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FINAL CONTAMINATION AND EXPOSURE ASSESSMENT FOR THE LEAD
CONTAMINATION WITHIN THE DEFENSE REUTILIZATION AND MANAGEMENT OFFICE
CNC CHARLESTON SC
10/1/1986
ENVIRONMENTAL SCIENCE AND ENGINEERING, INC.

FINAL
CONTAMINATION AND EXPOSURE ASSESSMENT
FOR THE LEAD CONTAMINATION WITHIN
THE DEFENSE REUTILIZATION AND
MANAGEMENT OFFICE

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Lead DRMO
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ENVIRONMENTAL SCIENCE
AND ENGINEERING, INC.

FINAL
CONTAMINATION AND EXPOSURE ASSESSMENT
FOR THE LEAD CONTAMINATION WITHIN
THE DEFENSE REUTILIZATION AND
MANAGEMENT OFFICE

Prepared for:

NAVAL FACILITIES ENGINEERING COMMAND
SOUTHERN DIVISION
Charleston, South Carolina

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1.0 INTRODUCTION AND BACKGROUND

1.1 OBJECTIVES

The Naval Facilities Engineering Command (NAVFACENGCOM), Southern Division, issued Contract No. N62467-85-C-0268 to Environmental Science and Engineering, Inc. (ESE) to conduct soil and/or ground water contamination investigations at various naval facilities. This report describes the results of an assessment of lead contamination and exposure at the Defense Reutilization and Management Office (DRMO), Charleston Naval Base (NAVBASE Charleston), Charleston, South Carolina.

The objective of this investigation was to define the extent of lead contamination at the DRMO site and within the DRMO buildings. This investigation consisted of an assessment of the areal and vertical extent of lead contamination in soils, lead content of dust in the DRMO buildings, and lead content of ambient suspended particulates (indoors and outdoors). The assessment also included an evaluation of the potential for human exposure to the lead and a hazard assessment. The exposure and hazard assessment resulted in a determination of an appropriate response level for remedial decontamination action at the site for the soils and the dust within the buildings.

1.2 LOCATION

NAVBASE Charleston is located on the banks of the Cooper River in Charleston County, South Carolina, approximately 5 miles north of the City of Charleston (Figure 1.2-1). The installation consists of two major areas: (1) an undeveloped spoil area on the east bank of the Cooper River on Daniel Island in Berkeley County, and (2) a developed area on the west bank of the Cooper River. The developed portion of NAVBASE Charleston lies on a peninsula, bounded on the west by the Ashley River and on the east by the Cooper River. The western boundary of the developed area adjoins the City of North Charleston, and the eastern boundary adjoins the Cooper River between river mile 10 and river mile 14.

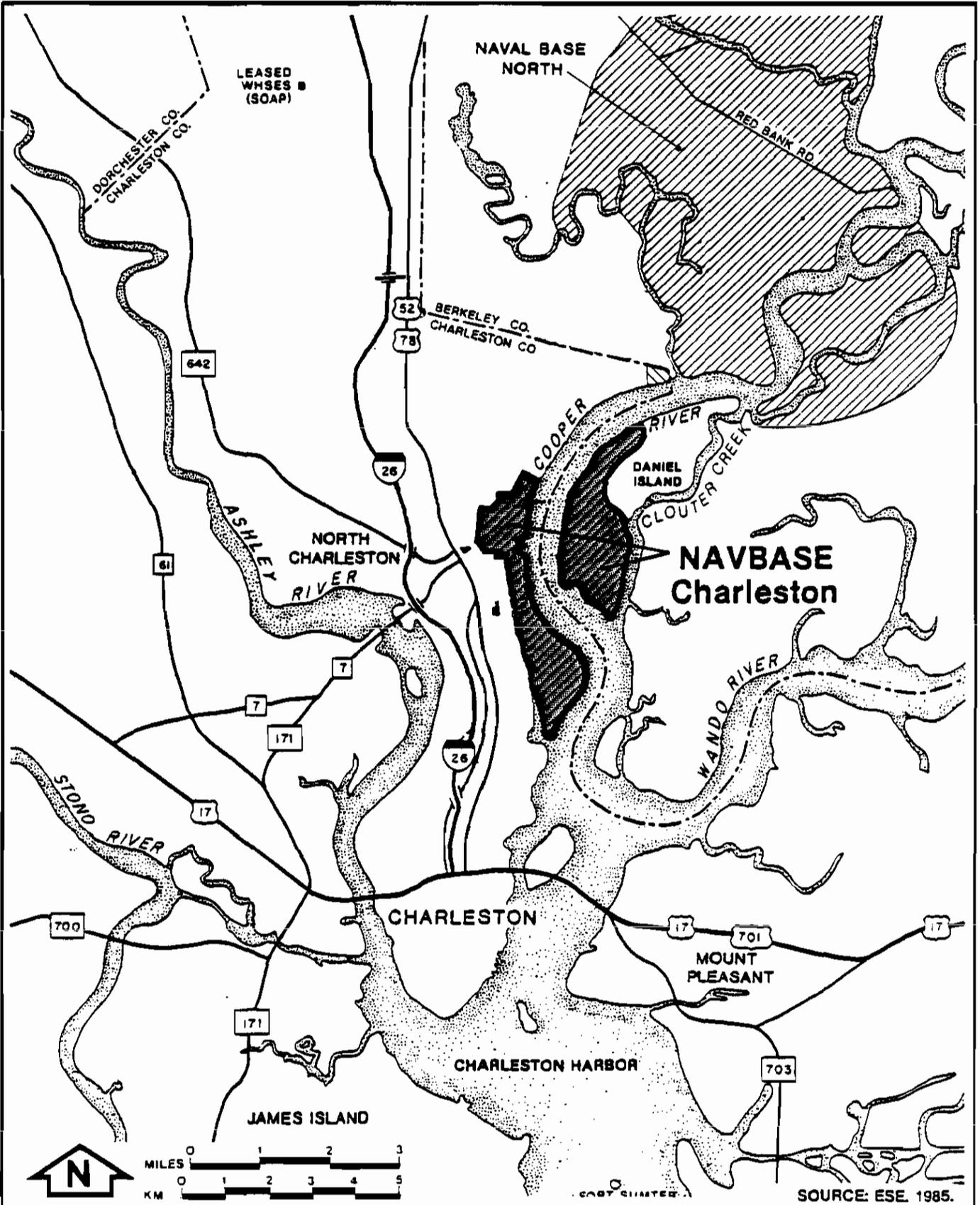


Figure 1.2-1
LOCATION MAP OF NAVBASE CHARLESTON

CONTAMINATION STUDY
NAVAL BASE CHARLESTON

The DRMO site is located at the extreme northern portion of NAVBASE Charleston. Figure 1.2-2 shows the general location of the DRMO area in relation to NAVBASE Charleston, and Figure 1.2-3 is a site map of the DRMO area.

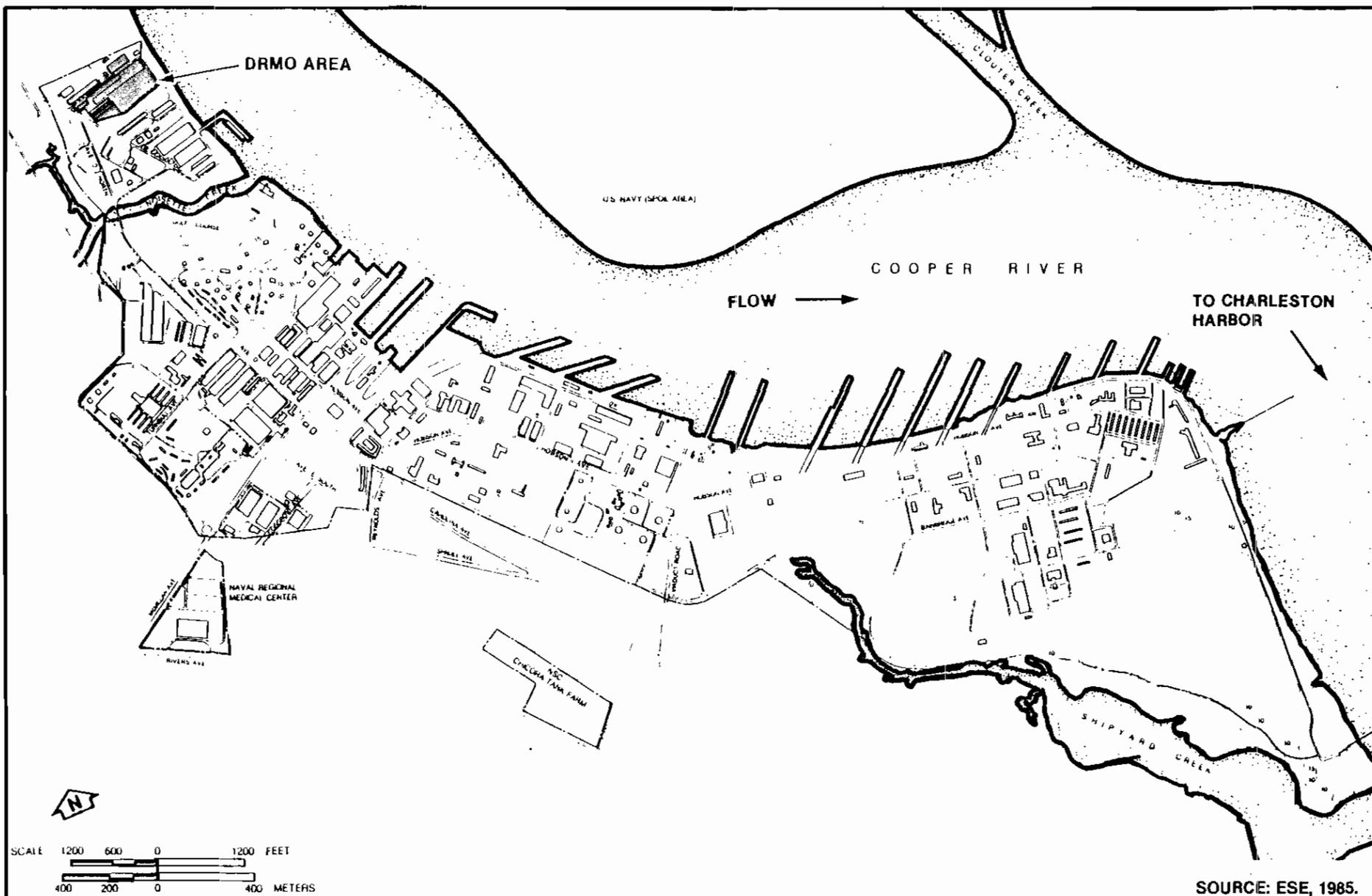
1.3 BACKGROUND

The DRMO at NAVBASE Charleston receives excess property from NAVBASE Charleston, as well as other Department of Defense (DOD) installations in the area. This material is then recycled within DOD, other federal or state agencies, or contract sold to the highest bidder.

Materials stored at the DRMO site are segregated according to type of metal (e.g., ferrous items, copper, brass, aluminum, etc.). Since the mid- to late-1960s, lead-acid batteries from submarines were stored in a materials salvage bin (Bin No. 03) in the DRMO area (see Figure 1.2-3) until picked up by a salvage contractor. The ground surface adjacent to Bin No. 03 is contaminated with a reddish-brown material. Soil samples collected by the Charleston Naval Hospital Industrial Hygiene personnel showed lead contamination in this area of up to 33 percent [330,000 micrograms (ug) of lead per gram (g) of soil]. The principal oxides of lead (PbO, Pb3O4, and PbO2) range in color from yellowish-red to brown (Weast, 1984).

The salvage bins are located on a concrete foundation, while the area in front of the bins consists of asphalt paving or concrete. An open drainage ditch is located immediately behind the bins and transmits surface runoff in a westerly direction to an underground catch basin and storm sewer system (Figure 1.2-3). The soils in the drainage ditch are visually contaminated by the reddish-brown material for a distance of 50 to 100 feet west of Bin No. 03.

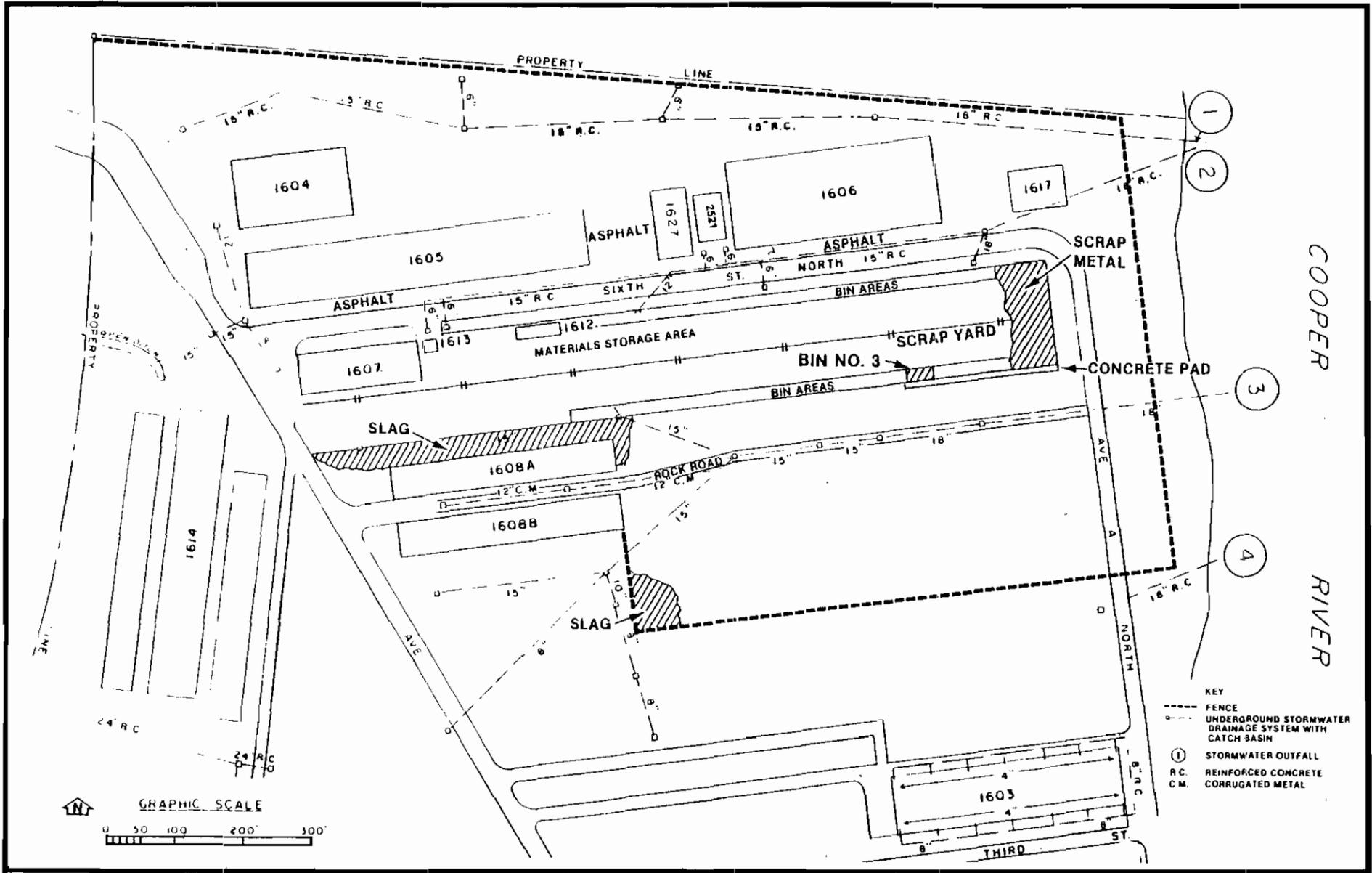
Activity in the DRMO yard area generates fugitive dust, thus creating a potential for lead transport via atmospheric routes. Sampling and



1-4

Figure 1.2-2
LOCATION OF DRMO AREA ON NAVBASE CHARLESTON

CONTAMINATION STUDY
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Figure 1.2-3
SITE MAP OF DRMO AREA

SOURCE: ESE, 1988.

CONTAMINATION STUDY
NAVAL BASE CHARLESTON

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analysis of dust from several buildings (Buildings 1606, 1607, 1608a, 1613, 1627, and 2521) in the DRMO area by the NAVBASE industrial hygiene personnel revealed lead contamination within the buildings ranging from less than 0.02 to 4.4 milligrams (mg) per 100 square centimeters (cm²). The lead-contaminated soils in the DRMO area present a potential exposure hazard via inhalation of dust-containing lead.

2.0 SITE CHARACTERISTICS

This section describes the general environmental conditions at the site, including climatology, physiography, geology, and hydrological characteristics.

2.1 CLIMATOLOGY

Due to the proximity of the ocean, the climate of Charleston is mild and temperate. Daily weather is controlled largely by the movement of pressure systems across the country and by the diurnal effects of the land-sea breeze. Exchanges of air masses are relatively few in summer, when masses of warm, humid, maritime-tropical (mT) air persist for long periods under Bermuda high pressure conditions. Winters are characterized by movements of frontal systems and by replacement of mT air with cool, dry, continental-polar (cP) air.

Average daily temperatures recorded during each month by the National Weather Service at the Charleston Municipal Airport are shown in Table 2.1-1. The coldest month is January, when daily temperatures typically range from approximately 37 to 60 degrees Fahrenheit (°F). In July, the warmest month, the average daily temperature extremes vary between approximately 72 and 90°F. The smaller diurnal temperature variation in summer is due to higher moisture content of the atmosphere on the average day. The record high and low temperatures measured at the airport are 102.9°F and 8.0°F, respectively. Normally, 60 days per year temperatures will be at 90°F or above, while freezing temperatures will predominate 33 days of the year. The average first occurrence of freezing temperatures is 10 October, while the average last occurrence is 19 February [Army, 1976; U.S. Soil Conservation Service (USSCS), 1971; NAVFACENCOM, 1976].

