the Piscataqua River are largely sinistral strike-slip faults with near-vertical, north-south fault planes with less than one-meter displacement. The Portsmouth Fault Zone was mapped as a narrow (1/8th mile wide) zone, oriented east-northeast between Seavey Island and New Castle Island to the south (Hussey and Bothner, 1995). The resulting bedrock fracture pattern, is highly complex. Additional geological information can be found in other references.[13, 16, 17]

3.1.5 Hydrogeology

Groundwater is encountered within both the unconsolidated materials and the bedrock. In general, the unconsolidated materials appear to be moderately to highly permeable. Bedrock permeability is generally less than that of the unconsolidated materials, and the groundwater flow withing the bedrock is controlled by fractures. Groundwater levels at the PNS are shallow and are controlled by the bedrock surface topography and by the thickness of glacial till and fill material overlying bedrock or former tidal flat areas. Groundwater flow directions onsite vary depending on ground surface topography, the thickness and composition of overburden, bedrock-overburden contact-surface dip, and tidal influence. Nonetheless, overall groundwater flow directions are from the original island interiors toward the island coastline and produce a radial pattern. Recharge to groundwater is derived from precipitation infiltration and tidal effects. Kittery's potable water supply is taken from surface reservoirs located in the vicinity of York, Maine. The shipyard is not currently using onsite groundwater. Additional hydrogeologic information can be found in other references.[16, 17]

3.1.6 Climatology

Precipitation is fairly evenly distributed over the year, with 2.7 to 4.6 inches falling per month for a 42.6-inch annual total. On average, approximately 130 days each year have more than a trace of precipitation. Most summer precipitation results from showers and infrequent thunderstorms. Winter precipitation is generally associated with storms caused by air masses moving up along the coast. Heavy precipitation events are usually caused by storm centers that form along the East Coast and move northeastward through New England.[17]

3.2 Operational Unit 3, Description and History

Operational Unit 3 (OU 3) consists of Site 8 - The JILF (including the Former Child Development Center, CDC), Site 9 - The Mercury Burial Sites (MBI and MBII), and Site 11 - The Former Waste Oil Tanks Nos. 6 and 7. OU3 is located in the eastern portion of PNS. Figure 5 shows the location of OU3 outlined in yellow on a USGS false color infrared photograph taken in April 1992. Figure 6 shows a map of Seavey Island with both Site 8 (OU3) and Site 32 (The Topeka Pier Site) outlined. Figure 7 is a map of the JILF and adjacent areas and shows the layout of OU3 bordered by the dark line labeled as Site 8 in the figure. With the exception of the Former CDC, the land encompassing most of OU-3 is contained within the boundary of the JILF.

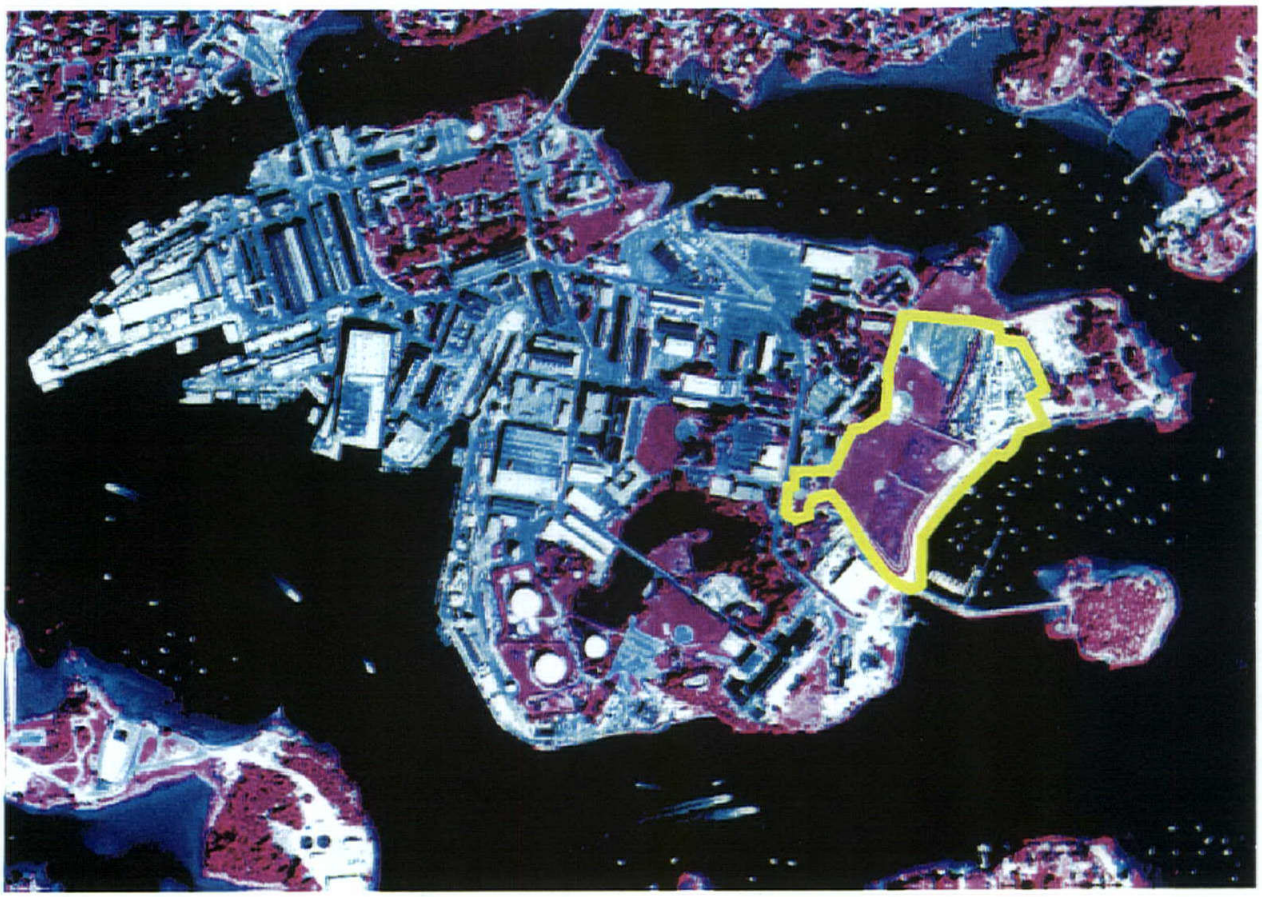

Figure 5. USGS aerial photograph of the PNS. The approximate boundary of OU3 is outlined in yellow.

