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Results of the Independent Radiological Verification Survey of the Remedial Action Performed at the Former Alba Craft Laboratory Site Oxford, Ohio (OXO001)

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ABSTRACT

Between October 1952 and February 1957, National Lead of Ohio (NLO), a primary contractor for the Atomic Energy Commission (AEC), subcontracted certain uranium machining operations to Alba Craft Laboratory, Incorporated, located at 10–14 West Rose Avenue, Oxford, Ohio. In 1992, personnel from Oak Ridge National Laboratory (ORNL) confirmed the presence of residual radioactive materials from the AEC-related operations in and around the facility in amounts exceeding the applicable Department of Energy (DOE) guidelines.

Although the amount of uranium found on the property posed little health hazard if left undisturbed, the levels were sufficient to require remediation to bring radiological conditions into compliance with current guidelines, thus ensuring that the public and the environment are protected. The Remedial Action Contractor for these properties was Bechtel National, Incorporated (BNI).

DOE requires that verification of completed cleanup work at DOE Formerly Utilized Sites Remedial Action Program (FUSRAP) sites such as this shall be performed and documented by an Independent Verification Contractor. The objective of verification activities is to certify that the remedial action reduced contamination levels to within authorized limits.

A team from ORNL conducted a radiological verification survey of the former Alba Craft Laboratory property between December 1994 and February 1995. The survey was conducted at the request of DOE and included directly measured radiation levels, the collection and analysis of soil samples to determine concentrations of uranium and certain other radionuclides, and comparison of these data to the guidelines. This document reports the findings of this survey.

The results of the independent verification survey of the former Alba Craft Laboratory property demonstrate that all contaminated areas have been remediated to radionuclide concentrations and activity levels below the applicable guideline limits set by DOE.

Results of the Independent Radiological Verification Survey of the Remedial Action Performed at the Former Alba Craft Laboratory Site, Oxford, Ohio (OXO001)

INTRODUCTION

During the approximate time period between October 1952 and February 1957, National Lead of Ohio (NLO), a primary contractor for the Atomic Energy Commission (AEC), subcontracted certain uranium machining operations to Alba Craft Laboratory, Incorporated, Oxford, Ohio. The facility, located at 10–14 West Rose Avenue, also housed operations in 1954 involving NLO personnel and NLO uranium material. It is not known how much material was machined at the site by NLO in 1954, but the total quantity of uranium machined by Alba Craft is estimated at several hundred tons. Figures 1 and 2 show the relative location of the City of Oxford in southwestern Ohio and the location of the property in Oxford.

Early investigations of the Alba Craft property had disclosed evidence of residual radioactive materials from the AEC-related operations at the site. At the request of the Department of Energy (DOE) under the Formerly Utilized Sites Remedial Action Program (FUSRAP), a radiological assessment was conducted in 1992 by personnel from Oak Ridge National Laboratory (ORNL) to locate and define the extent of the contamination on the site itself, and to determine whether any of these materials had migrated off-site.* The results of that survey confirmed the presence of residual radioactive material from the AEC-related operations in and around the Alba Craft facility in amounts exceeding the applicable DOE guidelines (Table 1).[1] Although the amount of uranium found posed little health hazard if left undisturbed, the levels were sufficient to require cleanup action to bring the property into compliance with current guidelines, thereby ensuring that the public and the environment are protected.

DOE's Environmental Restoration Program dictates that independent verification (IV) of completed cleanup work at DOE FUSRAP sites shall be performed and documented according to prescribed procedures prior to certification of the property for release for unrestricted use.[2,3] The objective of verification activities is to confirm that the remedial action reduced contamination levels to within authorized limits.

As the designated Independent Verification Contractor (IVC) for this site, ORNL's Measurement Applications and Development Group was assigned to validate the remedial action and restoration activities conducted by the Remedial Action Contractor, Bechtel National, Incorporated (BNI). At the time of the verification survey, the building had been completely razed, and the majority of the dismantled remains had been removed off-site. Figure 3 is a diagram indicating the former location of the Alba Craft Laboratory building and showing the grid established by BNI during the remedial activities to enable precise location of measurements and samples.

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*The survey was performed by members of the Measurement Applications and Development Group, Health Sciences Research Division, Oak Ridge National Laboratory under DOE contract DE–AC05-96OR22464 with Lockheed Martin Energy Research Corp.

SCOPE OF THE SURVEY

The outdoor survey of the property included:

- A gamma scan near the ground surface over 100% of the property.
- Collection of systematic surface and subsurface soil samples.
- Collection of biased surface soil samples.
- Measurements of gamma radiation levels at 1 m at soil sample locations.
- Selected beta-gamma scanning at suspect areas such as locations of former doors.
- On-site field screening with a portable gamma spectrometer to estimate uranium concentrations in soil samples.
- Measurements of radiation levels and sampling of drains, sewerlines, and areas downstream from Alba Craft gutter drains.

SURVEY METHODS

Descriptions of the typical methods and instrumentation providing guidance for this survey are given in *Procedures Manual for the ORNL Radiological Survey Activities (RASA) Program*, ORNL/TM-8600, April 1987, and in *Measurement Applications and Development Group Guidelines*, ORNL-6782, January 1995.[4,5]

SURFACE RADIATION MEASUREMENTS

Gamma radiation levels were determined using a portable NaI gamma scintillation meter. Because NaI gamma scintillators are energy dependent, measurements of gamma radiation levels in counts per minute (cpm) are normalized to pressurized ionization chamber (PIC) measurements to estimate gamma exposure rates in μR/h. Using a Geiger-Mueller pancake detector, beta-gamma radiation levels were measured in counts per minute (cpm) over selected soil surfaces to detect areas of elevated activity. The measurements were then converted to dose rates (mrad/h) and/or disintegrations per minute over 100 cm^2 (dpm/100 cm^2) for comparison with guideline values.

SAMPLING AND ANALYSES

Systematic surface (0– to 15–cm) soil samples were collected outdoors in all remediated areas at selected locations without regard to radiation levels (e.g., at grid points). Systematic samples were also collected at locations surrounding anomalies to define the boundaries of detectable contamination, and repeatedly at locations where remediation was incomplete. Where appropriate, subsurface soil samples were taken at these locations at increments of 15 cm below the surface to determine the completeness of cleanup. Biased soil samples were taken at locations of anomalous gamma or beta-gamma radiation levels.

A portable gamma spectrometer was used on-site in conjunction with beta-gamma measurements as a screening device to provide an immediate estimate of uranium content (pCi/g) in the field using the freshly collected soil samples. The reliability of the field screening method was established at another site by comparison of the field-estimated uranium concentration in a specific sample to the results found from later laboratory analysis of that same sample. When the comparisons proved to be dependable, the field screening method was relied upon to provide the basis for an immediate decision on further action. Cleanup could then be instituted immediately and followed promptly by the verification survey. The approach was conservative in that the maximum uranium concentration resulting from multiple field analyses performed on a single sample was selected for comparison with the site-specific ^{238}U guideline. The process of drying, weighing, grinding, and homogenizing samples according to the required QA procedures was performed in the laboratory at a later time as confirmation of radionuclide concentrations.

SURVEY RESULTS

Current DOE guidelines for FUSRAP sites are summarized in Table 1; the derived site-specific guideline for ^{238}U is also listed.[6] Typical background radiation levels for the Oxford, Ohio, area are presented in Table 2. These data are provided for comparison with the survey results presented in this report. Gamma radiation levels are reported in gross μR/h. Background concentrations have not been subtracted from radionuclide concentrations in soil, debris, or other materials.

RADIATION MEASUREMENTS

Verification activities began on December 6, 1994, when BNI notified ORNL that two of the grid blocks were ready for confirmation. The verification survey continued through February of 1995. Following remediation, gamma exposure rate measurements over the entire property ranged from 4 to 6 μR/h, values well below guidelines and less than the typical range of exposure rates for the Oxford area (Table 1).

SAMPLE RESULTS

Locations of soil sample collection are shown on Figs. 4 through 8. Figures 4 and 5 show the locations of all the systematic soil samples. Samples VS41 through VS43 (Fig. 5) were collected from surface soil over a storm drain leading from the former Alba Craft building to a common city pipeline north of the curb at S. Main Street. The path of the pipeline ran beneath a garage attached to the residential property just northeast of and adjoining the Alba Craft property.

Sampling of several remediated areas led ORNL to request that BNI repeat the excavation. In the process of re-excavating these areas, previously sampled uncontaminated soil was removed along with contaminated soil. These locations were necessarily sampled a second time. The initial samples were collected at the original soil surface and the later samples were taken from newly exposed surface soil. This occurred at locations 0N,0E, 20N,16E, 45N,20E, and 20N,20E for

samples VS44 and VS81, VS7 and VS191, VS63 and VS184, VS203 and VS229. For instance, sample VS44 was collected prior to excavation; VS81 was collected later from the new surface soil at the bottom of the trench that BNI dug to excavate the drainline from the NE corner of the Alba Craft site. Sample VS7 was the original surface soil sample; VS191 was collected later to verify the additional remediation. Figures 6 and 7 are enlargements of the north and south portions of Fig. 4. Figure 8 displays the locations of biased samples. Table 3 details the results of soil analysis.