The average annual rainfall in Charleston is 49.2 inches, with a summer peak of more than 7.5 inches occurring in July. The four summer months (June through September) experience over 50 percent of the annual

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Table 2.1-1. Annual and Monthly Climatological Data Recorded by the National Weather Service at Charleston Municipal Airport, Charleston, South Carolina

Time Year of Record	Normal Daily Temperature, °F		Normal Total Precipitation (inches) 1947-76	Prevailing Direction of Winds 1962-76	Heavy Fog (Days) 1956-76
	Maximum 1947-76	Minimum 1947-76			
January	61.2	38.3	2.54	SW	4
February	62.5	40.4	3.29	NNE	2
March	68.0	45.4	3.93	SSW	2
April	76.9	52.7	2.88	SSW	2
May	83.9	61.8	3.61	S	2
June	89.2	69.1	4.98	S	2
July	89.2	72.0	7.71	SW	1
August	88.8	70.5	6.61	SW	1
September	84.9	66.2	5.83	NNE	2
October	77.2	55.1	2.84	NNE	3
November	67.9	43.9	2.09	N	4
December	61.3	38.6	2.85	NNE	3
Annual	75.9	54.5	49.16	NNE	28

Source: Army, 1976.

rainfall. Rain storms during the summer are due to strong convective atmospheric motions, which trigger 72 percent of the average 57 thunderstorms per year. Rainfall during the winter is generally associated with the interface of cP frontal air masses replacing mT air. With the exception of the 7 inches dropped during the winter storm of 10-11 February 1973, only traces (less than 0.04 inch) of snow are usually experienced, mostly in January and February (Army, 1976; USSCS, 1971; NAVFACENCOM 1976).

The mean wind speed recorded at the Charleston Airport is 9 miles per hour (mph), with prevailing wind directions (Table 2.1-1) of north-northeast during the winter months and south-southwest during the summer months (Army, 1976; USSCS, 1971; NAVFACENCOM, 1976).

2.2 PHYSIOGRAPHY

NAVBASE Charleston is located on the eastern edge of a low, narrow finger of land separating the Ashley and Cooper Rivers (see Figure 1.2-1). The topography of the area is typical of South Carolina's Lower Coastal Plain, with low relief plains broken only by the meandering courses of the many sluggish streams and rivers flowing toward the coast and by an occasional marine terrace escarpment. Topography at NAVBASE Charleston is essentially flat, with elevations ranging from just over 20 feet in the northwestern part of the base to sea level at the Cooper River. Much of the original topography of NAVBASE Charleston has been modified by man's activities. The southern end of the base originally was a tidal marsh drained by Shipyard Creek and its tributaries. Over the last 70 years, this area has been filled with both solid wastes and dredged spoil. Most of the base is within the 100-year flood zone, which is below +10 feet mean sea level (MSL) in elevation.

2.3 GEOLOGY

The geology of the Charleston area is typical of the southern part of the Atlantic Coastal Plain. A seaward-thickening wedge of Cretaceous and

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younger sediments is underlain by older igneous and metamorphic basement rock (see Figure 2.3-1). At NAVBASE Charleston, recent and/or Pleistocene sands, silts, and clays of high organic content are exposed at the surface. These materials are underlain by a plastic calcareous clay known as the Cooper Marl. At NAVBASE Charleston, the Cooper Marl is underlain by the Santee Limestone and older rocks. Figure 2.3-2 shows a generalized north-south cross section along the approximate center of the base. As shown, the installation is underlain by several feet of sands, silts, and fill which are underlain by silts, clays, and the Cooper Marl.

A near-surface cross section constructed from recent foundation borings in the DRMO area is shown in Figure 2.3-3. As shown, the DRMO is underlain by 3 to 5 feet of fine, clayey sand. Silty clay and sand are encountered below the sand to an average depth of 60 feet below land surface. The Cooper Marl underlies the clay and sand. The soil borings were terminated in Cooper Marl at a depth of 75 feet below land surface.

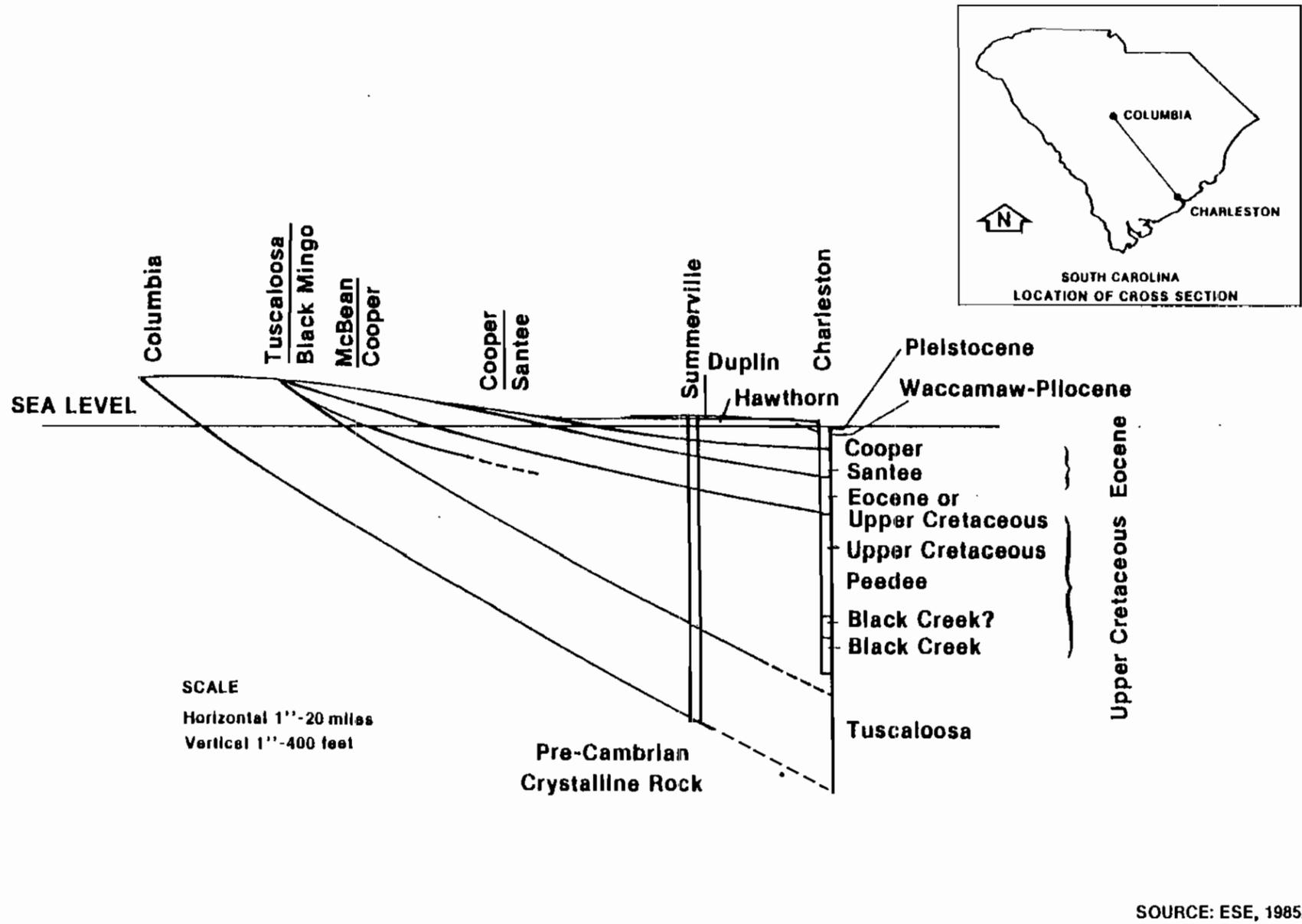
2.4 SURFACE HYDROLOGY

The southern portion of NAVBASE Charleston is drained by Shipyard Creek and the northern portion by Noisette Creek (see Figure 1.2-2). Both creeks drain into the Cooper River. Surface drainage for most of NAVBASE Charleston is directly into the Cooper River, which empties into Charleston Harbor.

The storm drainage system for the DRMO area consists of open ditches, catch basins, and underground concrete and/or corrugated metal conduits (Figure 2.4-1). Storm water from this area drains into the Cooper River via four 18-inch diameter outfalls.

2.5 GEOHYDROLOGY

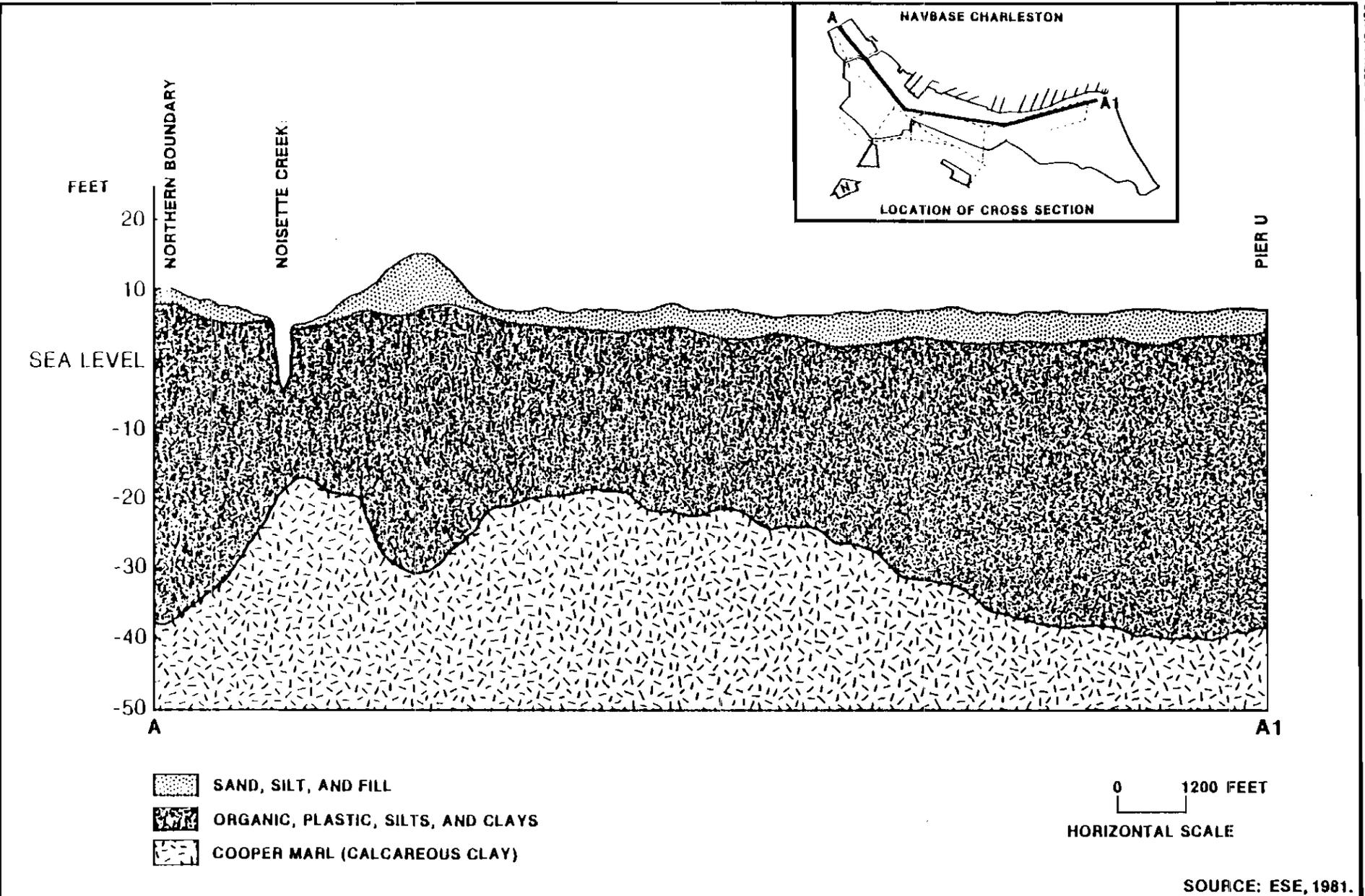
Most potable water on the Charleston peninsula is supplied by surface water sources. Although both the Cooper Marl and the Santee Limestone function as aquifers in other areas, neither is significantly developed in



2-5

Figure 2.3-1
EAST-WEST GEOLOGIC CROSS SECTION FROM THE
COAST INLAND THROUGH CHARLESTON, SOUTH CAROLINA

CONTAMINATION STUDY
NAVAL BASE CHARLESTON

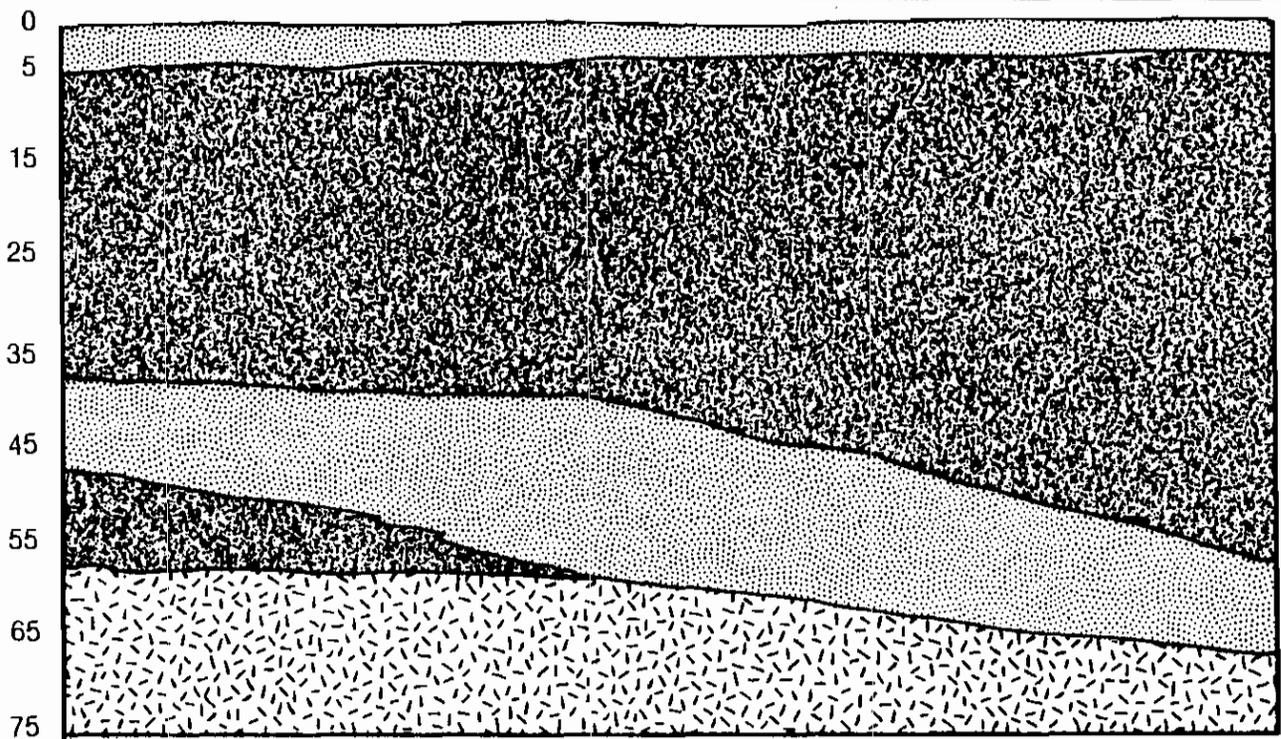


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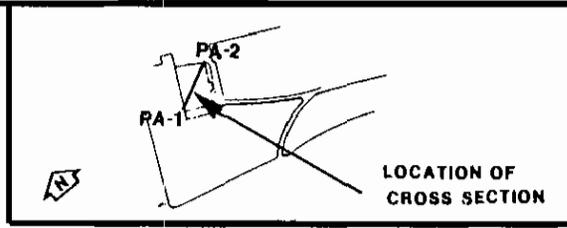
Figure 2.3-2
GENERALIZED GEOLOGIC CROSS SECTION
THROUGH NAVBASE CHARLESTON

CONTAMINATION STUDY
NAVAL BASE CHARLESTON

FEET BELOW SURFACE



-  SAND, SILT, AND FILL
-  ORGANIC, PLASTIC, SILTS, AND CLAYS
-  COOPER MARL (CALCAREOUS CLAY)

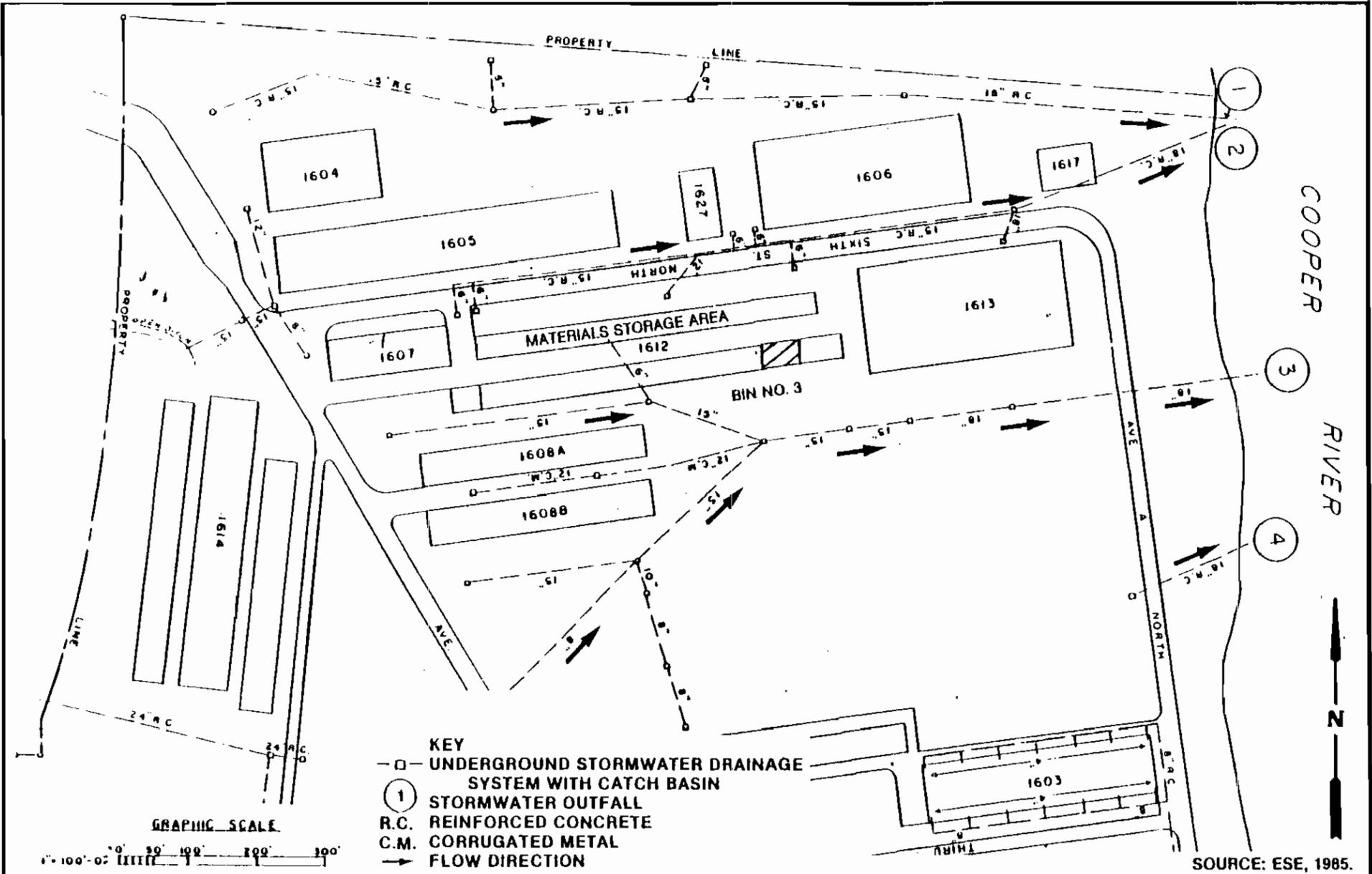


2-7

SOURCE: ESE, 1985.