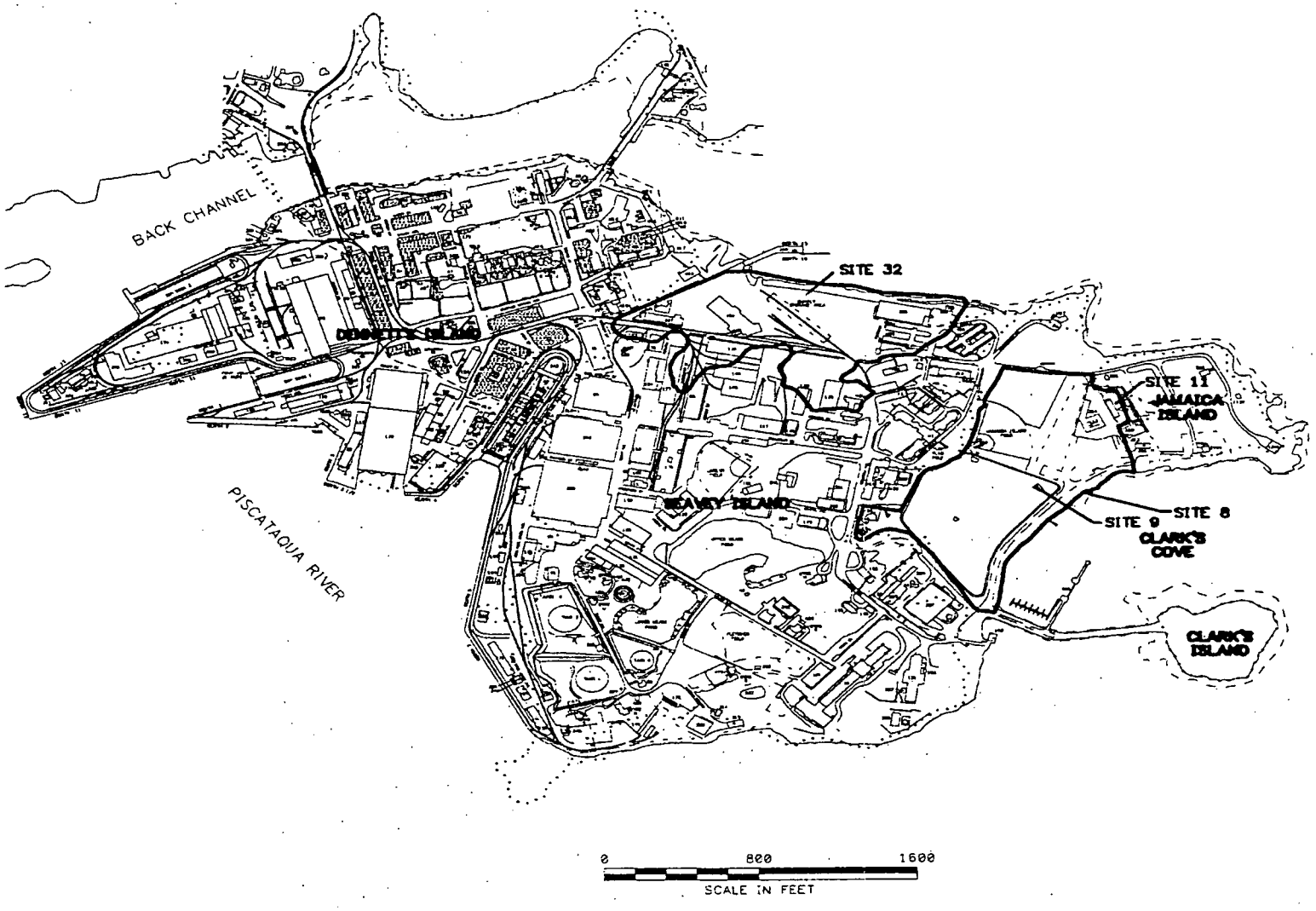

Figure 6. Map of the PNS and Seavey Island. Site 8 (OU-3) and Site 32 (The Topeka Pier Site) are outlined in black.

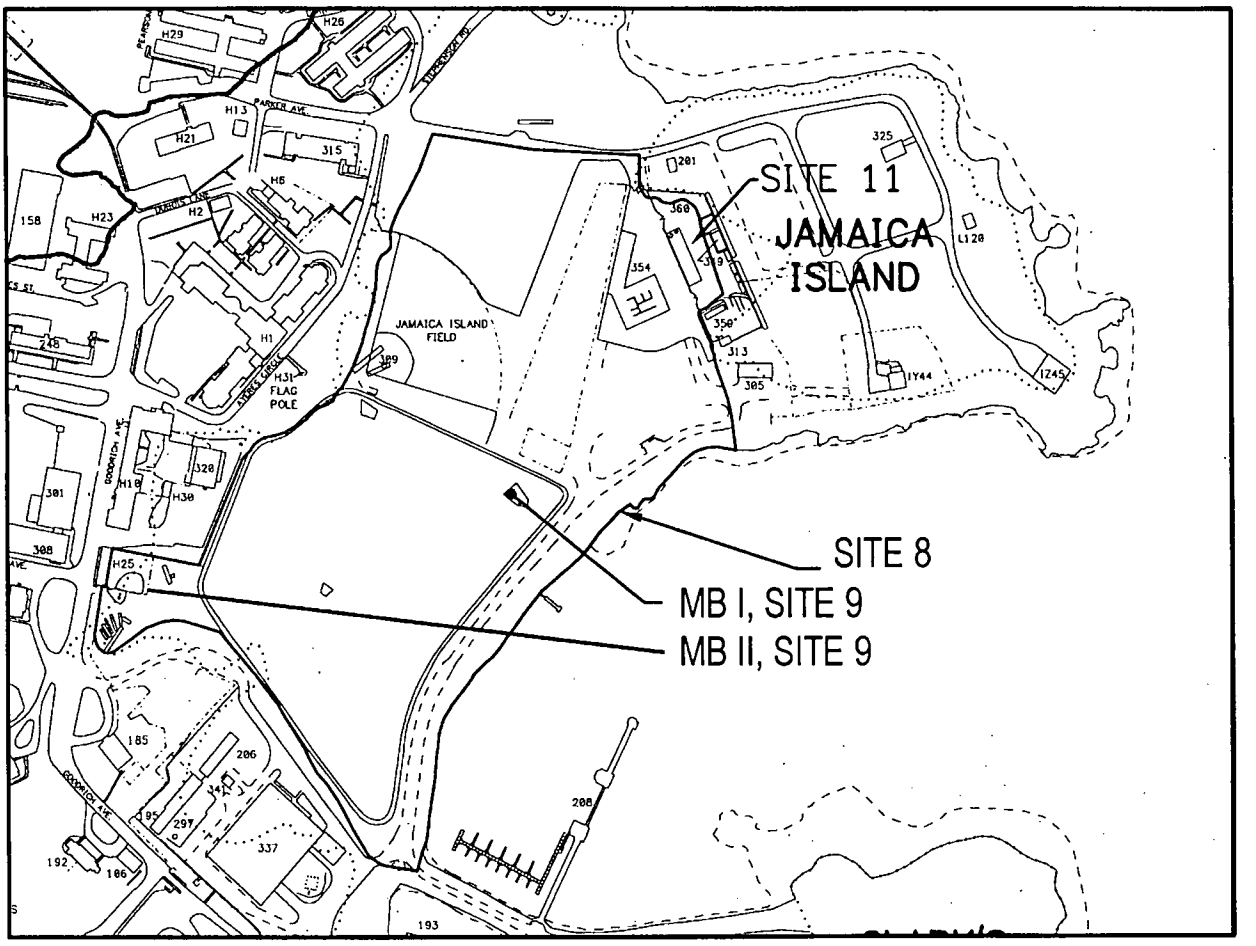

Figure 7. Map of the PNS showing the JILF. The OU-3 boundaries are given by the dark line labeled as Site 8.

