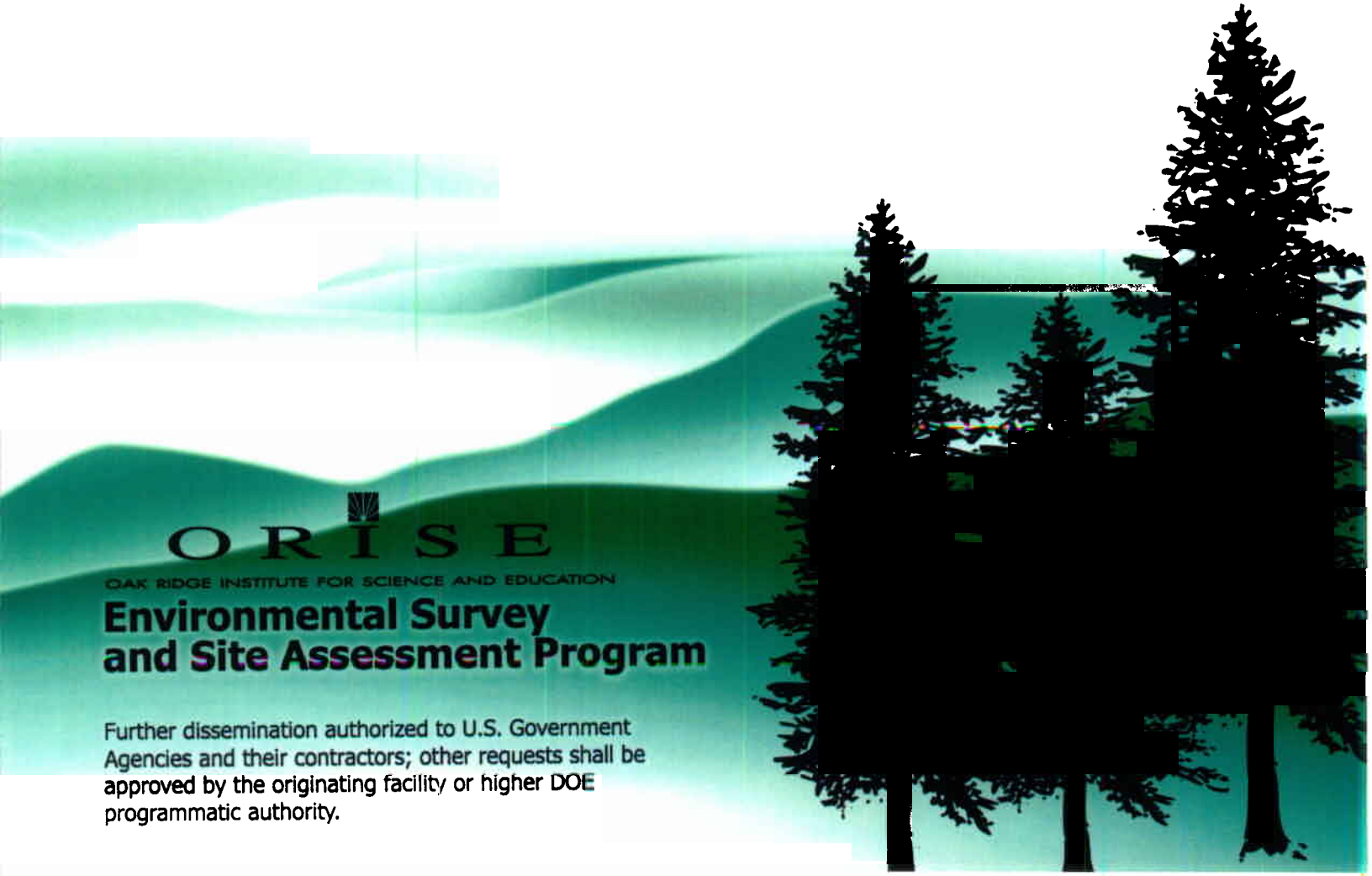
# VERIFICATION SURVEY OF THE BUILDING 4059 EXCAVATION SANTA SUSANA FIELD LABORATORY THE BOEING COMPANY VENTURA COUNTY, CALIFORNIA

T. J. VITKUS

Prepared for the
Oakland Environmental Programs
U.S. Department of Energy



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## NOTICES

# VERIFICATION SURVEY OF THE BUILDING 4059 EXCAVATION SANTA SUSANA FIELD LABORATORY THE BOEING COMPANY VENTURA COUNTY, CALIFORNIA

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Prepared for the

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**FINAL REPORT**

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**VERIFCATION SURVEY**
**OF THE BUILDING 4059 EXCAVATION**
**SANTA SUSANA FIELD LABORATORY**
**THE BOEING COMPANY**
**VENTURA COUNTY, CALIFORNIA**

