RADIOLOGICAL ASSESSMENT FOR THE VANCE ROAD FACILITY SOURCE VAULT OAK RIDGE INSTITUTE FOR SCIENCE AND EDUCATION OAK RIDGE, TENNESSEE

J.R. MORTON

Prepared for the
Facilities and Transportation Department
Oak Ridge Institute for Science and Education

ORISE
OAK RIDGE INSTITUTE FOR SCIENCE AND EDUCATION

Environmental Survey and Site Assessment

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RADIOLOGICAL ASSESSMENT
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VANCE ROAD FACILITY SOURCE VAULT
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OAK RIDGE, TENNESSEE

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ABBREVIATIONS AND ACRONYMS

ϵ_i	instrument efficiency
ϵ_s	source efficiency
µrem/h	microrem per hour
µR/h	microroentgens per hour
b_i	background counts in observation interval
BKG	background
cm	centimeter
cm^2	square centimeter
cpm	counts per minute
DOE	U.S. Department of Energy
dpm	disintegrations per minute
dpm/100 cm^2	disintegrations per minute per 100 square centimeters
EML	Environmental Measurements Laboratory
ESSAP	Environmental Survey and Site Assessment Program
FTD	Facilities and Transportation Department
GM	Geiger-Mueller
ITP	Intercomparison Testing Program
LSC	liquid scintillation counter
m	meter
m^2	square meter
mm	millimeter
MAPEP	Mixed Analyte Performance Evaluation Program
MDC	minimum detectable concentration
MDCR	minimum detectable count rate
NIST	National Institute of Standards and Technology
NRC	U.S. Nuclear Regulatory Commission
NRIP	NIST Radiochemistry Intercomparison Program
ORISE	Oak Ridge Institute for Science and Education
ORO	Oak Ridge Operations
s	seconds
SEPD	Safety and Environmental Protection Department
SVA	Source Vault Area
VRF	Vance Road Facility

RADIOLOGICAL ASSESSMENT
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INTRODUCTION AND SITE HISTORY

The Oak Ridge Institute for Science and Education (ORISE) occupies and maintains, on behalf of the Department of Energy's Oak Ridge Operations Office (DOE-ORO), the Vance Road Facility (VRF). Several radiological research laboratories formerly operated on the second floor of the VRF. These laboratories were used since the early 1950's for medical research activities involving both sealed and unsealed sources of a variety of radionuclides. Radionuclides such as ^{3}H, ^{14}C, ^{90}Sr, ^{67}Ga, ^{68}Ga, ^{68}Ge, ^{60}Co, $^{44}Sc/^{44}Ti$, ^{137}Cs, and ^{226}Ra were used in these laboratories along with other rare radionuclides, such as some short-lived alpha and beta emitters that have most likely decayed away. The radionuclides used in these laboratories were stored in a source vault located on the first floor of the facility. Later, the Source Vault Area (SVA) was converted into two laboratories which were identified as Rooms A107 and A107a. In 1997, the Facilities and Transportation Department (FTD) of ORISE remediated the second floor laboratories and converted them to office space. FTD also remediated Rooms A107 and A107a of the SVA during the spring of 2000 and requested that the Environmental Survey and Site Assessment Program (ESSAP) of ORISE perform a radiological assessment survey of the area.

SITE DESCRIPTION

The VRF is located at 140 East Vance Road and is west of the Methodist Medical Center Hospital in Oak Ridge (Figure 1). The SVA is located in the far northwest end of the ground floor of the VRF A Building (Figure 2).

Prior to the radiological assessment survey, the SVA contained equipment, temporary walls, floor coverings, a lowered ceiling, etc. which were removed during a remedial action survey (ORISE 2000a). The north wall of the room contains the source storage vault, which consists of a face that is seventeen feet long and eight feet high with 256 four-inch diameter horizontal tubular core holes (vaults) that transverse approximately one meter (m) deep into the source

vault concrete. Below the horizontal core holes there are five roll-out lead-lined drawers that require rails, which extend out into the floor approximately 1.5 m. Three of the five drawers could not be investigated during this survey due to existing piping, which prevented the drawers from being opened. The floor and wall surfaces were of concrete construction.

Within the SVA are three hoods which were not removed during this survey and will be addressed at a later date.

OBJECTIVE

The objective of this survey was to obtain sufficient data to evaluate the radiological condition of the SVA. Additional information was gathered to evaluate options for remediation of the structural surfaces of the SVA.

DOCUMENT REVIEW

As part of the radiological assessment activities, ESSAP reviewed available historical information regarding radionuclide usage within the facility.

PROCEDURES

In July, 2000, ESSAP performed a radiological assessment survey of the SVA. Survey activities were conducted in accordance with a plan dated March 14, 2000 and the ORISE/ESSAP Survey Procedures and Quality Assurance Manuals (ORISE 2000b, 1998, and 2000c). Deviations to the survey plan were made as the survey progressed and were recorded in the site logbook.

BACKGROUND MEASUREMENTS

Material-specific direct measurement backgrounds were performed on similar material types, but without a history of radioactive material use. These background measurements were used to correct gross surface activity measurements.

RADIOLOGICAL ASSESSMENT SURVEY PROCEDURES

Radiological assessment survey procedures were applied to the SVA structural surfaces including the exposed floor, overhead surfaces, wall, core holes, and vault drawers.

Surface Scans

Surface scans for alpha plus beta activity were performed on 100% of all accessible surfaces of the Source Vault wall and lead-lined drawers using hand-held gas proportional detectors. Surface scans for residual beta and gamma activity were also performed on 25% of the accessible surfaces of each source vault core using a GM detector. Random scans were also performed on the remaining overhead surfaces (light fixtures, heat and air ducts, pipes, etc.). All detectors were coupled to ratemeter-scalers with audible indicators.

Surface Activity Measurements

Direct measurements for alpha and beta surface activity were obtained from 73 locations on the floor and lower walls of the SVA (Figures 3 and 4). Also, three measurements were performed within the source vault drawers and one direct measurement was performed in each of the 256 core holes (Figure 5). Smears for determining removable gross alpha and gross beta contamination were collected at those floor and lower wall direct measurement locations exhibiting elevated activity and from each core hole. A separate set of smears was also collected at each smear sample location to determine removable ^{3}H and ^{14}C contamination, as the sensitivity of the field instrumentation either will not detect or has a low efficiency for detecting the low-energy beta emissions of these radionuclides. Direct measurements were performed using gas proportional and/or GM detectors coupled to ratemeter-scalers.

Exposure Rate Measurements

Background exposure rates were performed during a prior survey of the VRF (ORISE 1997). Exposure rates were measured at two locations within the SVA. All exposure rates were performed at one meter above the surface using a micro-rem meter.

SAMPLE ANALYSIS AND DATA INTERPRETATION

Samples and survey data were returned to the ESSAP Oak Ridge laboratory for analysis and interpretation. Sample analyses were performed in accordance with the ESSAP Laboratory Procedures Manual (ORISE 2000c). Smears were analyzed for gross alpha and gross beta activity using a low background gas proportional counter and for ^{3}H, ^{14}C, and ^{90}Sr using a liquid scintillation counter (LSC). The conversion of the LSC data for ^{90}Sr was not performed on all samples, just those with ratios indicating the presence of the radionuclide. Direct measurement and smear data were converted to units of disintegrations per minute per 100 square centimeters (dpm/100 cm^2). Exposure rates were recorded in microrem per hour (μrem/h) and reported in microroentgens per hour (μR/h). The data generated were compared with the DOE (as specified in DOE Order 5400.5) and U.S. Nuclear Regulatory Commission (NRC) guidelines.

FINDINGS AND RESULTS

DOCUMENT REVIEW

Historical data submitted for review by the Safety and Environmental Protection Department (SEPD) was limited to previous radiological laboratory survey data (maps and measurement locations) indicating the radionuclides that had been used during that time period. A memo, found on the concrete wall of the vault after the framed walls were removed, indicated that there was contamination in the lead drawers and their associated rails on the floors (ORAU 1973).

SURFACE SCANS

Surface scans identified multiple locations of elevated residual activity on the floors and lower walls within the SVA. Most of the elevated activity was on or adjacent to the vault drawers and their associated tracks. Surface scans of the core holes identified two holes with activity in excess of background levels. Scans of the overheads identified isolated locations of elevated surface activity.

SURFACE ACTIVITY LEVELS

Results of the total and removable surface activity levels for the radiological assessment survey are presented in Table 1. Alpha surface activity levels ranged from -8 to 32 dpm/100 cm^2 for the concrete floor and walls and -8 to 0 dpm/100 cm^2 for the source vault drawers. Beta surface activity levels ranged from -150 to 670,000 dpm/100 cm^2 for concrete floors, 13 to 11,000 dpm/100 cm^2 for concrete walls, 69 to 23,000 dpm/100 cm^2 for the source vault drawers, and -51 to 3,100 dpm/100 cm^2 for the source vault core holes. Removable surface activity levels ranged from 0 to 5 dpm/100 cm^2 for gross alpha, -6 to 110 dpm/100 cm^2 for gross beta, -17 to 71,320 dpm/100 cm^2 for ^{3}H, -5 to 3,741 dpm/100 cm^2 for ^{14}C, and -3 to 1,114 dpm/100 cm^2 for ^{90}Sr. Based on the absence of elevated alpha activity within the source vault facility, no alpha surface activity measurements were performed within the core holes.

EXPOSURE RATES

An appropriate background reference area, with the level of shielding provided by the SVA, could not be identied. Exposure rates for the SVA were 7 µR/h, including background. This low exposure rate can be attributed to the shielding from cosmic radiation.

COMPARISON OF RESULTS WITH GUIDELINES

The radionuclides of concern at VRF's Source Vault Area were ^{3}H, ^{14}C, ^{90}Sr, and ^{226}Ra. The DOE guidelines for residual radioactive materials and the current NRC guidelines for acceptable surface contamination levels for release of a facility for unrestricted use were considered, and in cases when these guidelines were not identical, the more conservative values were used to evaluate the survey results (DOE 1990 and NRC 1987). The primary beta contaminants of concern were ^{90}Sr, ^{60}Co, and ^{14}C. The more restrictive beta contamination guideline for ^{90}Sr was used for comparing direct beta surface activity levels.

