ORISE

OAK RIDGE INSTITUTE FOR SCIENCE AND EDUCATION

May 9, 2000

Mr. Mike Lopez
U.S. Department of Energy
Oakland Operations Office
1301 Clay Street 700N
Oakland, CA 94612-5208

SUBJECT: FINAL REPORT—VERIFICATION SURVEY OF THE 17TH STREET DRAINAGE AREA, SANTA SUSANA FIELD LABORATORY, THE BOEING COMPANY, VENTURA COUNTY, CALIFORNIA

Dear Mr. Lopez:

Enclosed is the final report describing the procedures and results for the verification survey of the 17th Street Drainage Area. Any comments provided on the draft report have been incorporated.

Please contact me at (865) 576-5073 or Eric Abelquist (865) 576-3740 should you have any questions.

Sincerely,

Timothy J. Vitkus
Survey Projects Manager
Environmental Survey and
Site Assessment Program

JRM:klp

Enclosure

cc: B. Fleming, DOE/HQ
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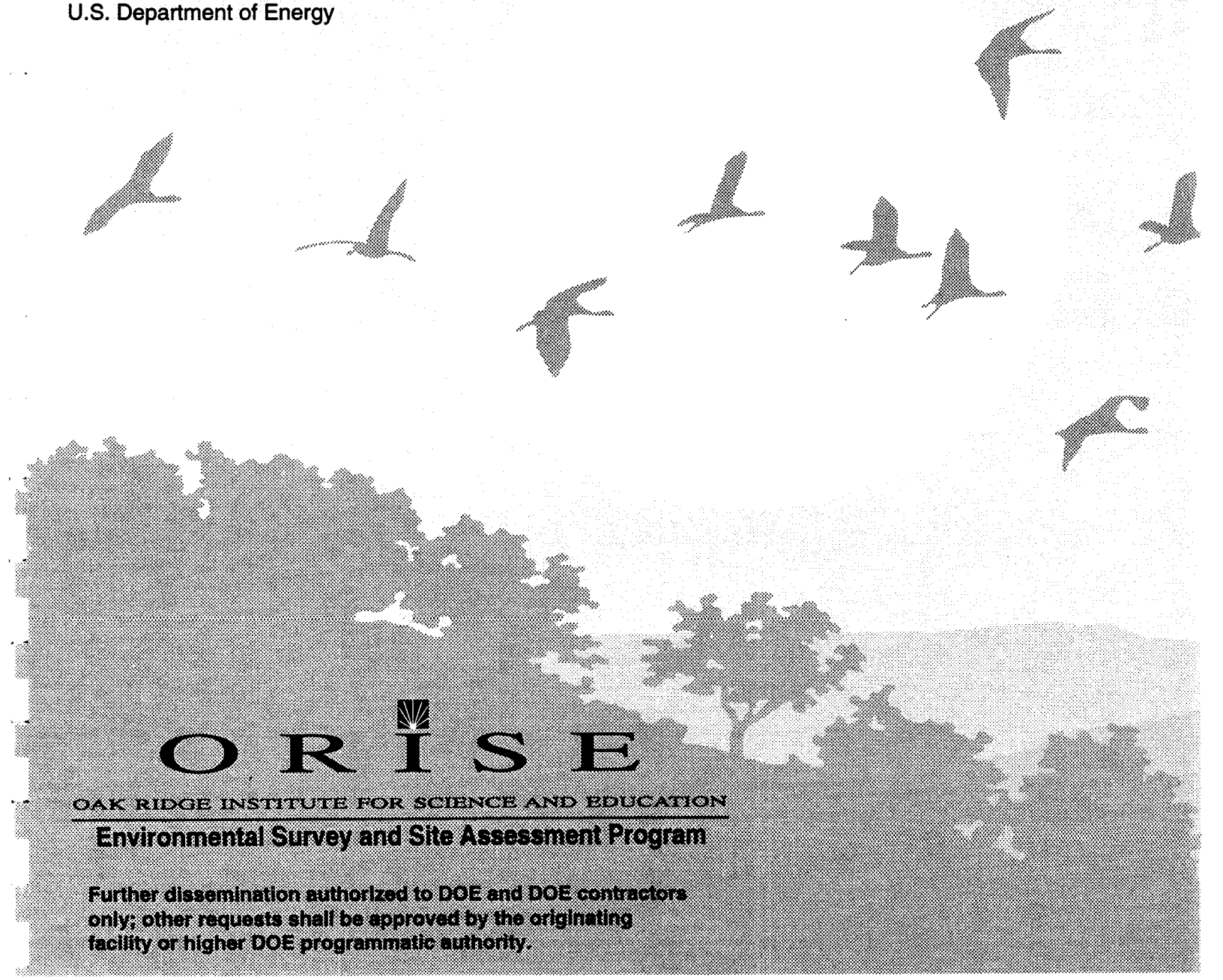
File/402

