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OAK RIDGE INSTITUTE FOR SCIENCE AND EDUCATION

September 4, 2001

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Region IV
Harris Tower
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SUBJECT: FINAL REPORT—CONFIRMATORY SURVEY OF PIT 4, SURVEY UNIT 3 OF THE CUSHING REFINERY SITE, CUSHING, OKLAHOMA (DOCKET NO. 070-03073; RFTA NO. 01-011)

Dear Mr. Garcia:

Enclosed is the final report for the confirmatory survey of Pit 4, Survey Unit 3 of the Cushing Refinery Site, Cushing, Oklahoma. Comments provided on the draft report have been incorporated.

Please contact me at (865) 576-3356 or Timothy J. Vitkus at (865) 576-5073 should you have any questions.

Sincerely,

Timothy J. Bauer
Assistant Project Leader
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TJB:klp

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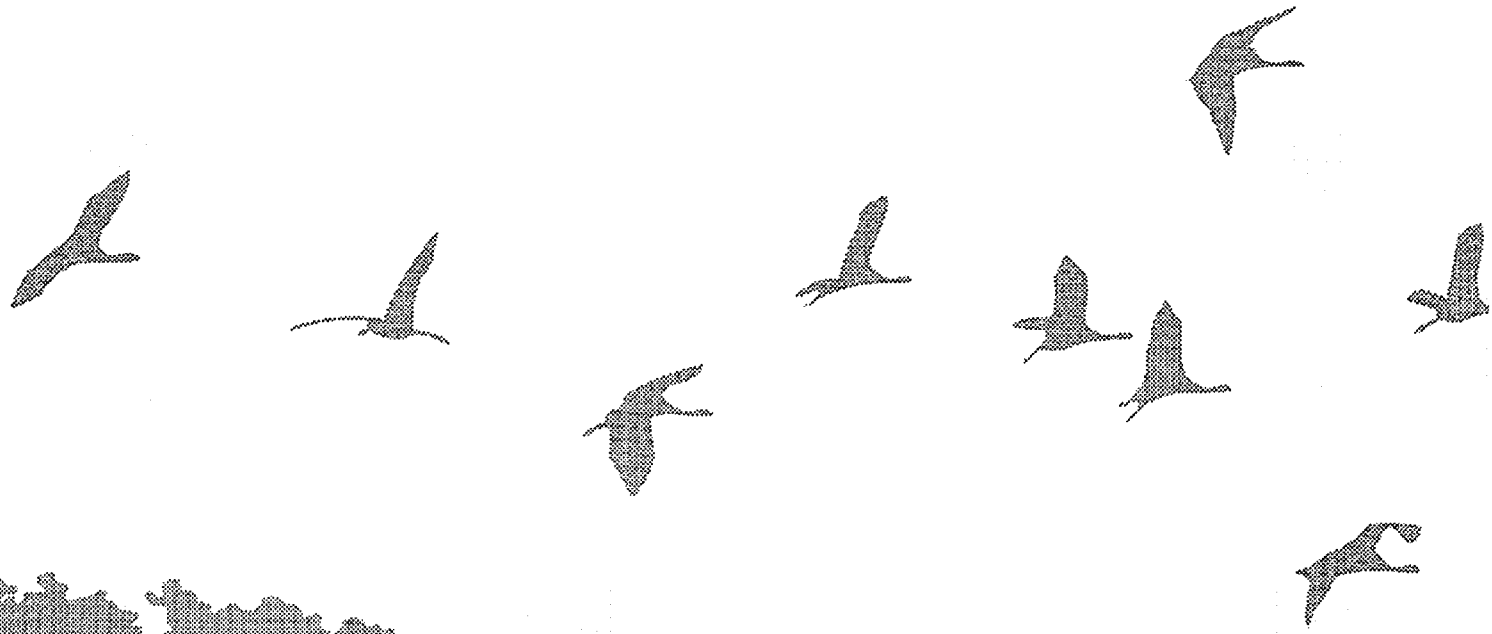
CONFIRMATORY SURVEY OF PIT 4, SURVEY UNIT 3 OF THE CUSHING REFINERY SITE KERR-MCGEE CORPORATION CUSHING , OKLAHOMA

T. J. BAUER

Prepared for the
Region IV
U. S. Nuclear Regulatory Commission



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

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NOTICES

CONFIRMATORY SURVEY OF PIT 4, SURVEY UNIT 3 OF THE CUSHING REFINERY SITE KERR-MCGEE CORPORATION CUSHING, OKLAHOMA

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Prepared for

Region IV
U.S. Nuclear Regulatory Commission

FINAL REPORT

AUGUST 2001

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CONFIRMATORY SURVEY
OF PIT 4, SURVEY UNIT 3
OF THE CUSHING REFINERY SITE
KERR-MCGEE CORPORATION
CUSHING, OKLAHOMA

