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MARTIN MARIETTA

PRELIMINARY RADIOLOGICAL CHARACTERIZATION OF THE HOMOGENEOUS REACTOR EXPERIMENT NO. 2 (HRE-2)

S. F. Huang 36
D. R. Simpson 36
L. K. Podolak
J. S. Eldridge 1
T. W. Oakes 36

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

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Environmental and Occupational Safety Division

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Date of Issue — September 1984

Prepared by the
OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee 37831
operated by
MARTIN MARIETTA ENERGY SYSTEMS, INC.
for the
U.S. DEPARTMENT OF ENERGY
under Contract No. DE-AC05-84OR21400

CONTENTS

LIST OF FIGURES v

LIST OF TABLES vii

ACKNOWLEDGMENTS ix

ABSTRACT xi

1. INTRODUCTION 1

2. DESCRIPTION OF HRE-2 1

   2.1 LOCATION 1

   2.2 OPERATING HISTORY AND OCCUPANCY 1

   2.3 FUNCTION 4

   2.4 PAST SURVEY RECORDS 4

3. IDENTIFICATION OF POTENTIAL RADIATION HAZARDS 4

   3.1 WASTE RETENTION POND 4

   3.2 DECONTAMINATION PAD 5

   3.3 46,000-L WASTE STORAGE TANK 5

   3.4 3800-L WASTE STORAGE TANK 5

   3.5 RADIOACTIVE WASTE PROCESS LINES 5

   3.6 BURIAL GROUND 5

   3.7 CHARCOAL ADSORBER PIT 5

   3.8 EVAPORATOR LOADING PIT 5

   3.9 WASTE VALVE PIT 5

   3.10 LOADING PIT 5

   3.11 DEMINERALIZED WATER SYSTEM 5

   3.12 STORAGE POOL 6

   3.13 REACTOR CELL 6

   3.14 CHEMICAL PROCESSING CELL C 6

   3.15 WASTE EVAPORATOR CELL 6

   3.16 PROCESSING CELL B 6

4. SURVEYS AND RESULTS 6

   4.1 OUTDOOR AREAS 7

      4.1.1 Purpose and Boundary 7

      4.1.2 Survey Procedures 7

         4.1.2.1 Sample collection 7

         4.1.2.2 Sample screening 9

         4.1.2.3 Sample preparation 12

         4.1.2.4 Sample analysis 12

      4.1.3 Results 12

         4.1.3.1 Background 12

         4.1.3.2 Surface contamination (0 to 30 cm) 12

         4.1.3.3 Subsurface contamination (deep soil coring) 14

      4.1.4 Discussion 15

         4.1.4.1 Surface (0 to 30 cm) 15

         4.1.4.2 Subsurface (30 cm and deeper) 18

4.2 INDOOR AREAS 20
4.2.1 Purpose and Boundary 20
4.2.2 Survey Methodology 21
4.2.3 Results 21
4.2.3.1 Waste evaporator, Building 7502 21
4.2.3.2 Main floor, Building 7500 21
4.2.3.3 North sublevels, Building 7500 25
4.2.3.4 South sublevels, Building 7500 25
4.2.4 Discussion 25
5. SUMMARY OF OUTDOOR AND INDOOR AREAS 35
5.1 OUTDOOR AREAS 35
5.1.1 Surface Contamination 35
5.1.2 Subsurface Contamination 36
5.2 INDOOR AREAS 37
6. REFERENCES 39

LIST OF FIGURES

1	ORNL area map (1 in. = 250 m)	2
2	HRE-2 facilities	3
3	Direct beta-gamma readings in mrad/h (1 mrad = 10 μGy) above 0.1 mrad/h at the ground surface in the vicinity of HRE-2	8
4	Hand coring a soil sample	10
5	Screening a soil sample	11
6	Beta-gamma direct readings in mrad/h (1 mrad = 10 μGy), from 1-m^2 grid areas, exceeding 0.1 mrad/h at 10 cm from surface (decontamination pad south of Building 7500)	14
7	Beta-gamma direct readings in mrad/h (1 mrad = 10 μGy), from 1-m^2 grid areas, exceeding 0.1 mrad/h at 20 cm from surface (waste evaporator)	22
8	Beta-gamma transferable contamination (dpm/100 cm^2), from 1-m^2 grid areas, exceeding 200 dpm/100 cm^2 (3.3 Bq/100 cm^2) (waste evaporator)	23
9	Beta-gamma direct readings in mrad/h (1 mrad = 10 μGy), from 2 $\times$ 2-m grid areas, exceeding 0.1 mrad/h at 10 cm from surface (Building 7500, main floor, ground level)	24
10	Beta-gamma transferable contamination (dpm/100 cm^2), from 1-m^2 grid areas, exceeding 200 dpm/100 cm^2 (3.3 Bq/100 cm^2) (Building 7500, first north sublevel)	26
11	Beta-gamma direct readings in mrad/h (1 mrad = 10 μGy), from 1-m^2 grid areas, exceeding 0.1 mrad/h at 10 cm from surface (Building 7500, second north sublevel)	27
12	Beta-gamma transferable contamination (dpm/100 cm^2), from 1-m^2 grid areas, exceeding 200 dpm/100 cm^2 (3.3 Bq/100 cm^2) (Building 7500, second north sublevel)	28
13	Beta-gamma direct readings in mrad/h (1 mrad = 10 μGy), from 1-m^2 grid areas, exceeding 0.1 mrad/h at 10 cm from surface (Building 7500, third north sublevel)	29
14	Beta-gamma transferable contamination (dpm/100 cm^2), from 1-m^2 grid areas, exceeding 200 dpm/100 cm^2 (3.3 Bq/100 cm^2) (Building 7500, third north sublevel)	30
15	Beta-gamma direct readings in mrad/h (1 mrad = 10 μGy), from 1-m^2 grid areas, exceeding 0.1 mrad/h at 10 cm from surface (Building 7500, first south sublevel)	31
16	Beta-gamma direct readings in mrad/h (1 mrad = 10 μGy), from 1-m^2 grid areas, exceeding 0.1 mrad/h at 10 cm from surface (Building 7500, second south sublevel)	32
17	Beta-gamma direct readings in mrad/h (1 mrad = 10 μGy), from 1-m^2 grid areas, exceeding 0.1 mrad/h at 10 cm from surface (Building 7500, third south sublevel)	33
18	Beta-gamma transferable contamination (dpm/100 cm^2), from 1-m^2 grid areas, exceeding 200 dpm/100 cm^2 (3.3 Bq/100 cm^2) (Building 7500, third south sublevel)	34

LIST OF TABLES

1	ORNL coordinates for deep soil core sites	9
2	Background measurements of radionuclide concentrations in soil	13
3	Radionuclide concentrations of contaminated soil samples from the top layer (30 cm) of earth	13
4	Sample sequence numbers and their corresponding depths	15
5	Preliminary gamma screening results for deep core soil samples	16
6	Radionuclide concentrations in deep coring soil samples	18
7	Quantitative results for alpha-emitting radionuclides	19
8	Uranium concentration in soil samples	20
9	A summary of the highest transferable and direct beta-gamma activities detected in the indoor areas	38

ACKNOWLEDGMENTS

The authors would like to thank W.F. Ohnesorge for stimulating discussions and J.B. Watson for excellent field and laboratory work. Special thanks go to the Information Center Complex Publications Office for document preparation assistance.

ABSTRACT

A preliminary radiological characterization has been performed on the HRE-2 facilities. The contamination in the indoor areas is almost exclusively ^{137}Cs and ^{90}Sr. No alpha contamination, either direct or transferable, was detected above background level. In general, the accessible areas of Building 7500 appear to have low levels of contamination. The reactor cell, the processing cell C, the waste evaporator cell, and the storage pool present a greater indoor radiation hazard and will require extensive health physics coverage during decommissioning.

Radiological contamination is also found in soil from the vicinity of HRE-2. The area of greatest environmental concern is the site of the previous waste pond and its perimeter. In this area, both the surface and subsurface soils are contaminated. The underground pipes for the HRE-1 and HRE-2 waste disposal systems may still be in place and are likely to have heavy internal contamination. The major radionuclides in the soil are ^{137}Cs, ^{90}Sr, and trace quantities of transuranics.

1. INTRODUCTION

The decontamination and decommissioning (D&D) activities at the Oak Ridge National Laboratory (ORNL) are part of the long-range Surplus Facility Management Program (SFMP) initiated by the Department of Energy (DOE). Most of these surplus facilities had been used for research and development (R&D) in the nuclear field.[1] At the completion of their designed purposes, their functions were no longer required. These facilities have been left in standby condition for 20 to 30 years; therefore, most of the short-lived radionuclides have decayed away. However, certain components of these facilities are probably deteriorating and may cause extra health physics, safety, and environmental concerns.

Currently, ORNL is in the process of decommissioning the Homogeneous Reactor Experiment No. 2, commonly abbreviated as HRE-2 or HRT. This facility includes Buildings 7500 and 7502, surplus instruments, and waste disposal systems. To assist in the development of planning, this preliminary radiological characterization was performed.

This study was divided into two parts: outdoor areas and indoor areas. The Department of Environmental Management (DEM) was responsible for most of the outdoor areas covering the immediate vicinity of HRE-2, with emphasis on locations where potential radiation-releasing sources existed.

The Radiation and Safety Surveys Department was responsible for the indoor areas, including Buildings 7500 and 7502 (waste evaporator) and the decontamination pad. A report on this survey has been published.[2]

2. DESCRIPTION OF HRE-2

The design, construction, function, and history of HRE-2 have been discussed in many sources.[3-11] This study focused on an initial radiological characterization. A summary of location, history, function, and past radiological surveys is provided in the following four sections.

2.1 LOCATION

The HRE-2 is located in Melton Valley 1 km southeast of ORNL's main complex. Figure 1 shows its relative location. This site is adjacent to solid waste disposal area no. 5.

Buildings 7500 and 7502 are situated on flat terrain. Approximately 90 m from the east and south walls of Building 7500, a small tributary of Melton Branch passes by. In the vicinity of HRE-2, this creek is about 5 m below the elevation of the previous waste pond and about 10 m below the elevation of Building 7500.

A waste retention pond was situated on the sloped area between Buildings 7500 and 7502 and this creek. Many components of the HRE-2 waste disposal system were located in this sloped area, except for the charcoal adsorber pit located on the east yard of Building 7505 and the steam drum and valve pit attached to the west wall of Building 7500 (shown in Fig. 2).

Building 7500 contains the reactor cell, the reactor fuel processing systems, and the control rooms shown in Fig. 2. The reactor and most of the highly contaminated parts of the system are located in the reactor cell and the chemical processing cell C and are covered with concrete shield blocks. The other area associated with the HRE-2 project is the waste evaporator located east of Building 7500 in Building 7502.

All contaminated components of the reactor and its associated chemical processing system (fuel processing system) are located within stainless steel lined concrete-shielded cells.

2.2 OPERATING HISTORY AND OCCUPANCY

Building 7500 was built and used for the Homogeneous Reactor Experiment (HRE-1) during the period 1951 to 1954.[3] At the end of 1954, it was decontaminated and remodeled for HRE-2 and was operated from 1957 to 1961. In 1961, the fuel and heavy water were removed and the

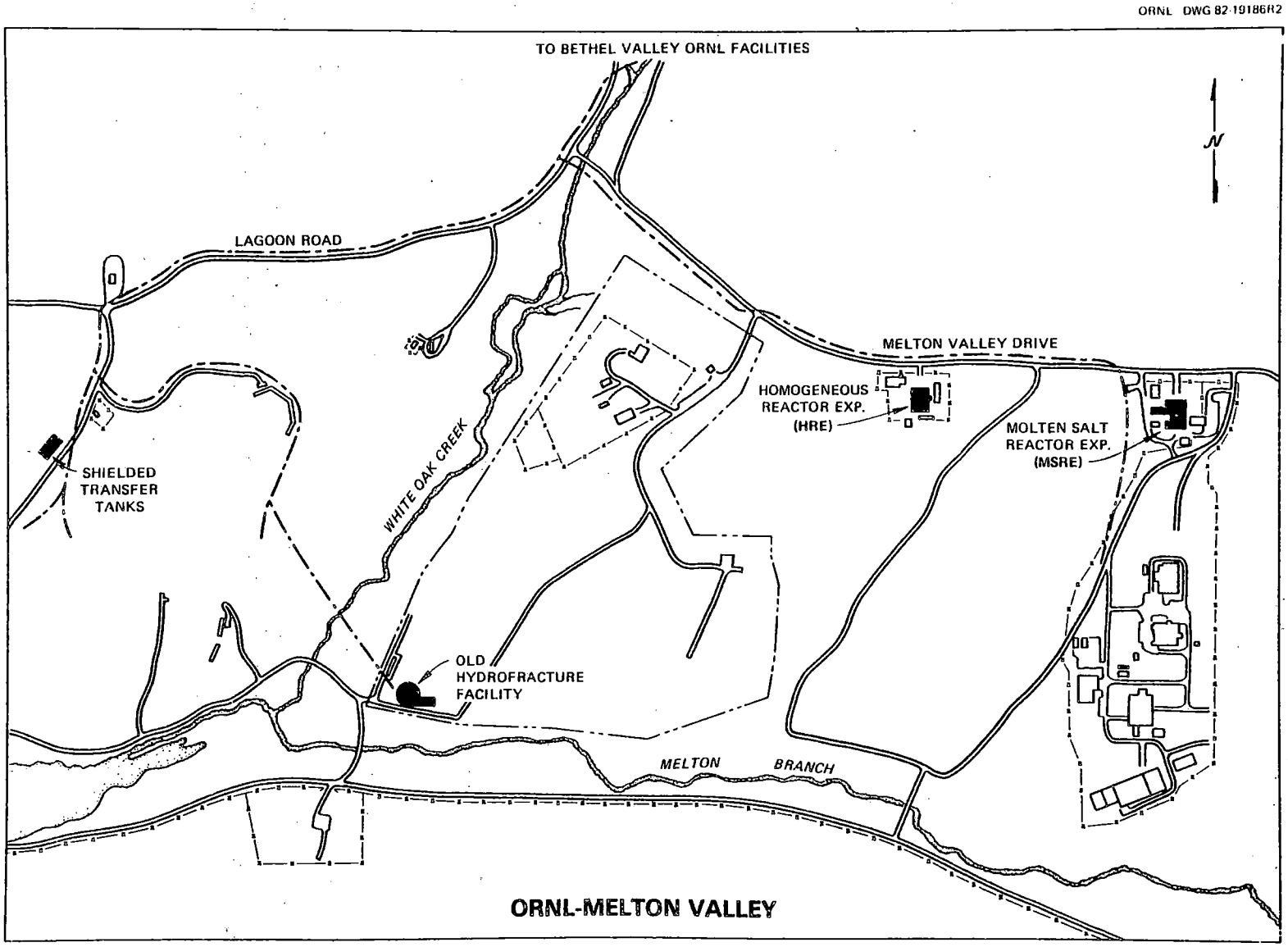

Fig. 1. ORNL area map (1 in. = 250 m).