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## ABBREVIATIONS AND ACRONYMS

| | |
|---|---|
| $\mu$R/h | microroentgens per hour |
| $\mu$rem/h | microrem per hour |
| AEC | Atomic Energy Commission |
| BKG | background |
| BMO | biological material oxidizer |
| cm | centimeter |
| D&D | decontamination and decommissioning |
| DOE | U.S. Department of Energy |
| ERDA | Energy Research and Development Administration |
| ESSAP | Environmental Survey and Site Assessment Program |
| ETEC | Energy Technology Engineering Center |
| FSS | final status survey |
| ha | hectares |
| ISM | integrated safety management |
| ITP | Intercomparison Testing Program |
| JHA | job hazard analysis |
| MARSSIM | Multi-Agency Radiation Survey and Site Investigation Manual |
| MAPEP | Mixed Analyte Performance Evaluation Program |
| MDC | minimum detectable concentration |
| MeV | million electron volts |
| $m^2$ | square meter |
| NaI | sodium iodide |
| NIST | National Institute of Standards and Technology |
| NRC | U.S. Nuclear Regulatory Commission |
| NRIP | NIST Radiochemistry Intercomparison Program |
| ORISE | Oak Ridge Institute for Science and Education |
| pCi/g | piocuries per gram |
| SSFL | Santa Susana Field Laboratory |
| SNAP | Systems for Nuclear Auxiliary Power |
| SU | survey unit |

# VERIFICATION SURVEY
# OF THE BUILDING 4059 EXCAVATION
# SANTA SUSANA FIELD LABORATORY
# THE BOEING COMPANY
# VENTURA COUNTY, CALIFORNIA

## INTRODUCTION AND SITE HISTORY

Boeing/Rocketdyne (Rocketdyne), formerly Rockwell International Rocketdyne Division, operates the Santa Susana Field Laboratory (SSFL). The Energy Technology Engineering Center (ETEC) is that portion of the SSFL, operated for the U.S. Department of Energy (DOE), which performed testing of equipment, materials, and components for nuclear and energy related programs. Contract work for the Atomic Energy Commission (AEC) and the Energy Research and Development Administration (ERDA), predecessor agencies to the DOE, began in the early 1950's. Specific programs conducted for AEC/ERDA/DOE involved engineering, developing, testing, and manufacturing operations for nuclear reactor systems and components. Other SSFL activities have also been conducted for the National Aeronautics and Space Administration, the U.S. Department of Defense, and other government related or affiliated organizations and agencies. Some activities have been licensed by the U.S. Nuclear Regulatory Commission (NRC) and by the State of California Radiologic Health Branch of the Department of Health Services.

Numerous buildings and land areas became radiologically contaminated as a result of the various operations which included ten reactors, seven criticality test facilities, fuel fabrication, reactor and fuel disassembly, laboratory work, and on-site storage of nuclear material. Potential radioactive contaminants identified at the site are uranium (in depleted and enriched isotopic abundances), plutonium, Am-241, fission products (primarily Cs-137 and Sr-90), and activation products (tritium [H-3], Co-60, Eu-152, Eu-154, Ni-63, Pm-147, and Ta-182). Chemical contaminants, mainly chlorinated organic solvents, have also been identified in groundwater, primarily as a result of rocket engine testing. Decontamination and decommissioning (D&D) of contaminated facilities began in the late 1960's and continues as the remaining DOE program operations at ETEC were terminated, effective September 30, 1995. As part of this D&D program, Rocketdyne has performed, or will perform, decommissioning and final status surveys of the facilities that supported the various nuclear-related ETEC operations. Environmental

management of DOE contaminated properties continues under the termination clause of the existing Management and Operation contract. Phase II of the Building 4059 decommissioning is currently being addressed.

Building 4059 was constructed during 1962 and 1963. The facility housed a research and development program known as the Systems for Nuclear Auxiliary Power (SNAP). The program was established to develop and test power systems for use as subsidiary nuclear power units in specialized applications. Atomic International developed the SNAP 8 reactor, under contract to the AEC, for use in this program. Reactor operation began in 1963 and was followed by a shutdown in 1964 to permit building modifications. The last test was conducted in 1969 at which time the reactor was shut down.

The SNAP project resulted in the radiological contamination of those portions of Building 4059 associated with reactor operations. Contamination was principally the result of neutron activation; the primary contaminants were Co-60, Ni-63, Ba-133, Eu-152, Eu-154, Fe-55, and H-3. Decommissioning of the facility was initiated in the 1970's followed by annual inspections and radiological survey work. Inspections performed in 1983 revealed that groundwater was leaking into the facility. Rocketdyne stabilized the problem and a water management plan was implemented. Structural deterioration was revealed in 1987 after water was discovered in previously dry areas. Due to the potential risk of contamination through pathways between the outside and the vault interior, the Building 4059 Vault Remediation Program was initiated. The initial remedial activities removed the most highly activated sources, including the vacuum duct, vacuum vessel, and north test cell shielding concrete. Further remediation of structural concrete would have compromised the structural integrity of the building. Therefore, Rocketdyne completed decommissioning Building 4059 in two phases. Phase I involved remediating and performing final release surveys of all non-activated above- and below-grade areas, followed by demolition of those portions of the facility. Phase II involves the demolition of the activated sub-grade portion of the structure, followed by final status surveys (FSS) of the resultant excavation. The initial Phase II final status survey included a Class 1 and Class 2 survey unit. After the excavation is backfilled, a second final status survey of the backfilled and surrounding

area will be performed. Rocketdyne conducted the FSS in accordance with guidance provided in the Multi-Agency Radiation Survey and Site Investigation Manual [MARSSIM (NRC 2000)].

DOE is responsible for oversight of remedial actions that are conducted at the SSFL. It is the policy of DOE to perform independent (third party) verification of remedial action activities. The purpose of these independent verification activities is to confirm that remedial actions have been effective in meeting established and site-specific guidelines and that the documentation accurately and adequately describes the radiological conditions at the site. The Environmental Survey and Site Assessment Program (ESSAP) of the Oak Ridge Institute for Science and Education (ORISE) was designated as the organization responsible for this task at SSFL, and was requested to verify the current radiological status of the Building 4059 excavation.

