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CONFIRMATORY RADIOLOGICAL SURVEY FORMER BURIAL GROUND CIMARRON CORPORATION FACILITY CRESCENT, OKLAHOMA

B. M. SMITH

Environmental Survey and Site Assessment Program
Energy/Environment Systems Division

FINAL REPORT
JULY 1992

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CONFIRMATORY RADIOLOGICAL SURVEY
FORMER BURIAL GROUND
CIMARRON CORPORATION FACILITY
CRESCENT, OKLAHOMA

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Region III Office

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CONFIRMATORY RADIOLOGICAL SURVEY
FORMER BURIAL GROUND
CIMARRON CORPORATION FACILITY
CRESCENT, OKLAHOMA

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CONFIRMATORY RADIOLOGICAL SURVEY
FORMER BURIAL GROUND
CIMARRON CORPORATION FACILITY
CRESCENT, OKLAHOMA

INTRODUCTION

The Kerr-McGee Corporation operated the Cimarron Facility in Crescent, Oklahoma to produce slightly enriched (approximately 3%) uranium fuel and mixed oxide (uranium plus plutonium) reactor fuel between 1965 and 1975. These activities were conducted under license SNM-928 with the Atomic Energy Commission, predecessor to the Nuclear Regulatory Commission (NRC). In 1983, Sequoyah Fuels Corporation (SFC) became the owner of the Cimarron Facility, when Kerr-McGee Nuclear Corporation was divided into SFC and Quivira Mining Corporation. Later, Cimarron Corporation, a subsidiary of the Kerr-McGee Nuclear Corporation, became responsible for the Cimarron Facility.

Decontamination of the Cimarron Facility began in 1979 with the goal of removing all contaminated equipment and materials so the facility could be released for unrestricted use. The decontamination and decommissioning project was divided into several phases, which involved the Mixed Oxide Plant, the Uranium Plant, the on-site Burial Ground, and the Sanitary Lagoons. Decontamination and decommissioning activities involving the Mixed Oxide Plant and the Sanitary Lagoons are nearing completion, and the Uranium Plant is in the process of being decontaminated.

Decontamination activities have been completed for the former Burial Ground. The Burial Ground was opened in March 1966 and used for the disposal of low level uranium wastes and thorium contaminated materials, transferred from another Kerr-McGee plant site; its use was discontinued in August 1970. Burial records indicate that 1,303 kg of depleted uranium, 148 kg of enriched uranium, and 5,555 kg of natural thorium were buried at this location. Excavation and removal of the buried waste and contaminated soil was initiated in 1986 and completed in 1988.

Initial decontamination activities for the former Burial Ground were completed by Cimarron Corporation in 1988. In August 1988, at the request of the NRC, Oak Ridge Associated Universities (ORAU) conducted a confirmatory survey of the former Burial Ground[1]. Survey activities consisted of gamma surface scans, exposure rate measurements, surface soil sampling, and subsurface soil and water sampling. Gamma scans identified 30 areas of elevated direct radiation. Clean-up of the areas was initiated immediately after their identification and follow-up surveys indicated that the clean-up was effective at all locations with the exception of Trench #1. At the time of the 1988 ORAU survey, contaminated soil meeting Option 2 (on-site burial) disposal concentration limits was stored at the south end of the Burial Ground, inside the fenced area. In April 1991, this material was moved to the yard beside the Uranium Plant. Additional decontamination was performed by Cimarron Corporation by excavation of approximately 14,000 cubic feet of soil, which was removed to the yard beside the Uranium Plant. No additional contaminated soil was identified by the final surveys[2] performed by Cimarron Corporation.

At the request of the NRC's Region III Office, the Environmental Survey and Site Assessment Program (ESSAP) of ORAU conducted a confirmatory radiological survey of the former Burial Ground at the Cimarron Corporation Facility. The survey was performed to provide supporting information to confirm the radiological status of the site relative to the applicable NRC guidelines for release of the former Burial Ground for unrestricted use. This report summarizes the procedures and results of the survey.

FACILITY DESCRIPTION

The Cimarron Corporation Facility is located on a site of approximately 450 hectares in Logan County, about 8 kilometers south of Crescent, Oklahoma (Figure 1). The site includes the Uranium Plant, the Mixed Oxide Plant, the former Burial Ground, two Sanitary Lagoons, and a Waste Evaporation Pond (Figure 2). The former Burial Ground occupies approximately

8,600 m^2 and is located at the northeast edge of the site. The former Burial Ground includes four trenches within a fenced area (Figure 3) which are approximately 3 meters deep and 1 to 2 meters wide.

PROCEDURES

OBJECTIVE

The objective of the independent survey was to provide supporting information to confirm that the results of the licensee's decontamination and decommissioning efforts were effective in meeting the NRC guidelines for unrestricted use. ESSAP also reviewed the supporting documentation, provided by the licensee, to evaluate the accuracy of the information and to assure that a complete description of the radiological status of the former Burial Ground was provided.

DOCUMENT REVIEW

As part of the confirmatory activities, ESSAP reviewed the final survey report prepared by Cimarron Corporation for the Burial Ground[2]. Data and survey results presented in the final report were reviewed to assess the adequacy of the decontamination activities and to compare the licensee's survey results to the established release guidelines.

SURVEY PROCEDURES

During the period of December 9 through 12, 1991, ESSAP performed a confirmatory radiological survey of the former Burial Ground at the Cimarron Corporation Facility. The survey was performed in accordance with a plan developed by ESSAP dated November 25, 1991[3] and submitted to the NRC.

Reference Grid

The 10 m reference grid utilized by the licensee was re-established by ESSAP for referencing measurements and sampling (Figure 3).

Surface Scans

Surface scans of the Burial Ground were performed using NaI(Tl) gamma scintillation detectors coupled to ratemeters with audible indicators. Locations of elevated direct radiation were marked for further investigation (Figure 4).

Exposure Rate Measurement

Exposure rate measurements were performed at 1 meter above the surface at all grid line intersections. Measurements were performed using NaI(Tl) gamma scintillation detectors coupled to ratemeters and cross-calibrated with a pressurized ionization chamber (PIC).

Soil Sampling

Surface soil samples (depth 0-15 cm) were collected from grid line intersections, trench walls (approximately 1 meter above the trench floor), four piles of soil stored outside of the fenced area, locations of elevated activity identified by Cimarron Corporation and ORAU during previous surveys, and at locations of elevated direct radiation identified by the surface scans during this survey (Figures 5 and 6).

Subsurface soil samples were collected at approximately 15 to 60 cm intervals from 16 boreholes, which measured in depth from 0 to 170 cm. Borehole drilling sites were selected from locations of elevated activity identified by Cimarron Corporation and ORAU during previous surveys (Figure 7).

SAMPLE ANALYSIS AND DATA INTERPRETATION

Samples and direct measurement data were returned to the ESSAP laboratory in Oak Ridge, TN for analyses and interpretation. Soil samples were analyzed by gamma spectrometry. Radionuclides of primary interest were U-235, U-238, and Th-232; however, spectra were also reviewed for other identifiable photopeaks. Selected soil samples were analyzed by alpha spectrometry for isotopic uranium.

Additional information concerning major instrumentation, sampling equipment, and analytical procedures is provided in Appendices A and B. Results of the independent measurements were compared to the NRC guidelines (Appendix C).

FINDINGS AND RESULTS

DOCUMENT REVIEW

The documentation provided by Cimarron Corporation was thorough and the radiological data provided in the final report demonstrated that the residual activity levels satisfied the established decommissioning guidelines.

SURVEY RESULTS

Surface Scans

Gamma scans of the former Burial Ground identified one area of slightly elevated direct radiation at 108N, 53E (Figure 4). This location was noted for further investigation.

Exposure Rate Measurements

Exposure rate measurements are summarized in Table 1. Exposure rates for the Burial Ground ranged from 9 to 14 μR/h.

Radionuclide Concentrations in Soil Samples

Twelve samples were analyzed by alpha spectrometry for isotopic uranium. The uranium concentrations for these samples are summarized in Table 2 and indicate slight enrichment above natural isotopic abundances for U-234 and U-235. Isotopic uranium concentrations ranged from 0.5 to 66.2 pCi/g for U-234, from 0.1 to 3.2 pCi/g for U-235, and from 0.4 to 26.2 pCi/g for U-238. The concentrations of total uranium ranged from 0.9 to 95.6 pCi/g. On the basis of alpha spectrometry analysis, the ratio of U-234 to U-235 is approximately 20:1. This ratio was used to calculate the total uranium concentrations in soil samples analyzed by gamma spectrometry.

Concentrations of radionuclides in surface soil samples are summarized in Table 1. Concentration ranged from 0.1 to 1.6 pCi/g for U-235 and from <1.2 to 10.8 pCi/g for U-238. The concentrations of total uranium in the surface soil samples ranged from <3.1 to 44 pCi/g. The highest concentration was identified at 69N, 62E, which was an area of elevated direct radiation identified during the previous survey.

Thorium concentrations determined for the surface soil samples are summarized in Table 1. Gamma spectra were reviewed and the thorium-232 series radionuclides were in equilibrium. Total thorium (Th-232 + Th-228) concentrations ranged from 0.4 to 5.5 pCi/g. The highest concentration was identified at 30N, 50E.

Uranium and thorium concentrations in subsurface soil samples are summarized in Table 3. Uranium concentrations ranged from 0.1 to 1.2 pCi/g for U-235, from <1.3 to 10.8 pCi/g for U-238, and from <5.5 to 33 pCi/g for total uranium. The highest concentration was identified

at 95N, 50E in the sample taken at a depth of 0-15 cm. Uranium concentrations for samples collected from the boreholes at 70N, 57E; 73N, 66E; 90N, 65E, and 95N, 45E increased with depth. The total thorium concentrations ranged from <1.5 to 4.9 pCi/g.

