ORISE
OAK RIDGE INSTITUTE FOR SCIENCE AND EDUCATION

July 27, 2004

Mr. Theodore Smith
MailStop: T-7F27
Division of Waste Management
U.S. Nuclear Regulatory Commission
11545 Rockville Pike
Rockville, MD 20852

**SUBJECT: REVISED FINAL REPORT—CONFIRMATORY SURVEY OF OPEN LAND AREA SURVEY UNITS AT THE CONNECTICUT YANKEE HADDAM NECK PLANT, HADDAM, CONNECTICUT (DOCKET NO. 50-0213, RFTA NO. 03-008)**

Dear Mr. Smith:

The Environmental Survey and Site Assessment Program (ESSAP) of the Oak Ridge Institute for Science and Education (ORISE) has prepared the subject confirmatory survey report which discusses the survey activities that were performed during the periods of September 29 through October 1, 2003 and March 16 through 17, 2004. Survey activities included document and data reviews, gamma surface scans, and soil sampling. A final report was submitted to the NRC on June 2, 2004. This revised report is being issued to provide clarification of the conclusions reached in the Comparison of Results with Guidelines section of the report as requested by the NRC site representative.

Enclosed are five copies of the subject report. If you have any additional questions, please direct them to me at (865) 576-0065 or Tim Vitkus at (865) 576-5073.

Sincerely,

Wade C. Adams
Project Leader/Health Physicist
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WCA:ar

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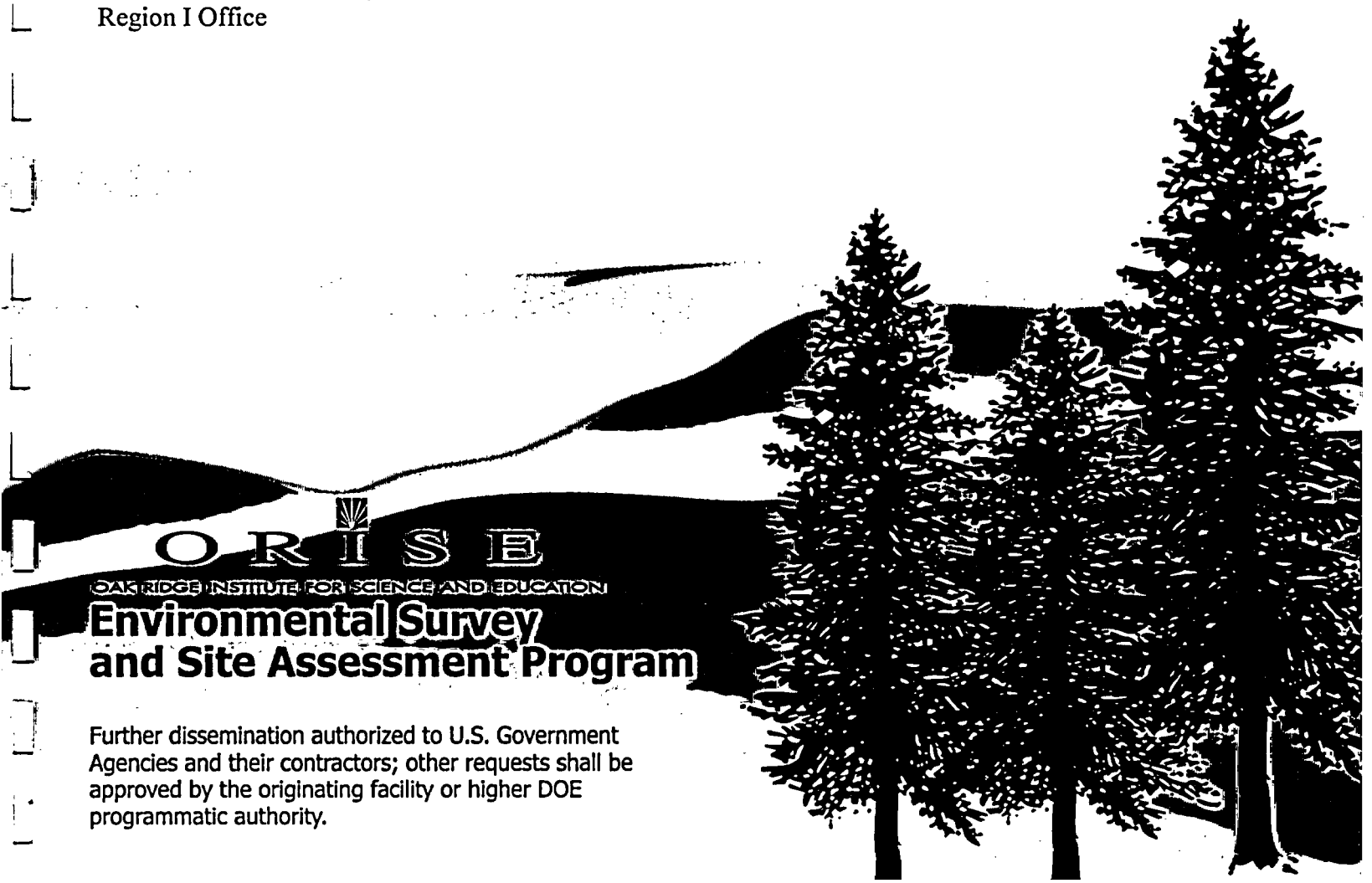
# REVISED FINAL REPORT

# CONFIRMATORY SURVEY OF OPEN LAND AREA SURVEY UNITS AT THE CONNECTICUT YANKEE HADDAM NECK PLANT HADDAM, CONNECTICUT [DOCKET NO. 50-0213, RFTA NO. 03-008)

W. C. ADAMS

Prepared for the
U.S. Nuclear Regulatory Commission
Division of Waste Management
Region I Office



ORISE
OAK RIDGE INSTITUTE FOR SCIENCE AND EDUCATION
Environmental Survey and Site Assessment Program

ORISE 04-0966

# CONFIRMATORY SURVEY OF OPEN LAND AREA SURVEY UNITS AT THE CONNECTICUT YANKEE HADDAM NECK PLANT HADDAM, CONNECTICUT

Prepared by

W. C. Adams

Environmental Survey and Site Assessment Program
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Prepared for the

U.S. Nuclear Regulatory Commission
Division of Waste Management

**REVISED FINAL REPORT**

**JULY 2004**

This report is based on work performed under an Interagency Agreement (NRC Fin. No. J-5403) between the U.S. Nuclear Regulatory Commission and the U.S. Department of Energy. Oak Ridge Institute for Science and Education performs complementary work under contract number DE-AC05-00OR22750 with the U.S. Department of Energy.

**CONFIRMATORY SURVEY**
**OF OPEN LAND AREA SURVEY UNITS**
**AT THE CONNECTICUT YANKEE HADDAM NECK PLANT**
**HADDAM, CONNECTICUT**

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## ABBREVIATIONS AND ACRONYMS

| | |
|---|---|
| Ag-108m | silver-108m |
| Am-241 | americium-241 |
| BKG | background |
| BMO | biological material oxidizer |
| C-14 | carbon-14 |
| cm | centimeter |
| Cm-243/244 | curium-243/244 |
| Co-60 | cobalt-60 |
| Cs-134, -137 | cesium-134, -137 |
| CYAPCO | Connecticut Yankee Atomic Power Company |
| DCGL | derived concentration guideline level |
| DOE | Department of Energy |
| EML | Environmental Measurements Laboratory |
| ESSAP | Environmental Survey and Site Assessment Program |
| ETD | easy-to-detects |
| Eu-152, -154,-155 | europium-152, -154, -155 |
| Fe-55 | iron-55 |
| FSS | final status survey |
| ft | feet |
| g | gram |
| GPS | global positioning system |
| H-3 | tritium |
| HNP | Haddam Neck Plant |
| HTD | hard-to-detects |
| ISFSI | independent spent fuel storage installation |
| ISM | integrated safety management |
| ITP | Intercomparison Testing Program |
| JHA | job hazard analysis |
| kg | kilogram |
| LTP | license termination plan |
| MAPEP | Mixed Analyte Performance Evaluation Program |
| MARSSIM | Multi-Agency Radiation Survey and Site Investigation Manual |
| MDC | minimum detectable concentration |
| MeV | million electron volts |
| Mn-54 | manganese-54 |
| mrem | millirem |
| msl | mean sea level |
| MW | megawatts |
| NaI | sodium iodide |
| Nb-94 | niobium-94 |
| Ni-63 | nickel-63 |
| NIST | National Institute of Standards and Technology |

## ABBREVIATIONS AND ACRONYMS (CONTINUED)

| | |
|---|---|
| NORM | naturally occurring radioactive material |
| NRC | Nuclear Regulatory Commission |
| NRIP | NIST Radiochemistry Intercomparison Program |
| ORISE | Oak Ridge Institute for Science and Education |
| pCi/g | picocuries per gram |
| PSDAR | Post Shutdown Decommissioning Activities Report |
| Pu-236, -238, -239/240,-241 | plutonium -236, -238, -239/240, -241 |
| RCA | radiologically controlled area |
| Sr-90 | strontium-90 |
| SU | survey unit |
| TAPs | total absorption peaks |
| Tc-99 | technetium-99 |
| TEDE | total effective dose equivalent |

# CONFIRMATORY SURVEY
# OF OPEN LAND AREA SURVEY UNITS
# AT THE CONNECTICUT YANKEE HADDAM NECK PLANT
# HADDAM, CONNECTICUT

## INTRODUCTION AND SITE HISTORY

The Connecticut Yankee Haddam Neck Plant (HNP), owned by the Connecticut Yankee Atomic Power Company (CYAPCO), began commercial operation in January 1968 under Atomic Energy Commission Docket Number 50-213, License Number DPR-61. The plant incorporated a four-loop closed-cycle pressurized water type nuclear steam supply system, a turbine generator and electrical systems, engineered safety features, radioactive waste systems, fuel handling systems, instrumentation and control systems, the necessary auxiliaries, and structures to house plant systems and other onsite facilities. The HNP was designed to produce 1,825 megawatts (MW) of thermal power and 590 MW of gross electrical power.

On December 4, 1996, the HNP permanently shut down after approximately 28 years of operation. On December 5, 1996, CYAPCO notified the U.S. Nuclear Regulatory Commission (NRC) of the permanent cessation of operations at the HNP and the permanent removal of all fuel assemblies from the Reactor Pressure Vessel and their placement in the Spent Fuel Pool. The CYAPCO board of directors voted to permanently cease further operation, decommission the plant, and then submitted the Post Shutdown Decommissioning Activities Report (PSDAR), in accordance with 10 CFR 50.82 (a)(4), on August 22, 1997. The PSDAR was accepted by the NRC. On January 26, 1998, CYAPCO transmitted an Updated Final Safety Analysis Report to reflect the plant's permanent shutdown status and on June 30, 1998, the NRC amended the HNP Facility Operating License to reflect this plant condition (CYAPCO 2002).

CYAPCO performed final status surveys (FSS) in most open land areas and will provide FSS data for each completed survey unit (SU) to the NRC as the data become available. The NRC Headquarters and Region I Offices requested that the Oak Ridge Institute for Science and Education's (ORISE), Environmental Survey and Site Assessment Program (ESSAP) perform confirmatory surveys of these open land areas after CYAPCO completes its FSS field activities for the survey units that are to be released. For this report, the NRC requested that ESSAP

perform confirmatory surveys on the following open land area survey units: 9521-0000, 9523-0000, 9525-0000, 9526-0000, 9526-0001, 9526-0002, 9528-0000, 9528-0002, 9528-0003, 9528-0004, 9531-0000, 9532-0000, 9536-0000, 9537-0000, and 9538-0000.

## SITE DESCRIPTION

The HNP is located at 362 Injun Hollow Road in the Town of Haddam, Middlesex County, Connecticut on the east bank of the Connecticut River at a point 21 miles south-southeast of Hartford, Connecticut, and 25 miles northeast of New Haven, Connecticut (Figure 1).

The HNP is a 525 acre site on a level, 600-foot (ft)-wide terrace at an elevation of 21 ft above mean sea level (msl) (Figure 2). A parking lot occupies the area to the north of the industrial area. Adjacent to the parking lot is a small man-made pond. A 5,500 foot-long cooling water discharge canal return was constructed and used during plant operation to return heated circulating water from the secondary plant back to the Connecticut River and to process and discharge liquids containing radioactivity. The discharge canal is separated from the Connecticut River by a 200 to 1,000 ft wide peninsula flood plain that ranges in elevation from about 5 to 15 ft above msl. A steep wooded hill slope rises immediately east of the industrial area to elevations over 300 ft above msl. The lowermost 30 to 40 ft of the hillside adjacent to the plant consists of nearly vertical rock cut.

The topography of the site originally consisted of a north-south trending promontory approximately 400 ft-wide that connected the steep hillside north of this area to a floodplain terrace along the river's edge. The steep hill slope extended southward to the northeastern most third of the Containment Building. The southern part of the promontory consisted of large bedrock outcroppings in the area of the Turbine Building. Wetlands extended for 1,000 ft or more to the northwest and southeast of the promontory. During construction of the HNP, the steep hill slope to the north and the higher portions of the promontory were cut. The discharge canal was excavated through the wetland, terrace, and floodplain to the southeast. The subsurface portions of the Containment Building, Primary Auxiliary Building, Turbine Building, Discharge Tunnel, and Spent Fuel Pool were excavated down to, or below, the original bedrock surface.

The HNP design includes several structures engineered and constructed to contain radioactive material. These structures include the Containment Building, the Primary Auxiliary Building, the Service Building, the Waste Storage Building, Ion Exchange Structure, Spent Resin Facility, and structures containing tanks for storage of radioactive liquids. These structures and facilities are located within the radiologically controlled area (RCA) boundaries. The site also includes ancillary facilities that were used to support normal plant operations. These facilities consist of warehouses, administrative office buildings, an information center and Emergency Operations Facility. Most buildings and facilities are centrally located on a 15 acre plot adjacent to the Connecticut River.