## SITE DESCRIPTION

The SSFL is located in the Simi Hills of southeastern Ventura County, California, approximately 47 kilometers (29 miles) northwest of downtown Los Angeles (Figure 1). The site is comprised of approximately 1,090 hectares (ha[2,700 acres]) and is divided into four administrative areas (Areas I through IV) and a Buffer Zone. DOE operations were conducted in Boeing/Rocketdyne-owned facilities located within the 117 ha Area IV. The ETEC portion of Area IV consists of government-owned buildings that occupy 36 ha.

Building 4059 was located at the intersection of 20$^{th}$ and "B" Streets in the north-central part of Area IV (Figure 2). The facility consisted of the sub-grade reactor vault and an above-grade support facility, all of which has been demolished during decommissioning. The site now consists of an approximately 10 meter deep excavation. The excavation consisted of two survey units. The 567 square meter ($m^2$) Class 1 survey unit (SU)-1 encompassed the lowest part of the excavation and is the area formerly associated with the building's basement, test cells, and pipe chase room. The Class 2 survey unit (SU)-2 measured 3,780 $m^2$ in area and included the remainder of the Building 4059 fenced-in land area. Figure 3 shows the plot plan of the area.

## OBJECTIVES

The objectives of the verification survey were to confirm that remedial actions have been effective in meeting established release criteria and that documentation accurately and adequately describes the final radiological conditions of the Building 4059 excavation.

## DOCUMENT REVIEW

ESSAP reviewed the final status survey procedure (Boeing 2004). Information was evaluated to assure that FSS procedures were appropriate for the radionuclides of concern and followed the guidance provided in MARSSIM. The site's final status survey report had not been issued at the time this report was prepared, although the final status survey data were provided to ESSAP for review. When issued, the report will be reviewed to ensure that the final status survey plan was implemented fully and that the data support the site's conclusions.

## PROCEDURES

ESSAP performed an independent verification survey of the two soil survey units associated with the Building 4059 excavation on October 19 and 20, 2004. The verification activities consisted of gamma surface scans and soil sampling performed in accordance with a site-specific survey plan, submitted to and approved by the DOE, and the ORISE/ESSAP Survey Procedures and Quality Assurance Manuals (ORISE 2004a, b, and c).

### REFERENCE SYSTEM

The grid and site drawings prepared by the contractor and prominent site features were used for referencing measurement and sampling locations.

### SURFACE SCANS

Surface scans for gamma radiation were conducted over 50 to 100 % of both the Class 1 and Class 2 survey units established for the Building 4059 excavation. The bottom of the excavation

within SU-1 was unavoidably inaccessible for scanning due to the accumulation of water from heavy rains encountered during the time of the confirmatory survey. For this area, verification relied on the review of Boeing's final status survey results. Additional gamma scans were performed of the overburden sand and dirt that had been excavated and stockpiled. Boeing plans to use this material as backfill. Surface scans were performed using a NaI scintillation detector coupled to a ratemeter with an audible indicator.

### EXPOSURE RATE MEASUREMENTS

Exposure rate measurements were performed at one meter above the surface at five locations in SU-2 and at four locations associated with the stockpiled sand/soil. Measurements were made using a microrem meter.

### SOIL SAMPLING

Surface soil samples (0 to 15 cm) were collected from five locations within both survey units (Figures 4 and 5). Two additional composite samples were collected, one each, from the stockpiled sand and soil.

## SAMPLE ANALYSIS AND DATA INTERPRETATION

Samples and data were returned to the ORISE/ESSAP laboratory in Oak Ridge, Tennessee for analysis and interpretation. Sample analyses were performed in accordance with the ORISE/ESSAP Laboratory Procedures Manual (ORISE 2004d). Soil samples were analyzed by gamma spectroscopy for the gamma-emitting primary radionuclides of concern. The spectra were also reviewed for other identifiable photopeaks. Samples were also analyzed for H-3. Soil sample results were reported in units of picocuries per gram (pCi/g). Exposure rates were reported in units of microroentgens per hour (μR/h). The data generated were compared with the approved release criteria established for the Building 4059 site. Appendices A and B provide additional information regarding survey and laboratory equipment and procedures.

# FINDINGS AND RESULTS

## DOCUMENT REVIEW

ESSAP's review of the final status survey procedures determined that the plan appropriately followed the guidance in MARSSIM and that the proposed procedures and data assessment processes would adequately address all contaminants of concern. The final status report has not been received for review at this time. The site has indicated that a combined report will be issued once the Building 4059 excavation is backfilled and the second final status survey is completed for the remaining land areas. When reviewed, ESSAP will provide any comments identified to the DOE.

## SURFACE SCANS

Gamma surface scans did not detect any locations of elevated direct radiation indicative of residual contamination.

## EXPOSURE RATES

Exposure rates are summarized in Table 1. The exposure rate range at measured locations was 9 to 16 μR/h. Background exposure rates were determined during a previous ESSAP survey at the site and were determined to average 14 μR/h (ORISE 1996).

## RADIONUCLIDE CONCENTRATIONS IN SOIL SAMPLES

The radionuclide concentrations in soil samples are provided in Table 1. All evaluated gamma emitting fission and activation products were statistically equal to zero and indicate that no residual contamination from operation of the SNAP reactor remained in the soils, including the sand/soil overburden. The H-3 results are also shown in Table 1. The maximum concentration was 5.1 pCi/g wet weight which is less than the 7 pCi/g minimum detectable concentration.