COMPARISON OF RESULTS WITH GUIDELINES

Background exposure rates were determined during the 1988 ORAU survey (Table 4) and averaged 10 μR/h. Surface scans identified one area of slightly elevated direct radiation at 108N, 53E. This area had a gamma exposure rate of 14 μR/h. Therefore, this area does not exceed the guideline of 10 μR/h above background, as specified in Appendix C, or the 5 μR/h above background guideline, currently in use by the NRC[4].

The guidelines for residual concentrations of thorium and uranium wastes in soil are presented in Appendix C. The primary contaminants of concern for this site are enriched uranium, depleted uranium and natural thorium. Applicable soil concentration guidelines are:

Enriched Uranium	30 pCi/g
Depleted Uranium	35 pCi/g
Natural Thorium*	10 pCi/g

*With all daughters present and in equilibrium.

Since the residual activity may be a combination of enriched and depleted uranium, and the alpha spectrometry analyses indicate that the uranium is slightly enriched in U-234 and U-235, the more conservative guideline value of 30 pCi/g was used for comparison with the uranium results.

These guidelines are expressed in terms of concentrations above normal background levels. Background radionuclide concentrations in soil were determined during the 1988 ORAU survey (Table 4). Total uranium concentrations ranged from <1.2 to 2.0 pCi/g (1.6 pCi/g average)

and total thorium concentrations ranged from 0.9 to 2.1 pCi/g (1.4 pCi/g average). Therefore, the sample analysis results indicating that the NRC guidelines have been exceeded are 31.6 pCi/g for total uranium and 11.4 pCi/g for total thorium.

Gamma spectrometry analysis identified 2 surface soil samples with total uranium concentrations which exceeded the guideline value. These samples included the soil samples collected from the previously identified area of elevated activity at 69N, 62E (44 pCi/g), and from the borehole located at 95N, 50E (33 pCi/g, sample depth 0-15 cm). Alpha spectrometry analysis identified 3 surface soil samples which exceeded the guideline value for uranium. These samples included the soil samples collected from a previously identified area of elevated direct radiation at 91N, 42E (33.2 pCi/g), the area of elevated direct radiation identified by this survey at 108N, 53E (95.6 pCi/g) and the borehole at 25N, 70E (43.6 pCi/g, sample depth 0-15 cm).

Total thorium concentrations in all surface and subsurface soil samples were less than the 10 pCi/g above background guideline value.

SUMMARY

At the request of the Nuclear Regulatory Commission Region III Office, the Environmental Survey and Site Assessment Program of Oak Ridge Associated Universities conducted a confirmatory radiological survey of the former Burial Ground at the Cimarron Corporation Facility during December 9 through 12, 1991. The survey included surface scans, exposure rate measurements, and the determination of radionuclide concentrations in soil samples.

Surface scans identified one area of slightly elevated direct radiation; however, the exposure rate measurement was within the guideline value.

Total thorium concentrations in all samples were below the concentration guideline. Total uranium concentrations in all samples, except five, were below the uranium concentration guideline. Five surface soil samples exceeded the concentration guideline; these samples were

collected from 69N, 62E; 95N, 50E; 91N, 42E; 108N, 53E and 25N, 70E and total uranium concentrations were 44 pCi/g, 33 pCi/g, 33.2 pCi/g, 95.6 pCi/g, and 43.6 pCi/g respectively.

The results of the confirmatory radiological survey indicate that all samples, with 5 exceptions, were below the concentration guidelines for total uranium and total thorium. The locations which exceed the uranium concentration guideline are scattered over the former Burial Ground Area.