Concentrations of ^{226}Ra in all samples were within the range of typical background values with a maximum concentration of 1.2 pCi/g (Tables 1 and 3). Concentrations of ^{232}Th were generally within the range of typical background values with the exception of 8 samples. Those samples exceeded that highest background concentration (0.99 pCi/g, Table 1) with a maximum of 2.2 pCi/g. However, concentrations of ^{226}Ra and ^{232}Th are well within the guideline values in all samples.

The results of laboratory analysis of systematic soil samples taken from all excavated areas demonstrate final concentrations of ^{238}U ranging from 0.83 to 53 pCi/g (Table 3). Seventeen systematic samples contained concentrations of ^{238}U exceeding the derived guideline of 17.5 pCi/g (Table 2). Elevated concentrations of ^{238}U ranging from 22 to 73 pCi/g were found in 4 of 6 biased samples. However, averaging the results of the elevated samples along with the results of others collected within each immediate 100–m^2 area results in an average value that meets the guideline in every case.

SIGNIFICANCE OF FINDINGS

The results of the independent verification survey of the former Alba Craft Laboratory property demonstrate that all contaminated areas have been remediated to radionuclide concentrations and activity levels below the applicable guidelines for unrestricted use set by DOE.

REFERENCES

1. M. E. Murray, K. S. Brown, and R. A. Mathis, *Results of the Radiological Survey at the Former Alba Craft Laboratory Site Properties, Oxford, Ohio (OXO001)*, ORNL/RASA-92/14, Martin Marietta Energy Systems, Oak Ridge Natl. Lab., March 1993.

2. R. P. Whitfield, Deputy Assistant Secretary for Environmental Restoration, U.S. DOE, memorandum to J. J. Fiore, Director, Office of Eastern Area Programs, Office of Environmental Restoration, U.S. DOE, May 6, 1992.

3. *Verification and Certification Protocol--Supplement No. 2 to the FUSRAP Summary Protocol*, Rev. 1, U.S. DOE, Office of Nuclear Energy, Division of Facility and Site Decommissioning Projects, November 1985.

4. *Procedures Manual for the ORNL Radiological Survey Activities (RASA) Program*, ORNL/TM-8600, Martin Marietta Energy Systems, Inc., Oak Ridge Natl. Lab., April 1987.

5. *Measurement Applications and Development Group Guidelines*, ORNL-6782, Martin Marietta Energy Systems, Oak Ridge, Natl. Lab., January 1995.

6. W. A. Williams, Designation and Certification Manager, Division of Off-Site Programs, Office of Eastern Area Programs, Office of Environmental Restoration, U.S. Department of Energy, memorandum, "Uranium Guidelines for the Alba Craft Site, Oxford, Ohio, to L. K. Price, Director, Former Sites Restoration Division, Oak Ridge Field Office, U.S. Department of Energy,

ORNL-DWG 92-9817

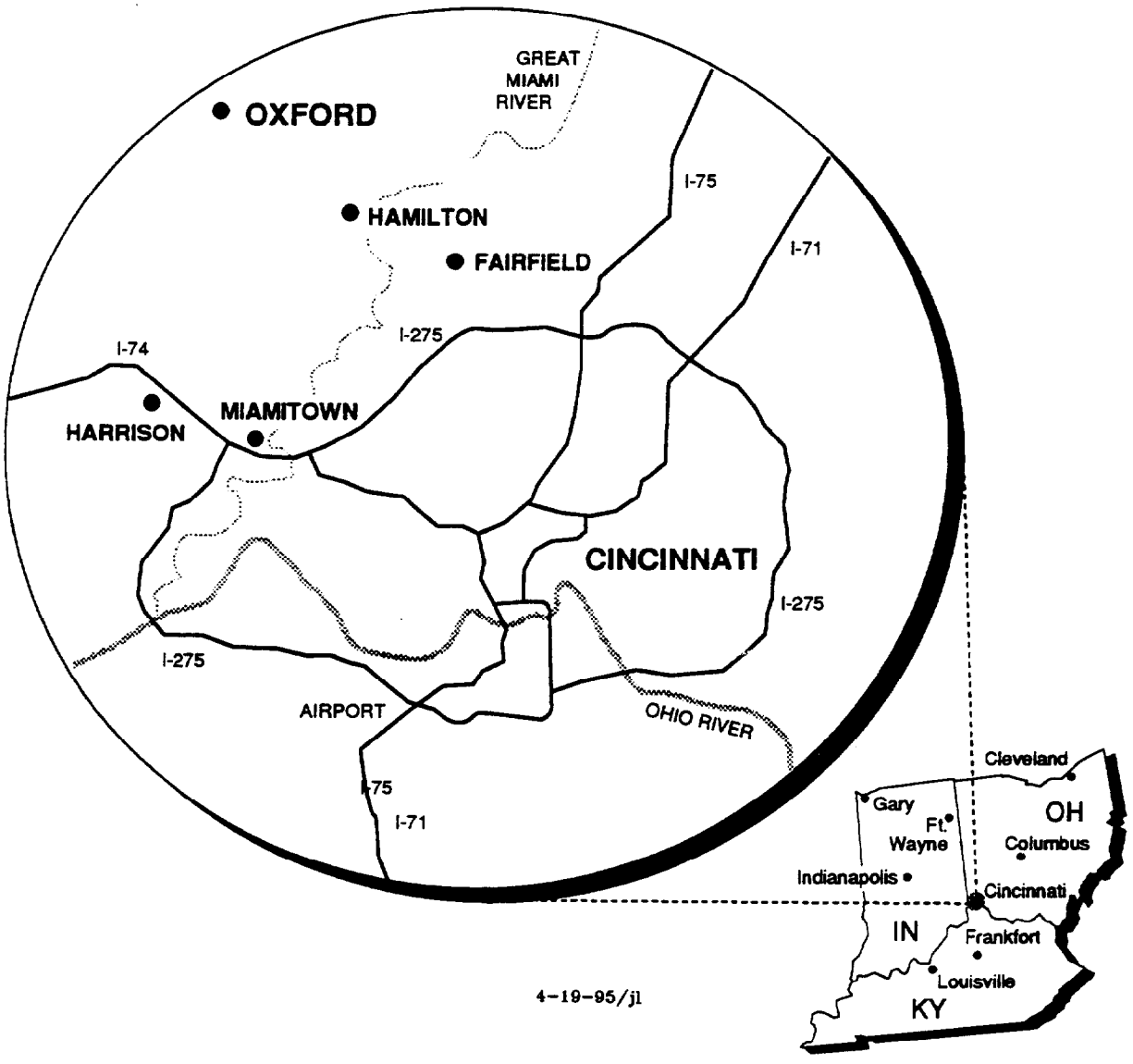

Fig. 1. Diagram showing the general location of Oxford, Ohio.