VERIFICATION SURVEY OF THE 17 TH STREET DRAINAGE AREA SANTA SUSANA FIELD LABORATORY THE BOEING COMPANY VENTURA COUNTY, CALIFORNIA

J. R. MORTON

Prepared for the
Office of Site Closure
U.S. Department of Energy



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

The Oak Ridge Institute for Science and Education (ORISE) was established by the U.S. Department of Energy to undertake national and international programs in education, training, health, and the environment. ORISE and its programs are operated by Oak Ridge Associated Universities (ORAU) through a contract with the U.S. Department of Energy. Established in 1946, ORAU is a multiuniversity consortium.

VERIFICATION SURVEY OF THE 17TH STREET DRAINAGE AREA SANTA SUSANA FIELD LABORATORY THE BOEING COMPANY VENTURA COUNTY, CALIFORNIA

Prepared by

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Prepared for the
Office of Site Closure
U.S. Department of Energy

FINAL REPORT

APRIL 2000

This report is based on work performed under a contract with the U.S. Department of Energy.

VERIFICATION SURVEY
OF THE 17th STREET DRAINAGE AREA
SANTA SUSANA FIELD LABORATORY
THE BOEING COMPANY
VENTURA COUNTY, CALIFORNIA

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ACKNOWLEDGMENTS

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ABBREVIATIONS AND ACRONYMS

µrem/h	microrem per hour
µR/h	microroentgens per hour
AEC	Atomic Energy Commission
ASME	American Society of Mechanical Engineers
cm	centimeter
D&D	decontamination and decommissioning
DOE	U.S. Department of Energy
EML	Environmental Measurements Laboratory
ERDA	Energy Research and Development Administration
ESSAP	Environmental Survey and Site Assessment Program
ETEC	Energy Technology Engineering Center
ha	hectare
ITP	Intercomparison Test Program
kg	kilogram
km	kilometer
m	meters
m^2	square meters
MAPEP	Mixed Analyte Performance Evaluation Program
MeV	million electron volts
M&O	Management and Operation
NaI	sodium iodide
NIST	National Institute of Standards and Technology
NRC	U.S. Nuclear Regulatory Commission
ORISE	Oak Ridge Institute for Science and Education
pCi/L	picocuries per liter
pCi/g	picocuries per gram
SSFL	Santa Susana Field Laboratory

VERIFICATION SURVEY
OF THE 17TH STREET DRAINAGE AREA
SANTA SUSANA FIELD LABORATORY
THE BOEING COMPANY
VENTURA COUNTY, CALIFORNIA

INTRODUCTION AND SITE HISTORY

Rocketdyne Propulsion and Power of the Boeing Company (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 Radiologic Health Branch of the State of California 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 (predominantly in 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 and Ni-63). 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, but accelerated in the 1990's as the remaining DOE program operations at ETEC were terminated. As part of this D&D program, Rocketdyne performed decommissioning and final status surveys of a number of facilities that supported the various nuclear-related ETEC operations during the latter

part of the 1950's and continuing through to the present. Environmental management of DOE contaminated properties continues under the termination clause of the existing Management and Operation (M&O) contract. An area that was recently addressed was the 17th Street drainage area.

The 17th Street drainage area is the site of a natural rainwater channel where a berm was constructed in 1962 to permit the area to serve as a hold-up pond. Since that time, the area became overgrown with shrubs and trees and filled with silt. Characterization surveys performed in 1997 and 1998 identified elevated levels of Cs-137 within samples collected from the area. As a result, the area was remediated during 1998 and a final status survey performed.

DOE's Office of Site Closure—previously the Office of Environmental Restoration, Northwestern Area Programs—is responsible for oversight of a number of remedial actions that have been, or will be 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 17th Street drainage area.

SITE DESCRIPTION

The SSFL is located in the Simi Hills of southeastern Ventura County, California, approximately 47 kilometers (km [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.

The 17th Street drainage area is located to the southeast of the intersection of "G" Street and 17th Street in the central portion of Area IV (Figure 2). The former hold-up pond area measures approximately 85 m^2. The entire impacted area measures 2,230 m^2.

OBJECTIVES

The objectives of the verification process were to provide independent document reviews and measurement and sampling data for use by the DOE in determining the radiological status of the 17th Street drainage area and whether or not the area meets the guideline requirements for release without radiological restrictions.