## COMPARISON OF RESULTS WITH RELEASE CRITERIA

The primary radionuclides of concern for the Building 4059 excavation are H-3, Fe-55, Co-60, Ba-133, Eu-152 and Eu-154. The applicable site-specific guidelines are provided in Table 2 and have been approved by both the DOE and State of California (DOE 1996 and State of California 1996). To demonstrate compliance with the Table 2 criteria each radionuclide concentration should be less than its respective guideline—with consideration for small areas of elevated activity—as well as application of the unity rule. The unity rule requires that the sum of the concentration of each contaminant divided by the respective guideline is less than one. Alternatively, a surrogate approach may be used where the concentration of one or several radionuclides may be inferred from a single measured radionuclide. This surrogate approach is based on the relative fraction of the inferred radionuclide(s) to the surrogate, measured radionuclide. Boeing used this approach and modified the Eu-152 criteria to account for all other potential contaminants. The Eu-152 guideline was modified from the Table 2 value of 4.51 pCi/g to 2.79 pCi/g. Evaluation of just the Eu-152 concentrations in verification soil samples also shows compliance with this criterion.

For the area of SU-1 that ESSAP was unable to access for scanning and sampling, the review of Boeing's final status survey data from this area showed that, other than the naturally occurring radionuclides, only Ni-63 and H-3 were present at concentrations that could be confidently considered as greater than zero. The general reported concentrations for all radionuclides, where both ESSAP and Boeing reported data, compared favorably. The maximum detectable concentrations in Boeing's SU-1 samples were 5.8 pCi/g for H-3 and 10.7 pCi/g for Ni-63—well below the respective guidelines of 31,900 pCi/g and 55,300 pCi/g.

Exposure rates were compared to the DOE exposure rate guideline for exterior areas of 20 $\mu$R/h above background (DOE 1993). All verification exposure rate measurements were less than this guideline.

## SUMMARY

At the request of the U. S. Department of Energy, the Environmental Survey and Site Assessment Program of the Oak Ridge Institute for Science and Education conducted a verification survey of the Building 4059 excavation at the Santa Susana Field Laboratory in Ventura County, California. Verification activities were performed during the period of October 19 through 20, 2004 and included data reviews, surface scans, exposure rate measurements, and soil sampling. Surface scans did not identify any indications of residual contamination, exposure rates were less than the applicable guidelines, and radionuclide concentrations in soil were less than all applicable criteria. Therefore, it is ESSAP's opinion that the Building 4059 excavation satisfies the criteria for release for unrestricted use.