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ACKNOWLEDGMENTS

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ABBREVIATIONS AND ACRONYMS

µR/h	microroentgens per hour
AEC	Atomic Energy Commission
cm	centimeter
DOE	Department of Energy
EML	Environmental Measurements Laboratory
ESSAP	Environmental Survey and Site Assessment Program
ITP	Intercomparison Testing Program
kg	kilogram
KMC	Kerr-McGee Corporation
m	meter
m^2	square meter
MAPEP	Mixed Analyte Performance Evaluation Program
MDC	minimum detectable concentration
MeV	million electron volts
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	picocuries per gram
RMA	radioactive material area

CONFIRMATORY SURVEY
OF PIT 4, SURVEY UNIT 3
OF THE CUSHING REFINERY SITE
KERR-MCGEE CORPORATION
CUSHING, OKLAHOMA

INTRODUCTION AND SITE HISTORY

The Cushing refinery site is located two miles north of the City of Cushing in Payne County, Oklahoma and was operated from 1915 to 1972. Kerr-McGee Corporation (KMC) purchased the Cushing site from General American Oil Company of Texas in 1956 and operated an oil refinery there from 1956 to 1972. From 1962 to 1966, KMC used part of the Cushing refinery site to process natural thorium and natural, depleted, and enriched uranium under two Atomic Energy Commission (AEC) licenses, SMB-664 and SNM-695.

AEC license SMB-664 was issued to KMC on November 7, 1962 and authorized unlimited quantities in a variety of chemical forms of uranium and thorium. The bulk of uranium material received was UF_6 (uranium hexafluoride). Typical products were oxides, carbides, fluorides, nitrates, metal, etc. Thorium material was received in the form of concentrates. Typical products were oxides or carbides or combinations of uranium and thorium compounds at various ratios of thorium to uranium (KMC 1995).

AEC license SNM-695 was issued to KMC on April 23, 1963 and authorized possession of any enrichment of uranium in any form, except metal, including scrap recovery, not to exceed 1000 kilograms (kg) of uranium-235. The uranium was received in the form of UF_6 and other chemical compounds and was converted to other compounds of uranium suitable for nuclear fuels. AEC license SNM-695 was amended to permit reduction of high enriched UF_4 (green salt) to uranium metal buttons.

Enriched uranium was processed at Cushing from early 1963 until September 1965 and thorium processing was performed from December 1964 until February 1966. In April 1966, KMC reported to the AEC that as of April 26, 1966, all special nuclear material had been transferred from the Cushing site to KMC's new Cimarron facility in Crescent, Oklahoma and that all Cushing buildings in which licensed activities had been performed were cleaned and decontaminated. The AEC conducted a close-out survey of the Cushing facility on July 6, 1966.

On the basis of this survey, and in response to KMC's request for authorization to release the facility for unrestricted use, licenses SMB-664 and SNM-695 were terminated on July 25, 1966 (KMC 1995).

KMC has performed characterization surveys and subsequent remediation for a large portion of their site. During cleanup activities, some radioactively contaminated materials were placed in burial trenches, old petroleum storage tank dike areas, and part of a hydrocarbon waste impoundment, Pit 4. Pit 4 contained acidic hydrocarbon sludge (heavy hydrocarbon containing sulfuric acid) from the lubricating oil manufacturing operation. Characterization data showed the northern portion of Pit 4 to be non-acidic, which was segregated from the acidic portion and renamed Waste Pit (WP) 30. Uranium was present in low concentrations, near background, throughout Pit 4. Thorium contamination was identified in the northwestern portion of Pit 4, while the remaining portions were near background concentrations.

KMC has remediated Pit 4 and performed the final status survey in accordance with draft NUREG/CR-5849 (NRC 1992). At the request of Region IV of the U. S. Nuclear Regulatory Commission (NRC), the Environmental Survey and Site Assessment Program (ESSAP) of the Oak Ridge Institute for Science and Education (ORISE) performed an independent confirmatory radiological survey of Pit 4, Survey Unit 3. This report summarizes the procedures and results of the survey.

SITE DESCRIPTION

The KMC Cushing site is located in Payne County, Oklahoma, two miles north of the City of Cushing. Cushing lies about midway between Tulsa and Oklahoma City. The terrain of the region is rolling, oil-producing pasture land. Several oil fields were developed in the immediate area. The elevation of the refinery site ranges from 250 to 280 meters above sea level. The entire Cushing site encompasses approximately 178 hectares. Figure 1 shows the location of the Cushing Refinery Site.