DOCUMENT REVIEW

Survey plans and final status reports were reviewed for appropriateness of procedures and adequacy of the data for demonstrating compliance with established guidelines (Boeing 1999 and 2000a). Information was evaluated to ensure that areas identified as exceeding site guidelines had been decontaminated and that residual soil concentrations satisfied the established guidelines.

PROCEDURES

On October 27, 1999, ESSAP performed a verification survey of the 17th Street drainage area at the SSFL. The survey was performed in accordance with a survey plan, submitted to and approved by the DOE, and the ORISE/ESSAP Survey Procedures and Quality Assurance Manuals (ORISE 1999a, 1998a, and b).

REFERENCE SYSTEM

Measurement and sampling locations were referenced to the grid established by Rocketdyne.

SURFACE SCANS

Surface scans for gamma activity were performed over 100 percent of the remediated and adjacent impacted areas. Gamma scans were performed using NaI scintillation detectors coupled to ratemeters with audible indicators.

EXPOSURE RATE MEASUREMENTS

Exposure rates at one meter above the surface were measured at eight soil sample locations using a microrem meter (Figure 3). Background exposure rates, used for comparison, were performed during a previous site survey (ORISE 1996).

SOIL SAMPLING

Surface (0-15 cm) soil samples were collected from eight locations within the 17th Street drainage area (Figure 3). Background soil samples collected during a previous site survey were used for comparison purposes (ORISE 1996).

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 1999d). Soil samples were analyzed by gamma spectrometry and results reported in picocuries per gram (pCi/g). The radionuclides of interest were mixed fission and activation products, primarily Cs-137; however, gamma spectra were reviewed for other identifiable photopeaks. Exposure rates were reported in units of microroentgens per hour (μR/h). The data generated were compared with Rocketdyne documentation and the DOE generic and site-specific guidelines established for release for unrestricted use.

FINDINGS AND RESULTS

DOCUMENT REVIEW

ESSAP review of Rocketdyne's project documentation indicated that most procedures and methods used by Rocketdyne were appropriate and that data were accurate. Comments identified were provided to the DOE (ORISE 1999b and c). Rocketdyne adequately addressed these comments in a subsequent correspondence (Boeing 2000b).

Surface Scans

Surface scans for gamma activity did not identify any locations of direct radiation in excess of ambient background levels.

Exposure Rates

Exposure rates are summarized in Table 1. Background exterior exposure rates for SSFL averaged 14 μR/h, while ESSAP site exposure rates, including background, ranged from 14 to 19 μR/h.

Radionuclide Concentrations in Soil

Concentrations of radionuclides in soil samples collected from the 17th Street drainage area are provided in Table 1. The radionuclide concentrations were as follows: less than 0.2 pCi/g for Am-241, less than 0.1 to 1.6 pCi/g for Cs-137, 0.8 to 2.2 pCi/g for Ra-226, 1.2 to 3.5 pCi/g for Th-228, less than 16.5 pCi/g for Th-230, 1.2 to 3.7 pCi/g for Th-232, less than 0.4 to 0.4 pCi/g for U-235, and 1.3 to 5.2 pCi/g for U-238.

COMPARISON OF RESULTS WITH GUIDELINES

The applicable site-specific soil 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). The primary contaminant

of concern for the area was Cs-137. All Cs-137 concentrations were less than the Table 2 cleanup criterion. Concentrations of uranium and thorium were detected in excess of background concentrations, but individually were also less than the Table 2 cleanup criteria. One background-corrected sample exceeded the unity rule. Further evaluation of this criteria determined that Rocketdyne had adequately addressed this issue and satisfactorily demonstrated guideline compliance for the area.

The DOE's exposure rate guideline is 20 μR/h above background (DOE 1990), although Rocketdyne has elected to use a more restrictive guideline of 5 μR/h above background. All exposure rates were below this guideline.

SUMMARY

On October 27, 1999, the Environmental Survey and Site Assessment Program performed a verification survey of the 17th Street drainage area at the Santa Susana Field Laboratory. Verification activities included document reviews, surface scans, exposure rate measurements, and soil sampling.

The independent verification survey results indicate that soil concentrations for the 17th Street Drainage Area satisfied the applicable site-specific soil guidelines. In addition, exposure rates were comparable to background levels and satisfied both the DOE and the more restrictive exposure rate guideline that Rocketdyne has elected to use. The verification survey findings, therefore, support Rocketdyne's final status survey conclusion that the 17th Street Drainage Area radiological conditions satisfy the guidelines for release without radiological restrictions.