^{3}H Removable Activity

10,000 dpm/100 cm^2

Total Alpha Activity

100 dpm/100 cm^2 (Average over 1 m^2)
300 dpm/100 cm^2 (Maximum in 100 cm^2)
20 dpm/100 cm^2 (Removable in 100 cm^2)

Beta-Gamma Activity

1,000 dpm/100 cm^2 (Average over 1 m^2)
3,000 dpm/100 cm^2 (Maximum in 100 cm^2)
200 dpm/100 cm^2 (Removable in 100 cm^2)

The surface activity guidelines in DOE Order 5400.5 do not specifically address tritium. Because tritium typically penetrates the materials in which it comes into contact, the beta-gamma emitter surface activity guidelines are not applicable. Therefore, DOE assessed the potential doses associated with the release of property containing residual tritium and recommended an interim value of 10,000 dpm/100 cm^2 for removable tritium (DOE 1995).

The SVA structure had residual levels in excess of either the total surface or removable activity guidelines at several locations on the tracks and concrete adjacent to the vault drawers, within the vault drawers, the east lower wall, the overheads and the core holes.

The exposure rate guideline is 20 μR/h above background (DOE 1990). All exposure rates were below this guideline.

SUMMARY

During July 2000, the Environmental Survey and Site Assessment Program performed a radiological assessment survey of the Source Vault Area of the Oak Ridge Institute for Science and Education's Vance Road Facility.

Radiological assessment survey activities included surface scans, surface activity measurements, smear sampling and exposure rate measurements of the remaining SVA structure. Several locations on the floor, lower walls, overheads, vault drawers, and core holes, were identified as having levels in excess of the surface or removable activity criteria. These areas were documented and marked for future remedial actions.

FIGURES

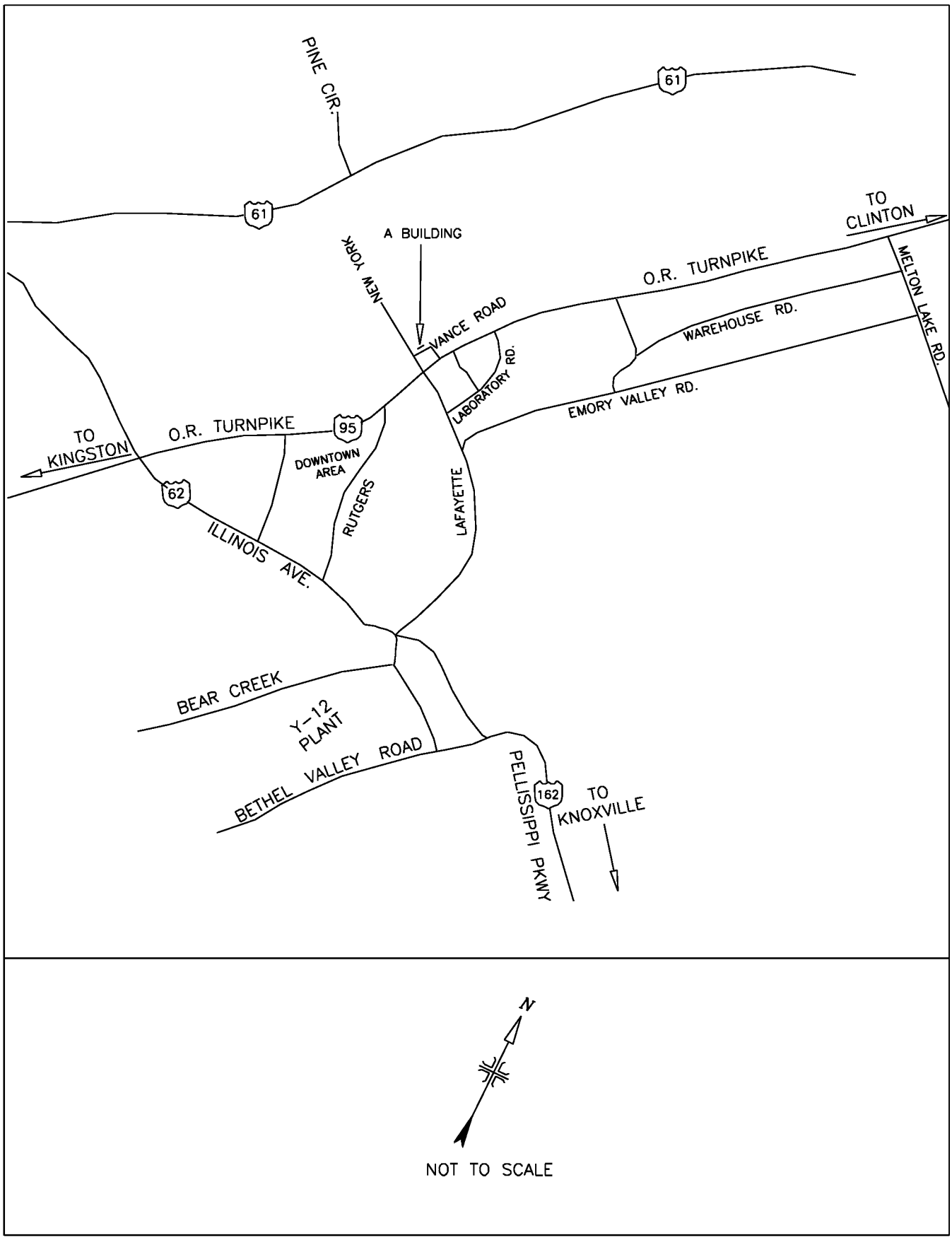

FIGURE 1: Location of Vance Road A Building

531-011 (x)