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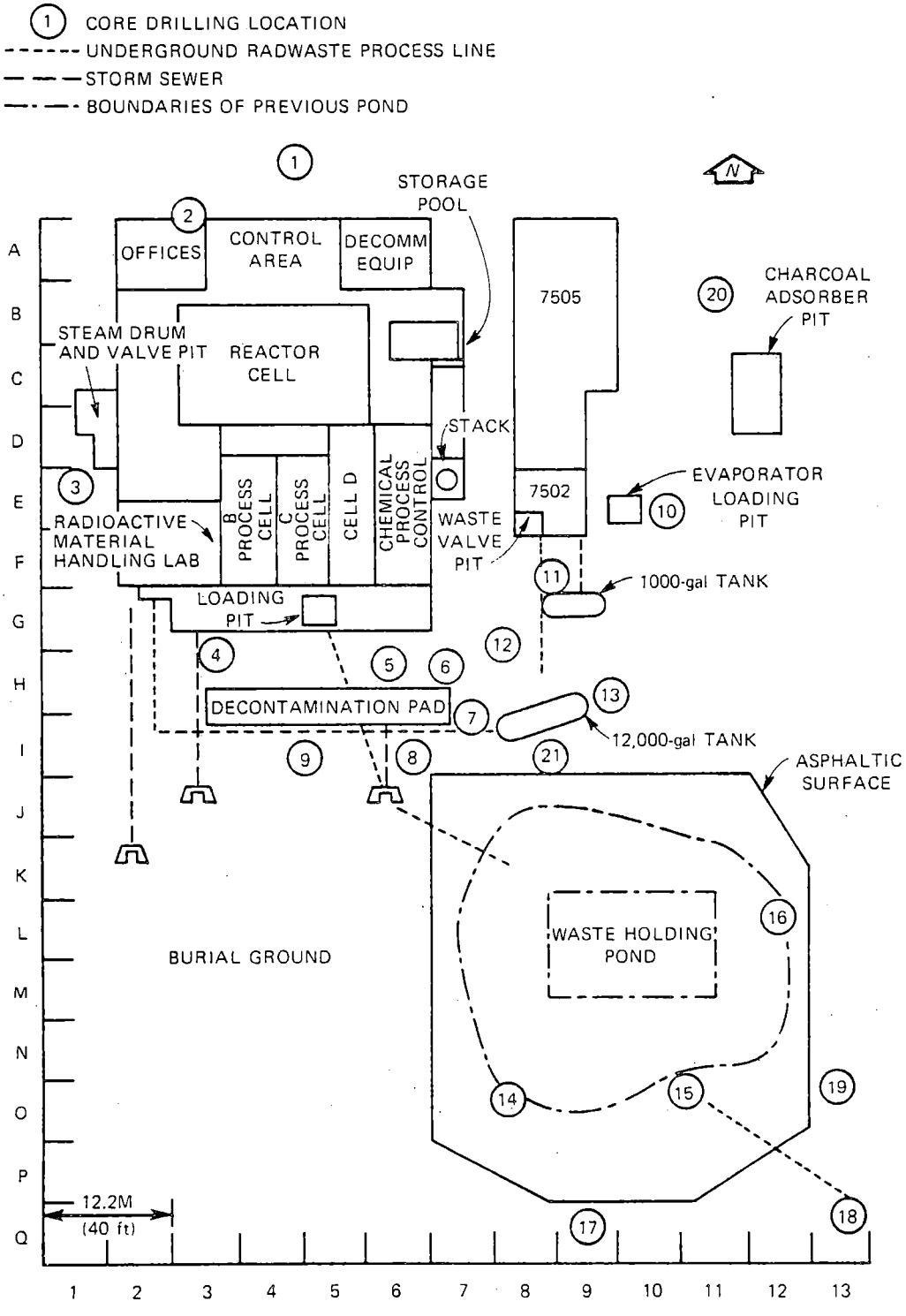

Fig. 2. HRE-2 facilities.

facility was sealed and placed in standby condition. In late 1962, a portion of the reactor core vessel was removed. Since 1963, a portion of the building has been occupied by the Nuclear Safety Pilot Plant (NSPP) for R&D studies. These areas include: cell B, the reactor control area, offices, the chemical processing control area, decontamination equipment, the radioactive material handling laboratory, the air compressor system, the stack, steam and normal electrical utilities, maintenance equipment, the 46,000-L waste storage tank, and an active waste process line. The function of NSPP and a list of currently operated equipment are provided elsewhere.[6,7,12]

2.3 FUNCTION

The HRE-2 was a two-region, aqueous, homogeneously fueled reactor. The two regions were the fuel and the blanket regions. It differed from cladded-fuel heterogeneous reactors in the area of fission product containment. In the homogeneously fueled reactor, the fuel and fission products were circulated and distributed throughout the reactor's primary system.

The fuel solution was enriched ^{235}U in the form of sulfate salt (U_2SO_4) dissolved in heavy water (D_2O). The blanket region was heavy water. Shortly after full operating power was achieved in 1957, a hole developed in the reactor core tank, allowing fuel solution to mix into the blanket region of the reactor. The reactor continued to operate until 1961.

2.4 PAST SURVEY RECORDS

In 1975, the roof plugs in the reactor cell were removed to perform a radiation survey.[11] Results of this survey are summarized below. The highest absorbed dose rate, up to 6 Gy/h (600 rad/h), was detected at the pressure vessel nozzle. Analysis of sediment samples determined that the contamination was primarily ^{90}Sr and ^{137}Cs. The liquid and gaseous waste disposal systems and the demineralized water system were also found to be radioactively contaminated.

3. IDENTIFICATION OF POTENTIAL RADIATION HAZARDS

Potential radiation hazards were defined as those areas or components that became contaminated during the operational years of HRE-2 and that could release inadequately contained, long-lived fission- and neutron-activated products into the vicinity. Sixteen potential sources were identified and are described in the following paragraphs.[3-11] Relative locations of these sources are marked in Fig. 2. In the following paragraphs, a brief description of each source is provided. Items 1 to 12 affect primarily outdoor areas, and items 13 to 16 affect mainly indoor areas.

3.1 WASTE RETENTION POND

This unlined earthen waste pond was built to receive low-level radioactive waste ($\leq$1000 cpm/mL) from HRE-2. During the period 1959 to 1960, it received highly contaminated fission products from the chemical processing system. It also received shield water (containing about 13 TBq or 340 Ci of beta-gamma activities) from the reactor tank.[12,13]

In 1970, the pond was filled, graded, and sprayed with approximately 500 kg of weed killer (sodium borate), then provided with a layer of crushed stone and capped with asphalt 3.8 cm thick. The finished area was about 1400 m^2. The actual sizes of pond surface and pond bottom were about 800 and 200 m^2, respectively. The pond had a 1.2-million-L capacity, a 3.9-m average depth, and a 5.2-m maximum depth. The asphalt surface was slightly sloped downward from the northwest corner to the southeast corner.

The elevation of the bottom of the pond before fill-in was approximately 244.8 m, the surface elevation of core sites 14 to 17 was approximately 245.4 m, and the elevation of the flat area (Buildings 7500 and 7502) was approximately 249.9 m.

During the years 1957 to 1961, this pond was drained continuously through a 20.3-cm diameter clay pipe to a weir box located at the southeast corner of the pond perimeter. The pipe is probably still underground; however, the weir box no longer exists.

3.2 DECONTAMINATION PAD

Located south of Building 7500 is a low-roofed shed measuring approximately 3 × 20 m. It was used to store and decontaminate "hot" equipment. The east half of it has a floor lined with stainless steel and is equipped with drains for decontamination work.

3.3 46,000-L WASTE STORAGE TANK

This tank, located outside the northern boundary of the asphalt surface of the waste retention pond, is still active. It received low-level radioactive waste from the HRE-2 project and is currently serving the Radioactive Material Handling Laboratory, located at the southwest corner of Building 7500 (Fig. 2).

3.4 3800-L WASTE STORAGE TANK

This tank, located to the south of Building 7502, is buried to a depth of about 1.5 m. This tank stored condensate concentrated in waste evaporator Building 7502 from 1957 to 1961. Since 1961, it has been empty and inactive.

3.5 RADIOACTIVE WASTE PROCESS LINES

Most radioactive waste process lines at HRE-2 are inactive and probably are still underground. Currently, the only active line runs from the Radioactive Material Handling Laboratory to the 46,000-L waste storage tank. This active line and a few inactive lines are marked in Fig. 2.

3.6 BURIAL GROUND

This area was located in the south yard of the decontamination pad. Unknown quantities of contaminated waste and equipment were packed in 193-L drums and buried there.

3.7 CHARCOAL ADSORBER PIT

This structure, the major part of the underground off-gas system, is located approximately 30 m east of Building 7500 and is buried under 3 m of earth. Pipes from this system are underground, extending from the east valve pit to the absorber and then from the absorber to the stack pad.

3.8 EVAPORATOR LOADING PIT

This pit, located outside the east wall of waste evaporator Building 7502, is inactive.

3.9 WASTE VALVE PIT

The waste valve pit is located in the east yard, approximately midway between the waste evaporator and the waste pond. It contains waste and vent piping from all of the waste system components.

3.10 LOADING PIT

Located at the south porch of 7500, this pit was once used for transporting carriers containing HRE fuel solution or chemical plant dissolved solids. Currently, it houses the NSPP metering tanks.

3.11 DEMINERALIZED WATER SYSTEM

The aboveground portion of this system, located outside the west wall of Building 7500, has been removed.

3.12 STORAGE POOL

This is a water-filled storage pool with inner dimensions of 2.1 × 5.5 × 5.2 m. It is located at the east end of Building 7500 and is used for storage of contaminated equipment and for activities requiring water shielding. It is equipped with a small cylindrical "cutting tank." Parts of the HRE-2 reactor core and fragmented equipment have been stored in it. No indication of leaking has been observed.

3.13 REACTOR CELL

The reactor cell is currently evacuated through filters to the atmosphere. It is an enclosed, concrete-steel-shielded structure 7.6 m wide × 16.5 m long × 7.6 m deep with 0.9-m thick walls and is situated completely underground. Concrete blocks would have to be removed to gain access. It is very likely that the inner cell surfaces and the equipment remaining in the cell are contaminated with long-lived fission products as a result of previous underwater maintenance.

As the structure was designed, the fission products were to be contained within the fuel system with only induced radioactivity expected in the blanket system. When the core vessel developed a hole, fission products spread into the blanket system as well. Approximately 30 to 40 kg of highly radioactive insoluble fission and corrosion products have been left in the reactor system. These activities probably are plated out on all inside surfaces of pipes and vessels and remain as sediment in stagnant and low-flow-rate areas.

3.14 CHEMICAL PROCESSING CELL C

Cell C, adjacent to the reactor cell, is also a completely underground structure 3.7 m wide × 7.3 m long × 7.6 m deep with 0.9-m thick walls. Although intended for underwater maintenance similar to the reactor cell, cell C is dry and is covered with two layers of concrete plugs. This cell's primary function was to remove fission and corrosion products. Hydroclones were used, and the removed solids were dissolved in sulfuric acid in a dissolver and temporarily stored for radioactive decay before removal to a carrier for disposal.

3.15 WASTE EVAPORATOR CELL

The evaporator cell is located east of Building 7500. It is a completely enclosed structure with concrete-steel-shielded walls 0.9 m thick and inner dimensions of 3.7 × 3.7 × 2.4 m deep. It was built for HRE-1 and later, in about 1957, was enclosed within Building 7502 along with its instruments and the evaporator drainage pit. The instruments and the drainage pit are located outside the south and west walls of the evaporator cell.

The waste evaporator cell was designed to concentrate high-level radioactive waste from the 3800-L waste storage tank prior to transfer into the ORNL liquid waste system. This cell also was used for the reactor fuel solution during recovery operations. Access into the evaporator cell was apparently through the concrete plugs in the roof, which had not been opened in years.

3.16 PROCESSING CELL B

Cell B, currently occupied by NSPP, is adjacent to cell C and has the same dimensions.

4. SURVEYS AND RESULTS

Different approaches and techniques were used to characterize the radiological conditions of outdoor and indoor areas. In this section, studies of outdoor areas are discussed first, followed by studies of the indoor areas.

4.1 OUTDOOR AREAS

4.1.1 Purpose and Boundary

The purpose of the outdoor survey was to determine the location, size, and radiological inventory of contaminated areas. This goal was achieved by collecting field data and soil and water samples.

The boundary of the survey area is shown in Figs. 2 and 3. This area covers all potential radiation-releasing sources. These sources are described in Sect. 3 and survey procedures and results are discussed in Sect. 4.2.1 through Sect. 4.1.4.2.

4.1.2 Survey Procedures

4.1.2.1 Sample collection

The survey procedures for the collection of soil and water samples are as follows.

Site identification. To document survey readings and to identify contaminated areas and samples, a grid layout was established. This grid layout applied a numerical scale in the east-west direction and an alphabetical scale in the north-south direction. Each grid cell was 6.1 m^2 and was identified by a number followed by a letter. Contaminated surface areas were identified by grid cells, and their actual location and size were measured. Wooden stakes and strings were used in marking this grid layout. A grid layout of a much smaller size (1 m^2) was used for the survey of the decontamination pad.

Deep soil coring sites were selected at or near the potential radiation-releasing sources discussed in the previous section. Each site was identified by a number, and the locations were specified by ORNL coordinates as shown in Table 1 and marked on Fig. 2.

Walk-over survey. Walk-over surveying was used to identify surface (ground-level) contaminations. A portable GM survey meter was used at approximately 1 to 3 cm above ground, and the entire area was surveyed systematically by following the grid layout.[14]

Hand coring. Surface contaminated areas were first identified by walk-over survey, and then a hand coring technique was used to collect top-layer (30-cm) soil samples. From the center of each contaminated area, two 30-cm soil segments were collected with a sampling tube* and combined as one sample. Figure 4 shows a technician using this device. The tube is 1.9 cm in diameter and 30 cm long and is manually hammered or pushed into the ground. A soil layer from 0 to 30 cm thick was sampled.