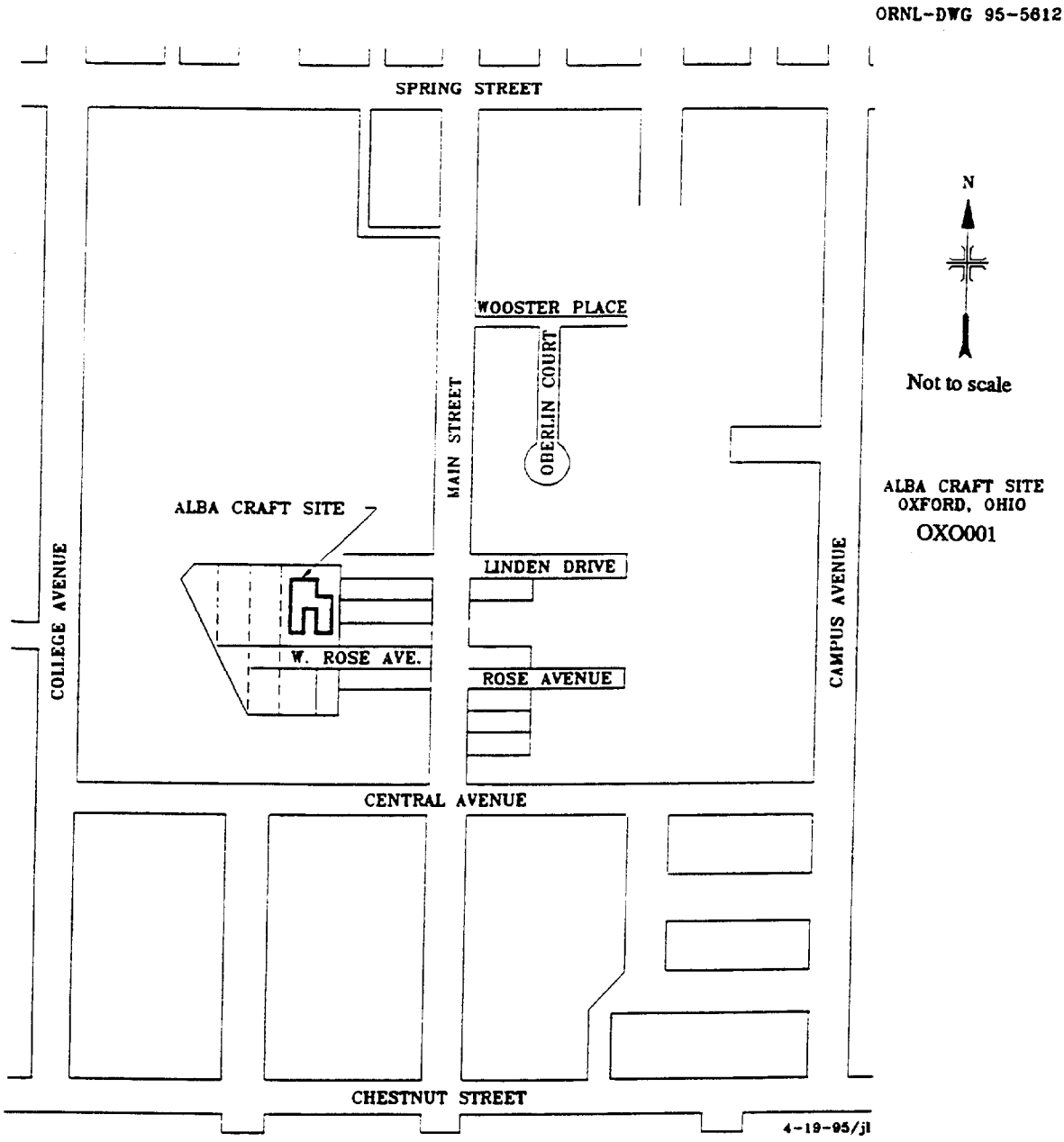

Fig. 2. Diagram showing the general location of the Alba Craft site, Oxford, Ohio.

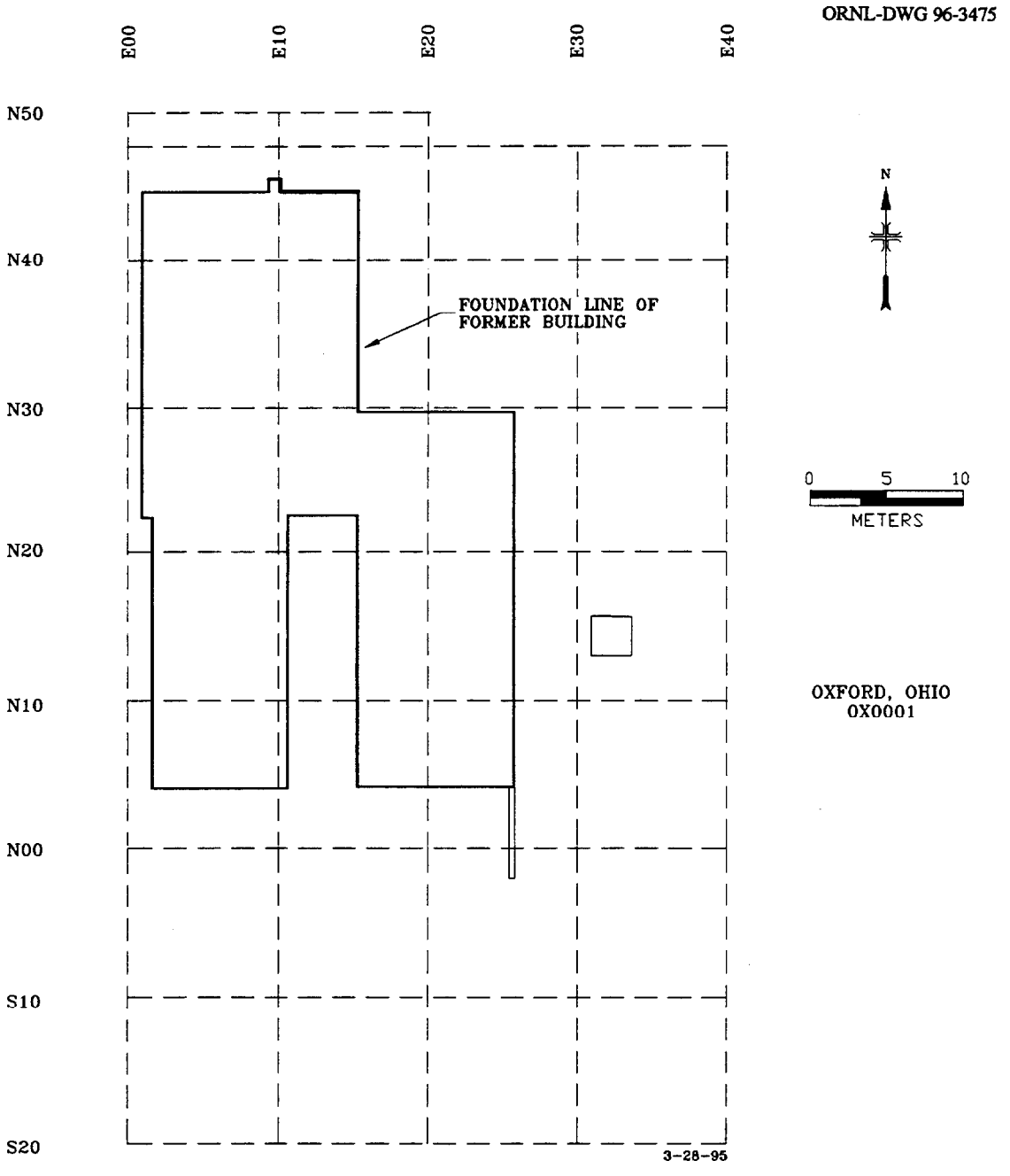

Fig. 3. Diagram of the ACL site showing the foundation line of the former building and the grid established for referencing data locations.

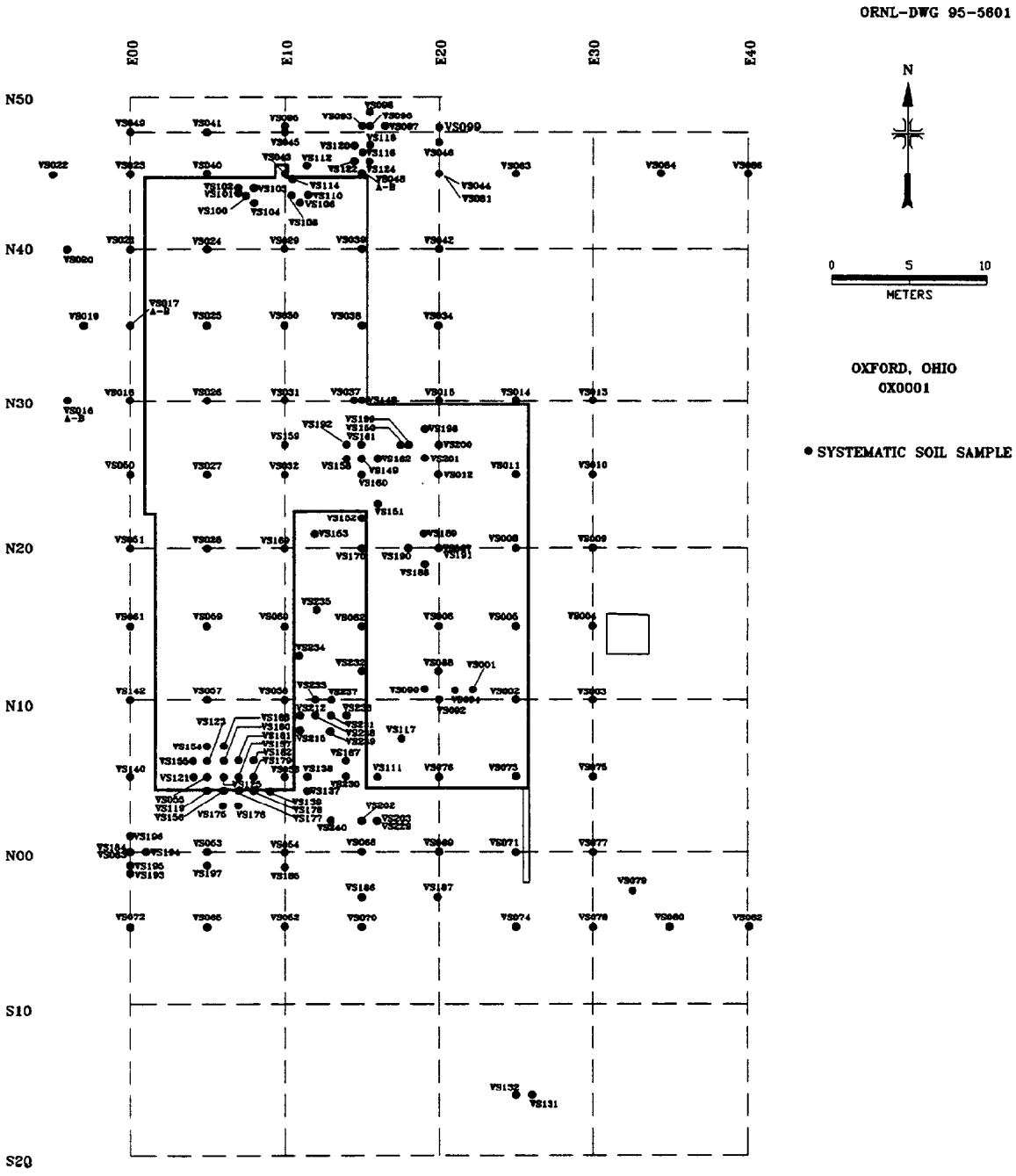

Fig. 4. Diagram showing the locations of most systematic samples collected at the ACL.