Figure 2.3-3
GEOLOGIC CROSS SECTION IN THE DRMO AREA

CONTAMINATION STUDY
NAVAL BASE CHARLESTON



2-8

Figure 2.4-1
STORM DRAINAGE SYSTEM IN THE DRMO AREA

CONTAMINATION STUDY
NAVAL BASE CHARLESTON

the Charleston area. In the vicinity of NAVBASE Charleston, the quality of the water from the Santee is not suitable for potable supply; total dissolved solids (TDS) range from 1,000 to 1,500 parts per million (ppm).

In the Charleston area, the Cooper Marl is impermeable and acts as the confining bed for the Santee, which forms a confined aquifer. Ground water in the Santee occurs at about -328 MSL in the Charleston area and flows generally to the southeast. Some wells in the vicinity of NAVBASE Charleston are pumping from the Santee for industrial purposes. In July 1981, the water level of a well in the Santee under NAVBASE Charleston measured 15 feet MSL, indicating that the gradient across the confining bed, the Cooper Marl, is upward; i.e., water from the Santee moves upward through the Cooper to discharge into the incised river valleys.

In the shallow aquifer on NAVBASE Charleston, water flows toward the Cooper River or Shipyard Creek, with the water table surface roughly parallel to the topography on the naval base. The water table is within 3 to 7 feet of the ground surface. The shallow ground water continually discharges to the Cooper River and Shipyard Creek.

3.0 FIELD INVESTIGATIONS, SAMPLING PROCEDURES, AND CHEMICAL ANALYSES

This section describes the field investigations and laboratory procedures used during the contamination assessment. Specific sampling locations and sampling procedures are described in this section.

3.1 GENERAL OBSERVATIONS

The ESE field investigation team arrived in Charleston, South Carolina on 9 December 1985. The investigation team included Susan Klinzing (team leader/hydrogeology), Phil Sandberg (air quality), Robert Burks (hydrology/biology), and David Smoak (hydrogeology). At 0830 hours on the following morning, 10 December, the ESE field team obtained security clearance into NAVBASE Charleston and a work pass for the DRMO area. The field team met with Chief White in the DRMO office at 1000 hours and briefly discussed sampling strategy for the investigation. Following the meeting, a site walkover was conducted and sampling locations were identified for implementation of the work plan. The field investigation included the following activities:

1. Construction of soil borings,
2. Collection of soil samples,
3. Ambient air quality sampling, and
4. Building dust sampling.

Dry and dusty conditions prevailed throughout ESE's field investigation and collection of samples. Daily breezes generated appreciable amounts of wind-blown particulates. Moderate vehicular traffic from routine operations of the site produced visible dust clouds in work areas, primarily in the vicinity of the storage bins.

Areas of visual contamination (reddish-brown in color) were observed in the vicinity of Bin No. 3, which was reported to contain obsolete submarine batteries, and extended in the direction of drainage pathways. Additional visual discoloration was noted adjacent to current battery storage areas located to the southeast of Bin No. 03.

3.2 SAMPLING SITE LOCATIONS AND PROCEDURES

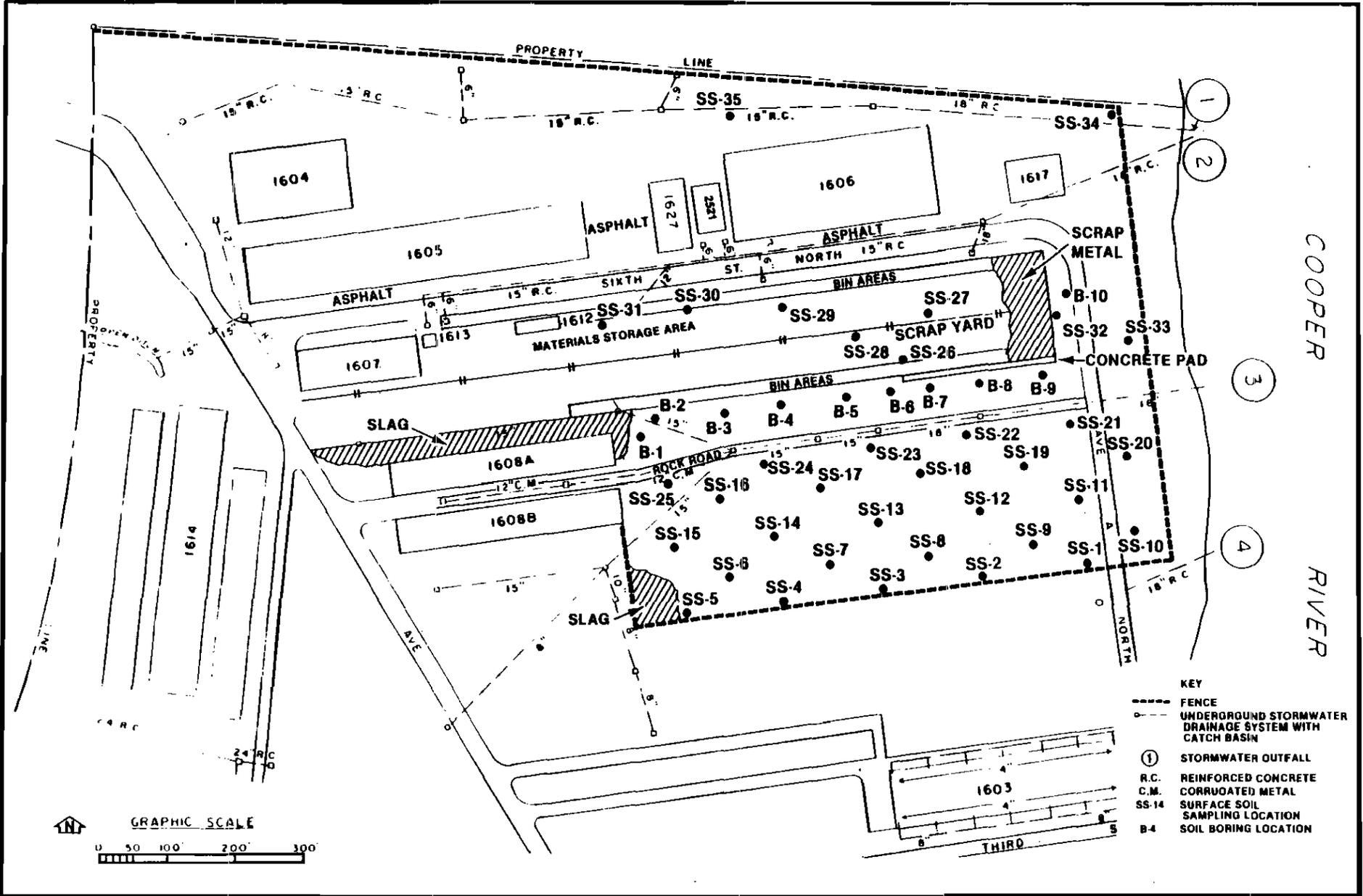
3.2.1 Soil Sampling

A total of 71 soil samples were collected from the DRMO site between 10 December and 12 December 1985. Of the 71 samples, 35 consisted of individual surface samples collected at selected locations, and the remaining 36 samples were collected from 10 soil borings drilled to depths ranging from 7.5 to 10 feet below land surface. Figure 3.2-1 identifies the surface soil sampling locations and soil boring locations.

A grid pattern was established in the large graveled storage field to the south of the storage bins, and 25 sample locations were staked for easy identification. Ten additional surface soil sampling locations were selected in and around the bin storage area.

Each individual surface soil sample was collected with a hand trowel. Each of these samples was composited from the upper 6 inches of soil at the specified location. Soil samples were transferred directly from the hand trowel to the sample container. Following sample acquisition at each location, the hand trowel was decontaminated by washing in a trisodium phosphate solution and rinsing with deionized water.

Soil auger borings were constructed with a 2-man power auger. The surface area in the vicinity of each boring was wetted down to prevent the generation and entrainment of suspended particulates. The field team members who conducted soil boring activities wore protective clothing consisting of tyvak coveralls, disposable liner gloves, solve outer gloves, steel-toed boots, and boot covers. Soil samples collected from six of the borings were taken at depths of 0 to 6 inches, 3 to 4.5 feet, 6 to 7.5 feet, and 8.5 to 10 feet. Samples from the remaining four soil borings were taken at the same depths except that the 8.5- to 10-foot interval was eliminated due to caving and sloughing problems which occurred at the base of the borings. The power auger was used to progress the boring to the desired sampling interval. At the sampling



3-3

Figure 3.2-1
SOIL SAMPLING LOCATIONS

SOURCE: ESE, 1986.

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depth, the auger was removed and an 18-inch split-spoon was inserted into the borehole. The split-spoon was driven through the sampling interval with a sledgehammer. Once the split-spoon had advanced approximately 18 inches, it was removed from the borehole. The split-spoon was separated and the soil sample was transferred directly into the sample container. The split-spoon sampler and acquisition tools were decontaminated between each sample collected by washing and cleansing in a trisodium phosphate solution, rinsing with distilled water, and pressure spraying with deionized water. Augers were thoroughly cleaned between each boring by pressure washing followed by the same decontamination procedure mentioned above.

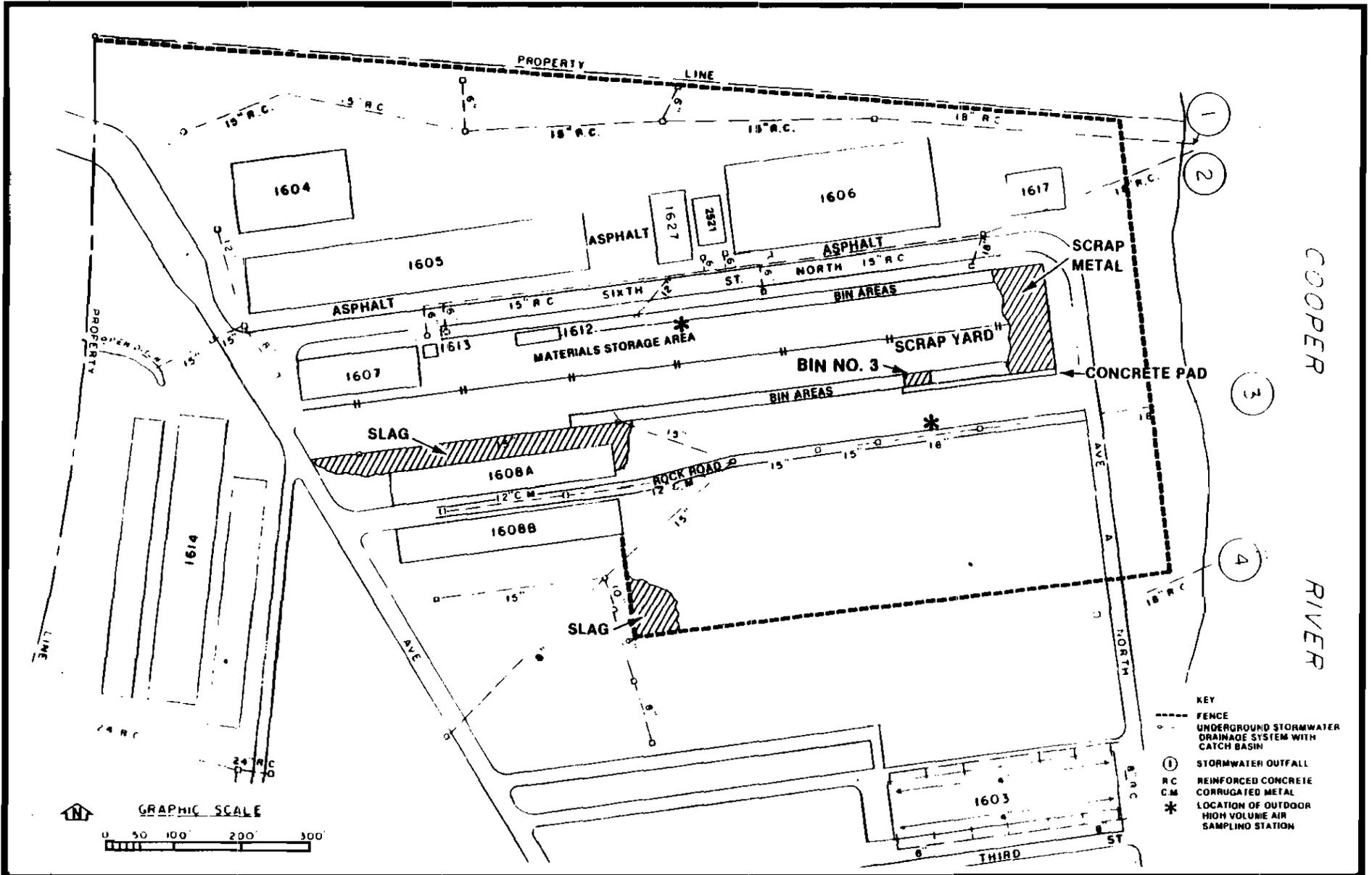
3.2.2 Ambient Air Sampling

Ambient air sampling was conducted both outdoors, in the materials storage area, and indoors, within seven buildings located within the DRMO site. Outdoor ambient air samples were collected using high volume (Hi-Vol) collectors. The Hi-Vol vacuum motors were calibrated prior to field deployment. The Hi-Vol collectors were located in the area of the visual soil contamination and downwind of this area (see Figure 3.2-2).

Indoor ambient samples were obtained using personnel samplers calibrated prior to field deployment. In general, indoor air samples were collected near the center of each of the designated buildings (Bldg. Nos. 1606, 1607, 1608A, 1612, 1613, 1627, and 2521). Figures A-1 through A-8 (see App. A) show the air sampling location(s) in each building.

3.2.3 Building Dust Sampling

A total of 35 wipe samples were collected from within Bldg. Nos. 1606, 1607, 1608A, 1612, 1613, 1627, and 2521 at the DRMO site. The wipe samples were collected in such a manner as to characterize the vertical lead deposition profile. Wipe sample locations are shown in Figures A-1 to A-8 (App. A). Samples were collected by wiping an area of 100 cm² using a preweighed Whatman smearthab[®] that had been dampened with laboratory-grade, deionized distilled water. The filters were folded in half and placed inside a sample vial.



3-5

**Figure 3.2-2
HI-VOL SAMPLING LOCATIONS**

SOURCE: ESE, 1988.

**CONTAMINATION STUDY
NAVAL BASE CHARLESTON**

3.3 CHEMICAL ANALYSIS PROGRAM

The chemical analysis program involved analysis for total lead in soils, lead in building wipe samples (dust), and lead in ambient air suspended particulate material. The analyses were performed at the ESE laboratory in Gainesville, Florida. Table 3.3-1 summarizes the analytical program. The following sections describe the sample extraction and instrumental analysis procedures utilized for chemical analysis.

3.3.1 Soils

Soil samples were digested (extracted) using the following procedure:

1. The sample was thoroughly mixed to maximize homogeneity and a 1.0- to 1.5-g portion of the sample was transferred to a 60 milliliter (mL) Nalgene bottle.
2. Three mL of concentrated nitric acid (suitable for trace metals analysis) was added. Deionized water was added to cover the entire sample.
3. The bottle caps were securely tightened and the samples were heated overnight in a hot water bath [80 to 90 degrees Celsius (°C)].
4. The samples were quantitatively transferred to a graduated cylinder and brought up to a volume of 50 mL.
5. Insoluble silicate material was removed by filtration.
6. Blanks, duplicates, spikes, and standard reference materials were digested along with the samples to provide adequate quality control.
7. After digestion, the samples were analyzed for lead by inductively coupled plasma-atomic emission spectrometry (ICP-AES) [Environmental Protection Agency (EPA) Method 200.7].
8. Moisture content was determined using a separate sample aliquot in order to report lead data on a dry weight basis.

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Table 3.3-1. Analytical Program Summary

Parameter	ANALYTICAL MATRIX (No. of Samples)			
	Soils*	Hi-Vol Glass Fiber Filter (Ambient Air-Outdoor)	Whatman SmearTab® Cellulose Filter (Building Wipes)	Cellulose Ester Filter (Ambient Air-Indoor)
% Moisture	71	0	0	0
Total Mass	0	4	36	8
Total Lead	71	4	36	8

* Two samples with the highest lead levels will be tested by the EPA Extraction Procedure (EP) for leachable lead (40 CFR 261.24).