The Pit 4 excavation (Survey Unit 3), located in Radioactive Material Area 3 (RMA-3) in Sector 4 of the site, and surrounding areas (Survey Units 1 and 2 and 4 through 7) encompasses a

total area of approximately 41,450 m^2. The Pit 4 excavation, Survey Unit 3, has an area of 9075 m^2. The location of Pit 4, Survey Unit 3, on the Cushing Refinery Site is shown in Figure 2.

OBJECTIVE

The objective of this survey was to provide independent radiological data, for use by the NRC, in evaluating the adequacy of the decontamination of Pit 4, Survey Unit 3, relative to the established guidelines.

DOCUMENT REVIEW

As part of the confirmatory activities, ESSAP reviewed the licensee's final status survey plan and final status survey sampling data. The radiological survey results were compared to the established NRC guidelines.

PROCEDURES

ESSAP performed confirmatory surveys at the KMC site during the period June 25 through 27, 2001. These surveys included independent measurements and sampling of Pit 4, Survey Unit 3. The surveys were performed in accordance with the ESSAP Survey Procedures and Quality Assurance Manuals and the site-specific survey plan submitted to and approved by the NRC (ORISE 2000 and 2001a and b). Additional information concerning major instrumentation, sampling equipment, and survey and analytical procedures may be found in Appendices A and B.

REFERENCE SYSTEM

Sampling locations were referenced to the site grid system and noted on a drawing of Pit 4, Survey Unit 3 provided by KMC.

SURFACE SCANS

Surface scans were conducted for gamma radiation over approximately 50% of the excavated area using NaI scintillation detectors coupled to ratemeters with audible indicators.

EXPOSURE RATE MEASUREMENTS

Exposure rate measurements were performed at one meter above the surface at each soil sampling location using a microrem meter (Figure 3).

SOIL SAMPLING

Surface soil (0-15 cm) samples were collected from 15 randomly selected locations and from one location of elevated direct radiation identified by surface scans (Figure 3).

SAMPLE ANALYSIS AND DATA INTERPRETATION

Samples and data were returned to ESSAP's Oak Ridge, Tennessee, facility for analysis and interpretation. Laboratory analyses were conducted in accordance with the ESSAP Laboratory Procedures Manual (ORISE 2001c). Soil samples were analyzed by solid-state gamma spectroscopy for the uranium isotopes U-238 and U-235 and the natural thorium isotopes Th-228 and Th-232. Spectra were also reviewed for any other identifiable photopeaks. Five soil samples were analyzed by alpha spectroscopy to determine the isotopic abundances of the uranium. Soil sample results were reported in units of picocuries per gram (pCi/g) dry weight. Exposure rate measurements were reported in microroentgens per hour (μR/h).

FINDINGS AND RESULTS

DOCUMENT REVIEW

ESSAP's review of the licensee's documentation indicated adequate and appropriate procedures and methods were employed to document the overall radiological status of Pit 4, Survey Unit 3. Final status survey data showed remediation of Pit 4, Survey Unit 3 had reduced uranium and thorium concentrations in soil to levels less than the NRC criteria for release for unrestricted use.

SURFACE SCANS

Surface scans identified one area of elevated direct gamma radiation. An area, primarily in Grid Block 79 (Figure 3), produced a response near two-times the background response. Sample 13 was collected at the point of the highest gamma response.

EXPOSURE RATE MEASUREMENTS

Exposure rate measurements ranged from 5 to 12 μR/h. Table 1 summarizes the exposure rate measurements. Background exposure rates ranged from 4 to 8 μR/h (ORISE 1996).

RADIONUCLIDE CONCENTRATIONS IN SOILS

Concentrations of Th-228, Th-232, total thorium, U-235, U-238, and total uranium in soil samples collected from randomly selected locations and at the location of elevated direct gamma radiation identified during surface scans are summarized in Table 1. Th-228 concentrations ranged from 0.7 to 1.6 pCi/g and Th-232 concentrations ranged from 0.7 to 1.6 pCi/g, as determined by gamma spectroscopy. The calculated total thorium concentrations ranged from 1.4 to 3.3 pCi/g. U-235 concentrations ranged from -0.1 to 0.2 pCi/g and U-238 concentrations ranged from 0.6 to 3.3 pCi/g, as determined by gamma spectroscopy. Samples 1, 2, 4, 13, and 15 were selected for analysis by alpha spectroscopy to determine the ratio of U-234 to U-238 used to calculate the total uranium concentration. Table 2 provides the alpha spectroscopy data. Using the alpha spectroscopy data, the U-234 to U-238 ratio ranged from 0.90 to 1.14—the most conservative value of 1.14 was chosen for use in calculating the total uranium concentration. The calculated total uranium concentrations ranged from 1.44 to 5.48 pCi/g. Background uranium and thorium contributions were not accounted for in the activity calculations.

