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RESULTS OF THE RADIOLOGICAL SURVEY AT THE VENTRON SITE, BEVERLY, MASSACHUSETTS

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FIGURES

TABLES

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ABSTRACT

The results of a radiological survey of the Ventron site (the Ventron Division of Morton Thiokol, Inc.) in Beverly, Massachusetts, are presented in this report. From 1942 through 1948, the site was used for various projects involving the production of uranium metal powder from uranium oxide and the recovery of uranium from scrap metal. After 1948, the Atomic Energy Commission surveyed the facility and performed decontamination and decommissioning activities in accordance with current procedural policies. In 1980 and 1982, a comprehensive radiological survey of the site was conducted by the Oak Ridge National Laboratory. Included were measurements of the following: residual alpha and beta-gamma contamination levels inside the buildings; external gamma radiation levels at 1 m above the surface and at the surface in the buildings and outdoors; and uranium, radium, and thorium concentrations in surface and subsurface soil outdoors and beneath the buildings.

The results show the presence of residual radioactive contamination, largely uranium with lesser amounts of thorium and radium, in outdoor soil and in fill material beneath Buildings B-1, B-2, and C-1. The spotty contamination found in Buildings A and A-1, and the Alfa Building on floors, walls, and overhead surfaces, and equipment included beta-gamma dose rates exceeding the limits set by current guidelines applicable to the release of property for unrestricted use. Surface contamination dose rates on the roof of Building A were comparable to those inside the buildings.

In summary, concentrations of residual radioactive material found in buildings and soils at the site are in excess of concentration guidelines established by the Department of Energy to determine if a site needs to be considered for remedial action. These guildelines are typically derived to ensure that unrestricted use of the facility (including residential use) will not result in above-guideline doses to the general public. An examination of work/occupancy scenarios for this site suggests that the annual radiation exposures to personnel from any credible current use scenario would be well below dose limits which would be applied to protect members of the general public from exposure to radiation.

1. INTRODUCTION

The Metal Hydrides Corporation was under contract to the Manhattan Engineer District (MED) and the Atomic Energy Commission (AEC) from 1942 to 1948 to convert uranium oxide to uranium metal powder. This procedure, as well as later operations involving recovering uranium from scrap uranium and turnings from the slug fabrication plant at Hanford, Washington, were conducted at the foundry site located in Beverly, Massachusetts. The city lies on Massachusetts Bay approximately 15 miles northeast of the central Boston area. The property, which comprises approximately three acres, is located at the confluence of the Bass and Danvers rivers and is bounded by Congress Street to the north (Fig. 1). During contract operations three buildings were used for uranium work. Two wooden buildings that housed the foundry facilities were demolished sometime between 1948 and 1950, and two other buildings have since been erected at these locations. The remaining original building contained furnace and leaching facilities, a mixing room, a drying room, and analytical laboratories. The Metal Hydrides Corporation became the Ventron Corporation in 1965, and in late 1976 the Thiokol Corporation acquired control of the company.[1] In 1982 Ventron became a Division of Morton Thiokol, Incorporated.

The AEC conducted a radiation survey of the facility in 1948. The two foundry buildings and various pieces of equipment were found to be contaminated and cleaning was recommended. Painted surfaces were sandblasted, and contaminated concrete floors and platforms were removed. Ocean dumping was the method used for disposing of contaminated equipment and rubble. In 1977, following acquisition of the property by the Thiokol Corporation, the Oak Ridge Operations office of the Department of Energy (DOE) and the Oak Ridge National Laboratory (ORNL) conducted a screening survey of the site in 1977. Based on the results of exploratory measurements, it was determined that a comprehensive radiological survey of the entire site was in order.

A radiological characterization survey of the outdoor portion of the site was conducted by members of the Health and Safety Research Division (HASRD) of ORNL during the period September 19-25, 1980. Buildings and structures on the site were surveyed February 22-28, 1982. A preliminary report, documenting a recommendation for the consideration of remedial action, was presented to DOE in December 1985.[2]

This report describes the results of the radiological survey in detail. A scaled drawing of the property showing the location of buildings and the grid network established for measurements outside the existing buildings is shown in Fig. 2. The locations of the original foundry buildings are also indicated. Photographs showing several of the buildings are presented in Figs. 3-5.

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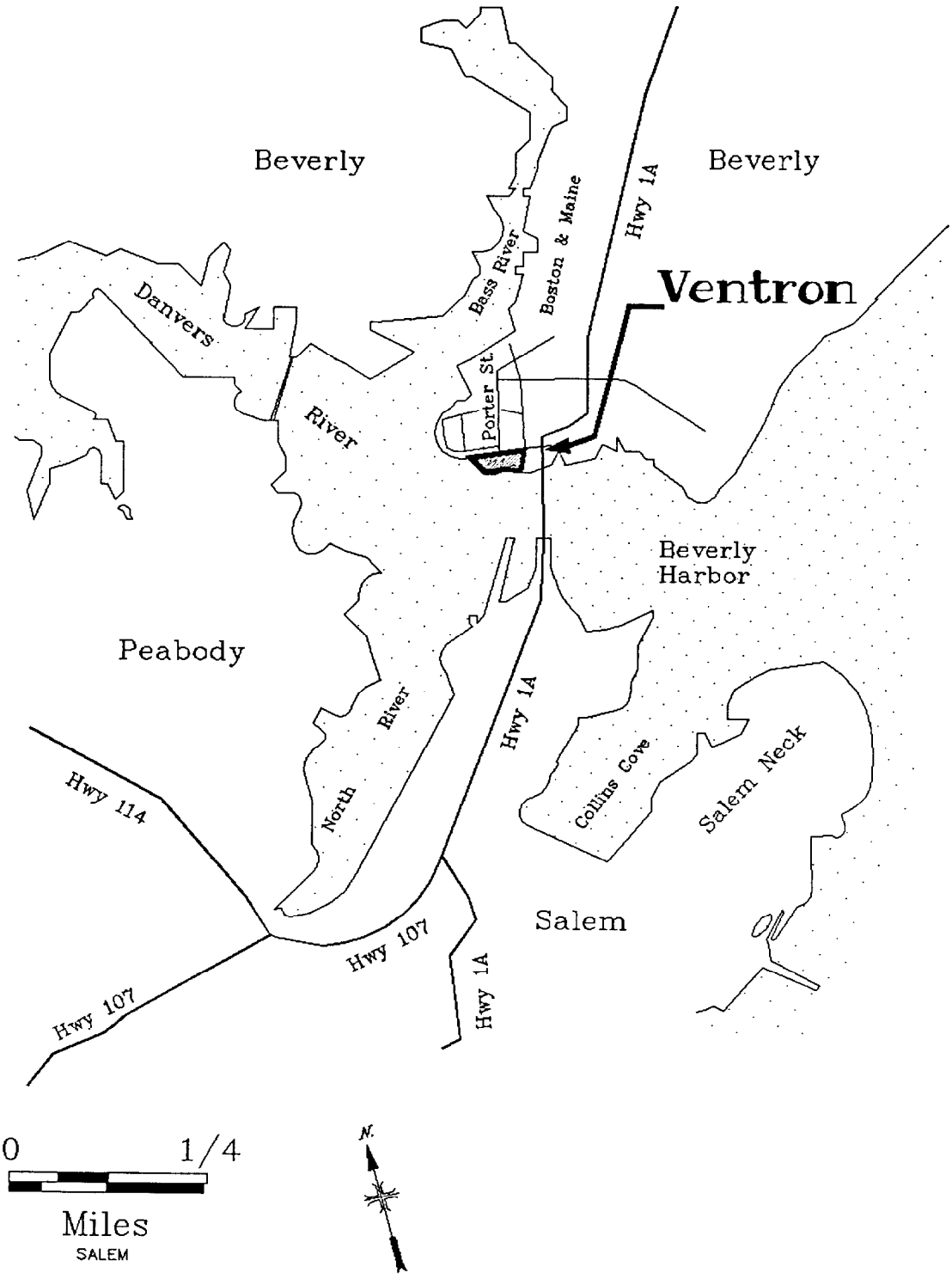

Fig. 1. Diagram showing general location of the Ventron site.

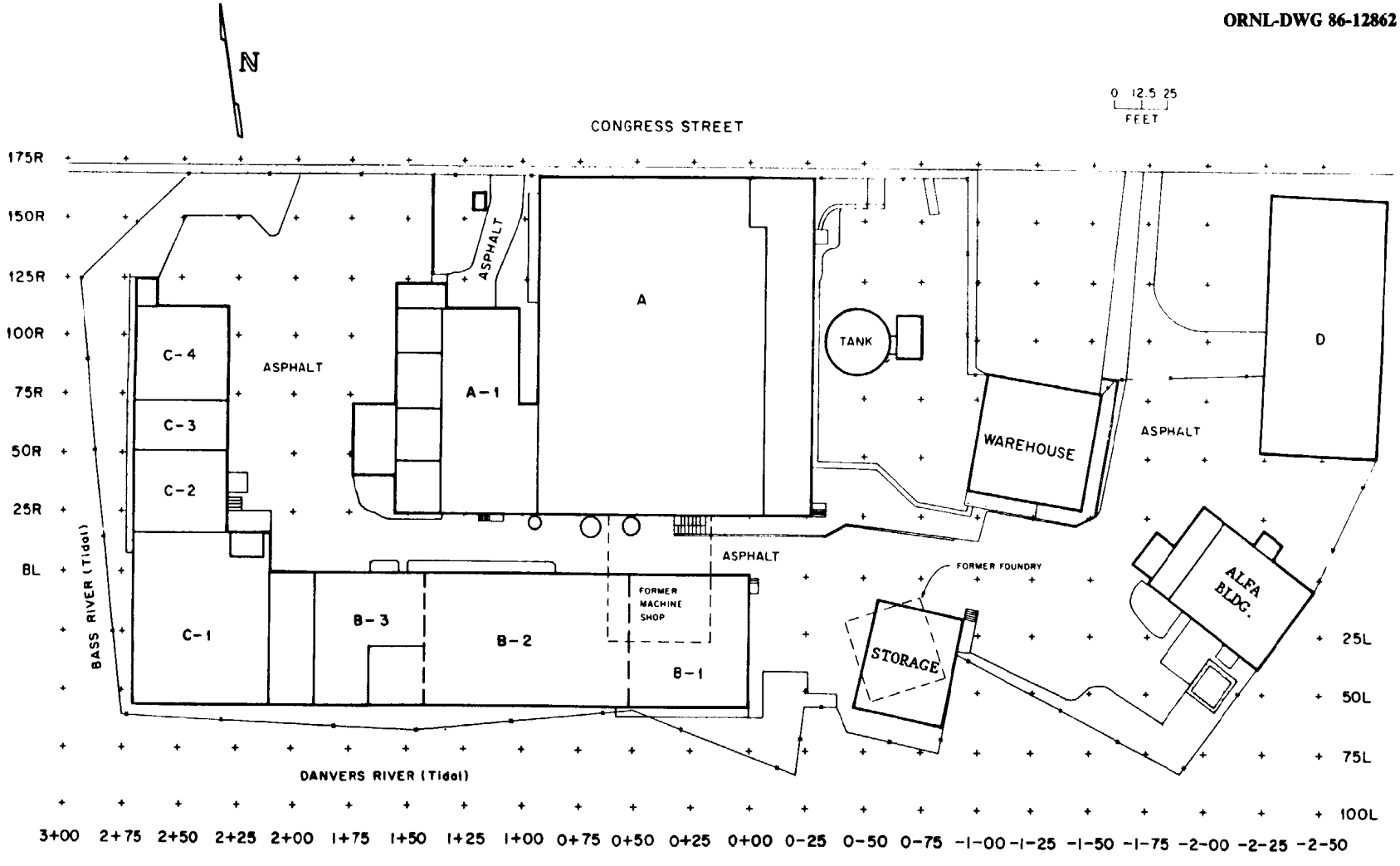

Fig. 2. Scaled drawing of the grid system used in the outdoor survey of the Ventron site.

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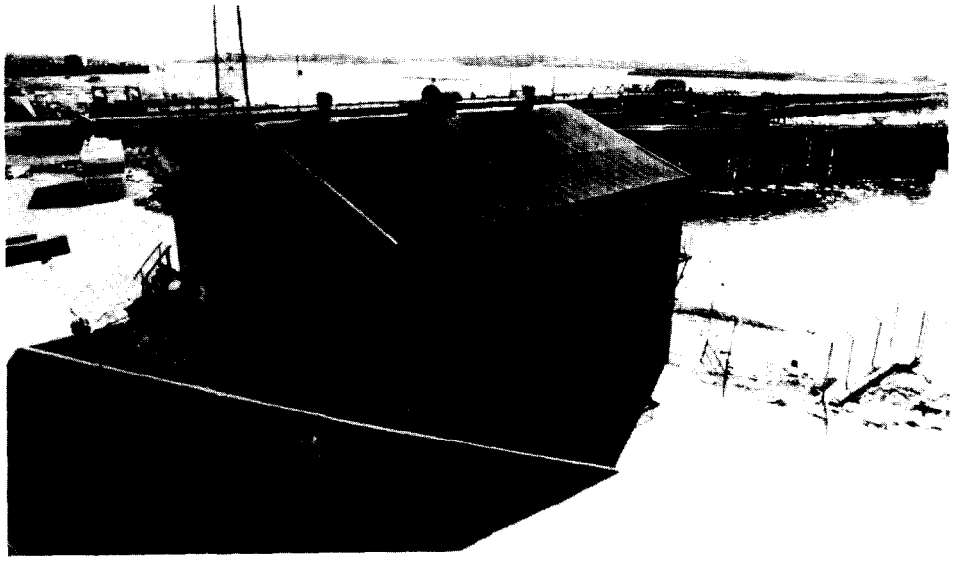

Fig. 3. View of the Storage Building looking southeast from Building A at the Ventron site.

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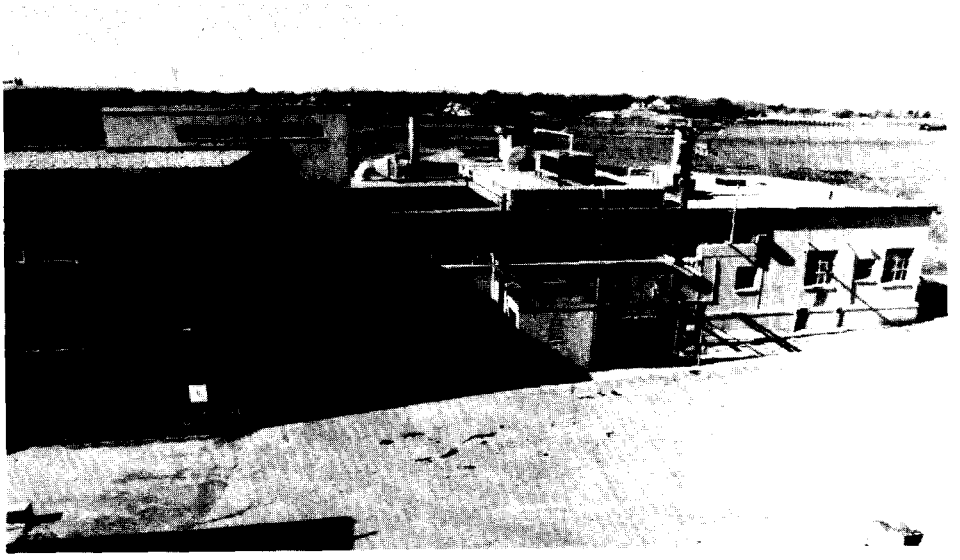

Fig. 4. View of Buildings C-2, C-3, and C-4 looking west from Building A at the Ventron site.

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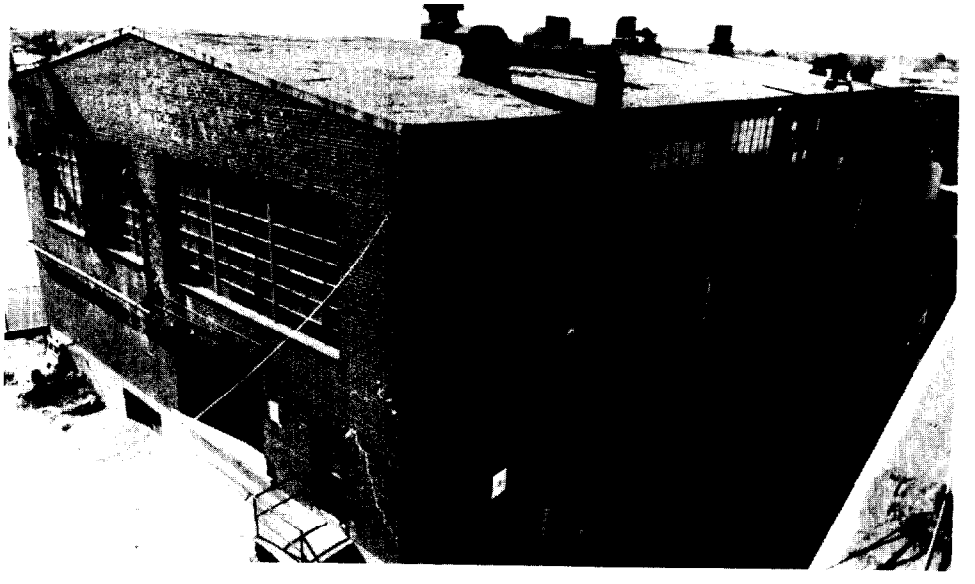

Fig. 5. View of Buildings B-1, B-2, B-3, and B-4 looking southwest from Building A at the Ventron site.

2. SURVEY METHODS

The radiological survey of this property included: (1) gamma exposure rates at 1 m above the ground surface and at the ground surface at outdoor grid locations; (2) gamma exposure rates at 1 m above the floor surface and at the floor surface at indoor grid locations; (3) gamma scanning of both indoor and outdoor areas; (4) radionuclide analysis of surface and subsurface soil samples; (5) logging of gamma radiation levels at various depths in auger holes; (6) radionuclide analysis of sediment samples from storm sewer manholes; and (7) direct and transferable alpha and beta-gamma activity inside the structures. A comprehensive description of the survey methods and instrumentation has been presented in another report.[3]

Large areas to be surveyed either indoors or outdoors were subdivided into "grid block" subsections for convenience in reporting results.

2.1 OUTDOOR SURVEY METHODS

The entire outdoor area was divided into 25-ft grid blocks. Unless otherwise stated in Sect. 2.1, each block was surveyed in the following manner: Accessible areas in each grid block were scanned with the portable gamma scintillation meter, and the area-weighted average found within the block was recorded. Measurements at 1 m above the ground surface and at the ground surface at the center point in each block were then made. Surface soil samples were taken at systematically selected locations and analyzed for ^{238}U, ^{226}Ra, and ^{232}Th content. At points showing elevated gamma rates, "biased" surface soil samples were taken for similar analyses.

To define the extent of subsurface soil contamination on the site, holes were augered to depths of 2.4 m and more in regions of suspected subsurface contamination. A plastic pipe was placed in each hole, and a NaI scintillation probe was lowered inside the pipe. The probe was encased in a lead shield with a horizontal row of collimating slits on the side. This collimation allows measurement of gamma radiation intensities resulting from contamination within small fractions of the hole depth. When possible, if the gamma readings in the hole were not uniform, a soil sample was scraped from the wall of the auger hole at the point showing the highest gamma radiation level. The auger hole loggings were used to select locations where further soil sampling would be useful. At points as close as practical to several selected auger holes, a split-spoon sampler was used to collect subsurface samples at known depths. Sediment samples were taken from several storm sewers to determine radionuclide concentration. The soil and sediment samples were analyzed for ^{238}U, ^{226}Ra, and ^{232}Th.

2.2 INDOOR SURVEY METHODS

Throughout this report, the term "lower walls" refers to wall surfaces up to a height of 6 ft. Whenever practical, floors and lower walls were divided into grid blocks defined by natural boundaries such as building supports. The size of the survey blocks generally

varied with the size of the building and room. Where possible, grid block designations are used in presenting results. However, in some cases, the complexity of the grid system would unnecessarily complicate the reporting of data. To circumvent this difficulty, grid block measurements taken inside the buildings have been averaged on a room-by-room basis when tabulated.

Unless otherwise stated in Sect. 3, each block was surveyed in the following manner: Accessible areas were scanned with a gamma scintillation detector, and the range and average gamma radiation levels were recorded. The gamma radiation levels at 1 m and at the surface were measured near the center of the block. Beta-gamma dose rate measurements were made at the point of maximum gamma radiation level in each block. One or more alpha measurements were taken at the surface near the center of each grid block, and the measurement or the average of the measurements was recorded. Smear samples were taken at systematically chosen locations and/or in areas of elevated beta-gamma dose rates. For the survey of overhead surfaces (including walls above 6 ft), measurements of direct and transferable alpha and beta-gamma contamination levels were made at numerous points as uniformly spaced as practicable. In addition to these measurements, holes were drilled through the floors of Buildings B-1, B-2, B-3, and C-1 to depths of 2.4 m (8 ft) or more, and soil samples were taken at various intervals. The samples were analyzed for ^{238}U, ^{226}Ra, and ^{232}Th.

3. SURVEY RESULTS

Typical radiation background levels in the Beverly, Massachusetts, area are presented in Table 1. These data are provided for comparison with the survey results presented in this section. Applicable federal guidelines for radiation exposure to the general public are summarized in Table 2.

With the exception of measurements of transferable activity, which are reported as net disintegration rates, all direct measurements presented in this report are gross readings; background radiation levels have not been subtracted. Similarly, background concentrations have not been subtracted from radionuclide concentrations in soil samples.

3.1 OUTDOOR SURVEY RESULTS

3.1.1 Gamma Exposure Rate Measurements

Gamma exposure rates taken at 1 m above the ground surface and at the ground surface near the center point in each grid block are listed in Table 3. The average exposure rate found during the scan of grid blocks is also given. These data show an overall average of 8 μR/h. Elevated measurements ranging from 10 to 450 μR/h were identified in several regions with the contamination at the south side of the property appearing to extend beyond the sea wall into the rip-rap and tidal areas. The regions of elevated gamma levels are indicated on Fig. 6 and the measurements appear in Table 4.

Table 1. Background radiation levels in the Beverly, Massachusetts, area

Type of radiation measurement or sample	Radiation level or radionuclide concentration	
	Range	Average
Gamma exposure rate at 1 m above floor or ground surface (μR/h)[a]	6–8	7
Concentration of radionuclides in soil (pCi/g)[a]		
^{238}U	0.92–2.7	1.6
^{226}Ra	1.0–1.8	1.3
^{232}Th	0.98–1.2	1.1

[a]Values obtained from three locations in the Beverly area.

Table 2. Applicable guidelines for protection against radiation[a]

Mode of exposure	Exposure conditions	Guideline value
Gamma radiation	Indoor gamma radiation level (above background)	20 μR/h
Surface contamination	^{238}U, U-natural	
	Fixed on surfaces	5000 dpm/100 cm^2
	Removable	1000 dpm/100 cm^2
	^{232}Th, Th-natural	
	Fixed on surfaces	1000 dpm/100 cm^2
	Removable	200 dpm/100 cm^2
	^{226}Ra	
	Fixed on surfaces	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	Maximum permissible concentration of the following radionuclides in soil above background levels averaged over 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
	^{232}Th	
	^{230}Th	
	^{228}Ra	
	^{226}Ra	
	^{238}U	Derived (site specific)

[a]U.S. Department of Energy Guidelines for Residual Radioactivity at Formerly Utilized Sites Remedial Action Program and Remote Surplus Facilities Management Program Sites (Revision 2, March 1987).

[b]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, ^{131}I, ^{129}I, ^{126}I, and ^{125}I.

Table 3. Outdoor gamma exposure rate measurements at the Ventron site

Grid location[a]	Center point measurements[b] (μR/h)		Average gamma exposure rate during scan of grid block[c] (μR/h)
	Gamma exposure rate at the surface	Gamma exposure rate at 1 m	
0−25, BL	8	7	8
0−50, BL	7	7	7
0−75, BL	7	6	7
−1−00, BL	8	6	8
−1−25, BL	6	6	6
−1−50, BL	6	6	6
−1−75, BL	6	5	6
−2−00, BL	8	7	7
−2−25, BL	d	d	8
−2−50, BL	d	d	8
−2−75, BL	d	d	8
0+00, BL	8	8	7
0+25, BL	7	8	7
0+50, BL	8	7	8
0+75, BL	7	7	8
1+00, BL	8	9	8
1+25, BL	9	8	8
1+50, BL	7	8	8
1+75, BL	6	6	8
2+00, BL	7	8	7
2+25, BL	d	d	7
2+50, BL	d	d	7
2+75, BL	8	7	d
0−50, 25R	9	7	8
0−75, 25R	8	7	8
−1−00, 25R	7	7	7
−1−25, 25R	d	d	7
−1−50, 25R	d	d	6
−1−75, 25R	6	5	6
2−00, 25R	5	5	6
2−25, 25R	6	6	7
2−50, 25R	7	5	8
1+50, 25R	9	6	7
1+75, 25R	6	6	7
2+00, 25R	7	7	7
2+25, 25R	d	d	7
2+50, 25R	d	d	6
0−50, 50R	8	8	8
0−75, 50R	6	6	8
−1−00, 50R	6	6	7
−1−75, 50R	5	6	7

Table 3 (continued)

Grid location[a]	Center point measurements[b] (μR/h)		Average gamma exposure rate during scan of grid block[c] (μR/h)
	Gamma exposure rate at the surface	Gamma exposure rate at 1 m	
−2−00, 50R	5	5	7
−2−25, 50R	7	5	7
1+50, 50R	d	d	7
1+75, 50R	5	6	7
2+00, 50R	7	7	7
2+25, 50R	d	d	7
2+50, 50R	d	d	6
0−50, 75R	7	6	8
0−75, 75R	6	5	7
−1−00, 75R	6	5	7
−1−25, 75R	6	6	7
−1−50, 75R	6	6	5
−1−75, 75R	6	6	6
−2−00, 75R	6	6	7
−2−25, 75R	7	6	6
0+75, 75R	d	d	7
1+50, 75R	6	7	7
1+75, 75R	6	6	7
2+00, 75R	6	6	7
2+25, 75R	d	d	7
2+50, 75R	d	d	6
0−50, 100R	7	6	6
0−75, 100R	6	6	6
−1−00, 100R	6	6	6
−1−25, 100R	6	6	6
−1−50, 100R	6	5	7
−1−75, 100R	7	6	7
−2−00, 100R	6	6	7
−2−25, 100R	6	6	7
0+75, 100R	d	d	8
1+00, 100R	d	d	8
1+25, 100R	d	d	7
1+50, 100R	6	6	7
1+75, 100R	6	6	7
2+00, 100R	7	6	7
2+25, 100R	d	d	7
2+50, 100R	d	d	6
2+75, 100R	d	d	6
0−50, 125R	d	d	6
0−75, 125R	d	d	6
−1−00, 125R	7	7	6
−1−25, 125R	6	6	6

Table 3 (continued)

Grid location[a]	Center point measurements[b] (μR/h)		Average gamma exposure rate during scan of grid block[c] (μR/h)
	Gamma exposure rate at the surface	Gamma exposure rate at 1 m	
−1−50, 125R	7	6	6
−1−75, 125R	7	6	6
−2−00, 125R	7	6	7
−2−25, 125R	7	6	7
0+75, 125R	d	d	7
1+00, 125R	9	7	7
1+25, 125R	6	5	7
1+50, 125R	5	5	7
1+75, 125R	6	6	7
2+00, 125R	6	6	7
2+25, 125R	6	6	7
2+50, 125R	7	7	7
2+75, 125R	d	d	6
0−25, 150R	d	d	7
0−50, 150R	d	d	6
0−75, 150R	d	d	6
−1−00, 150R	d	d	6
−1−25, 150R	d	d	7
−1−50, 150R	d	d	6
−1−75, 150R	d	d	6
−2−00, 150R	d	d	7
−2−25, 150R	d	d	7
−2−50, 150R	d	d	7
0+00, 150R	d	d	7
0+25, 150R	d	d	7
0+50, 150R	d	d	7
0+75, 150R	d	d	7
1+00, 150R	d	d	7
1+25, 150R	d	d	7
1+50, 150R	d	d	7
1+75, 150R	d	d	7
2+00, 150R	d	d	7
2+25, 150R	d	d	7
2+50, 150R	d	d	7
0−25, 25L	7	7	7
0−50, 25L	7	6	7
0−75, 25L	8	7	7
−1−00, 25L	6	6	6
−1−25, 25L	6	6	6
−1−50, 25L	6	6	6
−1−75, 25L	6	6	7
−2−00, 25L	9	21	21

Table 3 (continued)

Grid location[a]	Center point measurements[b] (μR/h)		Average gamma exposure rate during scan of grid block[c] (μR/h)
	Gamma exposure rate at the surface	Gamma exposure rate at 1 m	
1+75, 25L	7	6	7
2+00, 25L	7	7	7
2+50, 25L	d	d	21
0−25, 50L	7	7	7
0−50, 50L	7	6	7
0−75, 50L	d	d	7
−1−00, 50L	8	6	8
−1−25, 50L	7	6	6
−1−50, 50L	10	8	6
−1−75, 50L	6	6	18
−2−00, 50L	76	61	61
−2−25, 50L	d	d	7
1+75, 50L	7	6	7
2+00, 50L	8	8	7
2+50, 50L	d	d	24
0+00, 75L	d	d	7
0−25, 75L	d	d	5
0−50, 75L	d	d	7
0−75, 75L	d	d	7
−1−50, 75L	d	d	7
−1−75, 75L	45	47	45
−2−00, 75L	40	31	40
2−25, 75L	d	d	24
0+25, 75L	d	d	7
0+50, 75L	d	d	7
0+75, 75L	d	d	7
1+00, 75L	d	d	7
1+25, 75L	d	d	7
1+50, 75L	d	d	7
1+75, 75L	d	d	7
2+00, 75L	d	d	8
2+25, 75L	d	d	7
2+50, 75L	d	d	24

[a]Grid location shown on Fig. 2.
[b]Center point measurements are discrete measurements at the center of each grid block.
[c]Grid block measurements are obtained by a gamma scan of the entire block.
[d]Inaccessible.