The remaining site area is largely undeveloped and undisturbed land tracts. The topography ranges from rocky, open spaces to steep, rocky hillsides that are heavily wooded and overgrown with brush in many locations.

## OBJECTIVES

The objectives of the radiological confirmatory survey were to provide independent contractor field data reviews and radiological data for use by the NRC in evaluating the adequacy and accuracy of the licensee's procedures and FSS results. Information was gathered and survey data were collected to evaluate the radiological status of the open land areas as reported by the licensee.

## DOCUMENT REVIEW

ESSAP reviewed the licensee's survey classification supporting documentation and the final radiological survey data for adequacy and appropriateness, taking into account the License Termination Plan, Revision 1A (LTP) and Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM) considerations (CYAPCO 2002 and NRC 2000).

## PROCEDURES

ESSAP personnel visited the HNP facility during the periods of September 29 through October 1, 2003 and March 16 through 17, 2004 and performed visual inspections and independent

sampling of portions of the site. Survey activities were conducted in accordance with a site-specific survey plan and the ORISE/ESSAP Survey Procedures and Quality Assurance Manuals (ORISE 2003a, b, c, d and e and 2004a). Survey activities included gamma surface scans and soil sampling.

### REFERENCE SYSTEM

Sampling locations were referenced to the existing CYAPCO grid system or area landmarks. In addition, ESSAP used a global positioning system (GPS) and associated maps to reference several sampling locations.

### SURVEY UNIT CLASSIFICATION

The MARSSIM FSS process depends upon the use of characterization surveys and site history to divide the site into properly classified survey units of appropriate physical area. Modifications to the SU classification can be made based on new survey findings or information. SUs are limited in size based on their classification, exposure pathway modeling assumptions and site-specific conditions. CYAPCO assigned each open land area SU with an initial classification based on past surveys and on their historical site assessment (CYAPCO 2002).

Under MARSSIM, the level of survey effort required for a given SU is determined by the potential for residual contamination as indicated by the classification. SUs with a higher classification received a higher degree of survey effort. CYAPCO used the following MARSSIM classifications for the open land area SUs:

- Non-impacted: Areas that have no radiological impact from site operations.
- Impacted Areas: Areas that have some potential for containing residual contamination. Impacted areas include Class 1, 2, and 3 Areas defined as follows:
  - Class 1: Areas that have, or had prior to remediation, a potential for radioactive contamination (based on site history) or known contamination (based on previous surveys). Areas containing contamination in excess of the

derived concentration guideline level (DCGL) prior to remediation should be classified as Class 1 areas.

- Class 2: Areas that have, or had prior to remediation, a potential for radioactive contamination or known contamination, but are not expected to exceed the DCGL.
- Class 3: Any impacted areas that are not expected to contain any residual radioactivity, or are expected to contain levels of residual activity at a small fraction of the DCGL.

The following classifications were assigned by CYAPCO to the SUs for which ESSAP was tasked to perform confirmatory surveys:

- Non-impacted: 9532-0000.
- Class 1: No Class 1 SUs were available during these confirmatory survey activities.
- Class 2: 9526-0001, 9526-0002, 9528-0002, 9528-0003, 9528-0004, 9536-0000, 9537-0000, and 9538-0000. Confirmatory surveys were not performed on SU 9528-0004.
- Class 3: 9521-0000, 9523-0000, 9525-0000, 9526-0000, 9528-0000, and 9531-0000. Confirmatory surveys were not performed on SU 9525-0000.

### SURFACE SCANS

Surface scans for gamma radiation were performed systematically in Class 2 and 3 SUs as well as judgmentally selected locations in the non-impacted open land area SU where radioactivity may have concentrated during operations (e.g., transport routes, drainage areas, streambeds, areas of known radiological releases, etc.). Gamma scans were performed over approximately 50% of the soil surface area in Class 2 SUs, 10% of the soil surface area in Class 3 SUs and 1% of the surface soil area in the non-impacted SU.

Additional area scans were performed, depending on findings as the survey progressed and project time constraints. Particular attention was given to cracks and fissures in the ground or rock surfaces, areas of known radiological releases from the HNP, and other locations where material may have accumulated. Scans were performed using NaI scintillation detectors coupled to ratemeters with audible indicators. Locations of elevated direct radiation detected by

surface scans were marked for further investigation—to include additional surface scans as deemed necessary to delineate contamination boundaries and for possible soil sampling.

### SOIL SAMPLING

ESSAP collected soil samples from various locations within each SU that was selected for confirmatory survey. Selected sample locations focused on known areas of radiological releases from the HNP and major transport, shoreline, and trafficked areas. Samples were also collected in the vicinity of the newly constructed independent spent fuel storage installation (ISFSI) to document radiological conditions prior to fuel storage. Additionally, locations exhibiting gamma radiation distinguishable from background were also selected for sampling.

Eighty soil samples were collected from thirteen of the fifteen SUs that were ready for confirmatory surveys. Soil samples were not collected from SUs 9525-0000 and 9528-0004, both of which were underneath paved or newly constructed roadways (Figures 2 through 15). A minimum of five surface (0 to 15 cm) soil samples were collected at the locations of maximum elevated direct gamma radiation identified by surface scans within each SU that was surveyed. Subsurface soil samples were collected from two locations within SU 9536-0000, three locations within 9537-0000, and two locations within 9538-0000 in order to collect soil samples from original surfaces because there was evidence that overburden soils had been placed in these locations (Figures 13 through 15). Three samples collected by CYAPCO were also requested for laboratory comparison analyses.

## SAMPLE ANALYSIS AND DATA INTERPRETATION

Samples and data were returned to ORISE's ESSAP laboratory in Oak Ridge, Tennessee for analysis and interpretation. Sample analyses were performed in accordance with the ORISE/ESSAP Laboratory Procedures Manual (ORISE 2003f, g and h and 2004b and c). Soil samples were analyzed by gamma spectroscopy and results reported in units of picocuries per gram (pCi/g). The primary radionuclides of interest were cobalt-60 (Co-60) and cesium-137 (Cs-137); however, spectra were also reviewed for other gamma-emitting fission and activation products associated with the HNP and other identifiable total absorption peaks (TAPs).

Additional sample analyses were performed for the hard-to-detect (HTD) radionuclides for the three laboratory comparison samples.

The data generated were compared with the applicable site-specific guidelines established for the HNP site (CYAPCO 2002). Additional information concerning major instrumentation, sampling equipment, and analytical procedures is provided in Appendices A and B.

## FINDINGS AND RESULTS

### SURFACE SCANS

Gamma scans conducted over the surface soil areas of the SUs identified several locations of elevated gamma radiation. Further investigations identified the elevated gamma radiation as being from naturally occurring radioactive materials (NORM) within granite outcrops throughout the surveyed areas.

### SOIL SAMPLING

Radionuclide concentrations in soil samples are summarized in Tables 1 and 2. The concentrations in individual samples for the primary radionuclides of concern ranged as follows: 0.01 to 2.59 pCi/g for Cs-137 and -0.04 to 0.16 pCi/g for Co-60. For Table 2, the radionuclide concentrations for other potentially present gamma emitters is provided for five ESSAP collected samples based on elevated Cs-137 concentrations. The radionuclide concentrations for these five individual samples ranged as follows: -0.02 to 0.01 pCi/g for Mn-54, -0.02 to 0.16 pCi/g for Co-60, 0.00 to 0.01 for Nb-94, -0.02 to 0.00 pCi/g for Ag-108m, 0.04 to 0.08 pCi/g for Cs-134, 0.48 to 2.59 pCi/g for Cs-137, -0.04 to 0.02 for Eu-152, 0.00 to 0.10 pCi/g for Eu-154, 0.02 to 0.12 pCi/g for Eu-155 and 0.01 to 0.09 pCi/g for Am-241.

### LABORATORY COMPARISON ANALYSES

Three samples that CYAPCO had analyzed at a contracted, off-site laboratory were also analyzed by ESSAP. The analytical results for the comparative evaluation of the CYAPCO samples are

provided in Table 3 and indicated that the CYAPCO contractor laboratory data were consistent and in agreement with ESSAP's analytical results.

## COMPARISON OF RESULTS WITH GUIDELINES

The primary contaminants of concern for the HNP were beta-gamma emitters—fission and activation products—resulting from reactor operations. Cs-137 and Co-60 were identified during characterization as the predominant radionuclides present on surfaces and in the soils. CYAPCO developed site-specific DCGLs based on dose modeling not to exceed 25 mrem/year total effective dose equivalent (TEDE) as presented in Section 6 of the LTP (CYAPCO 2002). CYAPCO survey design reduced the soil DCGLs to 40% of the site-specific DCGL as an administrative control which meets 10 mrem/year TEDE. CYAPCO release plan incorporates an investigative level when soil samples exceed 50% of the administrative DCGL. The administrative control DCGLs for soils were 1.52 pCi/g for Co-60 and 3.16 pCi/g for Cs-137, in addition to the application of the unity rule. Of the 80 surface and subsurface soil samples that were collected from the HNP site, none exceeded the site-specific DCGLs for Co-60 or Cs-137 and the unity rule was also satisfied. Additional analyses were performed on several confirmatory soil samples for other gamma-emitting fission and activation products associated with the HNP and the results were negligible. Ni-63 was the only HTD where reported concentrations were statistically greater than the respective MDCs, with concentrations ranging from 9.7 to 23.1 pCi/g. The site-specific DCGL for Ni-63 in soil is 723 pCi/g. The results indicated that the majority of the SUs had been classified appropriately. However, samples within SUs 9521-0000 and 9528-0000 had Cs-137 results approaching the administrative DCGL. Applying the unity rule, one sample was at the administrative DCGL for multiple contaminants. CYAPCO chose to investigate Class 3 SUs when results exceed 50% of the administrative DCGL (or 20% of the site-specific DCGL). Therefore, CYAPCO did not exceed the LTP limits.

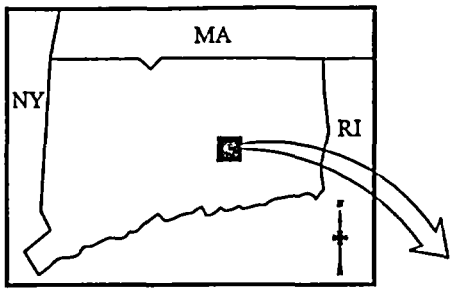
## SUMMARY

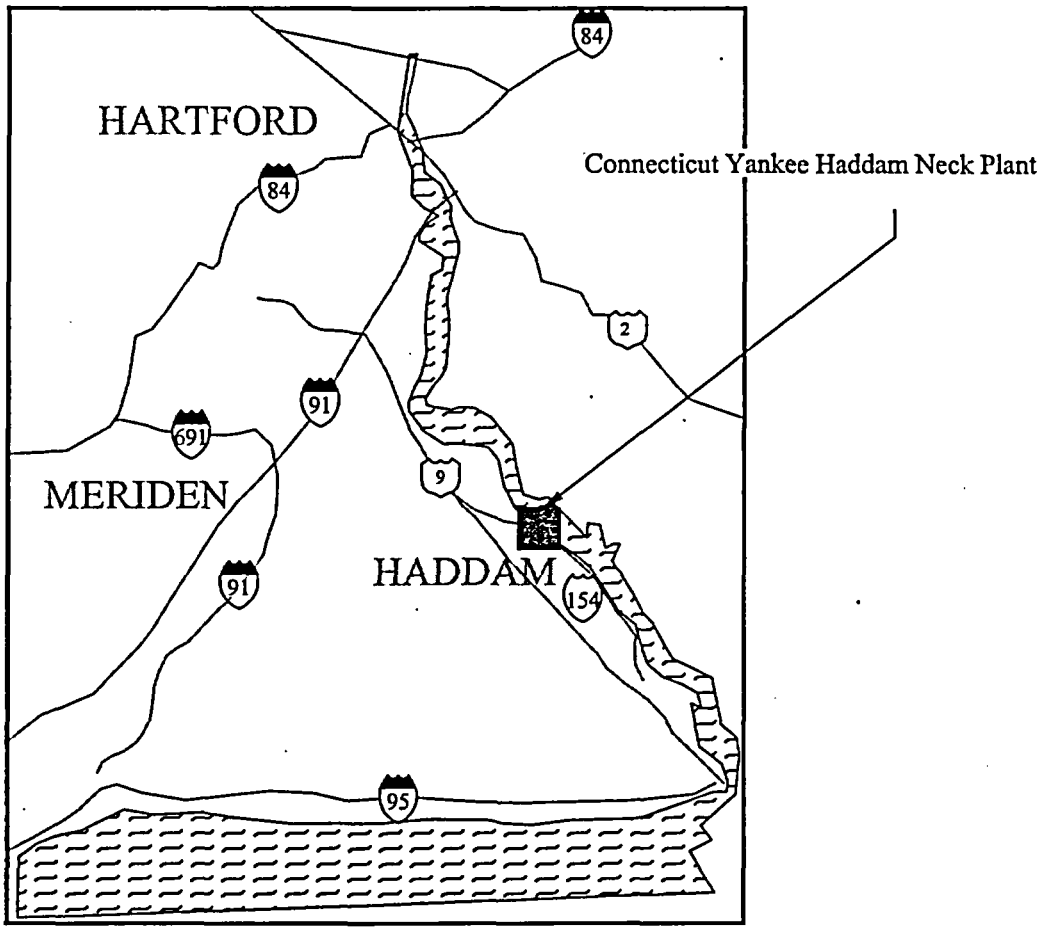
The Environmental Survey and Site Assessment Program of the Oak Ridge Institute for Science and Education performed confirmatory survey activities on selected open land area survey units at the Connecticut Yankee Haddam Neck Plant in Haddam, Connecticut during the period of September 29 through October 1, 2003 and March 16 through 17, 2004. Survey units included in the scope of the survey were as follows: 9521-0000, 9523-0000, 9526-0000, 9526-0001, 9526-0002, 9528-0000, 9528-0002, 9528-0003, 9531-0000, 9532-0000, 9536-0000, 9537-0000, and 9538-0000. Survey units 9525-0000 and 9528-0004 were not included as they were below roadways. Survey activities included a review of the final status survey data and performance of independent gamma scans and soil sampling.

