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Results of the Radiological Survey at the former Alba Craft Laboratory Site Properties, Oxford, Ohio (OXO001)

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MANAGED BY
MARTIN MARIETTA ENERGY SYSTEMS, INC.
FOR THE UNITED STATES
DEPARTMENT OF ENERGY

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HEALTH AND SAFETY RESEARCH DIVISION

Environmental Restoration and Waste Management Non-Defense Programs
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CONTENTS

LIST OF FIGURES

LIST OF TABLES

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ABSTRACT

At the request of the U.S. Department of Energy (DOE), a team from Oak Ridge National Laboratory conducted a radiological survey at the former Alba Craft Laboratory Site Properties, Oxford, Ohio. The survey was performed in July and September of 1992. The purpose of the survey was to determine whether the property was contaminated with radioactive residues, primarily ^{238}U, from uranium machining operations conducted for National Lead of Ohio, a prime Atomic Energy Commission contractor. The survey included scan measurement of direct radiation levels inside and outside the former laboratory, outdoors on eight properties adjoining the former laboratory, and the city right-of-way adjacent to the surveyed properties. Radionuclide concentrations were determined in outdoor surface and subsurface soil samples taken from each property and the exterior of the laboratory. Fixed surface residual radioactivity was measured inside the laboratory and outside the building. Air samples were collected, direct exposure was measured, and samples were collected to measure transferable radioactivity inside the building.

Results of the survey indicate areas where surface and soil contamination levels are above the DOE guidelines for uncontrolled areas.

Results of the Radiological Survey at the former Alba Craft Laboratory Site Properties, Oxford, Ohio (OXO001)*

INTRODUCTION

Alba Craft Laboratory, Incorporated was a subcontractor to National Lead of Ohio (NLO) from approximately October of 1952 until February of 1957. Alba Craft provided a variety of machine shop services on normal uranium metal for NLO, a primary contractor for the Atomic Energy Commission (AEC). Early work included general machining and developmental machining of threaded slugs at the Savannah River site. Final operations were on a large production scale and consisted of hollow drilling and turning slugs for Savannah River site and Hanford facility reactors. NLO also used the Alba Craft facilities in 1954 and supplied its own operators and material for machining. The total quantity of uranium machined by Alba Craft is estimated at several hundred tons; the quantity machined by NLO during 1954 is unknown.[1]

As a result of these and similar activities at AEC-contracted sites, equipment, buildings, and land at some of the sites became radiologically contaminated resulting in low levels of contamination on the properties. At contract termination, sites used by contractors were decontaminated in accordance with the standards and survey methods in use at that time. Since the original assessments, radiological criteria and guidelines for the release of such sites for unrestricted use have become more stringent. As a result, the Formerly Utilized Sites Remedial Action Program (FUSRAP) was established in 1974 to identify these formerly used sites and to reevaluate their radiological status.[2] The radiological survey detailed in this report was performed under the FUSRAP program.

The current owner bought and renovated the building and began using the building to support various business enterprises, disavowing any knowledge of the previous uranium machining operations. The site has been previously investigated to determine the extent of on-site radiological contamination.[3] As a follow-up to earlier investigations, and as a precaution to ensure that residual radioactive materials exceeding current U.S. Department of Energy (DOE) guidelines did not migrate off-site, DOE requested a radiological survey of the former laboratory and vicinity properties. A preliminary inspection in June of 1992 indicated uranium contamination inside and outside the building.

In July and September of 1992, a radiological survey was conducted at the former Alba Craft Laboratory Site Properties, 10-14 West Rose Avenue, Oxford, Ohio, by personnel from Oak Ridge National Laboratory at the request of DOE. Results of that survey are presented in this report. The general location of the former Alba Craft Laboratory Site Properties, Oxford, Ohio, is shown in Fig. 1.

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*The survey was performed by members of the Measurement Applications and Development Group of the Health and Safety Research Division at Oak Ridge National Laboratory under DOE contract DE-AC05-84OR21400.

BUILDING DESCRIPTION

The building is a composite of two or three once-separate structures joined to appear as one building. All exterior walls are composed of cinder blocks and support the roof. The roof consists of metal trusses supporting a wooden sublayer, and a tar-coated layer to provide waterproofing and protection. All floors are concrete with typical cracks and expansion joints. The building was recently remodeled to allow for expanding business operations.

At the time of the building survey, the building was being used to support three independent businesses. The east wing contained a chemistry laboratory and supporting offices. This area had been remodelled with stud walls, a drop ceiling and carpet. A temperature-controlled wine vault is also located in the east wing. The west wing was being used to produce custom-embroidered products such as shirts and caps. Limited remodeling to add shelves and overhead lighting had been done in this area. The north wing was being leased to a contractor to store packaged foods. Little remodeling had been done in this area, except for cosmetic changes such as painting.

The outside area between the east and west wings is newly concreted and is used to provide access for deliveries. During the time of the survey, five to eight people were employed in the building.

SCOPE OF THE SURVEY

The outdoor survey in the vicinity of the building included:

- A gamma scan at the ground surface over the site.
- Measurement of gamma exposure rates and beta contamination levels on the roof and on the concrete pad on the southern edge of the building.
- Collection and analysis of systematic and biased surface and subsurface soil samples on the site, and a sample of concrete chips remaining from recent demolition.

The indoor survey of the building included the following:

- Measurement of gamma exposure rates with a pressurized ionization chamber (PIC).
- Measurement of beta and gamma radiation levels in all accessible areas of the building.
- Sampling and radionuclide analysis of indoor debris materials.
- Measurement of direct and transferable alpha and beta-gamma radioactivity levels on selected surfaces.
- Radiological analysis of air particulate samples.

Surface scanning of gamma radiation levels was performed over the city right-of-way along West Rose Avenue south of the building, two vicinity properties south of the building, four vicinity properties east of the building, the city right-of-way between the four properties

and South Main Street, one vicinity property west of the building, and one vicinity property north of the building. Systematic and biased samples were also collected from surface and subsurface soil on these properties. Fig. 2 shows sample locations inside the building and over the surrounding properties. The parking lot northeast of the building was not surveyed.

SURVEY METHODS

A description of the typical survey methods and instrumentation providing guidance for the survey is given in *Procedures Manual for the ORNL Radiological Survey Activities (RASA) Program*, ORNL/TM-8600 (April 1987).[4]

Gamma radiation levels were determined using portable NaI gamma scintillation meters; beta/gamma measurements were made with GM "pancake" probes; alpha measurements were made with ZnS "beer mug" detectors, and exposure measurements were made with a PIC. Large-area proportional detectors were used to scan floors to monitor for contamination. Because NaI gamma scintillators are energy dependent, measurements of gamma radiation levels in counts per minute were normalized to PIC measurements to estimate gamma exposure rates in μR/h over areas where PIC measurements were not practical.

OUTDOOR SURVEY METHODS

Surface and subsurface soil samples were systematically collected outside the building and over the properties in a pattern sufficient to obtain a characterization of the radionuclide content of the soil. Figs. 2 and 3 show surveyed areas on the exterior of the building and surrounding properties. Soil samples were collected in 15-cm vertical increments. At some of the systematic locations, the soil was also sampled at 15-cm increments below the surface layers. Surface soil sampling was also performed in all outdoor areas of elevated gamma radiation identified by the walkover scan using NaI detectors. Such samples are referred to as biased samples and are more likely to contain elevated concentrations of radionuclides than are systematically chosen samples. In certain areas, biased samples were also taken from depths of 15-30, 30-45, or 45-60 cm to determine subsurface concentrations. Beta-gamma radiation levels were measured on flat areas of the roof exclusive of tarred areas. No one from the survey team accessed the tarred area of the roof because its structural integrity was uncertain. Beta scanning was performed on the concrete pad at the south end of the building. A sample of concrete chips was collected from debris remaining from recent demolition.

INDOOR SURVEY METHODS

A survey was conducted inside the building on the commercial property. Figs. 4-6 show the surveyed areas inside the building and locations of measurements and samples. All accessible floor areas and approximately half of the interior walls were surveyed. Gamma exposure rates were measured on floors and walls. Alpha radioactivity levels and beta-gamma radiation levels near floors, walls, and overhead trusses and ceiling surfaces were

determined by direct measurement. Removable radioactivity levels were assessed by analysis of smears taken on floors, overhead surfaces, and other flat surfaces likely to have retained uranium dust. The survey included collection of a sample of material from a concrete seam and samples of debris from surfaces of electrical boxes. Air inside the building was sampled for particulate contamination at various locations. Radionuclide analysis was performed on all samples.