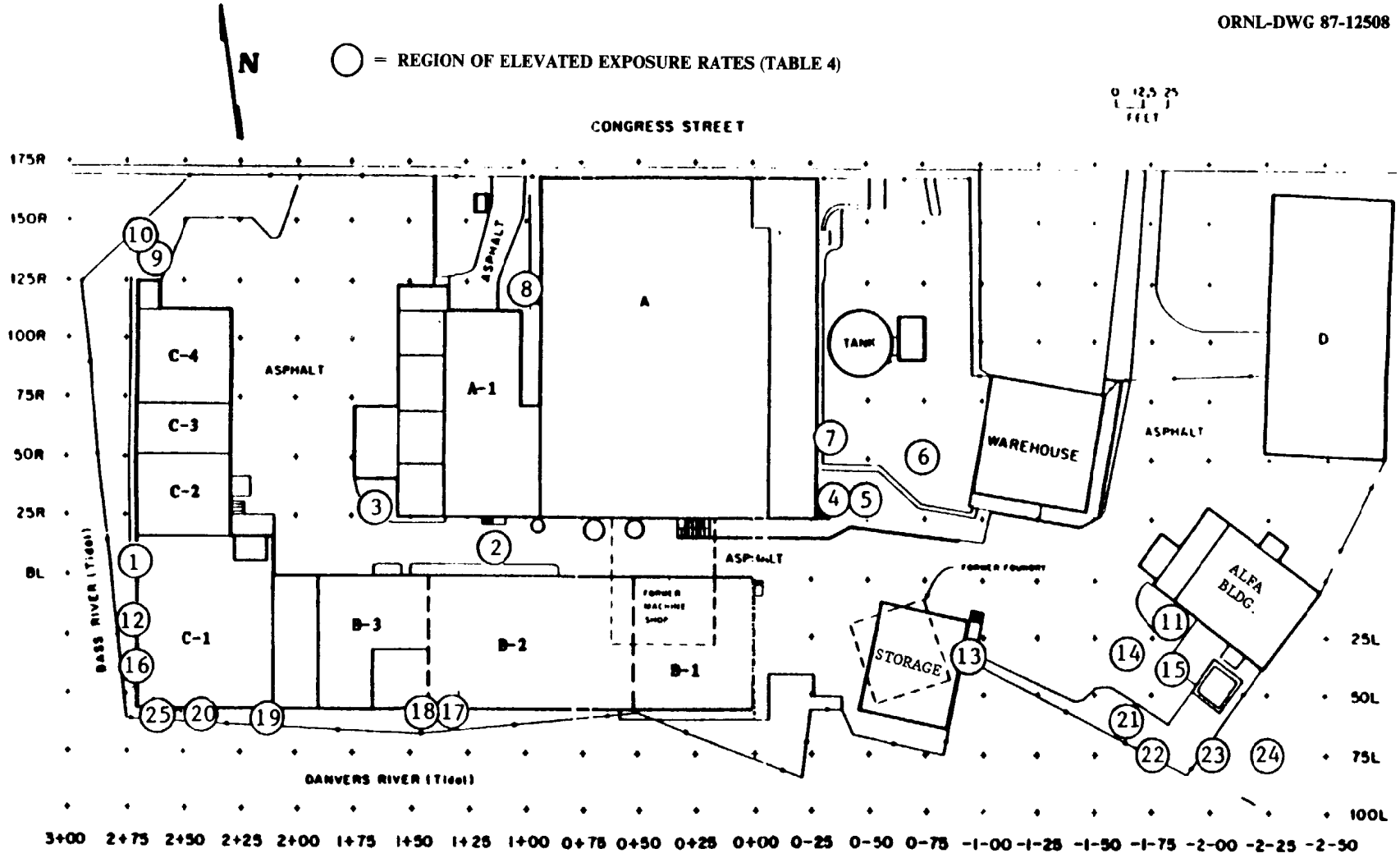

Fig. 6. Locations of elevated gamma exposure rate measurements outdoors at the Ventron site.

Table 4. Measurements taken in regions of elevated gamma exposure rates outdoors at the Ventron site

Location code[a]	Grid location	Maximum gamma exposure rate at surface (μR/h)[b]	Maximum gamma exposure rate at 1 m (μR/h)[b]	Beta-gamma dose rate at surface (mrad/hr)	Estimated area (m^2)
1	2+73, 05R	45	[c]	[c]	<0.1
2	1+10, 12R	24	[c]	[c]	<0.1
3	1+60, 27R	24	[c]	0.04	<0.1
4	0−30, 30R	10	[c]	[c]	<0.1
5	0−50, 30R	24	[c]	[c]	<0.1
6	0−75, 50R	10	[c]	[c]	0.28
7	0−30, 60R	20	[c]	[c]	[c]
8	0+98, 120R	30–55	23	0.5	1.5
9	2+62, 137R	24	6	0.06	<0.1
10	2+60, 145R	24	[c]	[c]	[c]
11	−1−85, 20L	30–150	[c]	[c]	1.9
12	2+70, 23L	45	[c]	[c]	<0.1
13	0−90, 35L	24	[c]	[c]	0.28
14	−1−65, 35L	67	[c]	[c]	<0.1
15[d]	−2−00, 50L	300	61	0.35	9.3
16[e]	2+50, 50L	120–450	45	5	~1.9
17	1+35, 60L	45	[c]	[c]	<0.1
18	1+45, 60L	45	[c]	[c]	<0.1
19	2+10, 60L	76	[c]	[c]	0.093
20	2+45, 60L	61	[c]	[c]	0.093
21	−1−65, 62L	73	[c]	[c]	<0.1
22	−1−75, 75L	240	45	0.45	2.8
23[f]	−2−00, 75L	91	[c]	[c]	2.8
24[g]	−2−25, 75L	24	[c]	[c]	[c]
25[e]	2+50, 75L	61–300	30	0.6	1.6

[a]Codes are shown on Fig. 6 in locations approximating grid points where anomalies were measured.

[b]Maximum gamma exposure rate measured during scan of grid block.

[c]No measurement taken.

[d]Maximum levels found in many spots within grid block.

[e]Maximum levels found in spotty regions next to building wall.

[f]Measurement located south of fence.

[g]Average gamma exposure rate during scan of grid block.

3.1.2 Surface Soil Samples

Surface (0-15 cm) soil samples were taken at locations S1 through S19 and B1 through B9 as exhibited on Fig. 7. The samples designated "systematic" (S1-S19) were taken at systematically chosen locations; those designated "biased" (B1-B9) were taken in areas showing elevated gamma radiation levels. Concentrations of ^{238}U, ^{226}Ra, and ^{232}Th in these samples are listed in Table 5.

Concentrations of ^{232}Th in systematic soil samples ranged from less than 1 to 370 pCi/g. Of the 20 systematic soil samples analyzed for ^{232}Th, all but four were at background levels. Concentrations as high as 3900 pCi/g of ^{232}Th were observed in biased samples. The maximum concentration of ^{232}Th exceeds the DOE guideline of 5 pCi/g above background in any top 15-cm layer of soil by a factor of approximately 800. Concentrations of ^{238}U in systematic surface soil ranged from 0.74 to 97 pCi/g and averaged 12 pCi/g. The maximum concentration of ^{238}U found in biased soil samples was 44,000 pCi/g. Fourteen of the twenty systematic soil samples contained uranium concentrations in excess of local background. All concentrations of ^{226}Ra in surface soil samples were well below the DOE guideline and were at or near background levels for the Beverly area.

3.1.3 Subsurface Soil Samples and Gamma Logging of Auger Holes

Holes were augered at the locations outdoors as shown on Fig. 8 and beneath Buildings B-1, B-2, B-3, and C-1 (see Sects. 3.2.3 and 3.2.4). One to several soil samples were taken from each hole at various depths ranging from the surface to 3.5 m. Selected auger holes were then "logged" using a gamma scintillation detector.

The logging technique used here is not radionuclide specific. However, the logging data, in conjunction with the soil analyses data, may be used to estimate the region of contamination in the auger holes. It appears from a comparison of these data that a reading of 1000 cpm or greater using the shielded scintillator indicates the presence of elevated (above background) concentrations of ^{238}U, ^{226}Ra, and ^{232}Th. Graphs of the gamma logging of the holes are provided in the appendix.

Concentrations of ^{238}U, ^{226}Ra, and ^{232}Th found in subsurface soil on this property are presented in Table 6. Concentrations of ^{238}U in soil samples taken from auger holes outside buildings ranged from 1.7 to 62,000 pCi/g. The maximum concentrations of ^{226}Ra and ^{232}Th found were 30 and 53 pCi/g, respectively. These concentrations exceed the DOE guideline concentration of 15 pCi/g in any 15-cm layer of soil beneath the surface by factors of approximately 2.0 and 3.5, respectively. The contaminated regions outdoors, as determined by the soil sample results, are shown on Fig. 9. Analyses of subsurface strata taken from beneath buildings showed concentrations of ^{238}U ranging from 1.8 to 71,000 pCi/g and averaging 1800 pCi/g. The maximum concentrations of ^{238}U found beneath Buildings B-1, B-2, B-3, and C-1 were 14,000, 71,000, 17, and 1400 pCi/g, respectively. Concentrations of ^{226}Ra and ^{232}Th ranged from 0.08 to 37 pCi/g and <0.08 to 3.3 pCi/g, respectively.

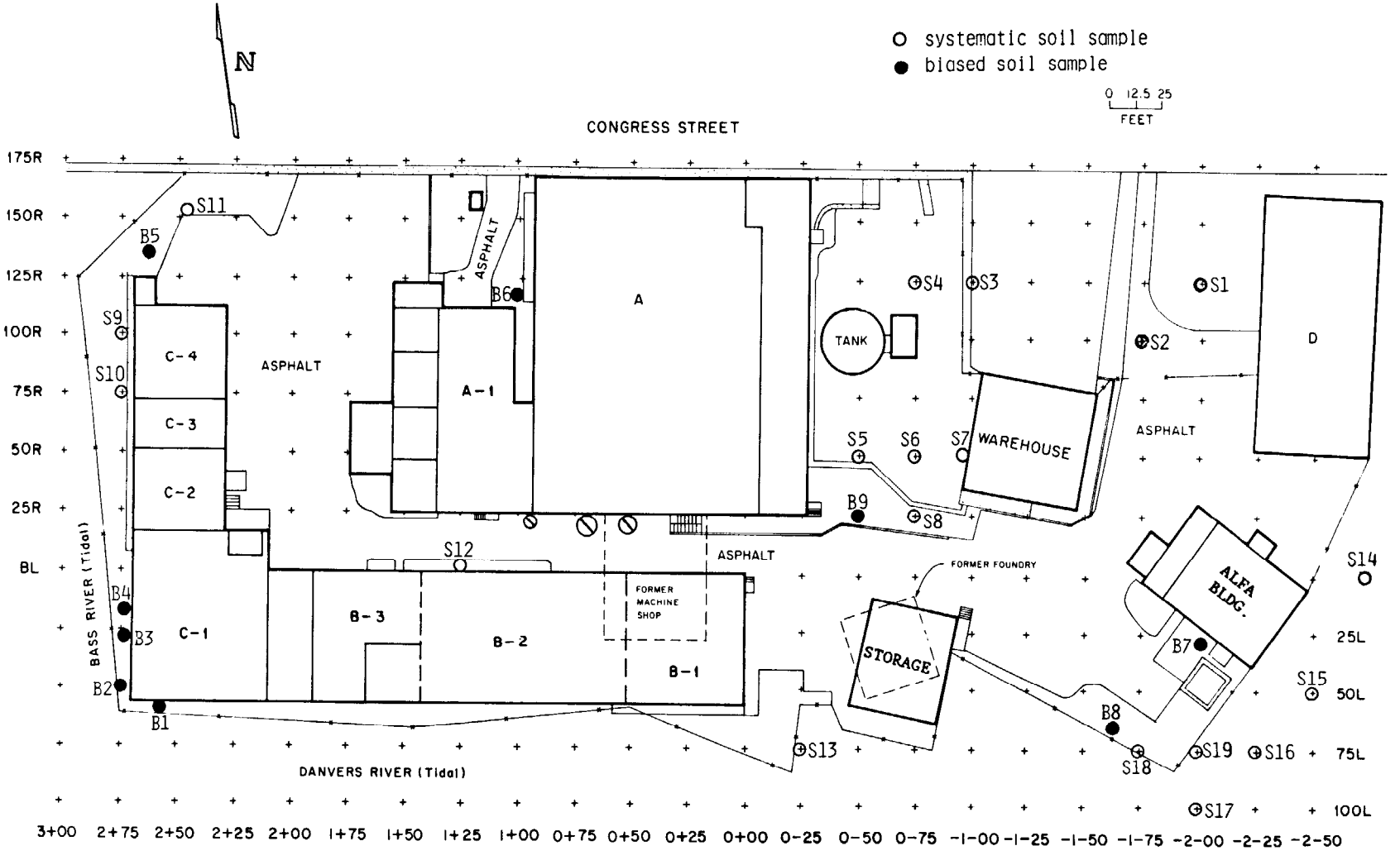

Fig. 7. Locations of surface soil samples at the Ventron site.

Table 5. Concentration of radionuclides in surface soil samples from the Ventron site

Sample number	Location[a]	Depth (cm)	Radionuclide concentration (pCi/g)		
			^{226}Ra[b]	^{232}Th[c]	^{238}U[d]
		Systematic Samples[e]			
1	−2−00, 125R	0−15	0.77 ± 0.04	0.83	0.74
2	−1−75, 100R	0−15	0.65 ± 0.04	0.65	1.0
3	−1−00, 125R	0−15	0.58 ± 0.04	0.78	8.4
4	−1−75, 125R	0−15	0.85 ± 0.03	0.88	0.81
5	−1−50, 50R	0−15	0.78 ± 0.1	0.81	50
6	0−75, 50 R	0−15	0.60 ± 0.04	0.69	9.9
7	−1−00, 50R	0−15	0.69 ± 0.06	0.74	6.4
8	0−75, 25R	0−15	0.70 ± 0.04	0.86	97
9	2+75, 100R	0−15	0.84 ± 0.05	0.77	1.1
10	2+75, 75R	0−15	0.91 ± 0.05	1.1	1.3
11	2+45, 155R	0−15	0.71 ± 0.1	0.70	5.0
12	1+25, 02R	0−15	0.76 ± 0.02	0.81	4.1
13	0−25, 75L	0−15	0.68 ± 0.07	0.72	1.0
14	−2−75, BL	0−15	0.88 ± 0.04	1.1	17
15	−2−50, 50L	0−15	0.68 ± 0.04	0.77	3.4
16	−2−25, 75L	0−15	0.86 ± 0.05	1.3	9.7
17	−2−00, 100L	0−15	1.1 ± 0.05	6.1	5.4
18A	−1−75, 75L	0−15	0.88 ± 0.04	23	2.9
18B	−1−75, 75L	35−50	3.0 ± 1	160	6.3
19	−2−00, 75L	0−15	2.9 ± 3	370	17
		Biased samples[f]			
B1	South, Bldg. C-1	0−15	6 ± 5	1,300	48
B2	West, Bldg. C-1	0−15	<1	340	120
B3	West, Bldg. C-1	0−15	<1	240	89
B4	West, Bldg. C-1	0−15	<1	<1	44,000
B5	2+63, 132R	0−15	0.91 ± 0.3	20	7.7
B6	1+00, 115R	0−15	1.7 ± 0.3	2.1	200
B7	−2−00, 30L	0−15	2.0 ± 0.4	390	24
B8	−1−65, 65L	0−15	<1	3,900	93
B9A	−0−50, 25R	0−15	0.73 ± 0.02	0.83	57
B9B	−0−50, 25R	45−50	0.62 ± 0.02	0.74	11

[a]Locations of soil samples are shown on Fig. 7.
[b]Indicated counting error is at the 95% confidence level (± 2 σ).
[c]The error of the reported radionuclide concentration is ± 5% (95% confidence level).
[d]Total analytical error of measurement results is less than ± 5% (95% confidence level).
[e]Systematic samples are taken at grid locations irrespective of gamma exposure.
[f]Biased samples are taken from areas shown to have elevated gamma exposure rates.

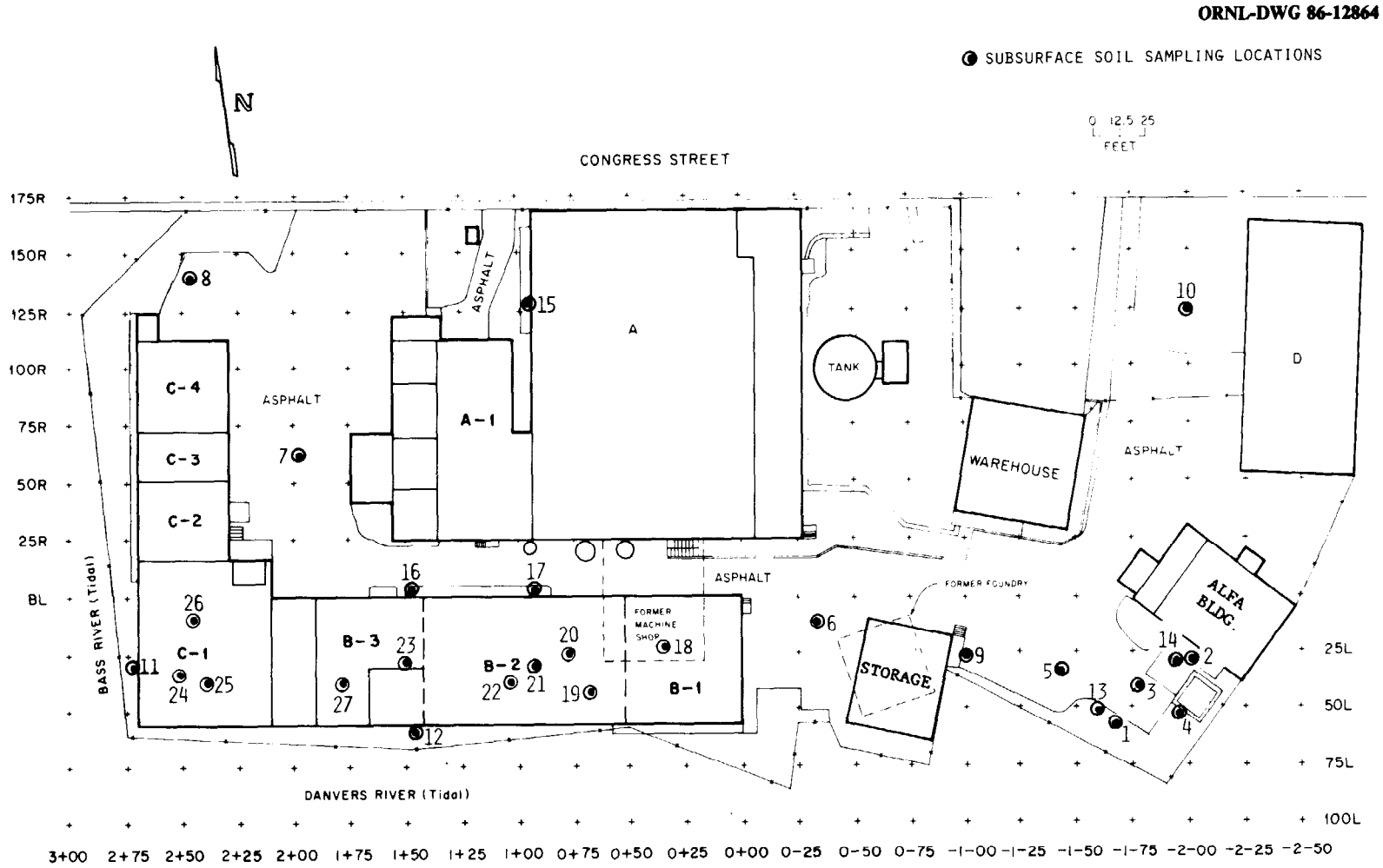

Fig. 8. Locations of auger holes and subsurface soil samples at the Ventron site.

Table 6. Concentration of radionuclides in subsurface soil samples from the Ventron site

Hole number	Location[a]	Depth (cm)	Radionuclide concentration (pCi/g)		
			^{226}Ra[b]	^{232}Th[c]	^{238}U[d]
		Outdoors			
1	−1−65, 65L	0–30	0.66 ± 0.07	15	3.7
2	−2−00, 30L	0–30	3.2 ± 0.4	12	26
3	−1−78, 40L	0–30	0.74 ± 0.02	1.4	6.5
4	−1−97, 55L	0–30	3.9 ± 0.1	1.2	6.3
5	−1−40, 33L	0–30	0.84 ± 0.08	5.0	5.6
6	0+35, 12L	0–30	0.77 ± 0.04	0.87	1.9
7	1+95, 60R	0–30	0.43 ± 0.06	0.42	5.4
8	2+42, 137R	0–30	0.87 ± 0.04	0.85	60
9	−1−00, 26L	0–30	0.91 ± 0.3	0.74	3.1
10	−2−00, 125R	0–30	0.77 ± 0.04	0.85	4.5
11	2+70, 30L	0–15	0.95 ± 0.2	1.5	88
		15–45	<1	<0.14	590
		45–60	<1	46	62,000
		60–75	<1	6.8	5,600
12	1+45, 60L	0–15	30 ± 0.7	0.82	45
		50	6.6 ± 1.8	2.1	12
13	−1−60, 55L	0–20	0.92 ± 0.4	53	7.2
		40–80	0.72 ± 0.04	0.97	1.7
		80–90	0.90 ± 0.2	1.9	8.1
		135–150	0.70 ± 0.03	0.81	4.2
14	−1−95, 30L	0–15	1.2 ± 0.05	41	19
		15–45	1.6 ± 0.1	11	34
		45–60	1.2 ± 0.03	7.3	12
		90–100	0.90 ± 0.2	2.2	9.7
		135–165	1.1 ± 0.04	1.3	18
		185–195	1.0 ± 0.06	4.5	28
		275–305	0.87 ± 0.03	1.1	30
15	0+96, 127R	0–15	1.4 ± 0.1	1.2	590
		15–45	1.6 ± 0.08	0.90	19
		45–50	0.84 ± 0.07	0.89	38
16	1+50, 3R	0–15	0.67 ± 0.04	0.85	3.7
		20–25	0.74 ± 0.09	0.70	3.7
17	0+98, 2R	0–10	0.78 ± 0.03	0.62	3.7
		10–20	0.64 ± 0.07	0.72	2.7
		Under Buildings			
18	Bldg. B-1	8–18	<1	<1	460
		18–30	<1	<1	14,000
		45–60	<0.11	<0.08	210

Table 6 (continued)

Hole number	Location[a]	Depth (cm)	Radionuclide concentration (pCi/g)		
			^{226}Ra[b]	^{232}Th[c]	^{238}U[d]
			Under Buildings		
		60–85	<0.08	<0.05	130
		85–105	0.72 ± 0.05	0.90	57
		105–120	0.60 ± 0.07	0.72	40
		120–140	0.65 ± 0.07	0.70	46
		140–155	0.62 ± 0.06	0.73	37
19	Bldg. B-2	10–35	<1	<1	71,000
		35–55	<1	<1	4,200
		55–75	4.4 ± 0.4	2.0	290
		75–95	3.5 ± 0.1	2.2	150
		95–120	5.6 ± 0.2	1.8	1,500
		120–145	2.7 ± 0.2	1.2	72
		145–180	37 ± 1	<0.23	940
		180–215	0.37 ± 0	<0.26	850
20	Bldg. B-2	15–30	2.7 ± 0.6	<1	1,900
		30–45	4.7 ± 0.1	1.4	170
		45–65	2.8 ± 0.2	1.7	39
		115–125	1.0 ± 0.06	0.94	35
		125–140	0.60 ± 0.03	0.60	16
		140–155	0.61 ± 0.03	0.58	13
21	Bldg. B-2	8–25	1.2 ± 20	1.2	440
		25–45	0.84 ± 0.1	1.8	76
22	Bldg. B-2	8–30	1.2 ± 0.08	0.97	90
23	Bldg. B-3	45–95	1.0 ± 0.7	0.40	10
		95–115	0.92 ± 0.04	0.80	7.1
		115–140	0.40 ± 0.08	0.67	1.9
		140–170	1.3 ± 0.09	1.2	7.6
24	Bldg. C-1	8–35	<1	<1	540
		35–65	2.0 ± 1	2.2	1,400
		65–85	0.66 ± 0.2	0.74	110
		85–110	1.5 ± 0.09	1.7	82
		110–135	3.0 ± 0.1	3.1	56
		135–155	2.1 ± 6	2.4	29
		155–180	2.5 ± 0.07	2.7	48
		180–205	2.5 ± 0.07	3.3	35
25	Bldg. C-1	15–30	<0.08	0.98	54
		85–110	0.70 ± 0.1	<1	460
		110–135	2.3 ± 0.3	2.3	150
		135–155	1.3 ± 0.2	1.2	130
		155–180	3.4 ± 1	3.1	940
		180–195	0.75 ± 0.05	0.64	810
		195–215	0.62 ± 0.19	0.79	130

Table 6 (continued)

Hole number	Location[a]	Depth (cm)	Radionuclide concentration (pCi/g)		
			^{226}Ra[b]	^{232}Th[c]	^{238}U[d]
		Under Buildings			
26	Bldg. C-1	10–35	0.82 ± 0.06	1.0	34
		35–60	0.98 ± 0.06	0.88	24
		60–85	0.68 ± 0.06	0.88	15
		85–105	2.3 ± 0.06	2.5	6.6
		105–130	2.7 ± 0.1	2.5	22
		130–150	2.2 ± 0.09	2.5	72
		150–175	2.1 ± 0.1	2.2	65
		175–195	2.3 ± 0.45	2.2	49
		195–245	0.77 ± 0.1	<1	36
27	Bldg. B-3	8–35	0.66 ± 0.03	0.69	5.3
		35–55	1.1 ± 0.12	0.9	17
		55–75	0.56 ± 0.05	0.67	16
		75–100	0.60 ± 0.06	0.75	1.8
		100–145	0.54 ± 0.06	0.67	5.6

[a]Locations of soil samples are shown on Fig. 8.

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

[c]The error of the reported radionuclide concentration is ± 5% (95% confidence level).

[d]Total analytical error of measurement results is less than ± 5% (95% confidence level).

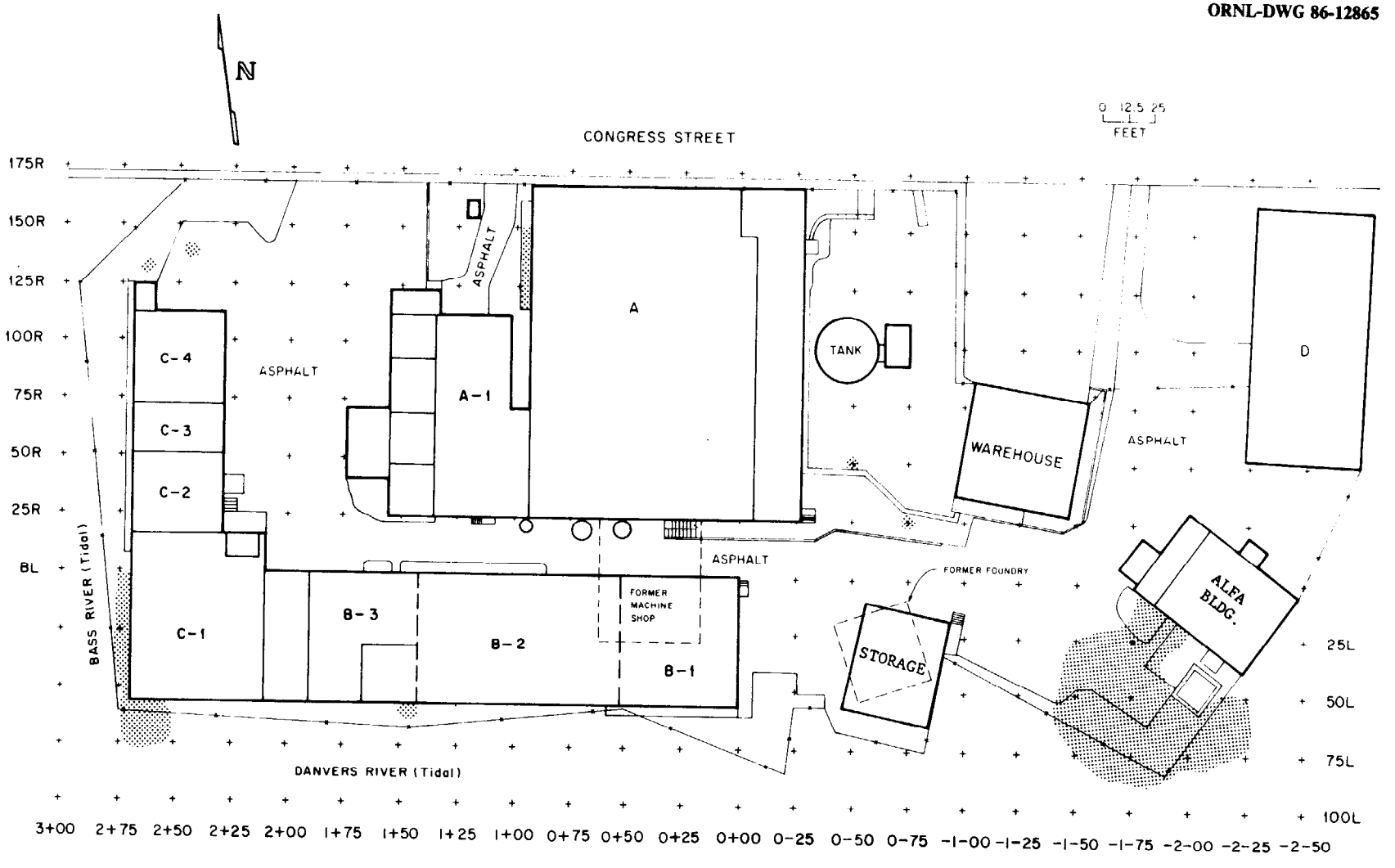

Fig. 9. Contaminated regions outdoors at the Ventron site as indicated by soil sample analyses.

Table 7. Extent of subsurface contamination at the Ventron site as indicated by scintillation probe loggings and soil sample analyses

Hole	Location[a]	Depth of hole (m)	Estimated vertical extent of contaminated soil[b] (m)	Region of maximum contamination (m)	Radionuclide concentration in region of maximum contamination (pCi/g)		
					^{226}Ra[c]	^{232}Th[d]	^{238}U[e]
1	−1−65, 65L	2.6	0–2.6	0–0.3	0.66 ± 0.07	15	3.7
2	−2−00, 30L	3.4	0–3.4	0–0.15	3.2 ± 0.4	12	26
3	−1−78, 40L	3.4	f	f	0.74 ± 0.02	1.4	6.5
4	−1−97, 55L	3.5	0–3.5	1.1–1.3	Not Sampled		
5	−1−40, 33L	2.3	0–2.3	0–0.3	0.84 ± 0.08	5	5.6
6	0+35, 12L	2.4	f	f	0.77 ± 0.04	0.87	1.9
7	1+95, 60R	0.76	f	f	0.43 ± 0.06	0.42	5.4
8	2+42, 137R	3.2	0–3.2	0–0.3	0.87 ± 0.04	0.85	60
9	−1−00, 26L	2.6	f	f	0.91 ± 0.3	0.74	3.1
10	−2−00, 125R	1.4	f	f	0.77 ± 0.04	0.85	4.5
11	2+70, 30L	0.75	0–0.75	0.45–0.6	<1	46	62,000
12	1+45, 60L	0.51	0–0.51	0–0.15	30 ± 0.7	0.82	45
13	−1−60, 55L	2.3	0–0.3	0–0.2	0.92 ± 0.4	53	8.1
14	−1−95, 30L	3.05	0–0.3	0–0.15	1.2 ± 0.05	41	30
15	0+96, 127R	0.50	0–0.5	0.15–0.45	1.4 ± 0.1	1.2	590
16	1+50, 3R	0.25	f	f	0.74 ± 0.09	0.70	3.7
17	0+98, 2R	0.20	f	f	0.78 ± 0.03	0.62	3.7
18	Bldg. B-1	1.6	0–0.91	0.18–0.3	<1	<1	14,000
19	Bldg. B-2	2.2	0–2.2	0.10–0.35	<1	<1	71,000
20	Bldg. B-2	1.6	0–0.76	0.15–0.3	2.7 ± 0.6	<1	1,900
21	Bldg. B-2	0.61	0–0.61	0.08–0.25	1.2 ± 20	1.2	440
22	Bldg. B-2	0.3	0–0.3	0.08–0.3	1.2 ± 0.08	0.97	90
23	Bldg. B-3	1.7	f	f	1.0 ± 0.07	0.40	10
24	Bldg. C-1	2.1	0–2.1	0.35–0.65	2.0 ± 1	2.2	1,400
25	Bldg. C-1	2.2	0.3–2.2	1.6–1.8	3.4 ± 1	3.1	940
26	Bldg. C-1	2.5	0.76–2.5	1.3–2.0	2.2 ± 0.09	2.5	72
27	Bldg. B-3	1.5	f	f	1.1 ± 0.12	0.9	17

[a]Location shown on Fig. 8.