The results of the survey activities confirmed that the radiological conditions of the open land area survey units that were part of these confirmatory survey activities met the approved site-specific DCGLs for Co-60 and Cs-137.

The results of the laboratory confirmatory analysis indicated that the CYAPCO contractor laboratory data were consistent and in agreement with ESSAP's analytical results.

# FIGURES





NOT TO SCALE

FIGURE 1: Location of the Connecticut Yankee Haddam Neck Plant - Haddam, Connecticut

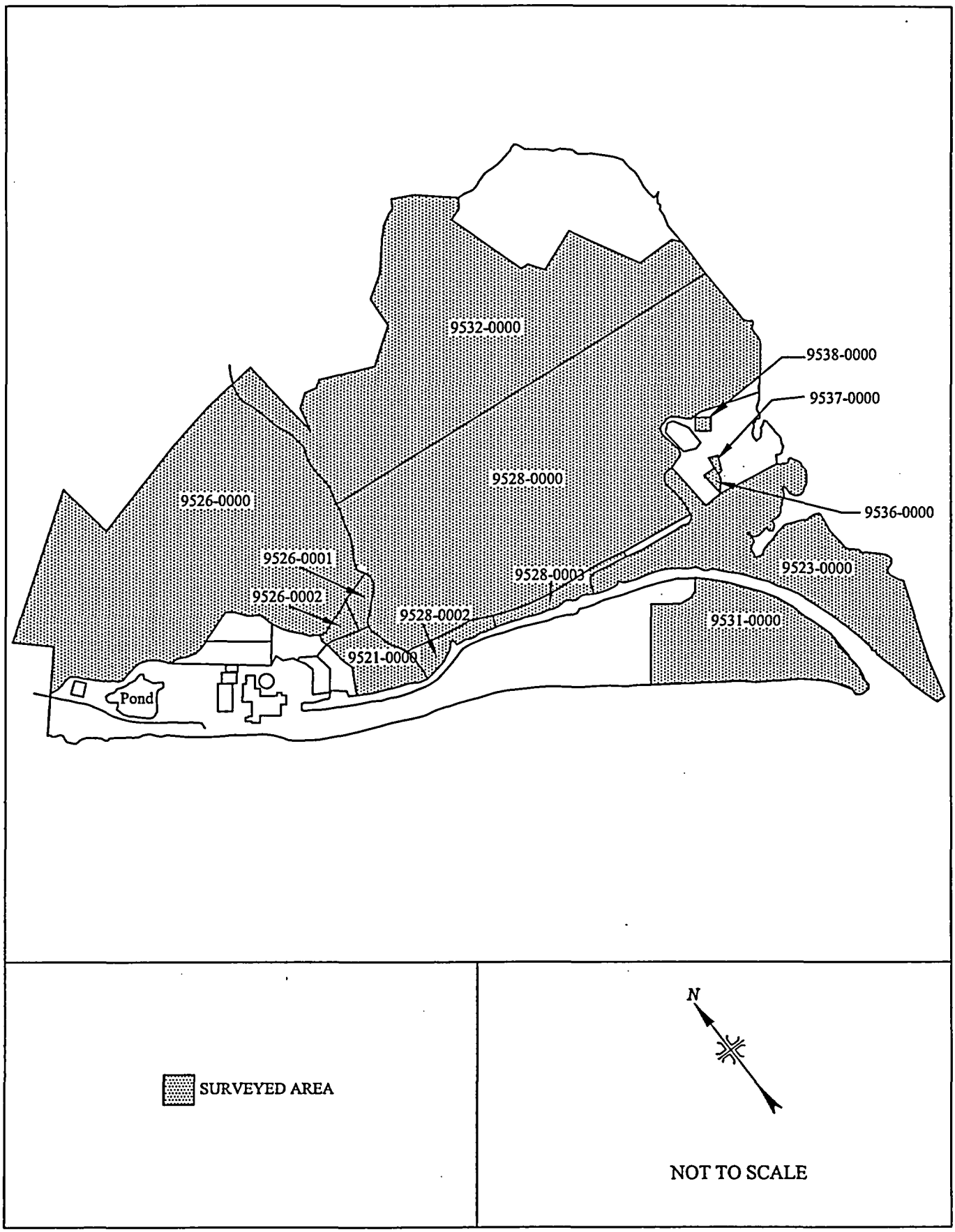



FIGURE 2: Connecticut Yankee Plot Plan Showing Survey Units Involved in Confirmatory Surveys