SURVEY RESULTS

DOE guidelines are summarized in Table 1. Typical background radiation levels for the Oxford, Ohio, area are presented in Table 2. These data are provided for comparison with survey results presented in this section. All direct measurement results presented in this report are gross readings except where noted; background radiation levels have not been subtracted. Similarly, background concentrations have not been subtracted from radionuclide concentrations measured in soil samples.

Photographs of the site taken in September 1992 are shown in Figs. 7 through 15.

FORMER LABORATORY PROPERTY SURVEY RESULTS

OUTDOOR RADIOLOGICAL RESULTS

Gamma Measurements

Scanning disclosed a range of gamma exposure rates, as shown on Fig. 2. Average levels for the general area exterior to the building were 6 to 10 μR/h. Several small spots were found to have gamma exposure rates significantly above average and were designated biased locations for sampling. These values are slightly above natural background levels in the Oxford area (Table 2) but are typical of exposure rates measured previously in Ohio.

Soil Samples

Systematic samples. Radionuclide analysis was performed on systematic samples collected at locations around the building as indicated on Fig. 2. Samples were taken from various depths. Results of analysis are listed in Table 3. Concentrations of ^{232}Th and ^{226}Ra were lower than DOE guidelines (Table 1) and typical of background concentrations in the area (Table 2). Concentrations of ^{238}U were lower than DOE guidelines used at other sites (Table 1) but slightly elevated compared to background concentrations in the area (Table 2).

Biased samples. Biased soil samples were taken from locations of elevated gamma exposure rates (Fig. 2). Results are detailed in Table 3. Except for ^{238}U, all concentrations of radionuclides were below DOE guidelines (Table 1). Samples B1A-D, B2A-C, B3A-B, B6A-B, B7A-B, B8A, B9A-B, B11A-B, B12A-D, B13A, B20A, B21 and B22 showed ^{238}U

concentrations at or above DOE guidelines used at other sites (Table 1). Samples B3C, B4, B5, B8B, B10, B13B, and B20B-C showed ^{238}U values at or below DOE guidelines used at other sites (Table 1). Sample B22 was taken from a storm drain on property directly east of the storm drain at the northeast corner of the building.

Samples taken at locations B4 and B5 were collected to establish a pattern based on elevated readings at locations B2 and B3. The measured pattern of contamination was different than expected because of excavation to install a water line for a city fire hydrant about 15 feet due west.

Concrete Sample

A sample of concrete chips (M1) was taken from a barrel located on the southeast edge of the concrete pad at the south end of the building (Fig. 2). The chunks of concrete in the barrel were debris remaining after demolition of the original pad. Sections of the original pad were being replaced as the building was renovated. Small chips were removed from material which had been the underside of the concrete pad. Radionuclide analysis (Table 3) revealed a ^{238}U concentration of 300 pCi/g, a value which exceeds DOE guidelines used at other sites (Table 1). This data in conjunction with two 14 μR/h spots found on the concrete pad with no associated beta activity implies contamination exists under the outdoor concrete areas.

Surface Radioactivity

Beta-gamma levels were measured on the concrete pad south of the building. Several spots were found with fixed contamination up to 50,000 dpm/100 cm^2. Beta-gamma values for contaminated spots along the perimeter of the roof typically ranged from 900 to 8,000 dpm/100 cm^2, with isolated spots of higher values (Fig. 3).

INDOOR RADIOLOGICAL RESULTS

Gamma Measurements

Gamma exposure rates from PIC readings measured at one meter from the floor inside the building varied from 5.5 to 7.2 μR/h (see Table 4). Gamma scanning revealed many isolated spots of higher measurements on the floor (Fig. 4). Three spots of 46 μR/h, 140 μR/h and 110 μR/h at the floor surface are located in the area of the building leased for storage. One spot on the floor of 44 μR/h is located in the shirt production area. All four spots are above the DOE indoor guideline (Table 1) at the floor surface, but are below the guideline at one meter.

Fixed Alpha Radioactivity Levels and Beta-Gamma Radiation Levels

Alpha activity levels in the building ranged up to 1100 dpm/100 cm^2 (Fig. 4). Beta-gamma contamination typically ranged from 3,000 to 9,000 dpm/100 cm^2. The maximum beta-gamma contamination was found to be approximately 750,000 dpm/100 cm^2 or 9 mrad/h, and exceeded the guideline of 1.0 mrad/h in any area of 100 cm^2. Beta-gamma

radiation levels on overhead surfaces ranged from 1,200 to 480,000 dpm/100 cm^2, with maximum levels on overhead light fixtures and electrical boxes (Fig. 5).

Smear and Sample Analyses

Analysis of smears taken on surfaces throughout the building indicated removable alpha and beta radioactivity levels below the respective minimum detectable activity (MDA) with the exception of Smears 4, 15, and 20 (Fig. 6). At the location of Smear 4, the removable alpha radioactivity level was 64 dpm/100 cm^2. Smear 15 showed removable alpha radioactivity of 552 dpm/100 cm^2 and removable beta radioactivity of 1030 dpm/100 cm^2. Smear 20 showed an alpha radioactivity level of 20 dpm/100 cm^2. These values are above the MDA but below applicable guidelines, with the exception of the beta radioactivity level for Smear 15.

Miscellaneous Sample Analyses

A sample of material from a concrete seam (M2) and samples of debris from surfaces of electrical boxes (M3-M5) were collected and analyzed for radionuclide content. The location of sample M2 is shown on Fig. 2. Locations of samples M3-M5 correspond to the locations of Smears 4, 5, and 7 on Fig. 6, and radionuclide concentrations for the four samples are listed in Table 3.

Analytical results for the material from the concrete seam (M2) showed ^{238}U concentrations of 100,000 pCi/g. Debris samples M3, M4, and M5 showed concentrations of 14,000, 160, and 400 pCi/g ^{238}U, respectively.

Air Samples

Four air samples designated as Z1-Z4, and ranging in volume from 10.3 m^3 to 12.9 m^3, were collected at the locations shown on Fig. 6. Radiological analysis of the samples revealed concentrations of ^{238}U at or below the MDA.

VICINITY PROPERTY SURVEY RESULTS

GAMMA EXPOSURE RATE MEASUREMENTS

A gamma scan was performed over the city right-of-way along West Rose Avenue south of the building, one vicinity property west of the building, two vicinity properties south of the building, four vicinity properties east of the building, the city right-of-way along South Main Street east of the building, and one vicinity property north of the building. Fig. 2 shows the layout of the vicinity properties and city rights-of-way surrounding the building. General exposure rates ranged from 6 to 10 μR/h. Background gamma radiation levels in the Ohio area generally range from 3 to 11 μR/h (Table 2). Areas above 10 μR/h were designated for biased samples.

SOIL SAMPLES

Systematic Soil Samples

Radionuclide analysis was performed on systematic samples collected at locations over the properties as indicated on Fig. 2. Samples were taken from various depths. Results of analysis are listed in Table 3. Concentrations of ^{238}U, ^{232}Th, and ^{226}Ra were lower than DOE guidelines used at other sites (Table 1).

Biased Soil Samples

Biased soil sample locations on the properties surrounding the building are shown on Fig. 2, and results of analyses are listed in Table 3. Concentrations of ^{226}Ra and ^{232}Th in all samples were below background for the Oxford area and below DOE guidelines (Tables 1 and 2). Uranium-238 concentrations ranged from 0.95 to 3300 pCi/g. All samples showed ^{238}U concentrations above typical background levels for the Oxford area (Table 2). Samples B14A-E, B17A, B18A, and B22 were above DOE guidelines used at other sites (Table 1). Samples B15, B16, B17B-E, B18B-C and B19 showed levels at or below DOE guidelines used at other sites (Table 1). Samples at locations B15 and B16 contained ashes which tend to concentrate the natural radioactivity found in wood and coal.

SIGNIFICANCE OF FINDINGS

The results of the radiological survey at the former Alba Craft Laboratory and some vicinity properties suggest that uranium contamination from former AEC-related activities still exist in and around the building in quantities exceeding current DOE guidelines. Because the exact property boundaries were not known, recommendations for specific individual properties are not made in this report.