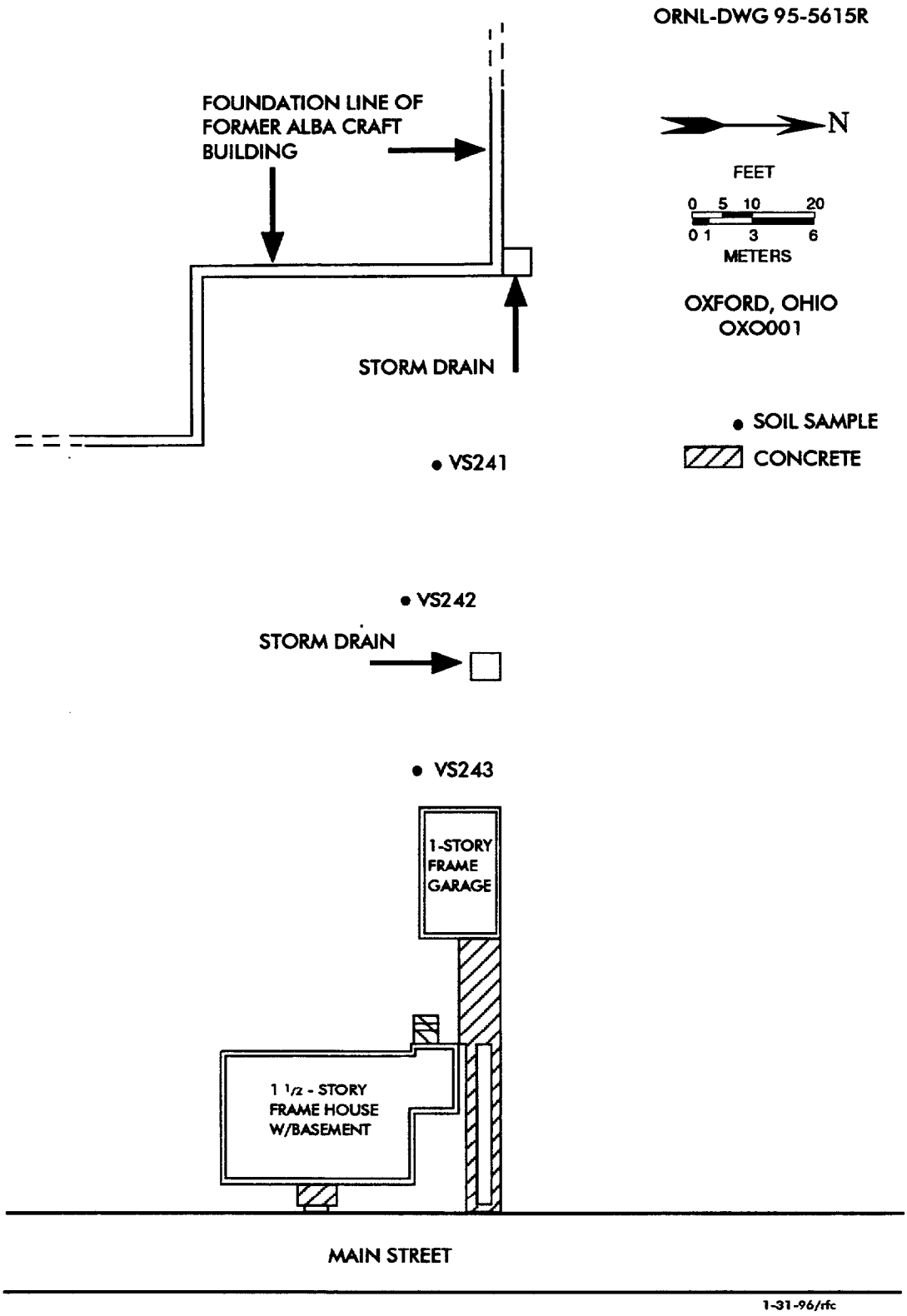

Fig. 5. Diagram showing locations of samples VS241, VS242, and VS243 collected over the sewer line between the corner of the former ACL building and the residential property to the northeast.

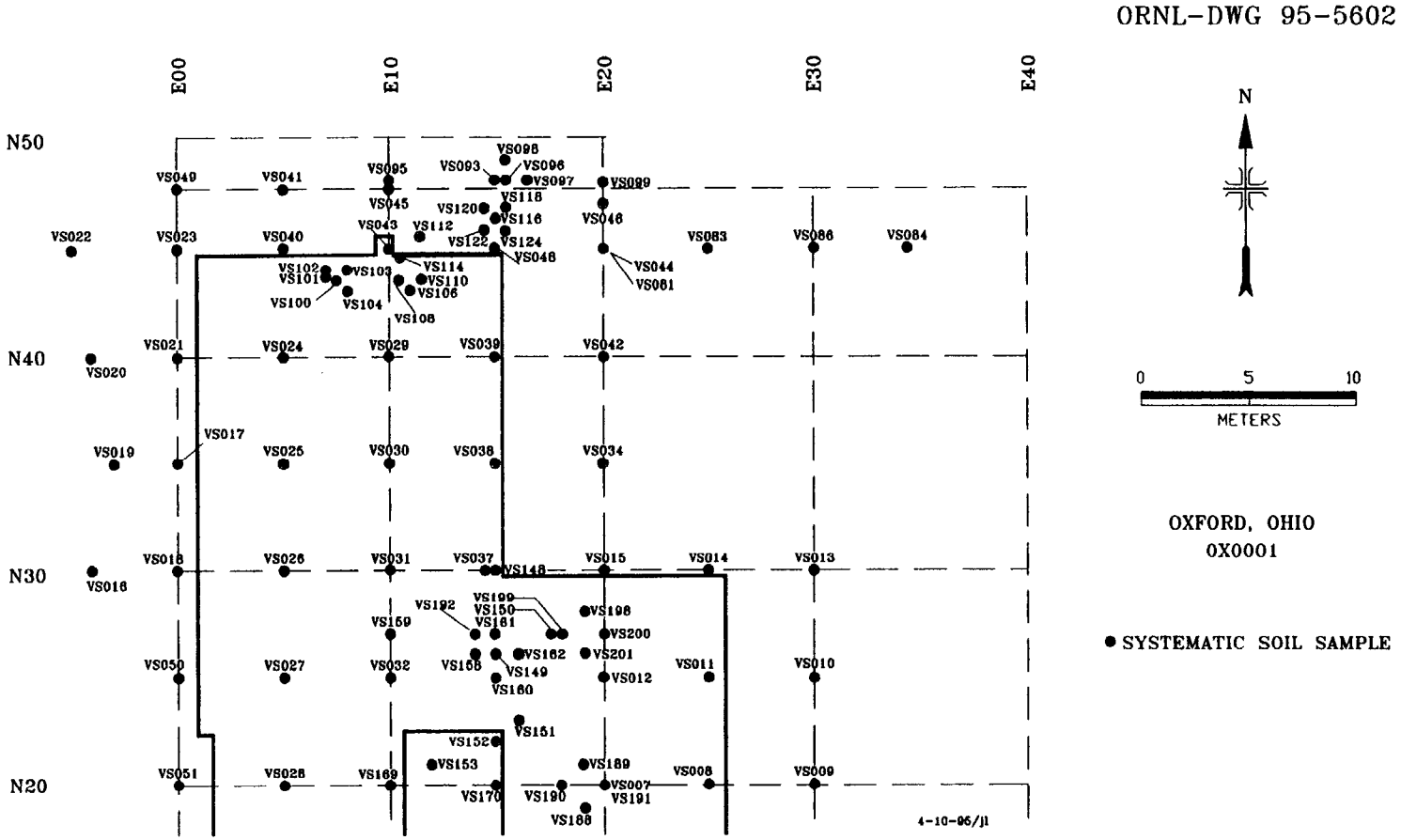

Fig. 6. Enlargement (from Fig. 4) showing locations of systematic samples collected at the north end of the ACL property from N20 to N50.