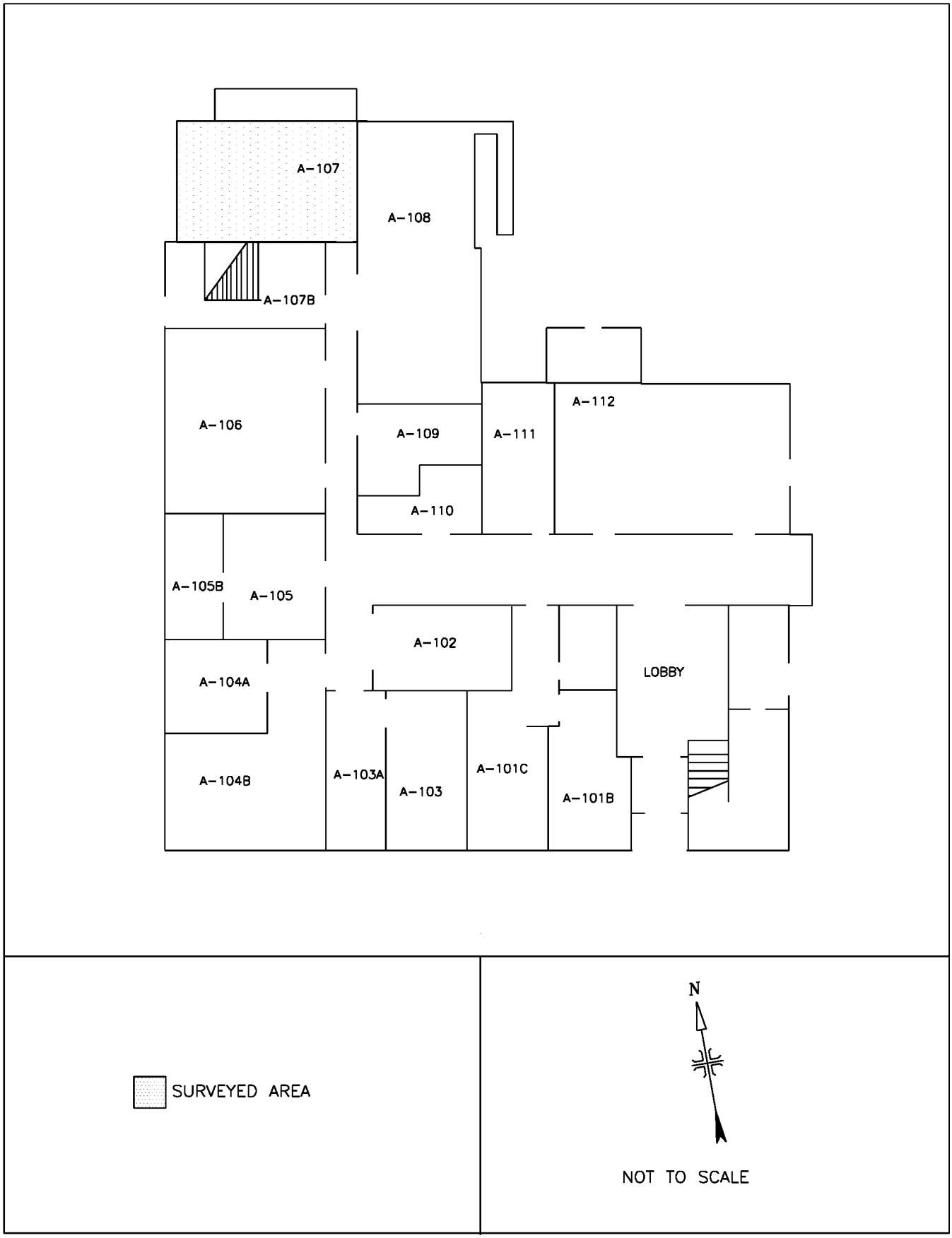

FIGURE 2: Vance Road A Building – Surveyed Area

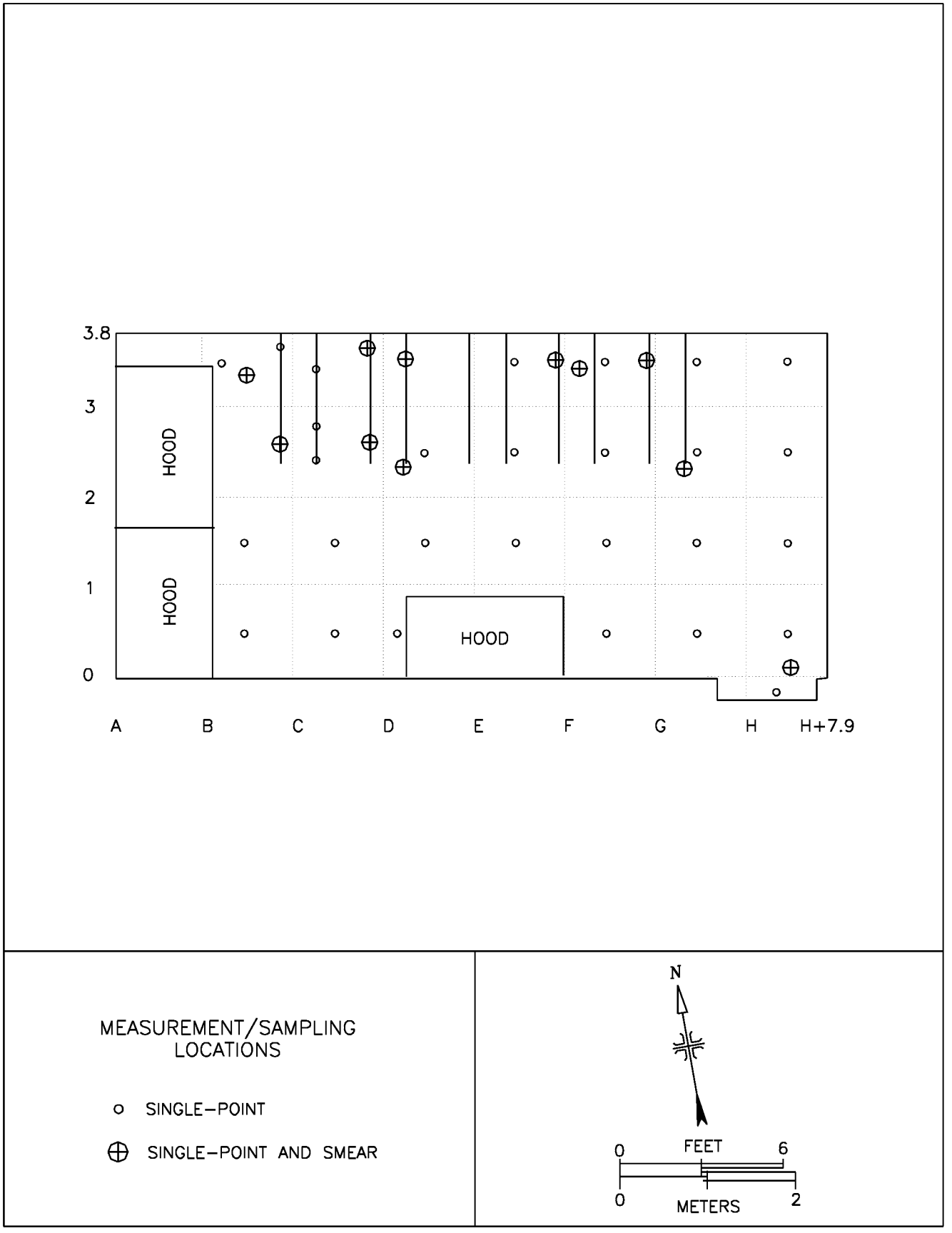

FIGURE 3: Source Vault Area, Radiological Assessment Survey – Floor Measurement and Sampling Locations

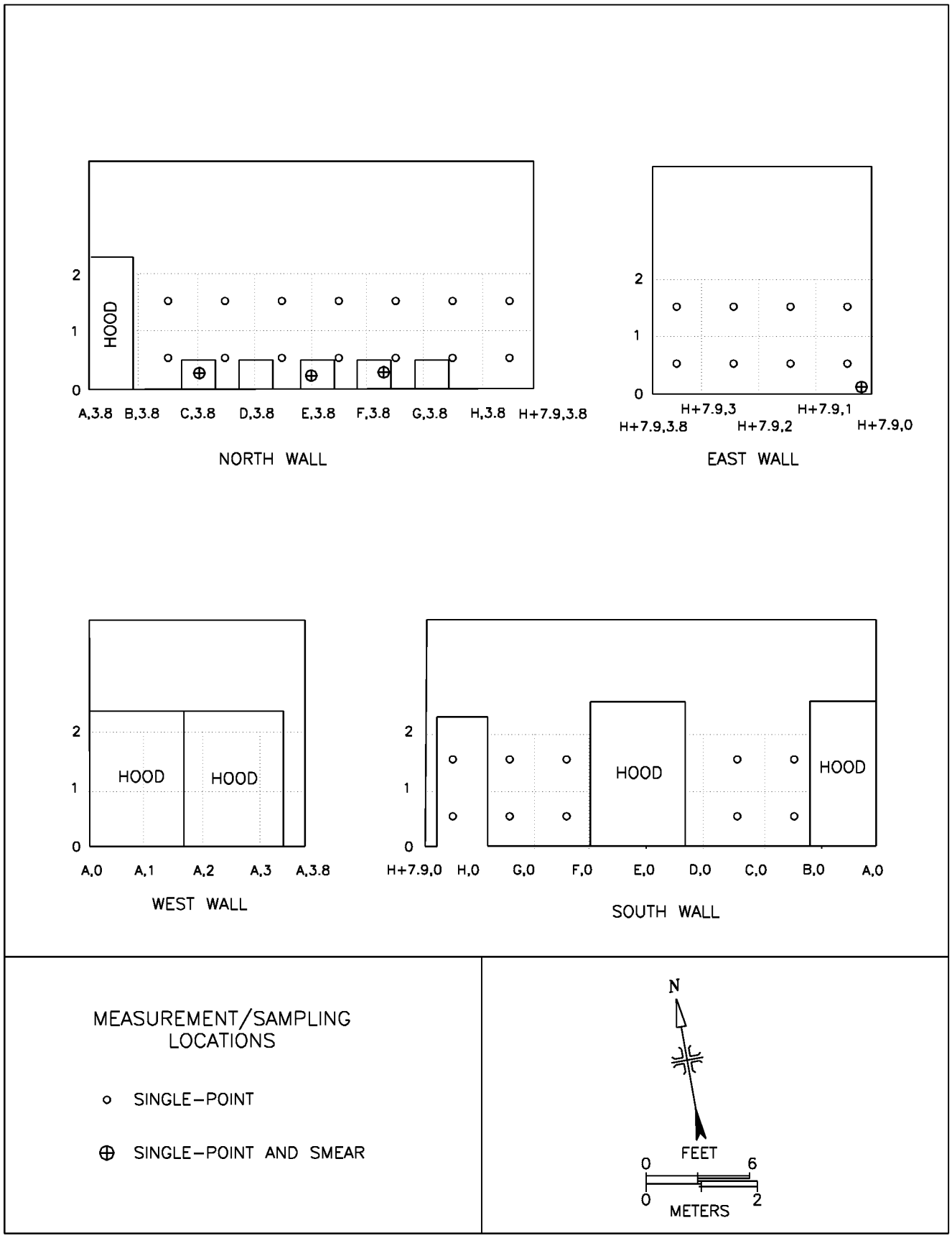

FIGURE 4: Source Vault Area, Radiological Assessment Survey – Lower Wall Measurement and Sampling Locations

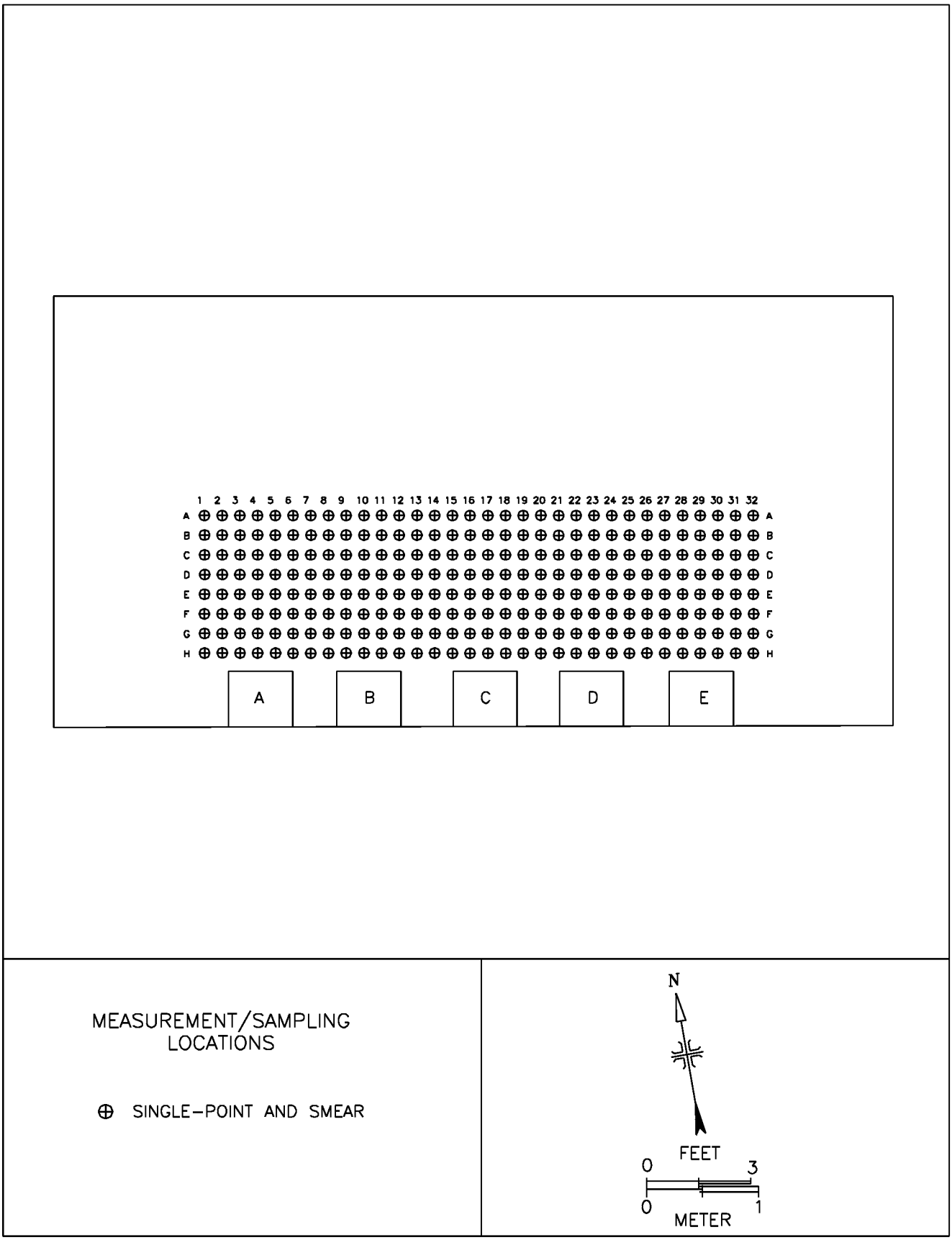

FIGURE 5: Source Vault Area, Radiological Assessment Survey – North Wall Core Holes Measurement and Sampling Locations