3.2.1 Site 8 - The JILF

The JILF covers an approximate area of 25 acres of filled land. Prior to land filling activities, tidal flats separated Jamaica Island from Seavey Island. It has been reported that drainage channels existed within these tidal flats.[13, 16, 17] From approximately 1945 to 1978 this area was filled with various industrial wastes. In addition to general refuse, trash, and construction rubble, the JILF reportedly accepted incinerator ash; plating sludges containing chromium, lead, and cadmium; asbestos insulation; volatile organic compounds including trichloroethene (TCE), methylene chloride, toluene, and methyl ethyl ketone (MEK); empty acetylene and chlorine gas cylinders; contaminated dredge spoils containing chromium, lead, small amounts of oils containing

polychlorinated biphenyls (PCBs), mercury and possibly phenols; waste paints and solvents; and spent sandblasting grit. Other items reported to have been used as fill at the JILF include reinforcing bars, chain-link fencing, and a small two-man submarine. Table 1 presents materials known to have been disposed of at the JILF and approximate date of disposal.

In 1978, PNS received approval to dredge more than 100,000 cubic yards of sediment from Berths 6, 11, and 13 and to dispose of the material in a portion of the JILF.[18-20] Concentrations of cyanide in two of the three samples collected from Berth 6 and one of the nine samples collected at Berth 13 were reportedly high. PCB concentrations were comparable with concentrations typically reported for polluted areas, however one PCB analytical result was significantly higher. Concentrations of oil and grease, as well as most heavy metals, were reported to be high. Fecal coliform was detected at Berths 11 and 13. Phosphate, nitrates, ammonia, nitrogen, chemical oxygen demand, DDT, sulfide, and phenol were all within normal limits. Approximately 9 acres of the landfill were covered with dredge spoils in 1978.

At the time of disposal of the dredge spoils in 1978, a new dike was designed to contain the dredge spoils and to prevent post-construction seepage or runoff from the contaminated spoil into the adjacent Piscataqua River. A rock dike was placed by the area receiving the deepest spoils. The rest of the disposal site was enclosed with a granular fill dike.[19] No documentation is available on the actual dike construction; however, the permit from the U.S. Army Corps of Engineers to conduct the dredging (No. ME-PORT-78-390) indicated that the dikes should be constructed in accordance with the Candidate Environmental Impact Statement (CEIS). A 2-foot-thick soil cover was placed on top of dredge spoils to minimize precipitation penetrating the dredge spoils. A layer of topsoil was placed on top of the entire contained area and seeded to create an erosion-resistant turf.[19] The design dimensions and locations of the dikes are provided in the permit. As indicated in the permit, the proposed dikes were to be built in the area where the running track runs along the shoreline; the rock dike along the southernmost top of the JILF, to contain the dredged material on the shore-side of the JILF; and the granular fill dike along the remaining shoreline in the vicinity of the running track.

During 1989 to 1992, as part of the RCRA Facility Investigation (RFI), surface and groundwater, and seep samples were collected at the JILF. During the RFI Data Gap Investigation

Table 1. Estimates of the quantities of waste disposed in the JILF.[18]

Substance	Estimated Quantity	Time Period	Comments
Plating Sludges **Chromium** **Lead** **Cadmium**	 **5,000-10,000 pounds** **5,000-10,000 pounds** **5,000-10,000 pounds**	 **1945-1972** **1945-1972** **1945-1972**	**Sludges were mixed in with normal refuse and were disposed of directly into the landfill. Exact location unknown.**
Asbestos insulation	**Several thousand pounds**	**1945-1960**	**Exact location unknown.**
Volatile Organics TCE, methylene, chloride, toluene, MEK	**20,000 gallons**	**1955-1975**	**Drums were taken to the landfill where wastes were drained out directly onto the ground.**
Acetylene and chlorine gas cylinders	**100-200 cylinders**	**1955**	**Cylinders were buried full(1)**
Contaminated dredge spoils containing: **Chromium** **Lead**	 **5,000 pounds** **20,000 pounds**	**1978**	**Total spoils deposited were 108, 000 cubic yards. Small amounts of PCBs and mercury were also found in dredge spoils. Dredge material came from sediments at Berths 6, 11, and 13.**
Waste paints and solvents	**500,000 gallons**	**1945-1965**	**Probably disposed of in whole drums.**
Spent sandblasting grit	**4,000-5,000 tons/year**	**1945-1975**	**Scattered throughout the site.**

(1) More recent information indicates that the valves were removed from the cylinders prior to disposal.

conducted in 1994, subsurface soils, hydrogeology and tidal influences were further investigated. Currently, the JILF is covered with topsoil, pavement, and gravel and, in part, is used for vehicle parking, and equipment storage.

At the time the RFI was conducted, the CDC was located to the west of the JILF. Sampling was conducted at the CDC to ensure that the children at the CDC were not being exposed to soil contaminated by wind dispersal of contamination from the JILF. Surface soil samples were collected

within and around the fenced area at the CDC to evaluate the potential for surface soil contamination. The CDC has since been moved to a different location, and this area is now called the Former CDC. This area is no longer used by children.

3.2.2 Site 9 - The Mercury Burial Sites I and II (MB I and MB II)

Poured concrete blocks and precast concrete pipes containing mercury-contaminated wastes were reportedly buried between 1973 and 1975 at two locations within the boundaries of JILF. The two mercury burial sites are referenced as MBI and MBII and were reportedly placed under 8 to 10 feet of fill. Mercury-contaminated wastes at these two sites are reported to include fluorescent bulbs, thermometers, mercury switches and rags, brooms, and dust pans.

During 1989 to 1992, as part of the RFI, attempts were made to locate both burial sites. The original excavation locations were based on existing concrete plaques that marked the presumed location of the burial sites. MBI was located in the field during the RFI investigation; however, MBII was not. During the RFI, the poured concrete blocks and precast concrete pipe at MBI were excavated and inspected for integrity. All of the concrete appeared to be in reasonably good condition. Concrete blocks and the vertical section of concrete pipe were encountered at approximately 7.5 feet. Each poured concrete block was supported by a 1-foot-thick concrete pad; the concrete sewer pipe was not. All the concrete appeared intact and was left in place and backfilled with original soil and fill material.[16, 17]

Subsurface soils and groundwater samples were collected at the Mercury Burial Site MB I and in areas believed to be located near MB II during the RFI. Locations of ground water monitoring wells and soil test borings are shown on Figure 8. During the RFI Data Gap Investigation conducted in 1994, the concrete pipe at MB I was excavated and disposed in an offsite landfill. The pipe was found to be plugged with concrete at both ends. Sampling results did not indicate an elevated concentration of mercury in soils collected.