Deep soil coring. The deep soil coring technique was used mainly to collect subsurface soil samples. A drilling team from Geotek collected samples at core sites 1, 2, and 3. Personnel from the Plant and Equipment Division collected samples at the rest of the core sites since they were located in potentially contaminated areas. Because the same kind of sampling tube (split-spoon) and similar techniques were used, the quality of soil samples was not affected by changing sampling teams.

Split spoons (3.8 cm in diam and 68 cm long) were used to collect soil segments (61 cm) in a continuous manner. The first 0.6 m of soil sample was collected, and then the augering would continue down to the next 0.6 m. This process continued until the projected depth was reached or to auger refusal.

To avoid accidental damage to the underground wiring and piping systems, the first 0.6 m of soil was hand excavated (except at remote areas). Before hand excavation, a surface sample was collected using hand coring techniques. A 30-cm-diam posthole digger was used for hand excavation. Surface samples were not collected from areas covered with asphalt or gravel.

Each sample was identified by two numbers separated by a hyphen (-). The first number (core number) specified the core site, and the second number (sequence number) specified the sequence relative to the depth at which each sample was collected (lower number corresponds to shallower depth).

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* JMC Clements Associates, Inc.

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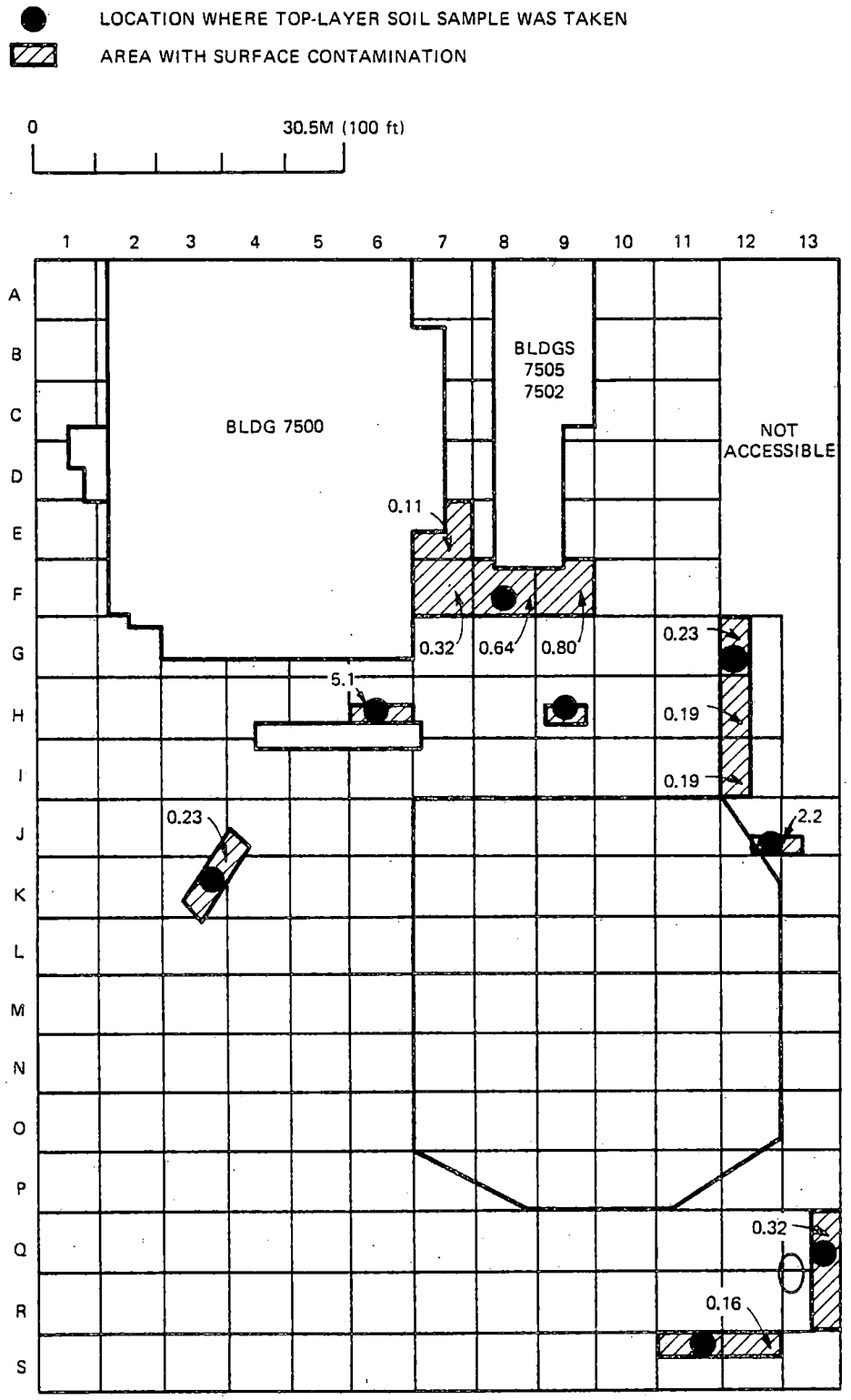

Fig. 3. Direct beta-gamma readings in mrad/h (1 mrad = 10 μGy) above 0.1 mrad/h at the ground surface in the vicinity of HRE-2.

Table 1. ORNL coordinates for deep soil core sites[a]

Core site identification	Coordinates N	Coordinates E	Core site identification	Coordinates N	Coordinates E
1	18,827	31,380	12	18,685	31,436
2	18,813	31,340	13	18,662	31,482
3	18,725	31,310	14	18,540	31,450
4	18,677	31,360	15	18,540	31,500
5	18,673	31,405	16	18,600	31,525
6	18,673	31,420	17	18,500	31,475
7	18,667	31,430	18	18,500	31,540
8	18,640	31,420	19	18,540	31,540
9	18,640	31,380	20	18,800	31,495
10	18,730	31,480	21	18,640	31,460
11	18,707	31,460			

[a]Measured in feet.

Water sampling. A water sample was collected at core site 20, about 6.1 m below ground level. Before sampling, a settling time of 24 h was allowed. This water sample was kept at a low temperature until further processing so that microorganism growth was minimized.

4.1.2.2 Sample screening

Each sample was screened twice for radioactivity, once in the field using a portable GM meter and once in a laboratory using a multichannel NaI(Tl) detector.

GM meter. To minimize cross-contamination, the higher-activity samples were separated from the less contaminated samples in the field. A portable GM meter was used for this purpose as the sample was recovered, as shown in Fig. 5. Samples with above-background radioactivity were classified as higher activity and were processed and analyzed separately from the rest of the samples.

Experience has shown that radiological distribution in soil usually occurs only in a thickness of a few inches. Radioactivity might be diluted if the "hot" segment was not isolated. In this study, samples recovered from the ground were either 30 or 60 cm long. However, no sample was subdivided because no detectable "hot" segment was monitored. The minimum reading obtained from the GM meter was about 0.03 mrad/h. Readings were measured in counts per minute (cpm); however, the conversion factor of the instrument is approximately 3100 cpm $\approx$ 1 mrad/h (10 μGy/h). This conversion is fairly accurate when only high-energy gamma rays are present.

NaI(Tl) detector. The sample was brought back to a laboratory, and its net weight was obtained. Without further preparation, the sample was counted on a 6-in.-diam NaI(Tl) detector for 5 min. The total integral counts and a gamma spectrum between the energy range of 100 to 1500 keV were obtained. This counting procedure is discussed in ref. 15.

This counting method was qualitative and discriminated against alpha and beta particles. The method served (a) to separate natural background samples from those contaminated with man-made gamma-ray emitting radionuclides and (b) to identify those radionuclides that have gamma energies between 100 and 1500 keV.

Samples with above background activity were further processed for quantitative analyses. A number of background samples were also selected as controls. The average background reading was 40 counts per second (cps) per kilogram of moist soil.

ORNL-PHOTO 4187-83

Fig. 4. Hand coring a soil sample.

ORNL-PHOTO 4189-83

Fig. 5. Screening a soil sample.

4.1.2.3 Sample preparation

Based on the gamma screening results, 54 out of 116 total soil samples and one water sample were further processed using the following preparation procedures.

Soil. The total weight (wet wt) of each sample was obtained before being dried in a 105°C oven. The total dry weight (dry wt) was obtained at the end of the drying period (approximately 8 h or more). The sample was then ground to a fine mesh using a Bico pulverizer, thoroughly mixed, and weighed.[16] The sample was then submitted for quantitative analyses.

Water. Groundwater was encountered at one location (core site 20). A water sample was collected and filtered through Whatman 42 ashless filter paper and a Milipore filter paper (0.45-m pore size). The filtered sample was placed in a Marinelli beaker, and nitric acid was added until a pH between 2 and 4 was obtained. It was then submitted for further analyses.

4.1.2.4 Sample analysis

All 55 processed samples (soil and water) were analyzed for gamma activity using high-resolution gamma-ray spectroscopy. Based on this result, a smaller number of samples was selected and analyzed for ^{90}Sr, ^{238}Pu, ^{239}Pu, ^{241}Am, and ^{244}Cm using destructive radiochemical analyses and uranium concentration by delayed neutron techniques.[17] Analytical results were calculated on a per gram of dry weight basis unless otherwise specified.

4.1.3 Results

4.1.3.1 Background

Currently, there are no definitive guidelines at ORNL concerning maximum allowable concentrations of radionuclides in soil. Table 2 shows the average radioactivities in surface soil (0-2.5 cm depth) for various radionuclides around the perimeter of the Oak Ridge DOE Reservation and at remote stations from 19 to 121 km from ORNL.[18]

4.1.3.2 Surface contamination (0 to 30 cm)

General area. Walk-over survey results are shown in Fig. 3. Eight areas with beta-gamma direct readings exceeding 0.1 mrad/h are identified. All readings were less than 2.3 mrad/h except for one reading of 5.1 mrad/h. For comparison, the ORNL Health Physics guide establishes low-level radiation zones at 3.0 mrad/h.[19]

Eight top-layer soil samples were collected from the middle of each contaminated area and were analyzed for radionuclide concentrations.

Radiological results of these eight samples are presented in Table 3. The contamination is mainly from ^{137}Cs and ^{90}Sr. Trace amounts of other radionuclides were also detected. Columns 5 through 8 of Table 3 presented results for ^{238}, ^{239}Pu, ^{241}Am, and ^{244}Cm concentrations. All samples contained ^{137}Cs activity, between 1.6 and 160 Bq/g. All samples contained ^{90}Sr activity (0.48 to 24 Bq/g).

The highest ^{137}Cs activity, 160 Bq/g, was detected in sample 12J. The highest ^{90}Sr activity, 24 Bq/g, was found in sample 11S. Sample 11S also contained a low level of ^{154}Eu (0.3 Bq/g).

Decontamination pad. A 1-m^2 grid layout was used in this area. Results of this survey are shown in Fig. 6. Equipment on the pad was not surveyed because it was already labeled and could be readily removed before decommissioning. No transferable contamination was found, and most of the elevated direct readings resulted from nearby equipment. However, readings (1.6 to 8.0 mrad/h) at grid cells 14A, 15A, and 17A were not associated with "hot" equipment and were highest on the side of the curb, indicating that contamination might have leached into the ground at that point. The experimental details for measuring the transferable contamination are discussed in Sect. 4.2.2.

Table 2. Background measurements of radionuclide concentrations in soil

Radionuclides	Background[a] (Remote)		Background (Perimeter)	
	(mBq/g)	(pCi/g)	(mBq/g)	(pCi/g)
^{137}Cs	52	1.4	49	1.3
^{226}Ra	NA[b]	NA	30	0.8
^{90}Sr	7	0.2	14	0.4
^{238}Pu	0.2	0.004	0.1	0.004
^{239}Pu	2.7	0.08	1.5	0.04
^{235}U	1.1	0.03	1.1	0.03
^{238}U	19	0.5	15	0.4

[a]Annual average radioactivities in soil samples from uncontrolled areas in East Tennessee.[18]

[b]NA indicates no available data.

Table 3. Radionuclide concentrations of contaminated soil samples from the top layer (30 cm) of earth

Sample identification	Radioactivities (Bq/g)[a]						
	^{137}Cs	^{60}Co	^{90}Sr	^{239}Pu	^{238}Pu	^{241}Am	^{244}Cm
6H	43	ND[b]	10	0.25×10^{-3}	$<0.3 \times 10^{-3}$	0.31×10^{-2}	0.46×10^{-3}
9H	1.6	ND	14	0.15×10^{-2}	0.62×10^{-3}	0.22×10^{-2}	0.19×10^{-2}
8F	5.7	0.01	1.2	0.62×10^{-2}	0.4×10^{-3}	0.38×10^{-2}	0.38×10^{-3}
12G	4.8	ND	1.1	0.29×10^{-3}	$<0.4 \times 10^{-3}$	0.73×10^{-2}	0.13×10^{-3}
3K[c]	48	0.01	0.48	1.9	0.6	<0.1	0.4
12J	160	0.05	8.4	9.0	1.2	0.4	0.4
13Q	14	ND	8.2	$<0.3 \times 10^{-3}$	0.11×10^{-2}	0.13×10^{-2}	0.58×10^{-2}
11S	48	0.13	24	1.5	0.2	0.6	15

[a]1 Bq/g = 27 pCi/g.

[b]ND indicates nondetectable.

[c]Contains ^{134}Cs (0.037 Bq/g).

ORNL–DWG 83-18119

DECONTAMINATION PAD AT SOUTH OF BLDG 7500

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
A								0.16			0.16		0.16	6.4	8.0	0.13	1.6	0.13	0.32	0.16
B	0.11		0.16	16.0	0.16								0.13	0.13			0.16			
C	0.32	0.16	0.16	0.32							8.0	1.6	0.32	0.16	0.19	0.16				

Fig. 6. Beta-gamma direct readings in mrad/h (1 mrad = 10 μGy), from 1-m^2 grid areas, exceeding 0.1 mrad/h at 10 cm from surface (decontamination pad south of Building 7500).

4.1.3.3 Subsurface contamination (deep soil coring)

Twenty-one soil cores were drilled. Their relative locations and actual coordinates were marked in Fig. 2 and provided in Table 1, respectively.

The average drilling depth per core was 3.5 m. The deepest core drilled was at core site 13 where 5.5 m of earth was penetrated and sampled. One hundred eight soil samples were collected. At core site 20, approximately 4.3 m below the ground surface, groundwater was encountered and a water sample was collected. Table 4 shows sample sequence numbers and their corresponding depths for easy identification of the depth from which each sample was collected.