The former Alba Craft Laboratory contains quantities of uranium that pose little health hazard if left undisturbed. However, occupants should be advised to consult the appropriate DOE individual prior to conducting any activities in the building which are different from those at the time of the survey.

REFERENCES

1. Memorandum, W. A. Williams, Designation and Certification Manager, Division of Off-Site Programs, Office of Eastern Area Programs, Office of Environmental Restoration, U.S. DOE, to File, February 11, 1992.

2. U. S. Department of Energy, *A Background Report for the Formerly Utilized Manhattan Engineer District/Atomic Energy Commission Sites Program*, DOE/EV-0097, September 1980.

3. R. L. Ruhe and C. E. Schumann, National Lead of Ohio, correspondence to J. A. Quigley, M. D., National Lead of Ohio, March 11, 1957.

4. T. E. Myrick, B. A. Berven, W. D. Cottrell, W. A. Goldsmith, and F. F. Haywood, *Procedures Manual for the ORNL Radiological Survey Activities (RASA) Program*, ORNL/TM-8600, Martin Marietta Energy Systems, Inc., Oak Ridge Natl. Lab., April 1987.

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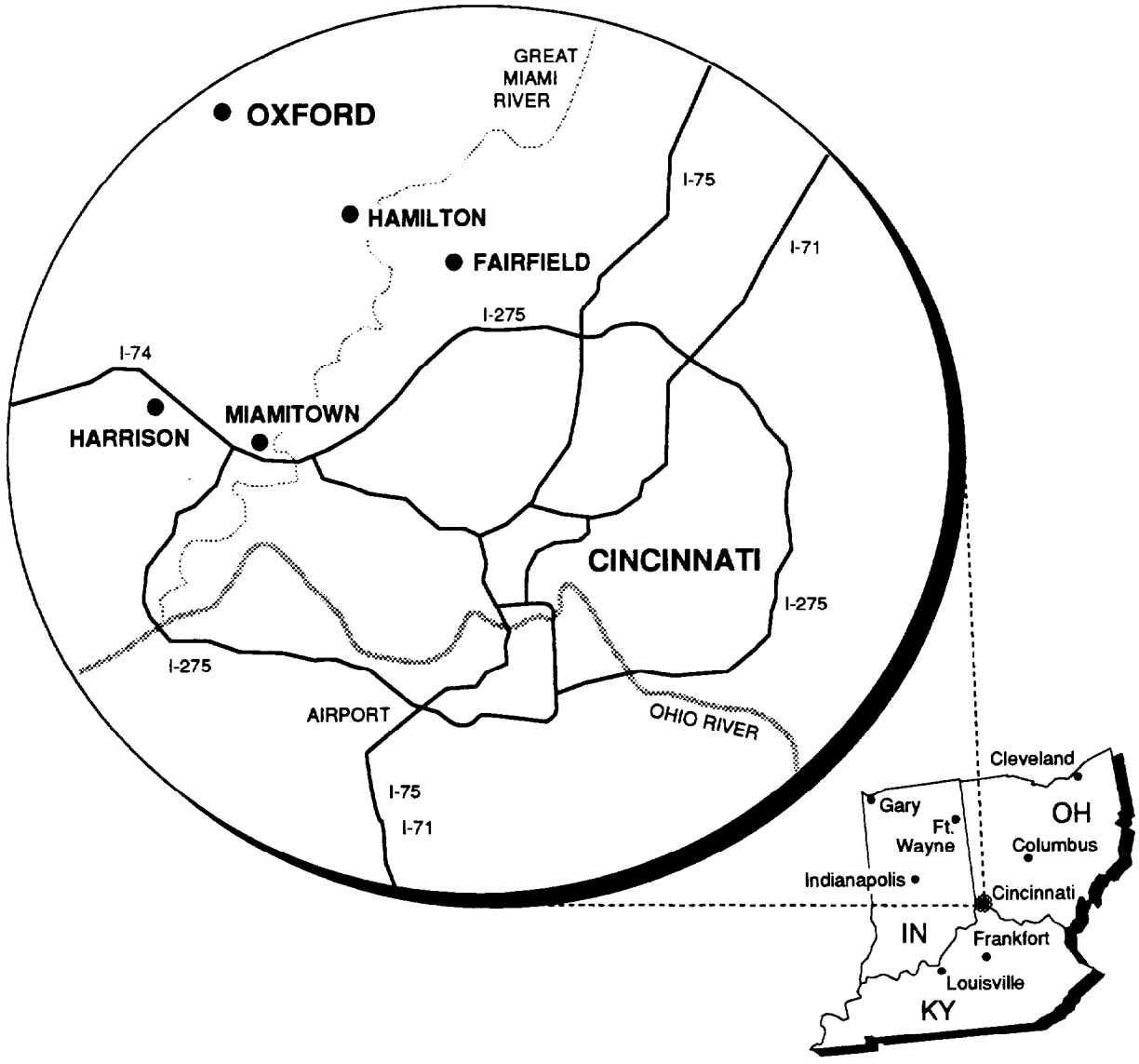

Fig. 1. Diagram showing the general location of the former Alba Craft Laboratory site properties, Oxford, Ohio.

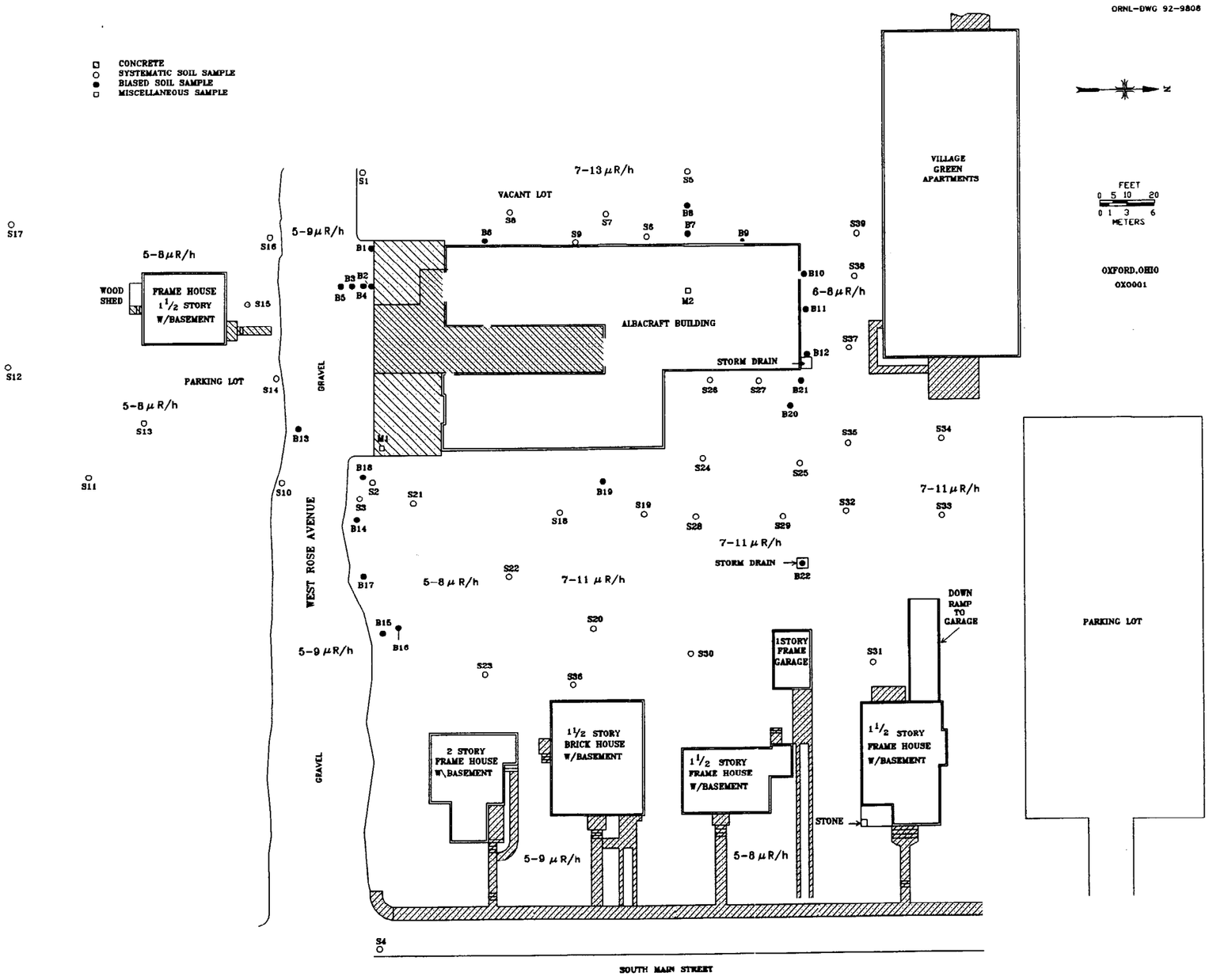

Fig. 2. Diagram of property surrounding the former Alba Craft Laboratory building showing all outdoor and indoor locations of soil samples and miscellaneous samples.