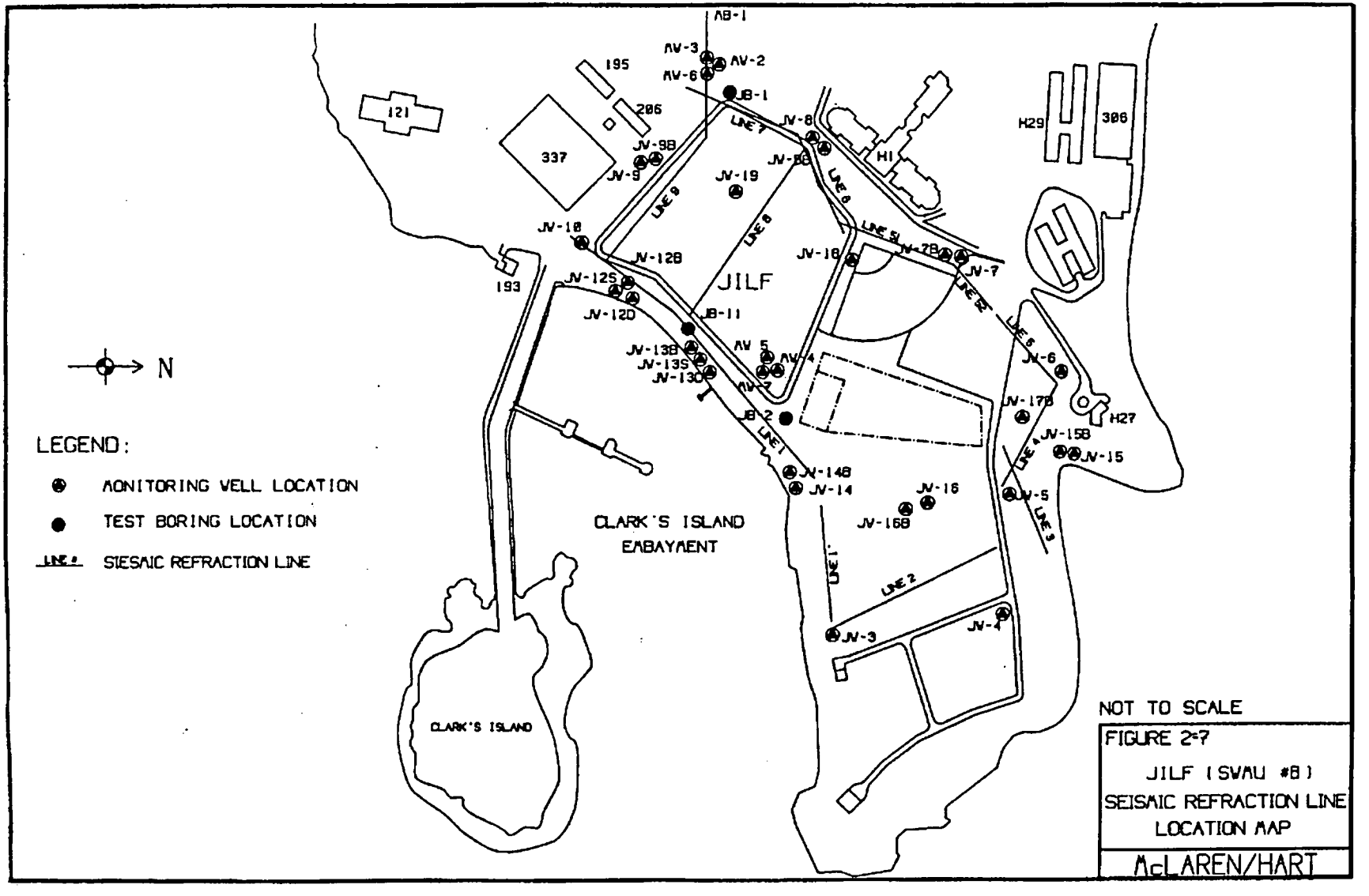

Figure 8. Locations of ground water monitoring wells and soil test borings on the JILF.

The reported location of MBII is in the western corner of the JILF, just south of the H25 Building parking lot. Information gathered by PNS personnel prior to the RFI Data Gap Field Investigation indicated that MBII may have been located south of the previous excavation or southeast of Building H25 just beyond or partially under its fenced-in and paved parking lot. These locations are shown in Figure 7. During the RFI Data Gap investigation another attempt, via test pit excavation, was made to locate MBII. Poured concrete blocks and precast concrete pipes were not located during the excavation activities. In September 1997, the remainder of MB I vaults were excavated and removed. Sampling results indicated no elevated levels of mercury in the soil.

3.2.3 Site 11 - Former Waste Oil Tanks Nos. 6 and 7

Former Waste Oil Tanks Nos. 6 and 7 have been referred to as Waste Oil Tank Number 12 in the past. These two 8,000-gallon underground steel tanks from railroad cars, in use from 1943 to 1989, were located at the northeastern end of the JILF. Figure 7 shows the location of Site 11. Waste oils from facility shops (including cooling and cutting oils, motor oils, transmission oils, and hydraulic oils) were stored in the tanks prior to offsite disposal. Waste oils may also have contained various metals. In 1979 the tanks were excavated, inspected, and reburied because there was no evidence of releases. In 1986, both tanks were tightness tested and found to be sound. These tanks were excavated and removed in 1989 according to state regulations and inspections.[22] Upon removal, both tanks appeared sound and neither tank showed signs of leakage or deterioration. Soil contamination is believed to have occurred from spillage during filling.

Following tank removal, sampling was conducted by PNS and the Maine Department of Environmental Protection (MEDEP). As a result of the elevated levels of lead and other contaminants, 332 tons of soil were excavated and disposed in an offsite, RCRA-permitted land disposal facility. Confirmation sampling of the excavation was not performed; however, the excavation effort was terminated because of its proximity to the JILF, not because all contaminated soil had been removed. Site 11 soils and groundwater were investigated in both the RFI and RFI Data Gap investigations.[16, 17]

In 1994 an investigation was conducted by C.T. Male Associates[23] to determine the presence or absence of soil contamination in the area of the planned Hazardous Waste Consolidation and Storage Facility (HWCSF). This investigation was part of the Military Construction (MILCON) project for the construction of the HWCSF. Information gathered is available for use by the IR Program. The report was submitted to the MEDEP in accordance with permit conditions.

3.3 Previous Geophysical Investigations at OU-3

The Draft RCRA Facility Report PNS[13] details several geophysical investigations conducted on the Jamaica Island Landfill (JILF), SWMU #8, in July 1992. The study took place in two phases. Phase I included a magnetic survey and ground penetrating radar (GPR) study. Phase II consisted of a seismic refraction survey.

The purpose of the investigation was to provide a non-intrusive characterization of SWMU #8. The goals of the study were to:

- Characterize the general geological features,
- Determine migration pathways of the contaminants,
- Determine the location and extent of subsurface features,
- Improve the accuracy and confidence levels of previous hydrogeological investigations,
- Establish sites for monitoring wells, and
- Locate areas to avoid when drilling.

The magnetic survey was conducted across the JILF, including areas believed to contain the Mercury Burial Sites. The purpose of this investigation was to define any magnetic anomalies within the landfill which may be attributable to buried objects such as drums, cylinders, etc. The GPR survey was conducted over areas exhibiting magnetic anomalies and over the two Mercury Burial Sites. The purpose of the GPR survey was to better define the location and source of any magnetic anomalies and to locate the Mercury Burial Sites. The seismic refraction survey was undertaken subsequent to review of the data from phase I and the soil gas survey. The primary purpose of this investigation was to provide depth to bedrock information.

The magnetic survey was taken on 50 ft grid spacings, and in some selected areas data was taken on 10 ft grid spacings. Also some gradiometric data was taken with sensor heights of 3 and

6 ft.[13] While no information was provided describing the sensors used, it is likely that the magnetic sensors were proton precession units. The update rate of these sensors limits measurements to moving from point to point taking one data point at each location. While this type of data can be used to construct course magnetic contour maps it is not particularly useful in locating individual targets.