Gamma screening results of the entire sample collection are shown in Table 5. Screening results of all samples were measured in counts per second per kilogram of moist sample. By averaging gamma activity measured in samples containing only naturally occurring radionuclides, an average background activity was calculated (40 cps/kg). The major gamma-ray-emitting radionuclides identified in these core drilling samples were ^{137}Cs and ^{60}Co. Bremsstrahlung, which was later identified as coming from ^{90}Sr, was also seen in some samples.

Based on the screening and geological characteristics, 46 samples were selected, processed, and analyzed for quantitative radionuclide concentrations.

Quantitative results for gamma-ray analyses are shown in Table 6. Four samples showed a significant amount* of ^{137}Cs activity. These four samples were 15-3 (2.2 Bq/g), 17-1 (5.9 Bq/g), 17-2 (5.2 Bq/g), and 17-3 (3.0 Bq/g).

Five samples (12-3, 17-3, 17-6, 15-5, and 17-1) contained trace amounts (<0.0074 Bq/g) of ^{60}Co activity. The ^{226}Ra concentration in all samples varied between 0.03 and 0.04 Bq/g, which is similar to the background found in most East Tennessee soils as shown in Table 2.

Analytical results for ^{90}Sr are shown in Table 6. Strontium-90 activity in most samples was slightly above 0.01 Bq/g except in soil samples collected at core sites 14, 15, 16, and 17 from depths of 1.2 to 3.1 m underground. Some of these samples contained much higher ^{90}Sr activity. The highest activity, 45 Bq/g, was found in sample 15-6.

Table 7 provides quantitative results for alpha activities; their concentrations were all insignificant.

Table 8, columns 2 and 4, presents concentrations of ^{235}, ^{238}U in the units of micrograms of uranium per gram of dry sample (μg/g) or parts per million (ppm). Columns 3 and 5 furnish corresponding radioactivities, which were calculated using the half-life and mass of these two radionuclides.[20]

The concentration of ^{235}U was determined by delayed neutron counting. The concentration of ^{238}U was derived from the ^{235}U concentration by assuming that the fraction of ^{235}U is only 0.7% of

* Above the ^{137}Cs concentration of East Tennessee soil samples.

Table 4. Sample sequence numbers and their corresponding depths

Sequence number	Depth	
	Meters	Feet
1	0–0.3	0–1
2	0.3–0.6	1–2
3	0.6–1.2	2–4
4	1.2–1.8	4–6
5	1.8–2.4	6–8
6	2.4–3.1	8–10
7	3.1–3.7	10–12
8	3.7–4.3	12–14
9	4.3–4.9	14–16
10	4.9–5.5	16–18

^{238}U. The ^{235}U concentrations were between 0.002 and 0.003 Bq/g, and the ^{238}U concentrations were between 0.03 and 0.06 Bq/g. As a comparison, the ^{235}U and ^{238}U concentrations in soil samples from the perimeter and remote areas of ORNL were 0.0011 and 0.017 Bq/g, respectively.

Analytical studies of the only water sample indicated low-level ^{226}Ra (2.6×10^{-3} Bq/mL) and ^{90}Sr (4.6×10^{-4} Bq/mL). The 1981 annual average of ^{90}Sr concentrations in the Clinch River was 6.3×10^{-4} Bq/mL.[18]

4.1.4 Discussion

4.1.4.1 Surface (0 to 30 cm)

Eight surface-contamination areas (with elevated direct beta-gamma readings) were indicated using walk-over survey techniques and are indicated in Fig. 4. They are all located in the southeast yard of the HRE-2 facility.

The major radionuclides detected in the top layers of the soil samples were ^{137}Cs and ^{90}Sr. Only trace quantities of ^{154}Eu and transuranics were detected. One sample, 3K, contained a trace amount of ^{134}Cs (0.037 Bq/g).

The highest concentration of ^{137}Cs was detected in sample 12J (160 Bq/g). The highest concentration of ^{90}Sr (24 Bq/g) was detected in sample 11S. Significant amounts of ^{90}Sr activity were detected in five samples (6H, 9H, 12J, 13Q, and 11S) which were collected from areas near the previous waste pond.

Radionuclides found in sample 3K could be introduced by the nearby storm sewer. Their relative locations are shown in Fig. 2. This sample also contained a measurable amount of ^{134}Cs (3.7×10^{-2} Bq/g). Considering its relatively short half-life (approximately two years), the appearance of

Table 5. Preliminary gamma screening results for deep core soil samples[a]

Sample identification	Gamma activities (cps/kg)	Sample identification	Gamma activities (cps/kg)
1-1	NS[b]	8-4[c]	44
1-2	NS	9-1[c]	41
1-3[c]	41	9-2[d]	55
1-4[c]	49	9-3[c]	37
1-5[c]	51	9-4[c]	40
1-6[c]	84	10-1	NS
2-1	NS	10-2	NS
2-2	NS	10-3[c]	40
2-3[c]	32	10-4[c]	41
2-4[c]	<3.0	10-5[c]	41
2-5[c]	<4.0	11-1	NS
2-6[c]	43	11-2	NS
2-7[d]	68.1	11-3[d]	47
3-1	NS	11-4[c]	44
3-2	NS	11-5[c]	45
3-3[c]	37	11-6[c]	50
4-1	NS	11-7[c]	40
4-2	NS	11-8[c]	36
4-3[c]	36	11-9[c]	42
4-4[d]	37	12-1	NS
4-5[c]	41	12-2	NS
4-6[c]	44	12-3[d]	60
4-8[c]	39	12-4[c]	36
5-1	NS	12-5[c]	38
5-2	NS	12-6[c]	40
5-3[d]	44	13-1[d]	52
5-4[d]	48	13-2[c]	53
5-5[d]	47	13-3[d]	83
5-6[d]	72	13-4[d]	45
6-1	NS	13-5[d]	53
6-2	NS	13-6[d]	44
6-3[d]	46	13-7[d]	49
6-4[c]	39	13-8[c]	48
6-5[c]	44	13-9	NS
6-6[c]	50	13-10[c]	52
7-1	NS	14-1	NS
7-2	NS	14-2	NS
7-3[c]	51	14-3[d]	78
7-4[c]	37	14-4[c]	40
7-5[c]	42	14-5[c]	38
7-6[c]	46	14-6[c]	100
7-7[c]	41	14-7[c]	41
7-8[c]	45	14-8[c]	43
8-1	NS	15-1	NS
8-2	NS	15-2	NS
8-3[c]	41	15-3[e]	470

Table 5. (continued)

Sample identification	Gamma activities (cps/kg)	Sample identification	Gamma activities (cps/kg)
15-4[c]	62	18-4[c]	28
15-5[c]	43	18-5[c]	48
15-6[c]	58	19-1	NS
15-7[c]	26	19-2	NS
15-8[c]	42	19-3[d]	41
15-9[c]	48	19-4[d]	75
16-1	NS	19-5[c]	36
16-2	NS	19-6[c]	33
16-3[e]	90	19.7[c]	45
16-4[d]	73	20-1	NS
16-5[c]	42	20-2	NS
16-6[c]	39	20-3[c]	40
16-7[c]	41	20-4[c]	64
16-8[c]	55	20-5[d]	41
17-1[d]	770	20-6[c]	49
17-2[d]	630	20-7[c]	38
17-3[d]	270	20-8[c]	33
17-4[d]	76	20-9[c]	41
17-5[d]	150	21-1	NS
17-6[d]	140	21-2	NS
17-7[c]	15	21-3[f]	97
17-8[c]	41	21-4[c]	45
17-9[c]	46	21-5[c]	40
18-1[d]	58	21-6[c]	42
18-2[c]	46	21-7[c]	52
18-3[c]	27		

[a]Total gamma activities between 100 and 1500 keV energy range, as measured on a 15-cm-diam NaI(Tl) detector. Instrument variation is approximately ±20%.

[b]NS indicates no sample was taken; asphalt or gravel covered ground.

[c]Background, no man-made radionuclide detected.

[d]Contained ^{137}Cs.

[e]Contained ^{137}Cs and Bremsstrahlung.

[f]Contained ^{60}Co.

^{134}Cs could indicate a recent low-level contamination that was washed down the sewer or a residual from past contamination during the functional years (1957 to 1961) of HRE-2. Should it be a residual from past contamination, the original ^{134}Cs activity of 22 years ago could have been 74 Bq/g. However, the normal isotopic ratio of ^{134}Cs to ^{137}Cs is about 1:10. Thus, it is unlikely that this is residual material since the ^{137}Cs is only 48 Bq/g in the same sample.

Samples 12J and 11S were collected from swampish areas located downslope from the previous pond site. The radionuclide, ^{90}Sr, found in these samples could be leached out from the pond sediment that had been left in the ground.

The lack of transferable contamination on the decontamination pad was probably the result of weathering because the pad is roofed but has open sides.

Table 6. Radionuclide concentrations in deep coring soil samples

Sample identification	^{137}Cs (Bq/g)[a]	^{90}Sr (Bq/g)[a]	Sample identification	^{137}Cs (Bq/g)	^{90}Sr (Bq/g)
1-3	0.7×10^{-2}	0.25×10^{-1}	15-6[b]	0.11	45
1-4	ND[c]	0.16×10^{-1}	15-8	ND	0.27
1-5	0.4×10^{-2}	0.11×10^{-1}	16-3[b]	0.33	12
1-6	0.7×10^{-2}	0.11	16-4[b]	0.20	12
2-3[d]	ND	0.3×10^{-1}	16-5[b]	0.15×10^{-1}	1.1
2-5[d]	ND	0.7×10^{-1}	16-6	0.15×10^{-1}	0.18
2-6[d]	ND	0.74×10^{-1}	17-1[b]	5.9	2.4
3-3	0.7×10^{-2}	0.4×10^{-1}	17-2[b]	5.2	2.2
6-3	0.8×10^{-1}	0.13	17-3[b]	3.0	2.3
7-4[d]	ND	0.3×10^{-2}	17-4[b]	0.29	0.61
8-4[d]	ND	0.78×10^{-1}	17-5[b]	0.29	24
9-2	0.7×10^{-1}	0.7×10^{-2}	17-6[b]	ND	3.9
11-3	0.8×10^{-1}	0.1	18-1[b]	0.2	0.65
12-3[b]	0.15	0.2	18-4[s]	ND	0.36
13-2	0.4×10^{-1}	0.6×10^{-2}	18-5[d]	ND	0.17
13-3	0.54	0.17	19-4	0.6×10^{-1}	0.89×10^{-1}
13-5	0.9×10^{-1}	0.78×10^{-1}	19-7[d]	ND	0.14
13-6	ND	0.35×10^{-1}	20-5[d]	ND	0.3×10^{-1}
14-3[b]	0.48	0.16	20-6	0.1×10^{-1}	0.84×10^{-1}
14-6	ND	15	20-9[d]	0.3×10^{-2}	0.1
14-7	ND	0.21	21-3	ND	0.84×10^{-1}
15-3[b]	2.2	0.51	21-5[d]	ND	0.18
15-5[b]	0.03	0.15	21-7[d]	ND	0.17
DOE Guide	0.75	0.75		0.75	0.75

[a]1 Bq = 27 pCi/g.
[b]Contained uranium activity.
[c]Nondetectable.
[d]The ^{90}Sr result is from Cerenkov counting.

The high readings, 1.6 to 8.0 mrad/h, found in grid cells 14A, 15A, and 17A of Fig. 6 are in good agreement with the independent walk-over survey discussed in the previous section. In that walk-over survey, contaminated area grid cell 6H was identified (shown in Fig. 3).

4.1.4.2 Subsurface (30 cm and deeper)

The major radionuclide found in subsurface soil samples was ^{90}Sr. Only trace amounts of ^{137}Cs, ^{60}Co, and transuranics were found. The ^{235}U and ^{238}U concentrations in all analyzed soil samples exceeded the background for East Tennessee soil.

The majority of ^{90}Sr activity was found in five samples collected from four core sites (14, 15, 16, and 17). These samples were taken from the earth layer 0.6 to 1.8 m below the ground surface. This layer corresponds to the bottom layer of the filled-in pond.

All four core sites were located downslope at the perimeter of the previous pond site. Only low-level ^{90}Sr activity (<0.2 Bq/g) was detected in samples collected from areas upslope from the pond. This result implies that ^{90}Sr probably was and possibly still is leaching out from the previous pond sediment.

Table 7. Quantitative results for alpha-emitting radionuclides

Sample identification	^{239}Pu (Bq/g)	^{238}Pu (Bq/g)	^{241}Am (Bq/g)	^{244}Cm (Bq/g)
1-3	$<0.1 \times 10^{-3}$	0.1×10^{-3}	0.27×10^{-3}	0.6×10^{-3}
1-4	0.14×10^{-3}	$<0.3 \times 10^{-4}$	0.11×10^{-3}	0.53×10^{-2}
1-5	0.1×10^{-3}	$<0.1 \times 10^{-3}$	0.7×10^{-4}	0.25×10^{-3}
1-6	0.2×10^{-3}	0.4×10^{-4}	0.3×10^{-3}	0.28×10^{-3}
3-3	0.57×10^{-3}	$<0.7 \times 10^{-4}$	0.26×10^{-3}	0.32×10^{-3}
9-2	0.19×10^{-3}	0.2×10^{-4}	0.12×10^{-3}	0.4×10^{-4}
12-3	0.23×10^{-3}	0.5×10^{-4}	0.22×10^{-3}	0.54×10^{-3}
13-2	0.34×10^{-3}	0.3×10^{-4}	0.75×10^{-3}	0.15×10^{-3}
14-3	0.27×10^{-3}	0.1×10^{-4}	0.46×10^{-3}	0.6×10^{-4}
14-6	$<0.2 \times 10^{-3}$	$<0.3 \times 10^{-3}$	0.16×10^{-2}	0.18×10^{-2}
14-7	$<0.2 \times 10^{-3}$	0.66×10^{-3}	0.17×10^{-2}	0.16×10^{-2}
15-3	0.1×10^{-4}	0.4×10^{-4}	$<0.7 \times 10^{-4}$	0.3×10^{-4}
15-5	$<0.3 \times 10^{-4}$	0.16×10^{-3}	$<0.5 \times 10^{-4}$	$<0.5 \times 10^{-4}$
15-6	$<0.1 \times 10^{-4}$	$<0.3 \times 10^{-4}$	0.26×10^{-3}	0.24×10^{-3}
15-8	$<0.8 \times 10^{-3}$	0.4×10^{-3}	0.96×10^{-3}	0.83×10^{-3}
16-3	0.1×10^{-3}	0.13×10^{-3}	0.55×10^{-3}	0.32×10^{-3}
16-4	0.1×10^{-4}	0.33×10^{-3}	$<0.8 \times 10^{-4}$	0.28×10^{-3}
16-5	0.1×10^{-4}	0.17×10^{-3}	0.37×10^{-3}	0.28×10^{-3}
16-6	0.34×10^{-3}	0.20×10^{-3}	0.11×10^{-3}	0.12×10^{-2}
17-1	0.43×10^{-3}	0.21×10^{-3}	0.40×10^{-2}	0.36×10^{-2}
17-2	0.41×10^{-3}	0.2×10^{-3}	0.16×10^{-2}	0.98×10^{-3}
17-3	0.2×10^{-3}	$<0.1 \times 10^{-3}$	0.82×10^{-3}	0.12×10^{-3}
17-4	0.7×10^{-4}	$<0.3 \times 10^{-4}$	$<0.5 \times 10^{-4}$	0.5×10^{-4}
17-5	0.9×10^{-4}	$<0.5 \times 10^{-4}$	0.3×10^{-4}	0.5×10^{-3}
17-6	0.14×10^{-3}	0.72×10^{-3}	0.84×10^{-2}	0.32×10^{-2}
18-1	0.22×10^{-3}	$<0.5 \times 10^{-4}$	0.5×10^{-3}	0.24×10^{-2}

In a recent study, it was found that low levels (0.04 Bq/mL) of ^{90}Sr were in the creek water collected from the HRE-2 vicinity.[21] This finding could imply that ^{90}Sr had migrated to the creek from the HRE-2 facility, which is approximately 70 m south from the boundary of the previous pond and 50 m from core site 17.