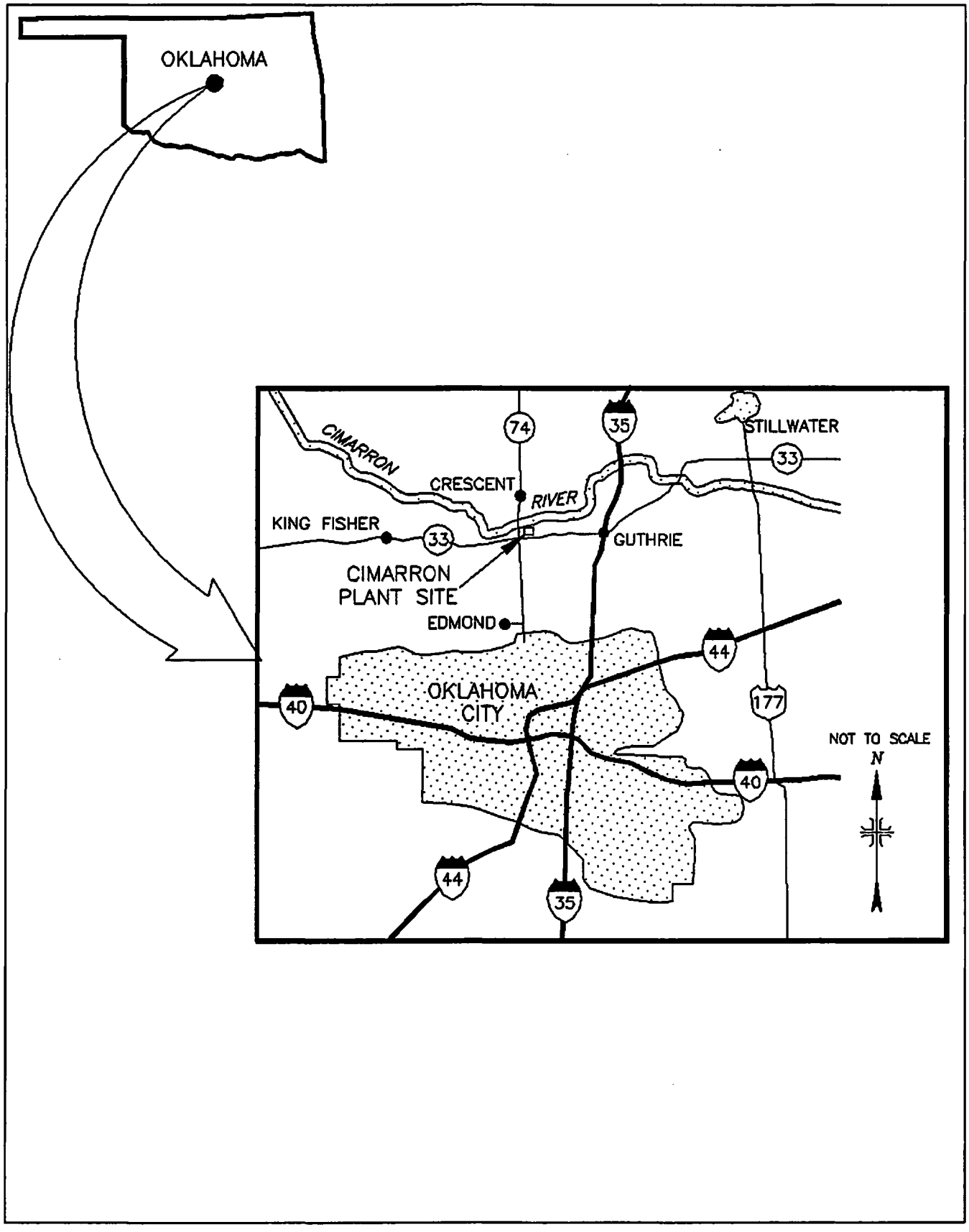

FIGURE 1: Location of the Cimarron Facility, Crescent, Oklahoma

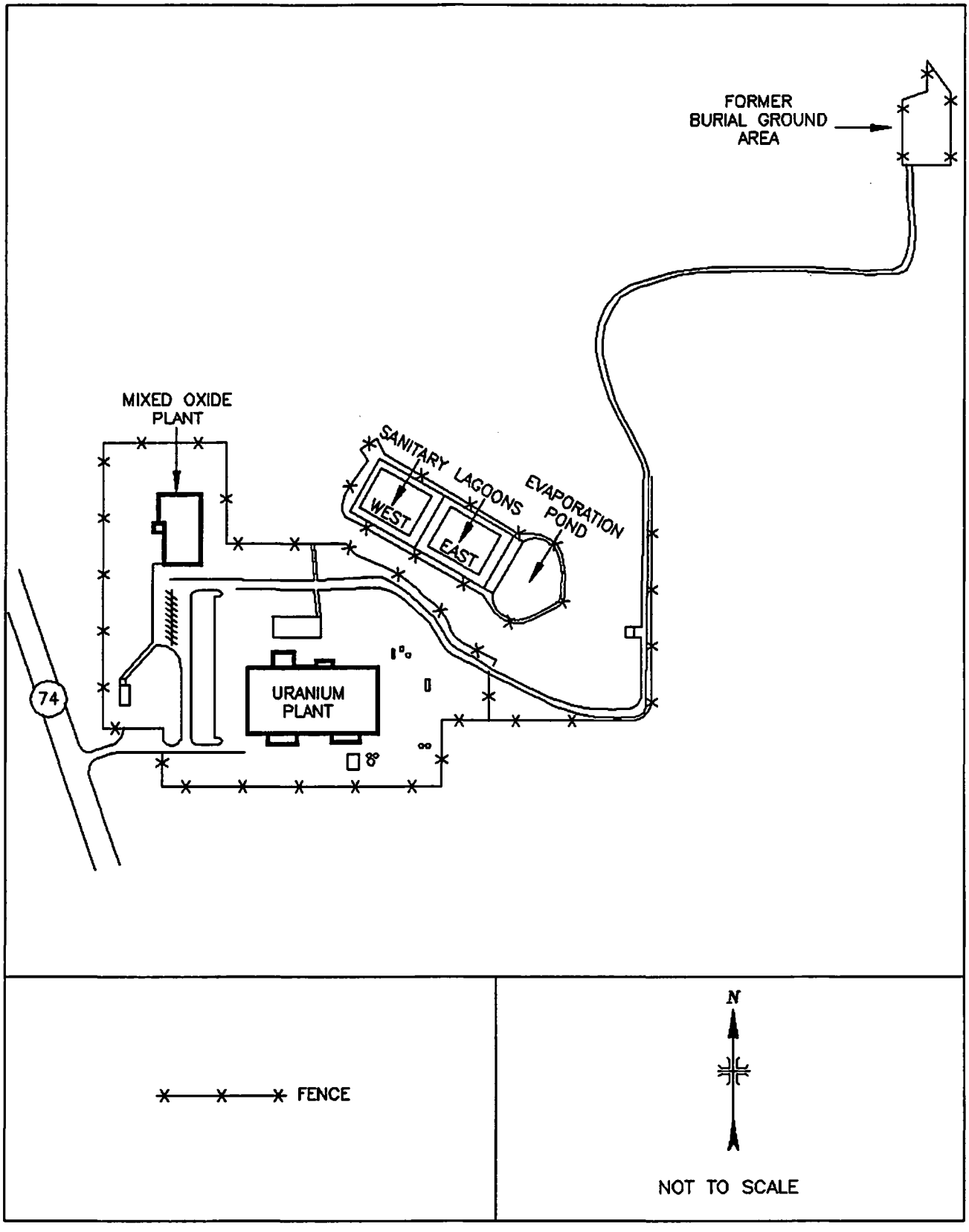

FIGURE 2: Plot Plan – Cimarron Facility

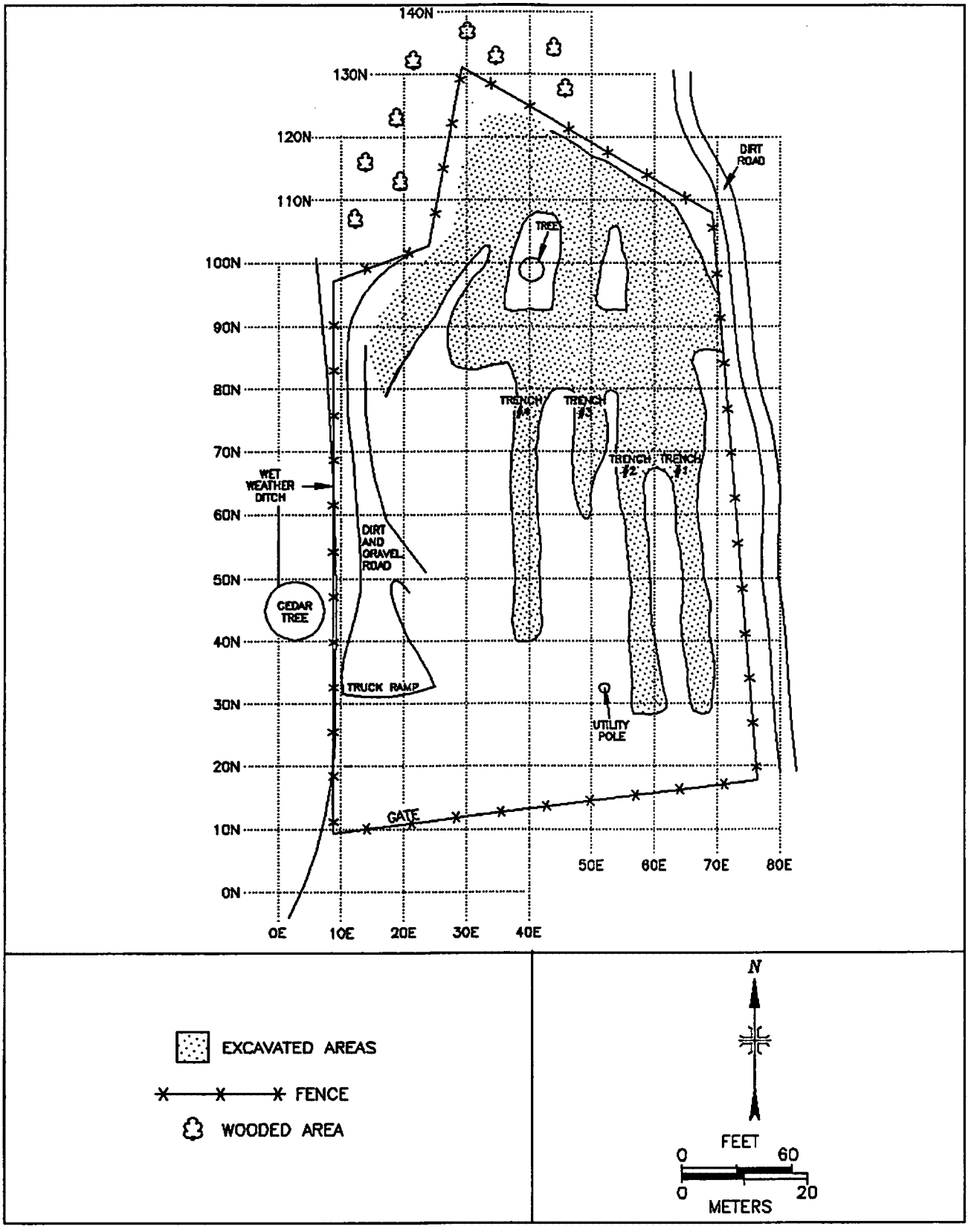

FIGURE 3: Former Burial Ground Area

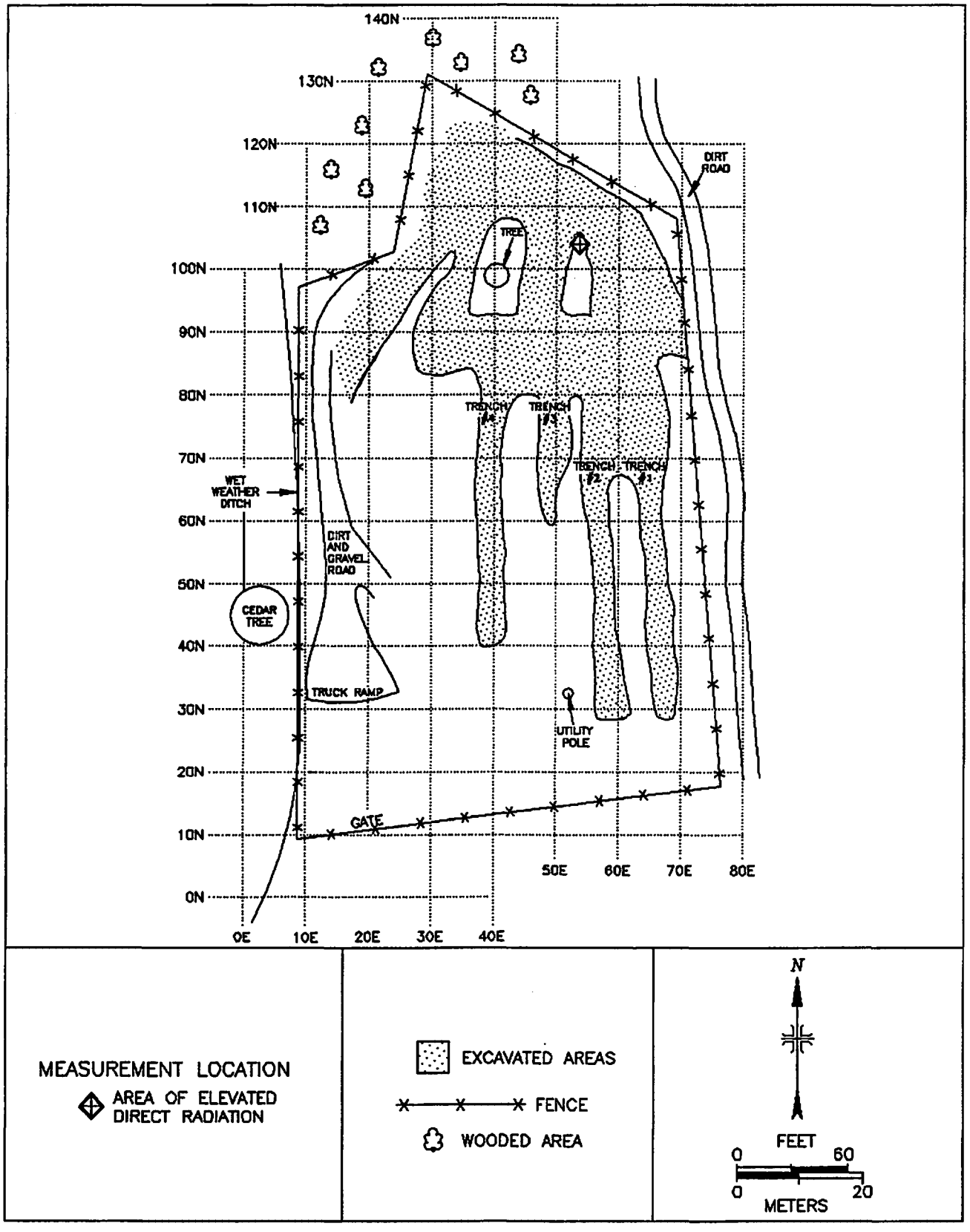