TABLES

TABLE 1

SUMMARY OF SURFACE ACTIVITY LEVELS
VANCE ROAD FACILITY SOURCE VAULT
STRUCTURE SURFACES
OAK RIDGE INSTITUTE FOR SCIENCE AND EDUCATION
OAK RIDGE, TENNESSEE

Location[a]	Total Surface Activity (dpm/100 cm²)		Removable Activity (dpm/100 cm²)				
	Alpha	Beta	Alpha	Beta	H-3	C-14	Sr-90
Floor							
B, 0	24	110	–[b]	--	--	--	--
B, 1	16	220	--	--	--	--	--
B, 2	0	3,400	0	2	49 ± 15 [c]	34.5 ± 5.9	
B, 3	8	9,900	--	--	--	--	--
B, 3	0	14,000	2	8	319 ± 25	157.8 ± 9.1	--
B, 3	-8	91,000	--	--	--	--	--
C, 3	0	4,800	3	3	77 ± 16	13.9 ± 5.2	--
C, 3	-8	2,000	--	--	--	--	--
C, 2	-8	2,500	0	1	50 ± 15	13.6 ± 5.2	--
C, 2	-8	2,300	--	--	--	--	--
C, 2	8	4,100	--	--	--	--	--
C, 1	8	250	--	--	--	--	--
C, 0	16	50	--	--	--	--	--
D, 0	32	130	--	--	--	--	--
D, 2	16	1,700	0	1	19 ± 14	11.3 ± 5.1	--
D, 2	8	150	--	--	--	--	--
D, 3	-8	1,400	0	5	1 ± 14	14 ± 5	1 ± 2

TABLE 1 (Continued)

SUMMARY OF SURFACE ACTIVITY LEVELS
VANCE ROAD FACILITY SOURCE VAULT
STRUCTURE SURFACES
OAK RIDGE INSTITUTE FOR SCIENCE AND EDUCATION
OAK RIDGE, TENNESSEE

Location[a]	Total Surface Activity (dpm/100 cm^2)		Removable Activity (dpm/100 cm^2)				
	Alpha	Beta	Alpha	Beta	H-3	C-14	Sr-90
Floor (continued)							
E, 3	16	-110	--	--	--	--	--
E, 3	0	120,000	0	3	2 ± 14	37 ± 6	7 ± 2
E, 2	24	110	--	--	--	--	--
E, 1	0	33	--	--	--	--	--
F, 0	16	390	--	--	--	---	--
F, 1	0	17	--	--	--	--	--
F, 2	-8	-36	--	--	--	--	--
F, 3	0	670,000	0	16	82 ± 18	193 ± 10	97 ± 4
F, 3	8	79	---	--	--	--	--
F, 3	8	45,000	2	8	63 ± 17	120 ± 8	39 ± 3
G, 3	0	33	--	--	--	--	--
G, 2	0	1,600	0	-1	-17 ± 13	7 ± 5	0 ± 2
G, 2	24	-99	--	--	--	--	--
G, 1	16	110	--		--	--	--
G, 0	-8	-150	--	--	--	--	--

TABLE 1 (Continued)

SUMMARY OF SURFACE ACTIVITY LEVELS
VANCE ROAD FACILITY SOURCE VAULT
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OAK RIDGE, TENNESSEE

Location[a]	Total Surface Activity (dpm/100 cm^2)		Removable Activity (dpm/100 cm^2)				
	Alpha	Beta	Alpha	Beta	H-3	C-14	Sr-90
Floor (continued)							
H, -2	8	-66	--	--	--	--	--
H, 0 - Floor Drain	24	2,800	--	--	--	--	--
H, 0	8	60	--	--	--	--	--
H, 1	0	160	--	--	--	--	--
H, 2	0	150	--	--	--	--	--
H, 3	0	130	--	--	--	--	--
North Wall							
B, 3.8, 1	32	150	--	--	--	--	--
B, 3.8, 0	0	230	--	--	--	--	--
C, 3.8, 0	8	9,800	0	19	7 ± 13	68 ± 7	15 ± 2
C, 3.8, 0	16	300	--	--	--	--	--
C, 3.8, 1	0	180	--	--	--	--	--
D, 3.8, 0	0	11,000	0	29	16 ± 13	45 ± 6	17 ± 2
D, 3.8, 0	8	350	--	--	--	--	--
D, 3.8, 1	16	230	--	---	--	--	--
E, 3.8, 1	8	190	--	--	--	--	--
E, 3.8, 0	8	190	--	--	--	--	--

TABLE 1 (Continued)

SUMMARY OF SURFACE ACTIVITY LEVELS
VANCE ROAD FACILITY SOURCE VAULT
STRUCTURE SURFACES
OAK RIDGE INSTITUTE FOR SCIENCE AND EDUCATION
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Location[a]	Total Surface Activity (dpm/100 cm^2)		Removable Activity (dpm/100 cm^2)				
	Alpha	Beta	Alpha	Beta	H-3	C-14	Sr-90
North Wall (continued)							
F, 3.8, 0	32	11,000	0	14	45 ± 15	82 ± 7	16 ± 2
F, 3.8, 0	8	260	–	–	–	–	--
F, 3.8, 1	16	140	–	–	–	--	--
G, 3.8, 1	8	200	–	–	–	--	--
G, 3.8, 0	0	120	–	–	–	--	--
H, 3.8, 0	0	350	–	–	–	--	--
H, 3.8, 1	8	260	–	–	–	--	--
East Wall							
H+7.9, 3.8, 1	16	290	–	–	–	--	--
H+7.9, 3.8, 0	8	360	–	–	–	–	--
H+7.9, 3, 0	24	290	--	--	--	--	--
H+7.9, 3, 1	0	340	--	--	--	--	--
H+7.9, 2, 1	16	210	--	--	--	--	--
H+7.9, 2, 0	0	200	--	--	--	--	--
H+7.9, 1, 0	-8	1,600	2	4	13 ± 13	-4 ± 5	5 ± 2
H+7.9, 1, 0	0	230	--	--	--	--	--
H+7.9, 1, 1	16	210	--	--	--	--	--

TABLE 1 (Continued)

SUMMARY OF SURFACE ACTIVITY LEVELS
VANCE ROAD FACILITY SOURCE VAULT
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Location[a]	Total Surface Activity (dpm/100 cm^2)		Removable Activity (dpm/100 cm^2)				
	Alpha	Beta	Alpha	Beta	H-3	C-14	Sr-90
South Wall							
H+7.9, 0, 0	16	96	--	--	--	--	--
H+7.9, 0, 1	8	13	--	--	--	--	--
H, 0, 1	0	230	--	--	--	--	--
H, 0, 0	-8	170	--	--	--	--	--
G, 0, 0	0	130	--	--	--	--	--
G, 0, 1	24	210	--	--	--	--	--
D, 0, 1	0	310	--	--	--	--	--
D, 0, 0	32	280	--	--	--	--	--
C, 0, 0	16	330	--	--	--	--	--
C, 0, 1	8	470	--	--	--	--	--
Source Vault Drawers -							
Drawer D (bottom)	0	23,000	1	70	-2 ± 12	570 ± 16	220 ± 6
Drawer D (front)	0	17,000	1	17	15 ± 13	20 ± 6	7 ± 2
Drawer E (bottom)	-8	69	--	--	--	--	--
Source Vault Core Holes							
H32	NA[d]	21	0	-1	36 ± 29	42 ± 12	1 ± 2
G32	NA	-26	1	-3	8 ± 26	13 ± 10	0 ± 2

TABLE 1 (Continued)

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Location[a]	Total Surface Activity (dpm/100 cm^2)		Removable Activity (dpm/100 cm^2)				
	Alpha	Beta	Alpha	Beta	H-3	C-14	Sr-90
Source Vault Core Holes (continued)							
F32	NA	7	0	4	25 ± 28	20 ± 10	2 ± 2
E32	NA	-12	0	-2	25 ± 28	19 ± 10	2 ± 2
D32	NA	2	0	2	11 ± 27	13 ± 10	1 ± 2
C32	NA	21	1	3	111 ± 35	76 ± 14	-1 ± 2
B32	NA	-13	1	3	4 ± 26	15 ± 10	0 ± 2
A32	NA	5	3	-2	-2 ± 25	7 ± 9	-3 ± 2
A31	NA	-8	0	-1	-1 ± 25	6 ± 9	-1 ± 2
B31	NA	-10	0	3	5 ± 26	6 ± 9	-2 ± 2
C31	NA	-18	0	3	114 ± 35	61 ± 13	-1 ± 2
D31	NA	-13	0	3	5 ± 26	9 ± 10	-2 ± 2
E31	NA	0	1	3	4 ± 26	12 ± 10	-1 ± 2
F31	NA	15	0	-2	5 ± 26	12 ± 10	0 ± 2
G31	NA	-12	0	1	5 ± 26	12 ± 10	0 ± 2
H31	NA	-20	5	1	11 ± 26	26 ± 11	3 ± 2
H30	NA	-13	0	1	1 ± 25	9 ± 10	-2 ± 2
G30	NA	-33	0	-2	5 ± 26	13 ± 10	0 ± 2
F30	NA	-23	3	1	-8 ± 24	8 ± 9	-2 ± 2