Radiological content inside the perimeter of the filled-in pond was not studied. It is possible that other long-lived, yet less mobile, radionuclides still exist in it along with ^{90}Sr.

The inventory of ^{90}Sr in subsurface soil in the surveyed area outside the boundary of the previous pond was approximately 3.7×10^{10} Bq (1 Ci) in approximately 1×10^{6} kg of soil if the contaminated earth layer is 1800 m^2 by 0.9 m thick. Contamination at the site of the previous pond, especially in the bottom of the pond, would be expected to be much higher if we assumed that all of the ^{90}Sr in the perimeter soil was coming from the bottom of the filled-in pond and that the concentration of ^{90}Sr in soil decreased steadily with increasing distance. The highest concentrations of ^{90}Sr in the soil at core sites 15 and 17 were 45 and 24 Bq/g, respectively, and the distances from the south boundary of the pond to core sites 15 and 17 were 10 and 22 m, respectively. The concentration of ^{90}Sr at the south boundary was estimated to be approximately 60 Bq/g.

Based on ORNL Health Physics Division records summarized by F.T. Binford, the total beta activity released into the pond in the 12 months between October 9, 1958, and October 1, 1959,

Table 8. Uranium concentration in soil samples

Sample identification	^{235}U		^{238}U[a]	
	μg/g (ppm)	mBq/g[b]	μg/g (ppm)	mBq/g
1-4	2×10^{-2}	2	2.8	30
12-3	2×10^{-2}	2	3.2	40
14-3	2×10^{-2}	2	3.0	40
15-3	2×10^{-2}	2	2.8	30
15-5	2×10^{-2}	2	3.0	40
15-6	2×10^{-2}	2	3.9	50
15-8	ND[c]	ND	ND	ND
16-3	2×10^{-2}	2	3.3	40
17-1	3×10^{-2}	2	4.8	60
17-2	3×10^{-2}	3	4.6	60
17-3	3×10^{-2}	3	4.0	50
17-4	2×10^{-2}	2	3.3	40
17-5	3×10^{-2}	3	4.0	50
17-6	3×10^{-2}	3	3.6	40
18-1	2×10^{-2}	2	3.2	40

[a]Derived from ^{235}U concentration, assuming $^{235}U = 0.007 \times {}^{238}U$.

[b]1 Bq = 27 pCi.

[c]ND indicates nondetectable.

was 1.84×10^{13} Bq (498 Ci).[22] Total beta activity released into the pond in the five years, 1957 to 1961, could be even higher. However, the actual activity that remains in the pond site should be much less because the contaminants released into the pond were short lived and have decayed after 22 years.

Health physics monitoring and protective techniques will be required to drill through the bottom of the previous pond. These precautions may include special work permits, C-zone clothing, respirators, and a containment tent.

Although drilling through the previous pond site could be hazardous, it seems beneficial and unavoidable in the future in order to determine the location and the volume of the highly contaminated earth layer and its radiological inventory.

Approximately 500 kg of sodium borate, a slightly toxic weed killer, was applied before the installation of the asphalt surface. However, because of its high solubility[23] in water and the long period of elapsed time (14 years), it is unlikely that residual amounts of this weed killer will be hazardous to humans.

4.2 INDOOR AREAS

4.2.1 Purpose and Boundary

The preliminary radiological characterization for indoor areas was designed to determine the extent of fixed and removable alpha and beta-gamma contamination in accessible areas of the building, to determine the isotopic content of selected samples, and to review the current condition to determine if any unusual radiation may exist.

Potential radiation sources have been identified and briefly described in Sect. 3. Most radiation sources with potential indoor radiation hazard are either completely enclosed in concrete-steel-shielded cells or are occupied by active research groups. A survey of these areas requires some planning and coordination with other divisions to prevent the spread of contamination and to minimize disruption of other work. In the current study, the following areas were not surveyed: (1) the

reactor cell, (2) the chemical processing cell C, (3) the evaporator cell, (4) the storage pool, and (5) the NSPP facilities.

The NSPP facilities include cell B, the control area, the radioactive material handling laboratory, the air compressor, the stack, steam and normal electrical utilities, and decontamination and maintenance equipment.

4.2.2 Survey Methodology

The methods and techniques used in this study were similar to those previously used at ORNL and to those developed for decommissioning monitoring in general.[24] Namely, each floor or area was divided into grids, and measurements were taken in each grid cell to ensure complete coverage. A grid size of 1 m was used for all lower levels of Building 7500 and for the waste evaporator. For the main floor of Building 7500, a grid size of 2 m was selected.

Standard ORNL radiation survey instruments were used for all surveys. Beta-gamma readings were made with an ORNL GM survey meter. Alpha contamination readings were made with the ORNL alpha scintillation survey meter.

Smear samples were taken over areas of approximately 100 cm^2 within the grid block and counted in ORNL alpha and beta-gamma sample counters.

Gamma analyses of selected samples were made using a TP-5000 pulse height analysis system coupled to a Ge(Li) detector. Strontium-90 and actinide levels were measured using a multichannel analyzer coupled to a Phoswich [NaI(Tl) + CaF_2(Eu)] detector. A Nuclear Measurements Corporation proportional counter (model PC-5) was used for qualitative indication of the presence of tritium.

4.2.3 Results

In the following paragraphs, survey results are presented according to their locations. For clarity, direct beta-gamma readings below 0.1 mrad/h are not shown. Also, transferable contamination below 0.33 Bq alpha and below 3.3 Bq beta-gamma are not shown. These values are below the current ORNL guidelines for establishment of low-level radiation zones.[19] Note that no alpha contamination, either direct or transferable, was detected above background levels. The absence of alpha contamination was confirmed by spectrometry of selected samples, which indicated that the contamination was almost exclusively ^{137}Cs and ^{90}Sr. Actinide levels in these samples were below detection limits. This finding is also in agreement with the preliminary radiological characterization of the HRE-2 vicinity.

4.2.3.1 Waste evaporator, Building 7502

The waste evaporator gave the highest indication of transferable and direct reading contamination of the accessible areas surveyed for this report. The Building 7502 waste evaporator consisted of a completely enclosed concrete block cell (or evaporator cell) and the south and west corridors containing controls and valves penetrating the block cell walls. In the current study, the evaporator cell was not surveyed; however, the south and west corridor were surveyed and were found to be highly contaminated. This finding indicated leaks and spills in this area in the past and a strong likelihood that the area within the evaporator cell was also highly contaminated. Direct readings obtained for the waste evaporator are given in Fig. 7, and transferable contamination levels are shown in Fig. 8.

4.2.3.2 Main floor, Building 7500

Beta-gamma direct readings exceeding 0.1 mrad/h (1 mrad = 10 μGy) at 10 cm from the surface are shown in Fig. 9. Elevated direct readings were primarily associated with the storage pool, the exhaust stack area on the east side, and the loading pit on the south side of the building. No transferable contamination was found on this floor. The grid size of this level was 2 × 2 m; however, in areas with elevated readings, extra survey readings were taken within the grid cell. When

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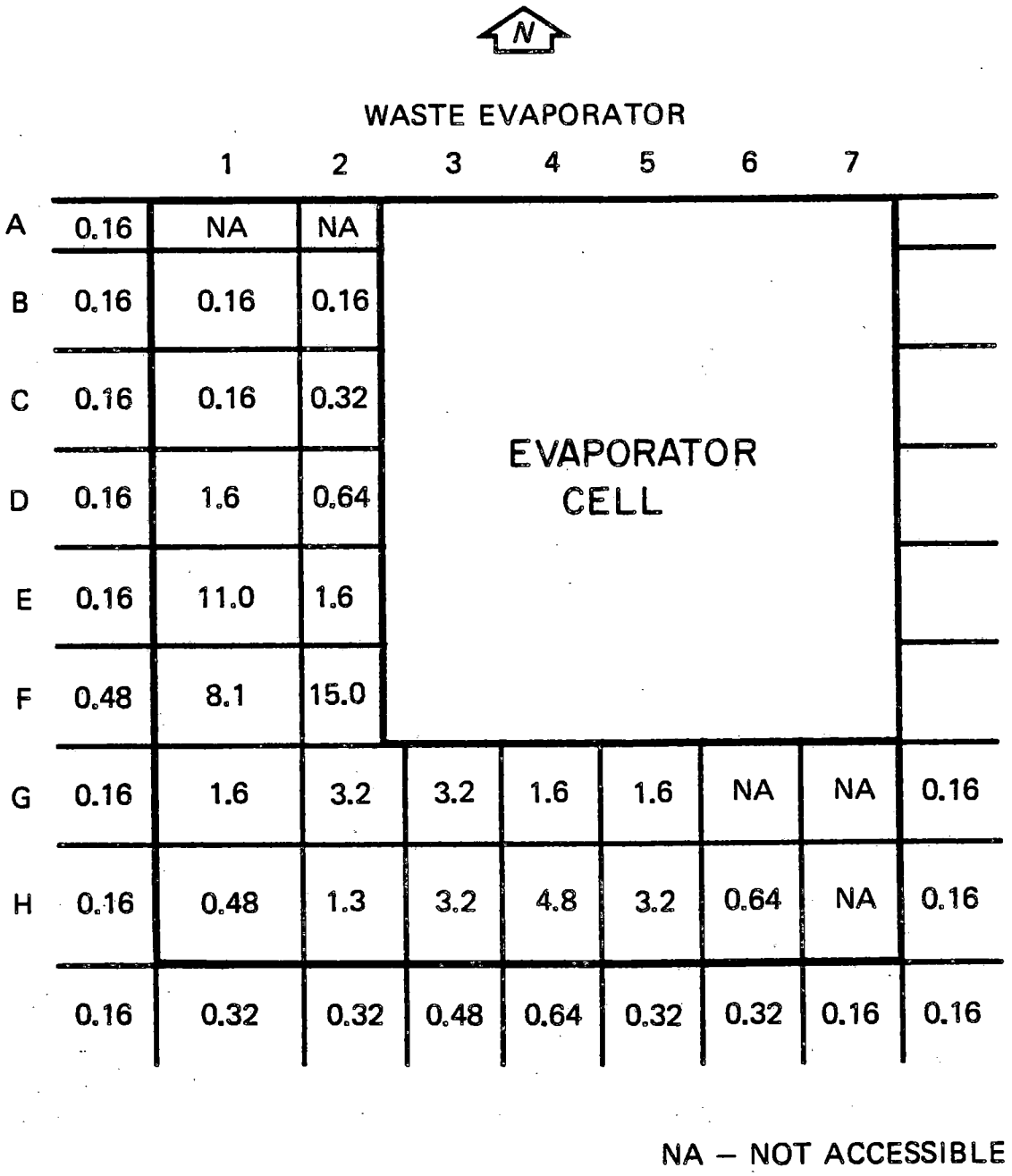

Fig. 7. Beta-gamma direct readings in mrad/h (1 mrad = 10 μGy), from 1-m² grid areas, exceeding 0.1 mrad/h at 20 cm from surface (waste evaporator).