FIGURE 4: Former Burial Ground Area – Elevated Direct Radiation Location

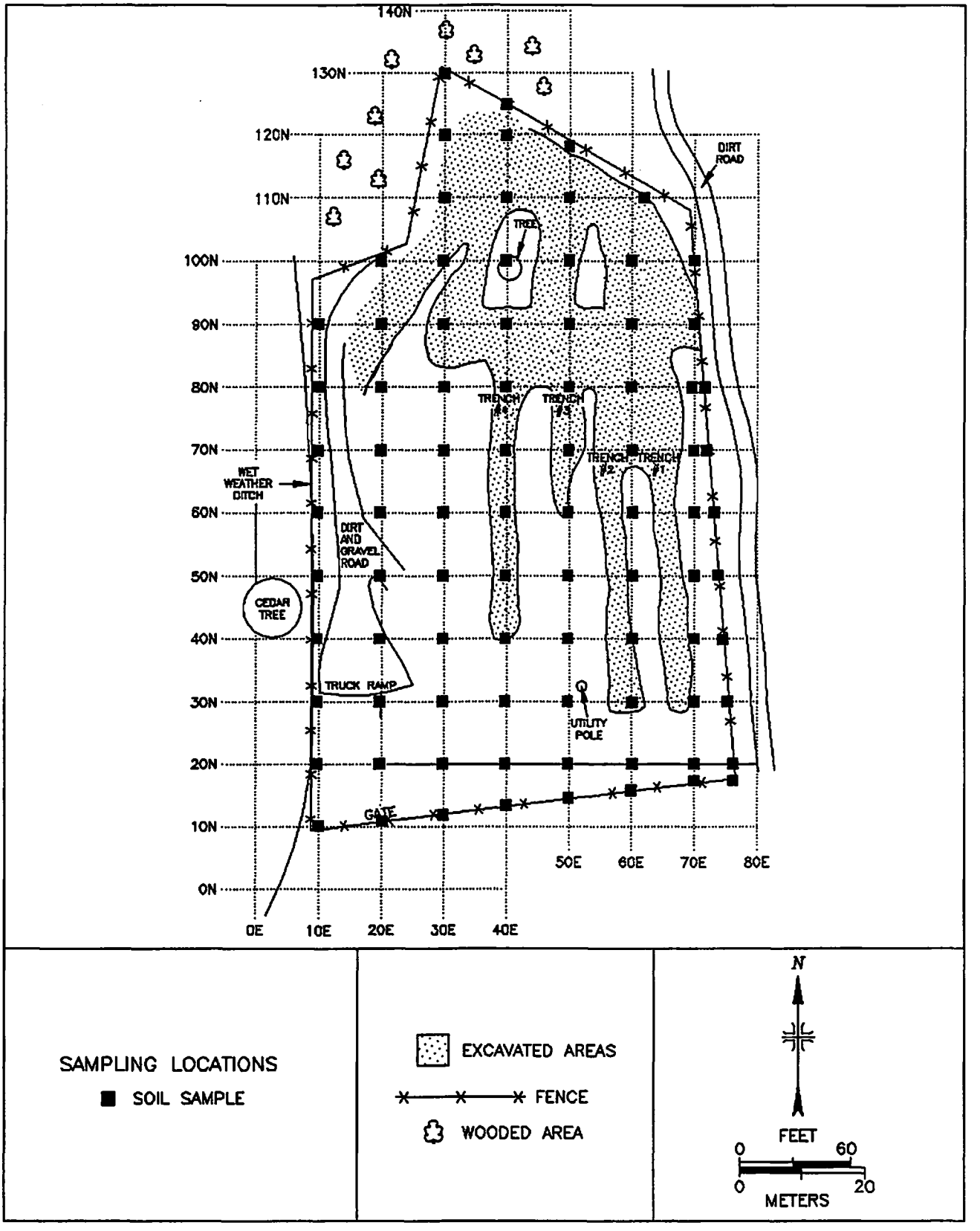

FIGURE 5: Former Burial Ground Area – Surface Soil Sampling Locations at Grid Line Intersections

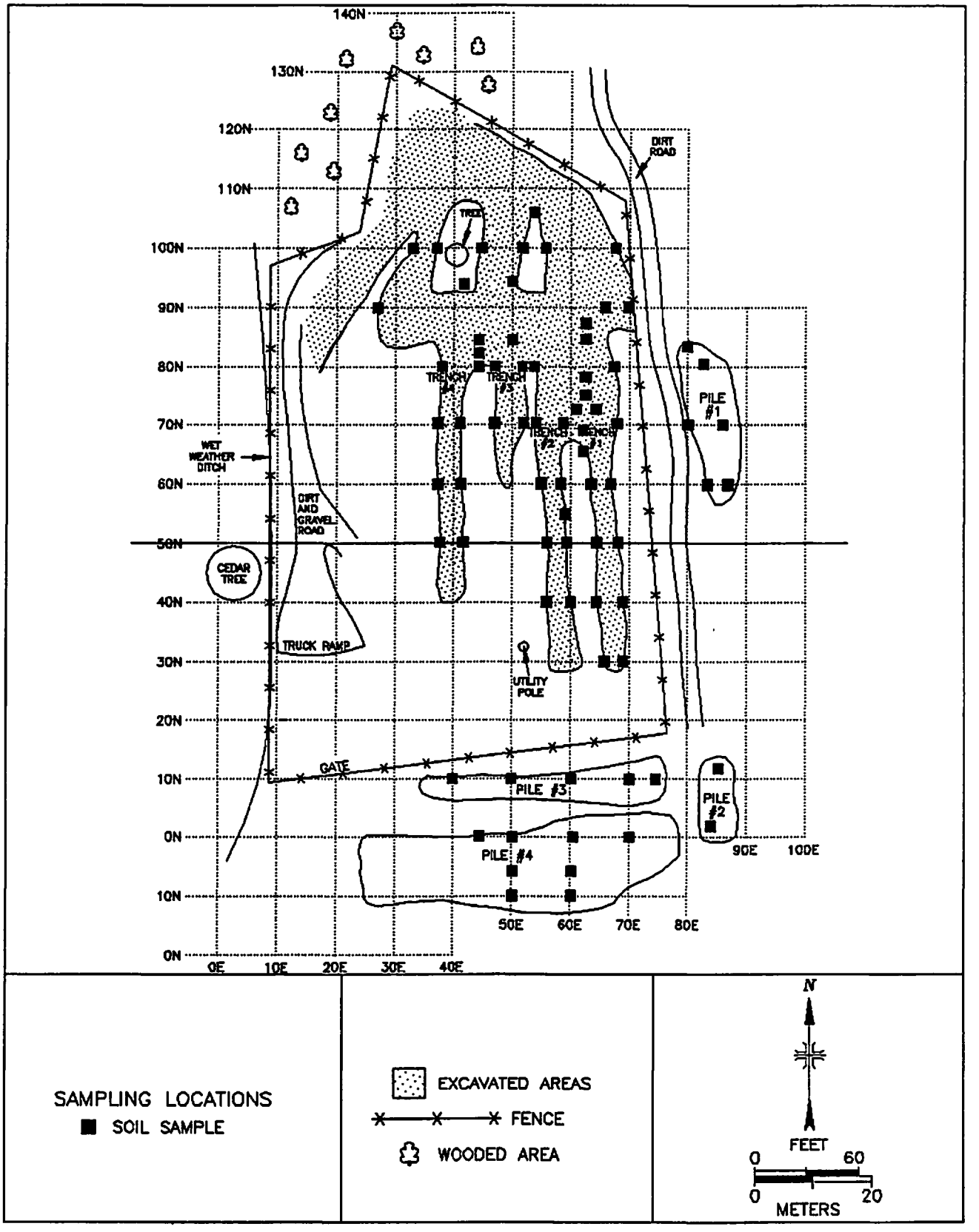

FIGURE 6: Former Burial Ground Area – Surface Soil Sampling Locations from Trench Excavations and Soil Piles