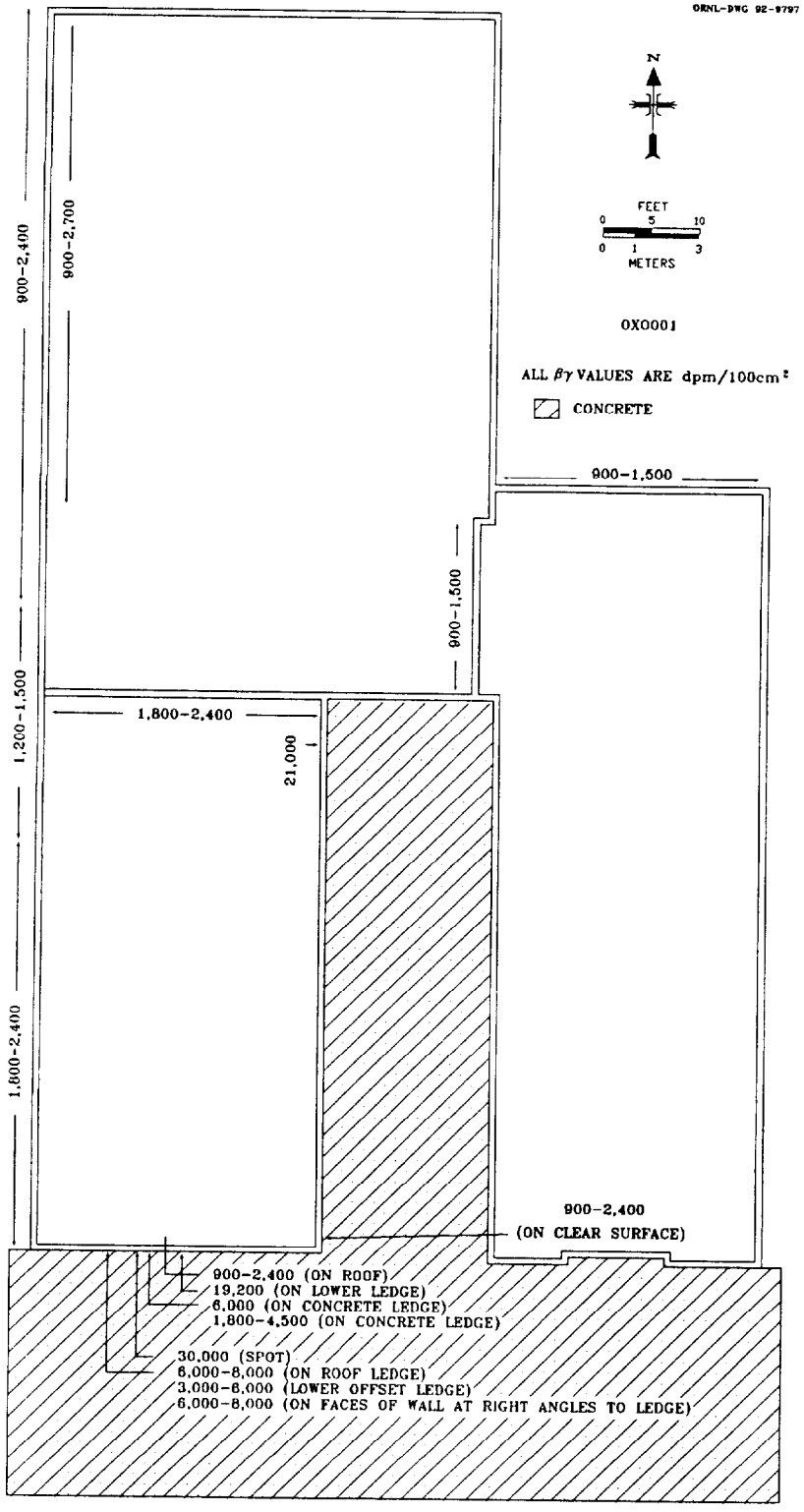

Fig. 3. Radiation levels measured on the roof of the building.

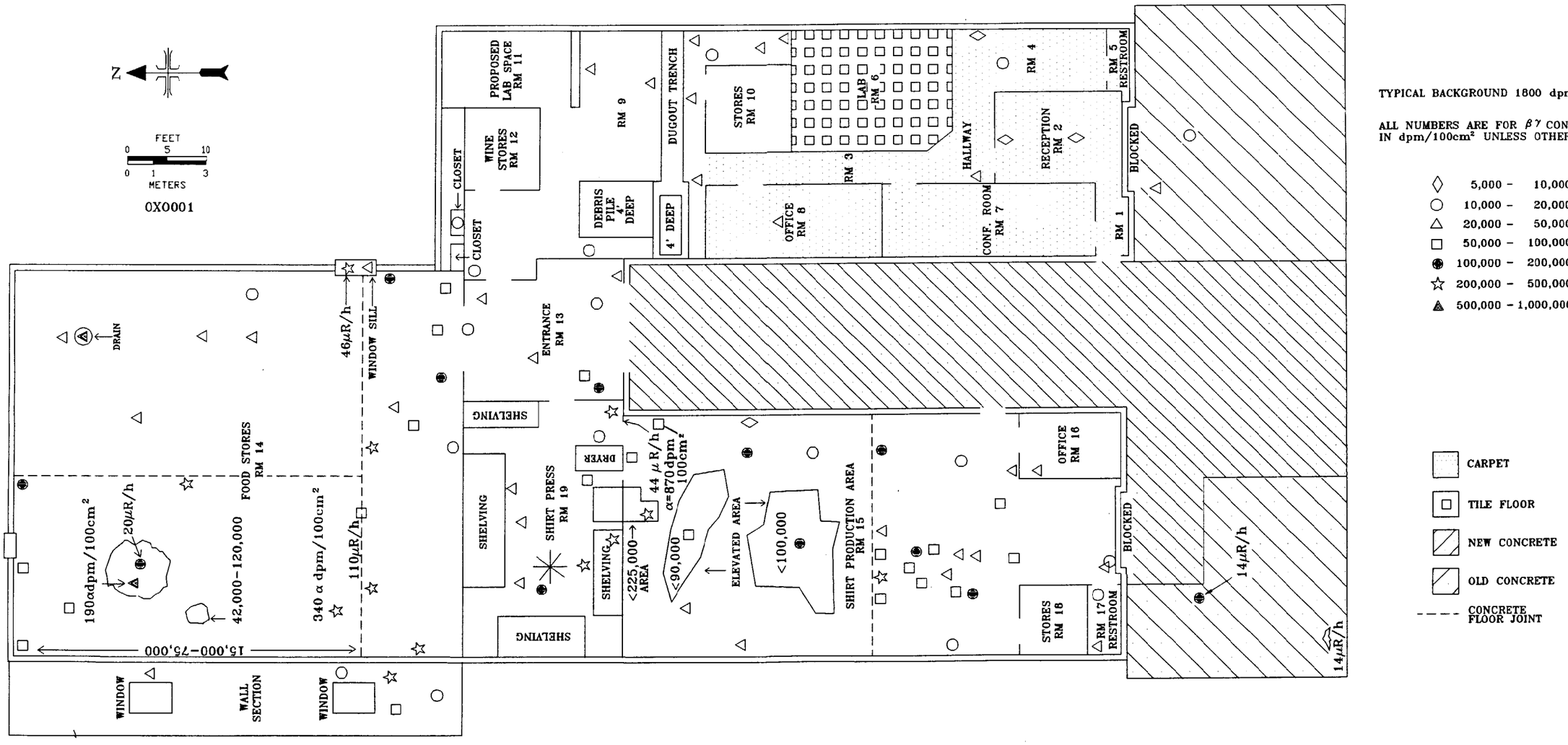

Fig. 4. Radiation levels measured on the floor inside the building.