[b]Contaminated soil is defined as soil having concentrations of ^{226}Ra or $^{232}Th \geq$ than the criteria given in Table 2, or giving rise to 1000 cpm or more on the shielded scintillator.

[c]Indicated counting error is at the 95% confidence level ($\pm 2\ \alpha$).

[d]The error of the reported radionuclide concentration is ± 5% (95% confidence level).

[e]The total analytical error is ± 5% (95% confidence level).

[f]No measurement above criteria given in [b] above.

The gamma logging data and the soil sample analyses results were used to estimate the depth of contamination in the bore holes (Table 7). Contamination beneath the basement floors of Buildings B-1, B-2, and C-1 extends to 2.5 m. In the southeast portion of the site (holes 2 and 4), the depth of contamination appears to be >3 m.

3.1.4 Sediment Samples

Sediment samples were taken from three of the four storm sewer manholes located as shown on Fig. 10. Table 8 lists the concentrations of ^{226}Ra, ^{232}Th, and ^{238}U found in those samples. Radionuclide analysis of the sediment samples indicated ^{226}Ra concentrations exceeded 5 pCi/g in all three samples and ^{232}Th was as high as 21 pCi/g in one sample (the other two were equal to background).

3.2 INDOOR SURVEY RESULTS

Surface contamination levels measured on the site are compared in this report with DOE guidelines for release of property for unrestricted use. The major contaminant on the Beverly site is ^{238}U. DOE guidelines specify that average and maximum direct alpha measurements of uranium and natural uranium (uranium in equilibrium with its decay products) should not exceed 5000 and 15,000 dpm/100 cm^2, respectively, and transferable alpha should not exceed 1000 dpm/100 cm^2. Records and survey data also indicate ^{232}Th was used at this site. Average and maximum surface contamination limits for ^{232}Th are 1000 and 3000 dpm/100 cm^2, respectively, and 200 dpm/100 cm^2 for transferable alpha. Furthermore, average and maximum beta-gamma dose rates for all radionuclides should not exceed 0.20 mrad/h and 1.0 mrad/h, respectively. Unless otherwise stated, beta-gamma dose rates between 0.20 mrad/h and 1.0 mrad/h reported in this document are average measurements over an area of not more than 1 m^2 and are considered to be above DOE guidelines.

Whenever feasible, data from the indoor survey are displayed in figures rather than tables. Where grid blocks are shown in a figure, it should be assumed that measurements were taken in each survey block as described in Sect. 2.2, unless stated otherwise in the text. The absence of data for a particular type of measurement in a grid block or other defined area on any given figure should be interpreted as meaning that that particular measurement was below guidelines. Blocks which were completely inaccessible are labeled as such. The following notation is used in many of the figures in this report:

$d\alpha$ = direct alpha measurements in dpm/100 cm^2,

$d\beta$-γ = directly measured beta-gamma dose rates in mrad/h measured at 1 cm distance from surfaces,

$t\alpha$ = transferable alpha contamination level in dpm/100 cm^2,

$t\beta$ = transferable contamination level in dpm/100 cm^2,

γ = gamma radiation level at the surface in $\mu R/h$.

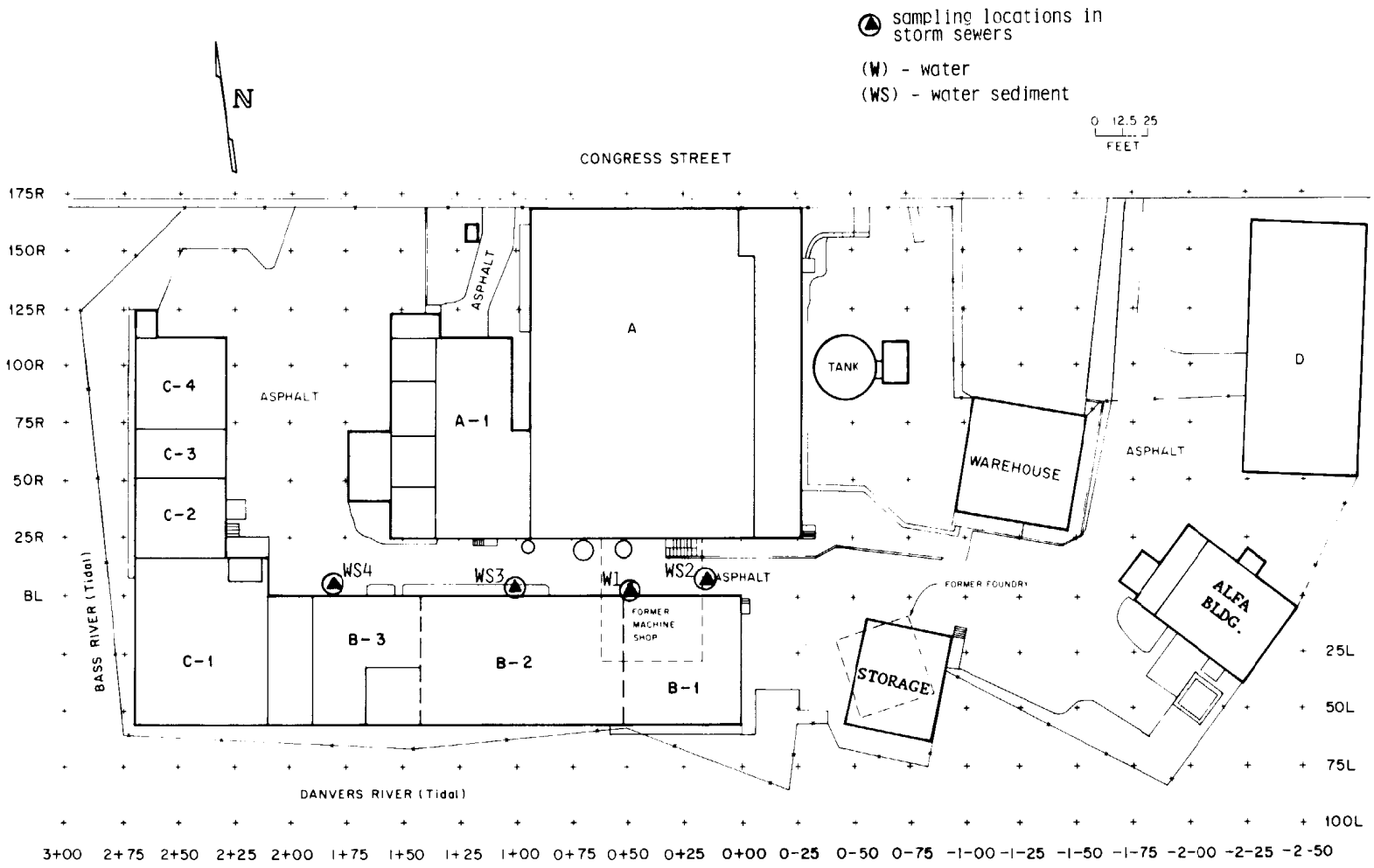

Fig. 10. Locations of sediment samples taken from storm sewers at the Ventron site.

Table 8. Concentration of radionuclides in sediment samples from storm sewers at the Ventron site

Sample number	Location[a]	Radionuclide concentration (pCi/g)		
		^{226}Ra[b]	^{232}Th[b]	^{238}U[c]
1	No sample taken			
2	0+10, 10R	100 ± 3	<1	1.5
3	1+00, 6R	13 ± 0.31	0.9 ± 0.05	25
4	1+80, 6R	7.4 ± 0.28	21 ± 0.28	1.2

[a]Locations of samples are shown on Fig. 10.
[b]Indicated counting error is at the 95% confidence level (± 2 σ).
[c]Total analytical error of measurement results is less than ± 5% (95% confidence level).

Any small oval, circular, or rectangular area shown on the figures and associated with an elevated measurement is intended only as a first approximation of the extent of the contaminated area and is not drawn to scale.

3.2.1 Building A

Building A was used for uranium processing activities and contains one main floor and a basement. On the first floor were offices and laboratories on the east side of the building, with shipping and receiving areas in the northwest quadrant. Some of the rooms had been converted from processing areas to office rooms by the addition of dropped ceilings, finished walls, etc. Processing activities were being carried out in the remainder of the first level. Figure 11 shows the layout of the entire building.

Gamma exposure rates measured near the center of grid blocks and during the scan of grid blocks in the building and on the roof are given in Table 9, averaged by room, grid block, or type of structure. Exposure rates in first floor and basement rooms ranged from 7 to 52 μR/h during the scan of accessible areas and averaged 12 μR/h both at 1 m above the surface and at the surface near the center points of grid blocks. Gamma levels in overhead regions ranged from 13 to 78 μR/h and were 7 to 160 μR/h on the roof.

Alpha and beta-gamma measurements taken inside the building and on the roof are listed by location in Table 10. Numerous regions in which levels were higher than the average for the same survey block were observed in rooms 20 and 29 where processing activities would be expected to result in residual contamination. By comparison, little contamination was detected during the grid block survey of other first floor rooms. However, measurements approaching and exceeding DOE guidelines were noted in several areas, including overhead regions, as indicated in Fig. 11 and associated Tables. The areas designated by lowercase letters (a through e) indicate locations of contamination on floors and/or lower walls. An area under a weighing table in room 19 gave a direct alpha measurement of 2500 dpm/100 cm^2. Two areas in room 27, one in the northeast corner and the other at the floor/wall interface at the south wall, had associated beta-gamma dose rates of 0.3 mrad/h. Finally, gamma exposure rates were 26 to 32 μR/h at the locations indicated in room 28.

Table 11 lists the radiological measurements taken in 13 regions of the floor drain troughs. The locations of the measurements are exhibited on Fig. 11. Surface contamination in the troughs was evidenced by direct alpha activities ranging to 2000 dpm/100 cm^2. Furthermore, beta-gamma dose rates were 0.2 mrad/h and higher in four of the trough regions. The maximum beta-gamma dose rate measured was 1.7 mrad/h.

The level of contamination in overhead regions in rooms other than 20 and 29 is indicated by the data given in Table 12. Beta-gamma dose rates of 0.01 to 1 mrad/h were found in association with alpha activities ranging from 40 to 350 dpm/100 cm^2. Gamma exposure rates were also elevated in several of the regions, ranging from 13 to 78 μR/h. Transferable alpha and beta-gamma contamination in one area in room 30 measured 52 and 122 dpm/100 cm^2, respectively (below the thorium limit). All other measurements of transferable contamination in overhead regions were lower. Most of the elevated gamma readings found in room 28 were due to contamination on the roof above.

Table 9. Gamma exposure rate measurements in Building A at the Ventron site

Location[a]	Center point measurements[b] (μR/h)		Range of gamma exposure rates from scan of grid blocks[c] (μR/h)	Average gamma exposure rate from scan of grid blocks[c] (μR/h)
	Average gamma exposure rate at 1 m	Average gamma exposure rate at the surface		
First level				
Room 1	10	10	9–11	10
2	12	12	8–15	12
3	14	15	12–19	16
4	12	12	10–14	12
5	9	10	7–12	10
6	8	8	7–10	8
7	15	15	12–17	14
8	15	13	12–15	14
9	11	11	10–14	12
10	12	12	10–15	13
11	11	12	12–17	14
12	15	15	12–16	14
13	11	11	10–13	11
14	9	10	7–11	9
15	10	11	7–11	10
16	12	12	11–14	12
17	12	12	10–15	13
18	13	13	11–15	13
19	12	12	10–14	12
20	12	12	7–52	12
21	10	11	10–12	11
22	10	10	10–12	10
23	11	12	11–15	12
24	11	12	12–14	13
25	17	16	10–17	19
26	17	13	12–19	14
27	16	16	12–19	20
28	21	17	10–32	19
29	14	16	11–32	16
30	10	10	7–17	10
31	13	13	12–15	14
32	10	11	8–14	11
33	11	12	7–15	11
34	8	10	8–11	9
35	11	11	11–17	13
36	10	12	8–14	11
37	12	12	10–14	12

Table 9 (continued)

Location[a]	Center point measurements[b] (μR/h)		Range of gamma exposure rates from scan of grid blocks[c] (μR/h)	Average gamma exposure rate from scan of grid blocks[c] (μR/h)
	Average gamma exposure rate at 1 m	Average gamma exposure rate at the surface		
Overhead				
Room 20	d	d	13–52	23
28	d	d	13–78	52
30	d	d	–	50
Basement				
Room 1	11	12	7–15	11
2	9	10	7–13	10
3	10	10	7–45	10
Roof				
Grid block A	d	d	7–160	30
B	d	d	7–130	13
C	d	d	7–13	9
D	d	d	6–12	8
E	d	d	5–17	8
Fan duct 37	d	d	–	36
Wall vents	d	d	11–15	14
Hooded vent 33	d	d	–	36

[a]Location shown on Figs. 11, 19, and 22.
[b]Center point measurements are discrete measurements near the center of each grid block.
[c]Grid block measurements are obtained by a scan of the entire block.
[d]No measurement taken.

Table 10. Alpha and beta-gamma measurements in Building A at the Ventron site

Location[a]	Directly measured contamination				Transferable contamination			
	Alpha (dpm/100 cm²)		Beta-gamma dose rate at 1 cm (mrad/h)		Alpha (dpm/100 cm²)		Beta-gamma (dpm/100 cm²)	
	Average	Range	Average	Range	Average	Range	Average	Range
First level								
Room 1	20	0–40	0.02	–	b	b	b	b
2	20	0–40	0.01	–	c	–	c	–
3	20	0–40	0.01	–	b	b	b	b
4	30	0–40	0.02	–	b	b	b	b
5	20	0–40	0.02	–	b	b	b	b
6	20	0–40	0.02	–	b	b	b	b
7	30	20–40	0.02	–	b	b	b	b
8	20	0–40	0.02	–	b	b	b	b
9	10	0–20	0.02	–	b	b	b	b
10	10	0–20	0.02	–	c	–	c	–
11	10	0–40	0.03	–	c	–	82	–
12	30	20–60	0.02	–	b	b	b	b
13	30	20–40	0.02	0.01–0.02	b	b	b	b
14	30	20–40	0.01	–	b	b	b	b
15	20	0–40	0.01	–	b	b	b	b
16	20	0–40	0.01	–	b	b	b	b
17	20	0–40	0.01	–	b	b	b	b
18	10	0–20	0.02	–	c	–	27	–
19	370	0–2,500	0.02	–	3	–	c	–
20	270	0–4,200	0.56	0.02–3	c	–	c	–
21	30	0–40	0.02	–	c	–	c	–
22	<10	0–20	0.02	0.01–0.02	c	–	c	–
23	10	0–20	0.02	–	b	b	b	b
24	0	0–0	0.01	–	b	b	b	b
25	20	0–40	0.03	0.02–0.03	c	–	41	–
26	40	–	0.03	–	b	b	b	b
27	20	0–20	0.19	0.05–0.3	b	b	b	b
28	40	0–80	0.03	0.20–0.05	c	–	41	0–82
29	380	40–760	0.46	0.03–1.5	c	–	c	–
30	<97	0–2,900	0.03	0.01–0.25	b	b	b	b
31	20	0–40	0.01	–	b	b	b	b
32	30	20–40	0.02	0.01–0.02	c	–	95	–
33	30	0–60	0.02	0.02–0.02	c	–	54	–
34	30	20–40	0.01	–	b	b	b	b
35	30	20–40	0.02	–	b	b	b	b
36	30	20–40	0.02	–	b	b	b	b
37	20	0–40	0.03	–	b	b	b	b

Table 10 (continued)

Location[a]	Directly measured contamination				Transferable contamination			
	Alpha (dpm/100 cm²)		Beta-gamma dose rate at 1 cm (mrad/h)		Alpha (dpm/100 cm²)		Beta-gamma (dpm/100 cm²)	
	Average	Range	Average	Range	Average	Range	Average	Range
Overhead								
Room 10	300	–	0.02	–	3	–	68	–
11	10	–	0.02	–	b	b	b	b
12	10	–	0.02	–	b	b	b	b
19	130	60–210	0.14	0.05–0.3	b	b	b	b
20	10	0–110	0.3	0.02–2	b	b	b	b
28	130	40–280	0.13	0.01–0.2	b	b	b	b
29	580	100–760	0.26	0.01–0.85	b	b	b	b
30	70	0–350	0.19	0.01–1.3	52	–	122	–
32	30	0–120	0.05	0.01–0.15	c	c	c	c
Basement								
Room 1	50	0–200	0.21	0.02–1.9	b	b	b	b
2	100	40–570	0.26	0.01–1.3	b	b	b	b
3	80	0–280	0.06	0.02–0.3	b	b	b	b
Roof								
Grid block A	350	0–700	0.17	0.05–0.32	b	b	b	b
B	c	c	0.06	0.02–0.22	c	c	b	b
C	c	c	0.02	–	b	b	b	b
D	b	b	0.02		c	c	b	b
Fan duct	150		5	–	c	c	c	c
Wall vents	400	0–1,600	0.13	0.01–0.75	b	b	b	b
Hooded vents	7,500	4,900–10,000	1.1	0.01–2.2	c	c	c	c

[a]Location shown on Figs. 11, 19, and 22.
[b]No measurement taken.
[c]Measurement could not be distinguished from background.

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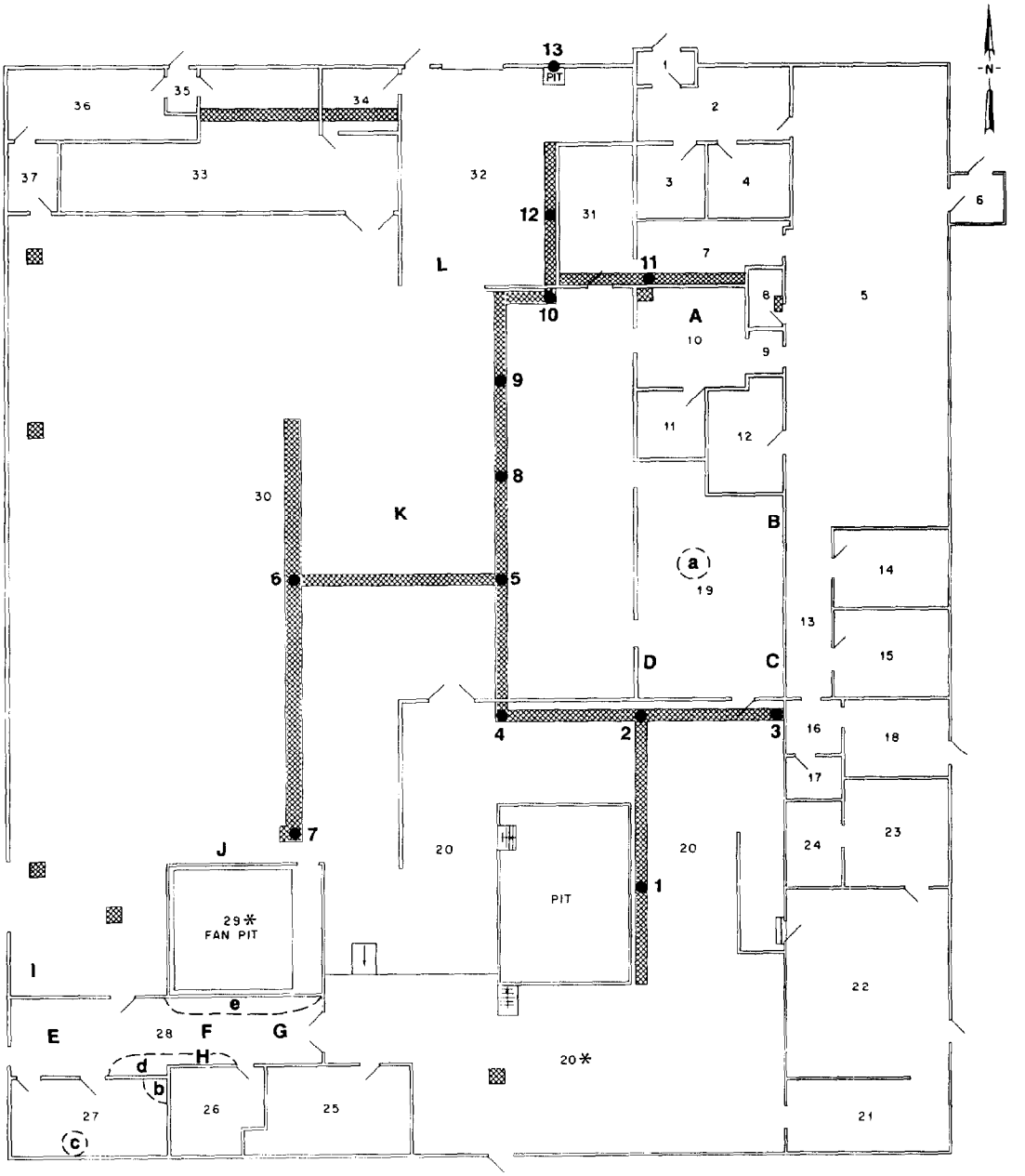

1 – 13 = LOCATIONS OF DRAIN TROUGH MEASUREMENTS (TABLE 11).
A – L = CONTAMINATED AREAS IN OVERHEAD REGIONS (TABLE 12).
(a) – (e) = CONTAMINATED AREAS DISCUSSED IN TEXT.
* = FIGS. 14 AND 15 SHOW CONTAMINATED REGIONS IN ROOMS 20 AND 29.

BUILDING "A" FIRST FLOOR

TREADPLATE COVERS OVER DRAIN TROUGHS AND CRAWL SPACE ACCESS

Fig. 11. Location of contaminated areas on the first level of Building A at the Ventron site.

Table 11. Alpha, beta-gamma, and gamma measurements in drain troughs in Building A at the Ventron site

Room/ Location[a]	Average direct alpha activity on surface (dpm/100 cm^2)	Beta-gamma dose rate at 1 cm above surface (mrad/hr)	Average gamma exposure rate (μR/h)
20/1	2000	1.7	26
20/2	130	0.1	45
20/3	600	0.2	15
20/4	[b]	0.05	16
30/5	[b]	0.02	10
30/6	[b]	0.01	7
30/7	[b]	0.01	10
30/8	[b]	0.03	10
30/9	1600	0.25	12
30/10	320	0.05	14
7/11	800	0.06	12
32/12	1500	0.3	14
32/13	500	0.05	14

[a]Location indicated on Fig. 11.
[b]Measurements could not be distinguished from background.

Table 12. Alpha, beta-gamma, and gamma measurements in contaminated areas of overhead regions of Building A at the Ventron site

Room/ location[a]	Directly measured contamination		Average gamma reading from scan (μR/h)
	Alpha (dpm/100 cm^2)	Beta-gamma dose rate at 1 cm from surface (mrad/h)	
10/A[b]	300	0.02	c
19/B	210	0.05	c
19/C	120	0.07	c
19/D	60	0.3	c
28/E	280	0.01	13
28/F	80	0.17	78
28/G	40	0.2	65
28/H	c	c	77
30/I	250	0.6	50
30/J[d]	350	1	c
30/K	100	0.01	c
32/L	120	0.2	c

[a]Location shown on Fig. 11.

[b]This area showed transferable alpha and beta-gamma contamination levels of 3 and 68 dpm/100 cm^2, respectively.

[c]Measurement could not be distinguished from background.

[d]This area showed transferable alpha and beta-gamma contamination levels of 52 and 120 dpm/100 cm^2, respectively.

In room 20, crushing, leaching, and retorting processes were carried out. A view of the base of the rotary kiln above the acid leaching pit is provided in Fig. 12. Another photograph taken from the pit shows the raised wooden roof above (Fig. 13). The regions where radiological measurements exceeded DOE guidelines or where alpha measurements exceeded 100 dpm/100 cm^2 (10% of the thorium limit) are identified on Fig. 14. Surface contamination exceeding guidelines was found on walls, floors, and overhead surfaces in this room. Beta-gamma dose rates ranged from 0.02 to 3 mrad/h, with the maximum occurring near a large piece of machinery located in the acid leach pit. Direct alpha measurements in the pit averaged 280 dpm/100 cm^2 with a maximum of 380 dpm/100 cm^2 in the center of the pit's north wall. Gamma radiation levels ranged from 20 to 31 μR/h on the walls and floor of the pit.

The maximum level of alpha contamination noted in room 20 was 4200 dpm/100 cm^2 and was found in the northwest corner of survey block D4 near the drain trough. At the same point, the beta-gamma dose rate was 1.7 mrad/h. A crack in the floor outside the northeast corner of the pit gave a beta-gamma dose rate of 0.6 mrad/h. Elevated beta-gamma dose rates ranging from 0.2 to 0.75 mrad/h were observed on top of, and inside, a shed located northwest of the pit and housing a rotary crusher. At the rotary kiln and surrounding gear above the pit, beta-gamma dose rates were 1.0 to 2.0 mrad/h. A fan overhead in the southeast corner of the pit gave a beta-gamma dose rate of 0.5 mrad/h. The alpha contamination levels overhead were generally 100 to 110 dpm/100 cm^2. Beta-gamma exposure rates overhead ranged to 2.0 mrad/h, and gamma radiation levels were 10 to 52 μR/h. Elevated gamma radiation levels measured overhead were increased significantly by secondary radiation from roof contamination.

The floor and walls of room 29, the fan pit, were divided into survey blocks as indicated on Fig. 15. Figure 16 is a view of the pit showing the process exhaust fan. A view looking above at the large fan duct and raised roof area is provided in Fig. 17. As indicated on the drawing in Fig. 15, there are a number of contaminated regions with measurements exceeding DOE guidelines. The maximum beta-gamma dose rate was 1.5 mrad/h with six measurements ranging between 0.2 and 1.5 mrad/h. In grid block B4' a variety of "hot spots" and miscellaneous structural cracks displayed beta-gamma contamination levels above guidelines. Gamma exposure rates were also elevated, ranging from 11 to 58 μR/h. Alpha activities ranging from 100 to 760 dpm/100 cm^2 were found by direct reading on the walls, windows, and overhead surfaces of the pit.

In room 30, white powder covering areas of the kilns (Fig. 18) displayed alpha activities ranging from 60 to 2700 dpm/100 cm^2. The surrounding surfaces of the bowls in the kilns read an average of 900 dpm/100 cm^2 with a maximum of 2900 dpm/100 cm^2. The beta-gamma dose rates averaged 0.25 mrad/h. At the time of the survey, the powder was being used in an ongoing commercial process.

Gamma measurements ranged from 5 to 160 μR/h on the roof of Building A. The locations of the grid blocks are shown on Fig. 19, and Table 13 details the level of contamination. Surface contamination was evident in scattered locations over the roof as well as in association with fan and vent structures as indicated. Residual contamination would be expected on these structures through which fumes and dust from the processing activities would have exited. In general, gamma exposure rates increased from northeast to

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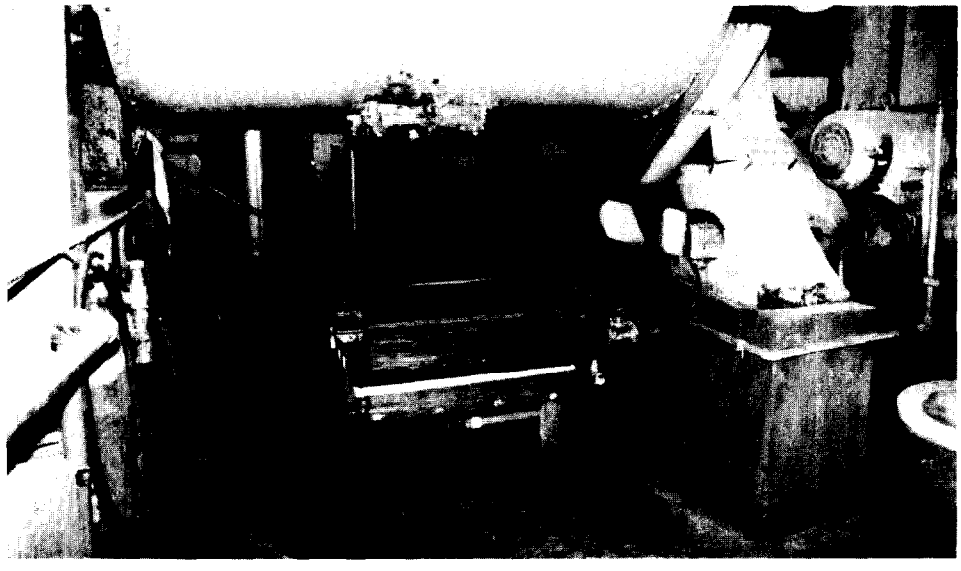

Fig. 12. View of rotary kiln in room 20, Building A, at the Ventron site.

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Fig. 13. View of region above pit in room 20, Building A, at the Ventron site.