The GPR survey was conducted using a SIR System Model 3 impulse radar. Real-time imaging was provided by a line scanning recorder with a 500 MHz shielded transducer. The GPR was used at one location. GPR was shown to be ineffective in and around the JILF due to a limited signal penetration depth which was blamed on the conductive nature of the landfill material and subsurface soils.

The seismic refraction survey investigation along the lines shown in Figure 8 profiled the bedrock surface. Additional seismic refractions survey objectives included identification of weathered or fractured bedrock and characterization of overburden materials.

3.4 The Topeka Pier Site

The Topeka Pier Site was created in the early 1900s when the Navy began to fill Jenkins Gut to create Drydock Number 2.[24] As the southern end of the gut was dredged, the material was deposited along the northern portion of Seavey Island. The limits of the Topeka Pier are shown on Figure 9. By 1910 the Navy began storing and milling lumber in this area. A timber basin and timber storage racks were also constructed during this period. A saw mill and several storehouses were constructed about 1920 because of increased activity during World War I. Dumping and landfilling continued in the area of Topeka Pier until approximately 1945, when the landfilling operation was completed. During this period, it was reported that various cans and drums (possible combustibles) were disposed of in this area. Additional refuse may have included sodium hydroxide, sulfuric acid, and other organic solvents. No geophsysical investigations have been performed at Topeka Pier.

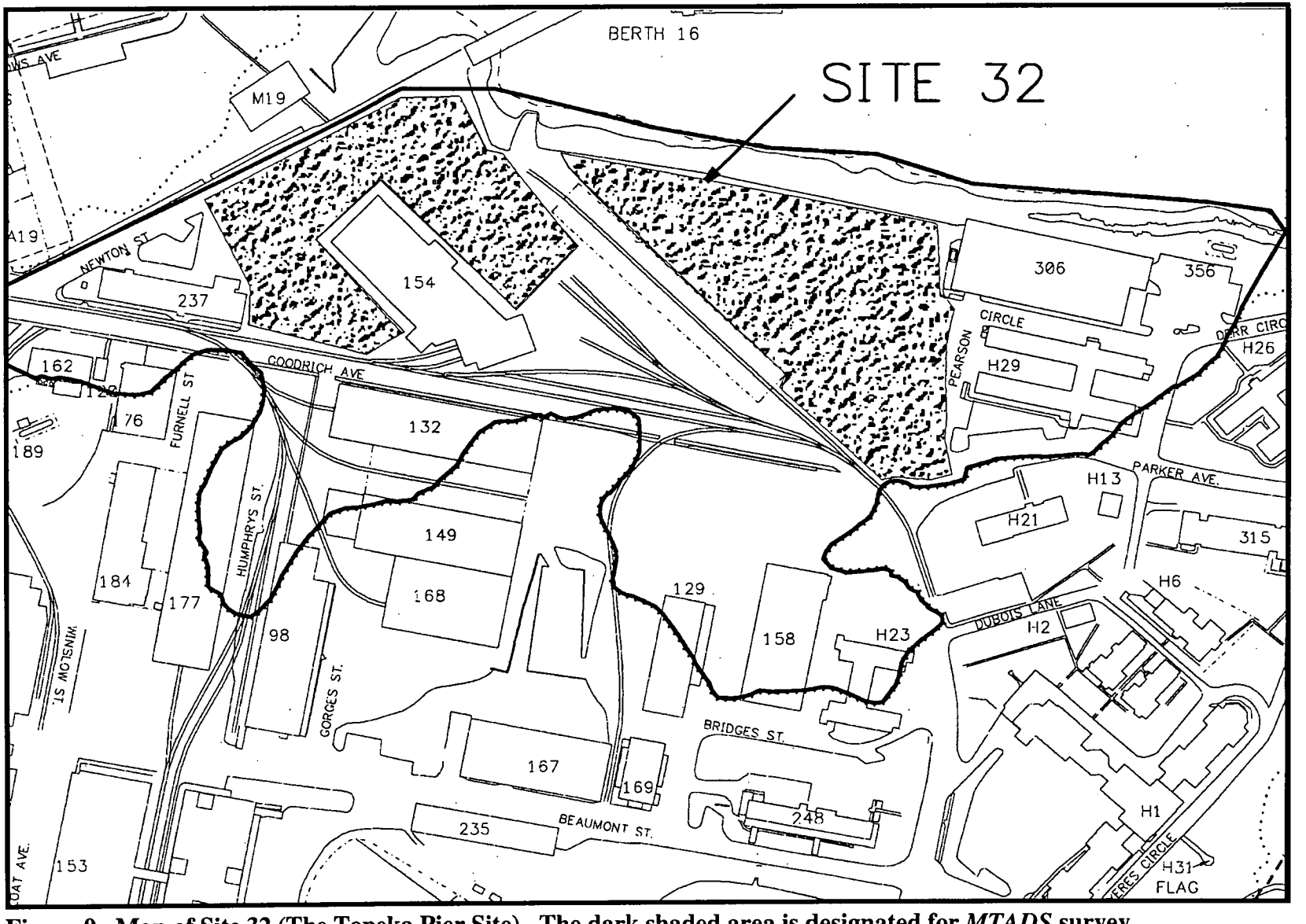

Figure 9. Map of Site 32 (The Topeka Pier Site). The dark shaded area is designated for *MTADS* survey.

4.0 *MTADS* Demonstration Approach

4.1 Performance Objectives and Site Specific Work Plan

A tentative performance plan and *MTADS* Survey Schedule is given below.

***MTADS* Survey Schedule**

Sept 15 - 17	Establish first order points
Oct 3	*MTADS* trailer arrives at PNS
Oct 5 (AM)	NRL unpacks MTADS
Oct 5 (PM)	Test Data Set
Oct 6 (AM)	Land mark Site #1
Oct 6 (PM) - 7	*MTADS* field survey, Site #1 - Magnetometer
Oct 8 - 9	*MTADS* field survey Site #1 - EM
Oct 10	Land mark/field survey, Site #2 - Magnetometer
Oct 11	*MTADS* field survey Site #2 - EM
Oct 12	Fill-in missed areas/other areas as needed
Oct 13	Pack *MTADS*
Oct 14	*MTADS* departs PNS

On 15 December 1997 a preliminary site assessment was done at PNS by representatives from NRL, NAVFAC/ND, and the PNS, Environmental Office to determine if the *MTADS* could effectively be used at the JILF to locate hazardous waste. A walk-over was made on the two sites. Site 1 is an area of 25 acres included in OU-3, also referred to in this document as the JILF. See Figure 7. Additionally, we investigated a small site about 3 acres in size near the Topeka Pier. See Figure 9. It was our evaluation that the *MTADS* can provide significant new geophysical information relevant to these sites. We will be able to precisely locate large individual buried metal-containing targets. The extent and limits of landfill areas can likely be characterized in relation to existing underground utilities and surface landmarks. This information can be provided in a format immediately compatible with existing and future GIS databases. A preliminary proposal[25] and cost estimate was subsequently provided to NAVFAC/ND.