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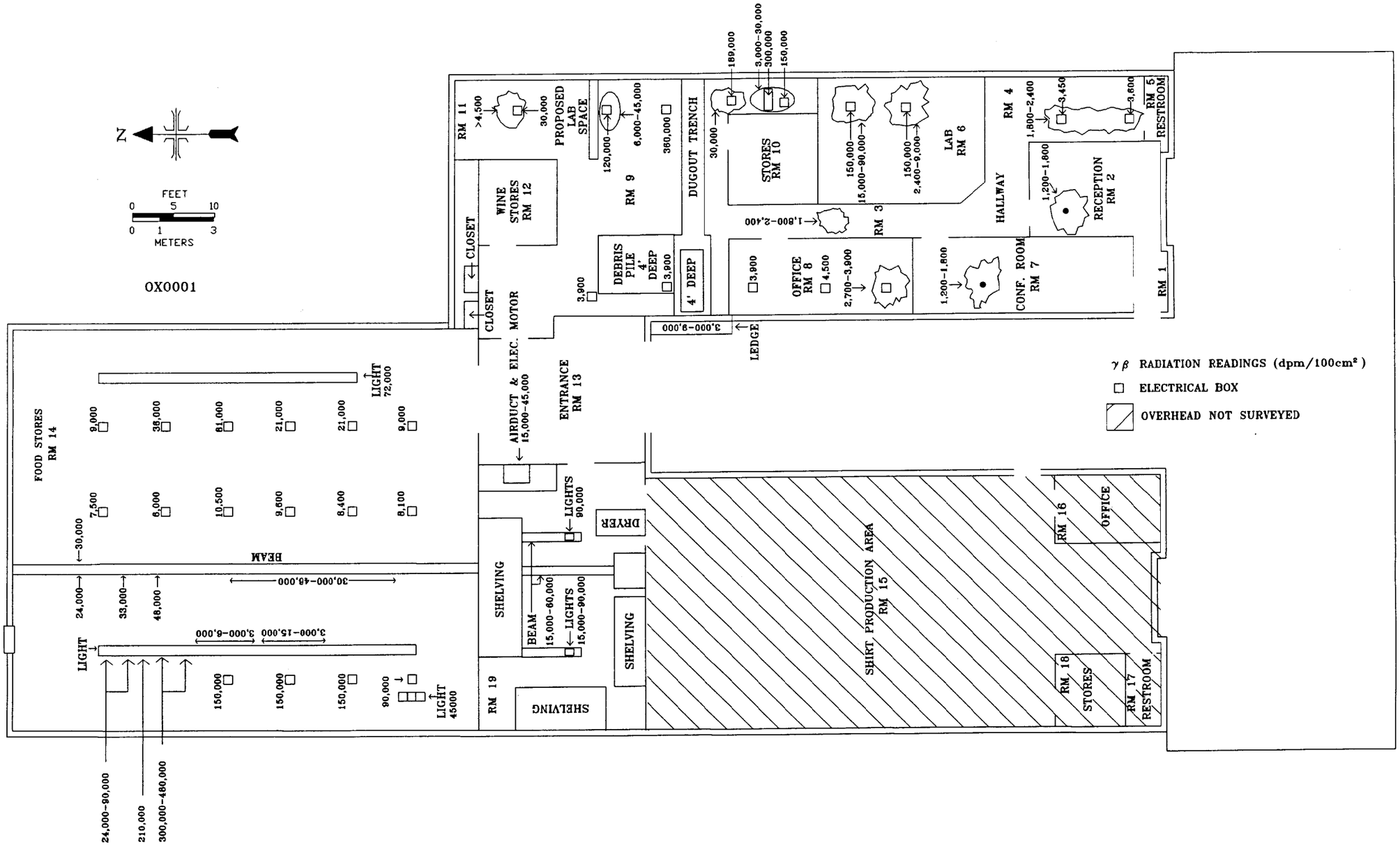

Fig. 5. Radiation levels from direct measurement of overhead surfaces inside the building.

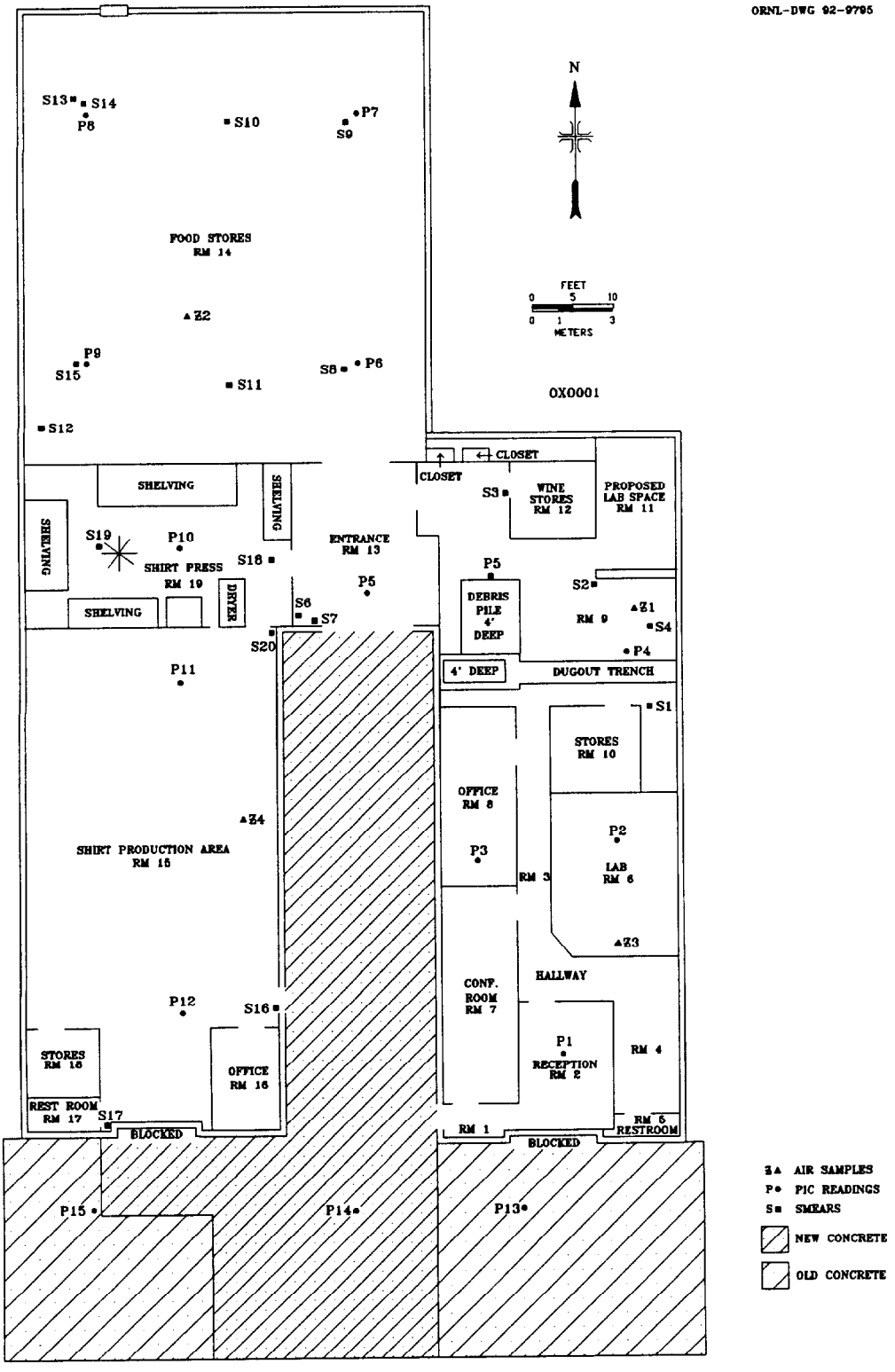

Fig. 6. Locations of air samples (Z), PIC readings (P), and smears (S) inside the former Alba Craft Laboratory.

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Fig. 7. View looking north at the entrance of the building.