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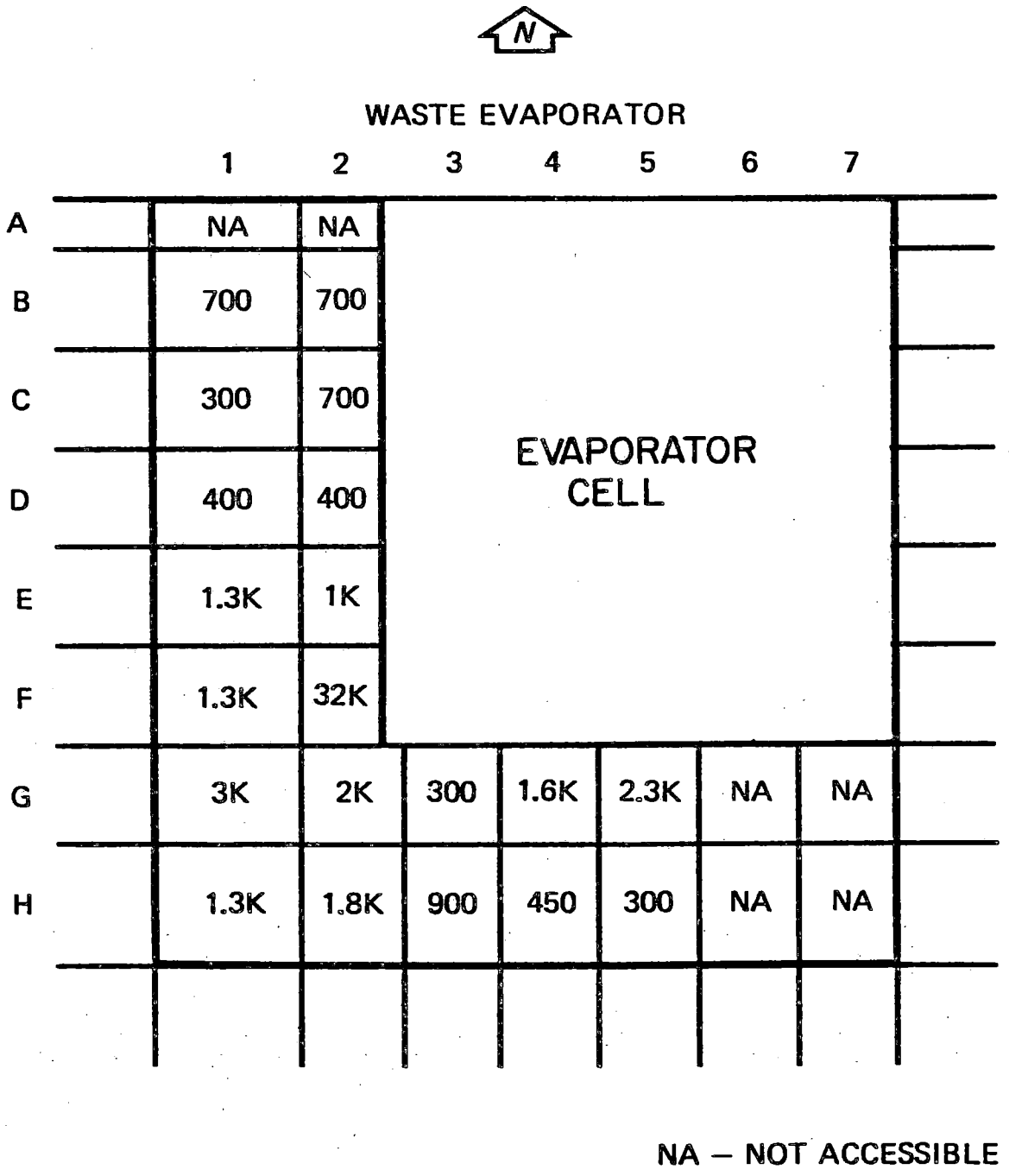

Fig. 8. Beta-gamma transferable contamination (dpm/100 cm^2), from 1-m^2 grid areas, exceeding 200 dpm/100 cm^2 (3.3 Bq/100 cm^2) (waste evaporator). K indicates the value should be multiplied by 1000 (3K = 3000).

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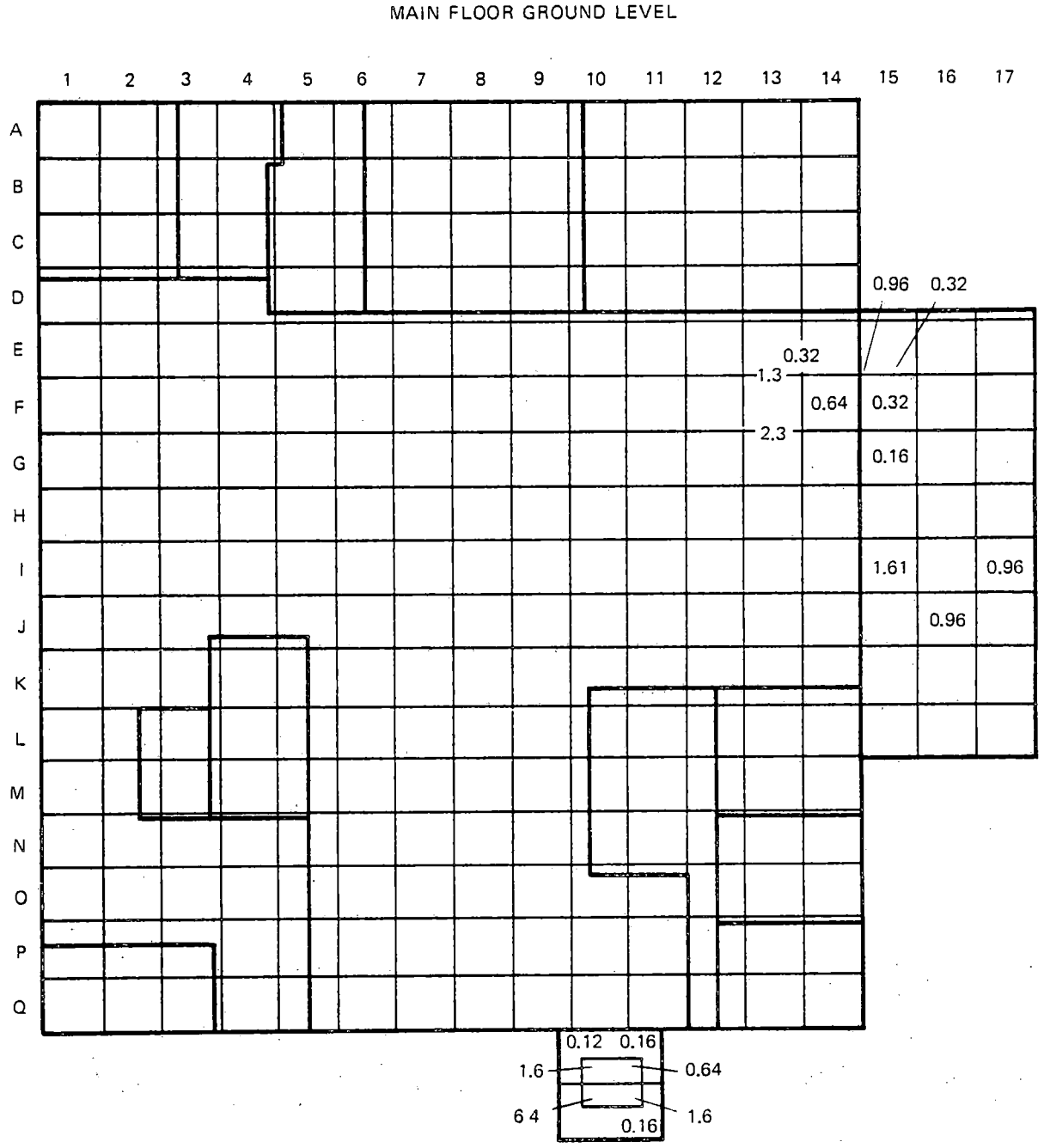

Fig. 9. Beta-gamma direct readings in mrad/h (1 mrad = 10 μGy), from 2 × 2-m grid areas, exceeding 0.1 mrad/h at 10 cm from surface (Building 7500, main floor, ground level).

localized readings were significantly higher than the average, these readings and their approximate locations are also shown in Fig. 9.

4.2.3.3 North sublevels, Building 7500

Figures 10 to 14 show survey results of the three sublevels located beneath the control room on the north side of the building. The first sublevel (Fig. 10) had no direct readings above background and only one area of transferable contamination, 6.3 Bq/100 cm^2 (380 dpm/100 cm^2).

The second sublevel (Figs. 11 and 12) showed some direct beta-gamma readings on the south wall, which is adjacent to the reactor pit, and on the floor near the east wall. Transferable contamination was found in only a few areas on the floor. The highest direct reading was approximately 0.65 mGy/h (65 mrad/h), and the highest transferable contamination was about 84 Bq/100 cm^2. One of the smearable areas was located in the same grid cells (14D, 14E, and 14F) as the high direct readings, indicating a possible spill or leak in the area in the past.

The third north sublevel (Figs. 13 and 14) showed direct beta-gamma readings not exceeding 65 μGy/h (6.5 mrad/h) and low levels of transferable contamination (<12 Bq/100 cm^2). Direct readings indicated that average levels are between 6 and 40 μGy/h (0.6 and 4 mrad/h). High direct readings were not always associated with the south wall (adjacent to the reactor cell), indicating the possibility of fixed contamination or piping in the floor.

The third north sublevel floor was partially covered with water during the survey. The water level appeared to vary with time and was apparently related to seepage from outside the building. Tritium was a suspected contaminant because of its production in the fuel mixture. A smear sample was analyzed for radionuclide contents, including tritium, but was found to contain none, indicating that the water did not come from HRE-2 systems.

Also, the third north sublevel was in a general state of disrepair, with concrete and paint chips falling off the walls. Note that the transferable readings at this level may vary considerably with time because of water leakage and deterioration of floor and wall surfaces.

4.2.3.4 South sublevels, Building 7500

Figures 15 to 18 show survey results of cells A and D, consisting of three sublevels on the south side of the building. The first two sublevels had no transferable contamination and only limited areas of fixed contamination ($\leq$1.6 mrad/h).

Again, the lowest level showed the strongest indications of fixed and transferable contamination. The highest direct beta-gamma readings on the third sublevel were approximately 50 μGy/h (5 mrad/h), and the highest transferable contamination was approximately 58 Bq/100 cm^2. This area remained dry throughout the survey and generally appeared to be in better condition than the lowest level on the north side.

4.2.4 Discussion

Radionuclide analyses indicated that the major contamination consisted of ^{137}Cs and ^{90}Sr, both long-lived fission products. No alpha contamination was found in any accessible area surveyed. However, some alpha contamination would be expected in the reactor cell, resulting from residual fuel.

The Building 7502 waste evaporator presented the most serious potential hazard of the accessible indoor areas of the HRE-2 facility. The accessible areas of this building were extensively contaminated, and the greater part of the area was blocked, with no way of easily determining contamination levels inside. The high contamination found in the south and west corridors indicated past leaks and spills in this area and a strong likelihood that the area within the evaporator cell was also highly contaminated.

This building was deteriorating and in need of repair and maintenance. A survey of the blockhouse area needs to be done before decontamination and decommissioning; however, this will need to be carefully planned because the access on the roof is open to the environment.

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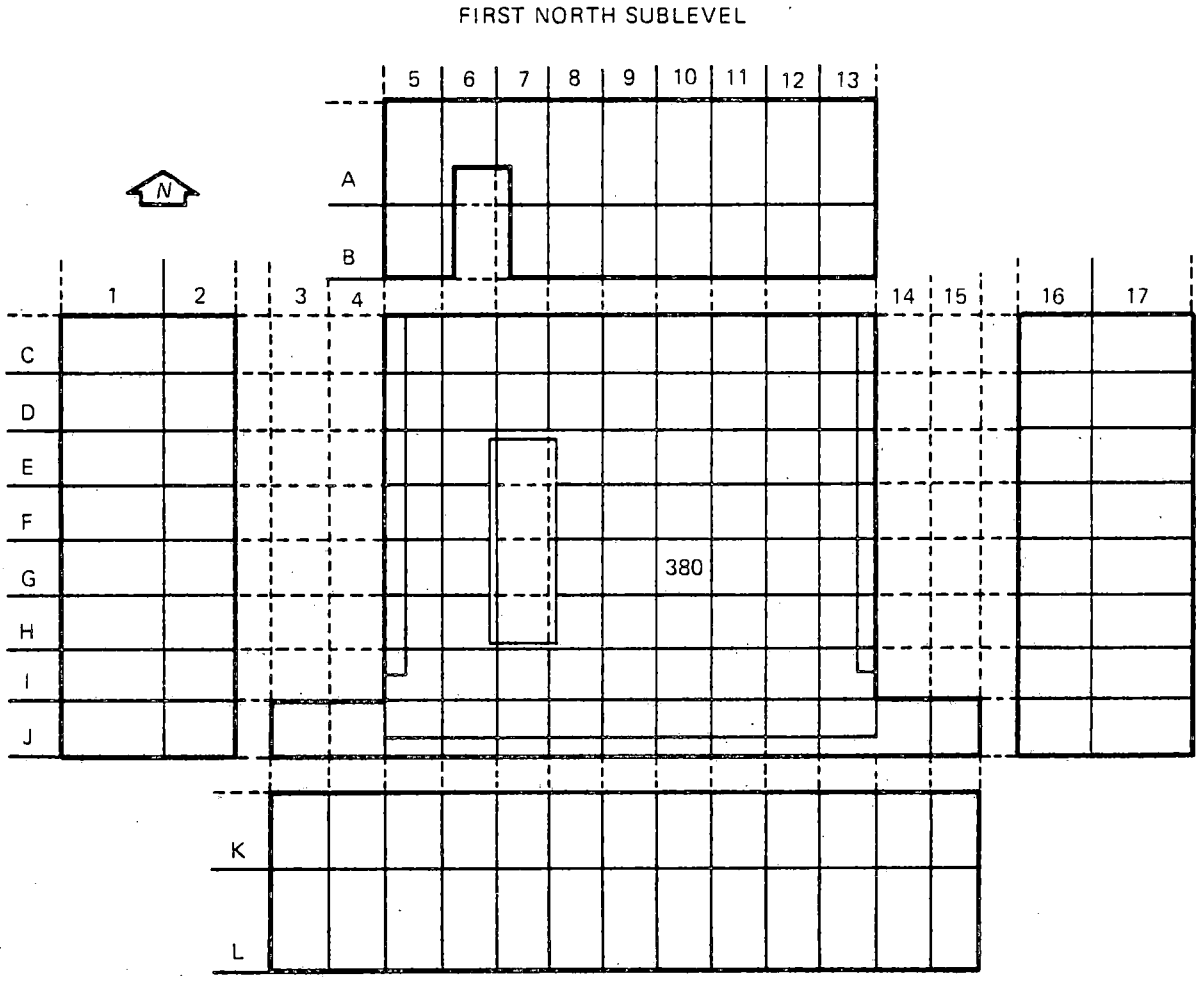

Fig. 10. Beta-gamma transferable contamination (dpm/100 cm^2), from 1-m^2 grid areas, exceeding 200 dpm/100 cm^2 (3.3 Bq/100 cm^2) (Building 7500, first north sublevel).