NRL will landmark selected physical points of interest at both sites. The points will be displayed on the magnetic anomaly maps generated by *MTADS* to give prospective to the visible magnetic signature information. Following the land marking, Site #1 will be surveyed, first with the magnetometer and then the EM system. The system will then be moved to Site #2 and the same

procedure followed. The field data will be removed from the tow vehicle Data Acquisition system (DAQ) approximately every two hours and viewed by the Data Analysis System (DAS) to ensure the quality of the data.

After returning to NRL the field data will be completely analyzed. Our observations and conclusions will be provided as a final report to NAVFAC/ND. The report will include color maps and target reports identifying landfill features and where possible, individual targets. Locations and depths of analyzable targets will be provided in tables. Positions will be provided in global coordinates making easy reacquisition at any future date.

4.2 Site Survey Plan

As required under 29 CFR Part 1910, the *MTADS* survey procedures are outlined here to establish the context for conducting a safe project. Given below is the general approach for the conduct of the survey and the organization required to accomplish the survey. The survey operation is divided into the following phases:

- Mobilization
- Land Marking
- *MTADS* Survey, Magnetometer
- *MTADS* Survey, EM
- Demobilization

4.2.1 Mobilization

NRL and their contractors will mobilize all personnel and equipment to the PNS by the required date. The *MTADS* will be transported from the Chesapeake Bay Detachment, Naval Research Laboratory *via* tractor and trailer to the survey site. Storage of the trailer, housing for the field survey equipment including 110 volt AC power for charging batteries will be on site. Office space will be provided for the DAS system. Mobilization will be complete when all equipment has been deployed and operationally checked out.

4.2.2 Site Preparation

NRL will use existing first order survey points at the PNS and likely bring in a commercial survey company to establish control points to support the surveys.

4.2.3 Site Boundaries

The site boundaries were established during the preliminary site assessment at PNS. The existence of structures, large ferrous materials in ground storage chain link fences may render some area to be unsurveyable. No shrubbery or vegetation will be cut or removed by NRL or their contractors.

4.2.4 Land Marking

NRL shall land mark objects of interest within or near the survey sites that are important in establishing the orientation when viewing the target maps or registration in GIS overlays. The targets will be designated in the target report in global coordinates.

4.2.5 Geophysical Investigations and Mapping

NRL shall conduct a nonintrusive survey and evaluation of the project sites. The investigation will be conducted using the *MTADS* equipment, employing passive magnetometers and EM sensor arrays. The total cumulative area to be evaluated is approximately 28 acres. All sensor data shall be preprocessed for sensor offsets, diurnal magnetic variations, and correlated with navigation data. Magnetic anomaly or EM anomaly sensor data will be mapped onto a Global coordinate system (Lat/Long or UTM in meters). Each day prior to commencement of survey activities, the *MTADS* requires partial assembly and checkout. The components that require assembly are:

- Tow Vehicle with sensor platform,
- Base Navigation System, and
- Diurnal Variation Station (reference magnetometer)

Daily comprehensive checkout of all systems is performed to ensure that high quality data is collected at all times and that a minimum of errors occurs during field operation. Checkout procedures verify correct operation of the following items:

- GPS Navigation System; including accuracy, and data logging,
- Diurnal Variation Station; including accuracy, and data logging,
- Platform Array (functionality),
- *MTADS* Data Acquisition System,

- Tow Vehicle Engine, Drive train, Tires, Brakes, and Suspension,
- Platform Suspension, Tires, and Bar Adjust Mechanism, and Auxiliary Sensors.

Various support functions are required to ensure conducting an efficient survey. They are described below:

- Nitrogen charging - There are parts of the system that require that they be charged with nitrogen gas from time to time. A full bottle of nitrogen and a charging valve are required at the survey area to provide nitrogen charging to these parts of the system before and anytime during the survey when required.
- Recharging batteries - The batteries in the vehicle, and the remote batteries for the Diurnal Variation Station and Base Navigation Station, require daily recharging.

Survey data will be transferred from the vehicle at regular intervals and at other times at the discretion of the vehicle operator. The diurnal variation station also requires data transfer. Data Processing and Analysis will commence upon the receipt of data at the Data Processing Center. The primary mission of the *MTADS* software is to rapidly process large volumes of data from the vehicular systems and create anomaly images for analysis. The data processing software for *MTADS* is resident on a Silicon Graphics Iris Indigo workstation. An operator can then view these images in a window of the computer screen, and using an interactive mouse-defined area of interest extracts the location and estimates the size and depth for each target. The DAS provides:

- a unique target identification number,
- target position in Global coordinates (Lat/Lon and local coordinates),
- estimated minor diameter and azimuth, assuming target is typical ordnance item, and
- estimated depth to center of target.

4.2.6 Demobilization

Demobilization will commence at project completion. All equipment will be cleaned prior to packing and checked for proper operation. Equipment needing repair will be repaired on site or tagged for subsequent repair. All equipment will be packed and secured for transport. Rental equipment will take priority in the demobilization schedule.

4.3 Deliverables

A Final Report presenting all data, analyses, and conclusions shall be prepared and submitted by NRL within 90 days of the completion of survey activities. All data, including the raw analytical

and electronic data generated under this effort are the property of the DoD, and the Government has unlimited rights regarding their use. NRL will provide briefings to NAVFAC/ND or other designated DOD agencies describing all activities conducted on site, and the results of the survey.

5.0 References

1. "Hand-held Gradiometer Survey Test at The Marine Corps Air Ground Combat Center, Twentynine Palms, CA," NACEODTECHCEN TR, September, 1992. This report describes hand-held magnetometry surveys of the MCAGCC, Magnetic Test Range conducted by military EOD teams. Their ordnance detection efficiency at this site varied between 25 and 35%.

2. "Magnetic Sensor Field Tests and Evaluations for Towed-Array Systems, Ft. Devens, MA," J.R. McDonald and Richard Robertson, NRL/PU/6110--96-303, 2 April 1996.

3 "Multi-sensor Towed Array Detection System *(MTADS)*. An Automated High-Efficiency Survey System for Characterization of Ordnance and Explosive Waste (OEW) Sites," J.R. McDonald and Richard Robertson, Proceedings of the UXO FORUM 1996, Williamsburg, VA, 26-28 March 1996, p. 53.

4. "Performance of Electromagnetic Induction Sensors for Detecting and Characterizing UXO," Bruce Barrow, Nagi Khadr, and H.H. Nelson, Proceedings of the UXO FORUM 1996, Williamsburg, VA, 26-28 March 1996, p. 308.

5. "Magnetic Sensor Field Tests and Evaluations for Towed Array Systems, Ft. Devens, MA," J.R. McDonald and Richard Robertson, Proceedings of the Symposium on the Application of Geophysics to Engineering and Environmental Problems, Pub. The Environmental and Engineering Geophysical Society, Keystone, CO, 28 April - 2 May 1996, p. 451.

6. "The Combined Use of Magnetic and Electromagnetic Sensors for Detection and Characterization of UXO," Bruce Barrow, Nagi Khadr, Robert DiMarco, and Herbert H. Nelson, Proceedings of the Symposium on the Application of Geophysics to Engineering and Environmental Problems, Pub. The Environmental and Engineering Geophysical Society, Keystone, CO, 28 April - 2 May 1996, p. 469.