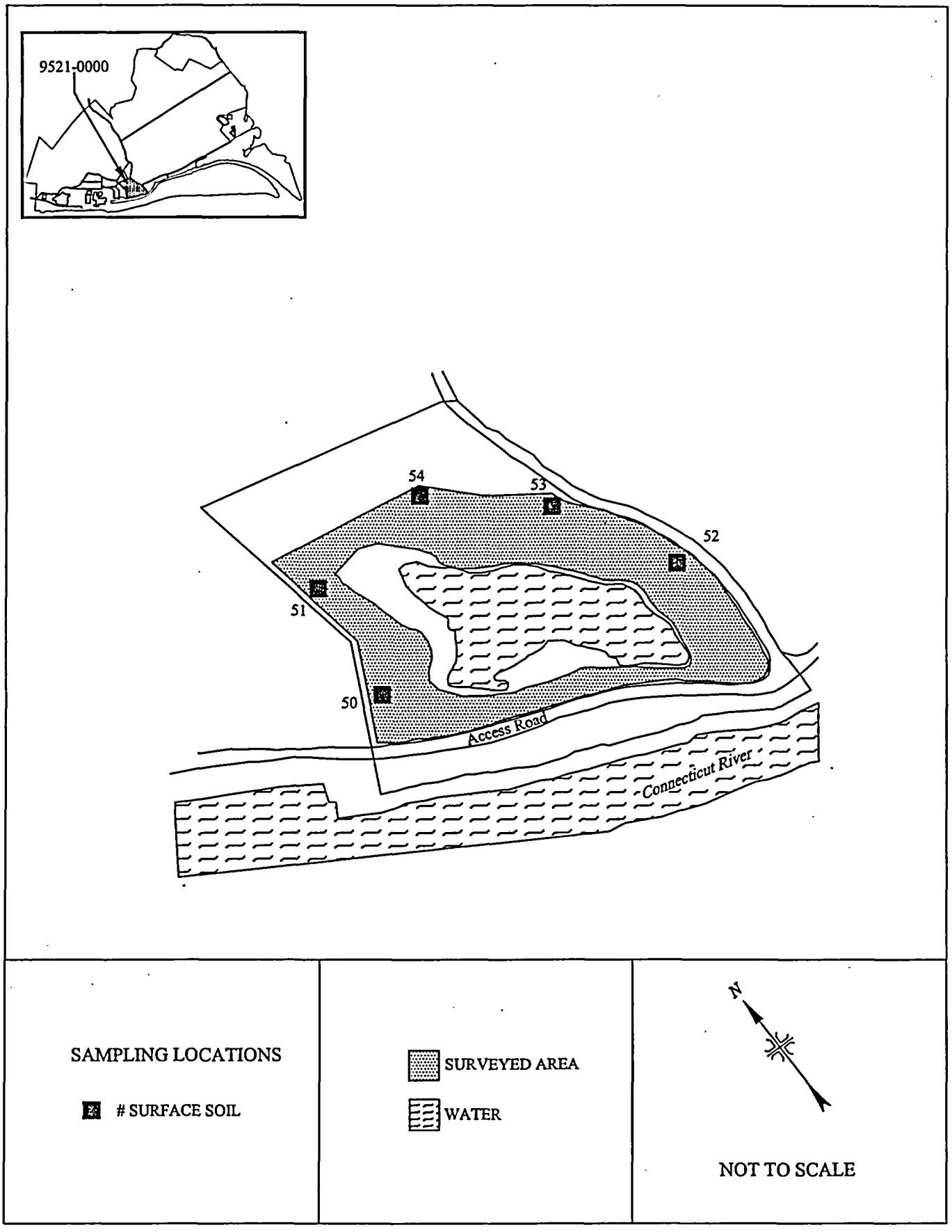



FIGURE 3: Survey Unit 9521-0000 - Sampling Locations

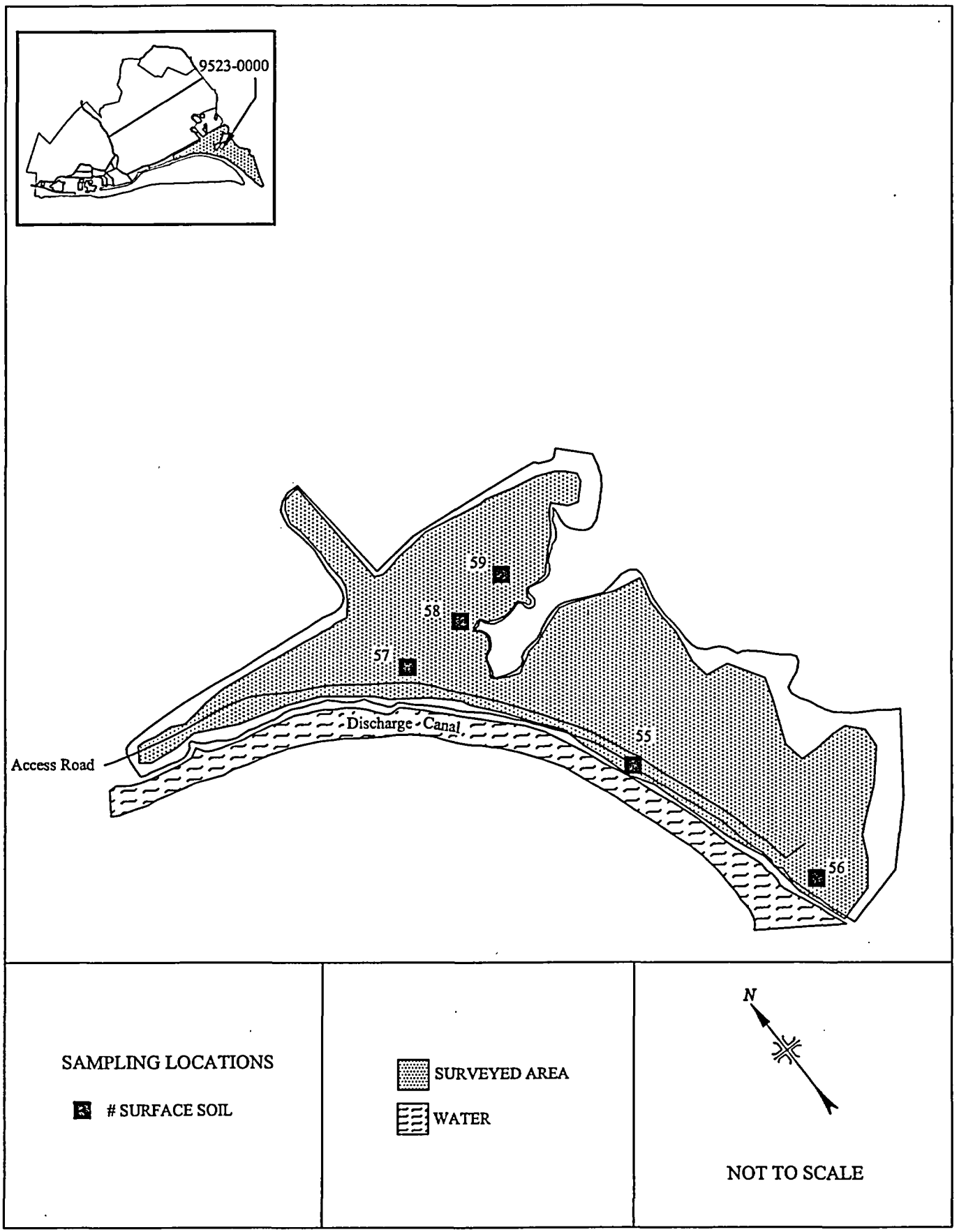



FIGURE 4: Survey Unit 9523-0000 - Sampling Locations

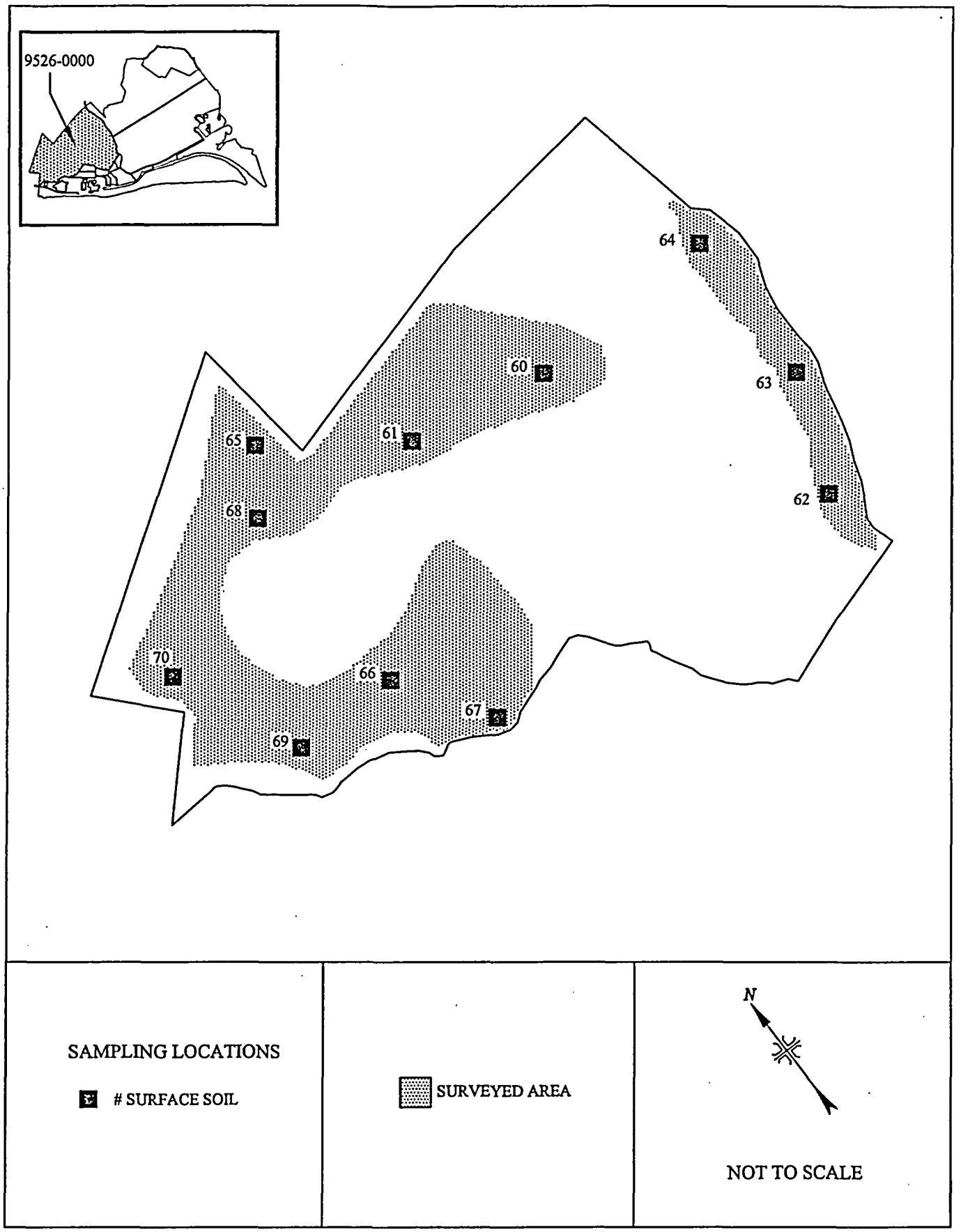



FIGURE 5: Survey Unit 9526-0000 - Sampling Locations

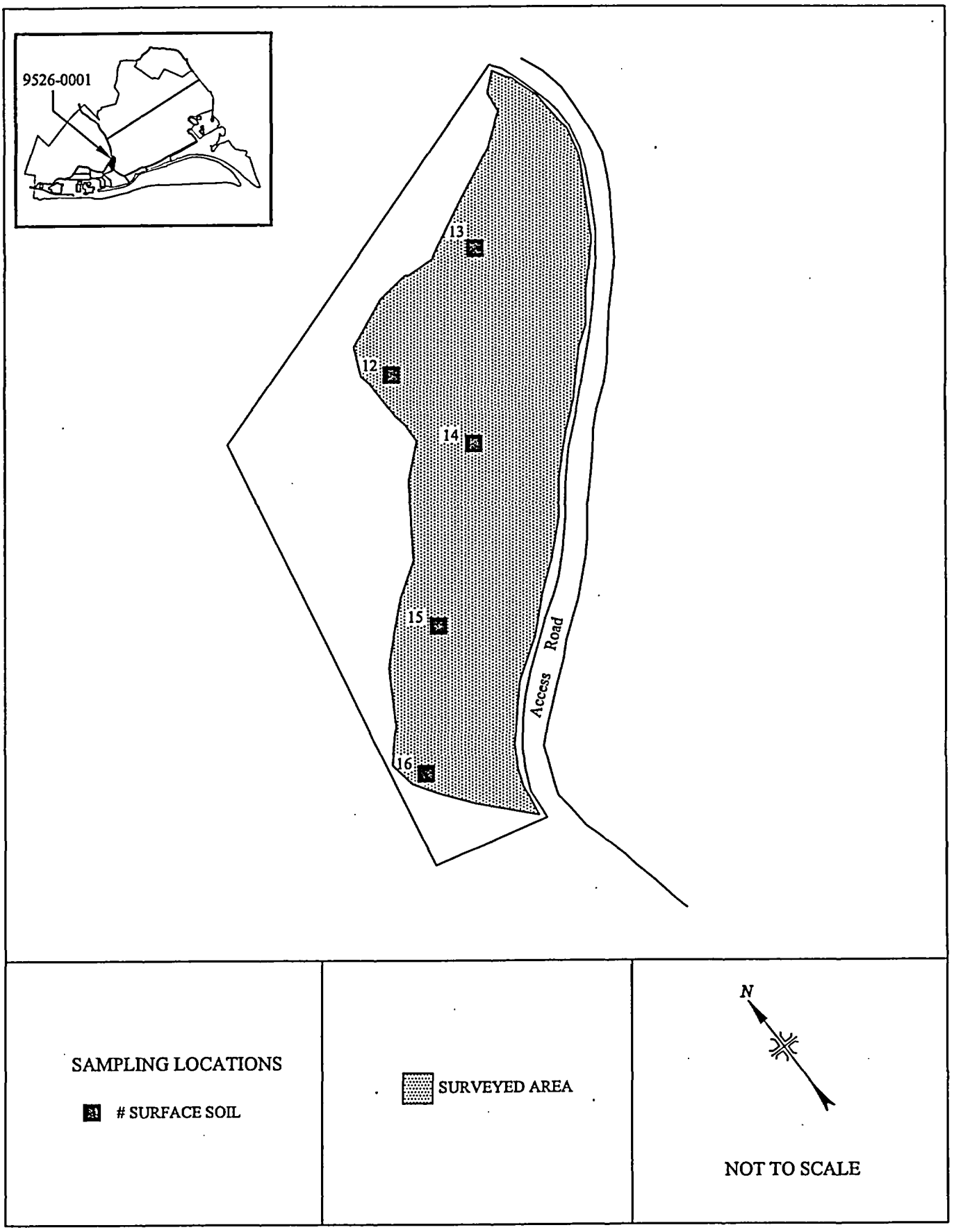



FIGURE 6: Survey Unit 9526-0001 - Sampling Locations

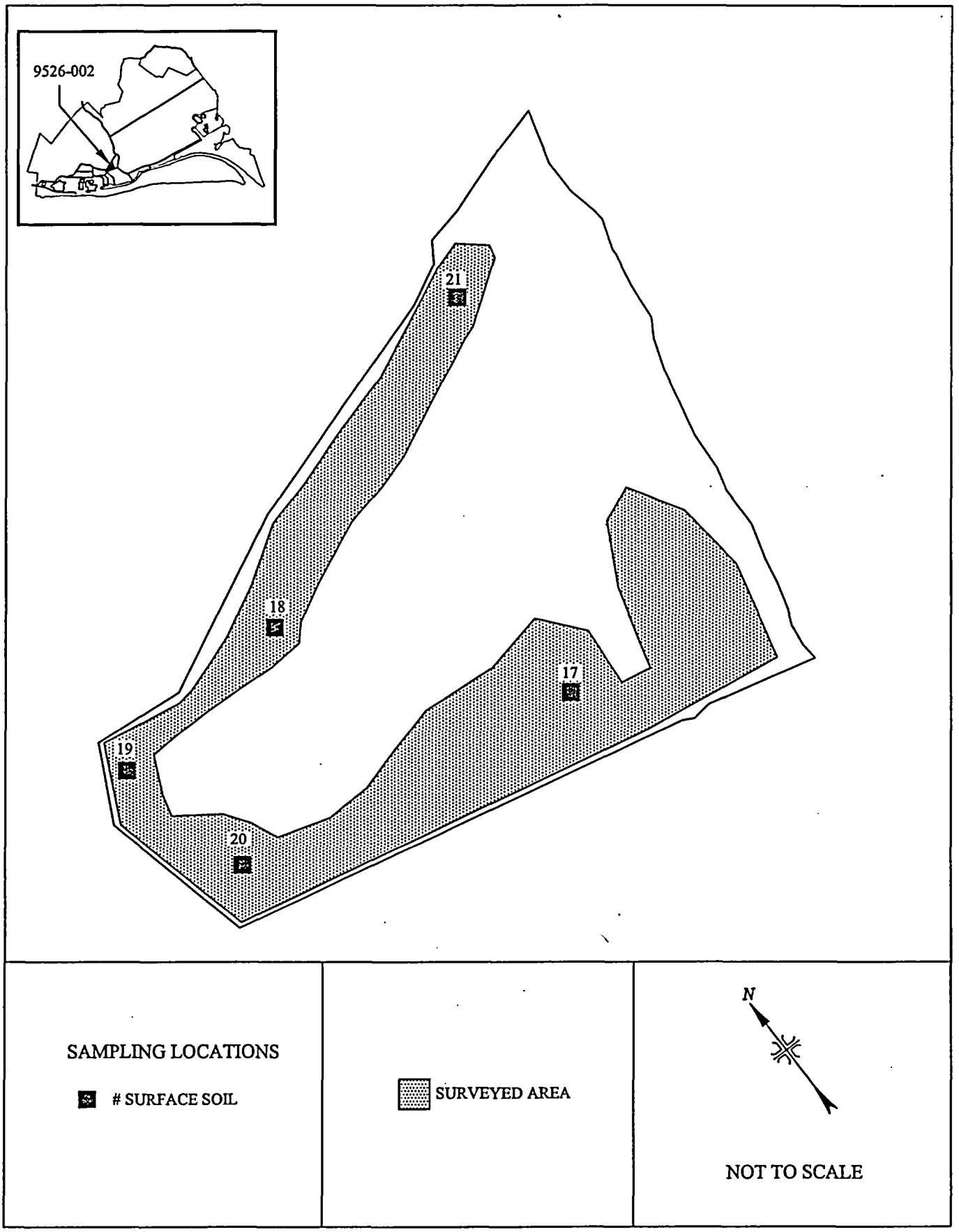
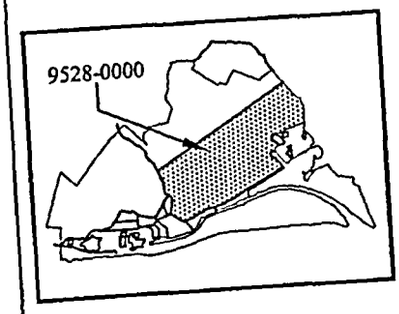
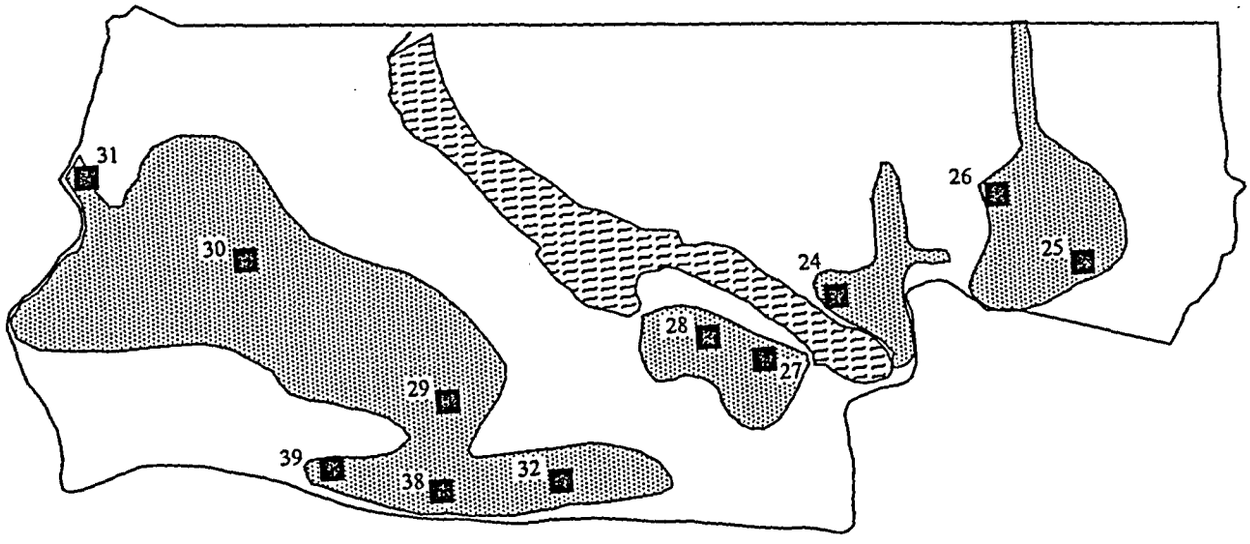



FIGURE 7: Survey Unit 9526-0002 - Sampling Locations

857-007 (2)