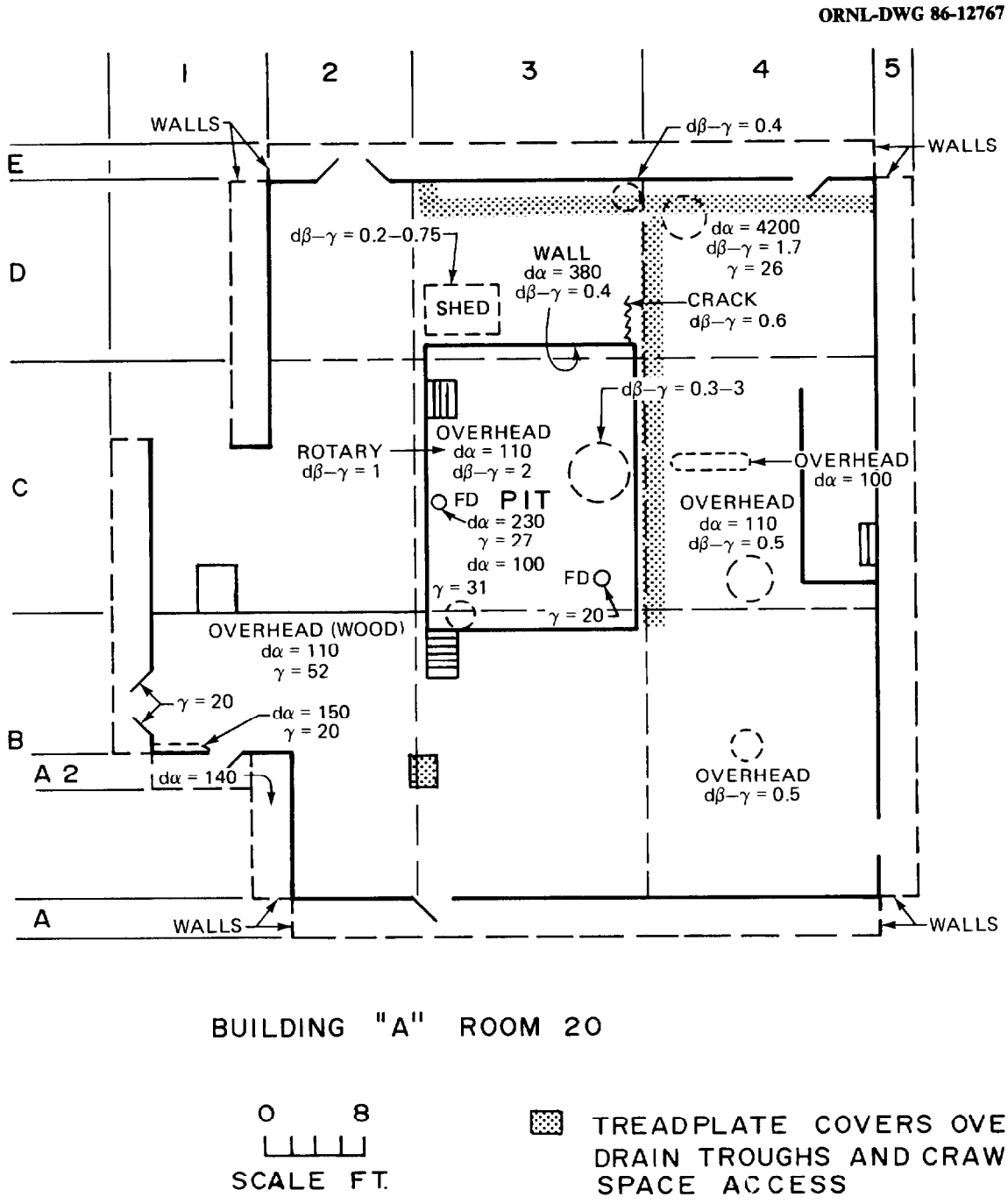

Fig. 14. Location of contaminated areas in room 20, Building A, at the Ventron site.

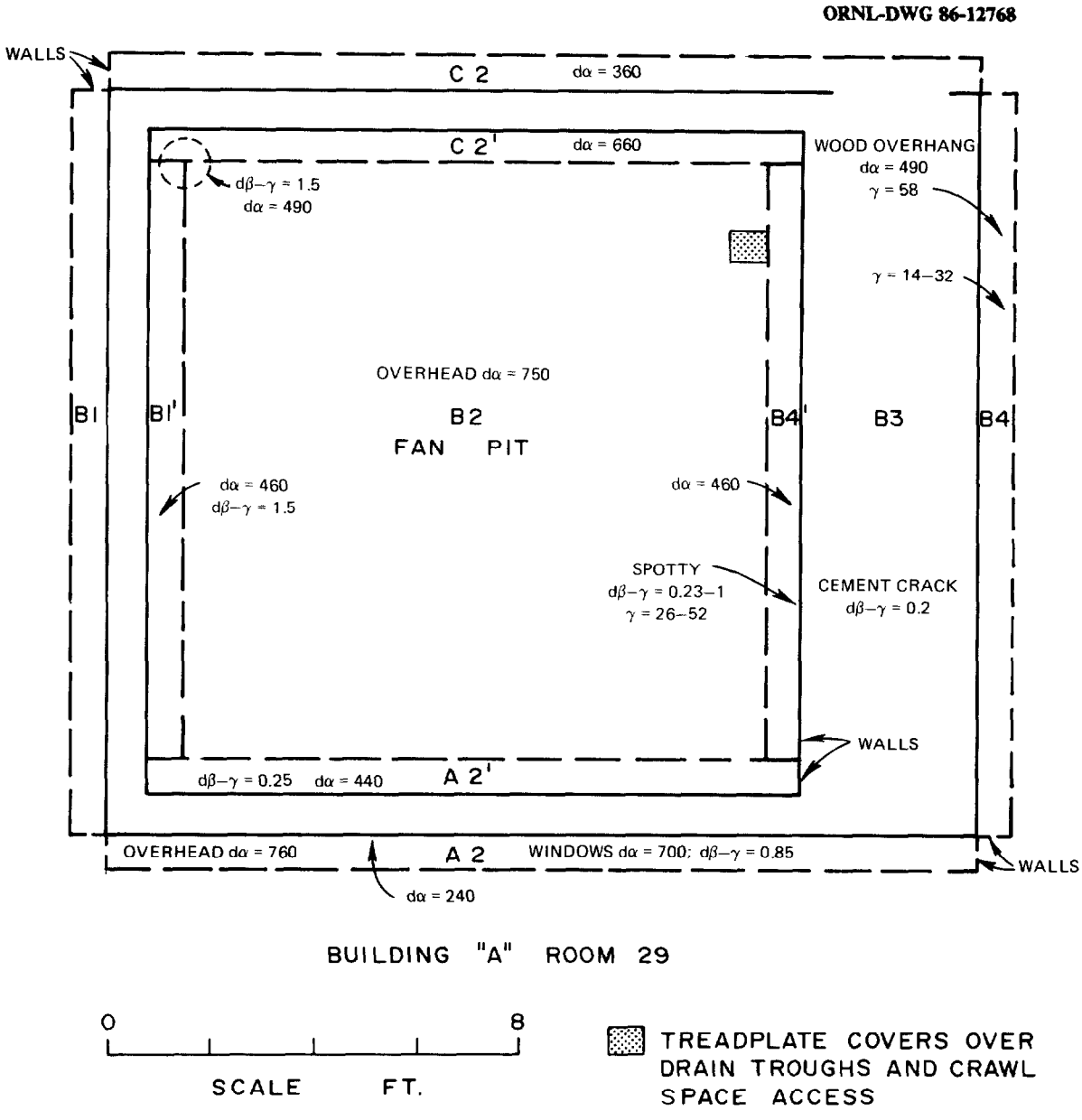

Fig. 15. Location of contaminated areas in room 29, Building A, at the Ventron site.

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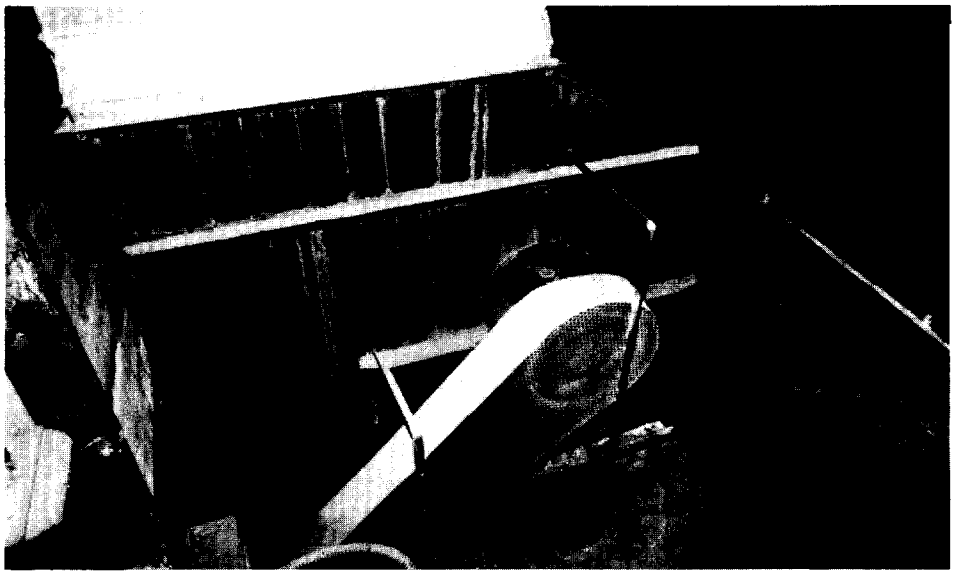

Fig. 16. View of the exhaust fan in room 29, Building A, at the Ventron site.

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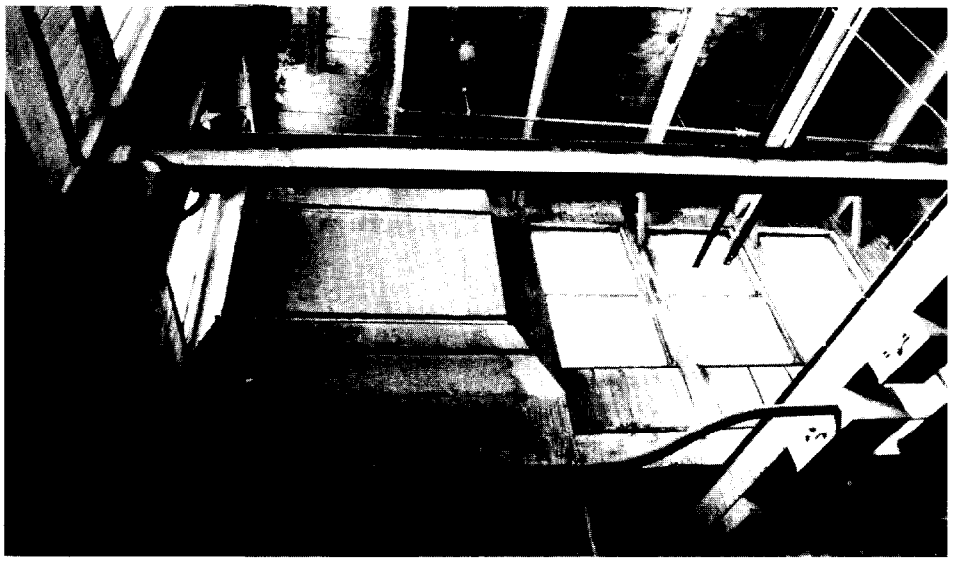

Fig. 17. View of the fan duct and raised roof above room 29, Building A, at the Ventron site.

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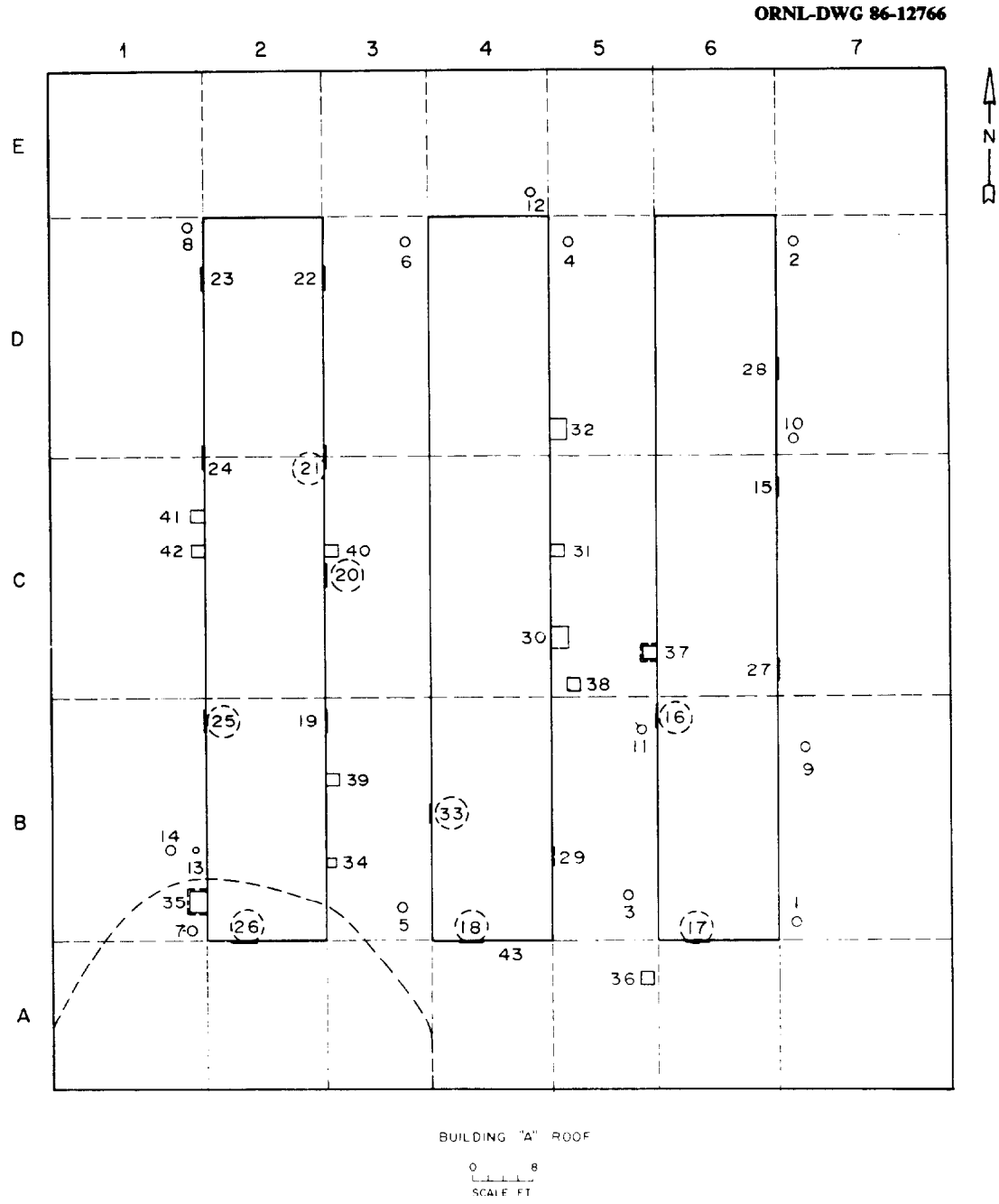
Fig. 18. View of kilns in room 30, Building A, at the Ventron site.



NOTE: HATCHED LINES INDICATE AREAS OF ELEVATED MEASUREMENTS.

Fig. 19. Location of contaminated areas on the roof of Building A at the Ventron site.

Table 13. Alpha, beta-gamma, and gamma measurements in contaminated areas on the roof of Building A at the Ventron site

Location[a]	Directly measured contamination		Average gamma reading from scan (μR/h)
	Alpha (dpm/100 cm^2)	Beta-gamma dose rate at 1 cm above surface (mrad/h)	
Grid block			
A1	[b]	[b]	39
A2	700	0.32	78
A3	[b]	0.22	45
B3	[b]	0.22	13
Wall vent			
16	420	0.15	15
17	150	0.30	11
18	140	[b]	[b]
20	210	0.01	14
21	980	0.05	[c]
25	490	0.05	[c]
26	1,600	0.75	[c]
Hooded vent			
33	10,000	2.3	36
35	4,900	[b]	[d]
Fan duct			
37	150	5	36

[a]Location shown on Fig. 19.
[b]No measurement taken.
[c]Measurement could not be distinguished from background.
[d]No measurement possible due to nearby surface contamination.

southwest with the maximum measurement of 160 μR/h found in grid blocks A2 and A3 where, apparently, residuals were funneled from room 29 below through the hooded vent as shown in Fig. 20. A view of this contaminated region, facing northwest from the hooded vent, is shown in Fig. 21. Fan duct number 37 in survey blocks C5 and C6 is above the rotary leach tank in room 20 below. The level of alpha contamination in that duct was observed to be 150 dpm/100 cm^2 with an average beta-gamma dose rate of 5 mrad/h. Overall direct alpha measurements on the roof ranged from 140 to 10,000 dpm/100 cm^2 in the contaminated areas with directly measured beta-gamma dose rates ranging to 2.3 mrad/h.

Most radiological measurements taken in rooms 1 and 2 of the basement of Building A did not differ significantly from background. The areas identified as having maximum contamination levels are shown on Fig. 22. Only two of these areas exceed DOE guidelines. Beta-gamma dose rates of 1.3 mrad/h were measured on both sides of doors at the southwest end of room 2. Surface contamination in this area was indicated by alpha activities of 570 dpm/100 cm^2. A wall ledge along the east part of the north wall in room 1 disclosed a maximum beta-gamma dose rate of 1.9 mrad/h. The associated alpha activity was 200 dpm/100 cm^2. In room 3, survey blocks through which a trough ran east to west displayed an average alpha contamination level of 120 dpm/100 cm^2 and a maximum gamma exposure rate of 45 μR/h. Above floor drain number 2 in room 3, the directly measured beta-gamma dose rate was 0.1 mrad/h. Within the drain, it was 0.3 mrad/h. Additionally, alpha contamination was identified on several wall surfaces, ranging from 100 to 280 dpm/100 cm^2.

3.2.2 Building A-1

Building A-1 constitutes an addition to Building A and contained facilities for the production of distilled calcium and the drying of uranium oxide powder, a machine shop, and electric furnaces and kilns. A drawing of the interior floor plan is presented in Fig. 23.

Gamma exposure rates measured near the center of grid blocks and during the scan of grid blocks in Building A-1 and on the roof are given in Table 14. Exposure rates in first floor and basement rooms ranged from 7 to 45 μR/h during the scan of accessible areas, averaging 12 μR/h at 1 m from the surface and 13 μR/h at the surface near the center point of grid blocks. Gamma levels in overhead regions and on the roof ranged from 8 to 12 μR/h and from 7 to 26 μR/h, respectively.

Alpha and beta-gamma measurements taken within the building and on the roof are provided in Table 15. The location of regions in which measurements exceeded 100 dpm/100 cm^2 is shown in Fig. 23. Five of the regions, designated a through e, are located in room 5. The contamination, manifested in every case as alpha activity, showed direct measurements of 110 to 2600 dpm/100 cm^2. Two of the measurements in room 5 were found at vents to the ceiling. The maximum level of alpha contamination, 2600 dpm/100 cm^2, was measured at one of these vents. The other contaminated areas were located at the juncture of floors and walls. The alpha levels determined in regions f and g (180 and 160 dpm/100 cm^2 respectively) were measured during grid block scans of rooms 8 and 9.

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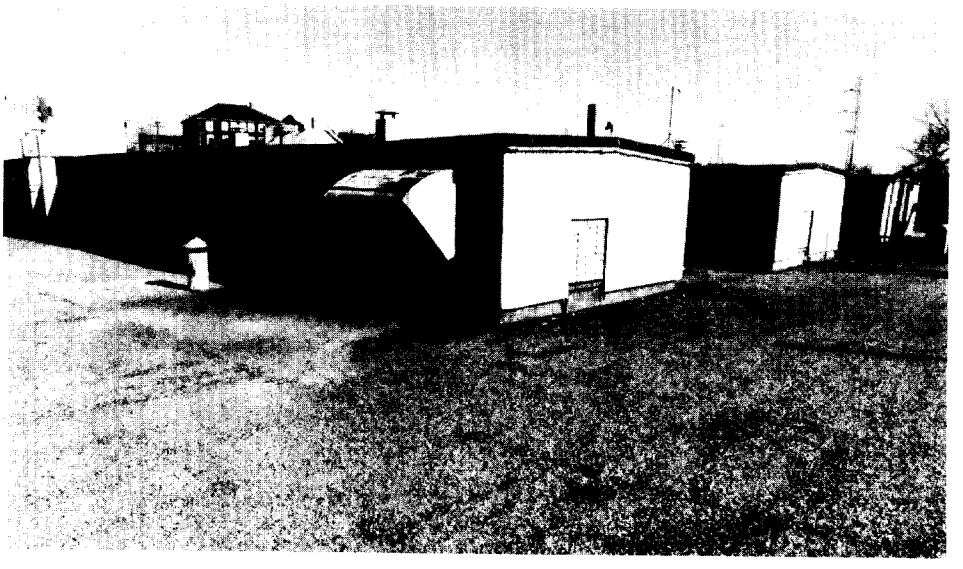

Fig. 20. View of the roof with hooded vent, Building A, at the Ventron site.

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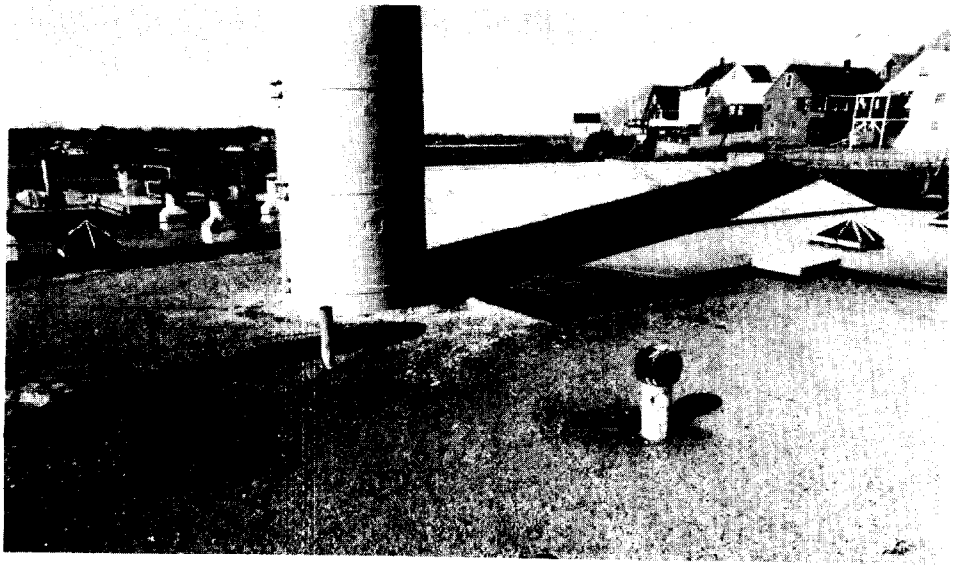

Fig. 21. View of the contaminated region of the roof, Building A, at the Ventron site.

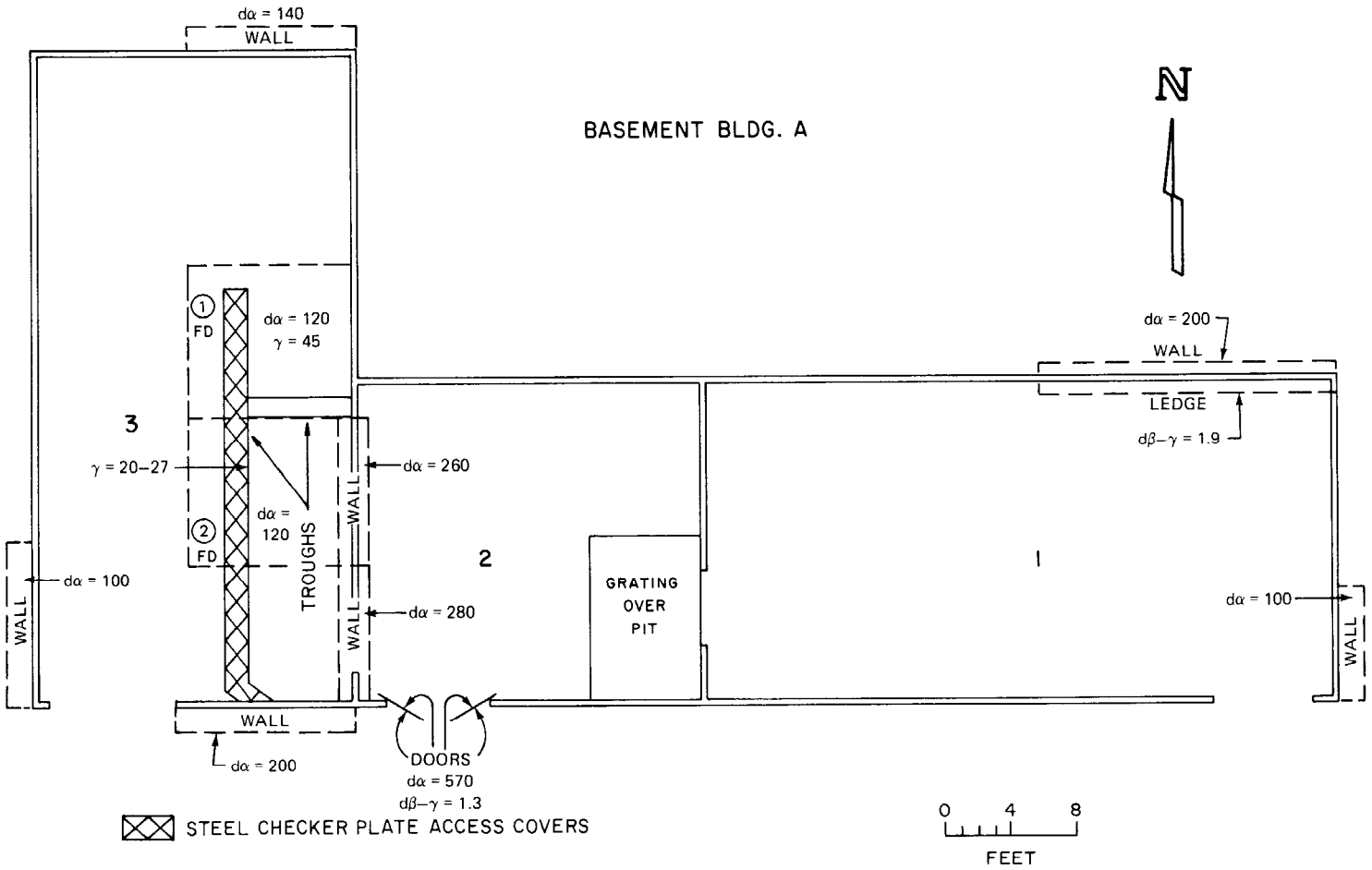

Fig. 22. Location of contaminated areas in the basement of Building A at the Ventron site.

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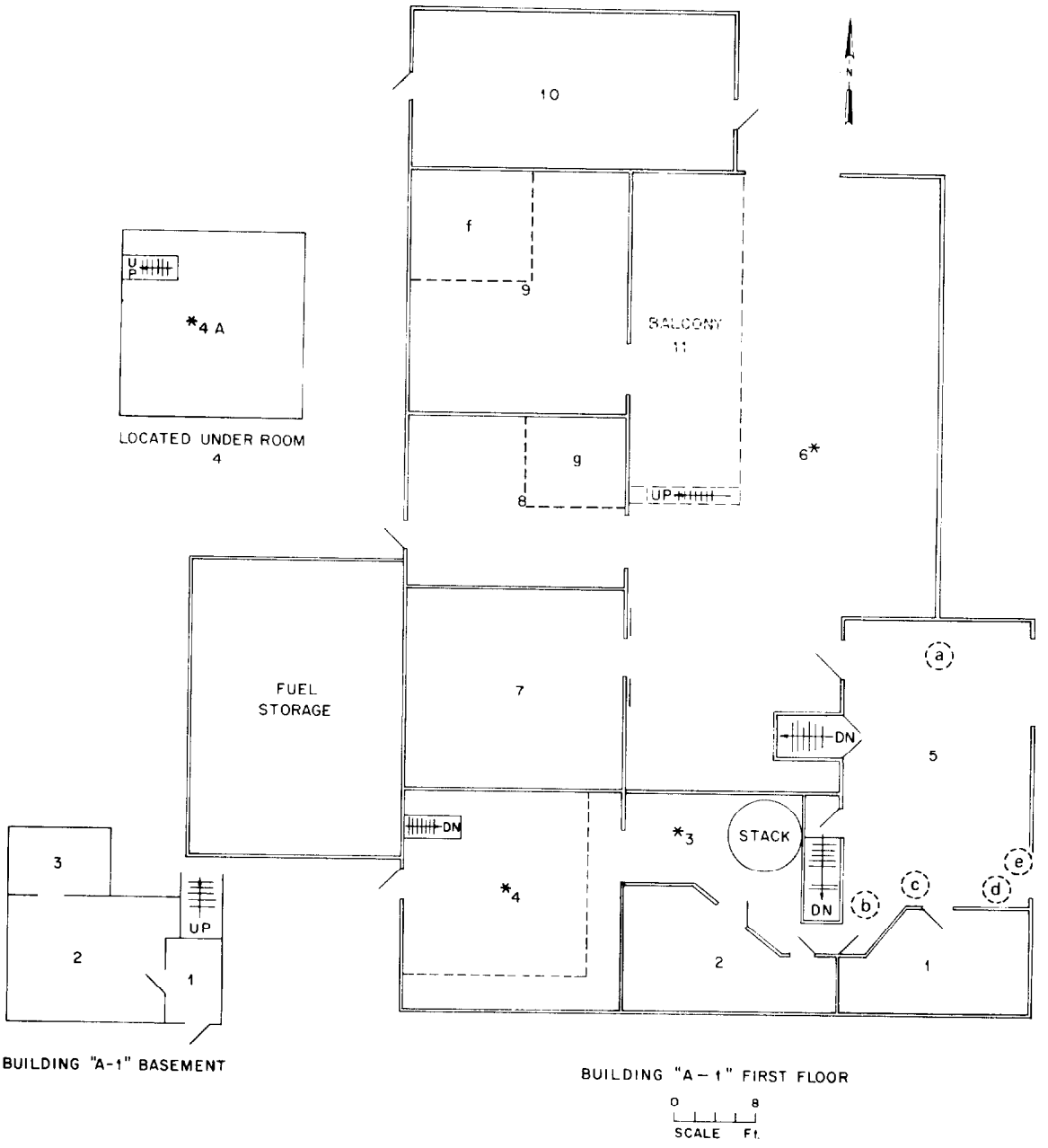

Fig. 23. Location of contaminated areas in Building A-1 at the Ventron site.

Table 14. Gamma exposure rate measurements in Building A-1 at the Ventron site

Location[a]	Center point measurements[b] (μR/h)		Range of gamma exposure rates from scan of grid blocks[c] (μR/h)	Average gamma exposure rate from scan of grid blocks[c] (μR/h)
	Average gamma exposure rate at 1 m	Average gamma exposure rate at the surface		
First level				
Room 1	13	14	11–17	14
2	13	13	11–17	13
3	16	16	12–29	16
4	12	13	10–19	12
5	13	13	10–19	12
6	12	12	7–45	12
7	12	13	8–16	12
8	12	12	11–19	12
9	12	12	10–17	13
10	13	13	10–19	14
Overhead				
Room 5	d	d	–	10
6	d	d	8–12	11
Basement				
Room 1	14	15	10–19	15
2	14	15	11–16	14
3	13	14	11–15	13
4	11	12	10–18	12
Roof				
Grid blocks	d	d	10–26	13
Skylights	d	d	7–19	12
Vents, drains	d	d	7–21	12

[a]Location shown on Figs. 23 and 31.

[b]Center point measurements are discrete measurements near the center of each grid block.

[c]Grid block measurements are obtained by a scan of the entire block.

[d]No measurement taken.