# FIGURES

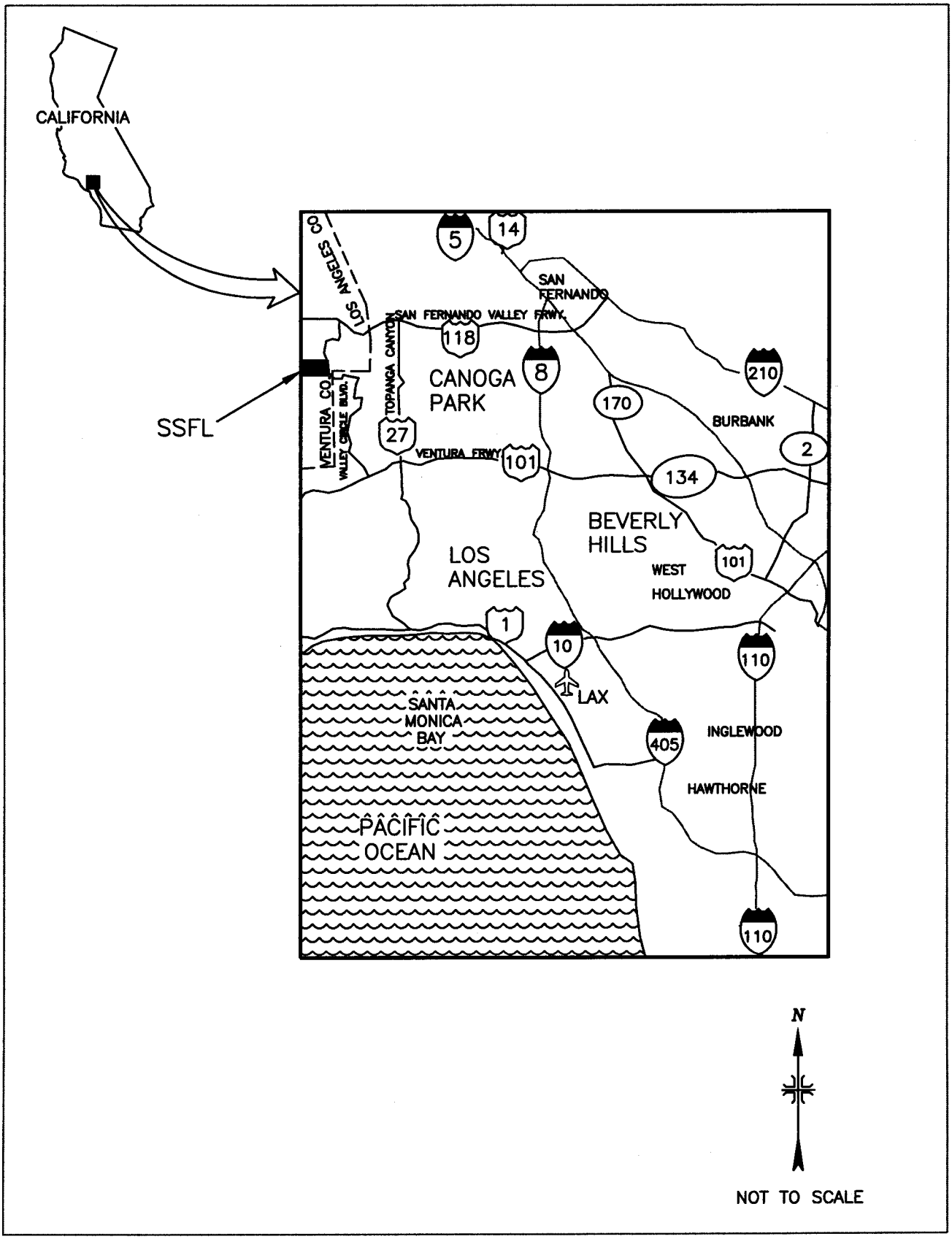



FIGURE 1: Los Angeles California Area – Location of Santa Susana Field Laboratory Site

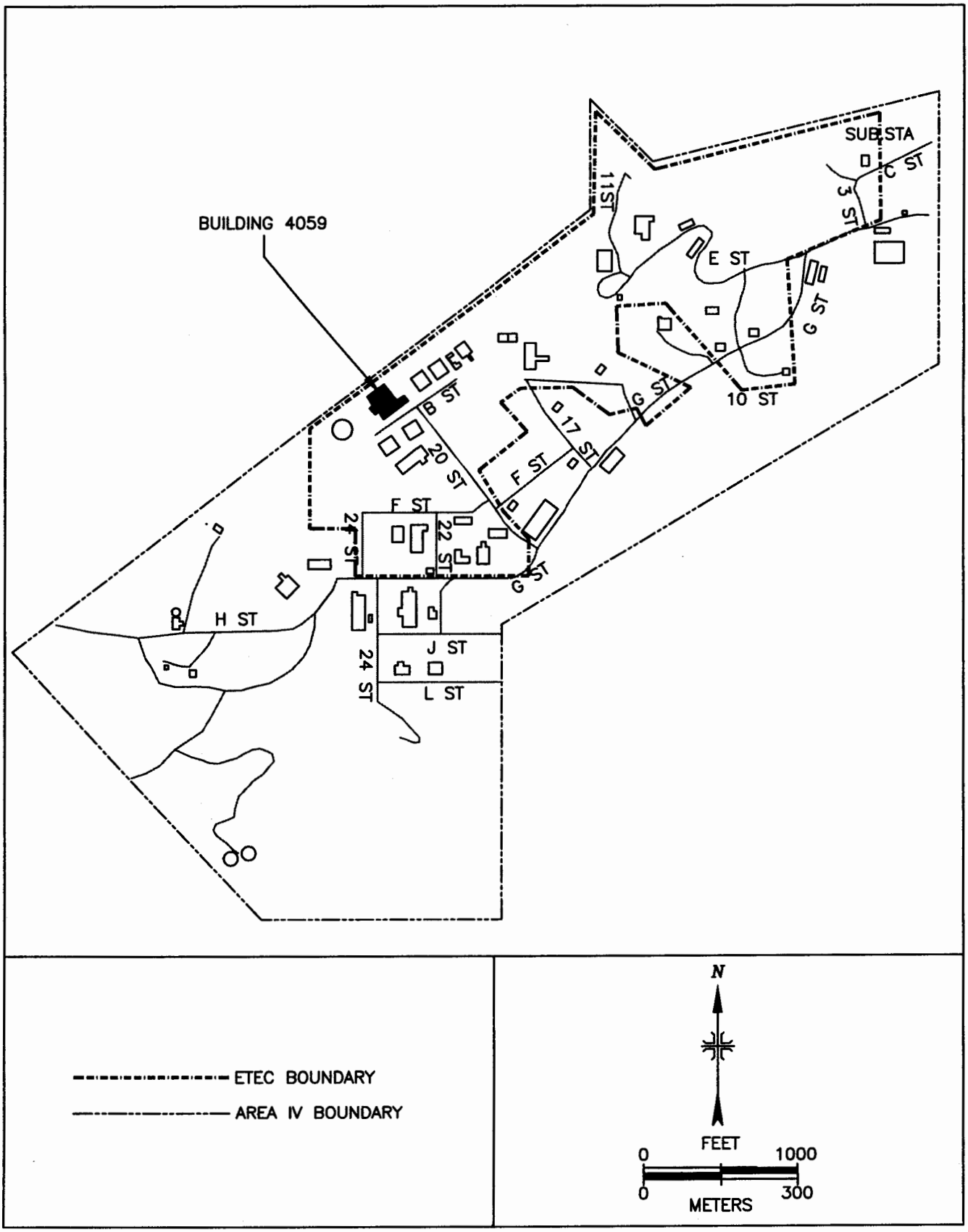



FIGURE 2: Santa Susana Field Laboratory Area IV, Plot Plan – Location of Building 4059