SAMPLING LOCATIONS

# SURFACE SOIL

SURVEYED AREA

WATER

N

NOT TO SCALE

FIGURE 8: Survey Unit 9528-0000 - Sampling Locations

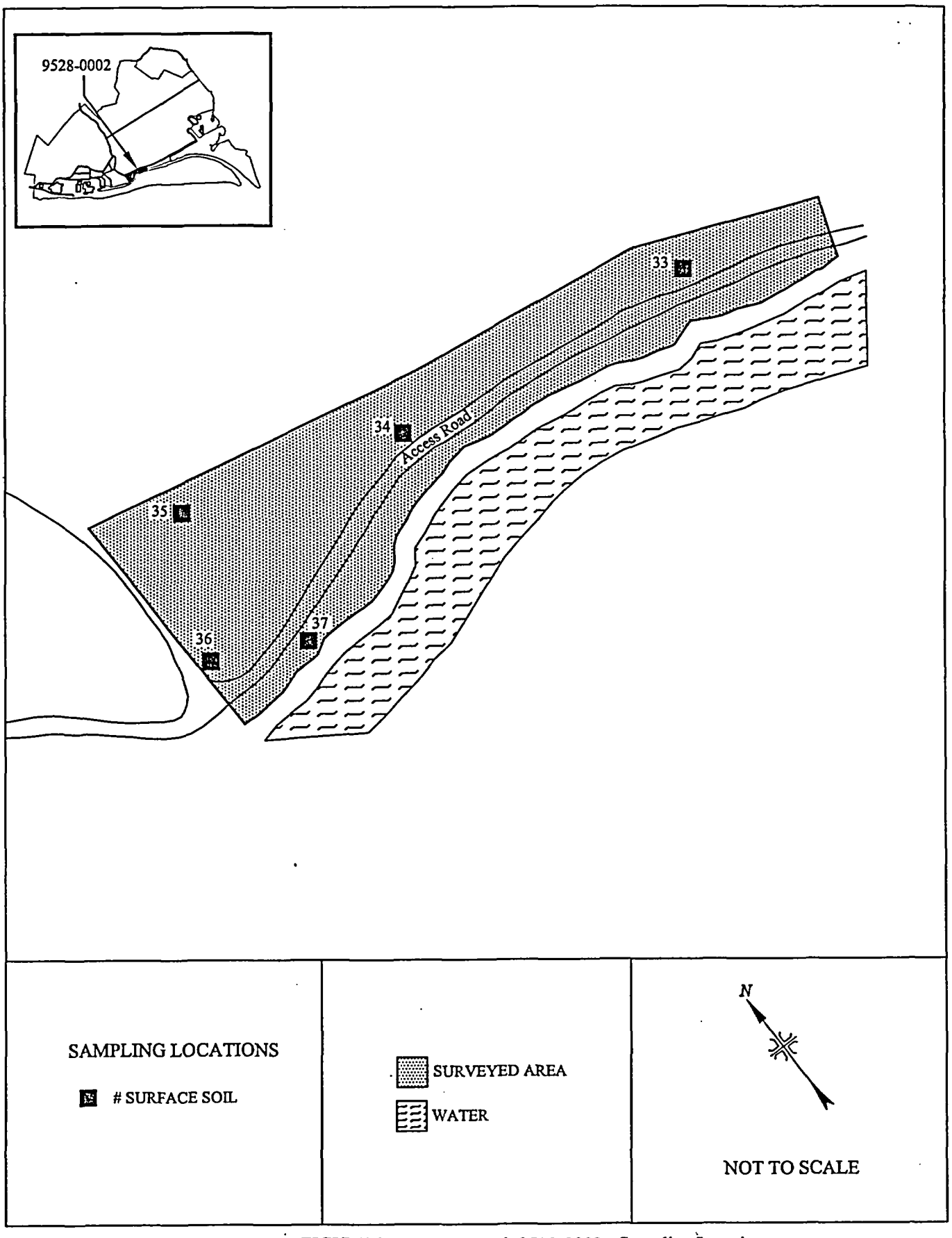



FIGURE 9: Survey Unit 9528-0002 - Sampling Locations

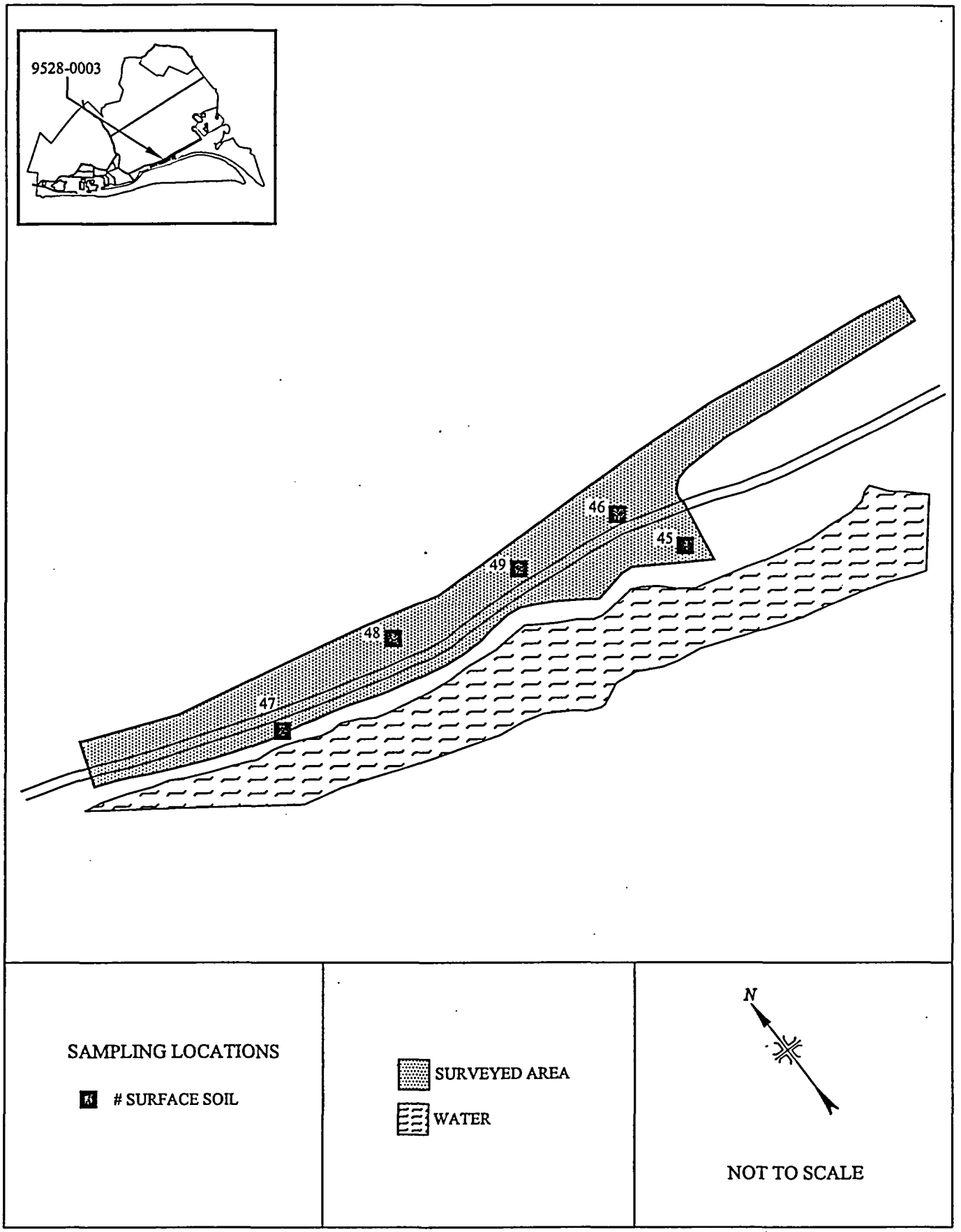



FIGURE 10: Survey Unit 9528-0003 - Sampling Locations

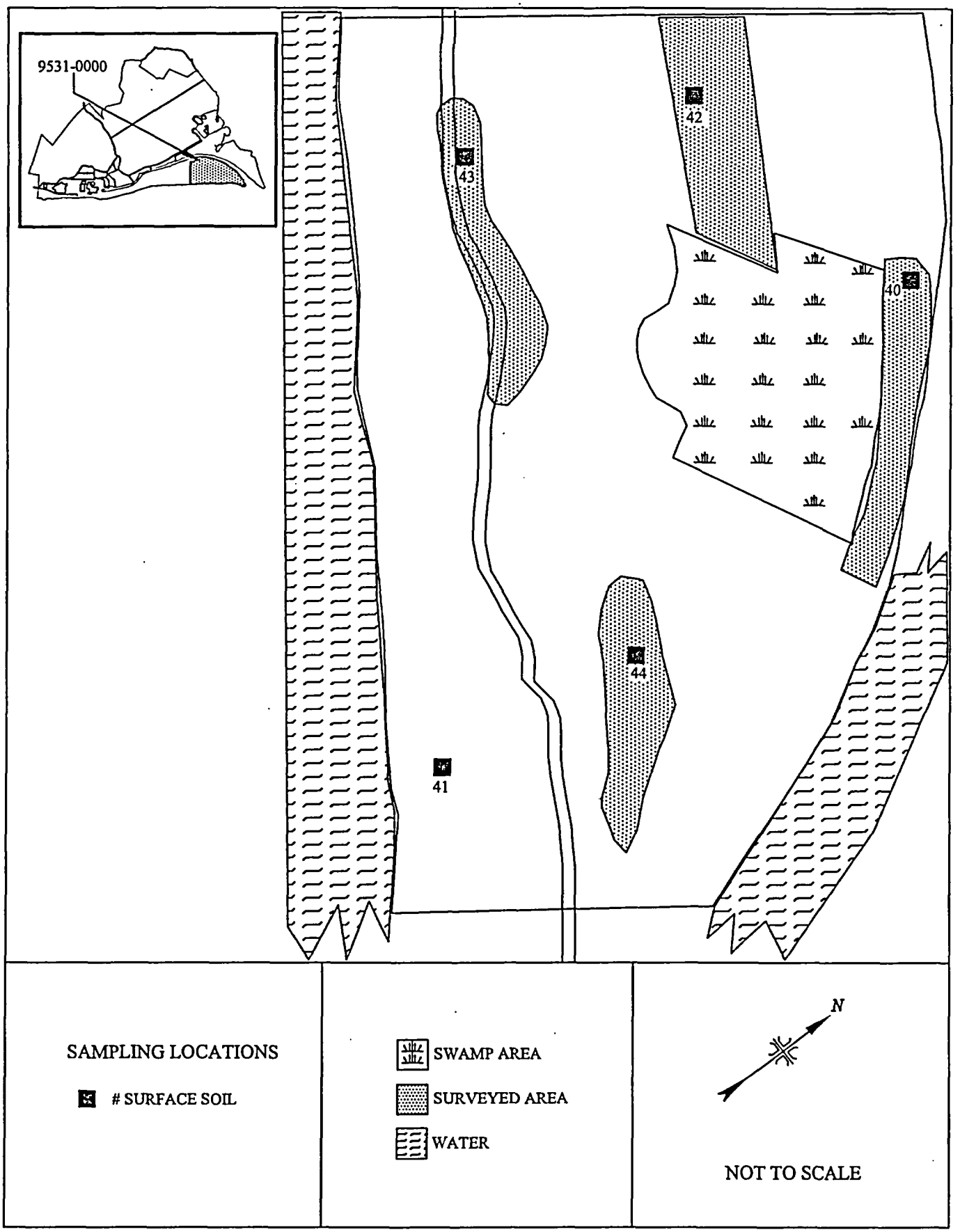



FIGURE 11: Survey Unit 9531-0000 - Sampling Locations