TABLE 1 (Continued)

SUMMARY OF SURFACE ACTIVITY LEVELS
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Location[a]	Total Surface Activity (dpm/100 cm^2)		Removable Activity (dpm/100 cm^2)				
	Alpha	Beta	Alpha	Beta	H-3	C-14	Sr-90
Source Vault Core Holes (continued)							
E30	NA	12	0	19	5 ± 26	9 ± 10	0 ± 2
D30	NA	-23	0	-3	1 ± 25	8 ± 9	-1 ± 2
C30	NA	-12	1	2	1 ± 25	10 ± 10	-1 ± 2
B30	NA	-17	0	-3	10 ± 26	17 ± 10	0 ± 2
A30	NA	-5	1	-2	18 ± 27	46 ± 12	3 ± 2
A29	NA	240	0	8	237 ± 44	166 ± 18	-1 ± 2
B29	NA	20	0	-2	-9 ± 24	10 ± 10	-2 ± 2
C29	NA	-26	1	2	3 ± 26	9 ± 10	-1 ± 2
D29	NA	-10	0	-3	2 ± 26	6 ± 9	-1 ± 2
E29	NA	-2	0	4	--	--	--
F29	NA	-30	0	2	1 ± 25	8 ± 9	-1 ± 2
G29	NA	0	0	-2	1 ± 25	9 ± 10	0 ± 2
H29	NA	30	1	15	9 ± 26	6 ± 9	-1 ± 2
H28	NA	-3	1	-1	8 ± 26	6 ± 9	0 ± 2
G28	NA	-33	1	3	-2 ± 25	10 ± 10	-1 ± 2
F28	NA	-3	0	-3	0 ± 25	8 ± 9	-1 ± 2
E28	NA	-38	1	5	1 ± 25	4 ± 9	-2 ± 2

TABLE 1 (Continued)

SUMMARY OF SURFACE ACTIVITY LEVELS
VANCE ROAD FACILITY SOURCE VAULT
STRUCTURE SURFACES
OAK RIDGE INSTITUTE FOR SCIENCE AND EDUCATION
OAK RIDGE, TENNESSEE

Location[a]	Total Surface Activity (dpm/100 cm^2)		Removable Activity (dpm/100 cm^2)				
	Alpha	Beta	Alpha	Beta	H-3	C-14	Sr-90
Source Vault Core Holes (continued)							
D28	NA	-23	1	-1	-7 ± 25	9 ± 10	-3 ± 2
C28	NA	-33	0	1	2 ± 26	10 ± 10	-1 ± 2
B28	NA	-5	0	-6	5 ± 26	6 ± 9	0 ± 2
A28	NA	130	1	2	102 ± 17	40 ± 6	1 ± 2
A27	NA	-10	0	-2	5 ± 13	2 ± 5	1 ± 2
B27	NA	100	0	1	7 ± 13	-1 ± 5	0 ± 2
C27	NA	-13	0	-4	17 ± 13	4 ± 5	0 ± 2
D27	NA	-40	0	-1	10 ± 13	4 ± 5	-1 ± 2
E27	NA	-15	1	1	8 ± 13	3 ± 5	1 ± 2
F27	NA	73	0	-1	5 ± 13	2 ± 5	1 ± 2
G27	NA	-33	0	2	3 ± 13	4 ± 5	-1 ± 2
H27	NA	-31	1	1	2 ± 13	-1 ± 5	1 ± 2
H26	NA	-13	0	-2	10 ± 13	5 ± 5	-1 ± 2
G26	NA	-20	0	1	0 ± 12	0 ± 5	0 ± 2
F26	NA	-7	1	-1	16 ± 13	4 ± 5	2 ± 2
E26	NA	-30	0	-1	4 ± 13	7 ± 5	0 ± 2

TABLE 1 (Continued)

SUMMARY OF SURFACE ACTIVITY LEVELS
VANCE ROAD FACILITY SOURCE VAULT
STRUCTURE SURFACES
OAK RIDGE INSTITUTE FOR SCIENCE AND EDUCATION
OAK RIDGE, TENNESSEE

Location[a]	Total Surface Activity (dpm/100 cm^2)		Removable Activity (dpm/100 cm^2)				
	Alpha	Beta	Alpha	Beta	H-3	C-14	Sr-90
Source Vault Core Holes (continued)							
D26	NA	-20	0	5	18 ± 13	1 ± 5	-1 ± 2
C26	NA	-8	1	-5	9 ± 13	3 ± 5	0 ± 2
B26	NA	8	0	-2	9 ± 13	1 ± 5	0 ± 2
A26	NA	12	0	59	30,540 ± 210	1,796 ± 27	2 ± 2
F25	NA	-7	0	2	11 ± 13	5 ± 5	0 ± 2
B24	NA	91	0	-2	16 ± 13	0 ± 5	0 ± 2
E23	NA	-15	0	1	29 ± 14	9 ± 5	0 ± 2
C22	NA	-41	0	-1	22 ± 14	3 ± 5	2 ± 2
H21	NA	0	1	2	19 ± 14	4 ± 5	0 ± 2
E20	NA	-2	0	-3	11 ± 13	9 ± 5	0 ± 2
D19	NA	-26	3	4	14 ± 13	3 ± 5	1 ± 2
G18	NA	-23	0	-1	-1 ± 12	-2 ± 5	0 ± 2
A17	NA	3,100	0	-1	1,282 ± 87	2,546 ± 64	1,114 ± 12
B17	NA	-25	0	-1	5 ± 13	0 ± 5	0 ± 2
C17	NA	-33	0	-1	8 ± 13	-1 ± 5	-2 ± 2
D17	NA	-25	5	18	-6 ± 12	0 ± 5	-1 ± 2

TABLE 1 (Continued)

SUMMARY OF SURFACE ACTIVITY LEVELS
VANCE ROAD FACILITY SOURCE VAULT
STRUCTURE SURFACES
OAK RIDGE INSTITUTE FOR SCIENCE AND EDUCATION
OAK RIDGE, TENNESSEE

Location[a]	Total Surface Activity (dpm/100 cm²)		Removable Activity (dpm/100 cm²)				
	Alpha	Beta	Alpha	Beta	H-3	C-14	Sr-90
Source Vault Core Holes (continued)							
E17	NA	-13	1	-2	-2 ± 12	4 ± 5	0 ± 2
F17	NA	-38	0	4	3 ± 13	1 ± 5	-1 ± 2
G17	NA	-36	0	-4	5 ± 13	-2 ± 5	0 ± 2
H17	NA	-26	1	1	-4 ± 12	-1 ± 5	-1 ± 2
H16	NA	-35	0	-5	9 ± 13	-3 ± 5	0 ± 2
G16	NA	-2	0	-4	-2 ± 12	-2 ± 5	0 ± 2
F16	NA	5	0	1	11 ± 13	1 ± 5	-1 ± 2
E16	NA	-2	0	1	-1 ± 12	-4 ± 5	0 ± 2
D16	NA	-25	1	-1	2 ± 13	2 ± 5	-1 ± 2
C16	NA	150	0	2	-4 ± 12	-1 ± 5	1 ± 2
B16	NA	-18	1	3	372 ± 26	31 ± 6	0 ± 2
A16	NA	13	0	23	8 ± 13	0 ± 5	-2 ± 2
A15	NA	2	1	4	-1 ± 12	-3 ± 5	-3 ± 2
B15	NA	-41	1	-1	2,255 ± 58	163 ± 9	-2 ± 2
C15	NA	-21	0	6	5 ± 13	0 ± 5	0 ± 2
D15	NA	-35	0	-4	2 ± 13	1 ± 5	-1 ± 2
E15	NA	-7	0	-2	-1 ± 12	6 ± 5	-1 ± 2

TABLE 1 (Continued)

SUMMARY OF SURFACE ACTIVITY LEVELS
VANCE ROAD FACILITY SOURCE VAULT
STRUCTURE SURFACES
OAK RIDGE INSTITUTE FOR SCIENCE AND EDUCATION
OAK RIDGE, TENNESSEE

Location[a]	Total Surface Activity (dpm/100 cm^2)		Removable Activity (dpm/100 cm^2)				
	Alpha	Beta	Alpha	Beta	H-3	C-14	Sr-90
Source Vault Core Holes (continued)							
F15	NA	-23	0	1	8 ± 13	0 ± 5	0 ± 2
G15	NA	12	0	2	-3 ± 12	-2 ± 5	-1 ± 2
H15	NA	-41	0	-2	9 ± 13	0 ± 5	0 ± 2
H14	NA	0	0	4	6 ± 13	-1 ± 5	0 ± 2
G14	NA	0	0	-1	4 ± 13	-1 ± 5	0 ± 2
F14	NA	-36	0	3	312 ± 24	89 ± 8	13 ± 2
E14	NA	7	0	-2	18 ± 13	0 ± 5	0 ± 2
D14	NA	-36	0	-3	3 ± 13	0 ± 5	0 ± 2
C14	NA	-50	0	-1	-7 ± 12	1 ± 5	0 ± 2
B14	NA	-28	0	-3	4 ± 13	3 ± 5	-1 ± 2
A14	NA	-15	1	1	1 ± 13	2 ± 5	-1 ± 2
A13	NA	-17	0	-3	-3 ± 12	3 ± 5	-1 ± 2
B13	NA	-18	0	-3	-1 ± 12	-2 ± 5	-1 ± 2
C13	NA	-38	0	-3	1 ± 13	1 ± 5	1 ± 2
D13	NA	-26	3	-1	-2 ± 12	1 ± 5	-2 ± 2
E13	NA	-33	0	2	-4 ± 12	1 ± 5	0 ± 2
F13	NA	0	0	1	1 ± 13	1 ± 5	-1 ± 2