Elevated Ra-226, 4.1 ± 0.5 pCi/g, was detected in Sample 13 which corresponded to the location of elevated direct gamma radiation previously discussed. Elevated levels of Ra-226 have been previously documented as being the result of past oil refinery operations which tended to concentrate Ra-226 within pipe scale (ORISE 1996). Ra-226 concentrations in all remaining soil samples ranged from 0.9 to 1.6 pCi/g.

COMPARISON OF RESULTS WITH GUIDELINES

Results of the survey were compared to the applicable NRC guidelines (NRC 1981). These guidelines are summarized in Appendix C. The primary contaminants at KMC Cushing Refinery Site are enriched uranium, depleted uranium, and natural thorium. The applicable NRC option 1 guidelines for release for unrestricted use for these contaminants are as follows:

Enriched Uranium	
Soluble	30 pCi/g
Insoluble	30 pCi/g
Depleted Uranium	
Soluble	35 pCi/g
Insoluble	35 pCi/g
Natural Thorium (Th-232 + Th-228) with daughters present and in equilibrium	10 pCi/g

Exposure rates were less than the guideline of 10 μR/h above background. No soil samples collected exceeded the NRC guideline values.

SUMMARY

At the request of the U.S. Nuclear Regulatory Commission, the Environmental Survey and Site Assessment Program of the Oak Ridge Institute for Science and Education conducted confirmatory survey activities of Pit 4, Survey Unit 3 at the Cushing Refinery Site in Cushing, Oklahoma. Confirmatory activities included independent surface scans and surface soil sampling during the period of June 25 through 27, 2001. ESSAP's confirmatory survey results indicated surface soil samples collected from Pit 4, Survey Unit 3 did not contain residual contamination in excess of the NRC guidelines for release for unrestricted use and therefore confirm KMC final status survey results.