7. "ESTCP *MTADS* Program Management Plan," J.R. McDonald and Richard Robertson, MTADS/6110-9511/Rev. 10, 4 Sept 1996.

8. "*MTADS* TECHEVAL Demonstration, October, 1996," H.H. Nelson, R. Robertson, and J.R. McDonald, NRL/PU/6110--97-348.

9. "Results of the *MTADS* Technology Demonstration #2 at the Magnetic Test Range at the Marine Corps Air Ground Combat Center, Twentynine Palms, CA.," J.R. McDonald, H.H. Nelson, Russell A. Jeffries and Richard Robertson, NRL/PU/6110-97-349.

10. "*MTADS* Evaluation at the Jefferson Proving Ground Test Site Following JPG III Surveys," in preparation.

11. "*MTADS* Unexploded Ordnance Operations at the Badlands Bombing Range on the Pine Ridge Reservation, Cuny Table, SD," J.R. McDonald, H.H. Nelson, J. Neece, R. Robertson and R.A. Jeffries, NRL/PU/6110-98-353.

12. http://www.em.doe.gov/rtc1995/pns.htm

13. "Draft, RCRA Facility Investigation Report, Portsmouth Naval Shipyard, Kittery, Maine," McLaren/Hart Environmental Engineering Corp., July 17, 1992 .

14. "Bedrock Geologic Map of Maine," P.H. Osberg, The Maine Geological Survey (1985).

15. "A Field Excursion to the Coastal Regin of New Hampshire and the Isles of Shoals," J. Brooks and S. Richerich, The New Hampshire Geological Society (1966).

16. "On-Shore Feasibility Study (FS) Report for Portsmouth Naval Shipyard, Kittery, Maine. Vol. 1., Comprehesive Long-Term Environmental Action Navy (CLEAN) Contract," Halliburton NUS Corp., March 1995.

17. "Draft On-Shore-Off-Shore Contaminant Fate and Transport Modeling Report," Prepared for the Portsmouth Naval Shipyard by Brown & Root Environmental, a Division of Halliburton NUS Corp. Wayne, PA, February 1997.

18. Department of the Navy, 1978. Correspondence from Commanding Officer, Northern Division, Naval Facilities Engineering Command to Resident Officer in Charge of Construction, Naval Shipyard Portsmouth, Sept. 11, 1978.

19. "A Candidate Environmental Impact Statement for Project P-152, Dredging Portsmouth Naval Shipyard, Portsmouth, NH, NAV FAC SPEC 04-76-024-3." Parsons, Brinckeroff, Quade & Douglas, Inc., Normandeau Associates, Boston, MA.

20. "A Candidate Environmental Impact Statement for Project P-152, Dredging, Portsmouth Naval Shipyard, Portsmouth, New Hampshire," Parsons, Brinckerhoff, Quade & Douglas, Inc., Normandeau Associates, March, 1978.

21. "Final Confirmation Study Report on Hazardous Waste Sites at the Portsmouth Naval Shipyard, Kittery, Maine," Loureiro Engineering Associates (1996).

22. "State of Maine Notice of Underground Oil Storage Tank Removal Registration Number 118630-6 and 11863-7, McLaren & Hart (1991).

23. "Report on the Subsurface Investigation of the Proposed Hazardous Waste Consolidation and Storage Facility, Portsmouth Naval Shipyard, Kittery, Maine," C.T. Male Associates, 1 July 1994

24. "Site Screening Work Plan, Building 184 (Site 30), West Timber Basin (Site 31), and Topeka Pier (Site 32) for Portsmouth Naval Shipyard, Kittery, Maine," Comprehensive Long-Term Environmental Action Navy (CLEAN) Contract, Brown & Root Environmental, April 1998.

25. NRL Proposal to Conduct an "*MTADS* Geophysical Survey at the Portsmouth Naval Shipyard," presented to NAVFAC/ND on 21 January 1998

Appendix A. Reviewers Comments and Responses

The United States Environmental Protection Agency (EPA) has reviewed the document entitled "Work Plan for MTADS Geophysical Mapping at the Portsmouth Naval Shipyard, Kittery, Maine." EPA's comments on this document are provided below.

Meghan F. Cassidy
Remedial Project Manager, September 4, 1998.

EPA Comment	Navy Response
<u>Editorial Comment</u>	
1. Some of the acronyms (i.e., MTADS, JILF) are not defined in the document. While this does not impact the proposed work, it is critical that any report of the findings of this survey work be documented in a report that is complete and readable.	1. Additional acronym definitions are provided.
<u>Technical Comments</u>	
2. Page 3, last sentence, first paragraph: It is assumed that "acoustic measurements" means refraction seismic surveys. Please clarify this information when preparing a report of findings.	2. Clarification added on page 3.
3. Page 5, first sentence: The statement is made that this technology has been described in detail previously. All future work plans and reports should reference where this information is available by providing a list of citations.	3. Citations were added to text.
<u>General Comments on Instrumentation</u>	
4. The Geometrics Model 822 magnetometer (with Cs vapor detectors) is an excellent (probably the best) instrument for this type of application (searching for shallow buried metallic objects). It can support very high sampling rates, therefore making it ideal for used in a towed system. When preparing a report of findings, please include information regarding the modifications that have been made to the sensors in the MTADS.. Include information regarding whether a gradiometer array was used in addition to a magnetometer array. If both types of arrays are to be used, ensure that the report describes the differences.	4. Additional information is now provided on page 5.

EPA Comments, continued

5. The Geonics EM-61 (a time-domain instrument) is ideal for identification and location of shallow buried metallic objects.

   When preparing the report of findings, include information regarding any modifications that have been made to the EM-61 instrument for use with the MTADS system.

Navy Response to Comment

6. Additional information is now provided on page 5.

8 September 1998

The Maine Department of Environmental Protection has reviewed the Draft Work Plan for *MTADS* Geophysical Mapping at the Portsmouth Naval Shipyard, Kittery, ME, US Naval Research Laboratory, Washington DC, July 1998. The Department's comments follow.

Iver McLeod
Project Manager
Bureau of Remediation and Waste Management

MDEP Comments

1. Cover

As this is a draft document, the word "Final" should not be on the cover.

2. 1.4 Applying UXO Technologies, p. 4 para 3

"Site #1 is 25 acres located on Jamaica Island..."

This statement is technically inaccurate as Site 1 (aka Site 8, the JILF) is between Jamaica Island and Seavey Island, not on Jamaica Island.

3. 3.2.1 Site 8 - The JILF, p. 13

This page lists the various industrial wastes reportedly accepted at the JILF. Please reference this information.

Navy Response

1. The cover has been revised to reflect the new "Final" draft date.

2. Wording is clarified on page 4.

3. Reference is provided.

MDEP Comments Continued

4. 3.2.1 Site 8 - The JILF, p. 14, para 1

"One PCB analytical result was significantly high, whereas all remaining samples were comparable with concentrations reported for polluted areas."

The latter half of this sentence is oddly worded. It seems to imply that there is little concern for "all remaining samples" simply because they are comparable to other polluted areas. While the MEDEP expects that sediments around the berths would be polluted, the fact that other industrial areas are polluted as well does not excuse the need to take remedial action, if necessary, for these sediments.