Table 15. Alpha and beta-gamma measurements in Building A-1 at the Ventron site

Location[a]	Directly measured contamination				Transferable contamination			
	Alpha (dpm/100 cm²)		Beta-gamma dose rate at 1 cm (mrad/h)		Alpha (dpm/100 cm²)		Beta-gamma dose rate at 1 cm from surface (dpm/100 cm²)	
	Average	Range	Average	Range	Average	Range	Average	Range
First level								
Room 1	20	0–40	0.01	0.01–0.01	b	–	b	–
Room 2	30	0–40	0.03	0.02–0.03	b	–	b	–
Room 3	200	20–1,000	0.08	0.02–0.18	2	0–3	b	–
Room 4	280	0–2,100	0.13	0.02–0.45	6	–	b	–
Room 5	190	0–2,600	0.05	0.01–0.18	b	–	b	–
Room 6	550	0–12,500	0.27	0.01–4	100	0–590	56	0–310
Room 7	17	0–20	0.02	0.02–0.02	6	–	41	–
Room 8	50	0–160	0.04	0.03–0.05	6	–	110	–
Room 9	60	0–180	0.03	0.02–0.05	b	–	14	–
Room 10	30	0–40	0.03	0.01–0.1	c	c	c	c
Overhead								
Room 1	40	–	0.01	–	c	c	c	c
Room 2	c	c	0.01	–	c	c	c	c
Room 3	53	40–80	0.02	–	c	c	c	c
Room 4	3,000	40–6,000	0.56	0.15–1	c	c	c	c
Room 5	33	0–60	0.02	–	c	c	c	c
Room 6	86	20–100	0.12	0.01–0.5	c	c	c	c
Room 7	42	28–56	0.06	0.01–0.1	c	c	c	c
Room 9	53	42–56	0.02	0.01–0.05	c	c	c	c
Basement								
Room 1	b	–	0.03	0.02–0.03	c	c	c	c
Room 2	b	–	0.02	–	c	c	c	c
Room 3	b	–	0.02	0.02–0.02	c	c	c	c
Room 4A	340	70–1,700	0.29	0.02–1	12	–	b	–
Roof								
Grid blocks	c	c	0.34	0.1–0.6	c	c	c	c
Skylights	c	c	0.01	0.01–0.02	c	c	c	c
Vents	c	c	0.02	0.01–0.03	c	c	c	c
Drain	c	c	0.25	–	c	c	c	c

[a]Location shown on Figs. 23, 24–26, and 30.
[b]Measurements could not be distinguished from background.
[c]No measurement taken.

In room 3 (Fig. 24), which contained a stack and furnace, gamma exposure rates ranged from 12 to 29 μR/h. Average direct alpha activities found on floor and wall surfaces ranged from 20 to 120 dpm/100 cm^2. Alpha levels were higher on the floor and at the base of the stack, measuring 280 and 660 dpm/100 cm^2, respectively. A direct beta-gamma dose rate of 0.18 mrad/h was detected at the base of the stack. The maximum direct alpha measurement of 1000 dpm/100 cm^2 was made in grid block B2.

Room 4 served as a drying area for uranium oxide powder and exhibited contamination in several regions as indicated on Fig. 25. The walls (survey blocks A2, A3, B1, and C1) had average alpha contamination levels ranging from 120 to 680 dpm/100 cm^2. An isolated alpha measurement of 210 dpm/100 cm^2 was detected on the top of a piece of machinery in block C2. One region overhead in C3 gave directly measured alpha and beta-gamma activities of 12,000 dpm/100 cm^2 and 1 mrad/h, respectively. Direct alpha activities ranging from 130 to 2100 dpm/100 cm^2 were found on, under, and around the furnaces in the south end of the room. Associated direct beta-gamma dose rates ranged from 0.25 to 0.45 mrad/h.

Room 6, in which the production of distilled calcium was carried out, was found to contain surface contamination in many accessible areas. Much of the room was impossible to survey due to the presence of equipment. Figure 26 identifies the locations with elevated levels including several exceeding DOE guidelines. The beta-gamma dose rates in the room ranged from 0.01 to 4 mrad/h. Direct alpha activities averaged 550 dpm/100 cm^2 in this room with the maximum found on contact with old wooden beams and braces underneath the balcony (Fig. 27). Measurements on these structures ranged from 2100 to 12,500 dpm/100 cm^2. Associated beta-gamma dose rates ranged from 0.15 to 1 mrad/h. Average alpha contamination levels on the balcony ranged from 40 to 140 dpm/100 cm^2. Measurements of transferable surface contamination were taken in eight locations on the floor in room 6. Values were indistinguishable from background except in survey blocks E2, F2, and G2 on the wooden portions of the bottom of the balcony. The alpha levels in E2 and G2 read 586 and 116 dpm/100 cm^2, respectively. The glazing along the windows and ledge in these survey blocks gave directly measured beta-gamma dose rates of 0.15 to 0.3 mrad/h with spots measuring 0.5 mrad/h. An interior view of some of the windows in room 6 is presented in Fig. 28. The contaminated ledge beneath the windows is shown in Fig. 29. In grid block E4, at the location of the maximum gamma rate measured (45 μR/h) the beta-gamma dose rate reached 4 mrad/h. The alpha activity measured there was 2200 dpm/100 cm^2. Overhead at C3, the average direct alpha activity was 100 dpm/100 cm^2. Four power tools (hacksaw, lathe, drill press, and sheet metal roller) located in room 6, which was being used as a machine shop at the time of the survey, showed beta-gamma surface contamination levels of 0.4 to 8.5 mrad/h.

No measurements above guidelines were observed in rooms 1, 2, and 3 of the basement of Building A-1. The lower walls and floor of room 4A were contaminated with levels of alpha activity exceeding 100 dpm/100 cm^2 (Fig. 30). The maximum direct alpha measurement, 1700 dpm/100 cm^2, was determined to be on a pipe running along the wall at A3. At the base of that wall, in B3, the alpha level was 530 dpm/100 cm^2. In C3, a point on the ceiling gave an alpha level of 350 dpm/100 cm^2 while the average alpha level measured on the ceiling was 240 dpm/100 cm^2. A hole in the ceiling in B2 showed a

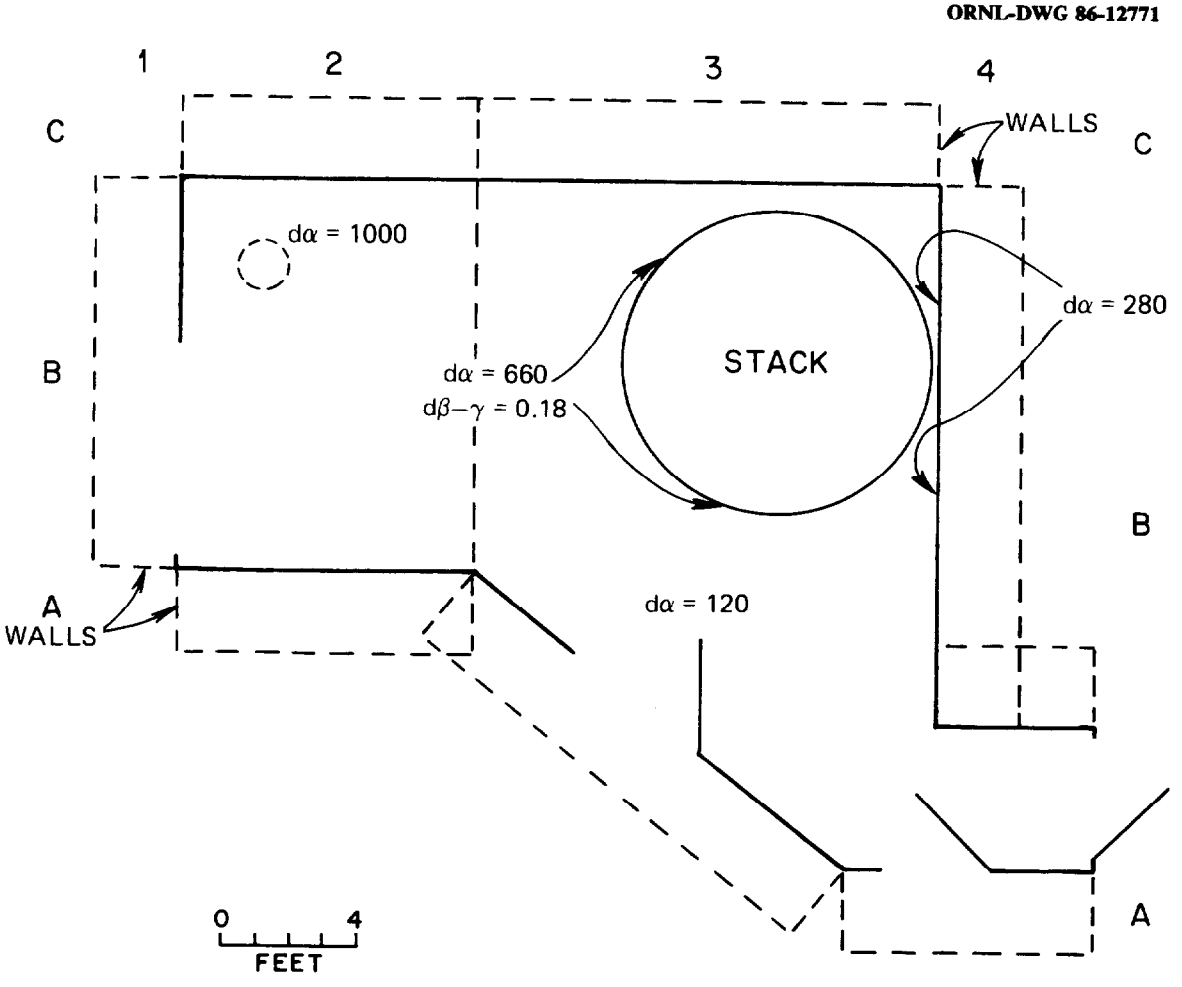

Fig. 24. Location of contaminated areas in room 3, Building A-1, at the Ventron site.

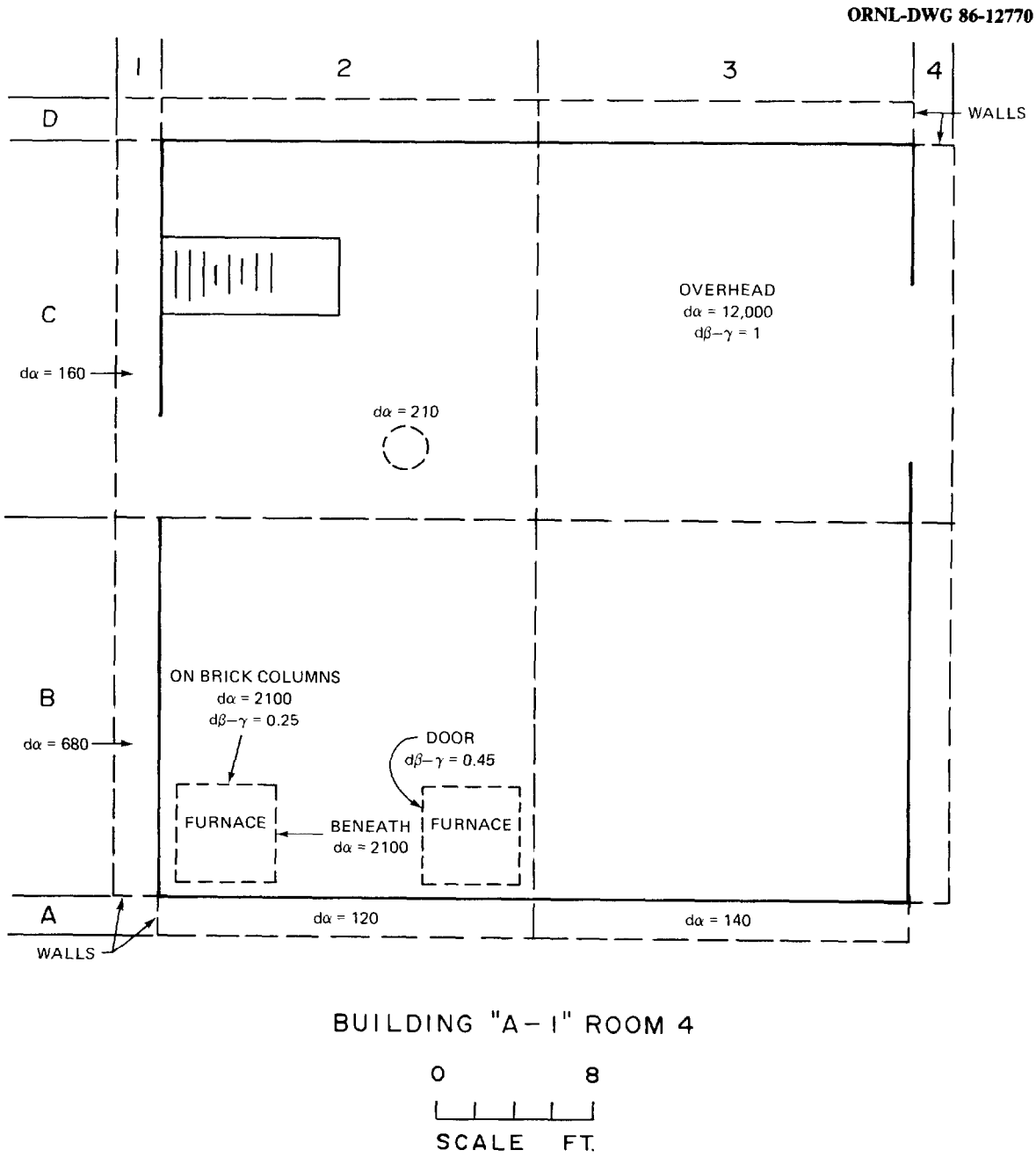

Fig. 25. Location of contaminated areas in room 4, Building A-1, at the Ventron site.

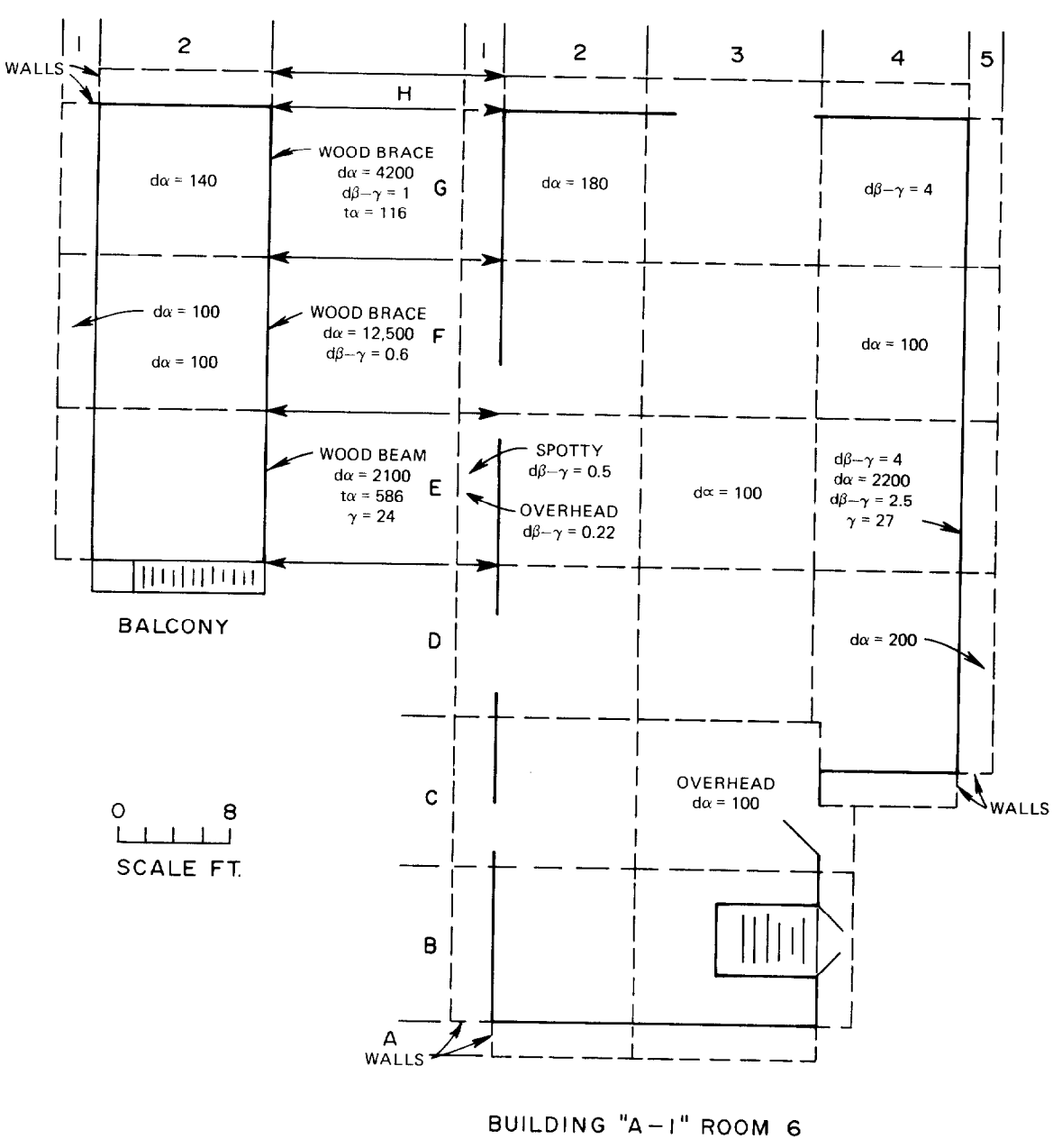

Fig. 26. Location of contaminated areas in room 6, Building A-1, at the Ventron site.

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Fig. 27. View beneath the balcony in room 6, Building A-1, at the Ventron site.

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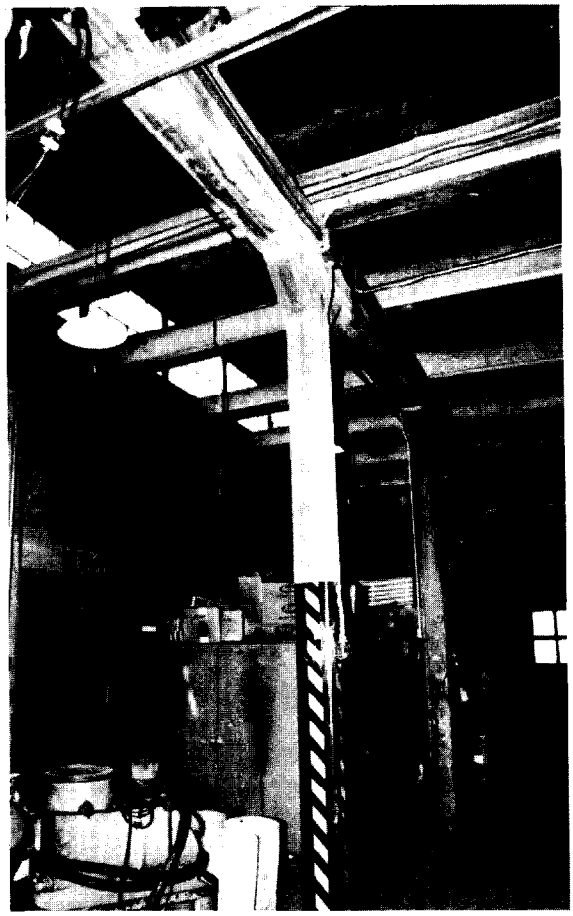

Fig. 28. View showing windows and roof area in room 6, Building A-1, at the Ventron site.

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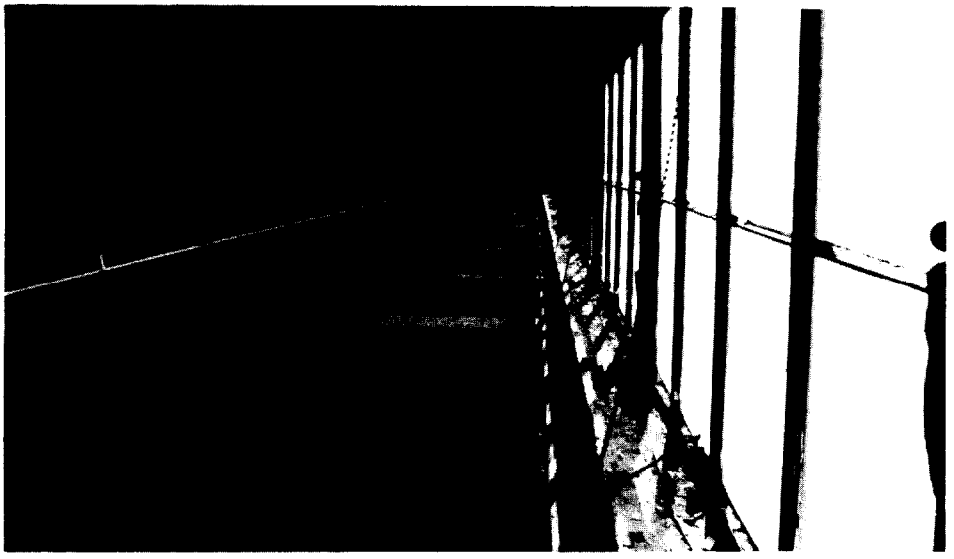

Fig. 29. View of the contaminated window ledge above room 6, Building A-1, at the Ventron site.

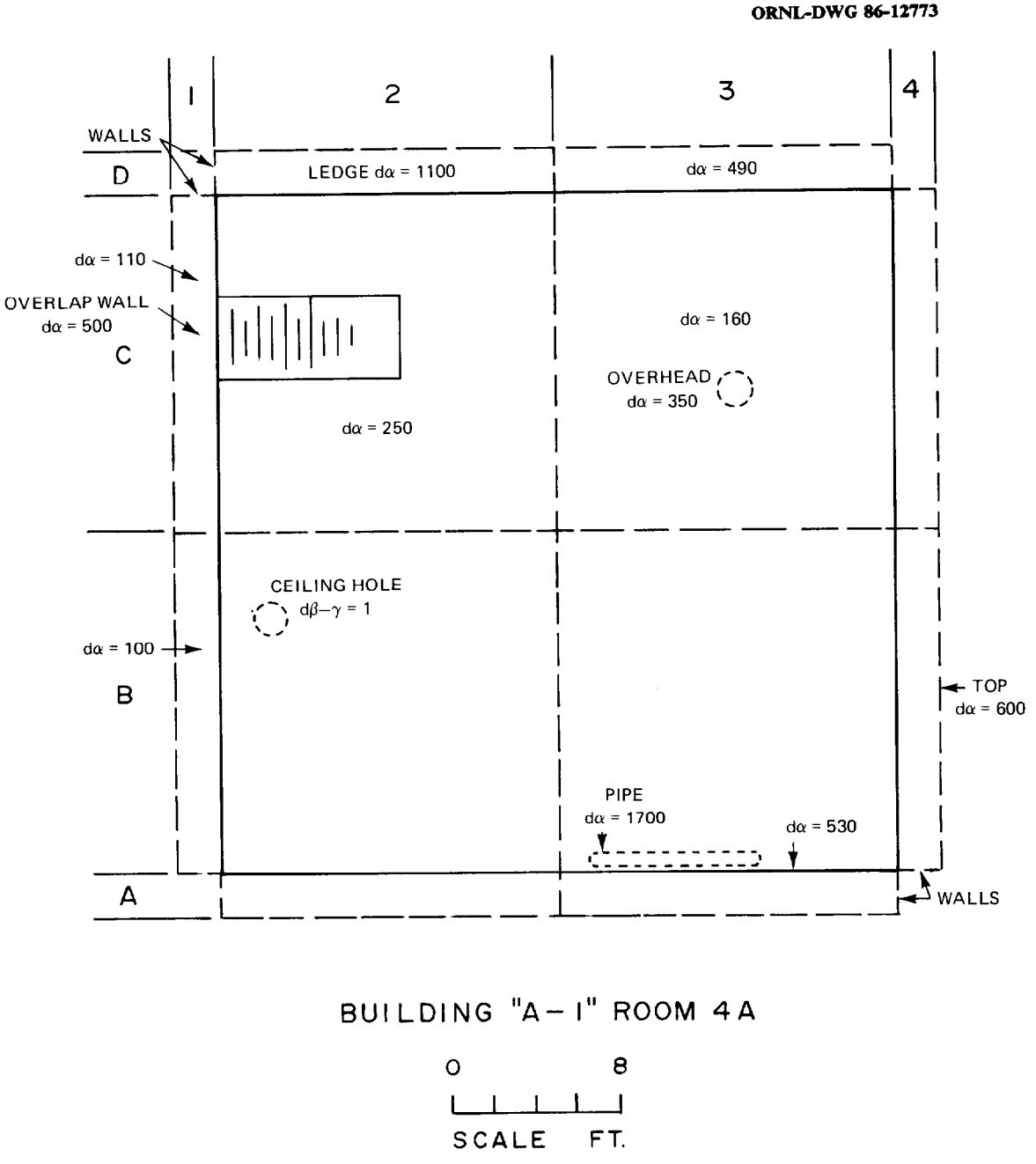

Fig. 30. Location of contaminated areas in room 4A, Building A-1, at the Ventron site.

beta-gamma dose rate of 1 mrad/h. An alpha contamination level of more than 1100 dpm/100 cm^2 was found on a ledge in block D2. Various wall areas were found to have alpha levels ranging from 100 to 600 dpm/100 cm^2 as shown, with the maximum measurement discovered at the top of wall B4.

Gamma measurements made on the roof of Building A-1, including those in survey blocks, skylights, and vents, ranged from 7 to 26 μR/h. Surface contamination evidenced by beta-gamma dose rates ranging from 0.2 to 0.6 mrad/h were observed in association with loose dirt in scattered regions of the roof. Figure 31 shows the location of some of the measurements exceeding guidelines. The data were typical of other widely dispersed regions not shown. The maximum gamma exposure rates were also associated with the loose dirt. A view of the roof, vent structures, and raised windows is given in Fig. 32.

3.2.3 Buildings B-1, B-2, and B-3

Buildings B-1, B-2, and B-3 are relatively new (built in 1950) and were used at the time of the survey for the manufacture of chemical hydrides. No residual radioactive materials would be expected within the buildings. A photograph, reproduced in Fig. 5, presents a view of the three attached buildings. This report is limited to the survey details of the basement areas because a gamma scan of upper levels established no evidence of contamination.

A gamma scan of the survey blocks laid out in the basements of the three buildings revealed a total range of gamma exposure rates from 7 to 32 μR/h. Because several regions of elevated gamma levels suggesting the presence of subsurface contamination were found in each building, 6-in diameter core holes were drilled with a concrete saw through the floors in the locations indicated on Fig. 33. Radionuclide analysis of soil samples retrieved from these holes (see Sect. 3.1.3) confirmed the presence of contaminated fill material beneath Buildings B-1 and B-2 to a depth of 2.5 m. Exposure rates ranged from 8 to 17 μR/h in Building B-1 and from 7 to 32 μR/h in Building B-2. The region of elevated gamma at the west end of Building B-1 extends to Building B-2. Exposure rates of 13 to 16 μR/h were detected at the sides of barrels stored in various locations within the three buildings at the time of the screening.

None of the surface measurements taken in the three buildings exceeded the appropriate DOE guidelines. Direct beta-gamma dose rates at 1 cm above the floor surface in the basements averaged 0.01 and 0.02 mrad/h in Buildings B-1 and B-3 while results averaged 0.03 mrad/h in Building B-2. The maximum measurement (0.07 mrad/h) was found in Building B-2. Only one direct alpha measurement taken in Building B-1, 30 dpm/100 cm^2, was distinguishable from background. Direct alpha activities averaged 25 and 34 dpm/100 cm^2 in Buildings B-2 and B-3, respectively. Representative sampling of transferable alpha and beta-gamma activities yielded readings no higher than 1 and 82 dpm/100 cm^2, respectively, in the three buildings.

3.2.4 Buildings C-1, C-2, C-3, and C-4

Buildings C-1, C-2, C-3, and C-4 (built in 1945) consist of analytical laboratories. The attached buildings are shown in Fig. 4 in a view looking west from the roof of Build-

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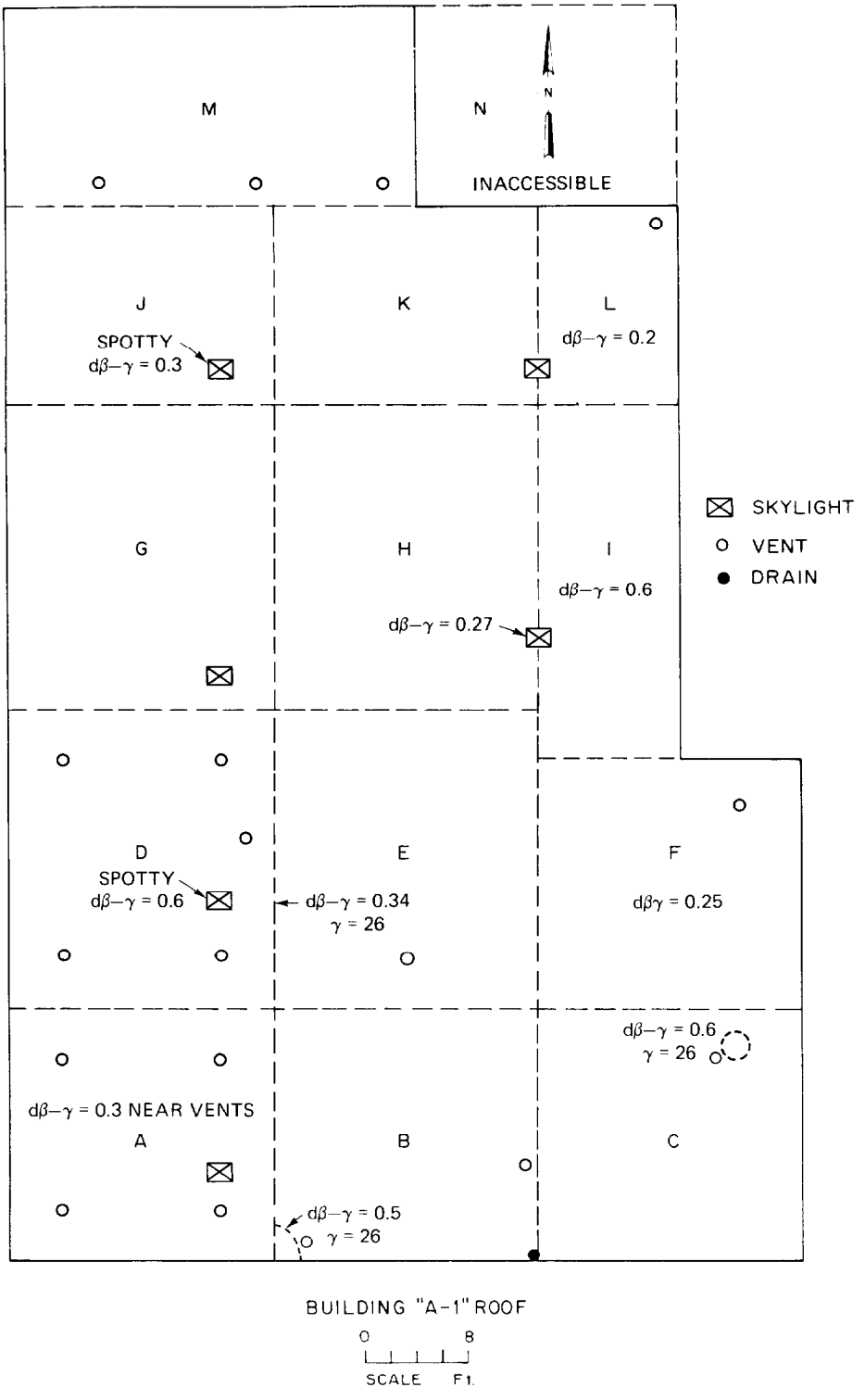

Fig. 31. Location of contaminated areas on the roof of Building A-1 at the Ventron site.