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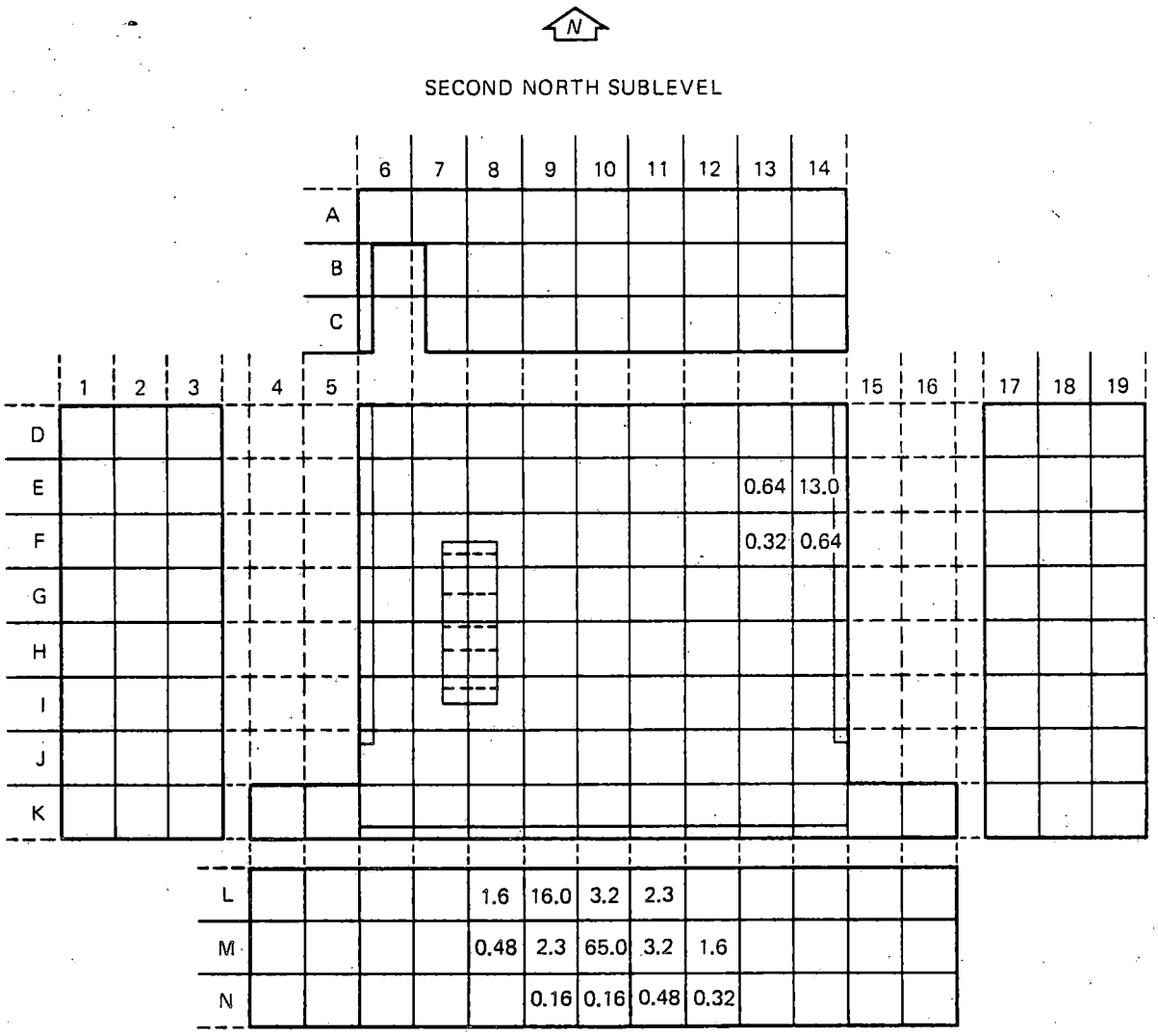

Fig. 11. Beta-gamma direct readings in mrad/h (1 mrad = 10 μGy), from 1-m^2 grid areas, exceeding 0.1 mrad/h at 10 cm from surface (Building 7500, second north sublevel).

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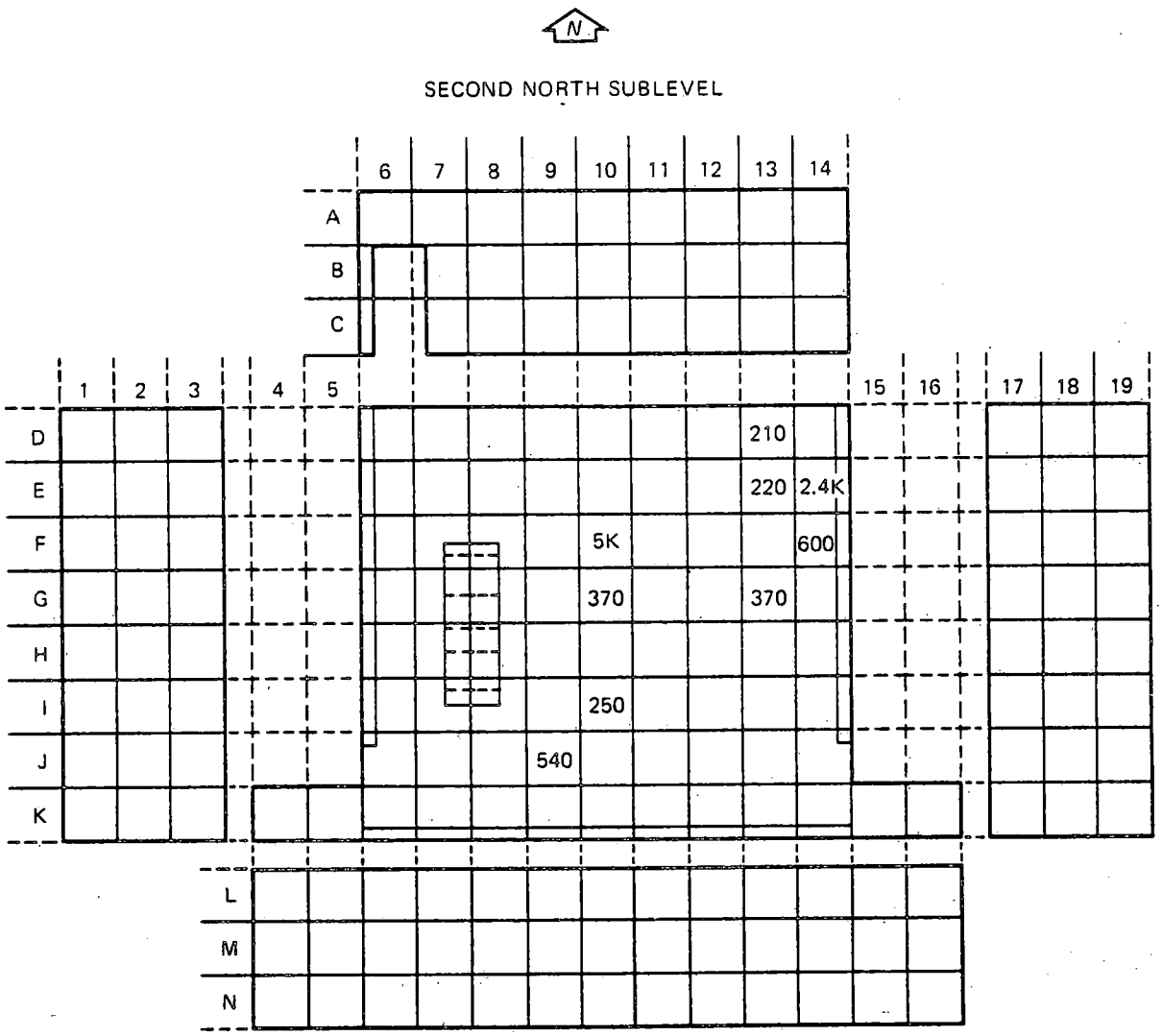

Fig. 12. Beta-gamma transferable contamination (dpm/100 cm^2), from 1-m^2 grid areas, exceeding 200 dpm/100 cm^2 (3.3 Bq/100 cm^2) (Building 7500, second north sublevel). K indicates the value should be multiplied by 1000 (3K = 9000).

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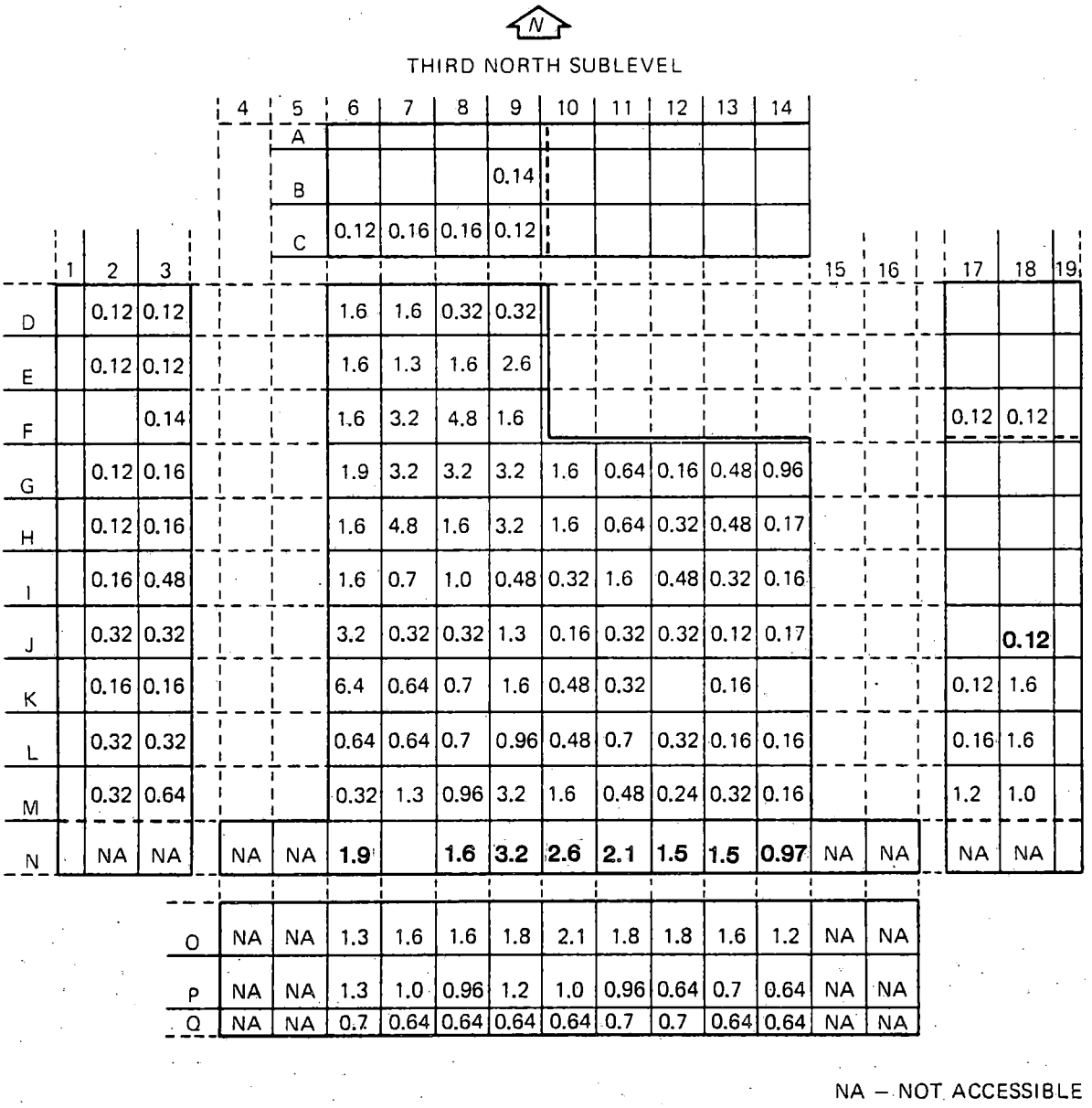

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
A																			
B									0.14										
C						0.12	0.16	0.16	0.12										
D		0.12	0.12			1.6	1.6	0.32	0.32										
E		0.12	0.12			1.6	1.3	1.6	2.6										
F			0.14			1.6	3.2	4.8	1.6								0.12	0.12	
G		0.12	0.16			1.9	3.2	3.2	3.2	1.6	0.64	0.16	0.48	0.96					
H		0.12	0.16			1.6	4.8	1.6	3.2	1.6	0.64	0.32	0.48	0.17					
I		0.16	0.48			1.6	0.7	1.0	0.48	0.32	1.6	0.48	0.32	0.16					
J		0.32	0.32			3.2	0.32	0.32	1.3	0.16	0.32	0.32	0.12	0.17				**0.12**	
K		0.16	0.16			6.4	0.64	0.7	1.6	0.48	0.32		0.16				0.12	1.6	
L		0.32	0.32			0.64	0.64	0.7	0.96	0.48	0.7	0.32	0.16	0.16			0.16	1.6	
M		0.32	0.64			0.32	1.3	0.96	3.2	1.6	0.48	0.24	0.32	0.16			1.2	1.0	
N		NA	NA	NA	NA	**1.9**		**1.6**	**3.2**	**2.6**	**2.1**	**1.5**	**1.5**	**0.97**	NA	NA	NA	NA	
O				NA	NA	1.3	1.6	1.6	1.8	2.1	1.8	1.8	1.6	1.2	NA	NA			
P				NA	NA	1.3	1.0	0.96	1.2	1.0	0.96	0.64	0.7	0.64	NA	NA			
Q				NA	NA	0.7	0.64	0.64	0.64	0.64	0.7	0.7	0.64	0.64	NA	NA			

Fig. 13. Beta-gamma direct readings in mrad/h (1 mrad = 10 μGy), from 1-m^2 grid areas, exceeding 0.1 mrad/h at 10 cm from surface (Building 7500, third north sublevel).