ORNL-PHOTO 1408-93

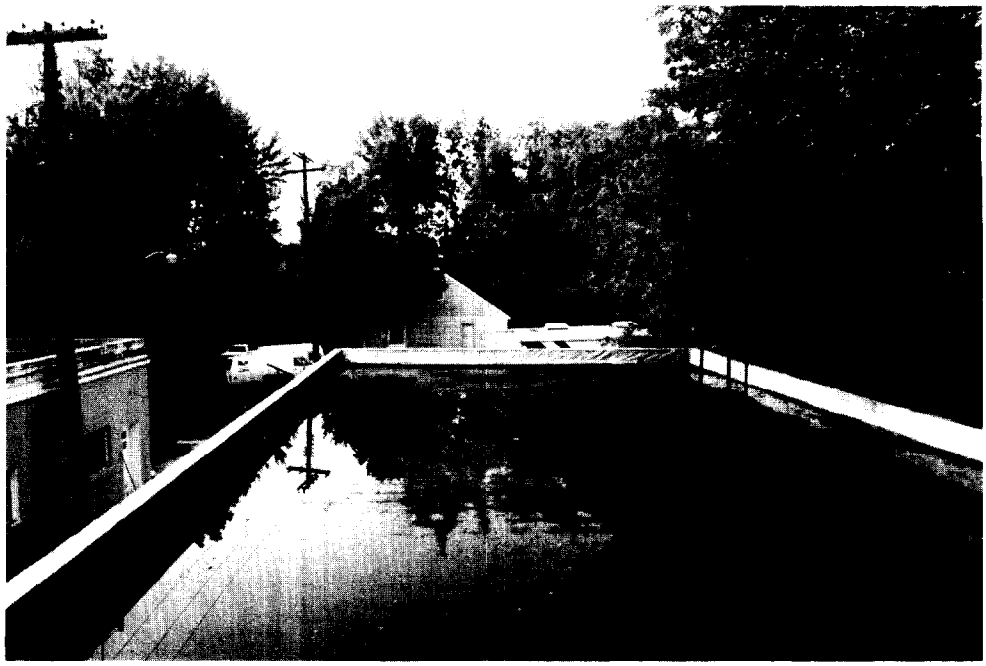

Fig. 8. View looking south at flat roof of building.

ORNL-PHOTO 1409-93

Fig. 9. View looking west at rear of building and edge of apartment building.

ORNL-PHOTO 1410-93

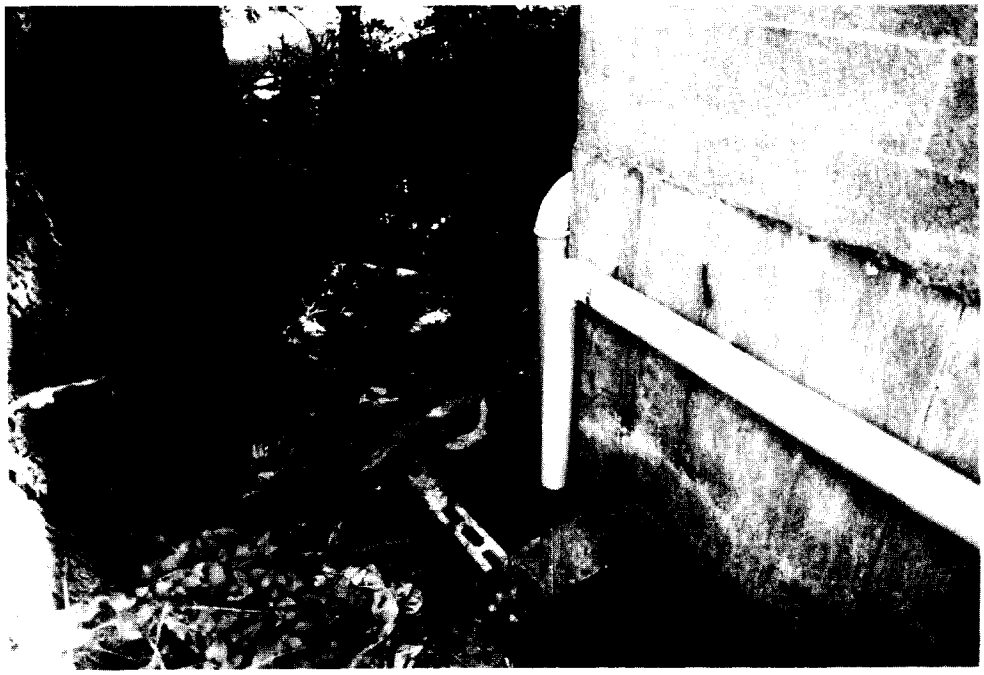

Fig. 10. View of northeast corner of building showing roof drains, drainage pit, and location of sample B21.

ORNL-PHOTO 1411-93

Fig. 11. Sampling of contaminated soil adjacent to concrete pad at south end of building (samples B1-B3).

ORNL-PHOTO 1412-93

Fig. 12. Sampling of contaminated soil on west side of building (sample B7).

ORNL-PHOTO 1413-93

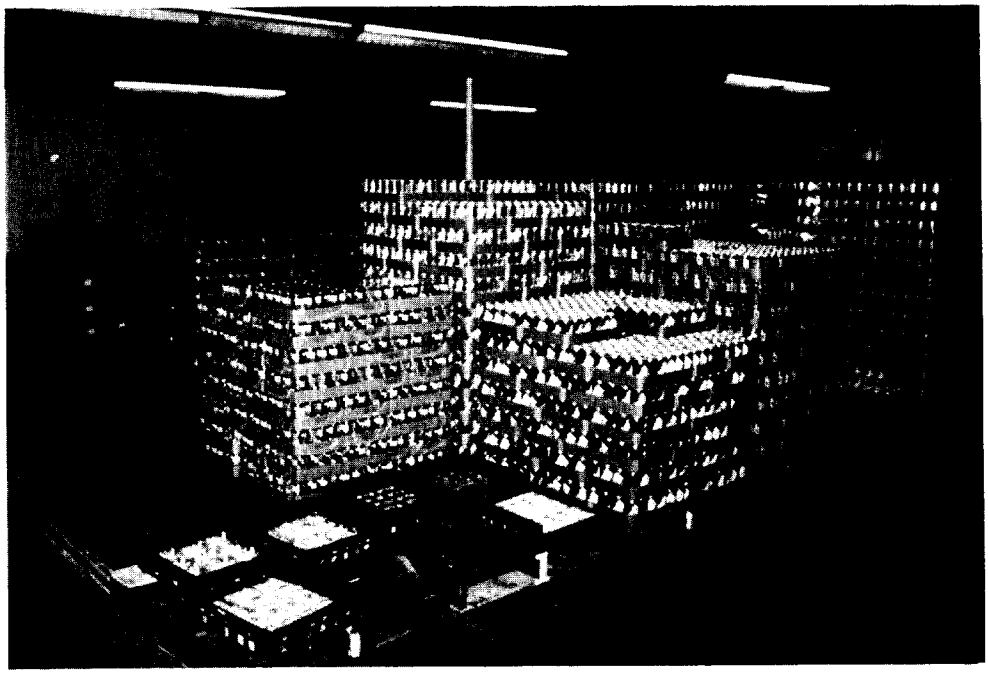

Fig. 13. View looking toward northwest corner of packaged food storeroom.

ORNL-PHOTO 1414-93

Fig. 14. Typical roof trusses showing areas of slight contamination.

ORNL-PHOTO 1415-93

Fig. 15. Typical electrical boxes showing slightly contaminated upper horizontal surfaces.

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]	
	Maximum	15,000 dpm/100 cm^2
	Average	5,000 dpm/100 cm^2
	Removable	1,000 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	Site specific[d]

[a]The 20 μR/h shall comply with the basic dose limit (100 mrem/year) 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, ^{129}I, ^{126}I, ^{125}I.

[d]DOE guidelines for uranium are derived on a site-specific basis. Guidelines of 30 pCi/g have been applied at other FUSRAP sites. *Source:* R. E. Rodriguez et al., *Results of the Radiological Survey at the Town of Tonawanda Landfill, Tonawanda, New York (TNY001)*, ORNL/RASA-92/12, Martin Marietta Energy Systems, Inc., Oak Ridge Natl. Lab., October 1992.

Sources: Adapted from U.S. Department of Energy, DOE Order 5400.5, April 1990, and U.S. Department of Energy, *Guidelines for Residual Radioactive Material at Formerly Utilized Sites Remedial Action Program and Remote Surplus Facilities Management Program Sites*, Rev. 2, March 1987.