FIGURES

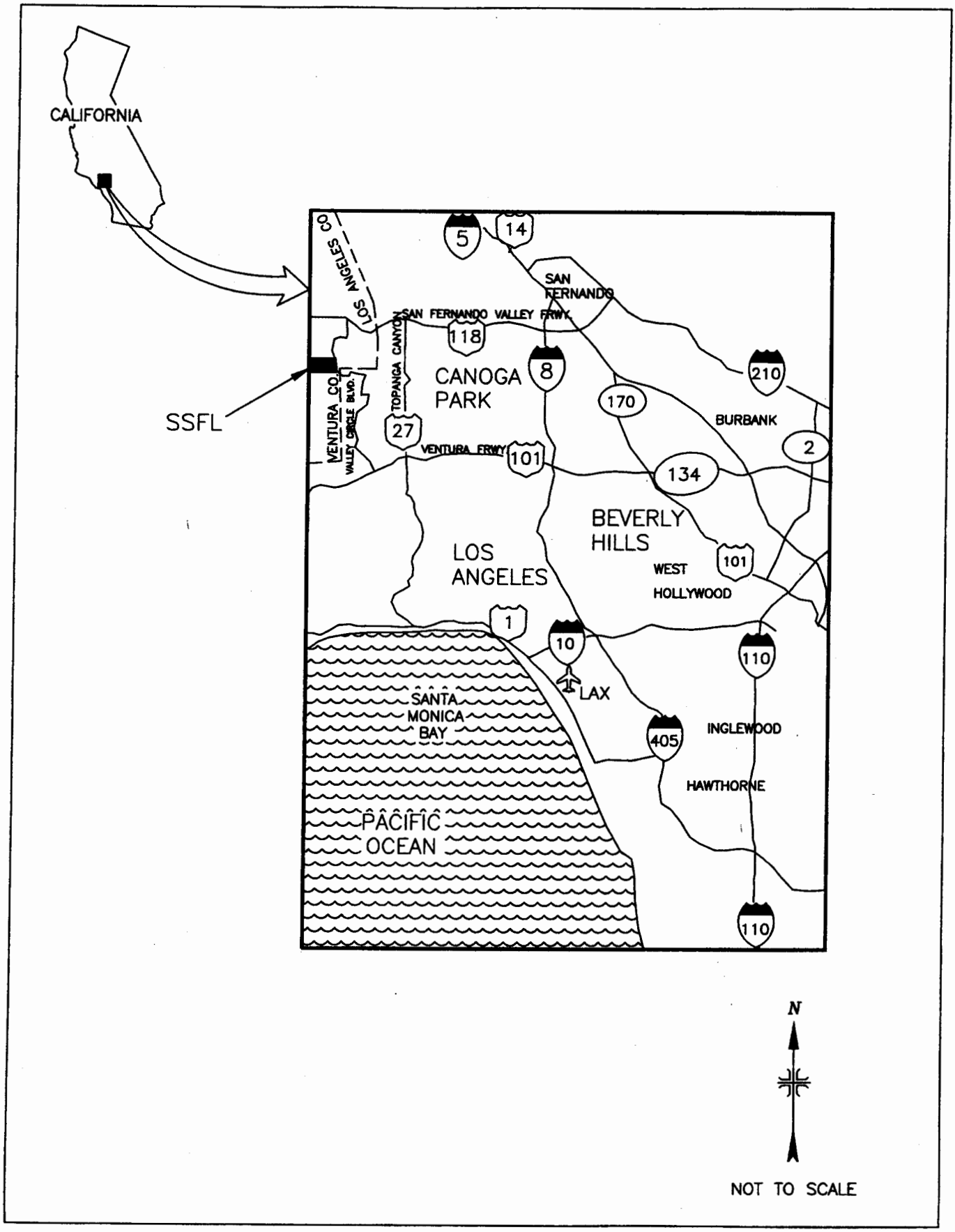


FIGURE 1: Los Angeles California Area – Location of Santa Susana Field Laboratory Site