Source: ESE, 1986.

3.3.2 Ambient Air Suspended Particulate

Outdoor ambient air samples were collected by drawing a known volume of air through an 8- by 10-inch glass fiber filter. A 7-inch by 9-inch section of the filter was actually exposed during the collection process.

The filters were extracted using the hot extraction procedure listed in Appendix H of 40 CFR 50. The extraction procedure is briefly summarized in the following steps:

1. The filter strip is folded in half twice and placed in a 150 mL beaker. Add 15 mL of 3 molar (M) nitric acid to cover the sample. The acid should completely cover the sample. Cover the beaker with a watch glass.
2. Place beaker on a hot plate, contained in a fume hood, and boil gently for 30 minutes. Do not let the sample evaporate to dryness.
3. Remove beaker from hot plate and cool to room temperature.
4. Quantitatively transfer the sample to a graduated cylinder and bring up to a volume of 50 mL. Allow solution to settle.
5. Filter, if necessary, to remove any insoluble silicate material.

After the samples had been digested, they were analyzed by ICP-AES (EPA Method 200.7).

National Institute for Occupational Safety and Health (NIOSH) procedures (NIOSH, 1984) were used for analysis of lead on suspended particulates collected indoors using personnel samplers. The extraction of lead from the filters is summarized as follows:

1. Open the cassette filter holders and transfer the samples and blanks to clean beakers.
2. Add 3 mL of HNO₃, and 1 mL of 30-percent H₂O₂ and cover with a watchglass.
3. Heat on hotplate (140 °) until most of the acid has evaporated.
4. Repeat two more times using 2 mL of concentration HNO₃ and 1 mL of 30-percent H₂O₂ each time.

5. Heat on a 140°C hotplate until a white ash appears.
6. When the sample is dry, rinse the watchglass and walls of the beaker with 3 to 5 mL of 10-percent HNO₃. Allow the solution to evaporate to dryness.
7. Cool each beaker and dissolve the residues in 1 mL of concentration HNO₃.
8. Transfer the solution quantitatively to a 10-mL volumetric flask and dilute to volume with distilled water.

Following digestion, the extract was analyzed for lead by ICP-AES (EPA Method 200.7).

3.3.3 Building Wipe Dust Samples

The building wipe dust samples were digested in the same manner as described above (Sec. 3.3.2) for ambient air suspended particulate matter. After digestion, the samples were analyzed by ICP-AES.

3.3.4 Extraction Procedure Toxicity Analysis

The extraction procedure (EP) simulates the leaching a waste will undergo when disposed of in a sanitary landfill. The method is described in "Test Methods for Evaluating Solid Waste" (EPA, 1982). Two samples containing the highest total lead concentrations were tested by the EP toxicity analysis for leachable lead. The procedure consists of the following five steps (see Figure 3.4-1):

1. Separation,
2. Structured integrity procedure/particle size reduction,
3. Extraction--24 hour period using 0.5 normal (N) acetic acid at pH 5.5 as the extraction medium,
4. Final separation--filtration, and
5. Analysis of EP extract by ICP-AES.

2 / CHARACTERISTICS - EP Toxicity

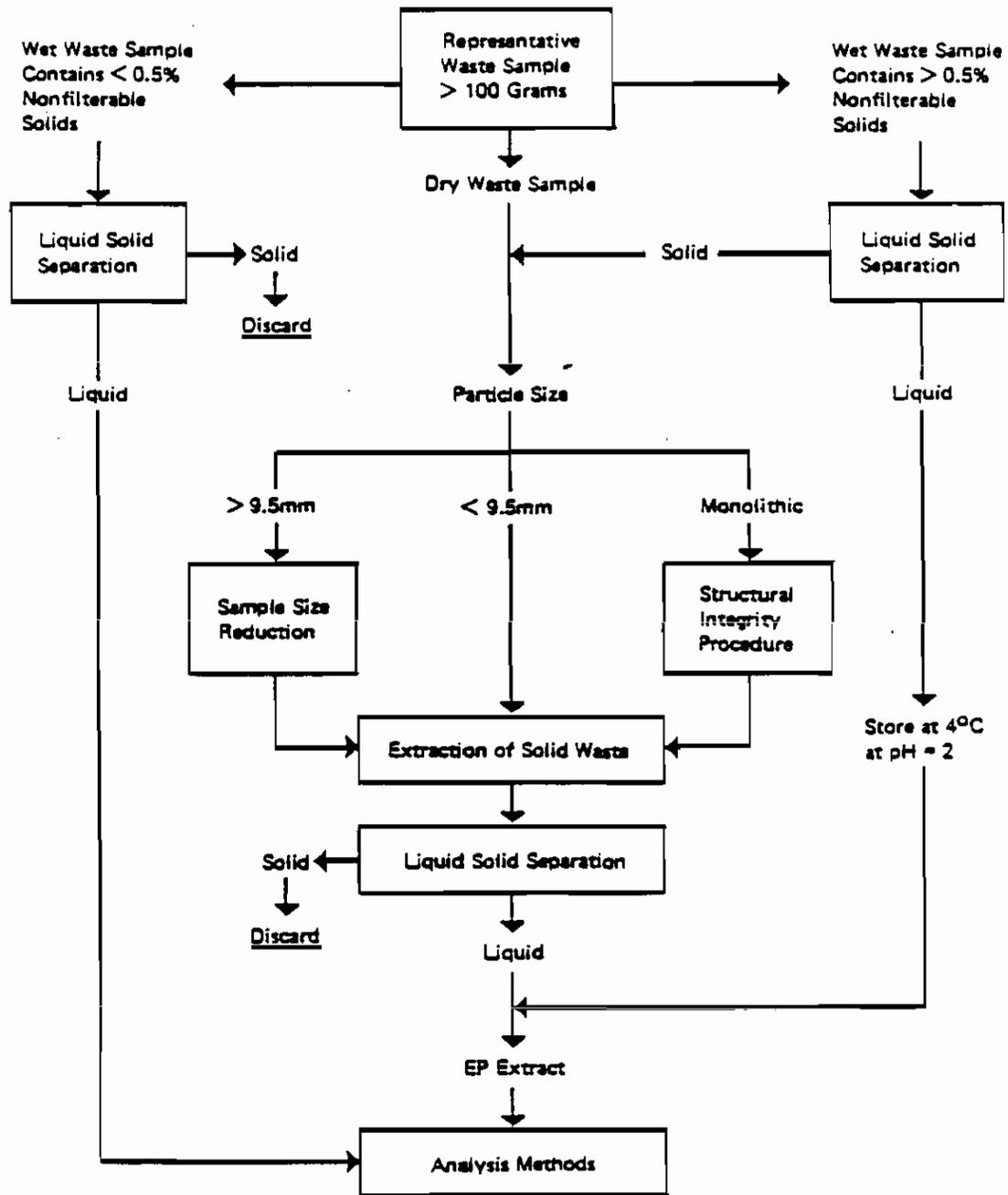


Figure 3.4-1
EXTRACTION PROCEDURE FLOWCHART

SOURCE: ESE, 1985.

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4.0 CONTAMINATION ASSESSMENT

This section describes the results of the sampling and analysis of soils, building dust wipe samples, and indoor/outdoor ambient air suspended particulate samples. A health effects assessment for lead and a discussion of existing lead criteria also are included in this section.

4.1 SOILS

A total of 71 soil samples were collected from the DRMO site; 35 samples consisted of surficial soils (surface to 0.5 ft. depth) and the remaining 36 samples were collected at various depth intervals from 10 individual soil borings (total depths of 7.5 to 10 ft. below land surface). The surficial soil samples were collected across a grid pattern to characterize the areal extent of lead contamination and the soil boring samples were collected to yield information on the extent to which lead had penetrated (migrated) vertically in the soils. Field sampling and analytical procedures are described in Section 3.0.

The locations of the soil sampling points in the DRMO Area are shown in Figure 3.2-1; analytical results are given in Table 4.1-1. All lead concentrations are expressed in units of mg lead/kg soil (dry-weight basis). As shown, the lead levels in soil exhibit a large range in concentration, ranging from <1.3 to 371,000 mg/kg.

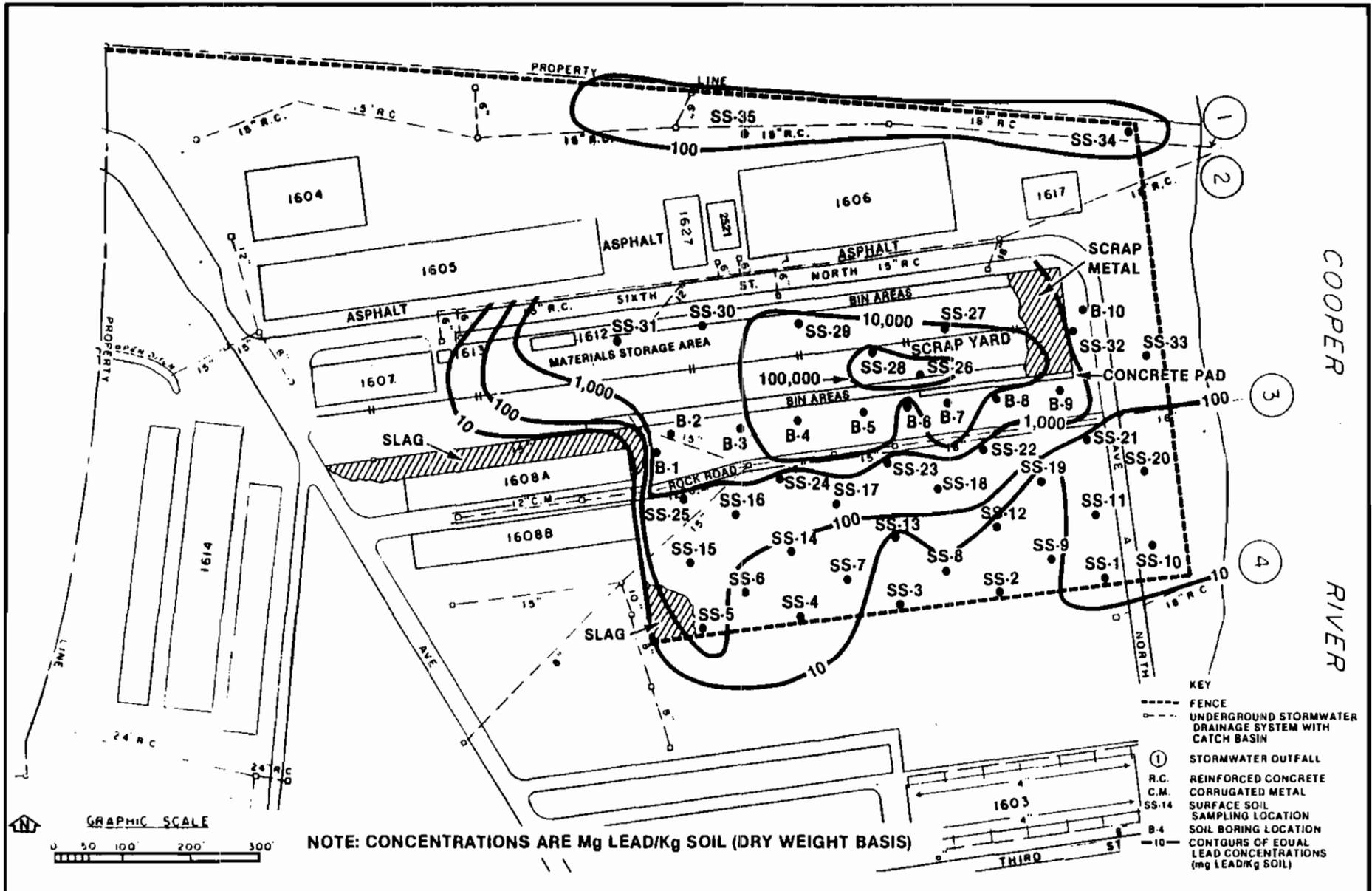
The lead data in Table 4.1-1 were plotted on a site map (shown in Figure 4.1-1) to visually depict the areal distribution of the lead contamination and to facilitate estimation of the area of contamination. As shown, lead concentrations are greatest in the area adjacent to and in front (north) of the former battery storage bin (sampling location Nos. SS26 to SS31). Lead concentrations decrease to background levels (10 to 100 mg/kg) over a distance of several hundred feet south of the bin area. The current activity (vehicles, etc.) in the materials storage area north of the bin has apparently spread the lead-contaminated soil over a large area. The area encompassed by the 1,000 mg/kg isopleth shown in

Table 4.1-1: Lead Concentrations In Surficial (Surface to 60.5 Ft.)
Soils In the DRMO Area

Sample Matrix	Soil Sampling Locations (See Fig. 3.2-1)	Lead Concentration (mg lead/kg soil) *
Surficial Soil	SS1	69.2
Surficial Soil	SS2	2.72
Surficial Soil	SS3	<1.3
Surficial Soil	SS4	28.5
Surficial Soil	SS5	137
Surficial Soil	SS6	<1.3
Surficial Soil	SS7	20.7
Surficial Soil	SS8	6.70
Surficial Soil	SS9	8.17
Surficial Soil	SS10	68.7
Surficial Soil	SS11	126
Surficial Soil	SS12	<1.3
Surficial Soil	SS13	<1.3
Surficial Soil	SS14	43
Surficial Soil	SS15	371
Surficial Soil	SS16	286
Surficial Soil	SS17	266
Surficial Soil	SS18	424
Surficial Soil	SS19	<1.3
Surficial Soil	SS20	40.4
Surficial Soil	SS21	54
Surficial Soil	SS22	328
Surficial Soil	SS23	717
Surficial Soil	SS24	488
Surficial Soil	SS25	32.7
Surficial Soil	SS26	371,000
Surficial Soil	SS27	10,500
Surficial Soil	SS28	107,000
Surficial Soil	SS29	1,260
Surficial Soil	SS30	9,320
Surficial Soil	SS31	2,810
Surficial Soil	SS32	907
Surficial Soil	SS33	298
Surficial Soil	SS34	533
Surficial Soil	SS35	411

Source: ESE, 1986

* Dry-weight basis



**Figure 4.1-1
SURFACE SOIL LEAD CONCENTRATION ISOPLETHS**

SOURCE: ESE, 1986.

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Figure 4.1-1 is estimated at 6 acres. Additionally, stormwater runoff of contaminated soil from the immediate vicinity of the former storage bin has spread the lead contamination along a surface drainage way located immediately south of the bin area and toward the stormwater catch basin at the eastern end of Bldg. 1608A (see Figure 4.1-1).

Soil borings were made in order to characterize the vertical extent of lead contamination in the soils. The soil borings were made along the surface drainageway south of the bin area; these locations are shown as sample location Nos. B-1 to B-10 in Figure 4.4-1. Soil samples were collected from six of the borings at four depth intervals: surface to 0.5 ft., 3 to 4.5 ft., 6 to 7.5 ft., and 8.5 to 10 ft. Samples from the remaining four borings were taken at the same depth intervals except that the sample from the 8.5 to 10 ft. interval was eliminated due to caving and sloughing which occurred at the base of the borings.

The results of lead analysis of the soil boring samples are given in Table 4.1-2. As shown, the lead contamination is principally confined to the surface soils (surface to 0.5 ft. depth interval). The lead concentration for each sample depth interval averaged over all 10 soil borings is as follows:

<u>Depth Interval</u>	<u>Lead Concentration (mg/kg)</u>
Surface to 0.5 ft.	16,103
3 to 4.5 ft.	255
6 to 7.5 ft.	274
8.5 to 10 ft.	509

These results indicate that, while there are very high lead levels in the surficial soils, the lead apparently is not migrating vertically through the soil column. Due to its ionic nature, lead is strongly adsorbed to soils, especially soils exhibiting a high clay content.

Table 4.1-2 Lead Concentrations in Soil Boring Samples Collected In the DRMO Area

Sample Matrix	Soil Sampling Location (See Fig. 3.2-1)	Sample Depth (ft.)	Lead Concentration (mg lead/kg soil)*
Soil Boring No. 1			
Soil	B1-S	Surf. - 0.5	4,040
Soil	B1-1	3 - 4.5	3.85
Soil	B1-2	6 - 7.5	1.3
Soil	B1-3	8.5 - 10	2.63
Soil Boring No. 2			
Soil	B2-S	Surf. - 0.5	5,000
Soil	B2-1	3 - 4.5	101
Soil	B2-2	6 - 7.5	2.13
Soil	B2-3	8.5 - 10	6.98
Soil Boring No. 3			
Soil	B3-S	Surf. - 0.5	5,600
Soil	B3-1	3 - 4.5	64.2
Soil	B3-2	6 - 7.5	24.4
Soil	B3-3	8.5 - 10	17.5
Soil Boring No. 4			
Soil	B4-S	Surf. - 0.5	48,600
Soil	B4-1	3 - 4.5	1,310
Soil	B4-2	6 - 7.5	411
Soil	B4-3	8.5 - 10	2,480
Soil Boring No. 5			
Soil	B5-S	Surf. - 0.5	39,200
Soil	B5-1	3 - 4.5	49
Soil	B5-2	6 - 7.5	34.1
Soil Boring No. 6			
Soil	B6-S	Surf. - 0.5	6,430
Soil	B6-1	3 - 4.5	14.2
Soil	B6-2	6 - 7.5	346
Soil Boring No. 7			
Soil	B7-S	Surf. - 0.5	29,500
Soil	B7-1	3 - 4.5	536
Soil	B7-2	6 - 7.5	1,090
Soil Boring No. 8			
Soil	B8-S	Surf. - 0.5	2,780
Soil	B8-1	3 - 4.5	174
Soil	B8-2	6 - 7.5	<1.3

Table 4.1-2 Lead Concentrations in Soil Boring Samples Collected In the DRMO Area (continued)

Sample Matrix	Soil Sampling Location (See Fig. 3.2-1)	Sample Depth (ft.)	Lead Concentration (mg lead/kg soil)*
<hr/>			
Soil Boring No. 9			
Soil	B9-S	Surf. - 0.5	3,820
Soil	B9-1	3 - 4.5	42.9
Soil	B9-2	6 - 7.5	11.3
Soil	B9-3	8.5 - 10	39.7
Soil Boring No. 10			
Soil	B10-S	Surf. - 0.5	518
Soil	B10-1	3 - 4.5	48.1
Soil	B10-2	6 - 7.5	3.95
Soil	B10-3	8.5 - 10	1.62

Source: ESE, 1986

* Dry-weight Basis

Two soil samples (SS26 and SS28) having the highest lead concentrations were tested using the extraction procedure (EP) to determine the hazard characteristic as defined in 40 CFR 261. The EP test simulates the leaching a solid waste would undergo if disposed in a landfill. The following EP test results were obtained for the two soil samples:

<u>Sample No.</u>	<u>Total Lead Concentration</u> <u>mg/kg</u>	<u>Extract Lead</u> <u>Concentration</u> <u>mg/l</u>
SS26	371,000	60.8
SS28	107,000	113

Since the extract concentrations are greater than the 5 mg/l specified in 40 CFR 261, these soil samples are classified as hazardous and, therefore, would require handling and disposal as a hazardous waste.