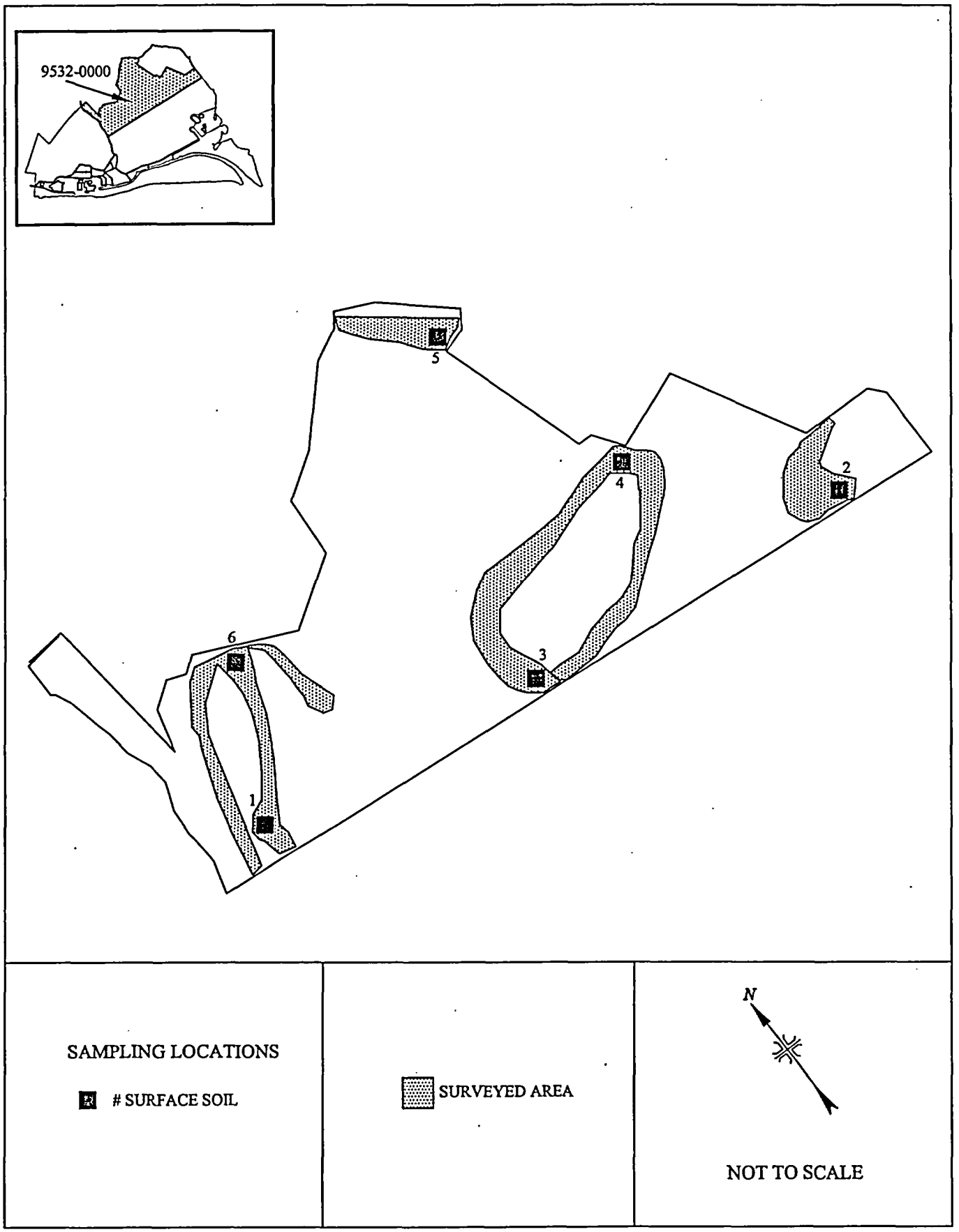



FIGURE 12: Survey Unit 9532-0000 - Sampling Locations

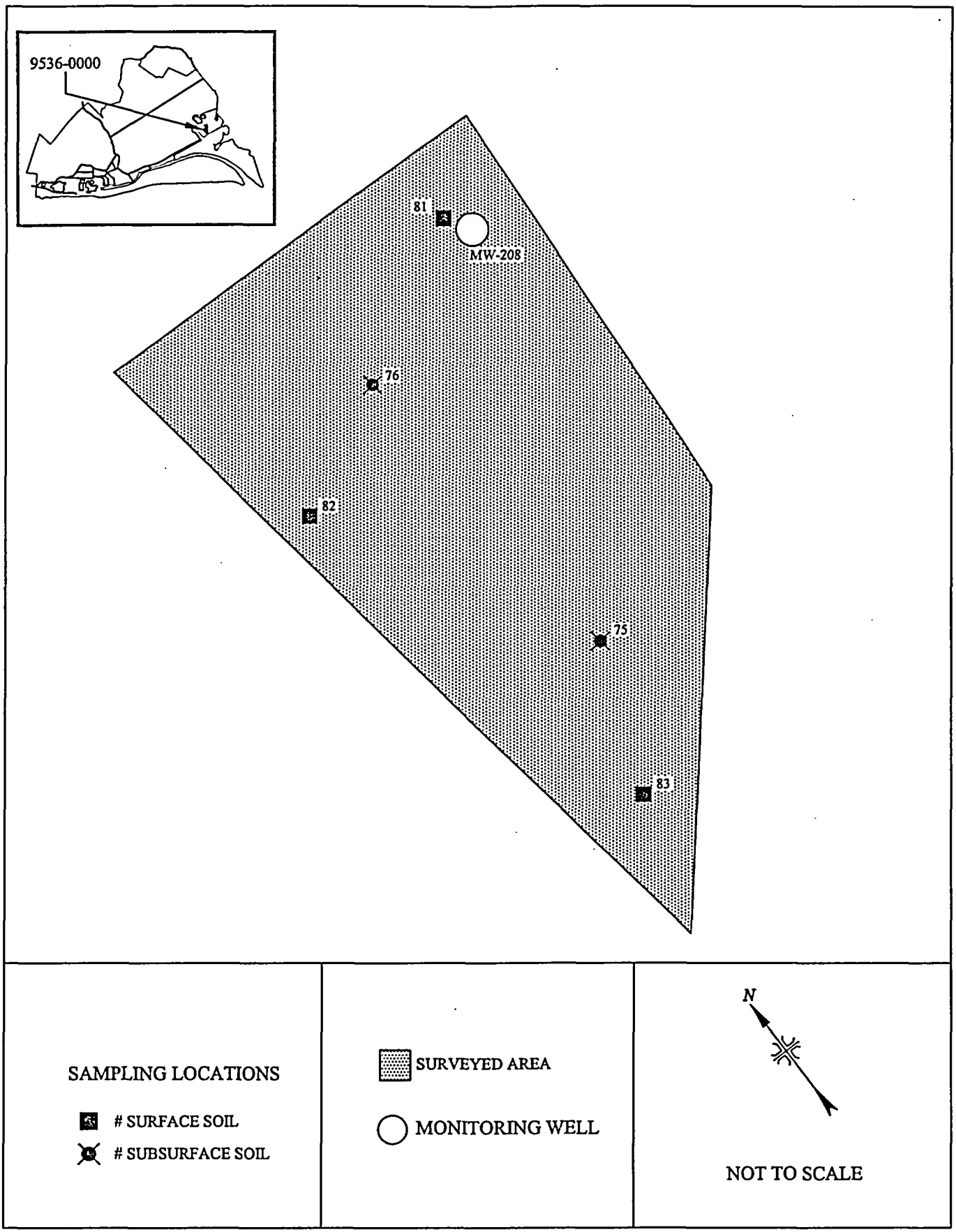



FIGURE 13: Survey Unit 9536-0000 - Sampling Locations

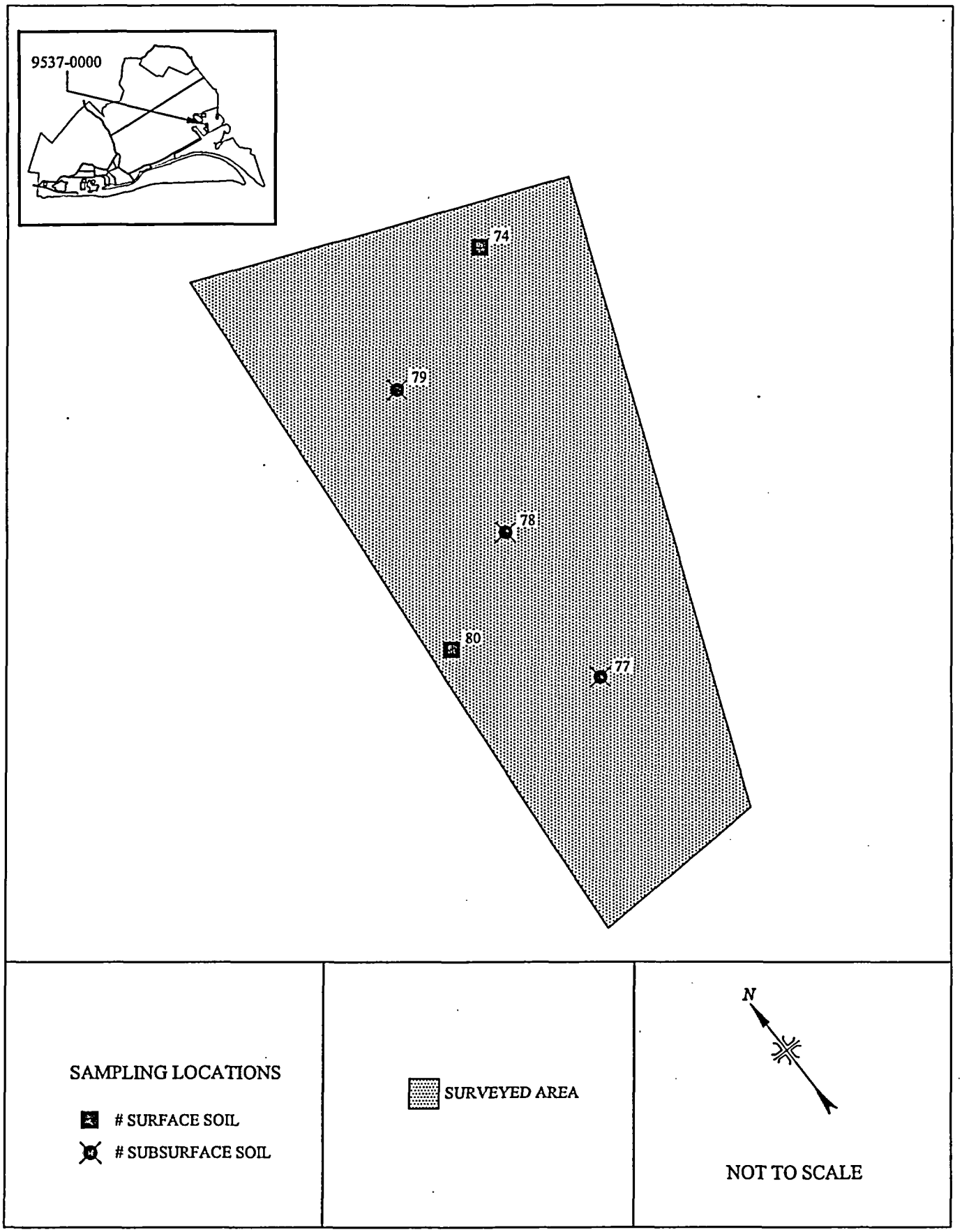
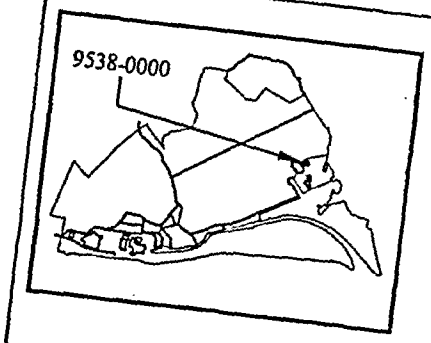
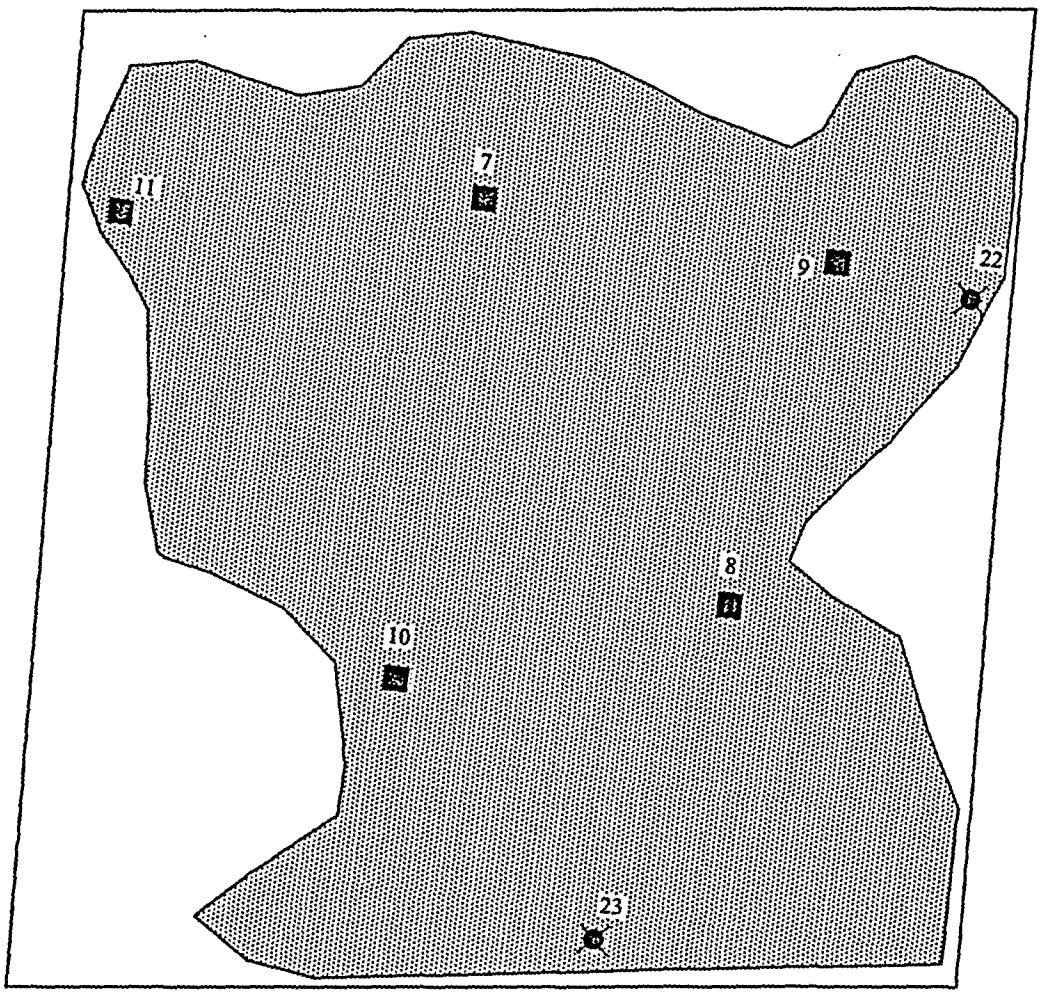



FIGURE 14: Survey Unit 9537-0000 - Sampling Locations

857-012 (2)