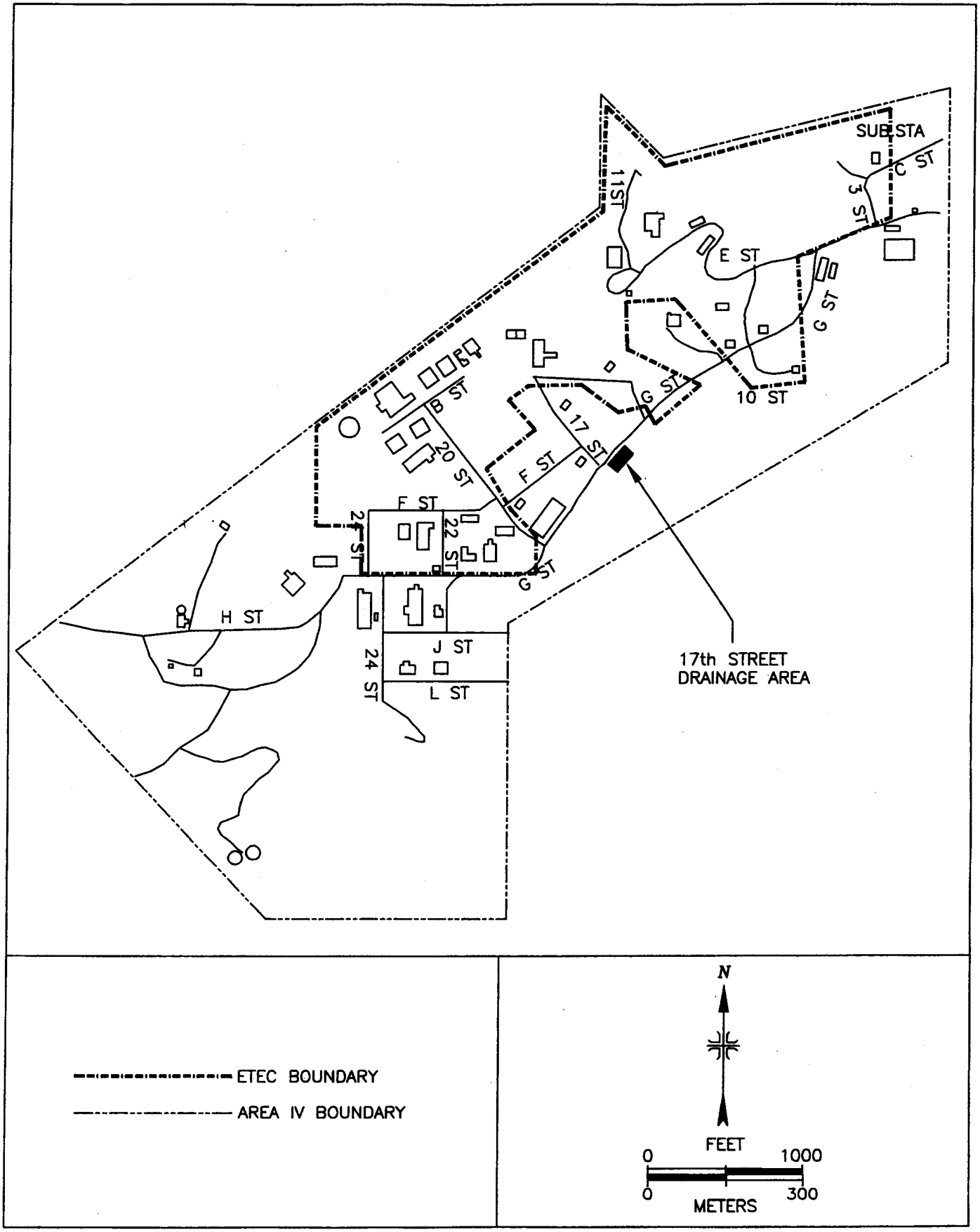
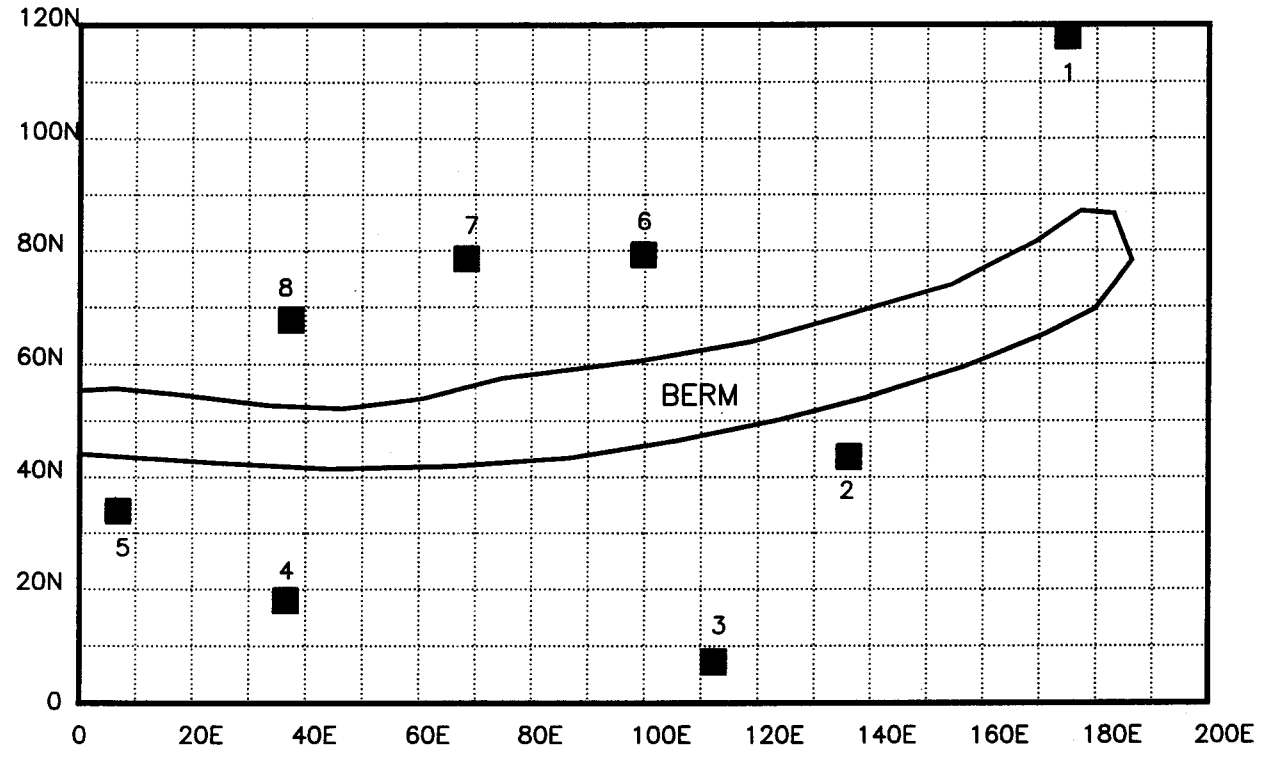