4.2 BUILDING DUST SAMPLES

A total of 35 wipe samples were collected from within Buildings 1606, 1607, 1608A, 1612, 1613, 1627, and 2521. Five samples were collected from each building; sampling locations are shown in Figures A-1 through A-8 in the Appendix. Sampling location points generally were selected to characterize the vertical depositional profile (e.g. top of light fixtures, locker tops, desk tops, and backs of chairs).

The analytical results of the building dust wipe samples are given in Table 4.2-1. All concentrations are expressed in units of mg lead per 100 cm² of surface area. As shown in Table 4.2-1, highest concentrations of lead were found in dust collected from the top of light fixtures (Bldgs. 1607 and 1612) and the top of a tool shed in Bldg. 1613. These sample points represent primary depositional and dust accumulation areas. Additionally, these three buildings are nearest to the areas having the highest soil lead concentrations. Activity in the DRMO materials storage area generates fugitive dust derived from the lead-contaminated soils which is then deposited and accumulates as dust in these buildings.

Table 4.2-1 Lead Concentrations In Dust Samples Collected In DRMO Buildings

Sample Matrix	Sample No. (See Figs. A-1 to A-8)	Location	Lead Concentration (mg/100 cm ²)
Building No. 1612			
Building-Wipes	Wipe 1	Locker Top	1.3
Building-Wipes	Wipe 2	Wall	0.8
Building-Wipes	Wipe 3	Light Fixture	3.4
Building-Wipes	Wipe 4	Wall	<0.1
Building-Wipes	Wipe 5	Basin Top	<0.1
Building No. 1606			
Building-Wipes	Wipe 6	Wall	<0.1
Building-Wipes	Wipe 7	Wall	0.2
Building-Wipes	Wipe 8	Wall	0.3
Building-Wipes	Wipe 9	Desk Top	0.1
Building-Wipes	Wipe 10	Wall	<0.1
Building No. 1607			
Building-Wipes	Wipe 11	Light Fixture	6.8
Building-Wipes	Wipe 12	Table Top	<0.1
Building-Wipes	Wipe 13	Wall	1.5
Building-Wipes	Wipe 14	Bin	0.1
Building-Wipes	Wipe 15	Wall	2.0
Building No. 1608A			
Building-Wipes	Wipe 16	Window Sill	0.6
Building-Wipes	Wipe 17	Desk	0.7
Building-Wipes	Wipe 18	Wall	0.6
Building-Wipes	Wipe 19	Wall	1.7
Building-Wipes	Wipe 20	Wall	0.2
Building No. 1613			
Building-Wipes	Wipe 21	Tool Shed	5.4
Building-Wipes	Wipe 22	Storage Rack	1.7
Building-Wipes	Wipe 23	Wall	1.0
Building-Wipes	Wipe 24	Wall	<0.1
Building-Wipes	Wipe 25	Bench Top	0.4
Building No. 2521			
Building-Wipes	Wipe 26	Light Fixture	<0.1
Building-Wipes	Wipe 27	Chair Back	<0.1
Building-Wipes	Wipe 28	Window Sill	0.6
Building-Wipes	Wipe 29	Light Fixture	<0.1
Building-Wipes	Wipe 30	Wall	<0.1

Table 4.2-1: Lead Concentrations In Dust Samples Collected In DRMO Buildings (continued)

Sample Matrix	Sample No. (See Figs. A-1 to A-8)	Location	Lead Concentration (mg/100 cm ²)
Building No. 1627			
Building-Wipes	Wipe 31	Wall	0.8
Building-Wipes	Wipe 33	Wall	0.1
Building-Wipes	Wipe 34	Wall	<0.1
Building-Wipes	Wipe 35	Wall	<0.1
Building-Wipes	Wipe 50	Wall	<0.1

Source: ESE, 1986

Prior to the extraction and analysis for lead, the building wipe samples were weighed to determine total mass of dust collected. This was performed in order to estimate the lead concentrations in the dust samples on a mass per mass basis. Based on the total mass of dust collected on the wipes and the measured lead levels, the concentrations of lead in the dust on the light fixtures and tool shed ranged from 10,000 to 100,000 mg lead/kg dust. These concentrations are typical of the lead levels measured in the adjacent soils (see Section 4.1).

4.3 AMBIENT AIR

Ambient air sampling was conducted during the site investigation (Dec. 9-12, 1985) both outdoors, in the materials storage area, and indoors, within seven buildings located within the DRMO site. Outdoor ambient air samples were collected using high volume (Hi-Vol) collectors which were located at a point directly in the area of the visual soil contamination and at a point downwind of this area. The Hi-Vol sampling locations are shown in Figure 3.2-2. Two ambient air Hi-Vol samples were collected at both locations during the site investigation.

Indoor ambient samples were obtained using personnel samplers calibrated prior to field deployment. In general, indoor air samples were collected near the center of each of the designated buildings (Bldgs. Nos. 1606, 1607, 1608A, 1612, 1613, 1627, and 2521). Figures A-1 through A-8 in the Appendix show the air sampling locations in each building.

The results of the ambient air sampling are given in Table 4.3-1. The lead concentrations are expressed in units of μg lead per cubic meter of air. As shown by the data in Table 4.3-1, the measured ambient air lead levels did not exceed OSHA, NIOSH, or ACGIH recommended occupational criteria (30 to 50 $\mu\text{g}/\text{m}^3$). One outdoor Hi-Vol sample (HVD2-1) did exhibit a lead level (2 $\mu\text{g}/\text{m}^3$) slightly above the National Ambient Air Quality Standard (1.5 $\mu\text{g}/\text{m}^3$). Apparently, lead contaminated dust is being dispersed from the primary contamination source (Bin No. 3) and is accumulating in soils in the area as well as in dust in the adjacent buildings. The levels in the air, however, were (at the time of sampling) within occupational criteria.

Table 4.3-1 Lead Concentrations in Indoor and Outdoor Ambient Air in the DRMO Area

Sample Matrix	Sample No.	Lead Concentration ($\mu\text{g}/\text{m}^3$)
Outside-Air	HVD1-1	<1
Outside-Air	HVD1-2	<1
Outside-Air	HVD2-1	2
Outside-Air	HVD2-2	1
Building-Air	AA1606 (Office) (Fig. A-1)	<20
Building-Air	AA1606 (Warehouse) (Fig. A-2)	<20
Building-Air	AA1607 (Fig. A-3)	<20
Building-Air	AA1608A (Fig. A-4)	<20
Building-Air	AA1612 (Fig. A-5)	<20
Building-Air	AA1613 (Fig. A-6)	<20
Building-Air	AA1627 (Fig. A-7)	<20
Building-Air	AA2521 (Fig. A-8)	<20

Source: ESE, 1986

4.4 HEALTH EFFECTS ASSESSMENT FOR LEAD AND EXISTING CRITERIA

This section briefly summarizes health effects associated with exposure to lead. The existing occupational and environmental criteria that have been established for lead also are described.

4.4.1 Toxicity Assessment For Lead

The two most common routes of entry of lead into the body are through the gastrointestinal tract and the respiratory tract. The amount of lead absorbed from the gastrointestinal tract is greatly influenced by the dietary levels of numerous substances including iron, calcium, fats, and proteins (Baritrop and Khoo, 1975). The vast majority of body lead is stored in the bones (adults = 90 to 95 percent; children = 70 percent) (Barry, 1975). Excretion in adults is mostly by urinary functions; however, in children, the dominant route is in the feces (Rabinowitz et al., 1973).

Toxic effects of lead exposure in humans and animals include damage to the brain and the central nervous system, kidneys, and the hematopoietic system (Hamond and Beliles, 1980). Chronic exposure can cause lead encephalopathy, which may result in permanent brain damage. Low levels of lead exposure in children may cause clinically undetectable, permanent learning disabilities, whereas moderate exposure levels [equivalent to blood lead levels between 40 to 80 micrograms (μg) per 100 milliliters (mL)] may cause diminished performance in psychoemetric performance and neurological tests (Bornschein et al., 1980). High-concentration exposure may cause progressive renal damage and possible renal failure. In a separate study, lead was shown to be carcinogenic in mice and rats; however, the evidence was not sufficiently conclusive to evaluate its carcinogenicity in humans.

Due to toxic effects associated with lead exposure, criteria for lead in air and water have been established by the federal government to protect humans and the environment. The following paragraphs describe the existing lead criteria.

4.4.2 Occupational Air Quality Criteria

Occupational Safety and Health Administration (OSHA) criteria for lead have been developed for worker exposure in an industrial setting. The OSHA standard is 50 $\mu\text{g}/\text{m}^3$ of lead, based on an 8-hour-per-day, 40-hour-work-week time-weighted average (TWA) (29 CFR 1910.1025). The American Conference of Governmental Industrial Hygienists (ACGIH) also has established a workplace threshold limit value (TLV) of 50 $\mu\text{g}/\text{m}^3$ (ACGIH, 1985). The industrial air criteria presuppose exposure of a less-sensitive population (i.e., adults) for a limited number of hours (8 hours per day); therefore, the occupational criteria are greater than the ambient air criteria to which the general population are exposed for 24 hours per day.

4.4.3 Ambient Air Quality Standards

EPA has established National Primary and Secondary Ambient Air Quality Standards. Primary standards define levels of air quality which EPA judges are necessary to protect public health. Secondary standards define levels of air quality which EPA judges are necessary to protect public welfare from any known or anticipated adverse effects of a pollutant. EPA has established an outdoor ambient air primary and secondary criterion for lead of 1.5 $\mu\text{g}/\text{m}^3$ (40 CFR 50.12).

4.4.4 Ambient Water Quality Criteria

EPA has established a National Interim Primary Drinking Water (NIPDW) maximum contaminant level (MCL) of 50 $\mu\text{g}/\text{L}$ for lead (EPA, 1985). The State of South Carolina DHEC has adopted this criterion as the state primary drinking water criterion. This criterion of 50 $\mu\text{g}/\text{L}$ for lead is also the standard set by DHEC for Class GB ground water.

The lead criterion to protect freshwater aquatic life (EPA, 1980) is an exponential function of water hardness given by:

$$\text{MCL (aquatic life)} = e\{1.22 [\ln (\text{hardness})] - 0.47\}$$

For a water hardness of 200 $\mu\text{g/L}$ as calcium carbonate, typical of Cooper River in the vicinity of NAVBASE Charleston, the aquatic life criterion for lead is 400 $\mu\text{g/L}$.

Table 4.4-1 summarizes the existing lead criteria in air and water. There are no criteria for lead in soils. The evaluation of a safe level of soil lead contamination developed in Section 5.0 is based on a consideration of exposure pathways and the existing occupational, air, and water criteria shown in Table 4.4-1.

Table 4.4-1 Criteria for Lead in the Workplace, in Ambient Air, Drinking Water, and for Protection of Aquatic Life

Occupational Air Criteria *	Ambient Air Criteria	Primary Drinking Water MCL	Ambient Water Quality Criteria †
50 $\mu\text{g}/\text{m}^3$	1.5 $\mu\text{g}/\text{m}^3$	50 $\mu\text{g}/\text{l}$	400 $\mu\text{g}/\text{l}$

* Based on an 8-hour-per-day, 40-hour work week

† Based on an ambient water hardness of 100 mg/l as CaCO_3

5.0 REMEDIAL RESPONSE OBJECTIVES AND EVALUATION OF SAFE LEVELS OF RESIDUAL LEAD CONTAMINATION

This section describes the evaluation of the concentration of lead in soil and dust that represents a "maximum safe contaminant level". Comparison of this "maximum safe contaminant level" with the lead concentrations actually observed during the site investigation (Section 4.0) will be the basis for recommending the performance of a focused feasibility study and remedial action.

As described in Section 4.0, onsite soils and soil-derived dust within several of the DRMO buildings contain elevated levels of lead. The lead in these soils and dust present a potential for human exposure and/or environmental degradation. The determination of a lead level that represents an acceptable level of risk to human health and the environment must take into consideration several factors, including:

1. Known or suspected health and environmental effects of lead;
2. The routes of human and environmental exposure to the lead contamination (e.g., inhalation, ingestion, entrainment in ambient air, leaching to ground water);
3. Existing Federal and State of South Carolina Department of Health and Environmental Control (DHEC) criteria; and
4. The type of contaminated media (i.e., soils, suspended particulate, or dust).

Figure 5.0-1 is a schematic representation of the potential for environmental endangerment, including occupational exposure to workers, degradation of ambient air quality, and degradation of ground water quality. The evaluation of a safe level of residual lead contamination described in this section is based on the exposure pathways shown in Figure 5.0-1.

5.1 REMEDIAL RESPONSE OBJECTIVES

The evaluation of a "maximum safe contaminant level" for lead is based upon the following set of objectives for remediation:

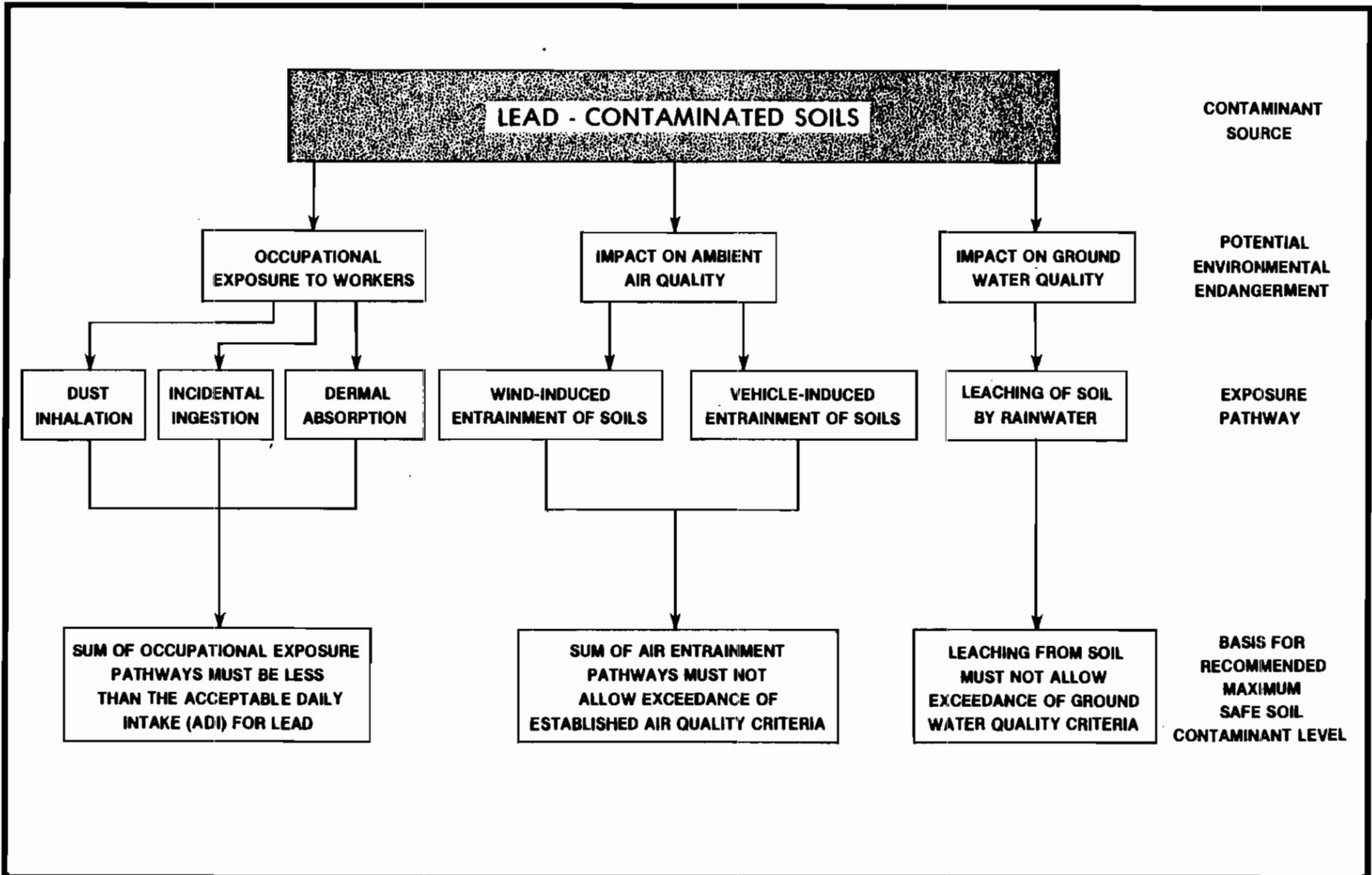


Figure 5.0-1
POTENTIAL ENVIRONMENTAL ENDANGERMENT, EXPOSURE
PATHWAYS, AND BASIS FOR RECOMMENDED MAXIMUM SAFE
SOIL CONTAMINANT LEVEL

SOURCE: ESE, 1986.

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1. Upon completion of remediation, workers in the DRMO area should not be exposed to contamination levels which pose a significant health risk;
2. Air quality within the DRMO area should not exceed ambient air quality standards; and
3. Ground water should not exceed water quality criteria.