TABLE 1 (Continued)

SUMMARY OF SURFACE ACTIVITY LEVELS
VANCE ROAD FACILITY SOURCE VAULT
STRUCTURE SURFACES
OAK RIDGE INSTITUTE FOR SCIENCE AND EDUCATION
OAK RIDGE, TENNESSEE

Location[a]	Total Surface Activity (dpm/100 cm^2)		Removable Activity (dpm/100 cm^2)				
	Alpha	Beta	Alpha	Beta	H-3	C-14	Sr-90
Source Vault Core Holes (continued)							
G13	NA	-7	0	-1	3 ± 13	1 ± 5	0 ± 2
H13	NA	-15	0	-2	2 ± 13	2 ± 5	-1 ± 2
H12	NA	-18	0	2	10 ± 13	-1 ± 5	1 ± 2
G12	NA	-7	0	-6	0 ± 12	1 ± 5	-1 ± 2
F12	NA	-15	0	-4	6 ± 13	2 ± 5	0 ± 2
E12	NA	-2	1	-2	2 ± 13	1 ± 5	-1 ± 2
D12	NA	-31	0	-3	5 ± 13	1 ± 5	-1 ± 2
C12	NA	3	0	-2	-2 ± 12	1 ± 5	0 ± 2
B12	NA	-36	1	2	-1 ± 12	-1 ± 5	-1 ± 2
A12	NA	-21	0	-1	6 ± 13	1 ± 5	0 ± 2
A11	NA	-35	0	-2	9 ± 13	-3 ± 5	-1 ± 2
B11	NA	-28	1	5	-1±12	2 ± 5	0 ± 2
C11	NA	0	0	10	0 ± 12	-2 ± 5	-1 ± 2
D11	NA	-43	0	-3	-7 ± 12	1 ± 5	-2 ± 2
E11	NA	3	0	1	5 ± 13	0 ± 5	0 ± 2
F11	NA	-35	0	-1	3 ± 13	-3 ± 5	0 ± 2
G11	NA	-40	0	5	0 ± 12	-1 ± 5	-1 ± 2

TABLE 1 (Continued)

SUMMARY OF SURFACE ACTIVITY LEVELS
VANCE ROAD FACILITY SOURCE VAULT
STRUCTURE SURFACES
OAK RIDGE INSTITUTE FOR SCIENCE AND EDUCATION
OAK RIDGE, TENNESSEE

Location[a]	Total Surface Activity (dpm/100 cm^2)		Removable Activity (dpm/100 cm^2)				
	Alpha	Beta	Alpha	Beta	H-3	C-14	Sr-90
Source Vault Core Holes (continued)							
H11	NA	-23	0	3	-3 ± 12	1 ± 5	0 ± 2
H10	NA	-15	0	2	3 ± 13	-2 ± 5	-1 ± 2
G10	NA	-26	0	-1	5 ± 13	0 ± 5	-1 ± 2
F10	NA	-41	0	-3	72 ± 16	9 ± 5	1 ± 2
E10	NA	-17	0	1	11 ± 13	2 ± 5	0 ± 2
D10	NA	-23	0	1	5 ± 13	3 ± 5	0 ± 2
C10	NA	-41	0	-1	9 ± 13	-3 ± 5	0 ± 2
B10	NA	-38	1	17	-2 ± 12	-1 ± 5	0 ± 2
A10	NA	-7	0	4	-6 ± 12	-1 ± 5	-1 ± 2
A9	NA	110	0	-1	1 ± 13	1 ± 5	0 ± 2
B9	NA	-7	1	-3	-1 ± 12	-1 ± 5	1 ± 2
C9	NA	-30	1	6	0 ± 12	-2 ± 5	-1 ± 2
D9	NA	-18	0	3	8 ± 13	2 ± 5	-1 ± 2
E9	NA	-30	0	4	12 ± 13	0 ± 5	1 ± 2
F9	NA	-18	0	-4	10 ± 13	1 ± 5	0 ± 2
G9	NA	-21	0	2	-3 ± 12	3 ± 5	-1 ± 2
H9	NA	18	0	-3	2 ± 13	5 ± 5	0 ± 2

TABLE 1 (Continued)

SUMMARY OF SURFACE ACTIVITY LEVELS
VANCE ROAD FACILITY SOURCE VAULT
STRUCTURE SURFACES
OAK RIDGE INSTITUTE FOR SCIENCE AND EDUCATION
OAK RIDGE, TENNESSEE

Location[a]	Total Surface Activity (dpm/100 cm^2)		Removable Activity (dpm/100 cm^2)				
	Alpha	Beta	Alpha	Beta	H-3	C-14	Sr-90
Source Vault Core Holes (continued)							
H8	NA	-18	0	-3	7 ± 13	4 ± 5	-1 ± 2
G8	NA	-43	1	-2	3 ± 13	3 ± 5	-1 ± 2
F8	NA	-46	0	-2	-1 ± 12	3 ± 5	-1 ± 2
E8	NA	-51	0	-1	4 ± 13	1 ± 5	0 ± 2
D8	NA	-36	0	4	-4 ± 12	0 ± 5	1 ± 2
C8	NA	-21	0	-2	8 ± 13	5 ± 5	-1 ± 2
B8	NA	-13	1	-1	6 ± 13	1 ± 5	0 ± 2
A8	NA	-20	1	-2	-1 ± 12	2 ± 5	-1 ± 2
A7	NA	-17	0	7	6 ± 13	4 ± 5	-1 ± 2
B7	NA	-20	0	-2	1 ± 13	3 ± 5	0 ± 2
C7	NA	-17	3	-1	91 ± 17	33 ± 6	2 ± 2
D7	NA	17	0	3	-2 ± 12	2 ± 5	-2 ± 2
E7	NA	-41	0	-2	6 ± 13	1 ± 5	2 ± 2
F7	NA	-2	0	-2	-3 ± 12	0 ± 5	1 ± 2
G7	NA	-31	0	-3	-6 ± 12	0 ± 5	0 ± 2
H7	NA	-36	0	1	-2 ± 12	-1 ± 5	0 ± 2
H6	NA	-20	0	-4	10 ± 13	-5 ± 5	0 ± 2

TABLE 1 (Continued)

SUMMARY OF SURFACE ACTIVITY LEVELS
VANCE ROAD FACILITY SOURCE VAULT
STRUCTURE SURFACES
OAK RIDGE INSTITUTE FOR SCIENCE AND EDUCATION
OAK RIDGE, TENNESSEE

Location[a]	Total Surface Activity (dpm/100 cm^2)		Removable Activity (dpm/100 cm^2)				
	Alpha	Beta	Alpha	Beta	H-3	C-14	Sr-90
Source Vault Core Holes (continued)							
G6	NA	-31	0	-3	1 ± 13	-3 ± 5	0 ± 2
F6	NA	2	0	-1	-12 ± 12	0 ± 5	1 ± 2
E6	NA	-30	0	2	0 ± 12	2 ± 5	1 ± 2
D6	NA	-48	0	-2	13 ± 13	9 ± 5	1 ± 2
C6	NA	-28	0	-1	6 ± 13	0 ± 5	1 ± 2
B6	NA	5	0	2	-1 ± 12	2 ± 5	-1 ± 2
A6	NA	-26	0	-1	-2 ± 12	0 ± 5	-2 ± 2
A5	NA	-8	0	-2	-7 ± 12	0 ± 5	-1 ± 2
B5	NA	-21	1	18	3 ± 13	5 ± 5	-1 ± 2
C5	NA	-12	3	-4	8 ± 13	5 ± 5	-1 ± 2
D5	NA	-17	0	1	-10 ± 12	3 ± 5	1 ± 2
E5	NA	-48	0	2	-9 ± 12	1 ± 5	0 ± 2
F5	NA	-45	0	-1	18 ± 13	1 ± 5	0 ± 2
G5	NA	-28	0	-2	5 ± 13	4 ± 5	0 ± 2
H5	NA	-3	0	-4	13 ± 13	0 ± 5	0 ± 2
H4	NA	-5	1	2	22 ± 14	7 ± 5	-2 ± 2
G4	NA	-25	0	4	-1 ± 12	-2 ± 5	-3 ± 2

TABLE 1 (Continued)

SUMMARY OF SURFACE ACTIVITY LEVELS
VANCE ROAD FACILITY SOURCE VAULT
STRUCTURE SURFACES
OAK RIDGE INSTITUTE FOR SCIENCE AND EDUCATION
OAK RIDGE, TENNESSEE

Location[a]	Total Surface Activity (dpm/100 cm^2)		Removable Activity (dpm/100 cm^2)				
	Alpha	Beta	Alpha	Beta	H-3	C-14	Sr-90
Source Vault Core Holes (continued)							
F4	NA	-15	0	2	-1 ± 12	2 ± 5	2 ± 2
E4	NA	-23	1	4	2 ± 13	2 ± 5	0 ± 2
D4	NA	-8	1	2	4 ± 13	4 ± 5	2 ± 2
C4	NA	-20	1	30	23 ± 14	6 ± 5	0 ± 2
B4	NA	-23	1	-1	4 ± 13	3 ± 5	0 ± 2
A4	NA	12	0	-1	8 ± 13	2 ± 5	2 ± 2
A3	NA	-8	0	-3	7 ± 13	-3 ± 5	-1 ± 2
B3	NA	20	0	-4	3 ± 13	2 ± 5	-1 ± 2
C3	NA	1,600	1	110	636 ± 33	858 ± 19	127 ± 5
D3	NA	-23	1	2	12 ± 13	9 ± 5	1 ± 2
E3	NA	-30	1	-3	-6 ± 12	2 ± 5	2 ± 2
F3	NA	0	0	7	3 ± 13	10 ± 5	0 ± 2
G3	NA	-21	0	-1	6 ± 13	-2 ± 5	1 ± 2
H3	NA	21	0	5	67 ± 16	68 ± 7	5 ± 2
H2	NA	-26	0	-3	7 ± 13	2 ± 5	0 ± 2
G2	NA	13	1	-4	-2 ± 12	1 ± 5	0 ± 2
F2	NA	-7	0	-4	6 ± 13	0 ± 5	1 ± 2