FIGURE 2: Santa Susana Field Laboratory Area IV, Plot Plan – Location of the 17th Street Drainage Area



MEASUREMENT/SAMPLING LOCATIONS

■ SURFACE SOIL AND EXPOSURE RATE

N

FEET 0 30

METERS 0 10

FIGURE 3: 17th Street Drainage Area – Measurement and Sampling Locations

TABLES

TABLE 1

RADIONUCLIDE CONCENTRATIONS IN SOIL
17th STREET DRAINAGE AREAS
SANTA SUSANA FIELD LABORATORY
ROCKWELL INTERNATIONAL
VENTURA COUNTY, CALIFORNIA

Location[a]	Exposure Rate 1m (μR/h)	Radionuclide Concentrations (pCi/g)							
		Am-241	Cs-137	Ra-226	Th-228	Th-230	Th-232	U-235	U-238
1	15	<0.2	1.4 ± 0.1[b]	1.5 ± 0.4	3.2 ± 0.9	<16.5	2.7 ± 0.4	<0.4	1.8 ± 1.2
2	15	<0.1	0.2 ± 0.1	0.9 ± 0.1	1.2 ± 0.1	<7.1	1.4 ± 0.2	0.2 ± 0.1	5.2 ± 0.9
3	15	<0.1	0.2 ± 0.1	1.8 ± 0.2	2.8 ± 0.3	<11.0	3.0 ± 0.4	<0.3	2.1 ± 1.0
4	14	<0.1	<0.1	1.0 ± 0.2	1.4 ± 0.4	<10.8	1.3 ± 0.2	<0.3	1.6 ± 0.7
5	16	<0.1	0.2 ± 0.1	0.8 ± 0.1	1.2 ± 0.1	<7.4	1.2 ± 0.2	<0.2	1.3 ± 0.7
6	15	<0.1	1.6 ± 0.1	2.2 ± 0.2	3.5 ± 0.3	<11.9	3.7 ± 0.5	0.4 ± 0.2	4.2 ± 1.1
7	16	<0.1	0.5 ± 0.1	1.1 ± 0.1	1.5 ± 0.2	<8.3	1.4 ± 0.3	<0.2	1.7 ± 0.7
8	19	<0.1	0.2 ± 0.1	1.1 ± 0.1	1.5 ± 0.1	6.4 ± 5.5	1.6 ± 0.2	<0.2	1.7 ± 0.6

[a] Refer to Figure 2.
[b] Uncertainties are total propagated uncertainties at the 95% confidence level.