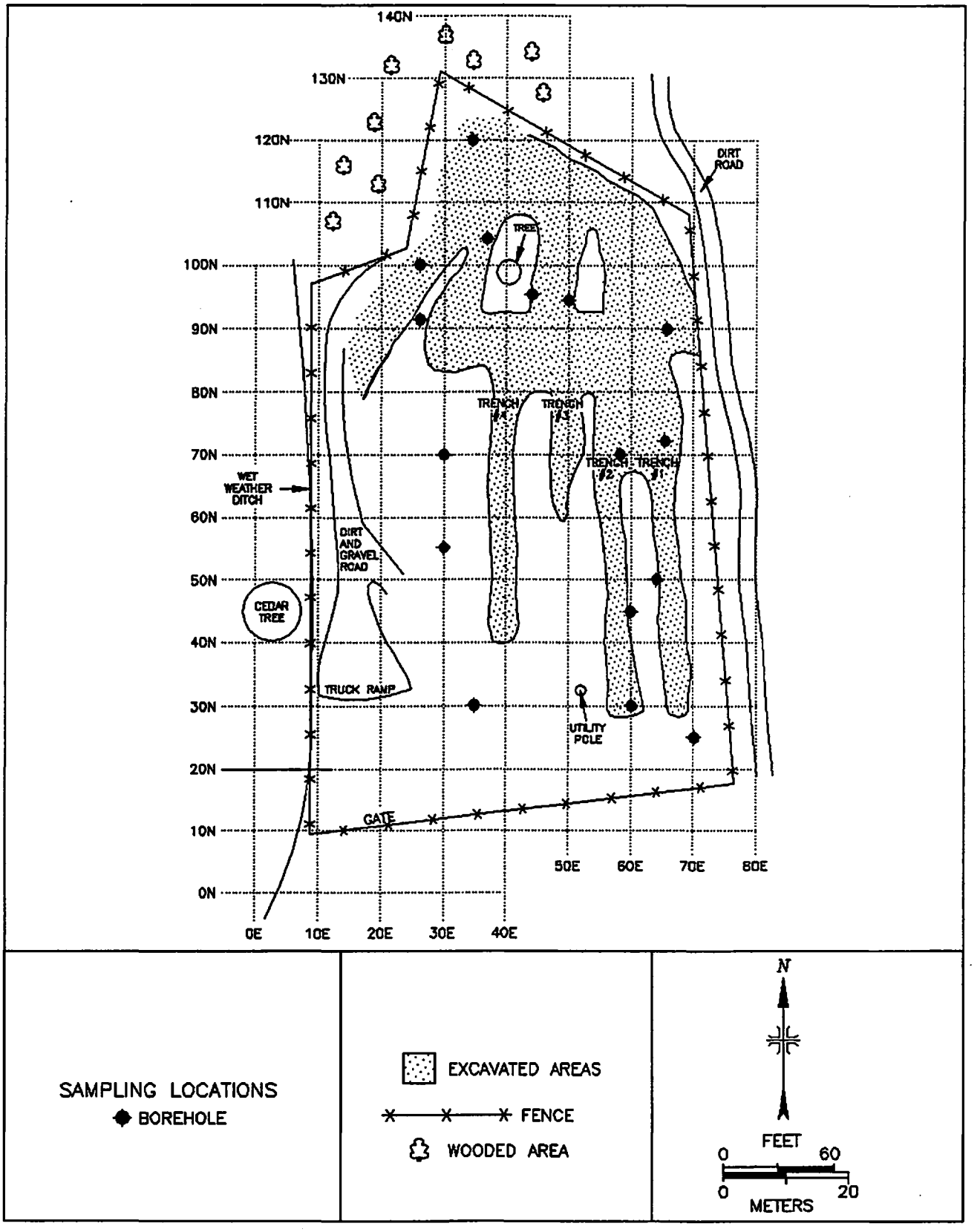

FIGURE 7: Former Burial Ground Area – Subsurface Soil Sampling Locations

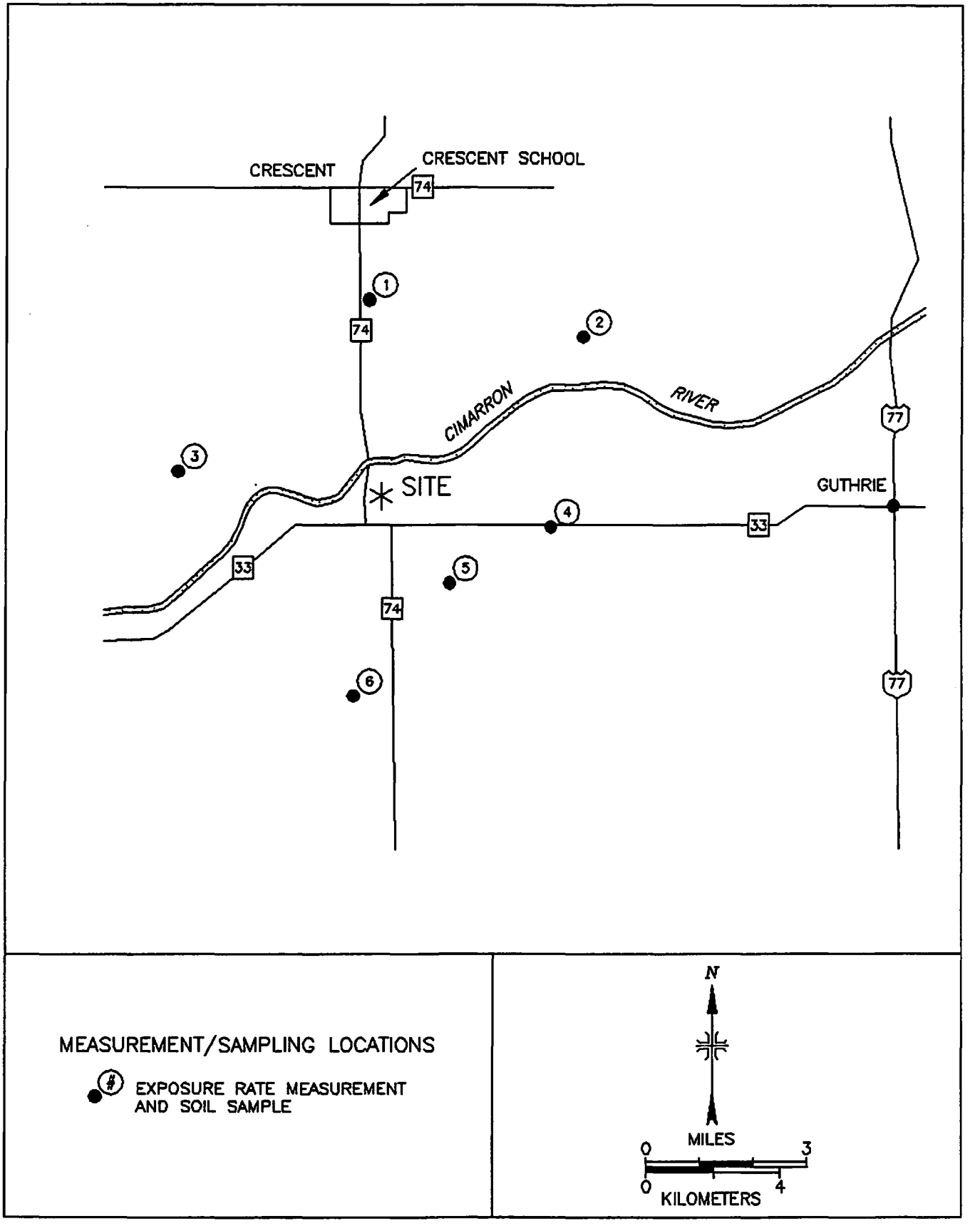

FIGURE 8: Background Measurement and Sampling Locations

TABLE 1

EXPOSURE RATE MEASUREMENTS
AND
RADIONUCLIDE CONCENTRATIONS
IN SURFACE SOIL SAMPLES
FORMER BURIAL GROUND
CIMARRON CORPORATION FACILITY
CRESCENT, OKLAHOMA

Location[a]	Exposure Rate (μR/h) at 1 m above surface	Radionuclide Concentration (pCi/g)[b]			
		U-235	U-238	Total U[c]	Total Th[d]
Grid Line Intersections					
10N, 10E	10	0.2 ± 0.4[e]	1.8 ± 1.5	6.0	1.7
11N, 20E	10	0.3 ± 0.1	1.5 ± 0.6	7.8	1.4
12N, 30E	10	0.3 ± 0.3	0.9 ± 1.2	7.2	1.3
14N, 40E	10	0.1 ± 0.1	3.4 ± 1.9	5.5	2.1
15N, 50E	10	0.2 ± 0.1	1.6 ± 0.8	5.8	1.9
15N, 60E	9	0.3 ± 0.1	4.2 ± 1.8	11	2.5
17N, 70E	10	0.7 ± 0.6	9.1 ± 2.3	24	1.6
17N, 75E	9	---[f]	---	---	2.6
20N, 10E	10	0.2 ± 0.1	1.7 ± 0.7	5.9	2.2
20N, 20E	9	0.3 ± 0.1	2.8 ± 1.3	9.1	0.7
20N, 30E	10	0.1 ± 0.1	1.3 ± 0.8	3.4	0.4
20N, 40E	10	0.2 ± 0.1	1.1 ± 0.9	7.3	2.0
20N, 50E	10	0.2 ± 0.1	3.2 ± 1.1	7.4	1.5
20N, 60E	10	0.1 ± 0.1	1.4 ± 0.8	3.5	1.7
20N, 70E	10	0.2 ± 0.1	2.5 ± 0.9	6.7	1.6
20N, 75E	10	---	---	---	2.2
30N, 10E	10	0.3 ± 0.1	<1.5	<7.8	1.9
30N, 20E	9	0.4 ± 0.3	3.1 ± 0.9	11	1.5
30N, 30E	10	0.2 ± 0.1	2.8 ± 1.6	7.0	2.2
30N, 40E	10	0.2 ± 0.1	1.9 ± 1.1	6.1	1.9

TABLE 1 (Continued)

EXPOSURE RATE MEASUREMENTS
AND
RADIONUCLIDE CONCENTRATIONS
IN SURFACE SOIL SAMPLES
FORMER BURIAL GROUND
CIMARRON CORPORATION FACILITY
CRESCENT, OKLAHOMA

Location[a]	Exposure Rate (μR/h) at 1 m above surface	Radionuclide Concentration (pCi/g)[b]			
		U-235	U-238	Total U[c]	Total Th[d]
30N, 50E	10	0.4 ± 0.5	7.4 ± 1.4	16	5.5
30N, 60E	10	0.3 ± 0.1	1.9 ± 0.8	8.2	1.9
30N, 70E	10	0.3 ± 0.1	3.6 ± 0.8	9.9	1.4
30N, 74E	9	0.3 ± 0.1	2.9 ± 0.9	9.2	1.5
40N, 10E	9	0.2 ± 0.1	1.7 ± 0.6	5.9	1.6
40N, 20E	9	0.3 ± 0.1	3.4 ± 0.9	9.7	1.6
40N, 30E	10	0.1 ± 0.2	1.5 ± 0.6	3.6	1.4
40N, 40E	10	0.5 ± 0.3	2.0 ± 0.7	13	2.0
40N, 50E	11	0.1 ± 0.1	1.3 ± 1.2	3.4	1.7
40N, 60E	10	0.1 ± 0.1	<2.0	<4.1	1.8
40N, 70E	9	0.1 ± 0.2	0.6 ± 0.8	2.7	1.1
40N, 74E	9	0.3 ± 0.3	3.7 ± 1.2	10	2.3
50N, 10E	10	0.1 ± 0.1	1.4 ± 1.4	3.5	1.5
50N, 20E	9	0.2 ± 0.1	2.0 ± 0.8	6.2	1.9
50N, 30E	10	0.2 ± 0.1	2.4 ± 1.3	6.6	1.8
50N, 40E	10	0.1 ± 0.1	3.5 ± 1.7	5.6	2.3
50N, 50E	11	0.3 ± 0.1	2.1 ± 1.0	8.4	2.8
50N, 60E	10	0.2 ± 0.1	1.4 ± 0.5	5.6	2.0
50N, 70E	10	0.3 ± 0.1	2.1 ± 1.0	8.4	2.3
50N, 73E	9	0.2 ± 0.1	1.4 ± 1.3	5.6	1.8

TABLE 1 (Continued)