Table 2. Background radiation levels for the Oxford, Ohio area

Type of radiation measurement or sample	Radiation level or radionuclide concentration
Average external gamma exposure rate at 1 m above ground surface	4.8 μR/h[a]
Range of external gamma exposure rate at 1 m typical of Ohio	3 to 11 μR/h[a]
Concentration of radionuclides in surface soil	
^{226}Ra	1.0 ± 0.04 pCi/g[b]
^{232}Th	0.98 ± 0.04 pCi/g[b]
^{238}U	0.86 pCi/g[c]

[a]Average of 3 to 4 measurements.
[b]Standard deviation is the 2σ value.
[c]Error in measurement is ±5% (2σ).

Source: T. E. Myrick, B. A. Berven, and F. F. Haywood, *State Background Radiation Levels: Results of Measurements Taken During 1975–1979*, ORNL/TM-7343, Martin Marietta Energy Systems, Inc., Oak Ridge Natl. Lab., November 1981.

Table 3. Concentrations of radionuclides in soil, concrete and debris samples from the former Alba Craft Laboratory Site Properties, Oxford, Ohio

Sample ID[a]	Depth (cm)	Radionuclide concentration (pCi/g)[b]		
		^{226}Ra	^{232}Th	^{238}U
		Systematic samples[c]		
S1A	0–15	1.03±0.1	0.76±0.2	5.1 ±0.4
S1B	15–30	1.3 ±0.1	1.1 ±0.2	4.2 ±0.4
S2A	0–15	0.68±0.08	0.34±0.08	8.9 ±2
S2B	15-30	1.4 ±0.1	1.07±0.2	6.0 ±0.3
S3A	0-15	0.66±0.09	0.39±0.1	6.4 ±0.5
S3B	15-30	0.78±0.02	0.55±0.04	4.6 ±0.8
S4A	0-15	0.45±0.06	0.23±0.08	1.5 ±0.5
S4B	15-30	0.42±0.02	0.22±0.03	1.6 ±0.2
S5	0-15	1.3 ±0.1	1.2 ±0.2	2.3 ±0.5
S6	0-15	1.6 ±0.2	0.98±0.3	3.4 ±0.6
S7	0-15	1.2 ±0.02	1.05±0.04	3.6 ±0.7
S8	0–15	1.3 ±0.03	1.04±0.04	1.4 ±0.3
S9	0–15	2.0 ±0.2	0.97±0.2	5.9 ±0.7
S10A	0–15	0.80±0.09	0.67±0.2	3.1 ±0.3
S10B	15–30	1.1 ±0.2	1.2 ±0.2	4.5 ±0.8
S11A	0–15	0.62±0.05	0.41±0.06	2.6 ±0.3
S11B	15–30	0.71±0.1	0.56±0.2	1.7 ±0.3
S12A	0–15	0.75±0.09	0.43±0.1	1.5 ±0.2
S12B	15–30	0.78±0.1	0.64±0.2	1.3 ±0.5
S13A	0–15	0.62±0.03	0.43±0.05	2.9 ±0.8
S13B	15–30	0.67±0.04	0.56±0.05	3.5 ±0.3
S14A	0–15	0.85±0.02	0.57±0.03	3.8 ±1
S14B	15–30	1.4 ±0.03	1.3 ±0.05	4.9 ±1
S14C	30–45	1.4 ±0.2	1.08±0.2	3.1 ±0.7
S15A	0–15	1.09 ±0.02	0.79±0.04	1.2 ±0.5
S15B	15–30	1.08 ±0.2	1.08±0.2	2.0 ±0.9
S16A	0–15	0.70 ±0.07	0.63±0.1	1.6 ±0.4
S16B	15-30	1.05 ±0.2	0.56±0.2	1.5 ±0.3

Table 3 (continued)

Sample ID[a]	Depth (cm)	Radionuclide concentration (pCi/g)[b]		
		^{226}Ra	^{232}Th	^{238}U
S17A	0–15	1.02±0.03	0.74±0.04	2.5 ±0.6
S17B	15–30	1.2 ±0.2	0.84±0.2	1.8 ±0.3
S18A	0–15	1.5 ±0.1	1.06±0.2	1.7 ±0.7
S18B	15–30	1.5 ±0.1	0.90±0.2	2.3 ±1
S19A	0–15	1.1 ±0.2	1.3 ±0.3	2.4 ±0.8
S19B	15–30	1.3 ±0.1	1.4 ±0.2	2.2 ±1
S20A	0–15	1.2 ±0.2	1.2 ±0.3	1.9 ±0.7
S20B	15-30	1.4 ±0.1	1.2 ±0.2	1.6 ±0.3
S21A	0–15	1.3 ±0.2	1.1 ±0.3	3.5 ±1
S21B	15-30	1.4 ±0.2	1.07±0.3	2.9 ±1
S22A	0–15	1.4 ±0.1	1.2 ±0.2	2.1 ±0.4
S22B	15-30	1.2 ±0.1	1.1 ±0.2	2.5 ±1
S23A	0–15	1.3 ±0.02	1.0 ±0.04	2.0 ±1
S23B	15-30	1.3 ±0.1	1.2 ±0.2	2.4 ±1
S24A	0–15	1.2 ±0.2	1.0 ±0.3	3.1 ±1
S24B	15-30	1.4 ±0.1	1.03±0.2	1.3 ±1
S25A	0–15	1.3 ±0.2	0.79±0.3	1.9 ±0.7
S25B	15-30	1.3 ±0.03	0.94±0.04	1.5 ±0.5
S25C	30-45	1.2 ±0.1	1.07±0.2	1.9 ±0.7
S26A	0–15	1.3 ±0.2	0.85±0.2	3.2 ±0.7
S26B	15-30	0.84±0.02	0.57±0.03	1.9 ±0.6
S27A	0–15	1.07±0.1	0.90±0.2	2.2 ±0.3
S27B	15–30	1.1 ±0.03	0.87±0.05	2.9 ±0.7
S28A	0–15	1.3 ±0.02	1.0 ±0.04	2.1 ±1
S28B	15–30	1.3 ±0.03	0.94±0.04	1.8 ±1
S29A	0–15	1.2 ±0.09	0.90±0.1	1.8 ±0.6
S29B	15–30	1.2 ±0.02	0.94±0.03	1.3 ±0.7
S30A	0–15	1.2 ±0.03	0.92±0.05	1.4 ±0.5
S30B	15-30	1.2 ±0.06	1.03±0.09	1.6 ±0.4
S31A	0–15	1.01±0.03	0.67±0.04	1.2 ±0.2
S31B	15-30	0.85±0.06	0.53±0.09	1.3 ±0.2
S32A	0–15	1.2 ±0.03	1.05±0.04	1.6 ±0.3
S32B	15-30	1.2 ±0.02	1.09±0.03	1.5 ±0.2
S32C	30-45	1.2 ±0.05	1.1 ±0.08	1.2 ±0.4

Table 3 (continued)