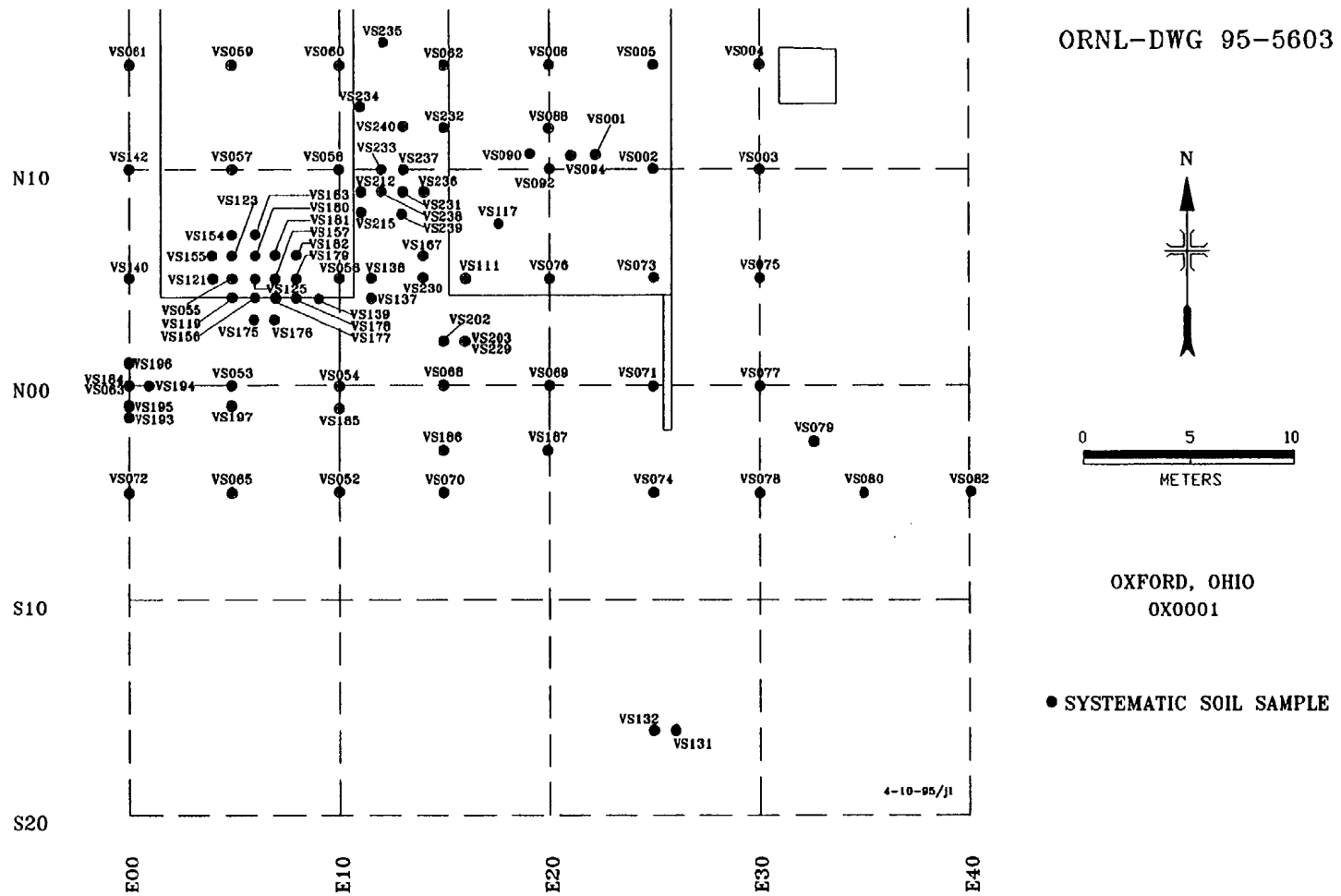

Fig. 7. Enlargement (from Fig. 4) showing locations of systematic samples collected at the south end of the ACL property from S20 to ~N18.

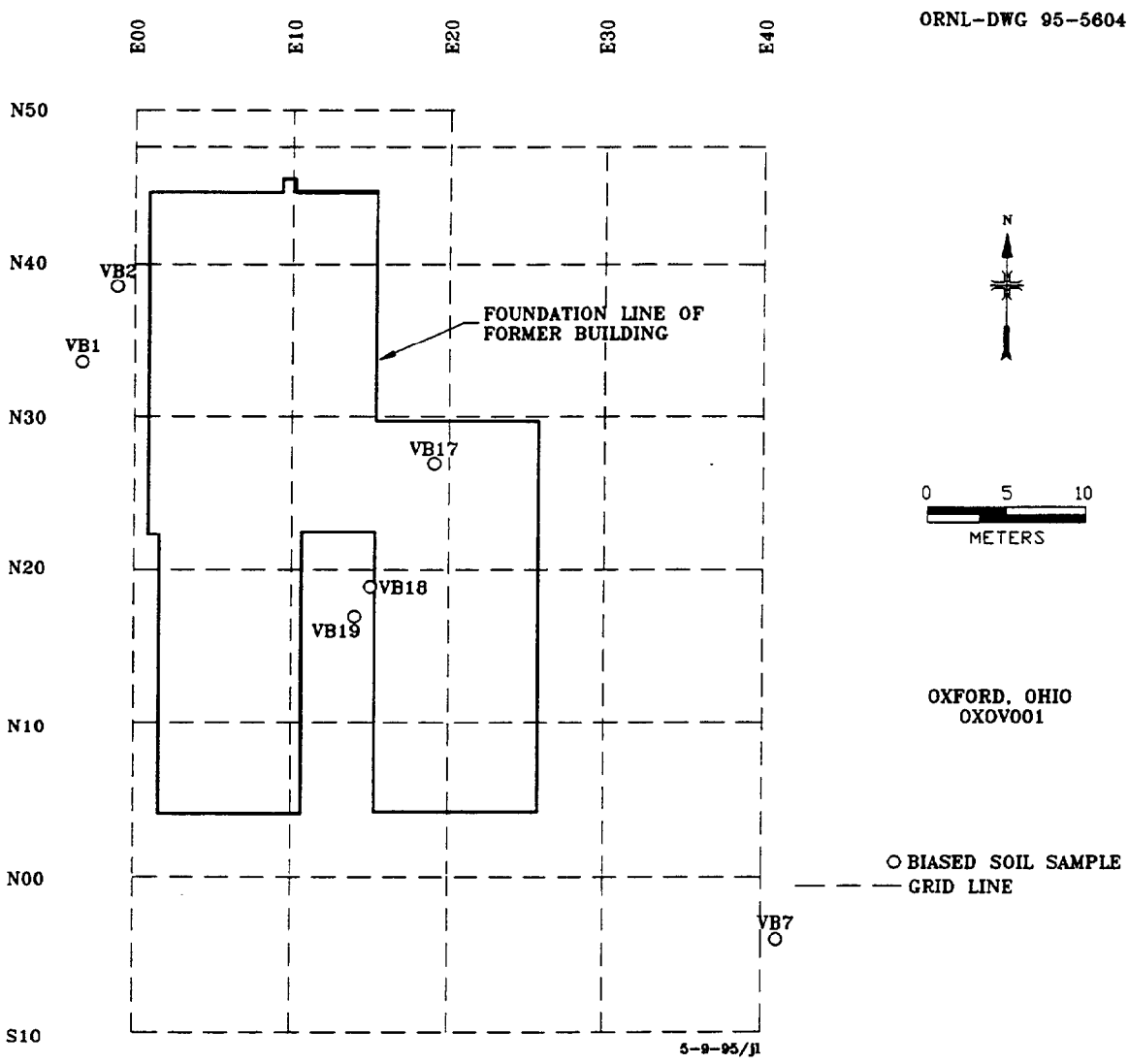

Fig. 8. Diagram showing locations of biased samples collected on the ACL property.

Table 1. Applicable guidelines for protection against radiation
(Limits for uncontrolled areas)

Mode of exposure	Exposure conditions	Guideline value
Gamma radiation	Indoor gamma radiation level (above background)	20 μR/h[a]
Total residual surface contamination[b]	^{238}U,^{235}U, U-natural (alpha emitters)	
	or	
	Beta-gamma emitters[c]	
	Fixed and removable	15,000 dpm/100 cm2
	Average	5,000 dpm/100 cm2
	Removable	1,000 dpm/100 cm^2
	^{232}Th, Th-natural (alpha emitters)	
	or	
	^{90}Sr (beta-gamma emitter)	
	Fixed and removable	3,000 dpm/100 cm^2
	Average	1,000 dpm/100 cm^2
	Removable	200 dpm/100 cm^2
	^{226}Ra, ^{230}Th, transuranics	
	Fixed and removable	300 dpm/100 cm^2
	Average	100 dpm/100 cm^2
	Removable	20 dpm/100 cm^2
Beta-gamma dose rates	Surface dose rate averaged over not more than 1 m^2	0.20 mrad/h
	Maximum dose rate in any 100-cm^2 area	1.0 mrad/h
Radionuclide concentrations in soil (generic)	Maximum permissible concentration of the following radionuclides in soil above background levels, averaged over a 100-m^2 area	5 pCi/g averaged over the first 15 cm of soil below the surface; 15 pCi/g when averaged over 15-cm-thick soil layers more than 15 cm below the surface
	^{226}Ra	
	^{232}Th	
	^{230}Th	
Derived concentrations	^{238}U	17.5 pCi/g[d]

[a]The 20 μR/h shall comply with the basic dose limit (100 mrem/yr) when an appropriate-use scenario is considered.

[b]DOE surface contamination guidelines are consistent with *NRC Guidelines for Decontamination at Facilities and Equipment Prior to Release for Unrestricted Use or Termination of Licenses for By-Product, Source, or Special Nuclear Material,* May 1987.

[c]Beta-gamma emitters (radionuclides with decay modes other than alpha emission or spontaneous fission) except ^{90}Sr, ^{228}Ra, ^{223}Ra, ^{227}Ac, ^{133}I, ^{126}I, ^{125}I.