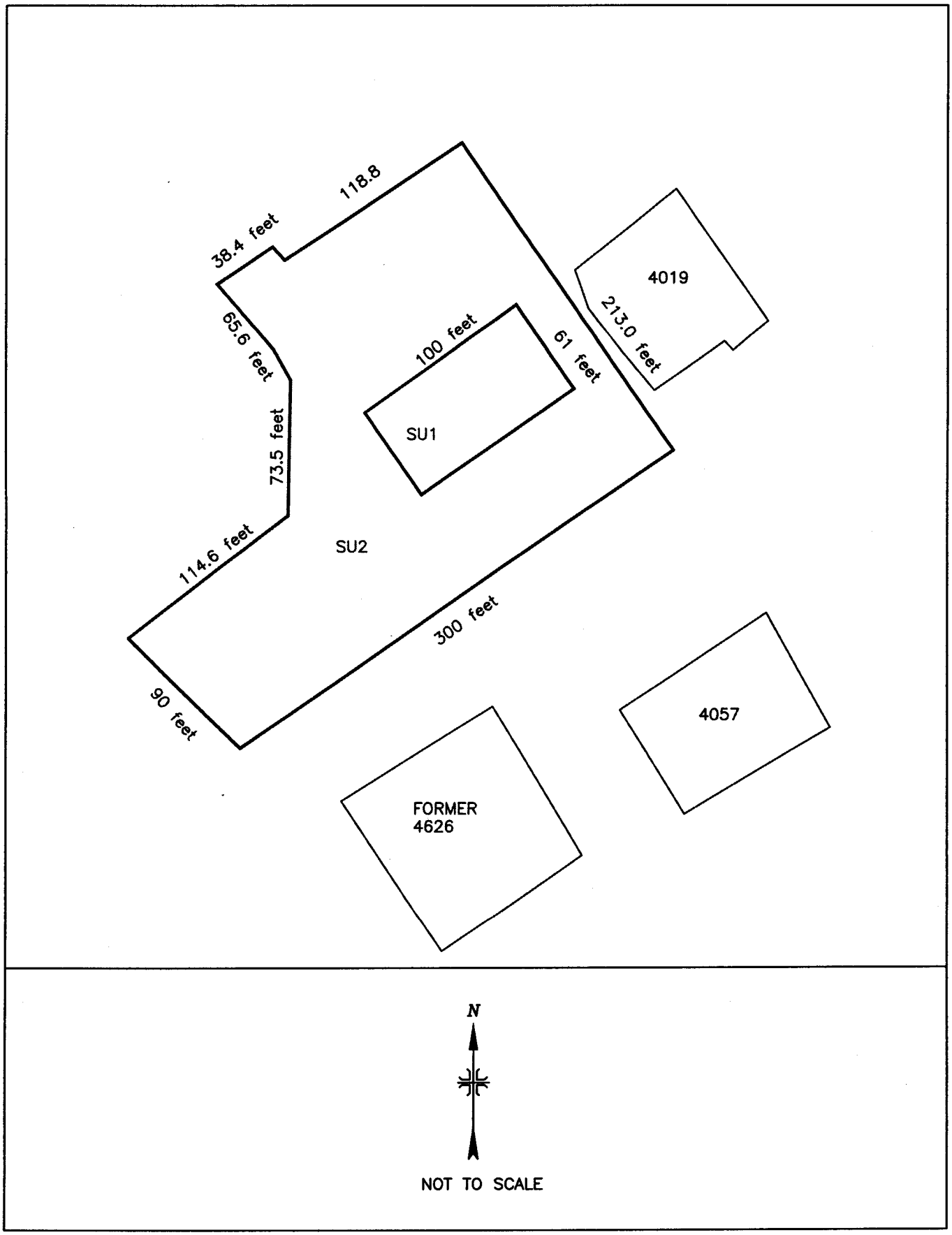
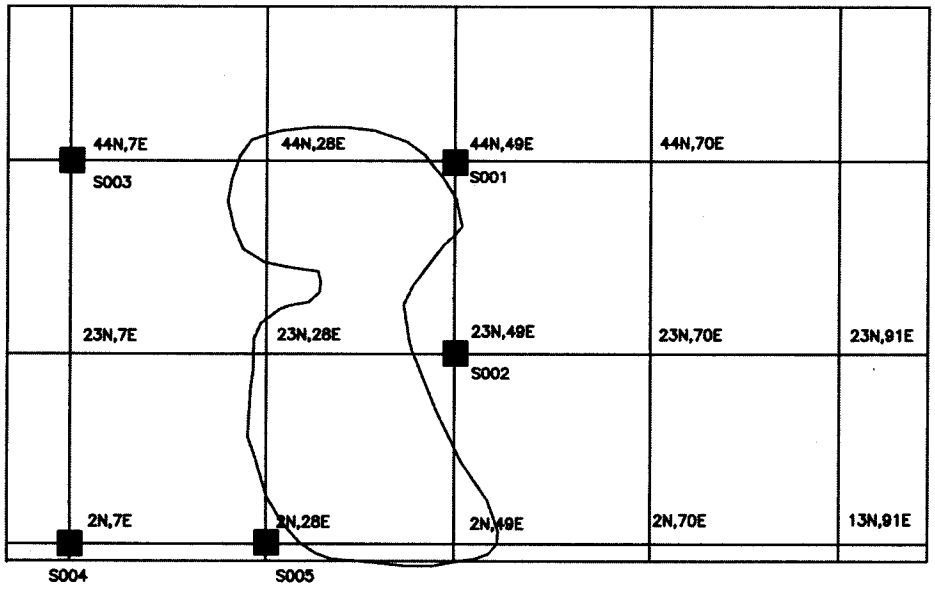