SAMPLING LOCATIONS

# SURFACE SOIL

# SUBSURFACE SOIL

SURVEYED AREA

N

NOT TO SCALE

FIGURE 15: Survey Unit 9538-0000 - Sampling Locations

# TABLES

TABLE 1

RADIONUCLIDE CONCENTRATIONS IN SOIL SAMPLES
OPEN LAND AREAS
CONNECTICUT YANKEE
HADDAM, CONNECTICUT

| Survey Unit/ Sample Location[a] | Radionuclide Concentrations (pCi/g) | |
|---|---|---|
| | Cs-137 | Co-60 |
| SU 9521-0000 Class 3 | | |
| 50 | 0.14 ± 0.03[b] | 0.03 ± 0.02 |
| 51 | 0.16 ± 0.03 | 0.02 ± 0.02 |
| 52 | 1.54 ± 0.12 | 0.02 ± 0.04 |
| 53 | 1.29 ± 0.11 | 0.01 ± 0.03 |
| 54 | 0.71 ± 0.06 | 0.02 ± 0.03 |
| SU 9523-0000 Class 3 | | |
| 55 | 0.08 ± 0.04 | 0.00[c] ± 0.03 |
| 56 | 0.20 ± 0.04 | -0.01 ± 0.02 |
| 57 | 0.07 ± 0.02 | -0.01 ± 0.02 |
| 58 | 0.53 ± 0.08 | 0.04 ± 0.04 |
| 59 | 0.91 ± 0.12 | 0.02 ± 0.04 |
| SU 9526-0000 Class 3 | | |
| 60 | 0.68 ± 0.06 | 0.00 ± 0.02 |
| 61 | 0.52 ± 0.06 | 0.01 ± 0.02 |
| 62 | 0.44 ± 0.06 | -0.01 ± 0.03 |
| 63 | 0.59 ± 0.06 | -0.01 ± 0.02 |
| 64 | 0.61 ± 0.07 | 0.00 ± 0.03 |
| 65 | 0.79 ± 0.09 | -0.02 ± 0.03 |
| 66 | 0.35 ± 0.04 | 0.00 ± 0.02 |
| 67 | 0.53 ± 0.05 | 0.01 ± 0.02 |
| 68 | 1.14 ± 0.09 | -0.01 ± 0.03 |
| 69 | 0.88 ± 0.08 | -0.02 ± 0.03 |
| 70 | 0.46 ± 0.06 | -0.02 ± 0.03 |
| SU 9526-0001 Class 2 | | |
| 12 | 0.57 ± 0.09 | -0.02 ± 0.03 |
| 13 | 0.49 ± 0.08 | -0.01 ± 0.03 |
| 14 | 0.40 ± 0.06 | -0.02 ± 0.03 |
| 15 | 1.42 ± 0.10 | -0.01 ± 0.03 |
| 16 | 0.62 ± 0.07 | 0.01 ± 0.03 |
| SU 9526-0002 Class 2 | | |
| 17 | 2.59 ± 0.16 | 0.03 ± 0.04 |
| 18 | 0.13 ± 0.02 | 0.00 ± 0.02 |
| 19 | 0.60 ± 0.06 | 0.00 ± 0.03 |
| 20 | 0.90 ± 0.08 | 0.01 ± 0.03 |
| 21 | 0.14 ± 0.03 | 0.00 ± 0.02 |

TABLE 1 (continued)

RADIONUCLIDE CONCENTRATIONS IN SOIL SAMPLES
OPEN LAND AREAS
CONNECTICUT YANKEE
HADDAM, CONNECTICUT

| Survey Unit/ Sample Location[a] | Radionuclide Concentrations (pCi/g) | |
|---|---|---|
| | Cs-137 | Co-60 |
| SU 9528-0000 Class 3 | | |
| 24 | 0.40 ± 0.04 | 0.01 ± 0.02 |
| 25 | 0.05 ± 0.03 | 0.01 ± 0.02 |
| 26 | 0.34 ± 0.05 | -0.02 ± 0.03 |
| 27 | 0.43 ± 0.07 | -0.01 ± 0.03 |
| 28 | 0.37 ± 0.05 | 0.03 ± 0.03 |
| 29 | 0.45 ± 0.07 | -0.01 ± 0.03 |
| 30 | 0.36 ± 0.04 | 0.02 ± 0.02 |
| 31 | 0.19 ± 0.04 | 0.01 ± 0.03 |
| 32 | 1.54 ± 0.13 | -0.02 ± 0.03 |
| 38 | 0.65 ± 0.08 | -0.01 ± 0.03 |
| 39 | 1.09 ± 0.08 | 0.00 ± 0.03 |
| SU 9528-0002 Class 2 | | |
| 33 | 0.15 ± 0.03 | 0.01 ± 0.02 |
| 34 | 0.18 ± 0.04 | 0.00 ± 0.03 |
| 35 | 0.45 ± 0.08 | 0.00 ± 0.03 |
| 36 | 0.21 ± 0.03 | 0.10 ± 0.03 |
| 37 | 0.37 ± 0.06 | 0.15 ± 0.07 |
| SU 9528-0003 Class 2 | | |
| 45 | 0.48 ± 0.05 | 0.16 ± 0.04 |
| 46 | 0.22 ± 0.04 | 0.00 ± 0.03 |
| 47 | 0.08 ± 0.02 | 0.03 ± 0.02 |
| 48 | 0.35 ± 0.04 | -0.01 ± 0.03 |
| 49 | 0.11 ± 0.04 | 0.01 ± 0.03 |
| SU 9531-0000 Class 3 | | |
| 40 | 0.13 ± 0.04 | 0.00 ± 0.03 |
| 41 | 0.14 ± 0.03 | 0.00 ± 0.02 |
| 42 | 0.45 ± 0.06 | 0.02 ± 0.03 |
| 43 | 0.35 ± 0.05 | 0.01 ± 0.02 |
| 44 | 0.05 ± 0.04 | 0.00 ± 0.02 |

TABLE 1 (continued)

RADIONUCLIDE CONCENTRATIONS IN SOIL SAMPLES
OPEN LAND AREAS
CONNECTICUT YANKEE
HADDAM, CONNECTICUT

| Survey Unit/ Sample Location[a] | Radionuclide Concentrations (pCi/g) | |
|---|---|---|
| | Cs-137 | Co-60 |
| SU 9532-0000 Non-Impacted | | |
| 01 | 0.80 ± 0.10 | -0.04 ± 0.03 |
| 02 | 0.56 ± 0.07 | 0.00 ± 0.03 |
| 03 | 0.20 ± 0.03 | 0.01 ± 0.02 |
| 04 | 0.22 ± 0.04 | 0.00 ± 0.02 |
| 05 | 0.22 ± 0.04 | -0.01 ± 0.02 |
| 06 | 0.50 ± 0.05 | 0.00 ± 0.02 |
| SU 9536-0000 Class 2 | | |
| 75[d] | 0.02 ± 0.02 | 0.01 ± 0.03 |
| 76[d] | 0.06 ± 0.03 | -0.01 ± 0.02 |
| 81 | 0.05 ± 0.04 | 0.02 ± 0.02 |
| 82 | 0.03 ± 0.02 | -0.01 ± 0.02 |
| 83 | 0.07 ± 0.02 | 0.01 ± 0.02 |
| SU 9537-0000 Class 2 | | |
| 74 | 0.12 ± 0.03 | 0.00 ± 0.02 |
| 77[d] | 0.01 ± 0.02 | 0.00 ± 0.02 |
| 78[d] | 0.05 ± 0.02 | 0.01 ± 0.02 |
| 79[d] | 0.03 ± 0.03 | 0.01 ± 0.02 |
| 80 | 0.05 ± 0.02 | 0.00 ± 0.02 |
| SU 9538-0000 Class 2 | | |
| 07 | 0.08 ± 0.04 | 0.01 ± 0.02 |
| 08 | 0.14 ± 0.03 | 0.00 ± 0.02 |
| 09 | 0.13 ± 0.03 | 0.01 ± 0.02 |
| 10 | 0.15 ± 0.02 | 0.00 ± 0.02 |
| 11 | 0.18 ± 0.04 | 0.02 ± 0.03 |
| 22[d] | 0.20 ± 0.02 | 0.00 ± 0.02 |
| 23[d] | 0.20 ± 0.05 | 0.05 ± 0.03 |

[a]Refer to Figures 3 through 15.
[b]Uncertainties represent the 95% confidence level, based on total propagated uncertainties.
[c]Zero values are due to rounding.
[d]Subsurface soil samples.

TABLE 2

ACTIVATION/FISSION PRODUCT CONCENTRATIONS IN
SELECTED SOIL SAMPLES
OPEN LAND AREAS
CONNECTICUT YANKEE
HADDAM, CONNECTICUT

| Sample Location[a] | 15 | 17 | 32 | 45 | 52 |
|---|---|---|---|---|---|
| Radionuclide | Radionuclide Concentrations (pCi/g) | | | | |
| Mn-54 | -0.01 ± 0.03[b] | 0.01 ± 0.03 | -0.02 ± 0.03 | -0.02 ± 0.02 | 0.00[c] ± 0.03 |
| Co-60 | -0.01 ± 0.03 | 0.03 ± 0.04 | -0.02 ± 0.03 | 0.16 ± 0.04 | 0.02 ± 0.04 |
| Nb-94 | 0.00 ± 0.02 | 0.01 ± 0.03 | 0.01 ± 0.02 | 0.01 ± 0.02 | 0.00 ± 0.03 |
| Ag-108m | -0.01 ± 0.02 | 0.00 ± 0.03 | -0.02 ± 0.02 | 0.00 ± 0.01 | 0.00 ± 0.03 |
| Cs-134 | 0.08 ± 0.04 | 0.07 ± 0.04 | 0.08 ± 0.04 | 0.04 ± 0.03 | 0.04 ± 0.03 |
| Cs-137 | 1.42 ± 0.10 | 2.59 ± 0.16 | 1.54 ± 0.13 | 0.48 ± 0.05 | 1.54 ± 0.12 |
| Eu-152 | -0.04 ± 0.07 | -0.01 ± 0.09 | 0.01 ± 0.09 | 0.02 ± 0.05 | -0.02 ± 0.09 |
| Eu-154 | 0.06 ± 0.11 | 0.00 ± 0.14 | 0.08 ± 0.15 | 0.01 ± 0.09 | 0.10 ± 0.15 |
| Eu-155 | 0.09 ± 0.09 | 0.12 ± 0.07 | 0.10 ± 0.07 | 0.08 ± 0.04 | 0.02 ± 0.08 |
| Am-241 | 0.04 ± 0.05 | 0.06 ± 0.06 | 0.09 ± 0.06 | 0.01 ± 0.03 | 0.05 ± 0.07 |

[a]Refer to Figures 3 through 15.
[b]Uncertainties represent the 95% confidence level, based on total propagated uncertainties.
[c]Zero values are due to rounding.

TABLE 3

ANALYTICAL COMPARISON OF CYAPCO SAMPLES
CONNECTICUT YANKEE
HADDAM, CONNECTICUT

| Radionuclide | Radionuclide Concentrations (pCi/g) | | | | | |
|---|---|---|---|---|---|---|
| | CYAPCO Results[a] | | | ESSAP Results[a] | | |
| | 857S071 | 857S072 | 857S073 | 857S071 | 857S072 | 857S073 |
| **Easy to Detects[b]** | | | | | | |
| Mn-54 | 0.01 ± 0.04[c] | -0.05 ± 0.05 | 0.02 ± 0.04 | 0.02 ± 0.03 | -0.02 ± 0.03 | -0.02 ± 0.04 |
| Co-60 | 0.50 ± 0.10 | 2.21 ± 0.31 | 1.71 ± 0.24 | 0.51 ± 0.08 | 1.84 ± 0.10 | 1.79 ± 0.13 |
| Nb-94 | 0.02 ± 0.03 | -0.01 ± 0.04 | 0.02 ± 0.04 | 0.02 ± 0.02 | 0.00[d] ± 0.03 | 0.01 ± 0.02 |
| Ag-108m | 0.06 ± 0.05 | -0.09 ± 0.11 | -0.04 ± 0.08 | 0.01 ± 0.03 | -0.02 ± 0.05 | 0.05 ± 0.07 |
| Cs-134 | 0.00 ± 0.04 | 0.03 ± 0.05 | 0.01 ± 0.04 | 0.04 ± 0.03 | 0.05 ± 0.03 | 0.05 ± 0.04 |
| Cs-137 | 11.3 ± 1.4 | 58.5 ± 7.1 | 41.3 ± 4.9 | 10.19 ± 0.44 | 49.7 ± 2.1 | 44.5 ± 1.8 |
| Eu-152 | 0.07 ± 0.13 | -0.17 ± 0.27 | 0.12 ± 0.21 | -0.03 ± 0.09 | -0.02 ± 0.14 | -0.22 ± 0.18 |
| Eu-154 | 0.01 ± 0.09 | -0.12 ± 0.10 | 0.09 ± 0.09 | -0.11 ± 0.12 | -0.07 ± 0.10 | -0.10 ± 0.14 |
| Eu-155 | -0.01 ± 0.13 | -0.05 ± 0.19 | 0.05 ± 0.16 | 0.08 ± 0.07 | 0.01 ± 0.09 | 0.02 ± 0.12 |
| Am-241[e] | 0.13 ± 0.22 | 0.23 ± 0.12 | 0.06 ± 0.15 | 0.06 ± 0.06 | 0.11 ± 0.07 | 0.10 ± 0.08 |
| **Hard to Detects[f]** | | | | | | |
| H-3 | 0.09 ± 0.06 | 0.07 ± 0.07 | 0.14 ± 0.08 | 0.9 ± 1.0 | 1.5 ± 1.1 | 3.2 ± 1.1 |
| C-14 | 0.23 ± 0.20 | 0.63 ± 0.21 | 0.40 ± 0.20 | 0.06 ± 0.55 | 1.22 ± 0.62 | 1.14 ± 0.60 |
| Fe-55 | 27 ± 12 | 9 ± 11 | -7 ± 11 | NA[g] | NA | NA |
| Tc-99 | -0.04 ± 0.15 | -0.03 ± 0.15 | -0.02 ± 0.15 | 0.25 ± 0.20 | 0.25 ± 0.19 | 0.28 ± 0.20 |
| Ni-63 | 8.9 ± 4.9 | 15.7 ± 5.5 | 16.0 ± 5.3 | 9.7 ± 1.7 | 23.1 ± 2.5 | 22.4 ± 2.5 |
| Sr-90 | 0.08 ± 0.05 | 0.19 ± 0.06 | 0.27 ± 0.13 | 0.04 ± 0.21 | 0.06 ± 0.19 | 0.19 ± 0.21 |
| Pu-236 | NA | NA | NA | -0.01 ± 0.01 | 0.01 ± 0.02 | 0.00 ± 0.02 |
| Pu-238 | 0.01 ± 0.02 | 0.08 ± 0.10 | 0.07 ± 0.06 | 0.02 ± 0.02 | 0.07 ± 0.04 | 0.03 ± 0.02 |
| Pu-239/240 | 0.02 ± 0.03 | -0.01 ± 0.01 | 0.07 ± 0.06 | 0.01 ± 0.01 | 0.03 ± 0.02 | 0.02 ± 0.01 |