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Fig. 32. View of the roof of Building A-1 at the Ventron site.

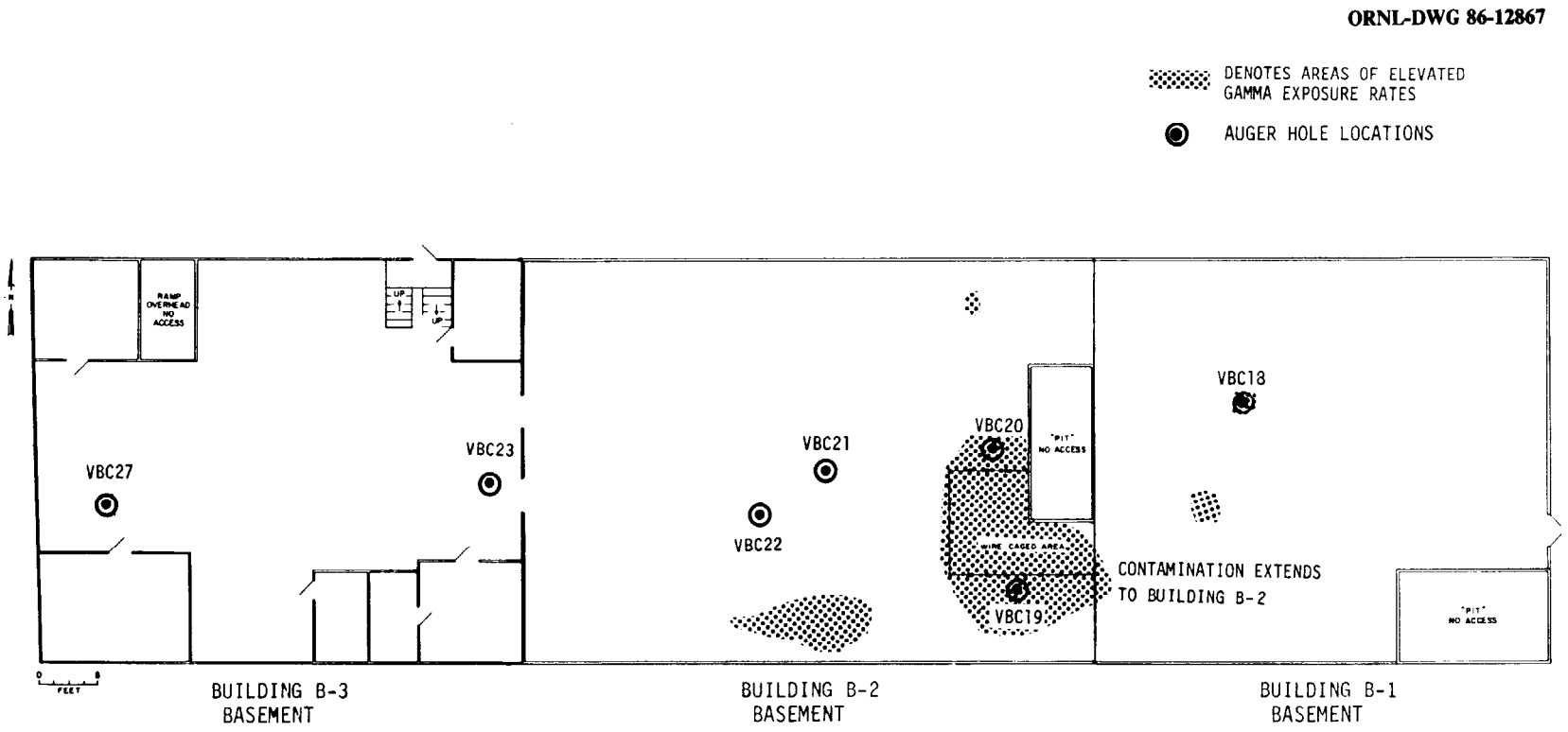

Fig. 33. Basements of Buildings B-1, B-2, and B-3 at the Ventron site showing regions of elevated gamma exposure rates and locations of auger holes.

ing A-1. Building C-1 at the time of the survey contained a library, research laboratories, and a basement used for miscellaneous storage. The results that follow are for the first levels of Buildings C-2, C-3, and C-4 and the basement of Building C-1. The first and second levels of Building C-1 and the second-level cafeteria over Building C-2 disclosed no gamma or direct alpha measurements suggesting the presence of residual radioactive materials.

The range of measurements found during the gamma scan of the four attached buildings as described was 5 to 17 μR/h. Average gamma exposure rates were 9 to 11 μR/h at 1 m from the floor surface and 10 to 11 μR/h at the surface. Soil samples were taken underneath the floor in the three regions of maximum gamma levels in the basement of Building C-1 to investigate the possibility of subsurface contamination. The results of radionuclide analysis substantiated the supposition (see Sect. 3.1.3), indicating contaminated fill material beneath the floor at the auger hole locations shown on Fig. 34. The contamination extends to a depth of 2.5 m.

Surface measurements taken in the four buildings were below guidelines. Direct alpha activities averaged 27 dpm/100 cm^2 in the basement of Building C-1 and were 20 dpm/100 cm^2 throughout Buildings C-2, C-3, and C-4. Direct beta-gamma dose rates for Building C-1 averaged 0.01 mrad/h while transferable alpha and beta-gamma activities on floor and wall surfaces were negligible.

3.2.5 Building D

Building D, built in 1967, was used for the research and development of biocides and is situated on the property as shown on Fig. 2.

The range of exposure rates disclosed by the scan of this building was 5 to 10 μR/h, with average readings of 6 and 7 μR/h at 1 m from the surface and at the surface, respectively. Elevated gamma levels of 65 μR/h were determined to be associated with three boxes of carbon arc filaments stored in room 25 at the time of the survey. All other readings were within the range of typical background values. Furthermore, the average beta-gamma dose rate of 0.03 mrad/h at 1 cm above surfaces is well below the DOE guideline of 0.2 mrad/h. No evidence was found of the presence of the contaminated fill material used beneath other buildings.

3.2.6 The Alfa Building

The Alfa Building, built in 1953, was used for crystal growing and other research related activities. Its location and interior floor plan may be seen in Figs. 2 and 35, respectively.

Overall gamma exposure rates determined during the scan of this building ranged from 5 to 19 μR/h, averaging 10 μR/h. Gamma levels at 1 m from the floor surface also averaged 10 μR/h, while the average at the floor surface was 11 μR/h. Areas of elevated exposure rates associated with radioactive process materials were found in rooms 2 and 6 as presented on Fig. 35. No suggestion of the presence of contaminated subsurface soil was detected.

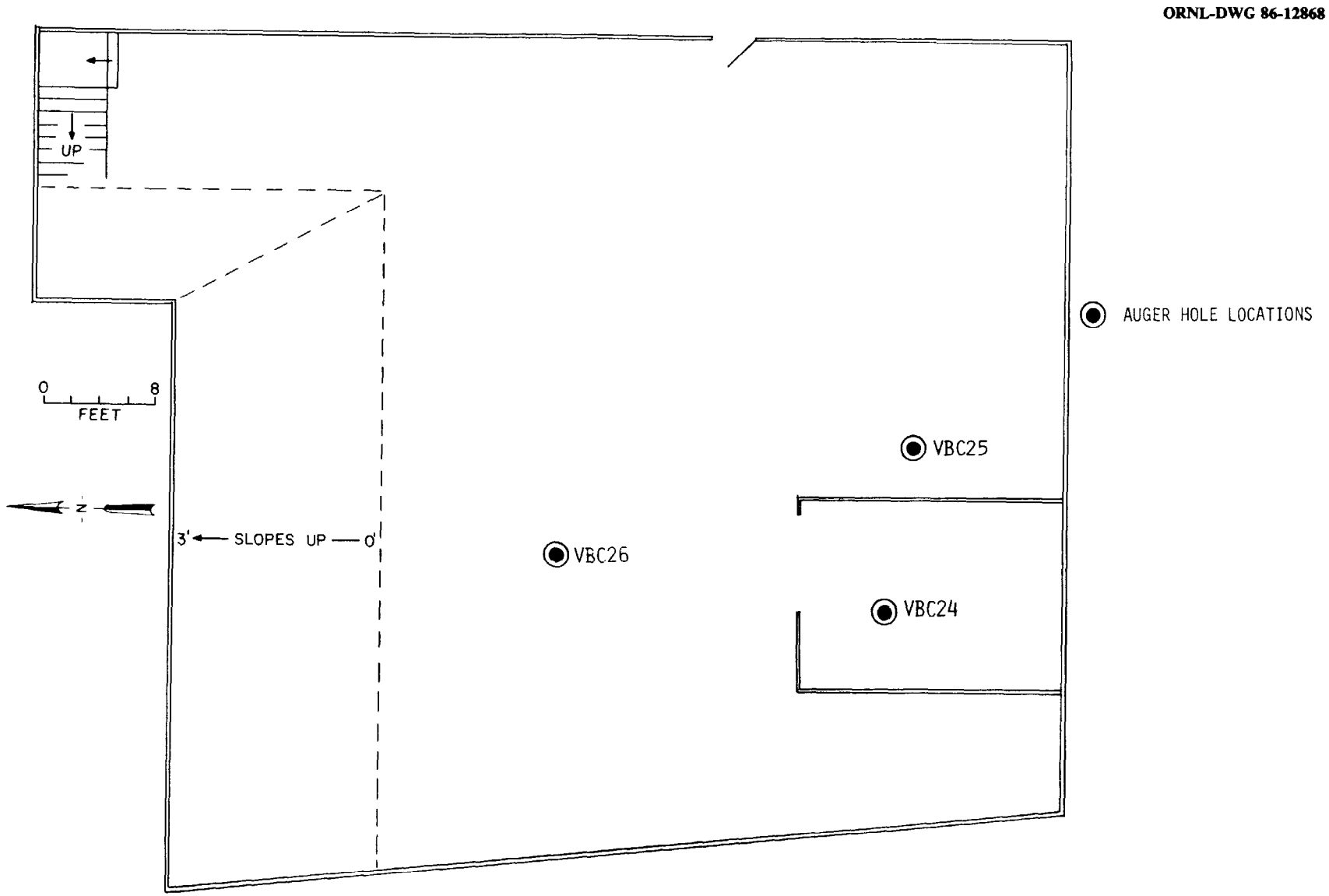

Fig. 34. Basement of Building C-1 at the Ventron site showing locations of auger holes.

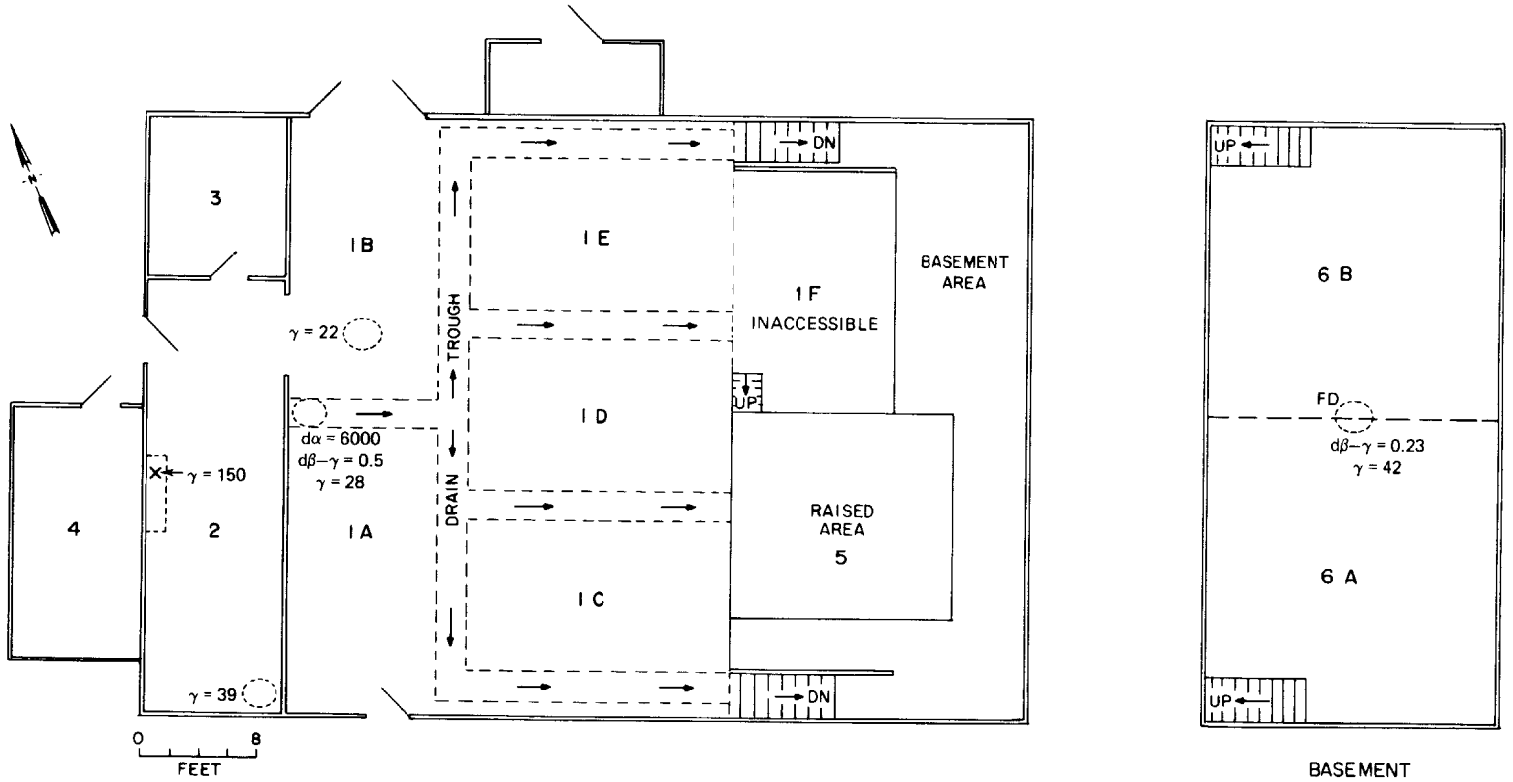

Fig. 35. Location of contaminated areas in the Alfa Building at the Ventron site.

Two vessels containing thorium crystals were discovered in the locations shown. One of these vessels rested on a cabinet along the west wall of room 2 as indicated and scanned 150 μR/h. This cabinet contained thorium-processing materials. The second vessel registered a gamma exposure rate of 39 μR/h. Additional anomalous regions were found in room 1 where a piece of equipment used in the thorium process and situated northwest of the drain trough registered 22 μR/h. A small area in the drain trough showed a beta-gamma dose rate of 0.5 mrad/h, which exceeds the DOE guideline of 0.20 mrad/h. Direct alpha activities at that spot were 6000 dpm/100 cm^2.

The beta-gamma dose rate (0.23 mrad/h) at the floor drain in the center of the basement level also exceeded 0.20 mrad/h and was accompanied by a gamma exposure rate of 42 μR/h. The alpha activity, however, at this spot was <1 dpm/100 cm^2. There was water present during the time measurements were being obtained.

Because the Alfa Building was built after the MED/AEC contract was terminated, elevated areas in this building would not be associated with MED/AEC operations.

3.2.7 Storage Building and Warehouse

Gamma scanning was conducted in accessible areas in the Storage Building and in the Warehouse located as shown on Fig. 2. A view of the Storage Building from the roof of Building A is shown in Fig. 3.

Surveying was prohibited in 75% of the first level of the Storage Building because of the barrels of solvents and other materials in stock. However, exposure rates in the center of the room were 5 and 7 μR/h at 1 meter and at the surface, respectively. No indication of contamination was found. Similarly, 50% of the basement of this building was unavailable to the team. Exposure rates averaged in the 7 to 14 μR/h range where scanning was possible. A maximum of 85 μR/h was measured on contact with a number of 3- to 5-gallon buckets of zinc oxide in storage.

Approximately 50% of the Warehouse was inaccessible to the survey team. However, gamma exposure rates scanned 5 to 10 μR/h, averaging 7 μR/h at both 1 m from the surface and at the surface. No contamination due to the presence of radioactive materials was observed in either building.

4. SIGNIFICANCE OF FINDINGS

The results of the radiological survey at the Ventron site demonstrate the presence of residual radioactive contamination. The primary contaminant is ^{238}U with lesser amounts of ^{232}Th and ^{226}Ra. The contamination occurs outdoors as both surface and subsurface contamination in soil and as contaminated fill material underneath Buildings B-1, B-2, and C-1. Buildings A and A-1 and the Alfa Building contain spotty surface contamination on floors, walls, overhead surfaces, equipment, and roofs.

A cursory gamma scan of the tidal area of the bay adjacent to the plant site revealed elevated levels of gamma radiation indicating the presence of radionuclides along the water line and in the mud of the tidal area. These findings verify historical information which indicates that there were uranium releases to the bay during MED operations and suggests that additional surveys should be completed to determine if there is residual uranium present in this area.

The maximum concentration of ^{238}U found on the site was 71,000 pCi/g and was measured in subsurface soil from beneath Building B-2. The maximum concentration of ^{238}U found in surface soil on the site was 44,000 pCi/g. The highest concentration of ^{232}Th measured in soil onsite was 3900 pCi/g. The DOE guideline concentration for ^{232}Th in surface soil is 5 pCi/g above background levels averaged over a 100 m^2 area (Table 2). The depth of contamination appeared to be greater than 3 m in the southeast portion of the site outdoors and extended to 2.5 m beneath the buildings.

Inside Building A, the surface contamination found in scattered regions was most evident in the rooms where leaching and retorting processes had been conducted (i.e., rooms 20 and 29) and in room 30 where current activities involved materials containing naturally occurring radionuclides. Directly measured alpha and/or beta-gamma levels exceeded DOE guidelines on floors, walls, overhead surfaces, and equipment. Contamination was also evident in the floor drain troughs. It was apparent that dust and particulates had been funneled through ducts and vents to the outdoors, particularly from room 29, resulting in the deposition of surface contamination over a portion of the roof. The maximum beta-gamma dose rate measured in Building A exceeded the DOE criterion (1.0 mrad/h) by a factor of 3. Levels of directly measured alpha contamination were as high as 4.2 times the thorium limit (Table 2).

DOE guidelines for surface contamination were also exceeded in Building A-1 in numerous regions, especially in rooms 3, 4, 4A, and 6. Again, the elevated measurements were found on floor, wall, overhead, and equipment surfaces. On the roof, the contamination was largely associated with the presence of loose dirt in scattered regions. Maximum direct alpha and beta-gamma count rate measurements exceeded criteria (Table 2) by <13 and <4 times, respectively, on structural surfaces. The beta-gamma dose rates measured on the power equipment (room 6) indicated levels as high as 8.5 mrad/h (more than 8 times the beta-gamma dose rate limit).

In the Alfa Building, elevated gamma exposure rates were found in association with thorium crystals and thorium-processing equipment not related to DOE predecessor activities. Directly measured alpha and beta-gamma levels were elevated in drains and drain troughs in several regions.

Surface measurements taken in Buildings B-1, B-2, B-3, C-1, C-2, C-3, C-4, and D were all below criteria. Elevated gamma levels discovered in areas of the basements of Buildings B-1, B-2, and C-1 suggested the presence of contamination beneath the floors. Radionuclide analysis of soil samples taken from holes drilled into the substrata confirmed that assumption. No evidence of the presence of radioactive residuals was found inside or beneath the Storage Building or the Warehouse.

The residual radioactivity on this site will produce slight radiation exposures to persons frequenting the contaminated areas. These exposures result primarily from beta-gamma and alpha radiations emitted by radionuclides retained in the soil and in some areas of the former process buildings (A and A-1). The present use of the site is industrial and its condition renders the soil unsuitable for growing crops. Consequently, it is highly unlikely that any significant exposure would be received by way of ingestion from eating vegetables or fruit grown on the site. Most of the area outside the buildings is covered by asphalt or concrete and the remaining area is covered by a heavy growth of lawn grass. This grass cover precludes any significant resuspension of particulate contamination from the land surface by wind or air currents; hence, radiation exposures from inhalation of radioparticulates is currently not a problem. If operations which involve considerable scraping or turning of dry soil were performed in areas showing high concentrations of radionuclides, radiation exposures from the inhalation pathway would need to be re-evaluated.

The average gamma exposure rate at one meter from the ground surface outdoors on the site was 8 μR/h. This level is essentially the same as the background exposure rate in the Beverly area (7 μR/h). One area in the southeast corner of the site located between the Storage and Alfa Buildings exhibited elevated gamma radiation levels ranging up to 60 μR/h at one meter from the ground. The maximum level (60 μR/h) occurred in a relatively small area ($\sim$10 m^2), and, at the time of the survey, this area appeared to be unoccupied except for occasional entry. If a worker occupied this area for 1/4 of a typical work year (two hours per shift or 500 h/y), that individual would receive a potential exposure of 30 milliroentgens annually (a dose of less than 30 mrem/y). For comparison, a basic dose limit of 100 mrem/y is used by the Department for limiting the radiation dose received by an individual member of the general public and 5,000 mrem/y is used for a radiation worker. Therefore, the worst case use of this area could result in a dose of less than 1/3 the dose limit for the general public. It is expected that occupancy in this area will continue to be much less than 500 h/y and, as a result, potential doses will be even lower than those projected here.

The maximum gamma radiation level measured at the perimeter of the plant (30 μR/h) occurred along the fence at the southeast corner of the site (location 22, Fig. 6). The ground outside the fence at this point drops off rather rapidly down a rocky bank to the bay. Therefore, the potential for any significant radiation exposure to members of the general public from this source is extremely low.

The average gamma radiation level measured one meter from floor surfaces in each of the former process buildings (A and A-1) was 12 μR/h. This level is 1.7 times the background level in the Beverly area and about 44% of the external gamma radiation level of 20 μR/h above background allowable by DOE in buildings or habitable structures to be released for unrestricted use by the general public. The maximum gamma level detected at one meter in either building was 21 μR/h in a hallway of Building A (Room 28, Fig. 11). Since this area is used only as a passageway, radiation exposures to personnel from this source would not be significant.

Residual radioactive surface contamination exceeded DOE guidelines in some areas inside Buildings A and A-1, and in the Alfa Building. Potential exposures from surface contamination could be from ingestion, inhalation, or from direct radiation by beta-gamma

emitting radionuclides. Very few measurements of transferable contamination exceeded DOE guidelines; hence, given the use of the building at the time of the survey, the risk of receiving significant exposures from inhalation or ingestion of radioactive material is extremely small. Beta-gamma dose rates from contaminated surfaces exceeded guidelines in some areas of Buildings A and A-1. These contaminated areas occurred in cracks in floors, on beams and ledges, and in floor drains, and do not lend themselves to extended contact with people; hence, potential exposures from these sources is judged to be insignificant. However, because measurements of fixed surface contamination exceeded guidelines in some buildings, if operations involving the generation of dust such as scraping contaminated surfaces were conducted, the potential for radiation exposures would need to be re-evaluated to determine if control measures are needed.

In summary, concentrations of residual radioactive material found in buildings and soils at the site are in excess of concentration guidelines established by the Department of Energy to determine if a site needs to be considered for remedial action. These guidelines are typically derived to ensure that unrestricted use of the facility (including residential use) will not result in above-guideline doses to the general public. An examination of work/occupancy scenarios for this site suggests that annual radiation exposures to personnel from any credible current use scenario would be well below the dose limits which would be applied to protect members of the general public from exposure to radiation.

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1. *A Background Report for the Formerly Utilized Manhattan Engineer District, Atomic Energy Commission Sites Program,* DOE/EV-0097A (September 1980).

2. W. D. Cottrell, *Preliminary Report of Ventron Site, Beverly, Massachusetts* (December 1985).

3. T. E. Myrick, B. A. Berven, W. D. Cottrell, W. A. Goldsmith, and F. F. Haywood, *Procedures Manual for the ORNL Survey Activities (RASA) Program,* Oak Ridge National Laboratory, ORNL/TM-8600 (April 1987).

APPENDIX

GAMMA PROFILE GRAPHS OF AUGER HOLES AT THE VENTRON SITE, BEVERLY, MASSACHUSETTS

ORNL-DWG 86-12784

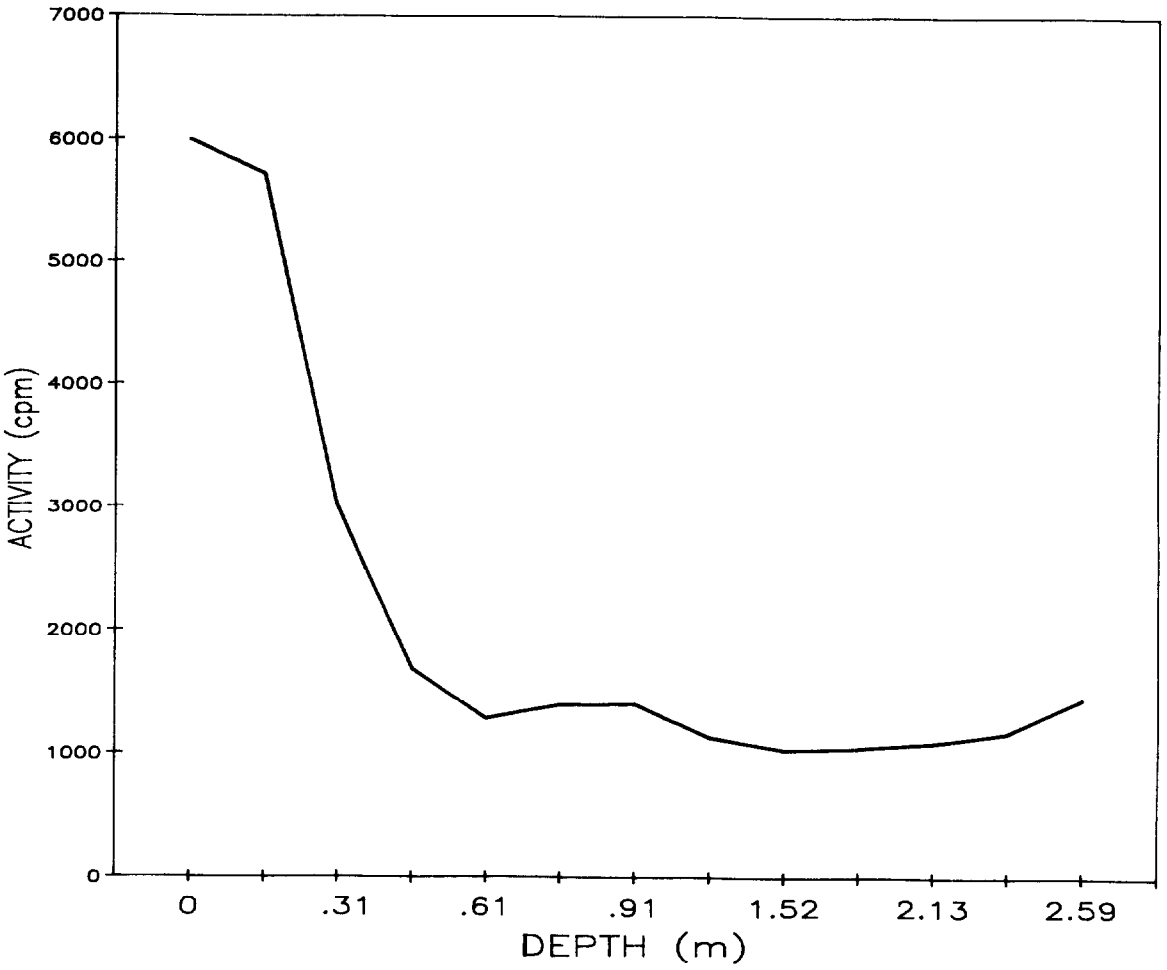

Fig. A.1. Gamma profile of auger hole 1.

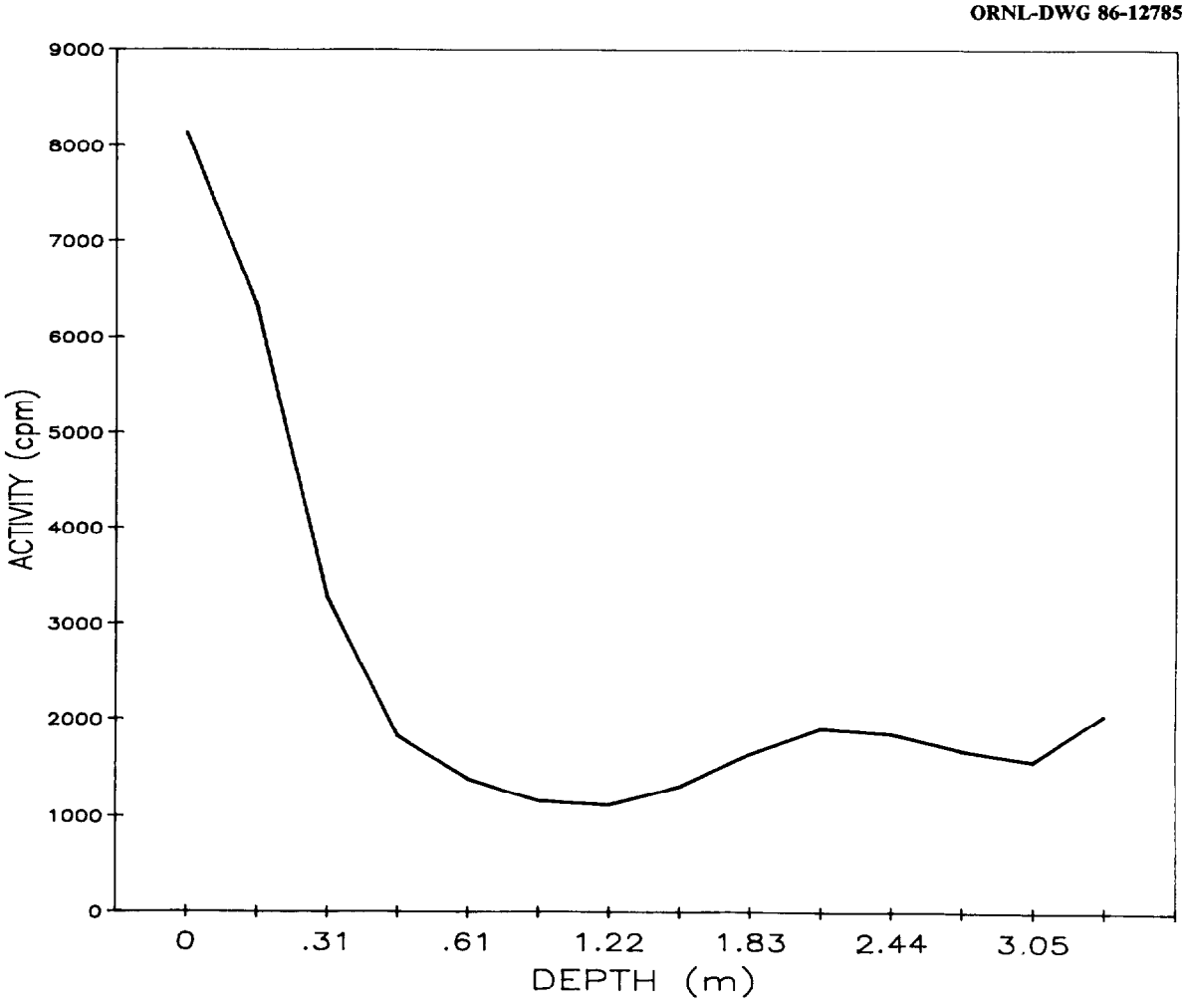

Fig. A.2. Gamma profile of auger hole 2.