FIGURES

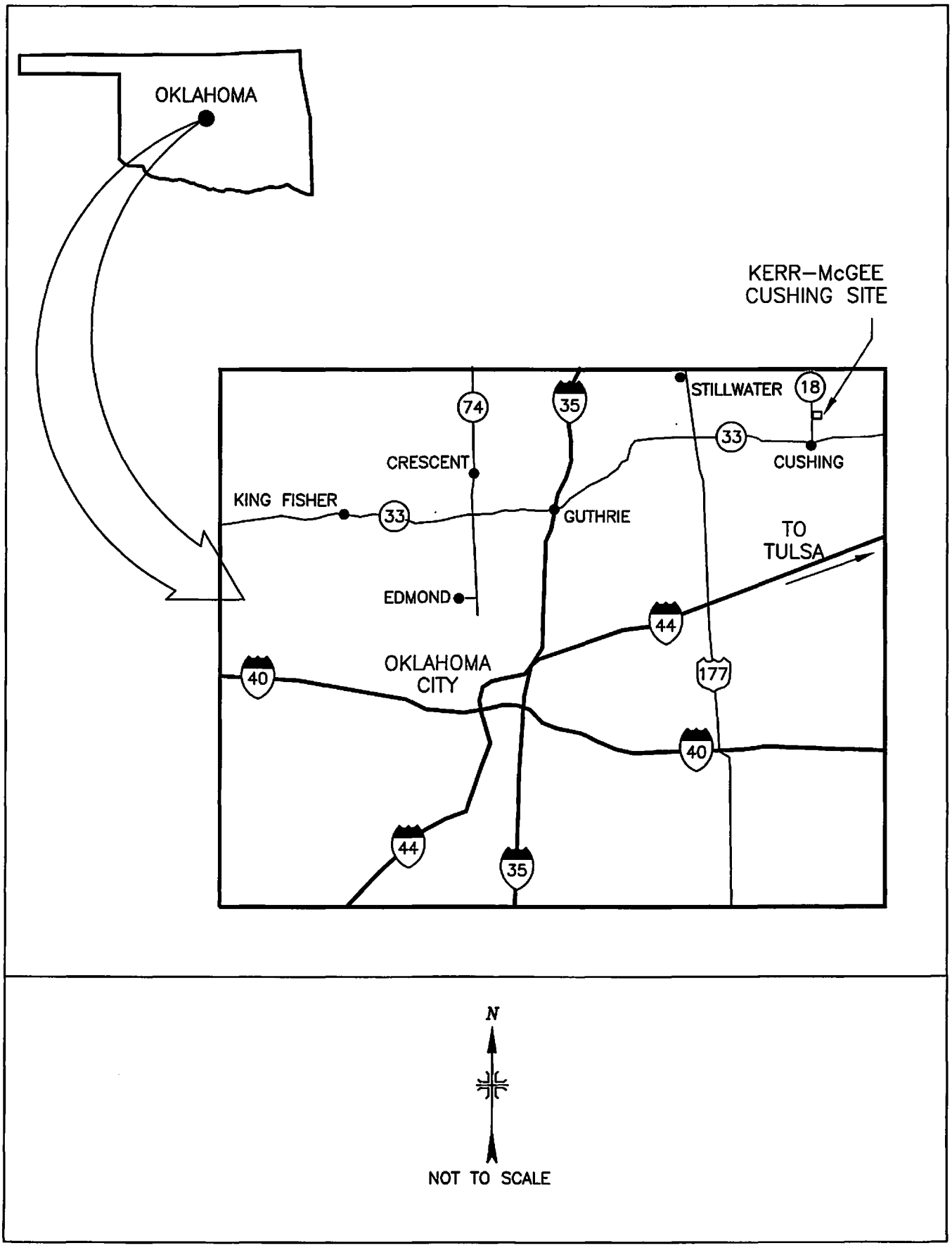

FIGURE 1: Location of the Kerr-McGee Corporation Site, Cushing, Oklahoma

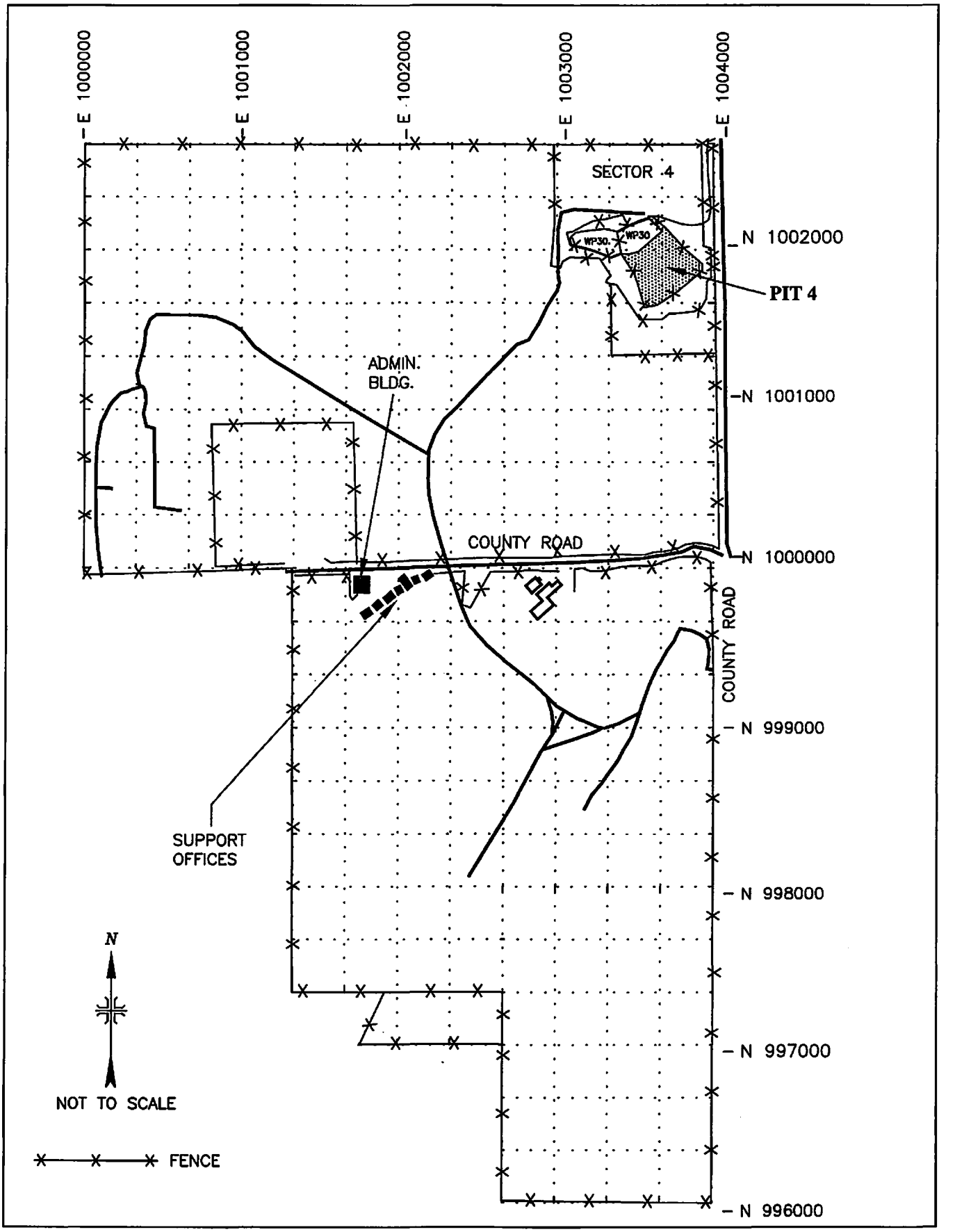

FIGURE 2: Location of Pit 4 – Cushing Refinery Site

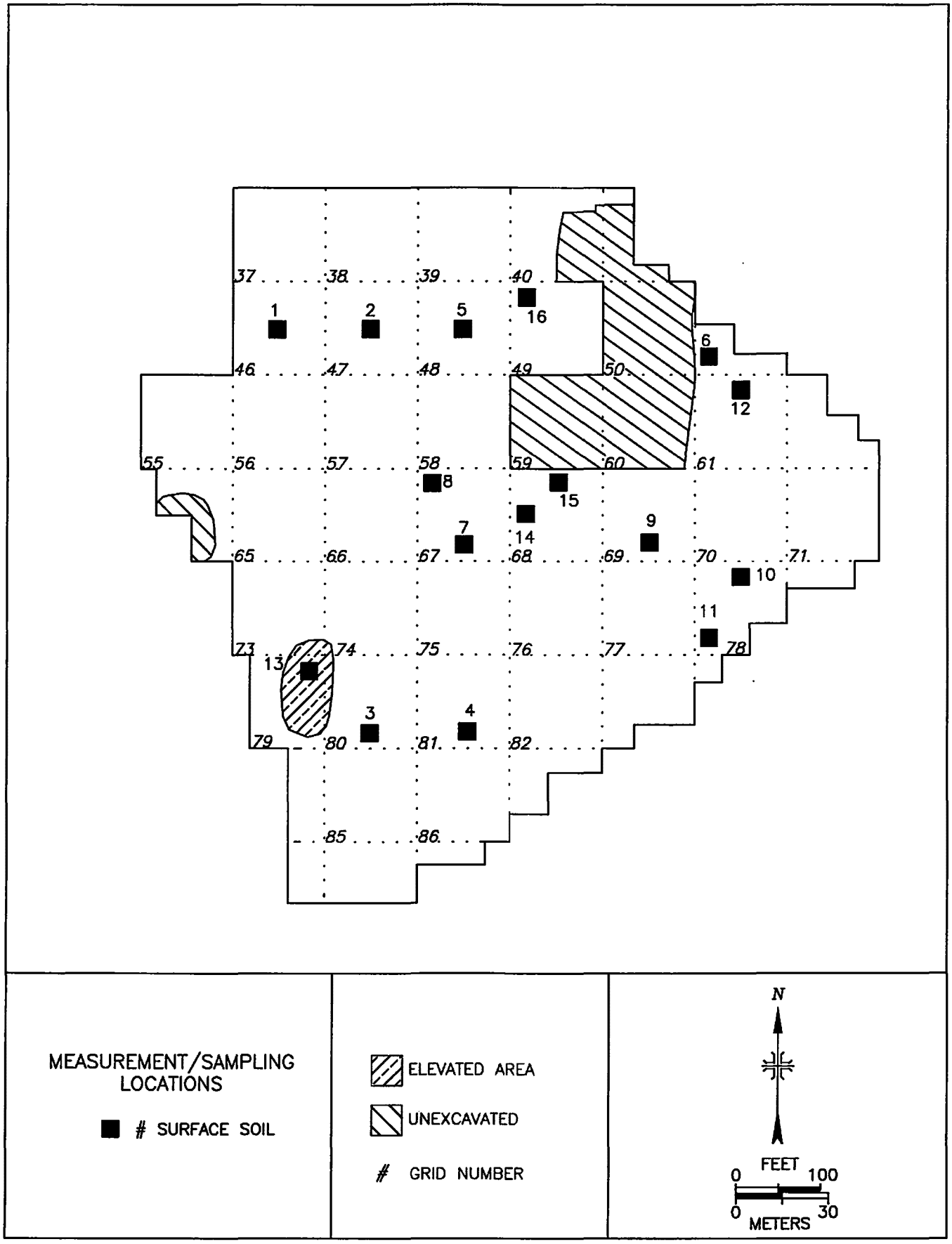

FIGURE 3: Cushing Refinery Site, Pit 4, Survey Unit 3 – Sampling Locations

TABLES

TABLE 1

URANIUM AND THORIUM CONCENTRATIONS IN SOIL DETERMINED BY GAMMA SPECTROSCOPY PIT 4, SURVEY UNIT 3 CUSHING REFINERY SITE CUSHING, OKLAHOMA