[d]DOE guidelines for uranium are derived on a site-specific basis. *Source:* W. A. Williams, Designation and Certification Manager, Division of Off-Site Programs, Office of Eastern Area Programs, Office of Environmental Restoration, U.S. Department of Energy, memorandum "Uranium Guidelines for the Alba Craft Site, Oxford, Ohio," to L. K. Price, Director, Former Sites Restoration Division, Oak Ridge Field Office, U.S. Department of Energy, July 15, 1994.

Sources: Adapted from U. S. Department of Energy, *Radiation Protection of the Public and the Environment,* DOE Order 5400.5, April 1990 and U.S. Department of Energy, *Guidelines for Residual Radioactive Material at FUSRAP and Remote SFMP Sites,* Rev. 2, March 1987; and *U. S. Department of Energy Radiological Control Manual,* DOE N5480.6 (DOE/EH-256T), June 1992.

Table 2. Background radiation levels and concentrations of selected radionuclides in soil samples taken near Oxford, Ohio

Type of radiation measurement or sample	Radiation level or radionuclide concentration	
	Range	Average
Gamma exposure rate at 1 m above ground surface (μR/h)[a]	6 – 9	8
Concentration of radionuclides in soil (pCi/g dry wt)[b]		
^{238}U	0.86 – 2.2	1.3
^{226}Ra	1.0 – 2.5	1.9
^{232}Th	0.71 – 0.99	0.89

[a]Results of measurements taken at three locations near Oxford, Ohio.

[b]Results of analysis of soil samples obtained from three locations near Oxford, Ohio.

Source: T. E. Myrick, B. A. Berven, and F. F. Haywood, *State Background Measurements Taken During 1975-1979*, ORNL/TM–7343, November, 1981.

Table 3. Results of radionuclide analysis of soil samples collected from the former Alba Craft Laboratory property, Oxford, Ohio

Sample I.D.	Grid location[b]	Depth (cm)	Radionuclide concentration(pCi/g)[a]			
			^{238}U[c]		^{226}Ra	^{232}Th
			Field	Lab		
			Systematic samples[d]			
VS1	10.75N, 22.2E	0-15	37	3.7 ± 0.85	0.87 ± 0.07	0.60 ± 0.09
VS2	10N, 25E	0-15	*e*	2.2 ± 0.27	0.78 ± 0.07	0.59 ± 0.09
VS3	10N, 30E	0-15	0.7	1.2 ± 0.32	1.1 ± 0.08	0.85 ± 0.11
VS4	15N, 30E	0-15	4.7	3.7 ± 0.38	1.2 ± 0.08	0.92 ± 0.14
VS5	15N, 25E	0-15	*e*	2.0 ± 0.29	0.93 ± 0.07	0.63 ± 0.10
VS6	15N, 20E	0-15	0.7	2.6 ± 0.78	1.1 ± 0.08	0.97 ± 0.12
VS7	20N, 20E	0-15	10	1.7 ± 0.34	0.61 ± 0.05	0.38 ± 0.08
VS8	20N, 25E	0-15	*e*	4.3 ± 0.81	0.83 ± 0.06	0.51 ± 0.09
VS9	20N, 30E	0-15	*e*	1.7 ± 0.80	1.2 ± 0.09	1.1 ± 0.14
VS10	25N, 30E	0-15	12	16 ± 1.1	1.2 ± 0.08	0.99 ± 0.14
VS11	25N, 25E	0-15	1.8	2.9 ± 0.56	0.77 ± 0.06	0.52 ± 0.10
VS12	25N, 20E	0-15	*e*	2.1 ± 0.30	0.54 ± 0.05	0.31 ± 0.06
VS13	30N, 30E	0-15	1.2	2.2 ± 0.32	1.2 ± 0.09	1.0 ± 0.12
VS14	30N, 25E	0-15	0.8	3.3 ± 0.32	0.94 ± 0.07	0.70 ± 0.11
VS15	30N, 20E	0-15	1.6	2.7 ± 0.33	0.96 ± 0.07	0.70 ± 0.10
VS16A	30N, 4.3W	0-15	5.5	2.5 ± 0.57	1.4 ± 0.09	0.86 ± 0.13
VS16B	30N, 4.3W	15-30	4.7	1.4 ± 0.40	1.5 ± 0.08	1.0 ± 0.13
VS17A	35N, 0E	0-15	6.2	4.0 ± 1.5	1.3 ± 0.08	0.92 ± 0.14
VS17B	35N, 0E	15-30	7.3	4.3 ± 0.50	1.3 ± 0.09	1.0 ± 0.13
VS18	30N, 0E	0-15	*e*	2.4 ± 0.37	0.94 ± 0.19	0.50 ± 0.14
VS19	35N, 3W	0-15	*e*	1.2 ± 0.25	0.65 ± 0.15	0.40 ± 0.15
VS20	40N, 4W	0-15	*e*	1.6 ± 0.30	0.95 ± 0.18	0.70 ± 0.20
VS21	40N, 0E	0-15	13	18 ± 0.95	1.0 ± 0.20	0.70 ± 0.20
VS22	45N, 5W	0-15	*e*	2.3 ± 0.35	0.90 ± 0.15	0.70 ± 0.20
VS23	45N, 0E	0-15	1.7	1.9 ± 0.32	1.0 ± 0.21	0.58 ± 0.07
VS24	40N, 5E	0-15	4.4	2.1 ± 0.50	0.80 ± 0.25	0.59 ± 0.10
VS25	35N, 5E	0-15	2.9	1.8 ± 0.42	0.78 ± 0.24	0.79 ± 0.25
VS26	30N, 5E	0-15	5.3	2.5 ± 0.36	1.0 ± 0.20	0.88 ± 0.20
VS27	25N, 5E	0-15	7.4	4.4 ± 0.48	1.1 ± 0.20	0.79 ± 0.18

Table 3. (continued)

Sample I.D.	Grid location[b]	Depth (cm)	Radionuclide concentration(pCi/g)[a]			
			^{238}U[c]		^{226}Ra	^{232}Th
			Field	Lab		
VS28	20N, 5E	0-15	*e*	2.0 ±0.30	0.68 ±0.15	0.26 ±0.09
VS29	40N, 10E	0-15	4.1	2.1 ±0.34	1.1 ±0.21	0.96 ±0.21
VS30	35N, 10E	0-15	5	1.8 ±0.32	1.1 ±0.21	0.64 ±0.17
VS31	30N, 10E	0-15	5.4	2.0 ±0.33	1.2 ±0.21	0.82 ±0.19
VS32	25N, 10E	0-15	3.1	1.9 ±0.31	1.2 ±0.21	0.80 ±0.18
VS34	35N, 20E	0-15	4.5	1.8 ±0.30	1.1 ±0.19	0.47 ±0.13
VS37	30N, 14.5E	0-15	6.1	4.2 ±0.67	0.98±0.27	0.86 ±0.28
VS38	35N, 15E	0-15	9	6.7 ±0.77	0.99±0.20	0.83 ±0.16
VS39	40N,15E	0-15	4.6	4.1 ±0.42	0.67±0.14	0.57 ±0.15
VS40	45N, 5E	0-15	11	11 ±0.70	1.0 ±0.14	0.77 ±0.11
VS41	47.7N, 5E	0-15	15	13 ±1.0	0.96±0.19	1.1 ±0.18
VS42	40N, 20E	0-15	4.6	1.9 ±0.44	0.93±0.26	0.89 ±0.29
VS43	45N, 10E	0-15	11	7.9 ±0.88	1.2 ±0.29	0.61 ±0.23
VS44	45N, 20E	0-15	15	19 ±1.4	0.87±0.20	0.72 ±0.17
VS45	47.7N, 10E	0-15	2.4	1.9 ±0.34	0.57±0.15	0.25 ±0.09
VS46	47N, 20E	0-15	5.8	4.3 ±0.55	0.91±0.21	0.50 ±0.17
VS48A	45N, 15E	0-15	2.1	5.4 ±0.60	0.90±0.15	0.56 ±0.11
VS48B	45N, 15E	15-30	10	12 ±0.82	1.1 ±0.21	0.51 ±0.16
VS49	47.7N, 0E	0-15	3.6	3.4 ±0.49	1.0 ±0.17	0.77 ±0.13
VS50	25N, 0E	0-15	5.4	1.4 ±0.30	0.98±0.16	0.77 ±0.12
VS51	20N, 0E	0-15	2.8	2.4 ±0.37	0.88±0.19	0.37 ±0.12
VS52	5S, 10E	0-15	*e*	0.95±0.21	0.50±0.09	0.36 ±0.07
VS53	0N, 5E	0-15	*e*	4.2 ±0.50	0.61±0.16	0.29 ±0.12
VS54	0N, 10E	0-15	4.4	6.9 ±0.68	1.1 ±0.17	0.87 ±0.14
VS55	5N, 5E	0-15	26	21 ±1.1	0.75±0.17	0.58 ±0.16
VS56	5N, 10E	0-15	8.6	6.0 ±0.62	1.0 ±0.21	0.59 ±0.18
VS57	10N, 5E	0-15	3	7.4 ±0.73	1.0 ±0.17	0.87 ±0.14
VS58	10N, 10E	0-15	8	11 ±1.4	0.92±0.14	0.92 ±0.13
VS59	15N, 5E	0-15	*e*	1.3 ±0.29	0.76±0.13	0.45 ±0.10
VS60	15N, 10E	0-15	*e*	1.6 ±0.29	0.65±0.16	0.34 ±0.13
VS61	15N, 0E	0-15	*e*	3.8 ±0.61	0.93±0.25	0.65 ±0.24
VS62	15N, 15E	0-15	8.1	7.1 ±0.77	0.70±0.16	0.78 ±0.16