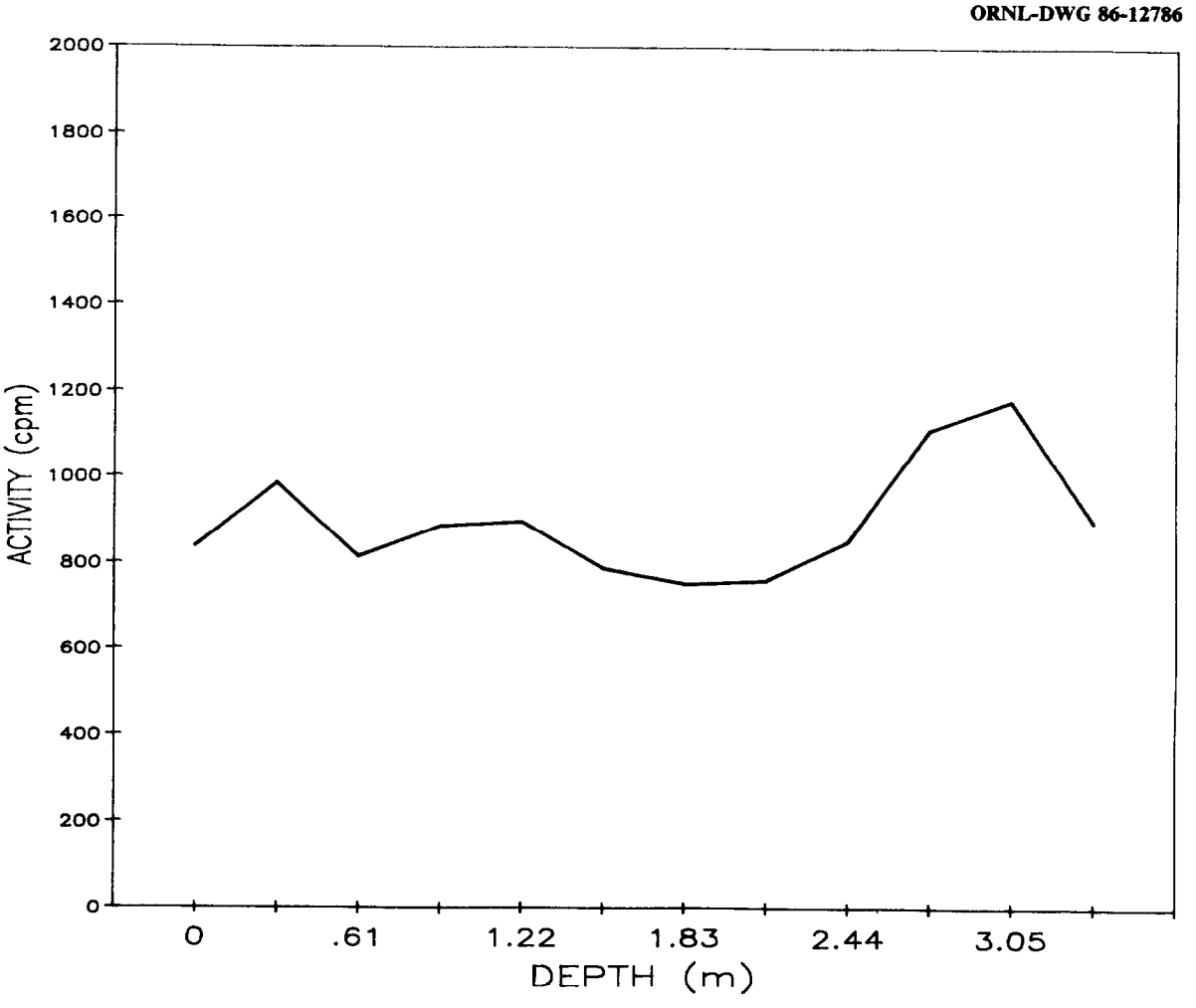

Fig. A.3. Gamma profile of auger hole 3.

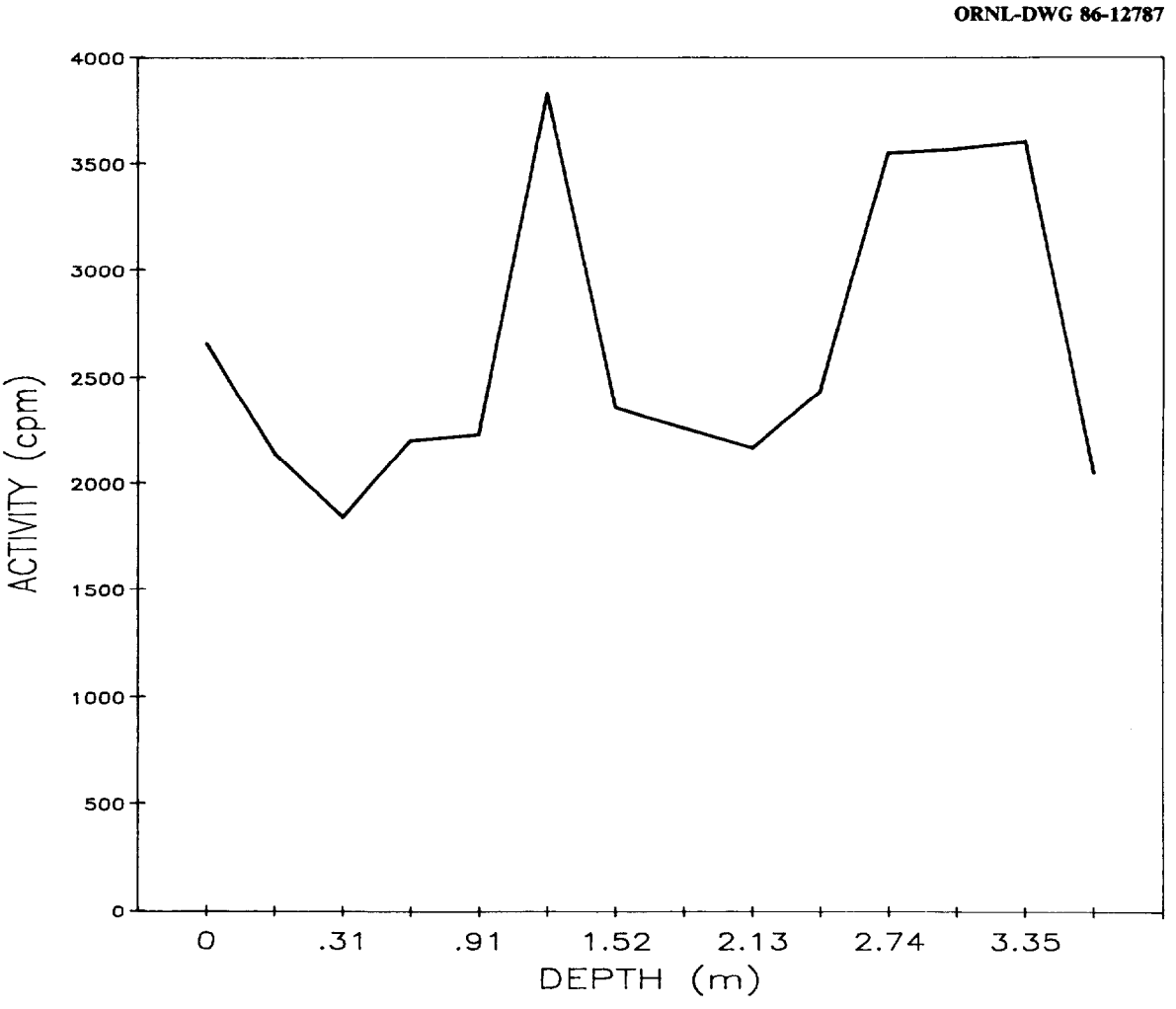

Fig. A.4. Gamma profile of auger hole 4.

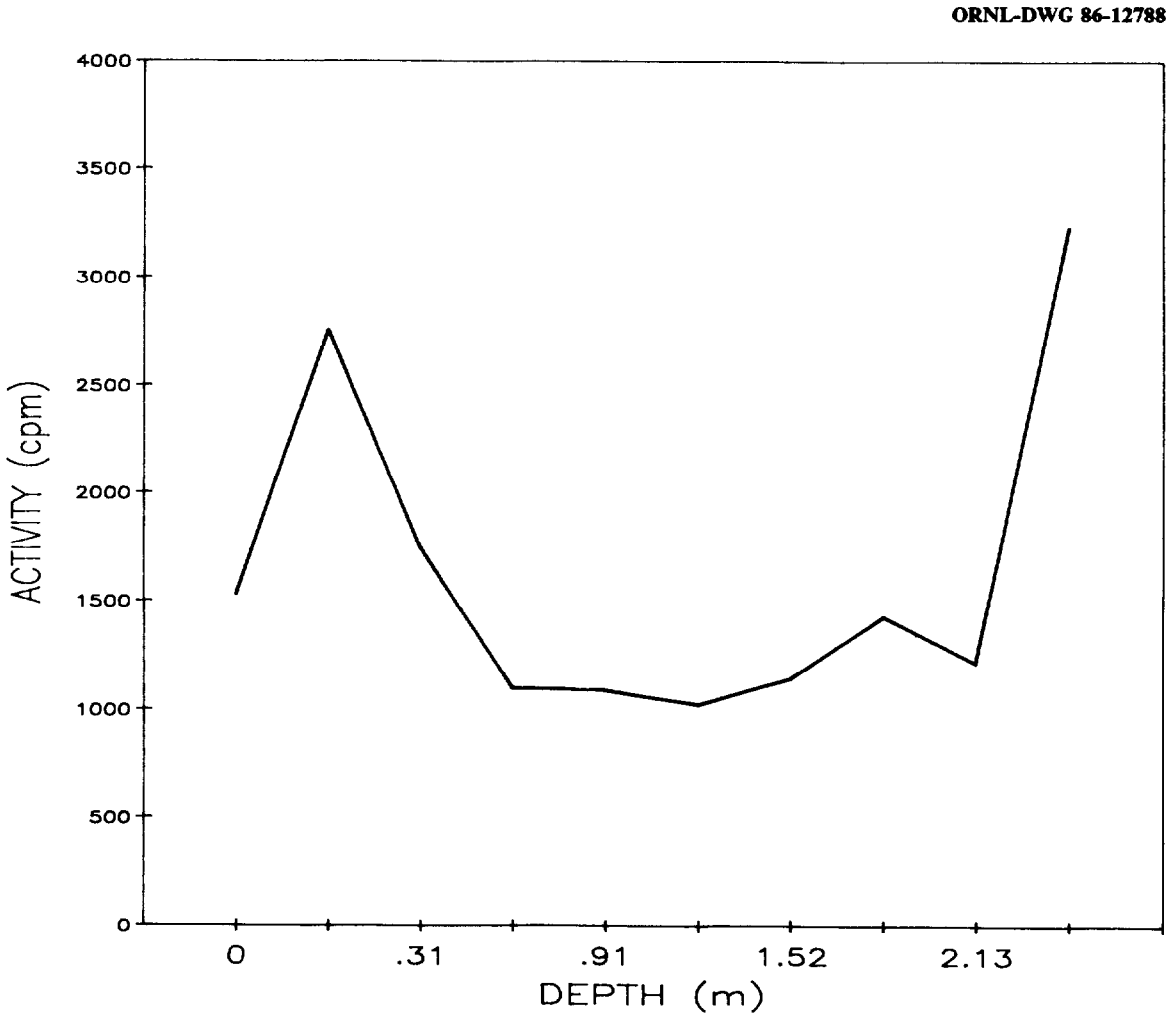

Fig. A.5. Gamma profile of auger hole 5.

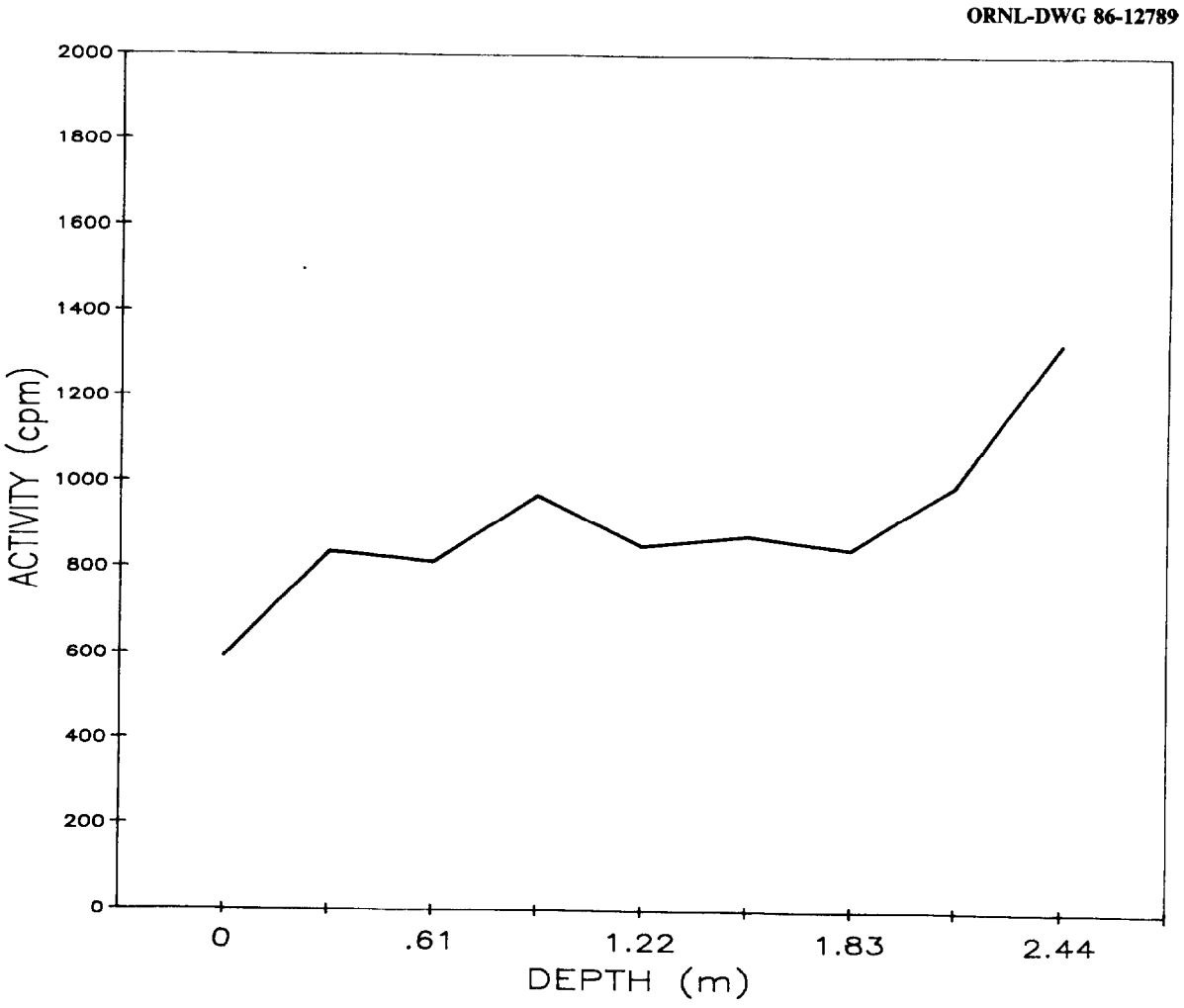

Fig. A.6. Gamma profile of auger hole 6.

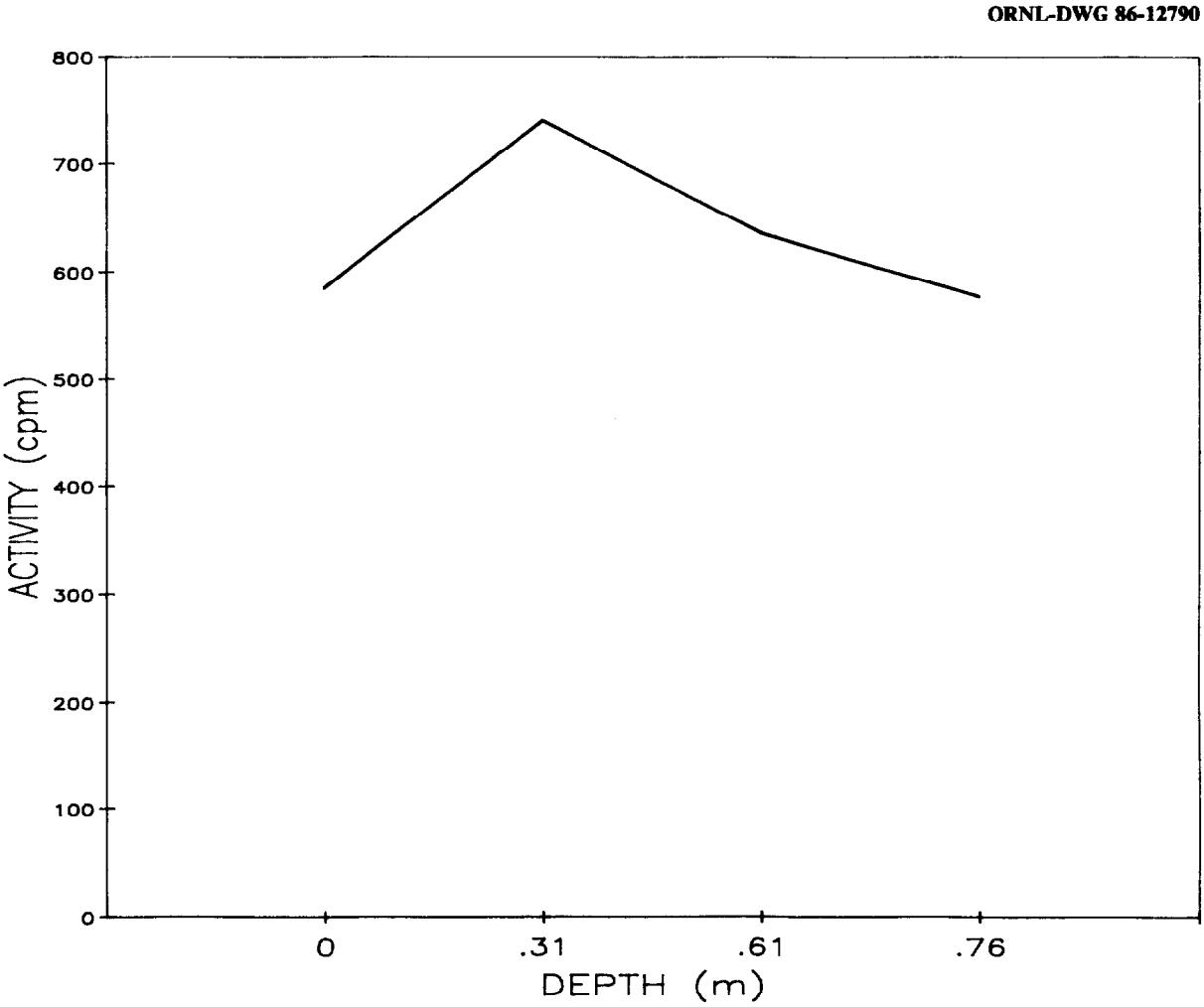

Fig. A.7. Gamma profile of auger hole 7.

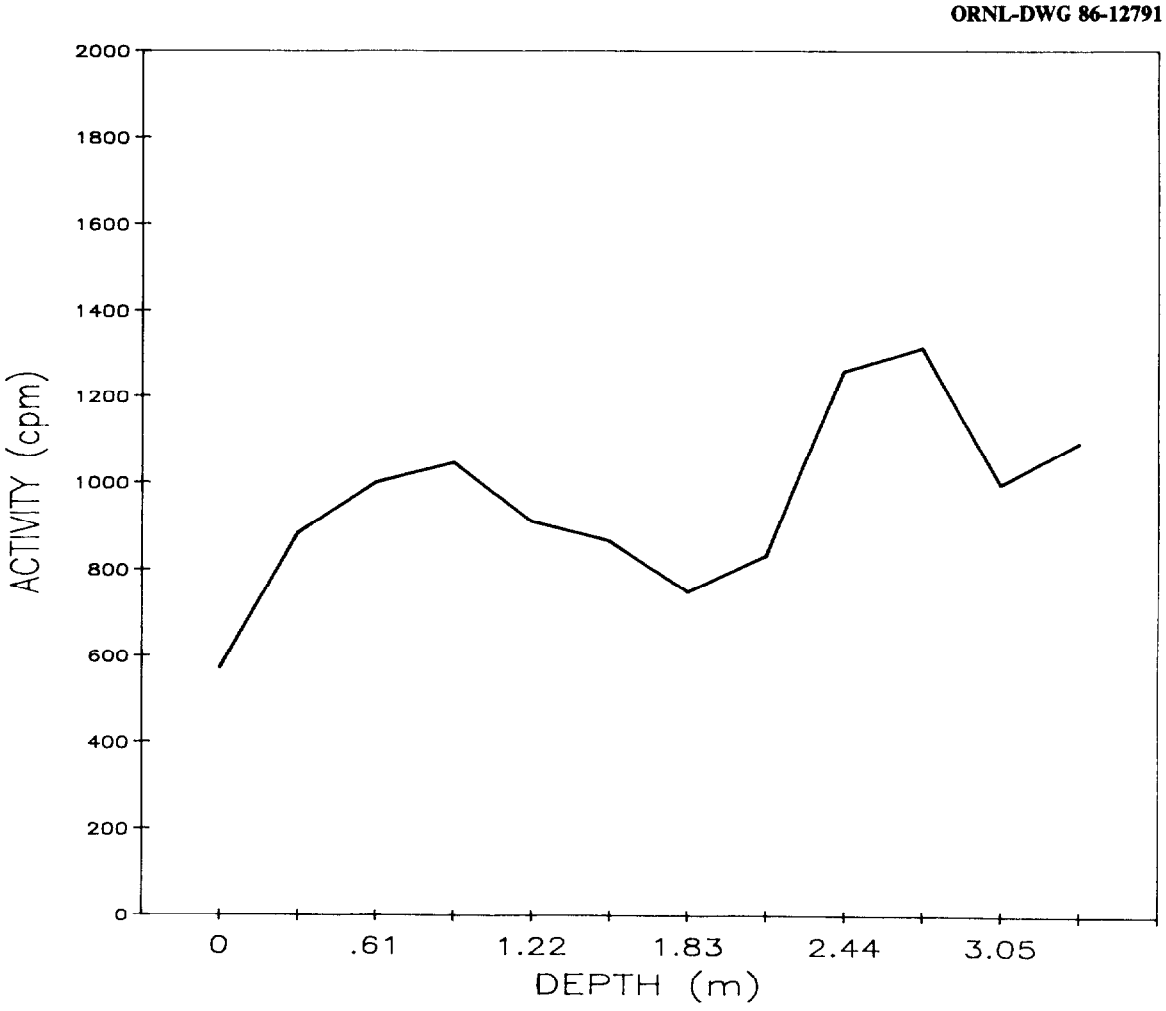

Fig. A.8. Gamma profile of auger hole 8.

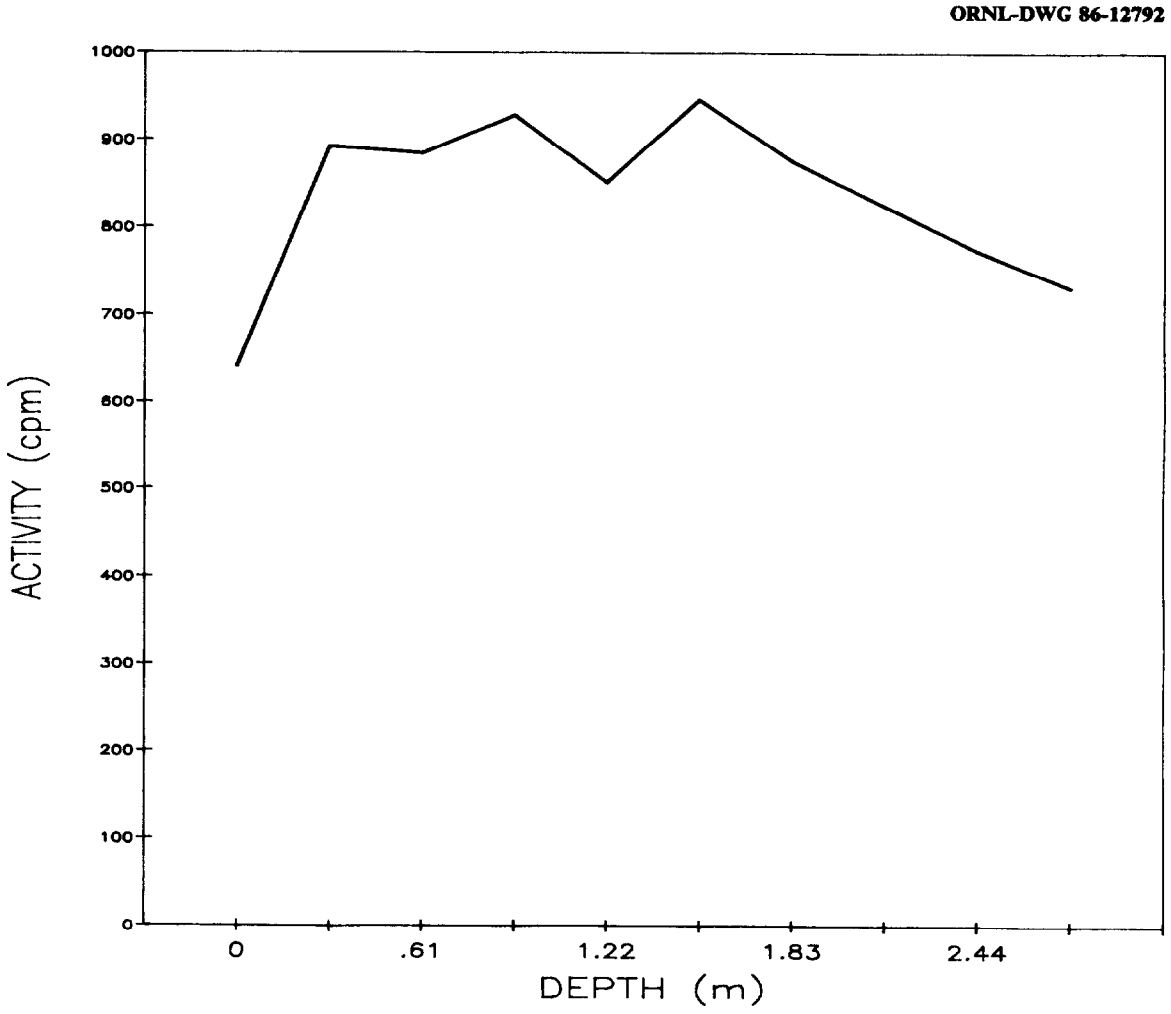

Fig. A.9. Gamma profile of auger hole 9.

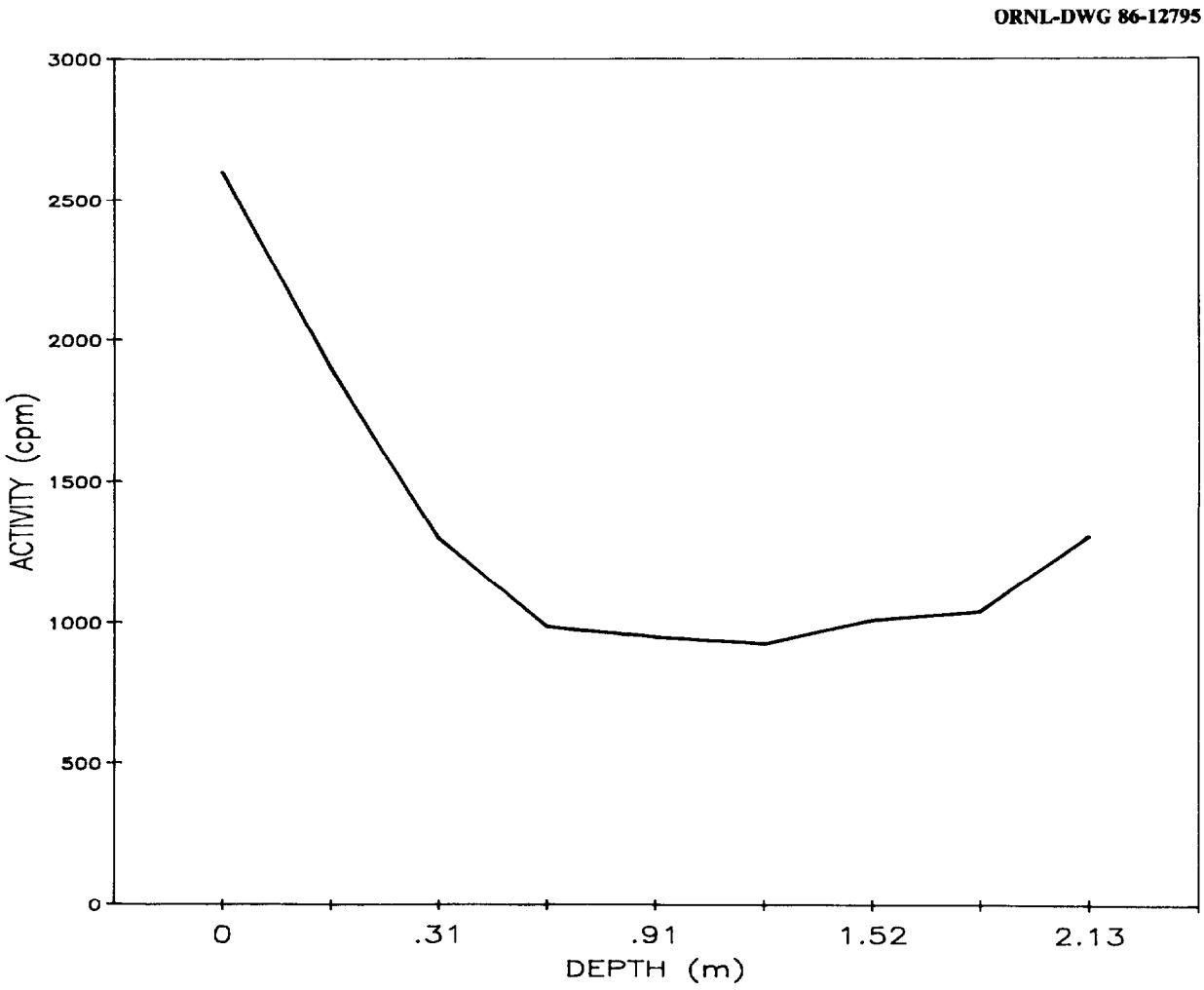

Fig. A.12. Gamma profile of auger hole 14.