TABLE 2

GENERIC LIMITS FOR SOIL AND WATER
(REFERENCE N001SRR140127)[a]
SANTA SUSANA FIELD LABORATORY
VENTURA COUNTY, CALIFORNIA

Radionuclide	Soil Guidelines (pCi/g)	Water (pCi/l)
Am-241	5.44	1.5
Co-60	1.94	200
Cs-134	3.33	75
Cs-137	9.20	110
Eu-152	4.51	840
Eu-154	4.11	570
Fe-55	629,000	9,000
H-3	31,900	20,000[b]
K-40	27.6	290
Mn-54	6.11	2,000
Na-22	2.31	480
Ni-59	151,000	26,000
Ni-63	55,300	9,500
Pu-238	37.2	1.7
Pu-239	33.9	1.6
Pu-240	33.9	1.6
Pu-241	230	80
Pu-242	35.5	1.6
Ra-226	5[d] and 15[d]	4.1
Sr-90	36.0	8[b]
Th-228	5[d] and 15[d]	6.8

TABLE 2 (Continued)

GENERIC LIMITS FOR SOIL AND WATER
(REFERENCE N001SRR140127)
SANTA SUSANA FIELD LABORATORY
VENTURA COUNTY, CALIFORNIA

Radionuclide	Soil Guidelines (pCi/g)	Water (pCi/l)
Th-232	5[d] and 15[d]	2.0
U-234	30[c]	
U-235	30[c]	total uranium 20[b]
U-238	35[c]	
Gross alpha (not including radon and uranium)	---	15[b]
Gross beta	---	50[b]

[a]Reference taken from Rocketdyne/Boeing 96ETEC-DRF-0374, Enclosure A, June 28, 1996.
[b]State of California Maximum Contaminant Levels, CCR Title 22.
[c]Generally more conservative NRC limits for uranium isotopes are proposed.
[d]DOE Order 5400.5 limits are proposed (5 pCi/g averaged over first 15 cm of soil depth and 15 pCi/g averaged over 15cm layers below the top 15 cm).

REFERENCES

Boeing. RS-00005,17th Street Drainage Area, Final Status Survey Procedure. Canoga Park, CA; July 21, 1999.

Boeing. "17th Street Drainage Area, Final Status Survey Report." R5-00009, Revision A, Santa Susana Field Laboratory. Canoga Park, CA; March 16, 2000a.

Boeing. Response to ORISE Comments on Final Status Survey Procedures for B/4059 Phase I, B/4020 and the 17th Street Drainage Area, and the final status survey reports for B/4059 Phase I and 17th Street Drainage Area. Canoga Park, CA; April 4, 2000b.

Oak Ridge Institute for Science and Education (ORISE). Verification Survey of the Interim Storage Facility; Buildings T030, T641, and T013; An Area northwest of Buildings T019, T013, T012, and T059; and a Storage Yard West of Buildings T626 and T038, Santa Susana Field Laboratory, Rockwell International, Ventura County, California. Oak Ridge, TN; February 1996.

Oak Ridge Institute for Science and Education. Survey Procedures Manual for the Environmental Survey and Site Assessment Program. Oak Ridge, Tennessee; January 1998a.

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Oak Ridge Institute for Science and Education. Document Review—Comments on the Final Status Survey Procedures for the 17th Street Drainage Area and Building 4059 Phase I, Santa Susana Field Laboratory, Ventura County, California. Oak Ridge, TN; August 30, 1999b.

Oak Ridge Institute for Science and Education. Document Review—Comments on the 17th Street Drainage Area, Final Status Survey, Santa Susana Field Laboratory, Ventura County, California. Oak Ridge, TN; October 28, 1999c.

Oak Ridge Institute for Science and Education. Laboratory Procedures Manual for the Environmental Survey and Site Assessment Program. Oak Ridge, Tennessee; October 1999d.

State of California, Department of Health Services. Authorized Sitewide Radiological Guidelines for Release for Unrestricted Use. August 9, 1996.

U.S. Department of Energy (DOE). Radiation Protection of the Public and the Environment. Washington, DC: DOE Order 5400.5; February 1990.

U.S. Department of Energy. Memorandum from S. Robinson to R. Liddle, "Sitewide Limits for Release of Facilities Without Radiological Restrictions," September 17, 1996.

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.