Table 3. (continued)

Sample I.D.	Grid location[b]	Depth (cm)	Radionuclide concentration(pCi/g)[a]			
			^{238}U[c]		^{226}Ra	^{232}Th
			Field	Lab		
VS63	0N, 0E	0-15	*e*	1.9 ± 0.34	0.72 ± 0.13	0.23 ± 0.05
VS65	5S, 5E	0-15	*e*	1.1 ± 0.22	0.55 ± 0.10	0.24 ± 0.06
VS68	0N,15E	0-15	15	11 ± 0.86	0.82 ± 0.21	0.33 ± 0.12
VS69	0N, 20E	0-15	4	1.9 ± 0.32	0.90 ± 0.19	0.61 ± 0.16
VS70	5S, 15E	0-15	*e*	1.2 ± 0.26	0.34 ± 0.12	0.28 ± 0.12
VS71	0N, 25E	0-15	*e*	2.9 ± 0.79	0.80 ± 0.13	0.40 ± 0.08
VS72	5S, 0E	0-15	*e*	1.4 ± 0.32	0.41 ± 0.10	0.42 ± 0.10
VS73	5N, 25E	0-15	*e*	2.3 ± 0.35	0.79 ± 0.14	0.51 ± 0.10
VS74	5S, 25E	0-15	*e*	2.7 ± 0.32	0.47 ± 0.11	0.15 ± 0.07
VS75	5N, 30E	0-15	4.4	3.2 ± 0.61	1.2 ± 0.31	0.29 ± 0.17
VS76	5N, 20E	0-15	9.5	16 ± 1.7	0.94 ± 0.14	0.57 ± 0.10
VS77	0N, 30E	0-15	4.7	3.7 ± 0.43	1.1 ± 0.20	0.47 ± 0.13
VS78	5S, 30E	0-15	10	7.1 ± 0.71	0.93 ± 0.22	0.77 ± 0.21
VS79	2.5S, 32.5E	0-15	4.2	5.3 ± 0.65	0.83 ± 0.22	0.49 ± 0.19
VS80	5S, 35E	0-15	6.1	2.3 ± 0.51	0.99 ± 0.19	0.48 ± 0.09
VS81	45N, 20E	0-15	6	6.2 ± 0.55	0.99 ± 0.14	0.75 ± 0.12
VS82	5S, 40E	0-15	2.3	2.2 ± 0.31	0.86 ± 0.16	0.45 ± 0.12
VS83	45N, 25E	0-15	3.8	1.9 ± 0.31	1.0 ± 0.15	0.72 ± 0.12
VS84	45N, 34.5E	0-15	1.1	3.4 ± 0.40	0.93 ± 0.17	0.25 ± 0.08
VS86	45N, 30E	0-15	4.5	3.0 ± 0.37	1.2 ± 0.20	0.49 ± 0.13
VS88	12N, 20E	0-15	0.1	5.6 ± 0.50	0.59 ± 0.10	0.26 ± 0.07
VS90	10.75N , 19E	0-15	*e*	2.6 ± 0.31	0.54 ± 0.12	0.20 ± 0.08
VS92	10N, 20E	0-15	0.5	2.8 ± 0.33	0.64 ± 0.13	0.18 ± 0.08
VS93	48N, 15E	0-15	*e*	2.4 ± 0.34	0.91 ± 0.18	0.52 ± 0.14
VS94	10.75N, 21E	0-15	1.6	2.2 ± 0.34	0.39 ± 0.12	0.19 ± 0.09
VS95	48N, 10E	0-15	2.9	2.5 ± 0.37	0.91 ± 0.14	0.69 ± 0.11
VS96	48N, 15.5E	0-15	3.5	18 ± 0.89	0.83 ± 0.17	0.52 ± 0.14
VS97	48N, 16.5E	0-15	0.8	2.0 ± 0.36	0.86 ± 0.15	0.59 ± 0.11
VS98	49N, 15.5E	0-15	0.9	2.3 ± 0.39	0.95 ± 0.21	0.35 ± 0.13
VS99	48N, 20E	0-15	4.3	3.6 ± 0.51	1.0 ± 0.17	0.79 ± 0.13
VS100	43.5N, 7.5E	0-15	4.4	2.9 ± 0.36	1.1 ± 0.19	0.65 ± 0.16
VS101	43N, 7E	0-15	12	8.1 ± 0.63	1.0 ± 0.19	0.68 ± 0.16

Table 3. (continued)

Sample I.D.	Grid location[b]	Depth (cm)	Radionuclide concentration(pCi/g)[a]			
			^{238}U[c]		^{226}Ra	^{232}Th
			Field	Lab		
VS102	44N, 7E	0-15	17	16 ± 1.1	1.1 ± 0.20	0.98 ± 0.16
VS103	44N, 8E	0-15	45	27 ± 1.2	0.93 ± 0.16	0.47 ± 0.07
VS104	43N, 8E	0-15	6.8	7.0 ± 0.62	1.1 ± 0.16	0.46 ± 0.08
VS106	44N, 11E	0-15	21	24 ± 1.1	1.1 ± 0.19	0.79 ± 0.18
VS108	43.5N, 10.5E	0-15	17	16 ± 0.84	0.87 ± 0.17	0.45 ± 0.12
VS110	43.5N, 11.5E	0-15	20	22 ± 1.0	1.1 ± 0.19	0.43 ± 0.13
VS111	5N, 16E	0-15	4.2	5.9 ± 0.58	0.81 ± 0.13	0.71 ± 0.12
VS112	44.5N, 11.5E	0-15	18	9.5 ± 0.71	0.81 ± 0.13	0.51 ± 0.10
VS114	44.5N, 10.5E	0-15	7.7	7.3 ± 0.62	1.2 ± 0.16	0.58 ± 0.10
VS116	46.3N, 15E	0-15	7	6.8 ± 0.60	1.2 ± 0.16	0.80 ± 0.12
VS117	7.5N, 17.5E	0-15	2	5.4 ± 0.99	0.85 ± 0.13	0.55 ± 0.09
VS118	46.8N, 15.5E	0-15	2	2.3 ± 0.32	0.86 ± 0.16	0.39 ± 0.11
VS119	4N, 5E	0-15	10	9.7 ± 0.62	0.74 ± 0.15	0.33 ± 0.10
VS120	46.8N, 14.5E	0-15	*e*	1.4 ± 0.24	0.76 ± 0.15	0.19 ± 0.07
VS121	5N, 4E	0-15	*e*	4.5 ± 1.0	0.88 ± 0.16	0.50 ± 0.11
VS122	45.8N, 14.5E	0-15	37	45 ± 10	1.2 ± 0.17	0.45 ± 0.08
VS123	6N, 5E	0-15	36	24 ± 1.1	0.77 ± 0.12	0.34 ± 0.06
VS124	45.8N, 15.5E	0-15	14	13 ± 1.0	1.1 ± 0.20	0.92 ± 0.16
VS125	5N, 6E	0-15	45	34 ± 1.3	0.90 ± 0.18	0.56 ± 0.13
VS131	16S, 26E	0-15	9.3	12 ± 0.79	1.1 ± 0.20	0.41 ± 0.11
VS132	16S, 25E	0-15	6	10 ± 0.76	1.1 ± 0.16	0.68 ± 0.12
VS137	4N, 11.5E	0-15	1.3	6.2 ± 0.54	0.78 ± 0.12	0.27 ± 0.05
VS138	5N, 11.8E	0-15	7.5	14 ± 0.84	0.63 ± 0.17	0.19 ± 0.11
VS139	4N, 9.8E	0-15	5.3	11 ± 0.78	0.91 ± 0.14	0.60 ± 0.10
VS140	5N, 0E	0-15	*e*	2.1 ± 0.46	0.86 ± 0.18	0.60 ± 0.12
VS142	10N, 0E	0-15	*e*	1.9 ± 0.38	0.82 ± 0.15	0.53 ± 0.10
VS148	30N, 15E	0-15	8.5	6.3 ± 0.71	0.52 ± 0.17	0.34 ± 0.16
VS149	26N, 15E	0-15	21	22 ± 1.3	0.82 ± 0.22	0.37 ± 0.18
VS150	27N, 17.5E	0-15	13	13 ± 0.92	0.85 ± 0.17	0.69 ± 0.13
VS151	23N, 16E	0-15	2.3	2.7 ± 0.22	0.70 ± 0.10	0.56 ± 0.09
VS152	22N, 15E	0-15	8.7	6.8 ± 0.83	0.92 ± 0.27	0.29 ± 0.06
VS153	21N, 12E	0-15	*e*	1.3 ± 0.34	0.79 ± 0.19	0.31 ± 0.15

Table 3. (continued)