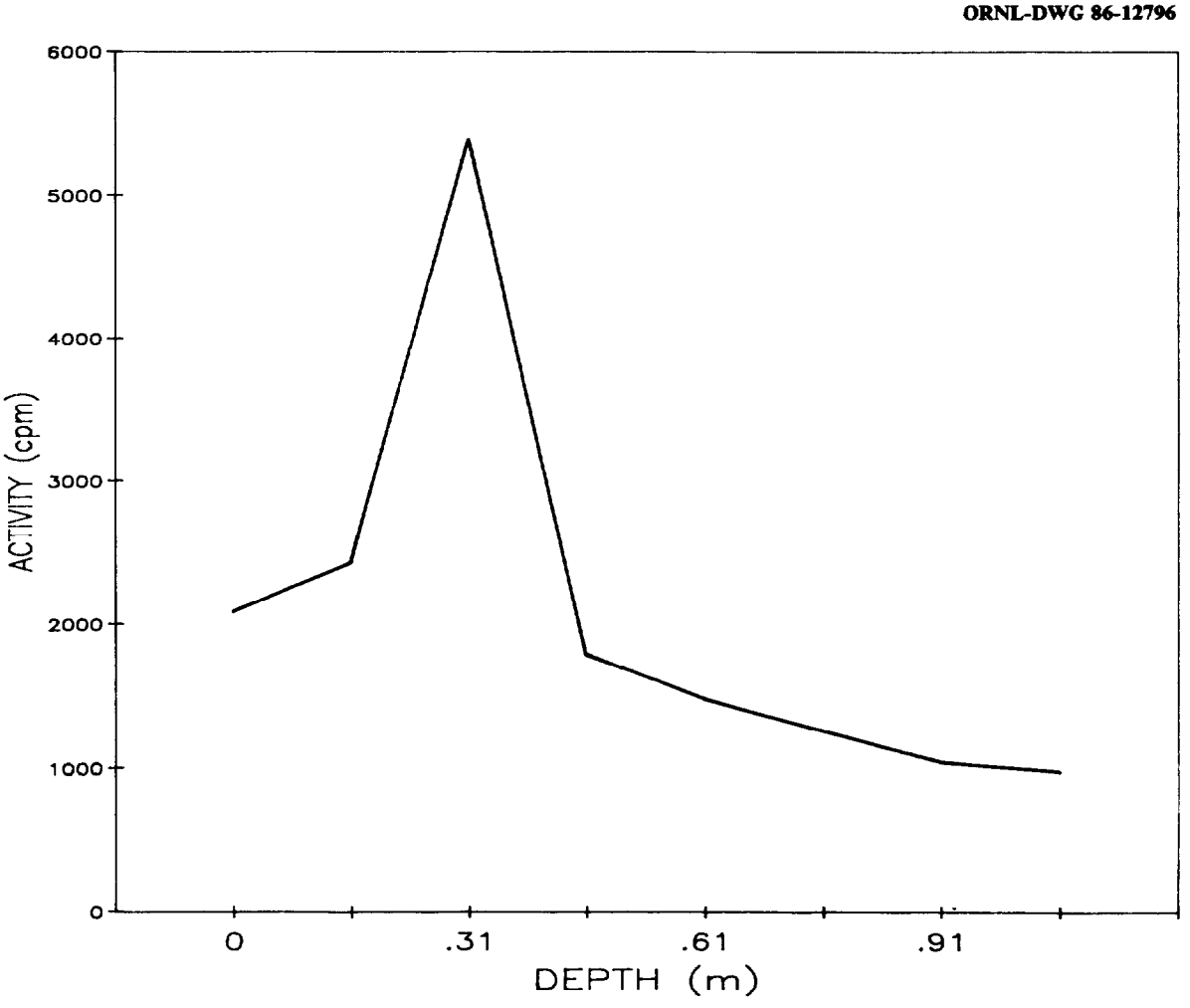

Fig. A.13. Gamma profile of auger hole 18.

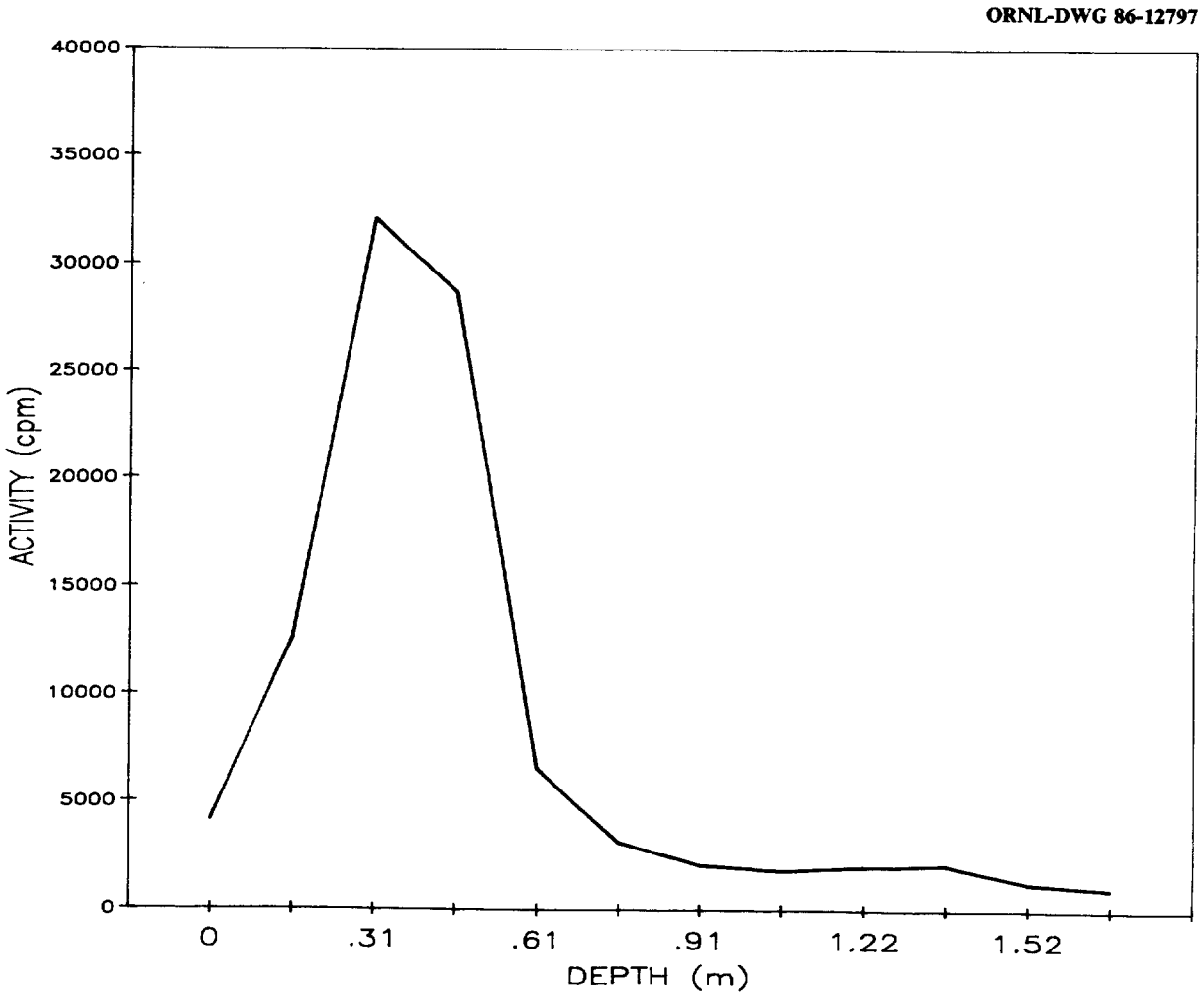

Fig. A.14. Gamma profile of auger hole 19.

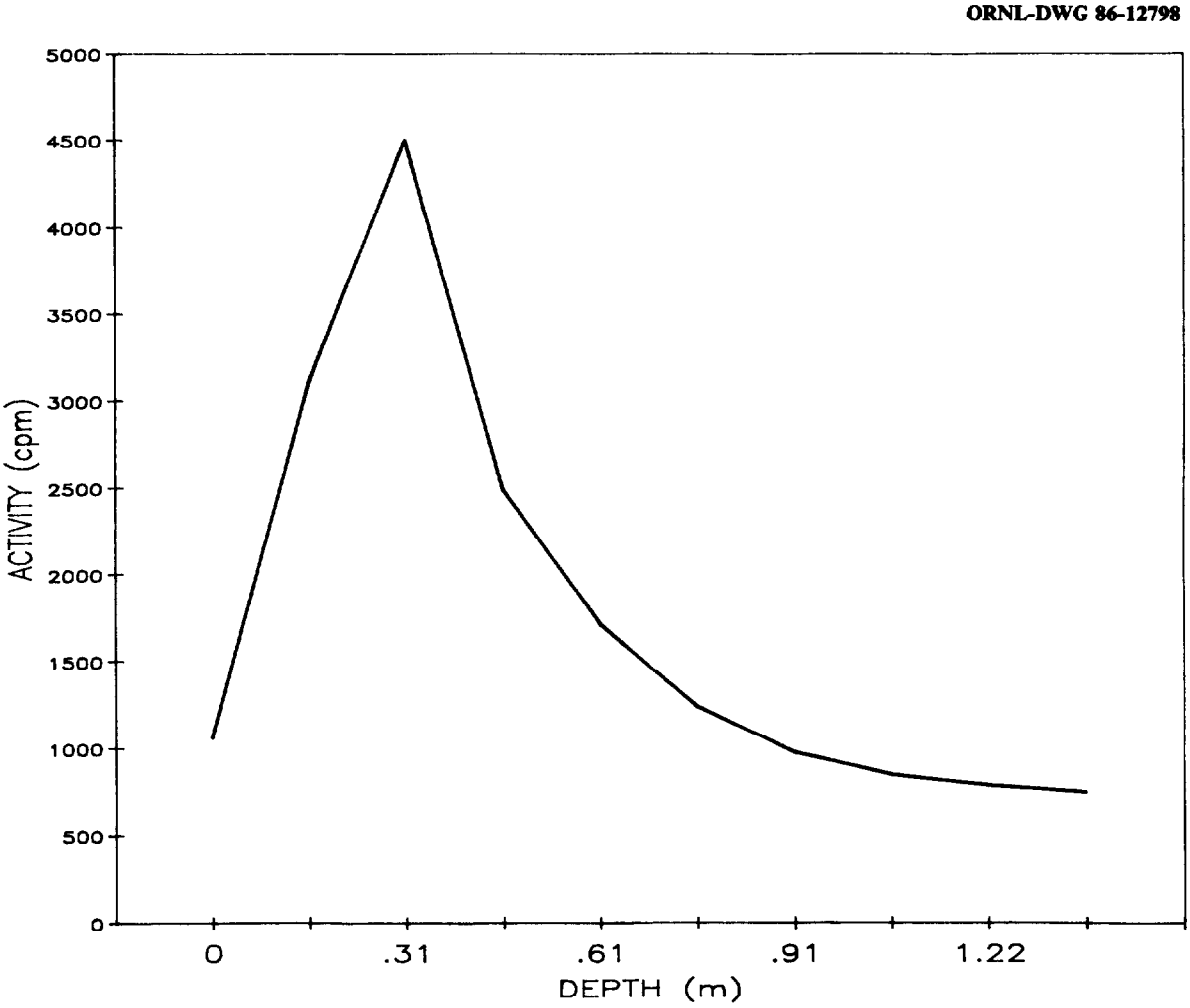

Fig. A.15. Gamma profile of auger hole 20.

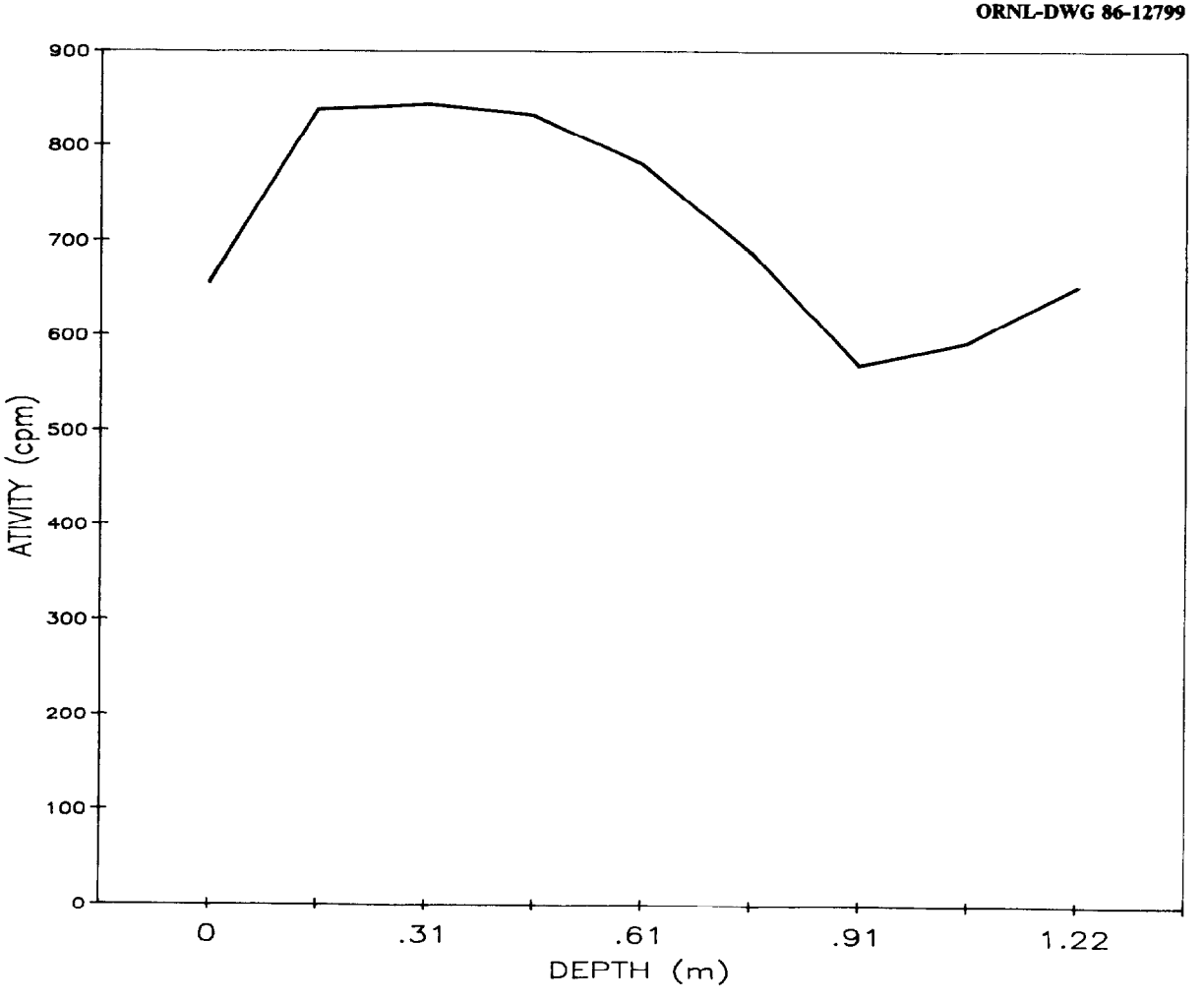

Fig. A.16. Gamma profile of auger hole 23.

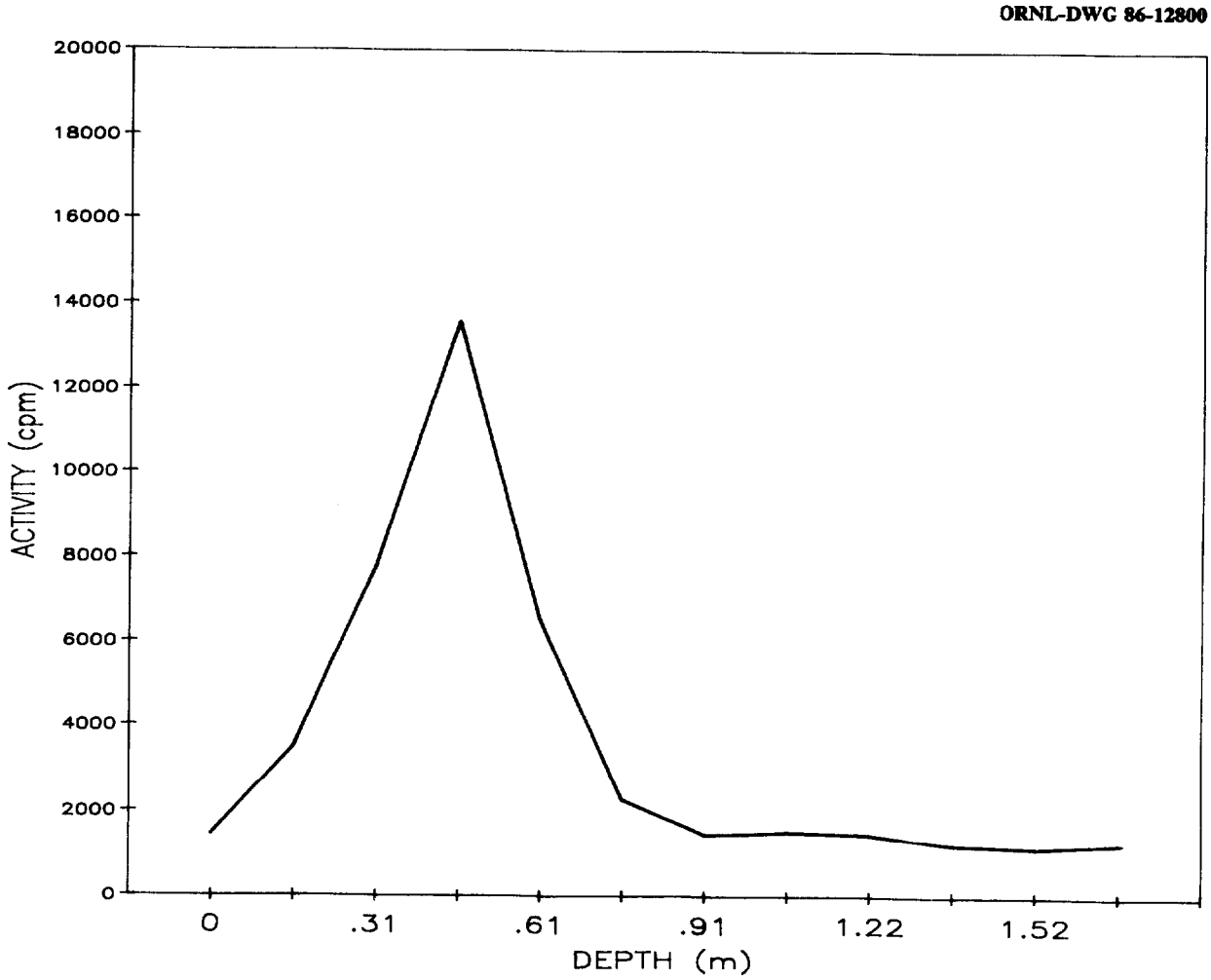

Fig. A.17. Gamma profile of auger hole 24.

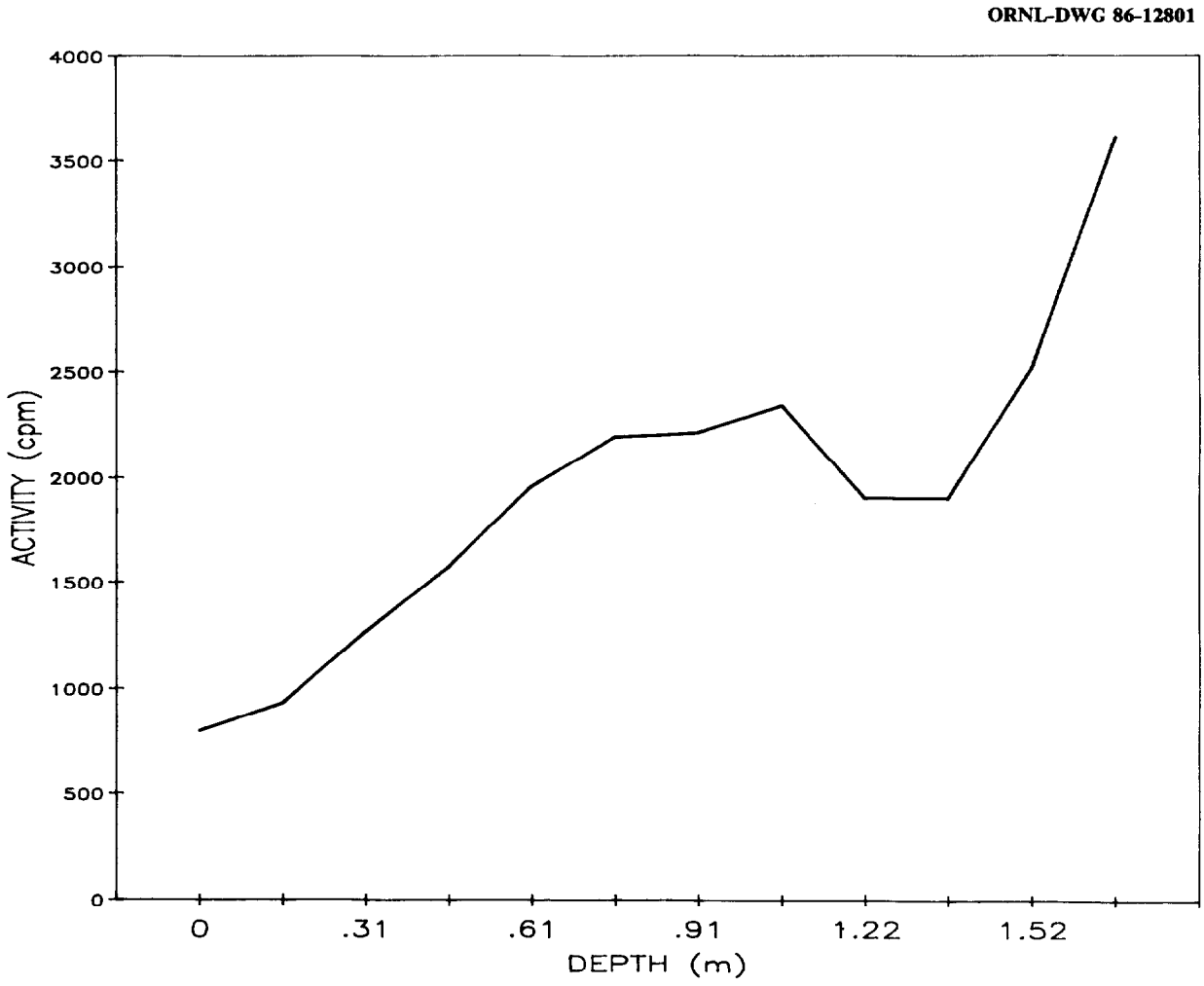

Fig. A.18. Gamma profile of auger hole 25.

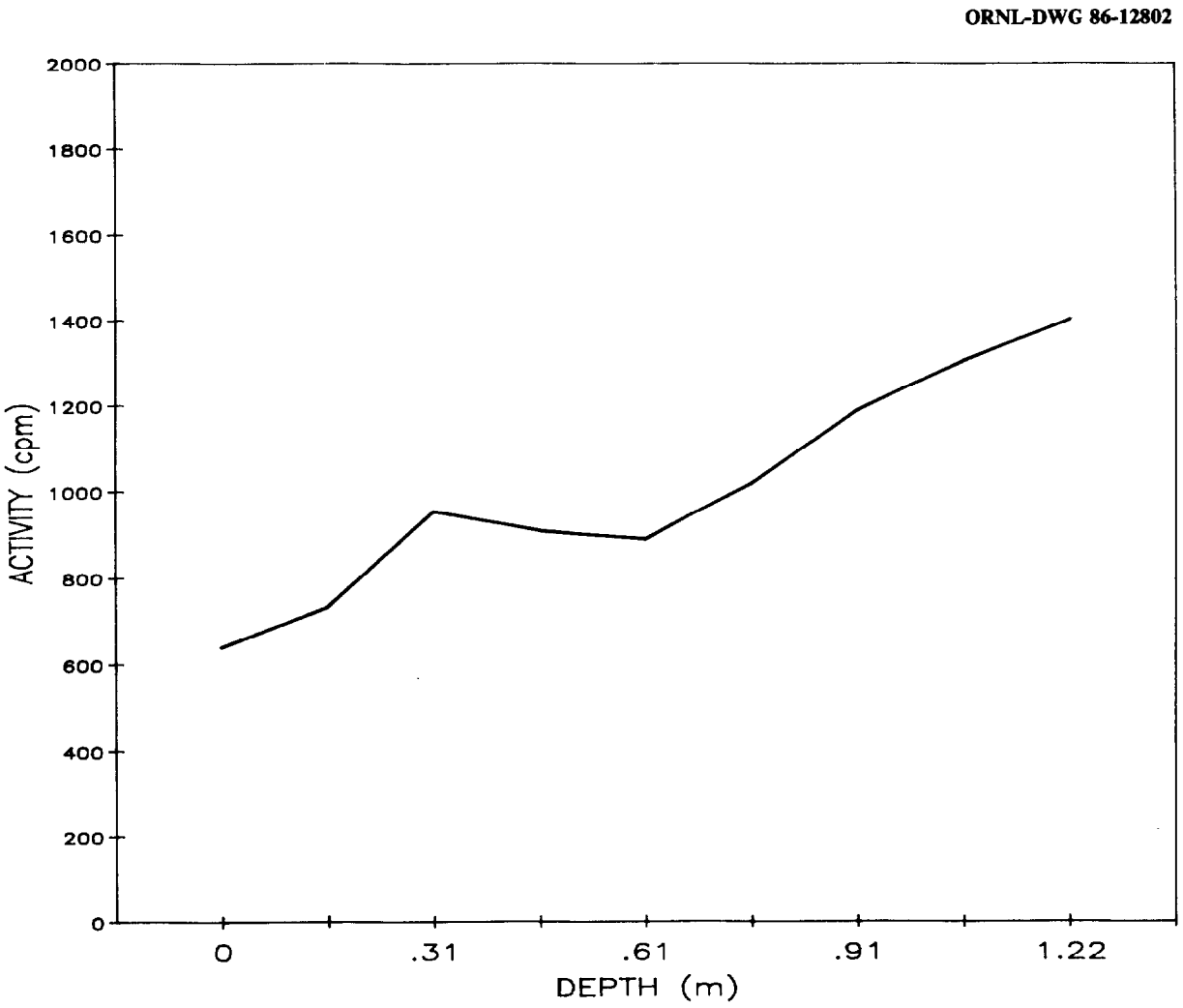

Fig. A.19. Gamma profile of auger hole 26.

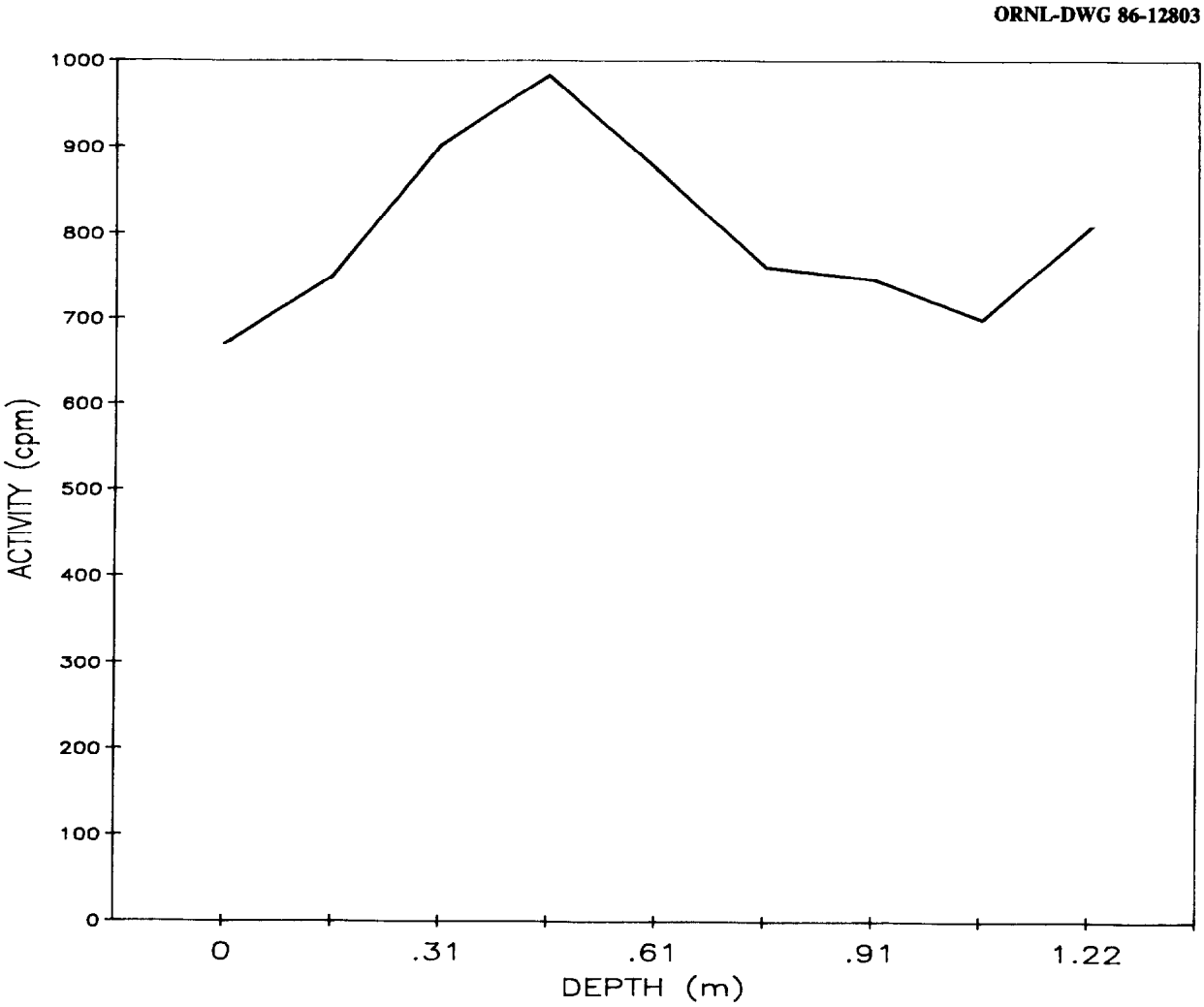

Fig. A.20. Gamma profile of auger hole 27.

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