EXPOSURE RATE MEASUREMENTS
AND
RADIONUCLIDE CONCENTRATIONS
IN SURFACE SOIL SAMPLES
FORMER BURIAL GROUND
CIMARRON CORPORATION FACILITY
CRESCENT, OKLAHOMA

Location[a]	Exposure Rate (μR/h) at 1 m above surface	Radionuclide Concentration (pCi/g)[b]			
		U-235	U-238	Total U[c]	Total Th[d]
60N, 10E	10	0.2 ± 0.1	2.2 ± 0.8	6.4	1.5
60N, 20E	10	0.1 ± 0.1	1.4 ± 0.9	3.5	2.1
60N, 30E	10	0.4 ± 0.5	4.2 ± 2.1	13	2.3
60N, 40E	10	0.2 ± 0.1	<1.2	<5.4	1.6
60N, 50E	11	0.3 ± 0.1	1.4 ± 1.1	7.7	2.0
60N, 60E	10	0.4 ± 0.1	2.9 ± 1.5	11	2.5
60N, 70E	9	0.2 ± 0.1	2.0 ± 1.2	6.2	1.9
60N, 72E	10	0.2 ± 0.3	1.9 ± 1.1	6.1	2.0
70N, 10E	10	0.1 ± 0.1	1.2 ± 1.0	3.3	1.9
70N, 20E	10	0.2 ± 0.1	1.2 ± 1.0	5.4	1.8
70N, 30E	10	0.9 ± 0.6	7.9 ± 1.6	27	2.3
70N, 40E	11	0.9 ± 0.5	10.8 ± 2.3	30	2.3
70N, 50E	11	0.3 ± 0.1	3.0 ± 1.1	9.3	1.7
70N, 60E	11	0.8 ± 0.4	6.3 ± 1.0	23	1.9
70N, 70E	10	0.2 ± 0.1	2.1 ± 0.8	3	2.1
70N, 72E	10	0.4 ± 0.5	5.6 ± 1.7	14	2.9
80N, 10E	10	0.3 ± 0.2	<1.4	<7.7	1.6
80N, 20E	11	0.2 ± 0.1	2.4 ± 1.7	6.6	2.1
80N, 30E	11	0.2 ± 0.1	2.2 ± 1.1	6.4	2.0
80N, 40E	10	0.2 ± 0.1	1.6 ± 0.9	5.8	2.1

TABLE 1 (Continued)

EXPOSURE RATE MEASUREMENTS
AND
RADIONUCLIDE CONCENTRATIONS
IN SURFACE SOIL SAMPLES
FORMER BURIAL GROUND
CIMARRON CORPORATION FACILITY
CRESCENT, OKLAHOMA

Location[a]	Exposure Rate (μR/h) at 1 m above surface	Radionuclide Concentration (pCi/g)[b]			
		U-235	U-238	Total U[c]	Total Th[d]
80N, 50E	11	0.9 ± 0.5	3.1 ± 0.9	22	1.9
80N, 60E	10	---	---	---	1.7
80N, 70E	10	0.3 ± 0.1	2.3 ± 1.6	8.6	2.5
80N, 71E	9	0.3 ± 0.4	2.8 ± 1.0	9.1	2.4
90N, 10E	10	0.2 ± 0.1	1.7 ± 1.4	5.9	1.7
90N, 20E	10	0.2 ± 0.1	2.1 ± 0.7	6.3	1.7
90N, 30E	10	0.5 ± 0.3	5.6 ± 2.0	16	2.2
90N, 40E	10	0.2 ± 0.1	1.1 ± 0.9	5.3	2.2
90N, 50E	10	0.6 ± 0.4	3.7 ± 1.4	16	1.2
90N, 60E	10	0.3 ± 0.3	6.5 ± 1.1	13	1.5
90N, 70E	10	0.2 ± 0.1	3.1 ± 1.5	7.3	1.9
98N, 10E	10	0.5 ± 0.3	1.7 ± 0.9	12	1.6
100N, 20E	11	0.1 ± 0.1	2.0 ± 1.3	4.1	1.7
100N, 30E	11	0.6 ± 0.3	5.8 ± 1.2	18	2.1
100N, 40E	10	0.2 ± 0.1	1.9 ± 1.2	6.1	<1.4
100N, 50E	12	0.5 ± 0.3	5.2 ± 1.0	16	1.8
100N, 60E	10	0.6 ± 0.1	6.1 ± 1.0	19	1.8
100N, 69E	10	0.3 ± 0.1	2.3 ± 0.8	8.6	1.8
110N, 30E	11	0.6 ± 0.4	4.2 ± 0.7	17	2.2
110N, 40E	11	0.5 ± 0.4	5.6 ± 1.0	16	2.2

TABLE 1 (Continued)

EXPOSURE RATE MEASUREMENTS
AND
RADIONUCLIDE CONCENTRATIONS
IN SURFACE SOIL SAMPLES
FORMER BURIAL GROUND
CIMARRON CORPORATION FACILITY
CRESCENT, OKLAHOMA

Location[a]	Exposure Rate (μR/h) at 1 m above surface	Radionuclide Concentration (pCi/g)[b]			
		U-235	U-238	Total U[c]	Total Th[d]
110N, 50E	11	0.7 ± 0.4	6.1 ± 2.0	21	1.9
110N, 62E	11	0.2 ± 0.1	1.6 ± 1.0	5.8	1.4
117N, 50E	10	0.5 ± 0.4	2.7 ± 1.1	13	2.1
120N, 30E	11	0.8 ± 0.4	5.0 ± 1.4	22	2.6
120N, 40E	10	0.3 ± 0.1	4.8 ± 2.0	11	1.5
124N, 40E	10	0.1 ± 0.1	<1.5	<3.6	2.1
130N, 30E	10	0.3 ± 0.4	2.7 ± 1.0	9.0	1.6
Trench #1					
30N, E Wall	10	0.1 ± 0.1	<1.9	<4.0	1.5
30N, W Wall	10	0.3 ± 0.1	<1.9	<8.2	1.9
40N, E Wall	10	0.2 ± 0.1	1.4 ± 1.1	5.6	1.7
40N, W Wall	10	0.2 ± 0.1	<1.1	<5.3	<1.7
50N, E Wall	10	0.1 ± 0.1	<1.6	<3.7	1.6
50N, W Wall	10	<0.4	<1.7	<10	1.4
60N, E Wall	11	0.1 ± 0.1	<1.0	<3.1	<1.0
60N, W Wall	10	0.2 ± 0.1	<1.3	<5.5	1.9
70N, E Wall	10	0.2 ± 0.1	1.7 ± 1.3	5.9	1.7
80N, E Wall	10	0.1 ± 0.1	<1.2	<3.3	2.0
100N, E Wall	10	0.3 ± 0.1	3.1 ± 1.8	9.4	2.2

TABLE 1 (Continued)

EXPOSURE RATE MEASUREMENTS
AND
RADIONUCLIDE CONCENTRATIONS
IN SURFACE SOIL SAMPLES
FORMER BURIAL GROUND
CIMARRON CORPORATION FACILITY
CRESCENT, OKLAHOMA

Location[a]	Exposure Rate (μR/h) at 1 m above surface	Radionuclide Concentration (pCi/g)[b]			
		U-235	U-238	Total U[c]	Total Th[d]
Trench #2					
40N, E Wall	10	0.2 ± 0.1	1.2 ± 0.7	5.4	1.4
40N, W Wall	10	<0.5	<2.0	<13	2.1
50N, E Wall	10	0.9 ± 0.1	3.9 ± 1.5	23	1.4
50N, W Wall	10	<0.5	<1.8	<12	<1.5
60N, E Wall	11	0.1 ± 0.1	<1.2	<3.3	1.8
60N, W Wall	11	<0.4	<1.9	<10	1.6
70N, W Wall	11	0.4 ± 0.1	3.8 ± 1.6	12	1.5
80N, W Wall	10	0.3 ± 0.1	1.5 ± 0.9	7.8	1.5
100N, W Wall	10	0.3 ± 0.1	<2.1	<8.4	2.0
Trench #3					
70N, E Wall	10	0.2 ± 0.1	<1.2	<5.4	1.9
70N, W Wall	11	<0.5	2.5 ± 1.2	13	1.9
80N, E Wall	11	---	---	---	<1.3
80N, W Wall	11	0.2 ± 0.1	1.8 ± 0.7	6.0	2.3
100N, E Wall	11	0.1 ± 0.1	<1.8	<3.9	2.0
100N, W Wall	11	0.1 ± 0.1	<1.2	<3.3	1.5
Trench #4					
50N, E Wall	10	0.1 ± 0.1	<1.9	<4.0	<1.7
50N, W Wall	11	0.3 ± 0.1	<1.2	<7.5	<1.7
60N, E Wall	10	0.2 ± 0.1	2.6 ± 1.3	6.8	2.2
60N, W Wall	10	0.2 ± 0.1	<1.3	<5.5	1.8

TABLE 1 (Continued)

EXPOSURE RATE MEASUREMENTS
AND
RADIONUCLIDE CONCENTRATIONS
IN SURFACE SOIL SAMPLES
FORMER BURIAL GROUND
CIMARRON CORPORATION FACILITY
CRESCENT, OKLAHOMA