FIGURE 3: Building 4059, Excavation Areas, Survey Units 1 and Unit 2 – Plot Plan




MEASUREMENT/SAMPLING LOCATIONS

■ # SURFACE SOIL

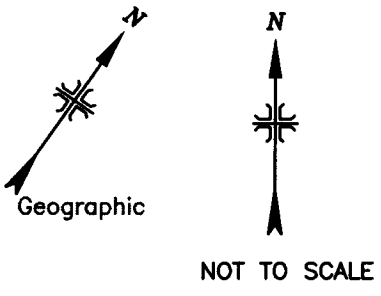
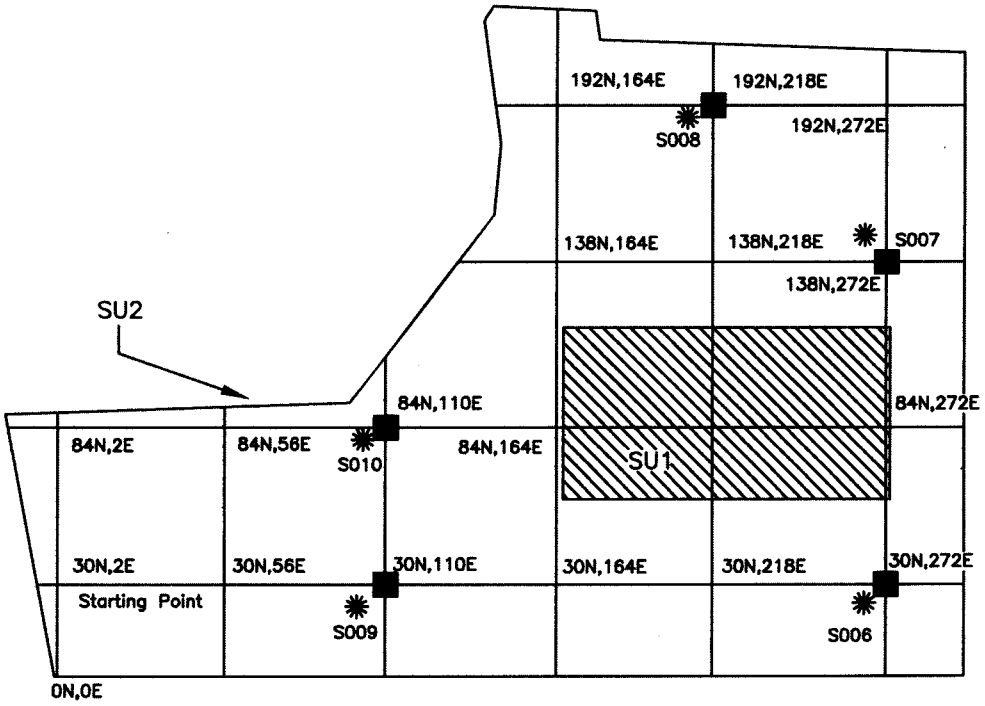



FIGURE 4: Building 4059, Excavation Area, Survey Unit 1 – Measurement and Sampling Locations




MEASUREMENT/SAMPLING LOCATIONS

■ # SURFACE SOIL

✱ # EXPOSURE RATE

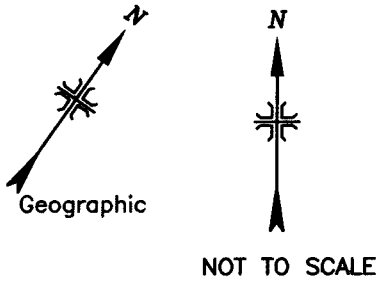



FIGURE 5: Building 4059, Excavation Area, Survey Unit 2 – Measurement and Sampling Locations

# TABLES

## TABLE 1

## RADIONCLUIDE CONCENTRATIONS IN SOIL SAMPLES
## BUILDING 4059 EXCAVATION
## SANTA SUSANA FIELD LABORATORY
## VENTURA COUNTY, CALIFORNIA