TABLE 3 (continued)

ANALYTICAL COMPARISON OF CYAPCO SAMPLES
CONNECTICUT YANKEE
HADDAM, CONNECTICUT

| Radionuclide | Radionuclide Concentrations (pCi/g) | | | | | |
|---|---|---|---|---|---|---|
| | CYAPCO Results[a] | | | ESSAP Results[a] | | |
| | 857S071 | 857S072 | 857S073 | 857S071 | 857S072 | 857S073 |
| **Hard to Detects (continued)** | | | | | | |
| Pu-241 | -0.28 ± 0.81 | 0.33 ± 0.73 | 0.05 ± 0.89 | -2.2 ± 2.8 | -1.9 ± 3.7 | -1.4 ± 2.9 |
| Am-241[e] | 0.04 ± 0.05 | 0.10 ± 0.10 | 0.18 ± 0.12 | 0.04 ± 0.03 | 0.05 ± 0.02 | 0.11 ± 0.04 |
| Cm-243/244 | 0.00 ± 0.03 | 0.11 ± 0.10 | 0.02 ± 0.04 | -0.01 ± 0.02 | 0.00 ± 0.01 | 0.02 ± 0.02 |

[a]Samples collected by CYAPCO and split with ESSAP. Sample 857S071 is CYAPCO sample number 9535-0001-022R, 857S072 is CYAPCO sample number 9535-0001-035R and 857S073 is CYAPCO sample number 9535-0001-SPOT.
[b]Easy to detects are samples analyzed by gamma spectroscopy.
[c]Uncertainties represent the 95% confidence level, based on total propagated uncertainties.
[d]Zero values are due to rounding.
[e]Am-241 analyses were performed by gamma and alpha spectroscopy.
[f]Hard to detects are sample analyses which required wet chemistry methods.
[g]Analysis not performed.

## REFERENCES


Connecticut Yankee Atomic Power Company (CYAPCO). License Termination Plan, Connecticut Yankee Decommissioning Project, Haddam Neck Plant, Revision 1A. Haddam, Connecticut; October 2002.

Oak Ridge Institute for Science and Education (ORISE). Proposed Confirmatory Survey Plan for the Open Land Area Survey Units, Connecticut Yankee Decommissioning Project, Haddam, Connecticut (Docket No. 50-0213; RFTA No. 03-008). Oak Ridge, TN; September 22, 2003a.

Oak Ridge Institute for Science and Education. Survey Procedures Manual for the Environmental Survey and Site Assessment Program. Oak Ridge, TN; February 28, 2003b and November 7, 2003c.

Oak Ridge Institute for Science and Education. Quality Assurance Manual for the Environmental Survey and Site Assessment Program. Oak Ridge, TN; May 14, 2003d; November 7, 2003e; and January 7, 2004a.

Oak Ridge Institute for Science and Education. Laboratory Procedures Manual for the Environmental Survey and Site Assessment Program. Oak Ridge, TN; February 28, 2003f; November 7, 2003g; December 16, 2003h; January 7, 2004b; and March 16, 2004c.

U.S. Nuclear Regulatory Commission (NRC). Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM). NUREG-1575; Revision 1. Washington, DC; August 2000.

# APPENDIX A

# MAJOR INSTRUMENTATION

# APPENDIX A

## MAJOR INSTRUMENTATION

The display of a specific product is not to be construed as an endorsement of the product or its manufacturer by the author or his employer.

### SCANNING INSTRUMENT/DETECTOR COMBINATIONS

#### Gamma

Eberline Pulse Ratemeter Model PRM-6
(Eberline, Santa Fe, NM)
coupled to
Victoreen NaI Scintillation Detector Model 489-55, Crystal: 3.2 cm x 3.8 cm
(Victoreen, Cleveland, OH)

### LABORATORY ANALYTICAL INSTRUMENTATION

High Purity Extended Range Intrinsic Detector
Model No. GMX-45200-5
(EG&G ORTEC, Oak Ridge, TN)
used in conjunction with:
Lead Shield Model SPG-16-K8
(Nuclear Data)
Multichannel Analyzer
DEC ALPHA Workstation
(Canberra, Meriden, CT)

High Purity Extended Range Intrinsic Detectors
Tennelec Model No: ERVDS30-25195
(Canberra, Meriden, CT)
Used in conjunction with:
Lead Shield Model G-11
(Nuclear Lead, Oak Ridge, TN) and
Multichannel Analyzer
DEC ALPHA Workstation
(Canberra, Meriden, CT)

## LABORATORY ANALYTICAL INSTRUMENTATION (CONTINUED)

Alpha Spectrometry System
Tennelec Model 256
(Canberra, Meriden, CT)
Used in conjunction with:
Ion Implanted Detectors
(Canberra, Meriden, CT) and
Multichannel Analyzer
DEC ALPHA Workstation
(Canberra, Meriden,CT)

Alpha Spectrometry System
Canberra Model 7401VR
(Canberra, Meriden, CT)
Used in conjunction with:
Ion Implanted Detectors and
Multichannel Analyzer
DEC ALPHA Workstation
(Canberra, Meriden, CT)

Low Background Gas Proportional Counter
Model LB-5100-W
(Tennelec/Canberra, Meriden, CT)

Tri-Carb Liquid Scintillation Analyzer
Model 3100
(Packard Instrument Co., Meriden, CT)

# APPENDIX B

# SURVEY AND ANALYTICAL PROCEDURES

# APPENDIX B

# SURVEY AND ANALYTICAL PROCEDURES

## PROJECT HEALTH AND SAFETY

The proposed survey and sampling procedures were evaluated to ensure that any hazards inherent to the procedures themselves were addressed in current job hazard analyses (JHAs). All survey and laboratory activities were conducted in accordance with ORISE health and safety and radiation protection procedures.

Pre-survey activities included the evaluation and identification of potential health and safety issues. Of particular concern for the outdoor area surveys was Lyme disease from infected tick bites and tripping hazards over heavily forested open land areas. Survey work was performed per the ORISE generic health and safety plans and a site-specific integrated safety management (ISM) pre-job hazard checklist. CYAPCO also provided site-specific safety awareness training.

## CALIBRATION AND QUALITY ASSURANCE

Calibration of all laboratory instrumentation was based on standards/sources, traceable to NIST, when such standards/sources were available. In cases where they were not available, standards of an industry-recognized organization were used.

Analytical and field survey activities were conducted in accordance with procedures from the following Environmental Survey and Site Assessment Program documents:

- Survey Procedures Manual (February and November 2003)
- Laboratory Procedures Manual (February, November, and December 2003, and January and March 2004)
- Quality Assurance Manual (May and November 2003 and January 2004)

The procedures contained in these manuals were developed to meet the requirements of Department of Energy (DOE) Order 414.1A and the U.S. Nuclear Regulatory Commission

*Quality Assurance Manual for the Office of Nuclear Material Safety and Safeguards* and contain measures to assess processes during their performance.

Quality control procedures include:

- Daily instrument background and check-source measurements to confirm that equipment operation is within acceptable statistical fluctuations.
- Participation in MAPEP, NRIP, ITP, and EML Laboratory Quality Assurance Programs.
- Training and certification of all individuals performing procedures.
- Periodic internal and external audits.

## SURVEY PROCEDURES

### Surface Scans

Surface scans were performed by passing the detectors slowly over the surface; the distance between the detector and the surface was maintained at a minimum—nominally about 5 to 10 cm. A NaI scintillation detector was used to scan for elevated gamma radiation on the soil surfaces. Identification of elevated levels was based on increases in the audible signal from the recording and/or indicating instrument.

The scan minimum detectable concentration (MDC) for the NaI scintillation detector for Co-60 and Cs-137 were obtained directly from NUREG-1507.[1] The scan MDCs were 5.8 and 10.4 pCi/g, respectively, for Co-60 and Cs-137.

### Soil Sampling

Approximately 1 kg of soil was collected at each sample location. Collected samples were placed in a plastic bag, sealed, and labeled in accordance with ESSAP survey procedures.

[1]NUREG-1507. Minimum Detectable Concentration with Typical Radiation Survey Instruments for Various Contaminants and Field Conditions. U.S. Nuclear Regulatory Commission. Washington, DC; June 1998.

## RADIOLOGICAL ANALYSIS

### Gamma Spectroscopy

Samples of soil were dried, mixed, crushed, and/or homogenized as necessary, and a portion sealed in a 0.5-liter Marinelli beaker or other appropriate container. The quantity placed in the beaker was chosen to reproduce the calibrated counting geometry. Net material weights were determined and the samples counted using intrinsic germanium detectors coupled to a pulse height analyzer system. Background and Compton stripping, peak search, peak identification, and concentration calculations were performed using the computer capabilities inherent in the analyzer system. All photopeaks associated with the radionuclides of concern were reviewed for consistency of activity. Photopeaks used for determining the activities of radionuclides of concern and the typical associated MDCs for a one-hour count time were:

| Radionuclide | Photopeak (MeV) | MDC soil (pCi/g) |
|---|---|---|
| Mn-54 | 0.834 MeV | 0.03 |
| Co-60 | 1.173 MeV | 0.05 |
| Nb-94 | 0.871 MeV | 0.03 |
| Ag-108m | 0.433 MeV | 0.02 |
| Cs-134 | 0.796 MeV | 0.04 |
| Cs-137 | 0.662 MeV | 0.05 |
| Eu-152 | 0.344 MeV | 0.11 |
| Eu-154 | 0.723 MeV | 0.13 |
| Eu-155 | 0.105 MeV | 0.07 |
| Am-241 | 0.059 MeV | 0.06 |

Spectra were also reviewed for other identifiable photopeaks.

### Alpha Spectroscopy

Soil samples were crushed, homogenized and dissolved by potassium fluoride and pyrosulfate fusion and the elements of interest were precipitated with barium sulfate. Barium sulfate precipitate was redissolved and the specific elements of interest—isotopic plutonium and

americium—were individually separated by extraction chromatography using Eichrom resins and re-precipitated with a cerium fluoride carrier. The precipitate was then analyzed using ion implanted detectors (Canberra), alpha spectrometers (Tennelec and Canberra), and a multichannel analyzer (Nuclear Data). The typical MDC(s) of the procedure for a 1000 minute count time is 0.02 pCi/g for solids.

## Nickel-63

Soil samples were precipitated as a nickel/dimethylglyoxime precipitate on an extraction chromatographic resin (Ni-63 Resin from Eichrom Technologies, Darien, IL). Potential interfering elements were removed from the column with a buffered ammonium citrate solution. Nickel was eluted off the column with dilute nitric acid. A batch yield was used to determine chemical recovery. Iron was removed from the soil prior to nickel separation using anion exchange chromatography. The Ni-63 activity was determined via a 60 minute count time using a liquid scintillation analyzer. The typical MDC of the procedure is 2.3 pCi/g.

## Strontium-90

Soil samples were dissolved by a combination of potassium hydrogen fluoride and pyrosulfate fusions. The fusion cake was dissolved and strontium was coprecipitated on lead sulfate. The strontium was separated from residual calcium and lead by reprecipitating strontium sulfate from EDTA at a pH of 4.0. Strontium was separated from barium by complexing the strontium in DTPA while precipitating barium as barium chromate. The strontium was ultimately converted to strontium carbonate and counted for 200 minutes on a low-background gas proportional counter. The typical MDC of the procedure is 0.8 pCi/g.

## Technetium-99

Solid samples were leached with dilute nitric acid. The leachates were passed through an extraction chromatographic column containing a resin which was highly specific for technetium in the pertechnatate form. The technetium was absorbed onto the extraction resin. The resin was

added to a scintillation vial containing an appropriate cocktail and counted for 60 minutes using a liquid scintillation analyzer. The typical MDC of the procedure is 0.33 pCi/g for a 5 g aliquot.

**Tritium**

Solid samples were combusted using a biological material oxidizer (BMO) system. The water vapor was trapped in an organic compound containing scintillation cocktail and counted for 60 minutes on a liquid scintillation analyzer. A matrix spike was run with each batch to determine chemical recovery. The typical MDC of the procedure is 2 pCi/g wet weight for soil.

**Carbon-14**

Undried solid samples were combusted using a BMO system. Carbon dioxide was carried through the system with an inert gas. The carbon dioxide was trapped in an organic compound containing scintillation cocktail and counted for 60 minutes in a liquid scintillation analyzer. A matrix spike was run with each batch to determine chemical recovery. The typical MDC of the procedure is 1.3 pCi/g wet weight for soils.

## UNCERTAINTIES AND DETECTION LIMITS

The uncertainties associated with the analytical data presented in the tables of this report represent the total propagated uncertainties for that data. These uncertainties were calculated based on both the gross sample count levels and the associated background count levels.

Detection limits, referred to as minimum detectable concentration (MDC), were based on 3 plus 4.65 times the standard deviation of the background count [$3 + (4.65\sqrt{BKG})$]. Because of variations in background levels, measurement efficiencies, and contributions from other radionuclides in samples, the detection limits differ from sample to sample and instrument to instrument.