Sample I.D.	Grid location[b]	Depth (cm)	Radionuclide concentration(pCi/g)[a]			
			^{238}U[c]		^{226}Ra	^{232}Th
			Field	Lab		
VS154	7N, 5E	0-15	1.5	2.5 ±0.45	0.68 ± 0.20	0.41 ± 0.17
VS155	6N, 4E	0-15	*e*	7.9 ±0.62	0.65 ± 0.13	0.56 ± 0.11
VS156	4N, 6E	0-15	62	42 ± 1.7	0.89 ± 0.22	0.20 ± 0.12
V157A	5N, 7E	0-15	49	35 ± 2.3	0.92 ± 0.25	0.71 ± 0.19
V157B	5N, 7E	15-30	31	15 ± 2.0	1.2 ± 0.24	2.2 ± 0.24
VS158	26N, 14E	0-15	12	5.9 ±0.50	0.82 ± 0.16	0.31 ± 0.12
VS159	27N, 10E	0-15	2.2	1.4 ±0.37	0.80 ± 0.22	0.62 ± 0.20
VS160	25N, 15E	0-15	14	5.6 ±0.53	0.74 ± 0.17	0.34 ± 0.14
VS161	27N, 15E	0-15	6.4	4.9 ±0.50	0.83 ± 0.17	0.52 ± 0.15
VS162	26N, 16E	0-15	4	2.1 ±0.43	0.94 ± 0.17	0.95 ± 0.14
VS167	6N, 14E	0-15	3.4	3.7 ±0.42	0.80 ± 0.17	0.39 ± 0.13
VS169	20N, 10E	0-15	9	4.0 ±0.47	0.78 ± 0.14	0.32 ± 0.06
VS170	20N, 15E	0-15	4.3	2.1 ±0.39	0.90 ± 0.16	0.78 ± 0.12
VS175	3N, 6E	0-15	5.4	8.2 ±0.60	0.78 ± 0.13	0.59 ± 0.10
VS176	3N, 7E	0-15	9.2	11 ±0.95	0.73 ± 0.18	0.73 ± 0.17
VS177	4N, 7E	0-15	35	53 ±2.1	0.81 ± 0.18	0.63 ± 0.16
VS178	4N, 8E	0-15	19	17 ±0.92	0.78 ± 0.15	0.55 ± 0.10
VS179	5N, 8E	0-15	26	21 ±1.5	0.84 ± 0.25	0.42 ± 0.18
VS180	6N, 6E	0-15	*e*	1.0 ±0.23	0.83 ± 0.16	0.28 ± 0.10
VS181	6N, 7E	0-15	*e*	0.83 ± 0.29	0.47 ± 0.16	0.22 ± 0.13
VS182	6N, 8E	0-15	3.8	3.0 ±0.37	0.55 ± 0.14	0.29 ± 0.12
VS183	7N, 6E	0-15	6.3	4.8 ±0.50	0.97 ± 0.19	0.43 ± 0.14
VS184	0N, 0E	0-15	18	13 ±1.1	0.79 ± 0.19	1.1 ±0.18
VS185	1S, 10E	0-15	4.1	3.2 ±0.43	0.82 ± 0.14	0.68 ± 0.12
VS186	3S, 15	0-15	7.1	5.9 ±0.52	0.84 ± 0.16	0.56 ± 0.14
VS187	3S, 20E	0-15	4.9	2.5 ±0.46	0.92 ± 0.17	1.2 ±0.16
VS188	19N, 19E	0-15	7.1	5.7 ±0.68	0.86 ± 0.23	0.41 ± 0.17
VS189	21N, 19E	0-15	9.2	6.3 ±0.71	0.62 ± 0.16	0.53 ± 0.13
VS190	20N, 18E	0-15	5.6	3.8 ±0.55	0.51 ± 0.17	0.17 ± 0.04
VS191	20N, 20E	0-15	6.2	4.7 ±0.64	0.67 ± 0.15	0.63 ± 0.13
VS192	27N, 14E	0-15	7.3	3.8 ±0.44	0.72 ± 0.16	0.59 ± 0.16
VS193	1.5S, 0E	0-15	3.8	1.4 ±0.38	0.97 ± 0.17	0.90 ± 0.14

Table 3. (continued)

Sample I.D.	Grid location[b]	Depth (cm)	Radionuclide concentration(pCi/g)[a]			
			^{238}U[c]		^{226}Ra	^{232}Th
			Field	Lab		
VS194	0N, 1E	0-15	13	9.9 ± 0.93	0.70 ± 0.23	0.30 ± 0.16
VS195	0N, 1W	0-15	*e*	1.0 ± 0.30	0.93 ± 0.16	0.88 ± 0.12
VS196	1N, 0E	0-15	3.2	1.9 ± 0.45	0.81 ± 0.18	0.45 ± 0.12
VS197	1S, 5E	0-15	0.38	1.5 ± 0.39	0.51 ± 0.18	0.20 ± 0.14
VS198	28N, 19E	0-15	9.8	10 ± 1.0	0.83 ± 0.23	0.28 ± 0.06
VS199	27N, 18E	0-15	11	7.5 ± 0.80	0.80 ± 0.18	0.56 ± 0.13
VS200	27N, 20E	0-15	4.5	2.4 ± 0.33	0.70 ± 0.15	0.27 ± 0.10
VS201	26N, 19E	0-15	*e*	2.5 ± 0.45	0.46 ± 0.16	0.14 ± 0.04
VS202	2N, 15E	0-15	2.4	2.4 ± 0.54	0.92 ± 0.18	0.86 ± 0.17
VS203	2N, 16E	0-15	12	19 ± 1.3	0.99 ± 0.25	0.41 ± 0.20
VS212	9N, 11E	0-15	18	11 ± 1.0	0.74 ± 0.19	0.74 ± 0.16
VS215	8N, 11E	0-15	0.98	2.7 ± 0.55	0.61 ± 0.21	0.16 ± 0.14
VS229	2N, 16E	0-15	*e*	1.8 ± 0.32	0.58 ± 0.14	0.15 ± 0.10
VS230	5N, 14E	0-15	*e*	3.0 ± 0.56	0.49 ± 0.19	0.29 ± 0.18
VS231	9N, 13E	0-15	18	20 ± 1.4	1.0 ± 0.23	0.73 ± 0.16
VS232	12N, 15E	0-15	*e*	5.2 ± 0.61	0.85 ± 0.22	0.17 ± 0.13
VS233	10N, 12E	0-15	4.9	4.7 ± 0.75	0.63 ± 0.18	0.27 ± 0.10
VS234	13N, 11E	0-15	3.4	8.3 ± 0.93	0.83 ± 0.21	0.50 ± 0.14
VS235	16N, 12E	0-15	*e*	1.2 ± 0.42	0.62 ± 0.22	0.24 ± 0.06
VS236	9N, 14E	0-15	*e*	2.2 ± 0.51	0.72 ± 0.19	0.22 ± 0.10
VS237	13N, 10E	0-15	15	13 ± 1.2	0.93 ± 0.23	0.76 ± 0.17
VS238	9N, 12E	0-15	*e*	2.5 ± 0.49	0.67 ± 0.21	0.29 ± 0.17
VS239	8N, 13E	0-15	15	16 ± 1.2	0.82 ± 0.20	0.63 ± 0.14
VS240	12N, 13E	0-15	2.2	4.5 ± 0.52	0.58 ± 0.16	0.13 ± 0.03
VS241	3.5S, 18W	0-15	*e*	1.3 ± 0.28	0.81 ± 0.13	0.55 ± 0.09
VS242	5S, 11W	0-15	5.3	1.5 ± 0.48	0.81 ± 0.20	0.89 ± 0.17
VS243	4.5S, 1.5W	0-15	2.1	1.4 ± 0.40	0.81 ± 0.23	0.28 ± 0.15
			Biased samples[f]			
VB1	33.5N, 3.4W	0-15	85	73 ± 5.0	1.2 ± 0.09	0.95 ± 0.13
VB2	38.5N, 1W	0-15	66	39 ± 3.3	1.1 ± 0.08	0.86 ± 0.15
VB7	S4, 41E	0-15	32	22 ± 1.4	1.1 ± 0.07	0.84 ± 0.11

Table 3. (continued)

Sample I.D.	Grid location[b]	Depth (cm)	Radionuclide concentration(pCi/g)[a]			
			^{238}U[c]		^{226}Ra	^{232}Th
			Field	Lab		
VB17	27N, 19E	0-15	33	22 ± 1.7	0.84 ± 0.07	0.54 ± 0.09
VB18	19N, 15E	0-15	15	11 ± 1.5	1.4 ± 0.09	1.0 ± 0.14
VB19	17N, 14E	0-15	13	9.0 ± 1.3	1.3 ± 0.08	0.97 ± 0.12

[a] Indicated counting error is at the 95% confidence level (± 2 σ).

[b] Locations are shown on Figs. 4 and 5.

[c] Field analyses provide a quick estimate of ^{238}U concentrations for cleanup recommendations in the field and do not provide a counting error. Laboratory analyses provide the most accurate results. The samples for field analyses are from the same location as the samples analyzed at ORNL, but are not the same material. Discrepancies may be due to non-homogeneous contamination.

[d] Systematic samples are collected without regard to gamma exposure rates.

[e] Sample concentration was not distinguishable from background.

[f] Biased samples were collected from locations of previous anomalies.

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