Location[a]	Exposure Rate (μR/h) at 1 m above surface	Radionuclide Concentration (pCi/g)[b]			
		U-235	U-238	Total U[c]	Total Th[d]
70N, E Wall	11	<0.5	<1.9	<12	2.1
70N, W Wall	11	0.2 ± 0.1	<1.3	<5.5	1.6
80N, E Wall	10	<0.5	<1.9	<12	1.8
80N, W Wall	10	0.2 ± 0.1	1.9 ± 1.0	6.1	1.3
90N, W Wall	10	0.2 ± 0.1	2.9 ± 0.9	7.1	<1.4
100N, E Wall	10	0.4 ± 0.2	3.8 ± 1.7	12	2.1
100N, W Wall	10	0.5 ± 0.1	3.8 ± 0.9	14	2.2
Pile #1					
60N, 82E	10	0.3 ± 0.1	4.7 ± 1.4	11	1.3
60N, 85E	10	0.3 ± 0.1	3.4 ± 0.9	9.7	1.4
70N, 80E	10	0.5 ± 0.3	5.0 ± 1.3	16	1.8
70N, 85E	10	0.2 ± 0.1	2.1 ± 0.8	6.3	2.3
80N, 83E	10	0.4 ± 0.4	4.5 ± 1.8	13	1.6
82N, 80E	10	---	---	---	1.2
Pile #2					
3N, 85E	11	0.2 ± 0.2	2.2 ± 0.9	6.4	2.0
11N, 85E	10	0.1 ± 0.1	1.1 ± 0.6	3.2	1.7
Pile #3					
10N, 40E	10	0.2 ± 0.1	1.2 ± 1.0	5.4	1.8
10N, 50E	10	0.1 ± 0.1	1.7 ± 0.7	3.8	1.7
10N, 60E	10	0.2 ± 0.1	1.8 ± 1.6	6.0	1.4
10N, 70E	10	0.2 ± 0.1	2.3 ± 0.7	6.5	1.6
10N, 75E	10	0.2 ± 0.1	2.0 ± 1.3	6.2	1.7

TABLE 1 (Continued)

EXPOSURE RATE MEASUREMENTS
AND
RADIONUCLIDE CONCENTRATIONS
IN SURFACE SOIL SAMPLES
FORMER BURIAL GROUND
CIMARRON CORPORATION FACILITY
CRESCENT, OKLAHOMA

Location[a]	Exposure Rate (μR/h) at 1 m above surface	Radionuclide Concentration (pCi/g)[b]			
		U-235	U-238	Total U[c]	Total Th[d]
Pile #4					
0, 45E	10	0.4 ± 0.2	5.1 ± 1.0	14	2.5
0, 50E	10	0.3 ± 0.3	7.8 ± 1.8	14	1.6
0, 60E	10	0.2 ± 0.1	2.0 ± 0.6	6.2	1.6
0, 70E	10	0.2 ± 0.1	1.1 ± 0.7	5.3	1.7
5S, 50E	10	0.3 ± 0.2	3.3 ± 0.9	9.6	2.3
5S, 60E	10	0.2 ± 0.1	2.0 ± 1.5	6.2	1.7
10S, 50E	10	0.6 ± 0.4	6.6 ± 2.0	19	2.7
10S, 60E	10	0.6 ± 0.3	9.2 ± 0.8	22	2.8
Previously Identified Areas of Elevated Activity					
57N, 64E	10	0.3 ± 0.1	3.0 ± 1.7	9.3	2.8
65N, 62E	11	0.2 ± 0.1	1.6 ± 1.4	5.8	3.6
69N, 62E	11	1.6 ± 0.5	9.9 ± 2.2	44	1.4
70N, 59E	11	---	---	---	2.2
71N, 61E	11	0.7 ± 0.3	7.0 ± 1.4	22	2.0
71N, 65E	11	0.2 ± 0.1	2.7 ± 0.8	6.9	3.0
75N, 63E	10	0.3 ± 0.1	3.5 ± 1.4	9.8	2.0
77N, 63E	10	0.4 ± 0.3	3.8 ± 1.0	12	2.0
78N, 63E	10	0.2 ± 0.3	3.9 ± 1.8	8.1	2.8

TABLE 1 (Continued)

EXPOSURE RATE MEASUREMENTS
AND
RADIONUCLIDE CONCENTRATIONS
IN SURFACE SOIL SAMPLES
FORMER BURIAL GROUND
CIMARRON CORPORATION FACILITY
CRESCENT, OKLAHOMA

Location[a]	Exposure Rate (μR/h) at 1 m above surface	Radionuclide Concentration (pCi/g)[b]			
		U-235	U-238	Total U[c]	Total Th[d]
83N, 45E	10	0.2 ± 0.1	1.7 ± 0.8	5.9	1.5
84N, 65E	10	0.5 ± 0.1	4.3 ± 1.3	15	2.3
85N, 45E	10	0.2 ± 0.1	2.4 ± 0.8	6.6	1.7
85N, 50E	10	0.5 ± 0.4	5.7 ± 1.8	16	1.4
87N, 65E	10	0.3 ± 0.4	5.4 ± 1.6	12	1.8
90N, 66E	10	0.3 ± 0.3	5.3 ± 1.0	12	1.9
90N, 68E	9	0.3 ± 0.3	1.8 ± 1.0	8.1	1.0
91N, 42E	10	---	---	---	1.8
95N, 50E	11	0.2 ± 0.1	3.4 ± 1.7	7.6	1.7
Area of Elevated Direct Radiation 108N, 53E	14	---	---	---	4.2

[a]Refer to Figures 4-6.
[b]Based on gamma spectrometry analysis.
[c]Calculated using a U-234:U-235 activity ratio of 20:1.
[d]Calculated by adding concentrations of Th-228 and Th-232.
[e]Uncertainties represent the 95% confidence level, based only on counting statistics.
[f]---Indicates analysis was performed by alpha spectrometry; see Table 2.

TABLE 2

ISOTOPIC URANIUM CONCENTRATIONS
IN SOIL SAMPLES
FORMER BURIAL GROUND
CIMARRON CORPORATION FACILITY
CRESCENT, OKLAHOMA

Location[a]	Uranium Concentration (pCi/g)[b]			
	U-234	U-235	U-238	Total U
Gridline Intersections				
17N, 75E	17.1 ± 0.8[c]	0.9 ± 0.3	7.6 ± 0.6	25.6 ± 1.0
20N, 75E	20.0 ± 0.9	0.8 ± 0.2	10.3 ± 0.6	31.0 ± 1.1
80N, 60E	10.4 ± 0.5	0.5 ± 0.1	7.6 ± 0.4	18.5 ± 0.7
Trench #3				
80N, E Wall	17.2 ± 0.7	0.9 ± 0.2	7.7 ± 0.4	25.8 ± 0.8
Pile #1				
82N, 80E	14.6 ± 0.6	0.8 ± 0.2	6.7 ± 0.4	22.1 ± 0.7
Previously Identified Areas of Elevated Activity				
70N, 59E	12.6 ± 0.7	0.5 ± 0.2	11.6 ± 0.7	24.7 ± 1.0
91N, 42E	21.7 ± 0.9	0.8 ± 0.2	10.7 ± 0.6	33.2 ± 1.1
Areas of Elevated Direct Radiation				
108N, 53E	66.2 ± 1.4	3.2 ± 0.4	26.2 ± 0.9	95.6 ± 1.7
Subsurface				
25N, 70E (0-15 cm)	22.2 ± 0.8	1.4 ± 0.2	20.0 ± 0.7	43.6 ± 1.1
55N, 30E (15-40 cm)	12.0 ± 0.6	0.7 ± 0.2	7.0 ± 0.4	19.7 ± 0.7
90N, 65E (15-35 cm)	12.8 ± 0.5	0.6 ± 0.1	5.3 ± 0.3	18.6 ± 0.6
120N, 35E (110-170 cm)	0.5 ± 0.1	0.1 ± 0.1	0.4 ± 0.1	0.9 ± 0.2

[a]Refer to Figures 4-7.
[b]Based on alpha spectrometry analysis.
[c]Uncertainties represent the 95% confidence level, based only on counting statistics.

TABLE 3

RADIONUCLIDE CONCENTRATIONS
IN SUBSURFACE SOIL SAMPLES
FORMER BURIAL GROUND
CIMARRON CORPORATION FACILITY
CRESCENT, OKLAHOMA

Location[a]	Depth (cm)	Radionuclide Concentration (pCi/g)[b]			
		U-235	U-238	Total U[c]	Total Th[d]
25N, 70E	0-15	---[e]	---	---	1.6
	15-40	0.5 ± 0.4[f]	10.8 ± 1.3	21	1.8
	40-80	0.3 ± 0.3	7.0 ± 1.9	13	1.4
	80-130	0.3 ± 0.1	3.6 ± 0.9	9.9	1.1
	130-150	0.2 ± 0.1	2.6 ± 1.4	6.8	1.7
30N, 35E	0-15	0.2 ± 0.1	3.4 ± 1.5	7.6	<1.5
	15-50	0.2 ± 0.1	<1.3	<5.5	1.5
	50-75	0.1 ± 0.1	1.8 ± 1.2	3.9	1.7
	75-120	0.1 ± 0.1	2.0 ± 0.9	4.1	1.4
	120-150	0.3 ± 0.1	1.7 ± 1.3	8.0	1.4
31N, 60E	0-15	0.3 ± 0.3	2.5 ± 1.4	8.8	2.4
	15-40	0.2 ± 0.1	1.1 ± 0.6	5.3	1.5
	40-80	0.2 ± 0.1	1.3 ± 1.0	5.6	1.7
	80-130	0.2 ± 0.2	2.2 ± 1.0	6.4	1.6
	130-150	0.3 ± 0.3	<1.7	<8.0	1.2
45N, 60E	0-15	0.6 ± 0.4	7.0 ± 1.2	20	4.9
	15-50	0.2 ± 0.3	2.7 ± 1.0	6.9	2.0
	50-90	0.2 ± 0.3	1.1 ± 0.8	5.3	2.0
	90-130	0.2 ± 0.1	1.9 ± 1.5	6.1	1.8
	130-150	0.2 ± 0.2	1.7 ± 0.7	5.9	2.0
50N, 66E	0-15	0.2 ± 0.1	1.9 ± 0.7	6.1	2.0
	15-45	0.2 ± 0.1	1.6 ± 1.0	5.8	1.4
	45-75	0.2 ± 0.2	0.8 ± 0.5	5.0	1.1
55N, 30E	0-15	0.2 ± 0.1	2.1 ± 0.9	6.3	1.6
	15-40	---	---	---	0.7
	40-50	0.1 ± 0.1	0.9 ± 0.6	3.0	1.1
70N, 30E	0-15	0.3 ± 0.1	2.1 ± 1.7	8.4	2.0
	15-40	0.2 ± 0.1	1.4 ± 0.8	5.6	2.5
	40-80	0.4 ± 0.4	0.4 ± 0.4	8.8	2.2
	80-120	0.4 ± 0.4	2.0 ± 0.8	10	1.7
	120-150	0.3 ± 0.3	2.8 ± 1.4	9.1	1.8