Sample ID[a]	Depth (cm)	Radionuclide concentration (pCi/g)[b]		
		^{226}Ra	^{232}Th	^{238}U
S33A	0–15	1.2 ±0.02	1.02±0.04	1.5 ±0.7
S33B	15-30	1.3 ±0.07	1.08±0.1	1.4 ±0.3
S34A	0–15	1.3 ±0.1	1.1 ±0.2	1.9 ±0.4
S34B	15-30	1.3 ±0.1	1.02±0.1	1.9 ±0.7
S35A	0–15	1.3 ±0.1	0.94±0.2	2.0 ±0.7
S35B	15-30	1.3 ±0.1	1.0 ±0.2	1.6 ±0.3
S35C	30-45	1.3 ±0.1	1.2 ±0.2	1.6 ±0.4
S36A	0–15	1.4 ±0.1	1.2 ±0.2	1.8 ±0.8
S36B	15-30	1.3 ±0.1	1.2 ±0.2	1.4 ±0.4
S36C	30-45	1.3 ±0.09	1.1 ±0.1	2.0 ±0.8
S37A	0–15	1.2 ±0.1	1.1 ±0.2	2.8 ±0.5
S37B	15-30	1.4 ±0.09	1.0 ±0.1	2.0 ±0.4
S37C	30-45	1.3 ±0.03	0.88±0.04	3.7 ±1
S38A	0–15	1.2 ±0.06	0.98±0.1	3.3 ±1
S38B	15-30	1.2 ±0.08	0.96±0.1	2.2 ±0.3
S39A	0–15	1.1 ±0.02	0.87±0.03	1.7 ±0.4
S39B	15-30	1.2 ±0.08	0.86±0.1	1.9 ±0.7
		Biased samples[d]		
B1A	0-15	0.74±0.1	0.67±0.2	86 ±5
B1B	15-30	0.94±0.1	1.2 ±0.2	85 ±6
B1C	30-45	1.3 ±0.2	1.2 ±0.3	94 ±10
B1D	45-60	1.6 ±0.2	1.4 ±0.3	80 ±5
B2A	0-15	0.69±0.1	<0.90	730 ±50
B2B	15-30	0.86±0.2	0.82±0.2	230 ±10
B2C	30-45	1.4 ±0.2	1.4 ±0.2	110 ±10
B3A	0-15	0.89±0.1	0.63±0.2	75 ±5
B3B	15-30	1.3 ±0.1	1.2 ±0.2	33 ±2
B3C	30-45	1.4 ±0.03	1.3 ±0.05	2.8 ±0.6
B4A	0-15	0.43±0.06	<0.50	3.8 ±0.4
B4B	15-30	0.53±0.07	0.20±0.09	1.4 ±0.3
B4C	30-45	0.50±0.02	0.20±0.02	0.95±0.3
B5A	0-15	0.47±0.06	0.20±0.09	2.2 ±0.4
B5B	15-30	0.47±0.02	0.19±0.03	1.2 ±0.3
B5C	30-45	0.53±0.09	0.26±0.08	<1.2
B6A	0-15	1.3 ±0.4	1.1 ±0.6	2700±300
B6B	15-30	1.5 ±0.2	1.2 ±0.4	960±50

Table 3 (continued)

Sample ID[a]	Depth (cm)	Radionuclide concentration (pCi/g)[b]		
		^{226}Ra	^{232}Th	^{238}U
B7A	0-15	1.4 ±0.2	0.90±0.3	130±5
B7B	15-30	1.2 ±0.1	1.1 ±0.2	43±2
B8A	0-15	1.3 ±0.2	0.90±0.2	280±5
B8B	15-30	1.2 ±0.1	1.0 ±0.2	27±2
B9A	0-15	1.1 ±0.2	1.0 ±0.3	190±10
B9B	15-30	1.2 ±0.1	1.2 ±0.2	29 ±2
B10A	0-15	0.18±0.05	0.23±0.1	5.8±2
B10B	15-30	0.15±0.08	0.24±0.1	14 ±3
B11A	0-15	1.2 ±0.2	1.5 ±0.4	850±50
B11B	15-30	1.5 ±0.2	1.1 ±0.3	280±10
B12A	0-15	1.5 ±0.3	0.98±0.5	3300±300
B12B	15-30	1.3 ±0.2	0.92±0.3	480±30
B12C	30-45	1.3 ±0.2	0.95±0.2	290±20
B12D	45-60	1.4 ±0.2	0.86±0.2	85±5
B13A	0-15	0.82±0.02	0.51±0.03	36±6
B13B	15-30	0.95±0.03	0.70±0.04	15 ±3
B14A	0-15	1.07±0.02	0.85±0.04	57±4
B14B	15-30	1.4 ±0.1	1.2 ±0.2	55±8
B14C	30-45	1.3 ±0.03	1.2 ±0.05	43±3
B14D	45-60	1.5 ±0.03	1.3 ±0.04	45±5
B14E	60-75	1.5 ±0.1	1.4 ±0.2	35±5
B15A	0-15	2.5 ±0.2	2.4 ±0.3	4.2±1
B15B	15-30	1.6 ±0.1	1.3 ±0.2	1.7±0.3
B15C	30-45	1.4 ±0.1	1.3 ±0.2	4.3±0.7
B15D	45-60	1.5 ±0.08	1.3 ±0.2	3.5±1
B16A	0-15	4.01±0.2	3.3 ±0.2	5.2±0.5
B16B	15-30	4.3 ±0.2	3.5 ±0.3	10±2
B16C	30-45	2.0 ±0.1	1.7 ±0.2	4.0±0.5
B17A	0-15	1.4 ±0.1	1.4 ±0.2	27±3
B17B	15-30	1.5 ±0.1	1.2 ±0.2	22±5
B17C	30-45	1.3 ±0.1	1.2 ±0.2	14±3
B17D	45-60	1.5 ±0.1	1.5 ±0.2	13±3
B17E	60-75	1.7 ±0.1	1.3 ±0.2	3.6±0.7

Table 3 (continued)

Sample ID[a]	Depth (cm)	Radionuclide concentration (pCi/g)[b]		
		^{226}Ra	^{232}Th	^{238}U
B18A	0-15	1.3 ±0.09	1.2 ±0.2	39±7
B18B	15-30	1.5 ±0.09	1.3 ±0.2	21±5
B18C	30-45	1.6 ±0.1	1.3 ±0.2	19±3
B19A	0-15	1.2 ±0.08	0.98±0.2	3.0±0.4
B19B	15-30	1.3 ±0.03	1.03±0.04	4.8±0.5
B19C	30-45	1.3 ±0.03	1.1 ±0.05	2.4±0.3
B20A	0-15	1.3 ±0.02	0.91±0.03	35 ±3
B20B	15-30	1.4 ±0.1	1.0 ±0.2	20 ±4
B20C	30-45	1.4 ±0.09	0.94±0.1	19 ±1
B21	0-15	1.3 ±0.1	0.88±0.1	60 ±10
B22	0-15	<1.0	<0.85	55 ±4
		Miscellaneous samples[e]		
M1	*f*	<0.48	<0.69	300±80
M2	*f*	<24	<40	100,000±20,000
M3	*f*	<12	<14	14,000±3,000
M4	*f*	<7.0	*g*	160±20
M5	*f*	<0.95	<1.1	400±80

[a]Sample locations are shown on Fig. 2, except for samples M3-M5, which correspond to locations for smears 4, 5, and 7 on Fig. 6.

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

[c]Systematic samples are taken at locations irrespective of gamma exposure rates.

[d]Biased samples are taken from areas shown to have elevated gamma exposure rates.

[e]Concrete and debris samples collected from the interior and exterior of the former Alba Craft Laboratory.

[f]Not applicable.

[g]No results reported.

Table 4. PIC exposure rate measurements inside the former Alba Craft Laboratory

Location[a]	PIC (μR/h) at 1 meter
P1	5.8
P2	5.7
P3	5.6
P4	5.9
P5	5.6
P6	5.6
P7	5.7
P8	6.2
P9[b]	6.5
P10	5.8
P11	6.2
P12	5.9
P13	5.5
P14	7.2
P15	6.7

[a]See Figure 6.
[b]Corresponds to location of contaminated spot showing gamma radiation level of 110 μR/h at the surface.

Table 5. Results of analysis of smears from the former Alba Craft Laboratory

Sample number	Alpha level (dpm/100 cm^2)	Beta-gamma level (dpm/100 cm^2)	Total activity[a] (dpm/100 cm^2)
S1	<MDA[b]	<MDA[c]	*d*
S2	<MDA	<MDA	*d*
S3	<MDA	<MDA	*d*
S4	64	100	31,000
S5	<MDA	<MDA	370
S6	<MDA	<MDA	*d*
S7	<MDA	<MDA	5900
S8	<MDA	<MDA	*d*
S9	<MDA	<MDA	*d*
S10	<MDA	<MDA	*d*
S11	<MDA	<MDA	*d*
S12	<MDA	<MDA	*d*
S13	<MDA	<MDA	*d*
S14	<MDA	<MDA	*d*
S15	552	1030	*d*
S16	<MDA	<MDA	*d*
S17	<MDA	<MDA	*d*
S18	<MDA	<MDA	*d*
S19	<MDA	<MDA	*d*
S20	<MDA	<MDA	*d*

[a]Combination of activity collected on the smear and a separate sample of loose debris in the same 100-cm^2 area.
[b]Minimum detectable activity for alpha is 12 dpm/100 cm^2.
[c]Minimum detectable activity for beta-gamma is 112 dpm/100 cm^2.
[d]A separate sample of loose debris was not collected at this smear location.

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