It should be noted that ground water resources in the DRMO area are not currently used for potable supply. The area is served by a municipal supply. The ground water, however, represents a potential future resource and, as such, is classified by the State of South Carolina DHEC as a Class GB ground water. The ground water, therefore, should not exceed the primary drinking water criterion for lead. Additionally, the shallow ground water potentially discharges into the Cooper River, which has been classified by the State of South Carolina DEHC as a Class SC surface water suitable for propagation and survival of aquatic fauna and flora. The discharge of water into Cooper River from the DRMO site therefore should not exceed the ambient water quality criteria for lead.

5.2 EVALUATION OF A SAFE LEVEL OF RESIDUAL LEAD CONTAMINATION

The lead contamination in soils and building dust in the DRMO area was documented during the sampling and analysis investigation (Section 4.0). This lead contamination presents a potential for direct exposure to workers in the DRMO area via inhalation, incidental ingestion, and dermal absorption. In addition, the lead-contaminated soils also pose a potential for wind- and/or vehicular-induced entrainment in air with resultant exceedence of ambient air quality lead standards and pose a potential for leaching from the soils by percolating rainwater with resultant exceedence of ground water quality lead standards (see Figure 5.0-1). This section describes in detail the development of a "maximum safe contaminant level" for lead in soils or dust that should not pose a potential for either risk to human health or environmental degradation.

5.2.1 Occupational Exposure to Workers

As described in Section 4.4, no criteria have been developed for lead in soils or dust; therefore, a "maximum safe contaminant level" was developed based on the Preliminary Pollutant Limit Value (PPLV) methodology developed by researchers at the U.S. Army Medical Bioengineering Research and Development Laboratory (USAMBRDL) (Rosenblatt et al., 1980; Dacre et al., 1980). The PPLV methodology represents an approach to criteria development based on a site- and scenario-specific exposure and risk assessment technique. In general, the PPLV methodology involves the following steps:

1. The pollutant (in this case, lead) and exposure pathways are determined. Figure 5.0-1 shows the exposure pathways for the DRMO site.
2. An acceptable daily intake (ADI) of toxicant (D_T) and partition (intermedia transfer) coefficients are determined.
3. Relevant data are gathered from the literature.
4. Single pathway preliminary pollutant limit values (SPPPLV) are calculated for each exposure pathway.

Each significant source-to-receptor pathway is quantified and the effects combined to ensure that an exposed individual will not receive an unacceptably large dose. Intermediate results of the methods (SPPPLV) represent residual levels of contamination that would be safe if only that single pathway were operating. Several exposure pathways are combined by the following equation:

$$PPLV = \frac{1}{\frac{1}{SPPPLV(1)} + \frac{1}{SPPPLV(2)} + \dots + \frac{1}{SPPPLV(N)}}$$

where: PPLV = combined concurrent exposure from N pathways, and
SPPPLV = exposure from a single pathway (e.g., Pathway
No. 1, No. 2, etc.)

A maximum intake level (ADI) of 600 µg of lead per day has been recommended (Kehoe, 1966) as safe for the majority of adults. This is the maximum lead exposure the average adult can tolerate without increased body burden, as reflected in elevated blood lead levels. Estimated lead intakes by adults from dietary sources must be deducted from this level. Water and beverages provide approximately 25 µg of lead per day (NAS, 1977), and other dietary components, primarily fruits, grains, and cereal products provide an additional 40 µg of lead per day (Kolbye et al., 1974). This leaves a maximum of 535 µg of lead per day for intake from exposure to other sources. This converts to an annual basis as follows:

$$D_T(\text{annual}) = \frac{535 \text{ } \mu\text{g lead}}{\text{day}} \times \frac{365 \text{ days}}{\text{year}} \times \frac{1 \text{ mg}}{1,000 \text{ } \mu\text{g}} = \frac{195 \text{ mg lead}}{\text{year}}$$

This yields a maximum allowable intake of 195 mg of lead per year from non-dietary sources (e.g., occupational exposure).

5.2.1.1 Inhalation Exposure Pathway

When workers are exposed to dust, each may be exposed to as much as 10 mg dust/m³. This specific value is the TLV for nuisance dust in workroom air (ACGIH, 1985). Because such a concentration of dust would be considered rather extreme outdoors or in nonindustrial surroundings, it is used in the PPLV calculation as a conservative (i.e., worst-case) estimate for worker exposure. A typical worker is assumed to work a 5-day, 8-hour-per-day week and work 250 days per year. The work day breathing rate is 12.1 m³ of air per 8-hour work day. The maximum dust respired per year, therefore, is calculated as follows:

$$\frac{10 \text{ mg dust}}{\text{m}^3} \times \frac{12.1 \text{ m}^3}{\text{day}} \times \frac{250 \text{ work days}}{\text{year}} \times \frac{1 \text{ kg}}{10^6 \text{ mg}} = \frac{0.03 \text{ kg dust}}{\text{year}}$$

Assuming the inhaled dust (0.03 kg/year) is derived from the lead-contaminated soils in the DRMO area, the maximum safe soil lead concentration to protect workers from exposure to the maximum allowable intake (195 µg of lead per year) via the inhalation pathway is:

$$\text{SPPPLV (inhalation)} = \frac{195 \text{ mg lead}}{\text{year}} \div \frac{0.03 \text{ kg dust}}{\text{year}} = 6,500 \frac{\text{mg lead}}{\text{kg dust}}$$

This concentration of lead in soil is the maximum level allowable to protect workers from inhalation of dust that is derived from the lead-contaminated soils in the area and not exceed the maximum allowable intake of lead (195 mg per year).

In addition to the above calculation, involving assumptions of workdays and maximum allowable lead intake, a safe concentration of lead in soil via the inhalation exposure pathway can be estimated by simply comparing the OSHA criteria for lead in air in the workplace (50 µg/m³; see Section 4.4) and the TLV for nuisance dust in air in the workplace (10 mg/m³). For a lead level of 50 µg lead/m³ to be maintained by airborne dust of 10 mg soil/m³ air concentration, a soil lead level of 5,000 mg lead/kg soil concentration is required. This is comparable to the 6,500 mg lead/kg soil concentration calculated above using pathway model assumptions of workdays and maximum allowable lead intake.

5.2.1.2 Incidental Ingestion Exposure Pathway

It has been estimated (Ford and Gurba, 1984) that approximately 1 x 10⁻⁴ kg of soil per day may be ingested through incidental contact (e.g., hands, food wrappers, and smoking materials). This results in an annual workplace ingestion of:

$$\frac{1 \times 10^{-4} \text{ kg soil}}{\text{day}} \times \frac{250 \text{ work days}}{\text{year}} = \frac{0.025 \text{ kg soil}}{\text{year}}$$

To protect workers from ingesting an amount of lead above the maximum allowable intake (195 mg of lead per year), the maximum residual soil lead concentration would be:

$$\text{SPPPLV (ingestion)} = \frac{195 \text{ mg lead}}{\text{year}} \div \frac{0.025 \text{ kg soil}}{\text{year}} = \frac{7,800 \text{ mg lead}}{\text{kg soil}}$$

Because both the inhalation and ingestion pathways of worker exposure act concurrently, the resulting total acceptable maximum level of soil contamination for occupational exposure is:

$$\begin{aligned} \text{PPLV (inhalation + ingestion)} &= \frac{1}{\frac{1}{\text{SPPPLV (inhalation)}} + \frac{1}{\text{SPPPLV (ingestion)}}} \\ &= \frac{1}{\frac{1}{\frac{6,500 \text{ mg lead}}{\text{kg soil}}} + \frac{1}{\frac{7,800 \text{ mg lead}}{\text{kg soil}}}} = \frac{3,545 \text{ mg lead}}{\text{kg soil}} \end{aligned}$$

This means that cleanup of contaminated soils greater than 3,500 mg lead/kg soil should result in protection of workers in the DRMO area from any adverse health effects due to lead.

5.2.1.3 Dermal Absorption Pathway

As shown in Figure 5.0-1, occupational worker exposure to the lead-contaminated soils may occur through three pathways: (1) inhalation of soil-derived dust; (2) incidental ingestion via contamination of hands, food wrappers, smoking materials, etc.; and (3) dermal absorption. The previous two sections (5.2.1.1 and 5.2.1.2) determined the maximum soil contamination to protect workers via the inhalation and ingestion pathways (3,500 mg lead/kg soil). The dermal absorption pathway is not

considered important in this case because the dose necessary for toxic effects through skin absorption of inorganic contaminants (e.g., lead) is significantly greater than for inhalation or ingestion.

5.2.2 Protection of Ambient Air Quality

The previous section described the rationale for recommendation of a safe residual level of lead in soil to protect workers from occupational exposure to lead in the DRMO Area. Since fugitive dust generated by wind and vehicular activity in the DRMO Area can be transported offsite (i.e., outside the DRMO Area), the protection of ambient air quality also must be considered (see Figure 5.0-1). The following paragraphs describe the calculation of emission rates for fugitive dust due to wind and vehicular activity in the DRMO Area. These emission rates are then summed and a gaussian plume model is used to estimate concentration profiles for the dust in the downwind direction.

The action of wind on the exposed soil in the DRMO Area will result in emissions of suspended particulates. The uncontrolled emission due to wind erosion from disturbed soil is given by the following empirical equation (EPA, 1978; 1979):

$$EF(\text{wind}) = \frac{3400 \left(\frac{e}{50}\right) \left(\frac{s}{15}\right) \left(\frac{f}{25}\right)(A)}{0.02 PE^2}$$

where EF(wind) = emission of suspended particulates due to wind erosion (lbs/yr)

e = erodibility factor (tons/acre/yr)

s = percent silt content of soil (%)

f = percent of time that wind speed exceeds 12 miles per hr. (mph)

A = area of exposed surface (acres)

PE = Thornwaite's precipitation - evaporation index (unitless)

For the soil type in the DRMO Area, the erodibility factor (e) is 56 tons/acre/yr (Jutze and Axetell, 1976), the percent silt content is 15 percent, the percent of time that the wind exceeds 12 mph in the Charleston, S.C. area is 27 percent, the exposed area with lead contamination is approximately 6 acres, and the precipitation-evaporation index for Charleston, S.C. is 92 (this is a measure of soil moisture based on precipitation and evaporation rates). Substituting these values into the equation yields:

$$EF(\text{wind}) = \frac{3400 \left(\frac{56}{50}\right) \left(\frac{15}{15}\right) \left(\frac{27}{25}\right) (6)}{0.02 (92)^2}$$

$$= 146 \text{ lbs dust/yr or } 0.4 \text{ lbs dust/day}$$

Vehicle activity in the DRMO Area also will result in emission of suspended particulate from the unpaved surface. Emission factors due to vehicle activity on unpaved roads have been derived from tests performed on dirt roads or roads surfaced with gravel or crushed slab (EPA, 1978; 1979). These factors contain terms incorporating vehicle speed, vehicle weight, soil silt content, number of dry days per year, and number of vehicle tires. The following empirical equation is used to estimate suspended particulate emissions from unpaved roads (EPA, 1979):

$$EF (\text{vehicles}) = 5.9 \left(\frac{s}{12}\right) \left(\frac{S}{30}\right) \left(\frac{W}{3}\right)^{0.7} \left(\frac{w}{4}\right)^{0.5} \left(\frac{365-P}{365}\right)$$

where: EF (vehicles) = emission of particulates due to vehicles
(lbs per vehicle mile traveled)

s = percent silt content (%)

S = mean vehicle speed (MPH)

W = Mean vehicle weight (tons)

w = number of wheels

p = number of days with at least 0.01 inches of
precipitation per year

For the soil type in the DRMO Area, the silt content is 15 percent. Vehicles traveling in the area are trucks, cars, fork lifts, etc. Due to the congested area, a mean vehicle speed of 5 mph was assumed. A mean vehicle weight of 2 tons with 4 wheels per vehicle also was assumed. For the Charleston, S.C. area, 0.01 inches of precipitation occurs on the average of 120 days per year. Substituting these values into the above equation yields:

$$\begin{aligned} \text{EF (vehicles)} &= (5.9) \frac{15}{12} \frac{5}{30} \frac{2^{0.7}}{3} \frac{4^{0.5}}{4} \frac{365 - 120}{365} \\ &= 0.62 \text{ lbs. dust per vehicle mile travelled} \end{aligned}$$

Assuming an average of 10 vehicle miles travelled per day for all vehicles using the area of contaminated soils yields:

$$\begin{aligned} \text{EF(vehicles)} &= (0.62 \text{ lbs. per vihecle miles travelled}) \times (10 \text{ vehicle miles per day}) \\ &= 6.2 \text{ lbs. dust/day} \end{aligned}$$

The total fugitive dust emission form the DRMO area due to both wind erosion and vehicular activity, therefore is estimated at approximately 7 lbs/day (0.4 + 6.2 lbs/day).

Using the above emission rate of 7 lbs dust/day due to combined wind and vehicular activity and an area source of 6 acres, a gaussian air dispersion model was used to estimate the ambient air concentration of dust downwind of the DRMO area. Dispersion modeling is an analytical tool used to relate pollutant emissions to airborne concentrations. Pollutants emitted into the air by a localized source become entrained in the ambient air flow and are carried downwind. Turbulent air motions will cause a parcel of polluted air to mix with the surrounding clean air, thereby reducing the pollutant concentration with travel time. A dispersion model mathematically simulates the downwind mixing of pollutants. The gaussian modeling technique is the basis for all air pollutant dispersion models currently in use.

The air dispersion modeling for DRMO site was performed by ESE's Air Resources Division using standard area source gaussian air dispersion models on ESE's Prime® 360 main frame computer. Several atmospheric stability scenarios were examined using a suspended particulate emission rate of 7 lbs per day (calculated above) and an area source of 6 acres. Since the installation boundary is approximately 100 meters (m) from the area of the DRMO site with the highest lead concentrations, the model scenarios were used to predict ambient air concentrations at a downwind distance of 100 m.

The results of the air dispersion modeling for fugitive dust generated by wind and vehicles in the DRMO Area are given in Table 5.2-1 as shown. Under worst-case atmospheric conditions (i.e., very stable atmosphere, hence little turbulent mixing and dilution), an air concentration of 10.8 $\mu\text{g}/\text{m}^3$ of suspended particulate is predicted.

As described in Section 4.4, the federal ambient air criterion for lead is 1.5 μg lead/ m^3 . For this level of lead to be maintained by airborne dust of 10.8 $\mu\text{g}/\text{m}^3$, a soil lead level of 140,000 mg lead/kg soil is

Table 5.2-1 Predicted Ambient Air Concentrations of Suspended Particulate Downwind of the DRMO Site at an Average Emission Rate of 7 lbs. per day.

Atmospheric Stability Class	Distance Downwind	Predicted 1-Hour Avg. Ambient Air concentrations of Suspended Particulate
A (very unstable)	100 M	1.0 $\mu\text{g}/\text{m}^3$
B (unstable)	100 M	1.6 $\mu\text{g}/\text{m}^3$
C (slightly unstable)	100 M	2.5 $\mu\text{g}/\text{m}^3$
D (neutral)	100 M	3.5 $\mu\text{g}/\text{m}^3$
E (slightly stable)	100 M	6.8 $\mu\text{g}/\text{m}^3$
F (very stable)	100 M	10.8 $\mu\text{g}/\text{m}^3$

Source: ESE, 1986

required. This means that clean-up of soils having concentrations of 140,000 mg lead/kg soil or greater would protect offsite air from exceedences of the federal ambient air lead criteria.

5.2.3 Protection of Groundwater Quality

This section describes the rationale for recommendation of a safe level of lead in soil to protect the quality of the shallow groundwater. The potential exists for infiltrating rainwater to leach lead from the contaminated soils with subsequent degradation of groundwater quality (see Figure 5.0-1). While the shallow groundwater is not currently utilized as a potable source in the vicinity of the DRMO, it does represent a potential usable future resource. Additionally, the shallow groundwater potentially discharges into the Cooper River, which is adjacent to the site.

Assuming infiltrating rainwater reaches equilibrium with the lead in the contaminated soils, the following relationship is applicable:

$$C_w = (K_{sw}) (C_s)$$

where: C_w = lead concentration in the infiltrating
rainwater (mg lead/l)

C_s = lead concentration in the soil (mg lead/kg
soil)

K_{sw} = partition coefficient between the soil and
water

The partition coefficient (K_{sw}) is a measure of the degree to which a pollutant (e.g. lead) adsorbs onto a solid substrate (e.g., soils). Since extractive procedure leaching studies were performed on the most highly lead-contaminated soil samples (see Section 4.1), an upper limit or worst-case partition coefficient can be estimated using site-specific data.

The extractive procedure was performed using a soil sample containing a total lead concentration of 371,000 mg lead/kg soil. The extractive procedure yielded a lead concentration of 61 mg lead/l in the extract. Using the above equation, a theoretical maximum partition coefficient can be calculated as follows:

$$C_w = K_{sw} C_s$$

$$(61 \text{ mg lead/l}) = K_{sw} (371,000 \text{ mg lead/kg soil})$$

$$K_{sw} = 1.6 \times 10^{-4}$$

It should be noted that the extractive procedure is a 24-hr. test performed in the laboratory and maintained under acidic conditions (solution pH = 4.5). Additionally, the sample is continuously mixed throughout the 24-hr. extraction. The partition coefficient derived above, therefore, does not represent the natural leaching of rainwater percolating through the in-situ soils. Assuming the partition coefficient based on the extractive procedure is a factor of 10 higher than would occur under natural conditions (for the reasons discussed above), an estimated partition coefficient for the rainwater-induced leaching of lead from the contaminated soils would be 1.6×10^{-5} .

The criterion for lead in groundwater is 0.05 mg lead/l, which is the primary drinking water MCL (see Section 4.4). Using this criterion and the partition coefficient derived above, a maximum soil lead level to protect groundwater can be calculated as follows:

$$C_w = K_{sw} C_s$$

$$0.05 \text{ mg lead/l} = (1.6 \times 10^{-5}) C_s$$

$$C_s = 3,100 \text{ mg lead/kg soil}$$

This is the maximum permissible level of lead in the soils in the DRMO Area that would be predicted to not result in an exceedence of the 0.05 mg lead/l criterion in the shallow groundwater. Since the aquatic life criterion for lead in surface water is 0.4 mg lead/l (i.e. greater than the drinking water MCL), this maximum permissible level of lead in soils would also protect the ambient surface water (Cooper River) from discharge of groundwater.