5. 4.0 *MTADS* Demonstration Approach, p. 22, first full para

a. "A preliminary site assessment was done at PNS..."

Please provide the date for the preliminary site assessment.

b. "...near the Topeka Pier. See Figure 8."

Figure 8 shows the JILF, not Topeka Pier.

6) 4.3 Deliverables, p. 26 para 1

"NRL will provide briefings to NAVFAC/ND or other designated DOD agencies describing all activities conducted on site, and the results of the survey."

Information from these briefings should be provided to the regulators and the RAB members.

Navy Response

4. The sentence has been reworded for clarity.

5.

a. Date is noted on page 22 as 12/15/97.

b. Correction made.

6. The Navy will provide information describing all activities conducted on site, and the results of the survey through the Navy's Remedial Project Manager."

Review of "Workplan for *MTADS* Geophysical Mapping at the Portsmouth Naval Shipyard," by Carolyn A, Lepage, C.G., President of Lepage Environmental Services, Inc., September 8, 1998.
Review prepared for: Peter Vandermark
Seacoast Anti-Pollution League
P.O. Box 1136
Portsmouth, New Hampshire 03802

Lepage Comments	Navy Response
1. **Page 1, Section 1.1 Objectives of the MTADS Survey**. It is not at all clear in this section what the objectives of the MTADS survey are, leaving the reader to search elsewhere for what is to be accomplished. The "main objective," to locate ferrous or steal reinforced concrete containers used to dispose of materials in landfill burials, is not clearly stated until page 4. Section 4.1 on page 22 also mentions that the extent and limits of the landfill areas can likely be characterized as well. The objectives of the MTADS survey need to be clearly stated in this part of the Introduction. Why is the Navy performing this geophysical survey? What does the Navy hope to learn? How will the information collected during the MTADS survey be used in future investigations and remediation at the sites?	1. Objectives are now clarified in 2nd sentence of section 1.1.
2. **Pages 1 & 2, Section 1.2 Tasks included in the MTADS Survey.** The tasks outlined include establishment of first order survey points and utilization of a Global Positioning System (GPS) to accurately locate the geophysical survey. how will any subsequent investigations be able to locate specific anomalies identified by MTADS? Will there be sufficient ground control so that the location of an anomaly can be measured from a nearby survey point or will a GPS be required?	2. Anomaly positions will be recorded in Global coordinates. They can be reacquired by any competent surveyor using the first-order monuments which we will establish.
3. **Page 3, Section 1.4 Applying UXO Technologies**. The final sentence of the first paragraph states that measurements at very closely spaced intervals "can precisely locate individual targets as small as coffee can." However, based on the information contained elsewhere in the work plan and presented at the June 25, 1998, Restoration Advisory Board (RAB) meeting, the ability to detect objects depends in part upon site conditions and interferences. The Navy should clarify if that statement applies to surveys conducted at any site, regardless of conditions, or it is applies to surveys conducted under ideal conditions.	3. Clarifying statements have been added to the text of the Work Plan.

Lepage Comments, Continued	Navy Response
4. **Page 3, Section 1.4 Applying UXO Technologies.** It appears that total field magnetic data will be collected. Gradient readings might provide better target resolution. Was a gradient magnetic survey, collecting both total field and gradient measurements, considered?	4. The EM surveys aid in interpreting the magnetometry data. If gradiometry is superior to full-field data, we will reconfigure our sensors to also take gradient data.
5. **Page 4, Section 1.4 Applying UXO Technologies.** The areas where the MTADS will be used are described in several places in the work plan, including the paragraph in the middle of page 4. At the June 25th RAB presentation, all accessible areas in the Jamaica Island Landfill and accessible areas of the Topeka Pier site were identified as targets of the MTADS survey. It is not clear what "accessible" means. How close can the MTADS apparetus get to buildings, fences, and other objects? Are there places within the areas to be surveyed that the vehicle cannot go? If there are, will data be collected by other means (on foot, perhaps) to fill the gap?	5. Only vehicular survey data will be collected. Accessibility limits require near continuous observation of at least 4 GPS satellites and sufficient space to maneuver the vehicle. Spurious data will be edited from the survey.
6. **Page 4, Section 1.4 Applying UXO Technologies.** The work plan states that no excavations will be performed as part of the MTADS survey. Does the Navy intend to perform some kind of "calibration" where the sensor array will be tested against known buried materials?	6. Calibration tests were discussed but not implemented because of time and budget constraints. They can be done later if it is decided that they are needed based upon observations.
7. **Page 9, Section 3.1.4 Geology and Stratigraphy.** Complete citations for reference 14 and 15, as well as the Hussey and Bothner, 1995, reference mentioned in the text, should be included in Section 5.0 References.	7. References 14, 15 and 17 have been revised.
8. **Page 16, Section 3.2.2 Site 9- The Mercury Burial Sites I and II (MBI and MBII).** The first sentence in the final paragraph should be connected to indicate that environmental samples have only been collected at MBI. The exact location of MBII has yet to be determined.	8. Wording on page 8 was changed to clarify the statements about sampling.
9. **Page 22, Section 4.1 Performance Objectives and Site Specific Work Plan.** The last paragraph indicates that selected physical points of interest at both sites will be "landmarked" and displayed on anomaly maps. The Navy should clarify what "landmarked" means and the criteria for selecting a point for landmarking.	9. Using GPS navigation, point locations or tracks can be recorded which can be displayed on imaged data. These may mark surface features to help in orienting the observer or may mark surface features that we expect will show up as magnetic anomalies.

Lepage Comments, Continued

10. **Page 23, Section 4.1 Performance Objectives and Site Specific Work Plan.** How will the quality of the data be judged? What happens if the data are found to be unacceptable?

11. **Page 24, Section 4.2.5 Geophysical Investigations and Mapping.** The materials handed out at the June 25th RAB meeting indicate that the EM survey will be conducted over parts of the Jamaica Island Landfill to "determine the value of the alternative sensor suite." Is this still the case? Does the Navy intend to collect EM data over only a portion of the landfill? With the MTADS providing a rapid means of data collection and because EM data is often more useful at landfill sites than magnetic data, EM data should be collected over the entire area.

12. **Page 25, Section 4.3 Deliverables.** With regard to anomaly maps, will the areas where data are not collected be identified or will the data be interpolated and contoured? If the latter, the maps will give the impression that an entire area was surveyed when, in fact, it was not. Will the anomaly maps show areas of uncertainty caused by surface or known burial materials, such as fences or foundations? What values will be represented on the anomaly maps?

13. **General Comment.** The MTADS method, while subject to interferences and uncertainties, is appropriate for locating buried metal objects in landfill areas. We look forward to reviewing the results of the survey.

Navy Response

10. There are internal checks on data quality. The quality of the interpretations will be subjective without calibration targets or ground truth based on remediation.

11. We intend to survey the full area with both magnetometer and EM arrays. If we feel that additional information can be gained, we will also survey areas with the magnetometer heights adjusted or the magnetometers deployed as gradiometers. Additional surveying is subject to time and budget constraints.

12. In general, we don't find contour data useful. Our anomaly images are typically interpolated, but interpo-lations will not extend more that 20cm beyond sensor readings. Buildings, foundations, etc. may be land marked or may be visualized from GIS overlays with other maps or images.

13.