TABLE 1 (Continued)

SUMMARY OF SURFACE ACTIVITY LEVELS
VANCE ROAD FACILITY SOURCE VAULT
STRUCTURE SURFACES
OAK RIDGE INSTITUTE FOR SCIENCE AND EDUCATION
OAK RIDGE, TENNESSEE

Location[a]	Total Surface Activity (dpm/100 cm^2)		Removable Activity (dpm/100 cm^2)				
	Alpha	Beta	Alpha	Beta	H-3	C-14	Sr-90
Source Vault Core Holes (continued)							
E2	NA	-31	0	-3	4 ± 13	-1 ± 5	-1 ± 2
D2	NA	-21	0	-1	11 ± 13	3 ± 5	1 ± 2
C2	NA	5	1	-2	8 ± 13	3 ± 5	1 ± 2
B2	NA	-13	0	1	6 ± 13	3 ± 5	2 ± 2
A2	NA	-2	0	2	-7 ± 12	1 ± 5	-1 ± 2
A1	NA	-23	0	1	7 ± 13	5 ± 5	-1 ± 2
B1	NA	420	3	6	33 ± 14	50 ± 7	17 ± 3
C1	NA	18	0	-2	3 ± 13	4 ± 5	1 ± 2
D1	NA	-38	0	6	-4 ± 12	-4 ± 5	-1 ± 2
E1	NA	-13	0	3	-1 ± 12	2 ± 5	1 ± 2
F1	NA	-5	0	1	1 ± 13	-2 ± 5	0 ± 2
G1	NA	-20	0	-1	-1 ± 12	-1 ± 5	0 ± 2
H1	NA	-15	0	3	3 ± 13	0 ± 5	0 ± 2
H18	NA	-25	0	4	-9 ± 12	3 ± 5	0 ± 2
F18	NA	-30	0	3	5 ± 13	2 ± 5	-1 ± 2
E18	NA	-50	1	2	-3 ± 12	6 ± 5	-1 ± 2
D18	NA	-31	0	1	18 ± 13	2 ± 5	0 ± 2

TABLE 1 (Continued)

SUMMARY OF SURFACE ACTIVITY LEVELS
VANCE ROAD FACILITY SOURCE VAULT
STRUCTURE SURFACES
OAK RIDGE INSTITUTE FOR SCIENCE AND EDUCATION
OAK RIDGE, TENNESSEE

Location[a]	Total Surface Activity (dpm/100 cm^2)		Removable Activity (dpm/100 cm^2)				
	Alpha	Beta	Alpha	Beta	H-3	C-14	Sr-90
Source Vault Core Holes (continued)							
B18	NA	0	0	1	8 ± 13	7 ± 5	-3 ± 2
A18	NA	0	0	-3	0 ± 12	2 ± 5	-1 ± 2
A19	NA	-23	0	-2	2 ± 12	5 ± 5	-2 ± 2
B19	NA	-12	0	21	4 ± 12	5 ± 5	0 ± 2
C19	NA	-40	0	-2	18 ± 13	7 ± 5	-3 ± 2
E19	NA	-21	1	2	12 ± 13	4 ± 5	1 ± 2
F19	NA	-7	3	3	30 ± 14	20 ± 5	2 ± 2
G19	NA	-40	1	4	9 ± 13	6 ± 5	-1 ± 2
H19	NA	-13	1	1	13 ± 13	7 ± 5	-1 ± 2
H20	NA	-5	0	-2	3 ± 12	7 ± 5	-2 ± 2
G20	NA	-41	0	1	31 ± 14	4 ± 5	-1 ± 2
F20	NA	-12	3	-3	17 ± 13	6 ± 5	-1 ± 2
D20	NA	-18	0	1	11 ± 13	7 ± 5	-1 ± 2
C20	NA	10	1	4	8 ± 13	10 ± 5	-3 ± 2
B20	NA	-28	0	-2	16 ± 13	5 ± 5	-2 ± 2
A20	NA	7	1	27	8 ± 13	4 ± 5	-1 ± 2
A21	NA	-7	0	3	10 ± 13	6 ± 5	-1 ± 2

TABLE 1 (Continued)

SUMMARY OF SURFACE ACTIVITY LEVELS
VANCE ROAD FACILITY SOURCE VAULT
STRUCTURE SURFACES
OAK RIDGE INSTITUTE FOR SCIENCE AND EDUCATION
OAK RIDGE, TENNESSEE

Location[a]	Total Surface Activity (dpm/100 cm^2)		Removable Activity (dpm/100 cm^2)				
	Alpha	Beta	Alpha	Beta	H-3	C-14	Sr-90
Source Vault Core Holes (continued)							
B21	NA	-20	3	2	5 ± 12	4 ± 5	-1 ± 2
C21	NA	-17	0	-1	15 ± 13	5 ± 5	-1 ± 2
D21	NA	2	1	-2	9 ± 13	4 ± 5	0 ± 2
E21	NA	-13	0	-1	14 ± 13	6 ± 5	-1 ± 2
F21	NA	8	0	-3	3 ± 12	4 ± 5	-1 ± 2
G21	NA	-7	0	-3	-1 ± 12	5 ± 5	-3 ± 2
H22	NA	-28	0	1	17 ± 13	8 ± 5	1 ± 2
G22	NA	-46	0	-3	10 ± 13	4 ± 5	-1 ± 2
F22	NA	-25	0	-3	24 ± 14	7 ± 5	-2 ± 2
E22	NA	-33	0	3	17 ± 13	8 ± 5	-1 ± 2
D22	NA	-28	0	-1	16 ± 13	2 ± 5	-2 ± 2
B22	NA	-15	0	3	14 ± 13	9 ± 5	-2 ± 2
A22	NA	-36	0	-4	15 ± 13	7 ± 5	-1 ± 2
A23	NA	12	1	1	13 ± 13	6 ± 5	0 ± 2
B23	NA	-17	0	3	12 ± 13	5 ± 5	-1 ± 2
C23	NA	-10	0	-1	23 ± 14	4 ± 5	0 ± 2
D23	NA	-33	0	-3	15 ± 13	6 ± 5	-1 ± 2

TABLE 1 (Continued)

SUMMARY OF SURFACE ACTIVITY LEVELS
VANCE ROAD FACILITY SOURCE VAULT
STRUCTURE SURFACES
OAK RIDGE INSTITUTE FOR SCIENCE AND EDUCATION
OAK RIDGE, TENNESSEE

Location[a]	Total Surface Activity (dpm/100 cm^2)		Removable Activity (dpm/100 cm^2)				
	Alpha	Beta	Alpha	Beta	H-3	C-14	Sr-90
Source Vault Core Holes (continued)							
F23	NA	-17	3	-4	8 ± 13	9 ± 5	-1 ± 2
G23	NA	-10	0	-1	15 ± 13	10 ± 5	0 ± 2
H23	NA	-41	0	-3	46 ± 15	13 ± 5	-2 ± 2
H24	NA	-3	0	3	49 ± 15	9 ± 5	0 ± 2
G24	NA	-2	3	1	156 ± 19	14 ± 5	-1 ± 2
F24	NA	-28	0	72	71,320 ± 330	3,741 ± 39	0 ± 2
E24	NA	-43	3	3	75 ± 16	12 ± 5	0 ± 2
D24	NA	-15	1	-3	238 ± 22	18 ± 5	0 ± 2
C24	NA	-21	3	-3	23 ± 14	11 ± 5	-1 ± 2
A24	NA	-13	1	-3	24 ± 14	5 ± 5	-2 ± 2
A25	NA	-5	0	-3	35 ± 14	10 ± 5	0 ± 2
B25	NA	-3	1	1	57 ± 15	10 ± 5	-2 ± 2
C25	NA	-2	0	-1	28 ± 14	8 ± 5	-2 ± 2
D25	NA	-12	0	-4	21 ± 13	9 ± 5	-2 ± 2
E25	NA	-18	0	-2	33 ± 14	12 ± 5	-1±2
G25	NA	-20	0	-2	134 ± 19	16 ± 5	-2 ± 2
H25	NA	3	0	21	26 ± 14	13 ± 5	-2 ± 2

[a] Refer to Figures 3 through 5.
[b] Sample not collected.
[c] Uncertainties are total propagated uncertainties at the 95% confidence level.
[d] NA=Measurement not performed.

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APPENDIX A
MAJOR INSTRUMENTATION

APPENDIX A

MAJOR INSTRUMENTATION

The display of a specific product is not to be construed as an endorsement of the product or its manufacturer by the author or his employer.

DIRECT RADIATION MEASUREMENT

Instruments

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

Ludlum Ratemeter-Scaler
Model 2221
(Ludlum Measurements, Inc.,
Sweetwater, TX)

Detectors

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

Ludlum Gas Proportional Detector
Model 43-68
Physical Probe Area, 126 cm^2
(Ludlum Measurements, Inc.,
Sweetwater, TX)

Eberline GM Detector
Model HP-260
Physical Probe Area, 20 cm^2
(Eberline, Sante Fe, NM)

LABORATORY ANALYTICAL INSTRUMENTATION

Low Background Gas Proportional Counter
Model LB-5100-W
(Oxford, Oak Ridge, TN)

Tri-Carb Liquid Scintillation Analyzer
Model 1900CA
(Packard Instrument Co., Meriden, CT)

APPENDIX B
SURVEY AND ANALYTICAL PROCEDURES

APPENDIX B
SURVEY AND ANALYTICAL PROCEDURES

PROJECT HEALTH AND SAFETY

All survey and laboratory activities were conducted in accordance with ORISE health and safety and radiation protection programs.

CALIBRATION AND QUALITY ASSURANCE

Calibration of all field and laboratory instrumentation was based on standards/sources, traceable to NIST, when such standards/sources were available. In cases where they were not available, standards of an industry-recognized organization were used.