Sample[a]	Exposure Rate at 1 m (μR/h)	Radionuclide Concentration (pCi/g)					
		Th-228	Th-232	Total Th[b]	U-235	U-238	Total U[c]
1	6	1.0 ± 0.1[d]	1.0 ± 0.1	2.0	0.0[e] ± 0.1	1.2 ± 0.2	2.6
2	11	1.1 ± 0.1	1.1 ± 0.2	2.2	0.1 ± 0.1	1.2 ± 0.6	2.7
3	12	1.3 ± 0.2	1.3 ± 0.2	2.6	0.1 ± 0.1	0.8 ± 0.6	1.8
4	9	1.1 ± 0.1	1.1 ± 0.1	2.2	0.1 ± 0.1	1.1 ± 0.3	2.5
5	11	1.3 ± 0.1	1.3 ± 0.2	2.6	0.0 ± 0.1	0.9 ± 0.5	1.9
6	7	1.0 ± 0.1	1.0 ± 0.2	2.0	0.0 ± 0.1	1.1 ± 0.6	2.4
7	9	0.9 ± 0.1	1.0 ± 0.1	1.9	0.0 ± 0.1	0.9 ± 0.3	1.9
8	7	1.2 ± 0.2	1.0 ± 0.2	2.2	0.0 ± 0.1	1.0 ± 0.6	2.1
9	8	1.6 ± 0.1	1.6 ± 0.2	3.2	-0.1 ± 0.1	0.9 ± 0.7	1.8
10	6	0.7 ± 0.1	0.7 ± 0.1	1.4	0.0 ± 0.1	0.6 ± 0.3	1.3
11	6	1.2 ± 0.1	1.1 ± 0.2	3.3	0.1 ± 0.1	1.2 ± 0.6	2.7
12	5	1.0 ± 0.1	1.0 ± 0.2	2.0	0.0 ± 0.1	0.7 ± 0.6	1.5
13	7	1.4 ± 0.1	1.5 ± 0.2	2.9	0.2 ± 0.1	3.3 ± 0.9	7.3
14	6	1.3 ± 0.1	1.3 ± 0.2	2.6	0.1 ± 0.1	1.1 ± 0.6	2.5
15	7	1.6 ± 0.1	1.6 ± 0.2	3.2	0.0 ± 0.1	1.6 ± 0.8	3.4
16	8	1.3 ± 0.1	1.4 ± 0.2	2.7	0.0 ± 0.1	1.0 ± 0.5	2.1

[a]Refer to Figure 3.
[b]Total thorium concentration determined by summing the concentrations of Th-228 and Th-232. Uncertainties not propagated.
[c]Total uranium concentration determined by multiplying the U-238 concentration by a factor of 1.14, based on the most conservative ratio of U-234 to U-238 as calculated using alpha spectroscopy data, then summing the measured U-235 and U-238 concentrations with the calculated U-234 concentration. Uncertainties not propagated.
[d]Uncertainties are total propagated uncertainties at the 95% confidence level.
[e]Zero values in this table are due to rounding.

TABLE 2

URANIUM CONCENTRATIONS IN SOIL DETERMINED BY ALPHA SPECTROSCOPY PIT 4, SURVEY UNIT 3 CUSHING REFINERY SITE CUSHING, OKLAHOMA

Sample[a]	Radionuclide Concentration (pCi/g)			
	U-234	U-235	U-238	Total U
1	0.86 ± 0.11[b]	0.03 ± 0.02	0.81 ± 0.10	1.70 ± 0.15
2	1.22 ± 0.14	0.05 ± 0.02	1.07 ± 0.13	2.34 ± 0.19
4	0.69 ± 0.09	0.04 ± 0.02	0.71 ± 0.09	1.44 ± 0.13
13	2.76 ± 0.27	0.08 ± 0.03	2.64 ± 0.26	5.48 ± 0.37
15	0.77 ± 0.10	0.04 ± 0.02	0.86 ± 0.10	1.67 ± 0.14

[a]Refer to Figure 3.
[b]Uncertainties are total propagated uncertainties at the 95% confidence level.

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Oak Ridge Institute for Science and Education. Survey Procedures Manual for the Environmental Survey and Site Assessment Program. Oak Ridge, TN; September 28, 2000.

Oak Ridge Institute for Science and Education. Quality Assurance Manual for the Environmental Survey and Site Assessment Program. Oak Ridge, TN; June 1, 2001a.

Oak Ridge Institute for Science and Education. Confirmatory Survey Plan for Pit 4, Survey Unit 3 of the Cushing Refinery Site, Cushing, Oklahoma. Oak Ridge, TN; June 22, 2001b.

Oak Ridge Institute for Science and Education. Laboratory Procedures Manual for the Environmental Survey and Site Assessment Program. Oak Ridge, TN; May 1, 2001c.

U.S. Nuclear Regulatory Commission (NRC). Disposal or Onsite Storage of Thorium and Uranium Wastes from Past Operations. Washington, D.C.: Federal Register 46 (205): 52061-52063; October 1981.