| ESSAP Sample ID[a] | Exposure Rate μR/h | Radionuclide Concentrations (pCi/g)[b] | | | | | |
|---|---|---|---|---|---|---|---|
| | | Ba-133 | Co-60 | Cs-137 | Eu-152 | Eu-154 | H-3 |
| 1 | ---[c] | -0.01 ± 0.02[d] | -0.01 ± 0.03 | -0.03 ± 0.02 | -0.04 ± 0.05 | -0.07 ± 0.11 | 2.6 ± 4.6 |
| 2 | --- | 0.01 ± 0.03 | 0.02 ± 0.04 | -0.01 ± 0.02 | 0.06 ± 0.07 | -0.02 ± 0.12 | 5.1 ± 3.6 |
| 3 | --- | 0.01 ± 0.02 | 0.00 ± 0.02 | -0.01 ± 0.02 | 0.02 ± 0.04 | -0.05 ± 0.08 | 2.7 ± 3.6 |
| 4 | --- | 0.00[e] ± 0.02 | 0.00 ± 0.03 | 0.00 ± 0.02 | 0.01 ± 0.05 | 0.06 ± 0.11 | 1.9 ± 3.9 |
| 5 | --- | 0.01 ± 0.03 | 0.02 ± 0.03 | -0.01 ± 0.02 | 0.00 ± 0.06 | 0.04 ± 0.11 | 0.1 ± 4.0 |
| 6 | 11 | 0.02 ± 0.02 | 0.01 ± 0.02 | 0.00 ± 0.02 | 0.01 ± 0.04 | -0.01 ± 0.08 | 3.5 ± 3.5 |
| 7 | 13 | 0.00 ± 0.03 | 0.00 ± 0.03 | -0.01 ± 0.02 | 0.01 ± 0.06 | 0.00 ± 0.12 | -0.7 ± 4.2 |
| 8 | 13 | 0.01 ± 0.02 | -0.02 ± 0.02 | 0.00 ± 0.02 | -0.02 ± 0.04 | -0.05 ± 0.12 | 0.7 ± 3.9 |
| 9 | 16 | 0.02 ± 0.03 | 0.00 ± 0.03 | -0.01 ± 0.02 | -0.04 ± 0.06 | -0.03 ± 0.12 | 1.0 ± 3.7 |
| 10 | 13 | 0.01 ± 0.03 | 0.05 ± 0.04 | -0.01 ± 0.02 | 0.01 ± 0.06 | -0.05 ± 0.12 | 1.8 ± 3.6 |
| 11[f] | 13 | -0.01 ± 0.02 | 0.01 ± 0.03 | 0.00 ± 0.02 | -0.01 ± 0.05 | 0.08 ± 0.09 | -0.3 ± 4.2 |
| 12[f] | 9 | 0.01 ± 0.02 | -0.01 ± 0.02 | -0.02 ± 0.02 | -0.01 ± 0.04 | -0.05 ± 0.09 | 0.1 ± 3.8 |

[a]Refer to Figures 4 and 5.
[b]Reported concentrations are dry weights with the exception of H-3 concentrations which are reported as wet weight.
[c]--- = No measurement performed.
[d]Uncertainties represent the 95% confidence interval based on total propagated uncertainties.
[e]Zero values are due to rounding.
[f]Composite samples collected from overburden soil/sand piles, not shown on figures.

## TABLE 2

## SOIL GUIDELINE RELEASE LIMITS

| Radionuclide | Soil Guidelines[1] (pCi/g) |
|---|---|
| Am-241 | 5.44 |
| Ba-133 | 16.4 |
| Co-60 | 1.94 |
| Cs-134 | 3.33 |
| Cs-137 | 9.20 |
| Eu-152 | 4.51 |
| Eu-154 | 4.11 |
| Fe-55 | 629,000 |
| H-3 | 31,900 |
| K-40 | 27.6 |
| Mn-54 | 6.11 |
| Na-22 | 2.31 |
| Ni-59 | 151,000 |
| Ni-63 | 55,300 |
| Pu-238 | 37.2 |
| Pu-239 | 33.9 |
| Pu-240 | 33.9 |
| Pu-241 | 230 |
| Pu-242 | 35.5 |
| Ra-226 | 5 and 15[a] |
| Sr-90 | 36 |
| Th-228 | 5 and 15[a] |
| Th-232 | 5 and 15[a] |
| U-234 | 30[b] |
| U-235 | 30[b] |
| U-238 | 35[b] |

NOTES: (a) DOE Order 5400.5 limits are 5 pCi/g averaged over the first 15 cm of soil depth and 15 pCi/g averaged over 15-cm layers below the top 15 cm.
(b) Generally, more conservative NRC limits for uranium isotopes are proposed.

[1]Rocketdyne Report N001SRR140131, "Approved Sitewide Release Criteria for Remediation of Radiological Facilities at SSFL", February, 1999

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# 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)

## DIRECT MEASUREMENT INSTRUMENT/DETECTOR COMBINATIONS

### Gamma

Bicron Micro-rem Meter
(Bicron Corporation, Newbury, 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)

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. Survey work was performed per the ORISE generic health and safety plans and a site-specific integrated safety management (ISM) pre-job hazard checklist. Boeing 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 (September 2004)
- Laboratory Procedures Manual (August 2004)
- Quality Assurance Manual (August 2004)

The procedures contained in these manuals were developed to meet the requirements of Department of Energy (DOE) Order 414.1B 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 and ITP 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 cm. A NaI scintillation detector was used to scan for elevated gamma radiation. The scan MDC for the NaI scintillation detector for Eu-152 in soil was approximately 5.8 pCi/g[1].

### Exposure Rate Measurements

Measurements of dose equivalent rates (μrem/h) were performed at 1 meter above the surface using a Bicron microrem meter. Although the instrument displays data in μrem/h, the μrem/h to μR/h conversion is essentially unity.

### Soil Sampling

Approximately 1 kilogram 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] The scan MDC for Eu-152 was estimated based on empirical calculations for NaI response versus gamma energy provided in *Decommissioning Health Physics: A Handbook for MARSSIM Users*, E.W. Abelquist; 2001.

## RADIOLOGICAL ANALYSIS

### Gamma Spectroscopy

Soil samples were transferred to 0.5 liter marinelli beakers 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 average associated MDCs for a 1-hour count time were:

| Radionuclide | Photopeak | MDC (pCi/g) |
|---|---|---|
| Ba-133 | 0.356 MeV | 0.03 |
| Co-60 | 1.173 MeV | 0.05 |
| Cs-137 | 0.662 MeV | 0.03 |
| Eu-152 | 0.344 MeV | 0.07 |
| Eu-154 | 0.723 MeV | 0.15 |

### 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 average MDC of the procedure was 7 pCi/g wet weight for soil.

## DETECTION LIMITS

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.