DIRECT RADIATION MEASUREMENT

Instruments

Eberline Pulse Ratemeter
Model PRM-6
(Eberline, Santa Fe, NM)

Detectors

Bicron Micro-Rem Meter
(Bicron Corporation, Newburg, OH)

Victoreen NaI Scintillation Detector
Model 489-55
3.2 cm x 3.8 cm Crystal
(Victoreen, Cleveland, OH)

LABORATORY ANALYTICAL INSTRUMENTATION

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

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

High Purity Germanium Detector
Model GMX-23195-S, 23% Eff.
(EG&G ORTEC, Oak Ridge, TN)
Used in conjunction with:
Lead Shield Model G-16
(Gamma Products, Palos Hills, IL) and
Multichannel Analyzer
DEC Alpha Workstation
(Canberra, Meriden, CT)

APPENDIX B

SURVEY AND ANALYTICAL PROCEDURES

APPENDIX B
SURVEY AND ANALYTICAL PROCEDURES

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 6 cm. Identification of elevated levels was based on increases in the audible signal from the recording and/or indicating instrument. The combination of detector and instrument used for the scans were:

Gamma - NaI scintillation detector with ratemeter

Exposure Rate Measurements

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

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.

ANALYTICAL PROCEDURES

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. Energy peaks used for determining the activities of radionuclides of concern were:

Am-241	0.059 MeV
Ra-226	0.351 MeV from Pb-214*
Th-228	0.239 MeV from Pb-212*
Th-230	0.067 MeV
Th-232	0.911 MeV from Ac-228*
U-235	0.143 MeV (or 0.186 MeV)
U-238	0.063 MeV from Th-234* (or 1.001 MeV from Pa-234 m)*
Cs-137	0.662 MeV

*Secular equilibrium assumed.
Spectra were also reviewed for other identifiable photopeaks.

UNCERTAINTIES AND DETECTION LIMITS

The uncertainties associated with the analytical data presented in the tables of this report represent total propagated uncertainty at the 95% confidence level. These uncertainties were calculated based on both the gross sample count levels and the associated background count levels. 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.

CALIBRATION AND QUALITY ASSURANCE

Calibration of all field and 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 documents of the Environmental Survey and Site Assessment Program:

- Survey Procedures Manual, (January 1998)
- Laboratory Procedures Manual, (October 1999)
- Quality Assurance Manual, (May 1998)

The procedures contained in these manuals were developed to meet the requirements of DOE Order 414.1A and ASME NQA-1 for Quality Assurance 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 EML, ITP, and MAPEP laboratory Quality Assurance Programs.
- Training and certification of all individuals performing procedures.
- Periodic internal and external audits.

APPENDIX C

SUMMARY OF DEPARTMENT OF ENERGY RESIDUAL RADIOACTIVE MATERIAL GUIDELINES

APPENDIX C

SUMMARY OF DEPARTMENT OF ENERGY RESIDUAL RADIOACTIVE MATERIAL GUIDELINES

BASIC DOSE LIMITS

The basic dose limit for the annual radiation dose (excluding radon) received by an individual member of the general public is 100 mrem/yr. In implementing this limit, DOE applies as low as reasonably achievable principles to set site-specific guidelines.

EXTERNAL GAMMA RADIATION

The average level of gamma radiation inside a building or habitable structure on a site that has no radiological restriction on its use shall not exceed the background level by more than 20 μR/h and will comply with the basic dose limits when an appropriate-use scenario is considered.

SOIL GUIDELINES

Radionuclides	**Soil Concentration (pCi/g) Above Background[a,b,c]**
Radium-226, Radium-228, Thorium-230, Thorium-232	5 pCi/g, averaged over the first 15 cm of soil below the surface; 15 pCi/g, averaged over 15-cm-thick layers of soil more than 15 cm below the surface.
Others	Calculated on a site-specific basis, using the DOE manual developed for this use.

[a] These guidelines take into account ingrowth of radium-226 from thorium-230 or thorium-232 and radium-228 and assume secular equilibrium. If either Th-230 and Ra-226 or Th-232 and Ra-228 are both present, not in secular equilibrium, the guidelines apply to the higher concentration. If other mixtures of radionuclides occur, the concentrations of individual radionuclides shall be reduced so that (1) the dose for the mixtures will not exceed the basic dose limit, or (2) the sum of ratios of the soil concentration of each radionuclide to the allowable limit for that radionuclide will not exceed 1 ("unity").

[b] These guidelines represent allowable residual concentrations above background averaged across any 15-cm-thick layer to any depth and over any contiguous 100 m^2 surface area.

[c] If the average concentration in any surface or below-surface area, less than or equal to 25 m^2, exceeds the authorized limit of guideline by a factor of $(100/A)^{½}$, where A is the area or the elevated region in square meters, limits for "hot spots" shall also be applicable. Procedures for calculating these hot spot limits, which depend on the extent of the elevated local concentrations, are given in the DOE Manual for Implementing Residual Radioactive Materials Guidelines. In addition, every reasonable effort shall be made to remove any source of radionuclide that exceeds 30 times the appropriate limit for soil, irrespective of the average concentration in the soil.