5.2.4 Comparison of Derived Safe Soil Lead Levels By the Various Exposure Pathways

Table 5.2-2 summarizes the maximum permissible soil lead levels derived for each exposure pathway. The values given in Table 5.2-2 are the maximum soil lead levels that would not be expected to result in a potential adverse effect to human health or environmental degradation via the specified exposure pathway. As shown, the lowest recommended soil lead level is approximately 3,000 mg lead/kg soil, therefore, clean-up of contaminated soils containing lead levels greater than 3,000 mg lead/kg soil would eliminate the potential for adverse effects to human health and/or environmental degradation.

Table 5.2-2. Maximum Permissible Soil Lead Levels Derived For Each Exposure Pathway

Exposure Pathway (See Fig. 5.0-1)	Recommended Maximum Permissible Soil Lead Level (mg lead/kg soil)
<hr/>	
<u>Occupational Exposure To Workers (Sec. 5.2-1)</u>	
Inhalation	6,500 ¹ ; 5,000 ²
Incidental Ingestion	7,800
Concurrent Inhalation + Ingestion	3,500
<u>Protection of Ambient Air Criterion (Sec. 5.2.2)</u>	140,000
<u>Protection of Groundwater Criterion (Sec. 5.2.3)</u>	3,100

¹ Based on workday and ADI assumptions

² Based on ratio of suspended particulate TLV and lead TLV

6.0 CONCLUSIONS

The sampling and analysis investigation and contamination assessment (Section 4.0) defined the extent of lead contamination at the DRMO site and within the DRMO buildings. The exposure and hazard assessment (Section 5.0) resulted in a determination of an appropriate response level for remedial decontamination action. The results of the contamination investigation and exposure assessment are summarized in the following paragraphs:

1. Soils in the DRMO area are contaminated with lead at levels ranging up to 300,000 mg/kg (30 percent). The lead contamination (1,000 mg/kg and higher) encompasses an area of approximately 6 acres.
2. The lead contamination is migrating areally due to generation of lead-contaminated dust by activities in the DRMO area and by runoff of stormwater. The lead contamination is confined to the surficial soils (surface to 1 ft.) and does not appear to be migrating vertically.
3. Dust within several of the DRMO buildings is contaminated with lead at levels ranging up to 100,000 mg/kg.
4. Indoor and outdoor ambient air data collected during the site investigation did not indicate lead levels above occupational criteria. One sample of outdoor air did contain lead at a level slightly above the National Ambient Air Quality Standard.
5. The exposure and hazard assessment resulted in the determination of a residual lead level (3,000 mg/kg) that would not pose a risk to human health or environmental degradation. Soil lead levels in some areas of the DRMO site and lead levels in building dust are greater than 3,000 mg/kg; therefore, the potential currently exists for adverse risk to human health and/or environmental degradation.

6.0 Results of Extractive Procedure (EP) testing of two soil samples having the highest concentrations of lead indicate that the soils are classified as hazardous according to 40 CFR 261 and, therefore, would require disposal in a permitted hazardous waste disposal facility.

7.0 RECOMMENDATIONS

The contamination investigation and exposure assessment has resulted in a determination that existing lead contamination in soils and dust present a potential risk to human health and/or environmental degradation.

Recommended actions are as follows:

1. Perform a focused Feasibility Study to determine the most effective and economical method of remediation. Remedial alternatives should include consideration of the following:
 - a) Soil excavation to 1 ft. depth within the area of the 1,000 mg/kg soil lead isopleth (Fig. 4.1-1). Following testing for hazardous characteristic, soil disposal would be offsite at a hazardous waste disposal facility.
 - b) Wet scrubbing/sweeping of the area of highest contamination in front (north) of the former bin storage area. Soil excavation to a depth of 1 ft. along the drainage way in back (south) of the bin area.
 - c) Installing an impervious covering (e.g. asphalt) over the area of contaminated soils.

2. Based on the focused Feasibility Study, implement remedial decontamination action of soils having lead concentrations greater than 1,000 mg/kg and accumulated dust in the DRMO buildings.