TABLE 3 (Continued)

RADIONUCLIDE CONCENTRATIONS
IN SUBSURFACE SOIL SAMPLES
FORMER BURIAL GROUND
CIMARRON CORPORATION FACILITY
CRESCENT, OKLAHOMA

Location[a]	Depth (cm)	Radionuclide Concentration (pCi/g)[b]			
		U-235	U-238	Total U[c]	Total Th[d]
70N, 57E	0-15	0.2 ± 0.2	3.6 ± 0.8	7.8	1.6
	15-30	0.8 ± 0.3	10.4 ± 3.1	27	2.1
73N, 66E	0-15	0.3 ± 0.2	2.7 ± 0.8	9.0	1.6
	15-30	0.5 ± 0.4	4.1 ± 2.1	15	1.7
90N, 65E	0-15	0.4 ± 0.2	4.8 ± 1.0	13	1.8
	15-35	---	---	---	1.6
	35-50	0.8 ± 0.3	8.6 ± 1.2	25	1.8
91N, 27E	0-15	0.4 ± 0.1	4.3 ± 1.4	12	1.6
	15-40	0.3 ± 0.1	1.7 ± 0.5	8.0	1.6
	40-90	0.2 ± 0.1	1.7 ± 1.0	5.9	1.9
	90-130	0.2 ± 0.1	1.9 ± 0.8	6.1	1.8
	130-150	<0.5	<1.9	<12	1.8
95N, 45E	0-15	0.2 ± 0.1	1.9 ± 0.8	6.1	1.7
	15-50	0.2 ± 0.1	<1.9	<6.1	1.6
	50-70	0.2 ± 0.1	2.4 ± 0.9	6.6	1.9
	70-130	0.2 ± 0.1	1.3 ± 1.2	5.4	1.5
	130-150	0.7 ± 0.3	7.8 ± 1.1	23	1.5
95N, 50E	0-15	1.2 ± 0.4	7.9 ± 0.8	33	2.0
	15-40	0.4 ± 0.1	4.3 ± 1.7	13	2.4
	40-50	0.4 ± 0.3	5.4 ± 1.2	14	2.2
100N, 25E	0-15	0.4 ± 0.3	4.3 ± 1.3	13	2.2
	15-40	0.2 ± 0.1	3.8 ± 1.2	6.0	2.5
	40-70	0.3 ± 0.3	2.7 ± 1.0	9.0	1.5
	70-120	0.2 ± 0.1	2.4 ± 1.3	6.6	1.5

TABLE 3 (Continued)

RADIONUCLIDE CONCENTRATIONS
IN SUBSURFACE SOIL SAMPLES
FORMER BURIAL GROUND
CIMARRON CORPORATION FACILITY
CRESCENT, OKLAHOMA

Location[a]	Depth (cm)	Radionuclide Concentration (pCi/g)[b]			
		U-235	U-238	Total U[c]	Total Th[d]
105N, 37E	0-15	0.5 ± 0.1	4.8 ± 2.2	15	1.2
	15-50	0.3 ± 0.2	3.0 ± 0.8	9.3	1.0
	50-80	0.2 ± 0.1	2.7 ± 1.4	6.9	1.2
	80-130	0.3 ± 0.1	2.2 ± 0.9	8.5	1.7
120N, 35E	0-15	0.4 ± 0.1	5.2 ± 2.1	14	2.3
	15-40	0.4 ± 0.1	5.8 ± 1.2	14	2.4
	40-75	0.4 ± 0.4	4.5 ± 1.5	13	1.5
	75-110	0.4 ± 0.1	4.8 ± 1.0	13	1.6
	110-170	---	---	---	1.6

[a]Refer to Figure 7.
[b]Based on gamma spectrometry analysis.
[c]Calculated using a U-234:U-235 activity ratio of 20:1.
[d]Calculated by adding concentrations of Th-228 + Th-232.
[e]---Indicate analysis was performed by alpha spectrometry analysis; see Table 2.
[f]Uncertainties represent the 95% confidence level, based only on counting statistics.

TABLE 4

BACKGROUND EXPOSURE RATES
AND RADIONUCLIDE CONCENTRATIONS
IN SOIL
FORMER BURIAL GROUND
CIMARRON CORPORATION FACILITY
CRESCENT, OKLAHOMA

Location[a]	Exposure Rate (μR/h) at 1 m above the surface	Radionuclide Concentration (pCi/g)[b]	
		Total U[c]	Total Th[d]
1	10	1.5	1.2
2	9	1.3	1.1
3	9	<1.7	0.9
4	10	2.0	1.4
5	10	1.9	1.9
6	10	<1.2	2.1
Average	10	1.6	1.4

[a]Refer to Figure 8.
[b]Based on gamma spectrometry analysis.
[c]Calculated based on natural activity ratios.
[d]Calculated by adding concentrations of Th-228 + Th-232.

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3. "Confirmatory Radiological Survey Plan for the On-Site Burial Ground of the Cimarron Corporation Facility, Crescent, Oklahoma," ORAU, November 1991.

4. "Policy and Guideline Directive FC91-2, Standard Review Plan: Evaluating Decommissioning Plans for Licenses Under 10 CFR Parts 30, 40, and 70," U.S. Nuclear Regulatory Commission, August 1991.

APPENDIX A

MAJOR SAMPLING AND ANALYTICAL EQUIPMENT

APPENDIX A

MAJOR SAMPLING AND ANALYTICAL EQUIPMENT

The display or description of a specific product is not to be construed as an endorsement of that product or its manufacturer by the authors or their employer.

A. Direct Radiation Measurements

Eberline PRM-6
Portable Ratemeter
(Eberline, Santa Fe, NM)

Victoreen NaI Scintillation Detector
Model 489-55
(Victoreen, Cleveland, OH)

Reuter-Stokes Pressurized Ionization Chamber
Model RSS-111
(Reuter-Stokes, Cleveland, OH)

B. Laboratory Analytical Equipment

High-Purity Germanium Coaxial Well Detector
Model GWL-1102010-PWS-S, 23% efficiency
(EG&G ORTEC, Oak Ridge, TN)

Used in conjunction with:
Lead Shield, G-16
(Applied Physical Technology, Atlanta, GA)

Multichannel Analyzer
ND-66/Micro VaxII
(Nuclear Data, Schaumburg, IL/Digital Equipment Corp., Maynard, MA)

Alpha Spectrometry System
Tennelec Electronics
(Tennelec, Oak Ridge, TN)

Solid State Surface Barrier Detectors
(EG&G Ortec, Oak Ridge, TN)
(Tennelec, Oak Ridge, TN)

Multichannel Analyzer
ND-66
(Nuclear Data, Schaumberg, IL)

APPENDIX B

MEASUREMENT AND ANALYTICAL PROCEDURES

APPENDIX B

MEASUREMENT AND ANALYTICAL PROCEDURES

Surface Scans

Surface scans were conducted using NaI scintillation detectors with ratemeters. The scans were performed by passing the probes slowly over the surface; the distance between the probe and the surface was maintained nominally at about 1 cm. Identification of elevated levels was based on increases in the audible signal from the recording or indicating instrument.

Gamma Exposure Rate Measurements

Measurements of gamma exposure rates were performed using portable ratemeters with gamma scintillation detectors. Count rates were converted to exposure rates (μR/h) by cross-calibrating with a pressurized ion chamber.

Gamma Spectroscopy

The samples were placed in an appropriate container chosen to reproduce the calibrated counting geometry. Net weights were determined and the samples counted using high purity intrinsic germanium detectors coupled to a Nuclear Data Model ND-66/Micro VaxII 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. Energy peaks, used for determination of radionuclides of concern, were:

U-238	0.093 MeV from Th-234*
U-235	0.143 MeV
Th-228	0.583 MeV from Tl-208*
Th-232	0.911 MeV from Ac-228*

*Secular equilibrium assumed.

Spectra were reviewed for other identifiable photopeaks at concentrations above those normally encountered in environmental media.

Alpha Spectroscopy

Soil samples were dried and homogenized, and aliquots were dissolved by pyrosulfate fusion and precipitated by barium sulphate. The barium sulphate precipitate was redissolved and the uranium was separated by liquid-liquid extraction. The uranium was then precipitated with a cerium fluoride carrier and counted using surface barrier detectors, alpha spectrometers, and a ND-66 multichannel analyzer.

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. When the net sample count was less than the 95% statistical deviation of the background count, the sample concentration was reported as less than the detection limit of the measurement procedure. 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. Additional uncertainties of $\pm$ 6 to 10%, associated with laboratory procedures, have not been propagated into the data presented in this report.

Quality Assurance

Analytical and field survey activities were conducted in accordance with procedures from the following documents:

- Survey Procedures Manual, Revision 6, February 1991
- Quality Assurance Manual, Revision 4, April 1991
- Laboratory Procedures Manual, Revision 6, April 1991

The procedures contained in these manuals were developed to meet the requirements of DOE Order 5700.6B.

Calibration of all field laboratory instrumentation is based on NIST-traceable standards, when such standards are available. In cases where they are not available, standards of an industry recognized organization will be used. Calibration of pressurized ionization chambers is performed by the manufacturer.

Quality Control procedures include:

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

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.