U.S. Nuclear Regulatory Commission. Draft NUREG/CR-5849. Manual for Conducting Radiological Surveys in Support of License Termination. Washington, D.C.; June 1992.

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

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

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

LABORATORY ANALYTICAL INSTRUMENTATION

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)

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)

High Purity Extended Range Intrinsic Detector
Model No. GMX-45200-5
(EG&G ORTEC, OAK RIDGE, TN)
used in conjuction 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

PROJECT HEALTH AND SAFETY

All survey and laboratory activities were conducted in accordance with ORISE health and safety and radiation protection procedures. ESSAP personnel also followed all safety requirements established by KMC for work at the Cushing Refinery Site.

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 (September 2000)
- Laboratory Procedures Manual (May 2001)
- Quality Assurance Manual (June 2001)

The procedures contained in these manuals were developed to meet the requirements of 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 1 cm. Identification of elevated levels was based on increases in the audible signal from the indicating instrument. Combinations of detectors and instruments used for the scans were:

Gamma - NaI scintillation detector with ratemeter

The scan minimum detectable concentrations (MDC) for the NaI scintillation detector for Th-232 in equilibrium with progeny in the decay series, depleted uranium, and enriched uranium were obtained directly from Table 6.4 of NUREG-1507[1]. The scan survey was designed to be consistent with the *a priori* considerations used to develop the scan MDCs provided in Table 6.4. The scan MDC for Th-232 was 2.8 pCi/g. The scan MDC for uranium varied with uranium enrichment, and ranged from 80.5 to 137 pCi/g, for depleted uranium (0.34% U-235) to 3% enriched uranium, respectively. The NaI scintillation detector was chosen to provide the necessary sensitivity to detect thorium, but not uranium contamination below the guideline criteria.

Soil Sampling

Approximately one 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.

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

ANALYTICAL PROCEDURES

Gamma Spectroscopy

Samples of soil were dried, mixed, crushed, homogenized, and a portion sealed in a 0.5-liter Marinelli beaker. 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	MDC soil (pCi/g)
Th-228	0.583 MeV from Tl-208* or	0.05
	(0.239 MeV from Pb-212*)	0.02
Th-232	0.911 MeV from Ac-228*	0.05
U-235	0.143 MeV (or 0.186 MeV)	0.06
U-238	0.063 MeV from Th-234*	0.21
	(or 1.001 MeV from Pa-234m)*	1.74

*Secular equilibrium assumed.

Spectra were also reviewed for other identifiable total absorption peaks.

Alpha Spectroscopy

Soil samples were crushed, homogenized, ashed, 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 uranium—were individually separated and re-precipitated with a cerium fluoride carrier. The precipitate was then analyzed using ion implanted detectors (Canberra), alpha spectrometer (Canberra), and a multichannel analyzer (Canberra). The typical uranium MDC of the procedure is 0.02 pCi/g.

UNCERTAINTIES AND DETECTION LIMITS

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

Detection limits, MDCs, were based on 3 plus 4.65 times the standard deviation of the background count $[3+(4.65\sqrt{BKG})]$. When the activity was determined to be less than the MDC of the measurement procedure, the result was reported as less than MDC. 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.

APPENDIX C

GUIDELINES FOR RESIDUAL CONCENTRATIONS OF THORIUM AND URANIUM WASTES IN SOIL

GUIDELINES FOR RESIDUAL CONCENTRATIONS OF THORIUM AND URANIUM WASTES IN SOIL

On October 23, 1981, the Nuclear Regulatory Commission published in the Federal Register a notice of Branch Technical Position on "Disposal or Onsite Storage of Thorium and Uranium Wastes from Past Operations." This document establishes guidelines for concentrations of uranium and thorium in soil, that will limit maximum radiation received by the public under various conditions of future land usage. These concentrations are as follows:

Material	Maximum Concentrations (pCi/g) for various options			
	1[a]	2[b]	3[c]	4[d]
Natural Thorium (Th-232 + Th-228) with daughters present and in equilibrium	10	50	---	500
Natural Uranium (U-238 + U-234) with daughters present and in equilibrium	10	--	40	200
Depleted Uranium:				
Soluble	35	100	---	1,000
Insoluble	35	300	---	3,000
Enriched Uranium:				
Soluble	30	100	---	1,000
Insoluble	30	250	---	2,500

[a]Based on EPA cleanup standards which limit radiation to 1 mrad/yr to lung and 3 mrad/yr to bone from ingestion and inhalation and 10 μR/h above background from direct external exposure.
[b]Based on limiting individual dose to 170 mrem/yr.
[c]Based on limiting equivalent exposure to 0.02 working level or less.
[d]Based on limiting individual dose to 500 mrem/yr and in case of natural uranium, limiting exposure to 0.02 working level or less.