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APPENDIX

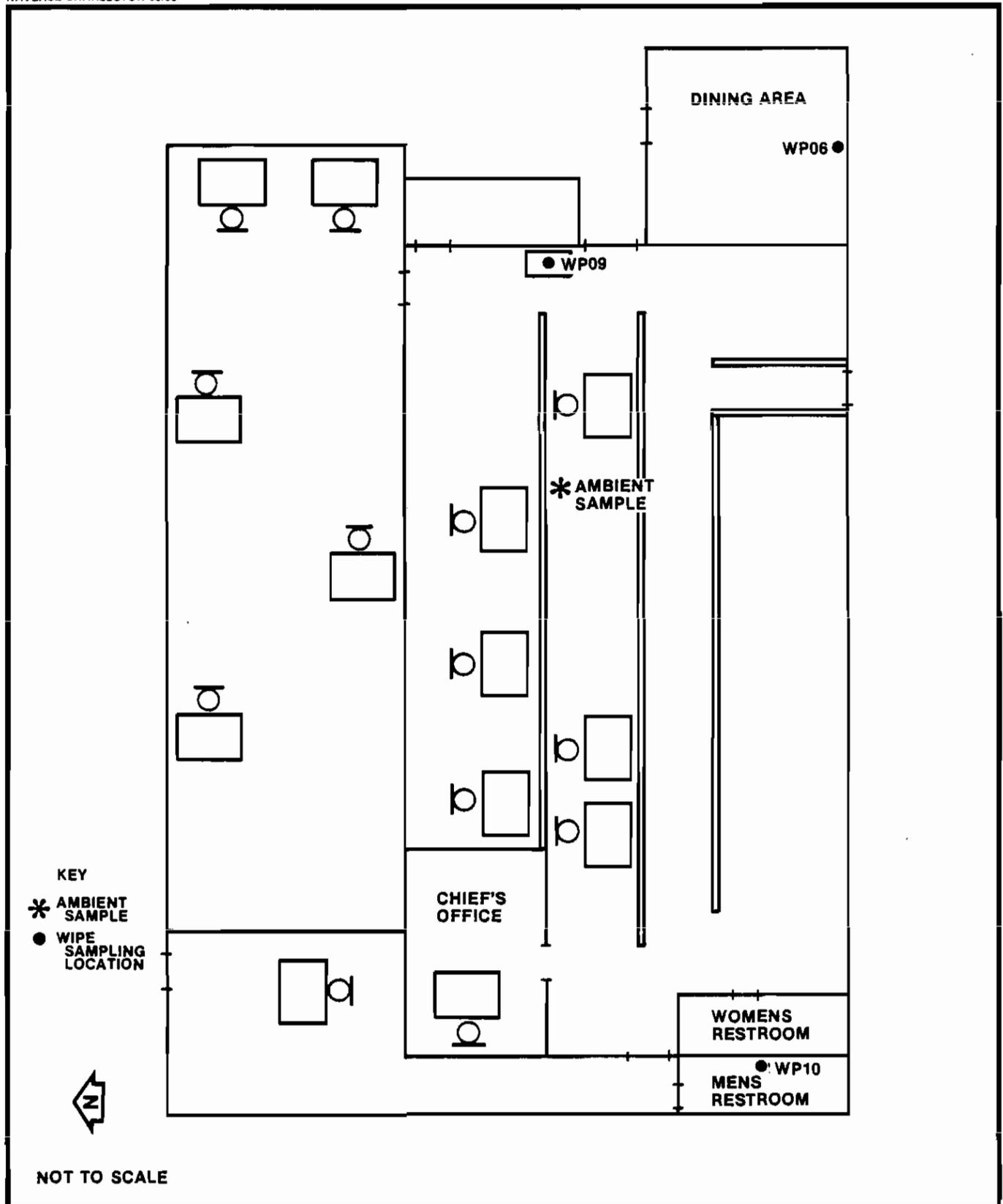


Figure A-1
BUILDING 1606, OFFICE AREA, AMBIENT AIR
SAMPLING POINTS AND WIPE SAMPLING
LOCATIONS

CONTAMINATION STUDY
NAVAL BASE CHARLESTON

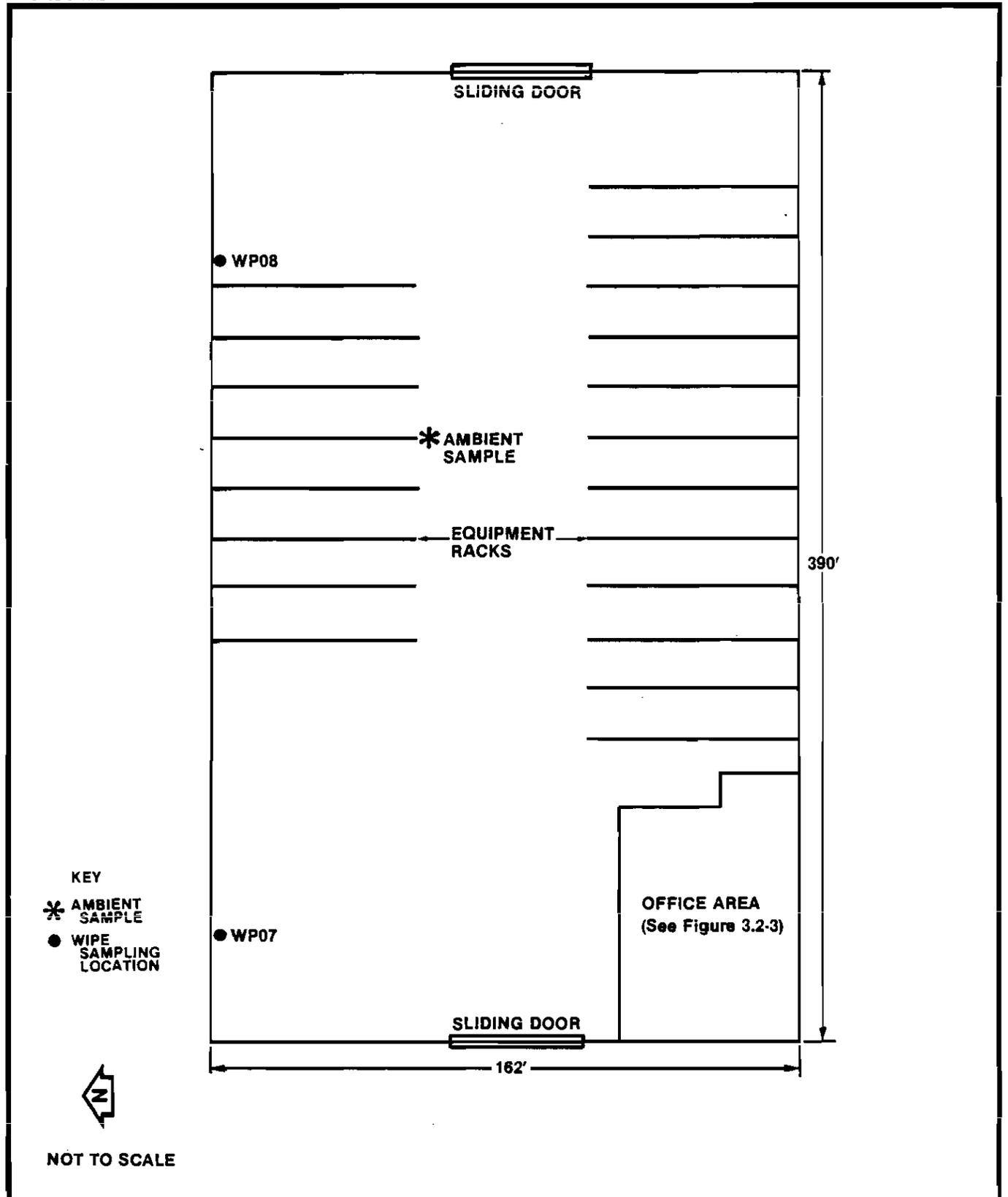


Figure A-2
BUILDING 1606, WAREHOUSE ISSUE SECTION,
AMBIENT AIR SAMPLING POINTS AND WIPE
SAMPLING LOCATIONS

CONTAMINATION STUDY
NAVAL BASE CHARLESTON

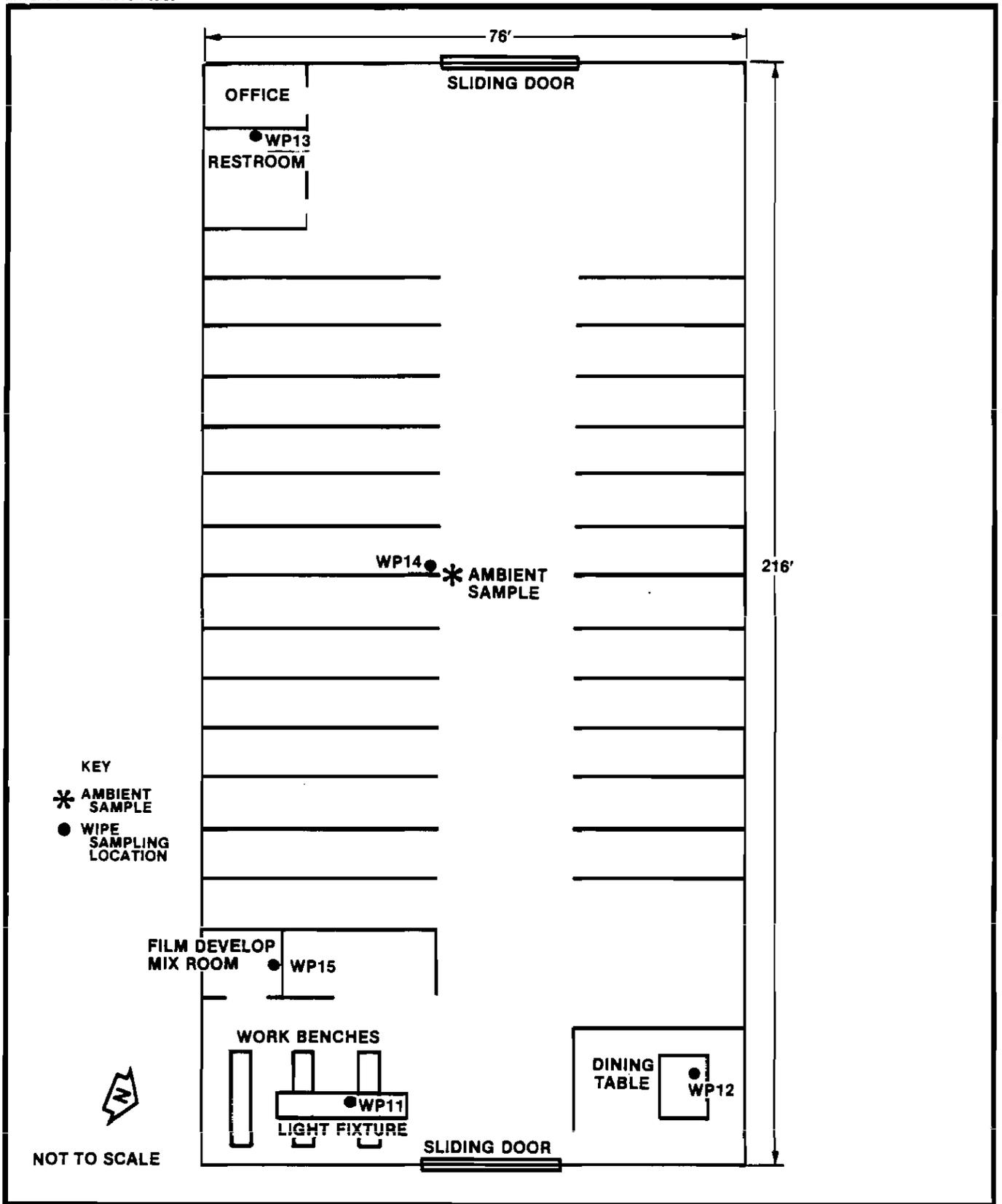


Figure A-3
BUILDING 1607, WAREHOUSE D, AMBIENT
AIR SAMPLING POINTS AND WIPE
SAMPLING LOCATIONS

CONTAMINATION STUDY
NAVAL BASE CHARLESTON

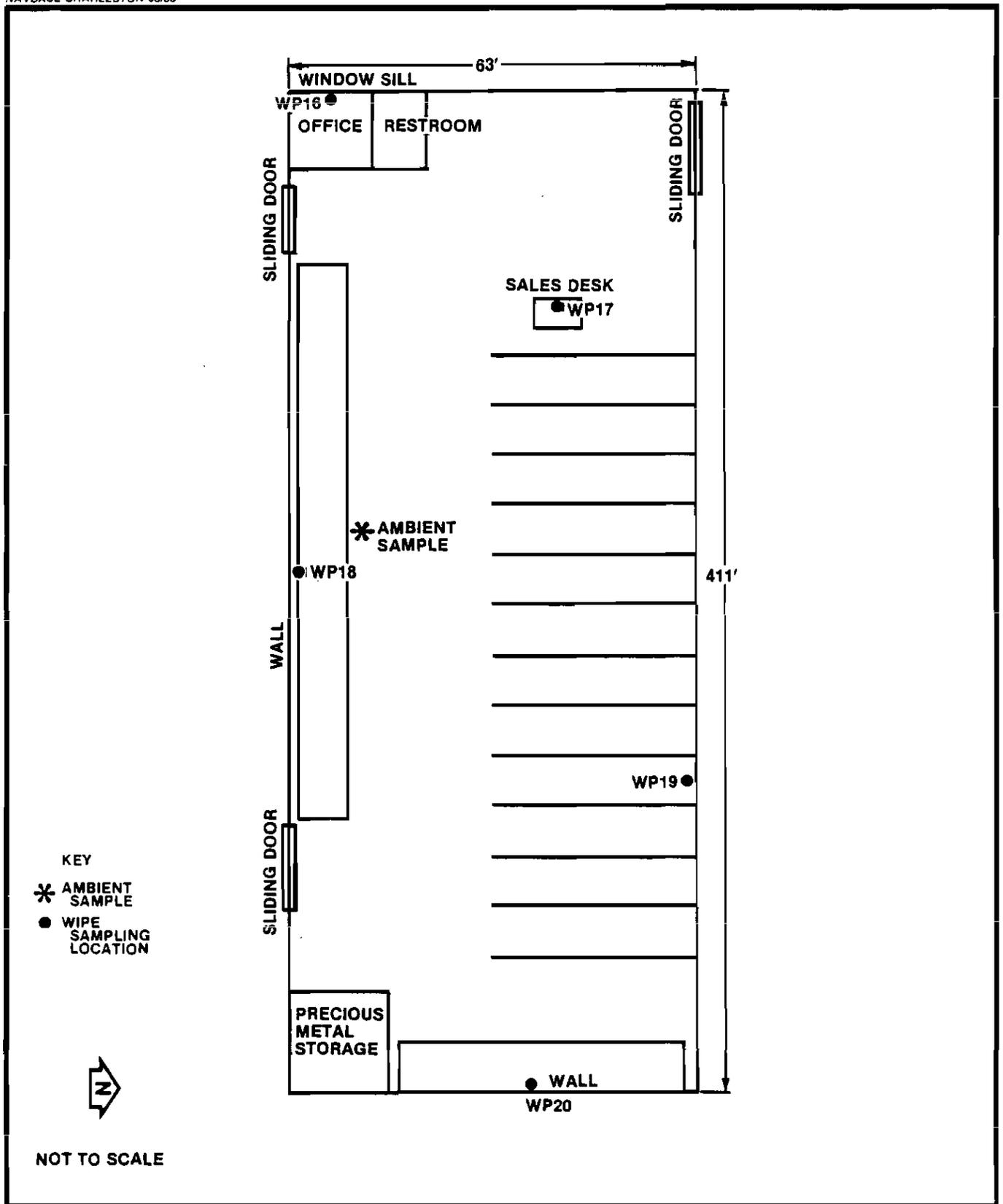


Figure A-4
BUILDING 1608A, SALES, AMBIENT AIR
SAMPLING POINTS AND WIPE SAMPLING
LOCATIONS

CONTAMINATION STUDY
NAVAL BASE CHARLESTON

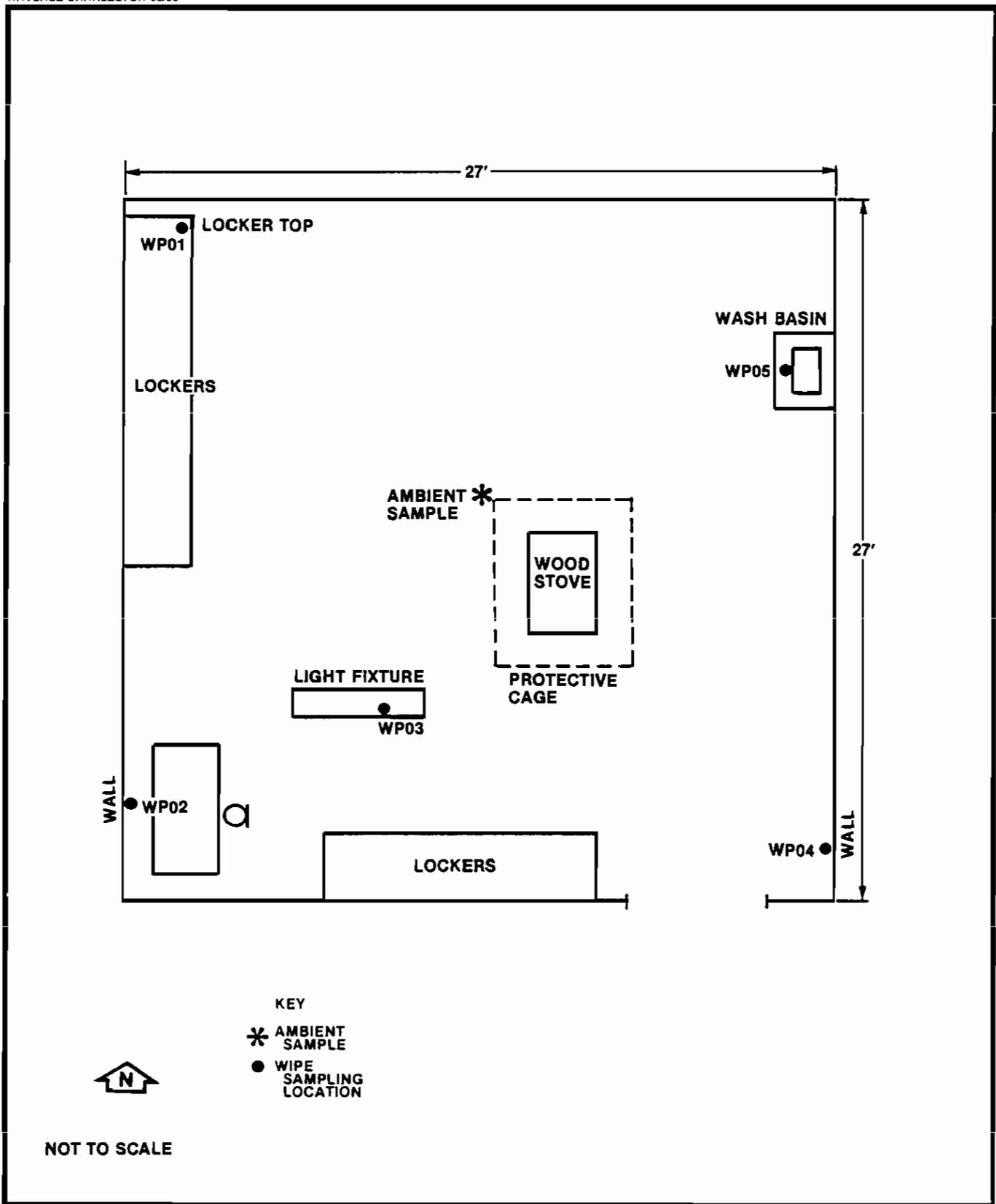


Figure A-5
BUILDING 1612, WARM-UP SHACK,
AMBIENT AIR SAMPLING POINTS
AND WIPE SAMPLING LOCATIONS

CONTAMINATION STUDY
NAVAL BASE CHARLESTON

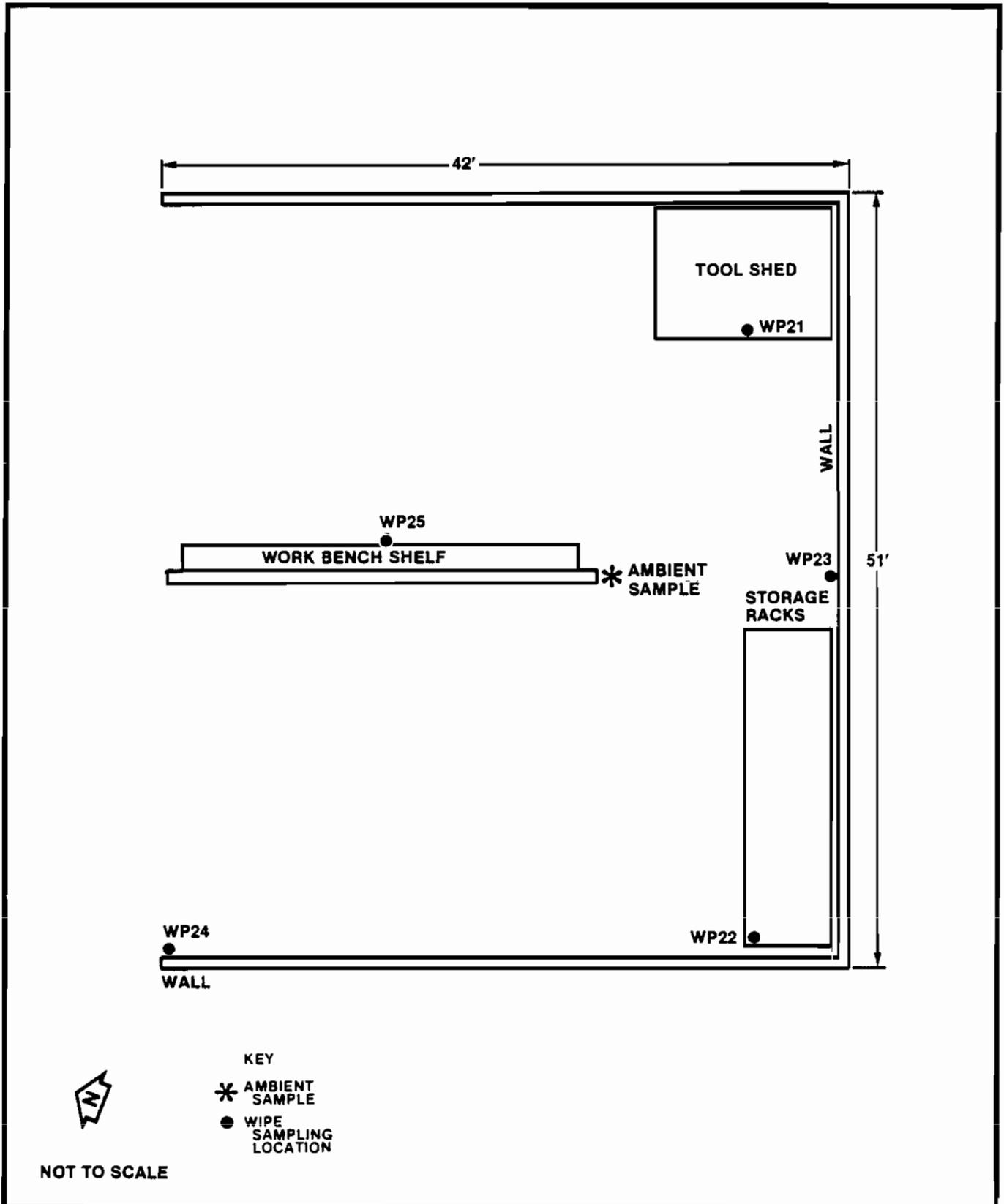


Figure A-6
BUILDING 1613, GARAGE OPEN STORAGE
SHED, AMBIENT AIR SAMPLING POINTS
AND WIPE SAMPLING LOCATIONS

CONTAMINATION STUDY
NAVAL BASE CHARLESTON

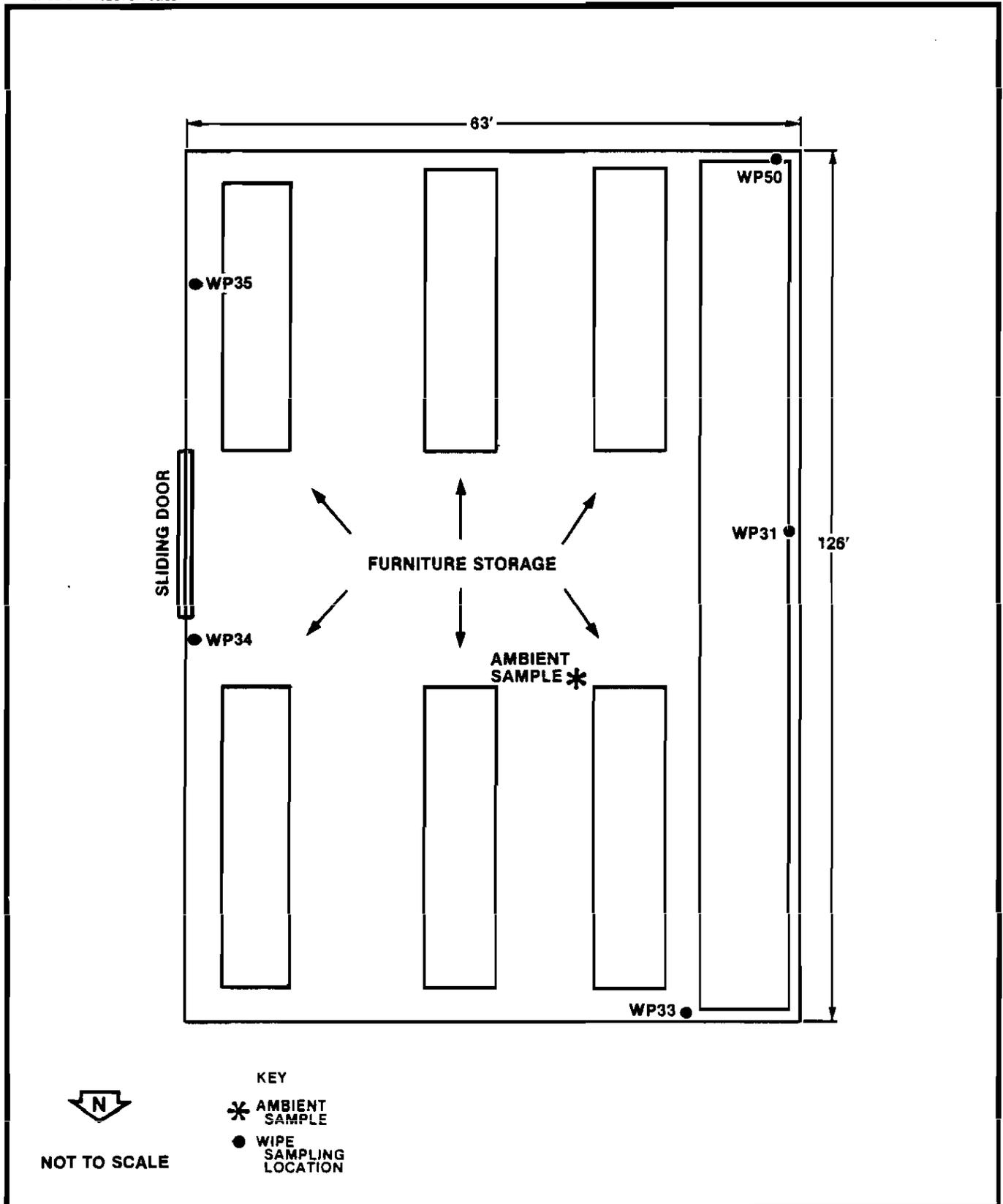


Figure A-7
BUILDING 1627, WAREHOUSE A
FURNITURE STORAGE, AMBIENT AIR
SAMPLING POINTS AND WIPE
SAMPLING LOCATIONS

CONTAMINATION STUDY
NAVAL BASE CHARLESTON

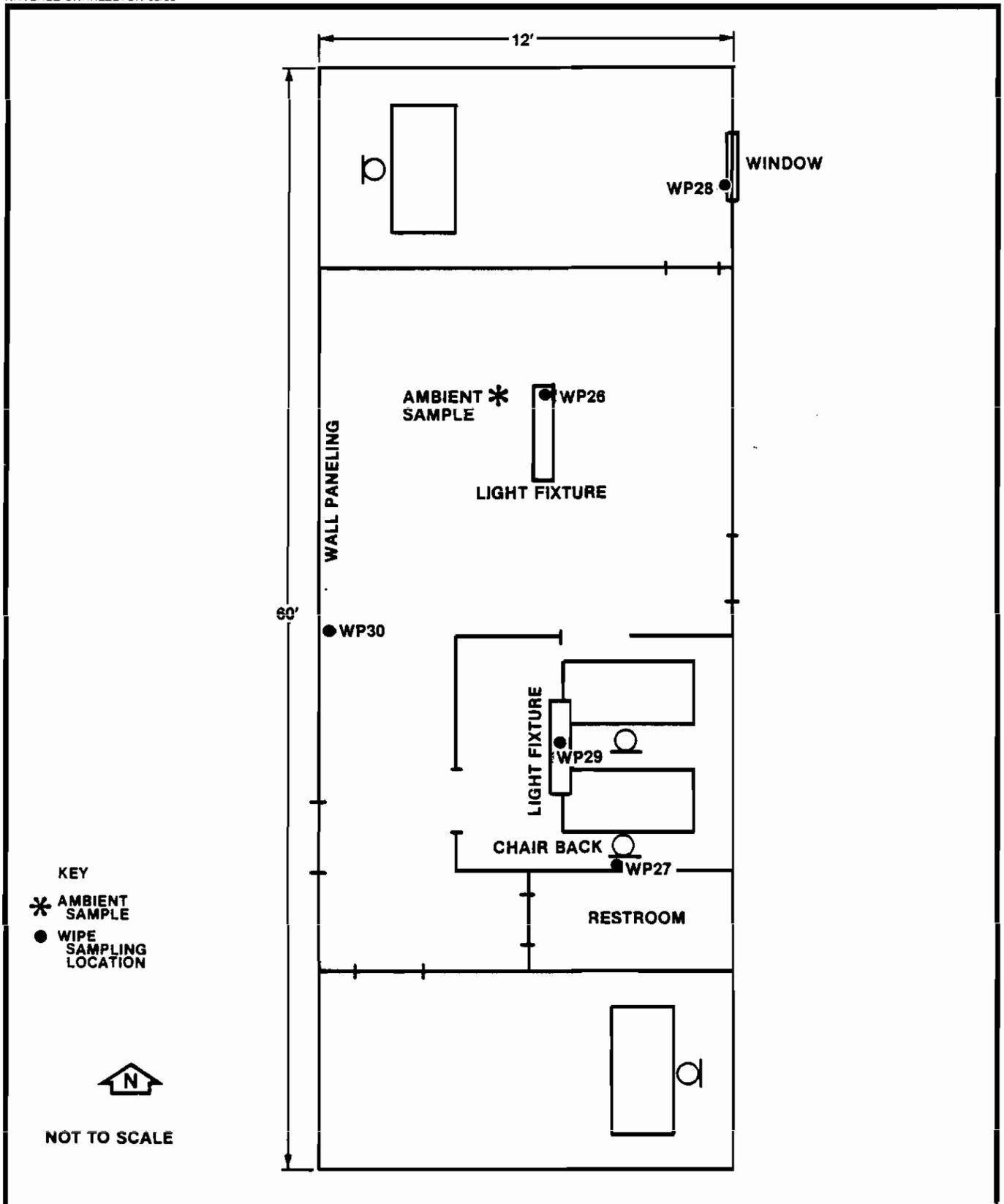


Figure A-8
BUILDING 2521, TRAILER OFFICE,
AMBIENT AIR SAMPLING POINTS
AND WIPE SAMPLING LOCATIONS

CONTAMINATION STUDY
NAVAL BASE CHARLESTON