Analytical and field survey activities were conducted in accordance with procedures from the following documents of the Environmental Survey and Site Assessment Program:

- Survey Procedures Manual (January 1998)
- Laboratory Procedures Manual (May 2000)
- Quality Assurance Manual (March 2000)

The procedures contained in these manuals were developed to meet the requirements of DOE Order 414.1A and ASME NQA-1 for Quality Assurance and contain measures to assess processes during their performance.

Quality control procedures include:

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

UNCERTAINTIES AND DETECTION LIMITS

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

Detection limits, referred to as minimum detectable concentration (MDC), were based on 3 plus 4.65 times the standard deviation of the background count [$3 + (4.65\sqrt{BKG})$]. When the activity was determined to be less than the MDC of the measurement procedure, the result was reported as the actual (positive or negative) value. Because of variations in background levels, measurement efficiencies, and contributions from other radionuclides in the vicinity of the measurement area, the detection limits may differ from measurement to measurement and instrument to instrument.

SURVEY PROCEDURES

Surface Scans

Surface scans were performed by passing the detectors slowly over the surface; the distance between the detectors and the surface was maintained at a minimum—nominally about 1 cm. Surfaces were scanned using small area (126 cm^2) gas proportional and GM detectors. Identification of elevated levels was based on increases in the audible signal from the recording and/or indicating instrument. Combinations of detectors and instruments used for the scans were:

Alpha	-	gas proportional detector with ratemeter-scaler
Beta	-	gas proportional detector with ratemeter-scaler
Beta + Gamma	-	GM detector with ratemeter-scaler

Scan minimum detectable concentrations (MDCs) were estimated using the calculational approach described in NUREG-1507.[1] The scan MDC is a function of many variables, including the background level. Typical beta background levels on floors and walls range from 250 to 450 cpm for the hand-held gas proportional detectors. Additional parameters selected for the calculation of scan MDCs include a four-second observation interval, a specified level of performance at the first scanning stage of 95% true positive rate and 25% false positive rate, which yields a d' value of 2.32 (NUREG-1507, Table 6.1), and a surveyor efficiency of 0.5. The instrument efficiencies for the hand-held gas proportional detectors calibrated to Th-230, Sr-90, and C-14 were 0.10, 0.24, and 0.08, respectively. To illustrate an example for the hand-held gas proportional, the minimum detectable count rate (MDCR) and scan MDC for beta activity can be calculated as follows:

b_i = (250 cpm)(4 s)(1 min/60 s) = 16.7 counts,

MDCR = (2.32)(16.7 counts)^{½} [(60 s/min)/(4 s)] = 142 cpm,

$MDCR_{surveyor}$ = 142/(0.5)^{½} = 201 cpm

The scan MDC is calculated assuming a source efficiency of 0.50 (for Sr-90):

$$Scan\ MDC = \frac{MDCR_{surveyor}}{(\epsilon_s)\ (\epsilon_i)\ (\frac{probe\ area}{100\ cm^2})} = dpm/100\ cm^2$$

For the given background range, the estimated scan MDC range for the hand-held gas proportional detector was 1,330 dpm/100 cm^2 to 1,790 dpm/100 cm^2 for Sr-90 and 7,980 dpm/100 cm^2 to 10,720 dpm/100 cm^2 for C-14.

Surface Activity Measurements

Measurements of total alpha and total beta surface activity levels were performed using gas proportional and GM detectors with portable ratemeter-scalers. Based on the low efficiency of the gas proportional detectors for gamma radiation and since alpha activity was not detected at

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

the elevated beta activity measurement locations, all recorded beta events were assumed to be due to beta particles, only. Surface activity measurements were performed on floors, lower walls, upper walls, some equipment, and at locations of elevated direct radiation, using gas proportional detectors coupled to ratemeter-scalers.

Count rates (cpm), which were integrated over one minute with the detector held in a static position, were converted to activity levels (dpm/100 cm^2) by dividing the net rate by the total efficiency ($\epsilon_i \times \epsilon_s$) and correcting for the active area of the detector. The 2π instrument efficiency factors (ϵ_i) were as follows: alpha efficiency factor was 0.39 for the gas proportional detectors calibrated to Th-230; beta efficiency factors were 0.31 and 0.47 for the gas proportional detectors calibrated to C-14 and Sr-90, respectively; and the beta efficiency factor for the GM was 0.37 calibrate to Sr-90. The source efficiency factor (ϵ_s) was 0.25 for alpha and C-14 and 0.5 for Sr-90. The total alpha, C-14 beta, and Sr-90 beta efficiency factors for the gas proportional detectors were 0.10, 0.08, and 0.24, respectively. For the modified GM detector, the total beta efficiency factor was 0.19.

Because different building materials (poured concrete, brick, wood, steel, etc.) may have different background levels, average background count rates were determined for each material encountered in the surveyed area at a location of similar construction and having no known radiological history.

The alpha activity background count rates for the gas proportional detector averaged 1 cpm for all surfaces. The beta activity background count rates for the gas proportional detector averaged 381 cpm for poured concrete floors, 333 cpm for the metal rails/tracks, and 240 cpm for all other surfaces. For the modified GM detector, the beta activity background for the concrete surfaces was 49 cpm. The alpha MDC was 61 dpm/100 cm^2 for all surfaces, while the static C-14 beta activity MDCs were 930 dpm/100 cm^2 for poured concrete floors, 870 dpm/100 cm^2 for the metal rails/tracks, and 740 dpm/100 cm^2 for all other surfaces. The static C-14 beta activity MDC was 350 dpm/100 cm^2 for the vault cores. The static Sr-90 beta activity MDCs were 310 dpm/100 cm^2 for poured concrete floors, 290 dpm/100 cm^2 for the metal rails/tracks, and 250 dpm/100 cm^2 for all other surfaces. The static Sr-90 beta activity MDC was 120 dpm/100 cm^2 for concrete surfaces. The physical probe area for the gas proportional and GM detectors were

126 and 20 cm^2, respectively. Using efficiencies derived from a Sr-90 calibration source and comparing to the Sr-90 guideline proved to be the most conservative approach for evaluating surface activity.

Removable Activity Measurements

Removable gross alpha and gross beta activity levels were determined using numbered filter paper disks, 47 mm in diameter. Moderate pressure was applied to the smear and approximately 100 cm^2 of the surface was wiped. Smears were placed in labeled envelopes with the location and other pertinent information recorded.

For tritium, C-14, and Sr-90 determination, a second smear was moistened with deionized water and an adjacent 100 cm^2 was wiped. The smear was then sealed in a labeled liquid scintillation vial with the location and pertinent information recorded.

Exposure Rate Measurements

Measurements of dose equivalent rates (µrem/h) were performed at one meter above the surface using a Bicron microrem meter. Although the instrument displays data in µrem/h, the µrem/h to µR/h conversion is essentially unity.

ANALYTICAL PROCEDURES

Gross Alpha/Beta

Smears were counted on a low-background gas proportional system for gross alpha and gross beta activity. The MDCs of the procedure were 9 dpm/100 cm^2 for gross alpha and 15 dpm/100 cm^2 for gross beta.

Liquid Scintillation

Smears were counted in a liquid scintillation counter for low-energy beta activity to determine H-3, C-14, and Sr-90 activity—typical MDCs for the procedures are 22, 8, and 44 dpm/100 cm^2, respectively.

APPENDIX C

SUMMARY OF DEPARTMENT OF ENERGY RESIDUAL RADIOACTIVE MATERIAL GUIDELINES

APPENDIX C

RESIDUAL RADIOACTIVE MATERIAL GUIDELINES SUMMARIZED FROM DOE ORDER 5400.5 (DOE 1990)

BASIC DOSE LIMITS

The basic dose limit for the annual radiation (excluding radon) received by an individual member of the general public is 100 mrem/yr. In implementing this limit, DOE applies as low as reasonably achievable principles to set site-specific guidelines.

EXTERNAL GAMMA RADIATION

The average level of gamma radiation inside a building or habitable structure on a site that has no radiological restriction on its use shall not exceed the background level by more than 20 μR/h and will comply with the basic dose limits when an appropriate-use scenario is considered.

SURFACE CONTAMINATION GUIDELINES

	Allowable Total Residual Surface Contamination (dpm/100 cm^2)[a]		
Radionuclides[b]	Average[c,d]	Maximum[d,e]	Removable[d,f]
Transuranics, Ra-226, Ra-228, Th-230 Th-228, Pa-231, Ac-227, I-125, I-129	100	300	20
Th-Natural, Th-232, Sr-90, Ra-223, Ra-224, U-232, I-126, I-131, I-133	1,000	3,000	200
U-Natural, U-235, U-238, and associated decay products	5,000α	15,000α	1,000α
Beta-gamma emitters (radionuclides with decay modes other than alpha emission or spontaneous fission) except Sr-90 and others noted above	5,000β-γ	15,000β-γ	1,000β-γ

[a] As used in this table, dpm (disintegrations per minute) means the rate of emission by radioactive material as determined by correcting the counts per minute measured by an appropriate detector for background, efficiency, and geometric factors associated with the instrumentation.

[b] Where surface contamination by both alpha- and beta-gamma-emitting radionuclides exists, the limits established for alpha- and beta-gamma-emitting radionuclides should apply independently.

[c] Measurements of average contamination should not be averaged over an area of more than 1 m^2. For objects of less surface area, the average should be derived for each such object.

[d] The average and maximum dose rates associated with surface contamination resulting from beta-gamma emitters should not exceed 0.2 mrad/h and 1.0 mrad/h, respectively, at a depth of 1 cm.

[e] The maximum contamination level applies to an area of not more than 100 cm^2.

[f] The amount of removable radioactive material per 100 cm^2 of surface area should be determined by wiping an area of that size with dry filter or soft absorbent paper, applying moderate pressure, and measuring the amount of radioactive material on the wipe with an appropriate instrument of known efficiency. When removable contamination on objects of surface area less than 100 cm^2 is determined, the activity per unit area should be based on the actual area and the entire surface should be wiped. The numbers in this column are maximum amounts.