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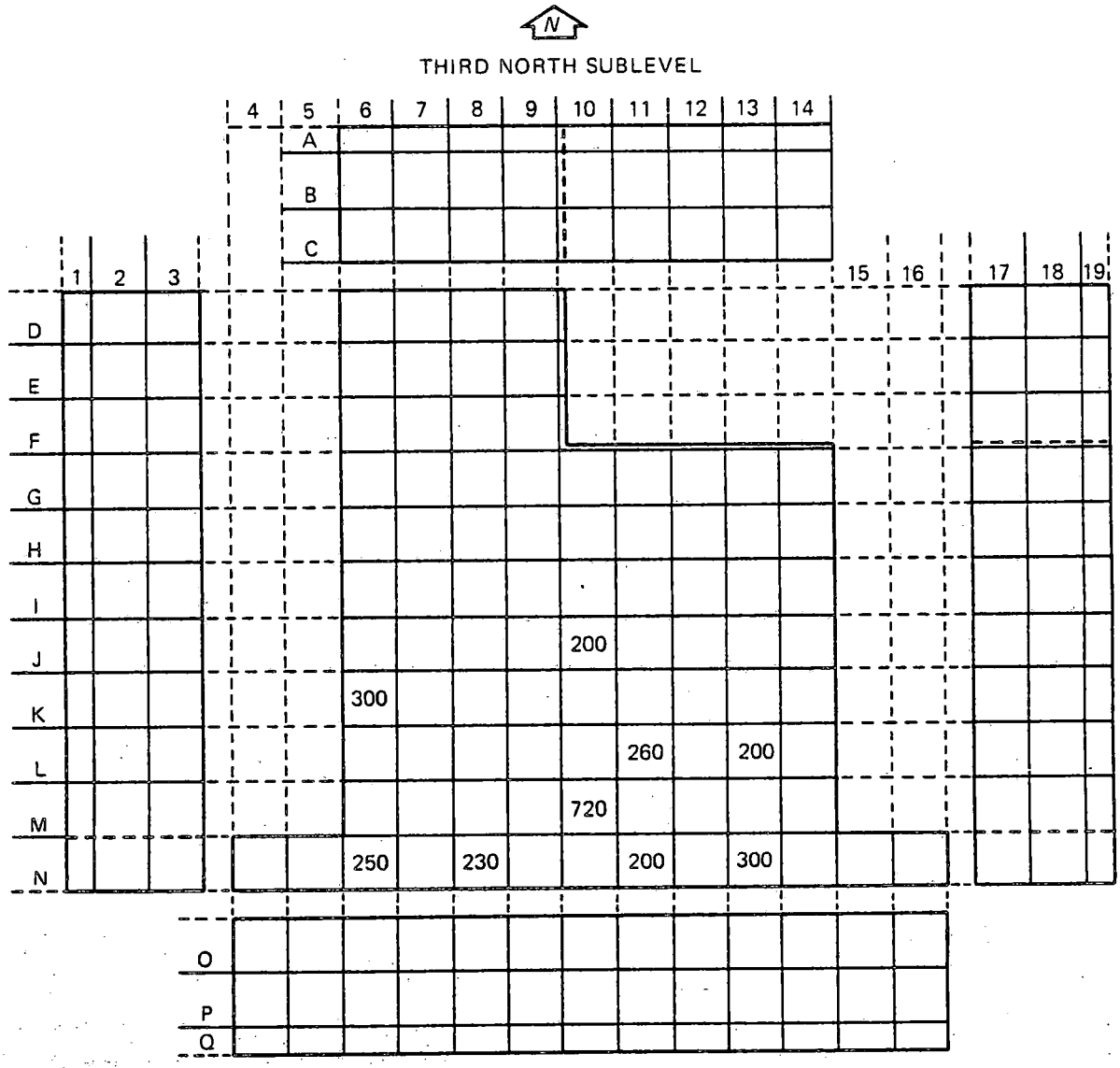

Fig. 14. Beta-gamma transferable contamination (dpm/100 cm^2), from 1-m^2 grid areas, exceeding 200 dpm/100 cm^2 (3.3 Bq/100 cm^2) (Building 7500, third north sublevel).

ORNL–DWG 83-18128

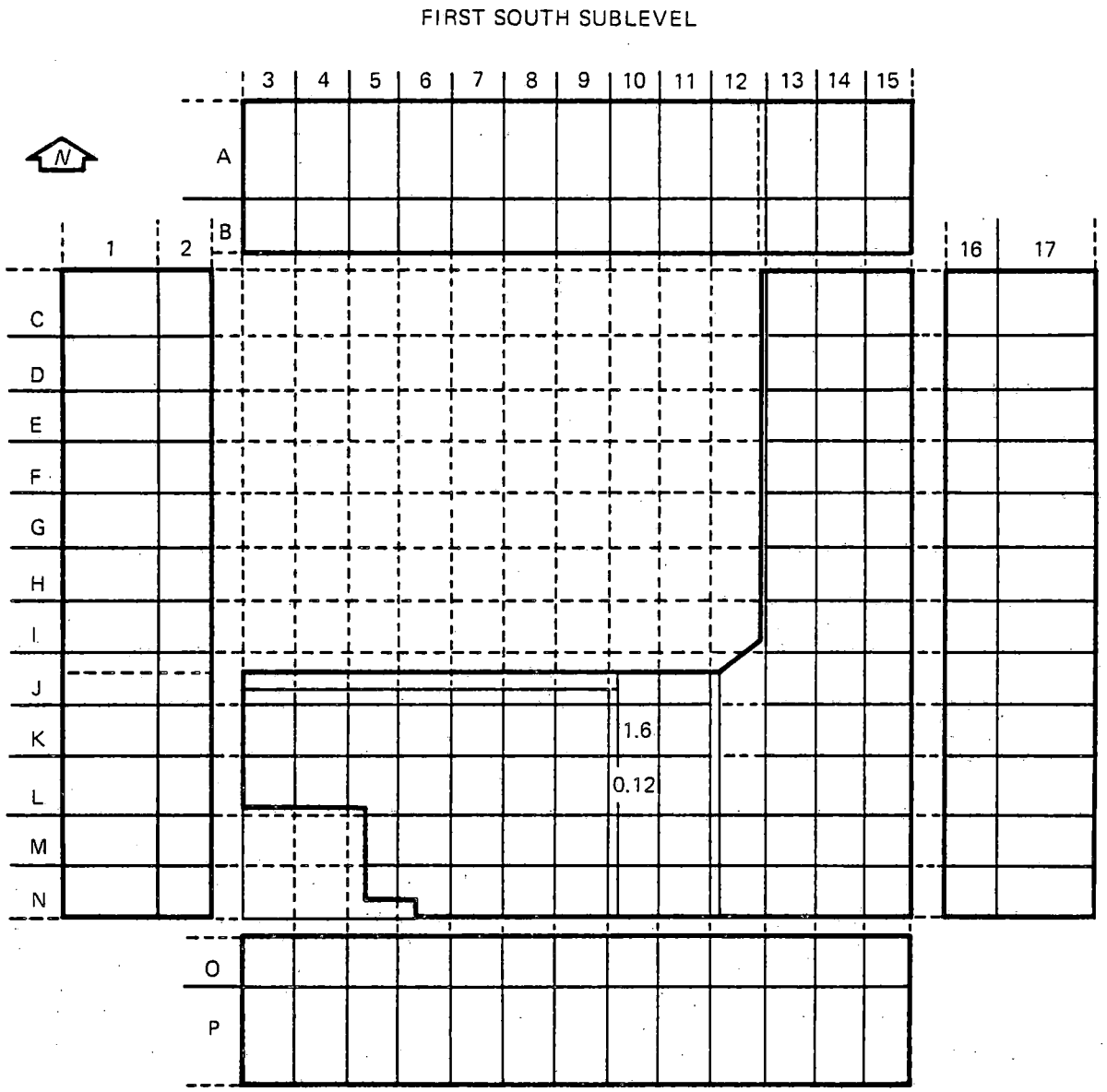

Fig. 15. Beta-gamma direct readings in mrad/h (1 mrad = 10 μGy), from 1-m^2 grid areas, exceeding 0.1 mrad/h at 10 cm from surface (Building 7500, first south sublevel).

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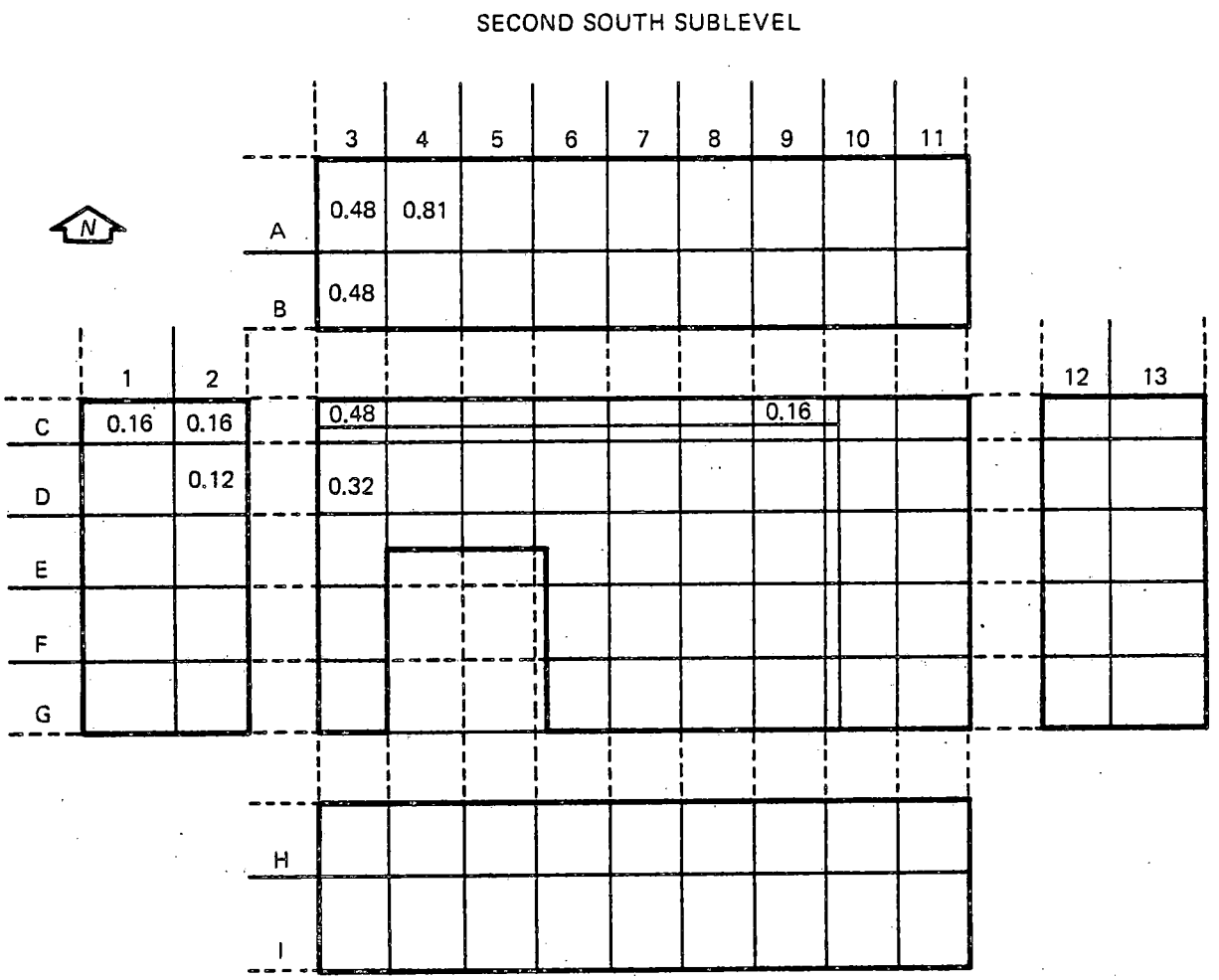

Fig. 16. Beta-gamma direct readings in mrad/h (1 mrad = 10 μGy), from 1-m^2 grid areas, exceeding 0.1 mrad/h at 10 cm from surface (Building 7500, second south sublevel).

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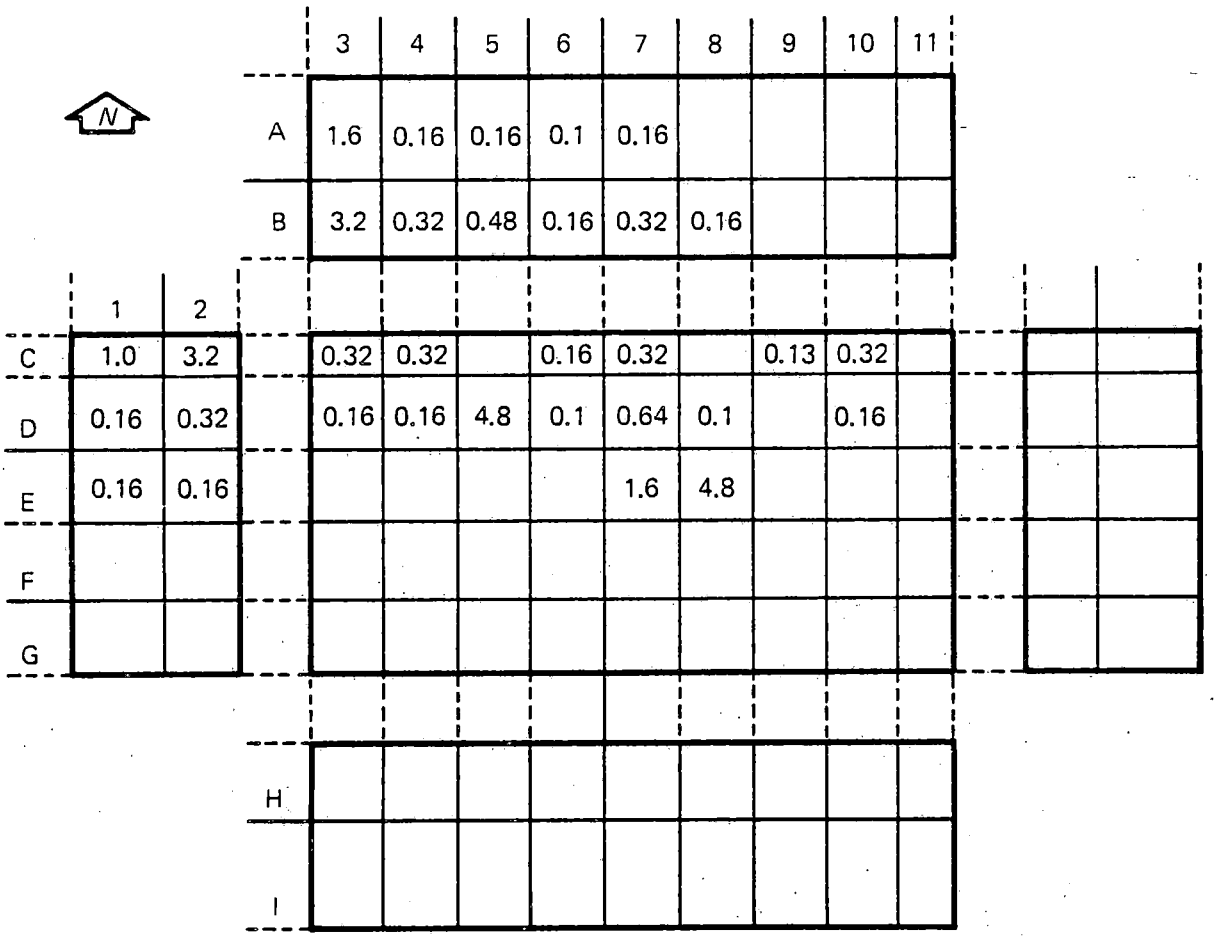

Fig. 17. Beta-gamma direct readings in mrad/h (1 mrad = 10 μGy), from 1-m² grid areas, exceeding 0.1 mrad/h at 10 cm from surface (Building 7500, third south sublevel).

ORNL–DWG 83-18131

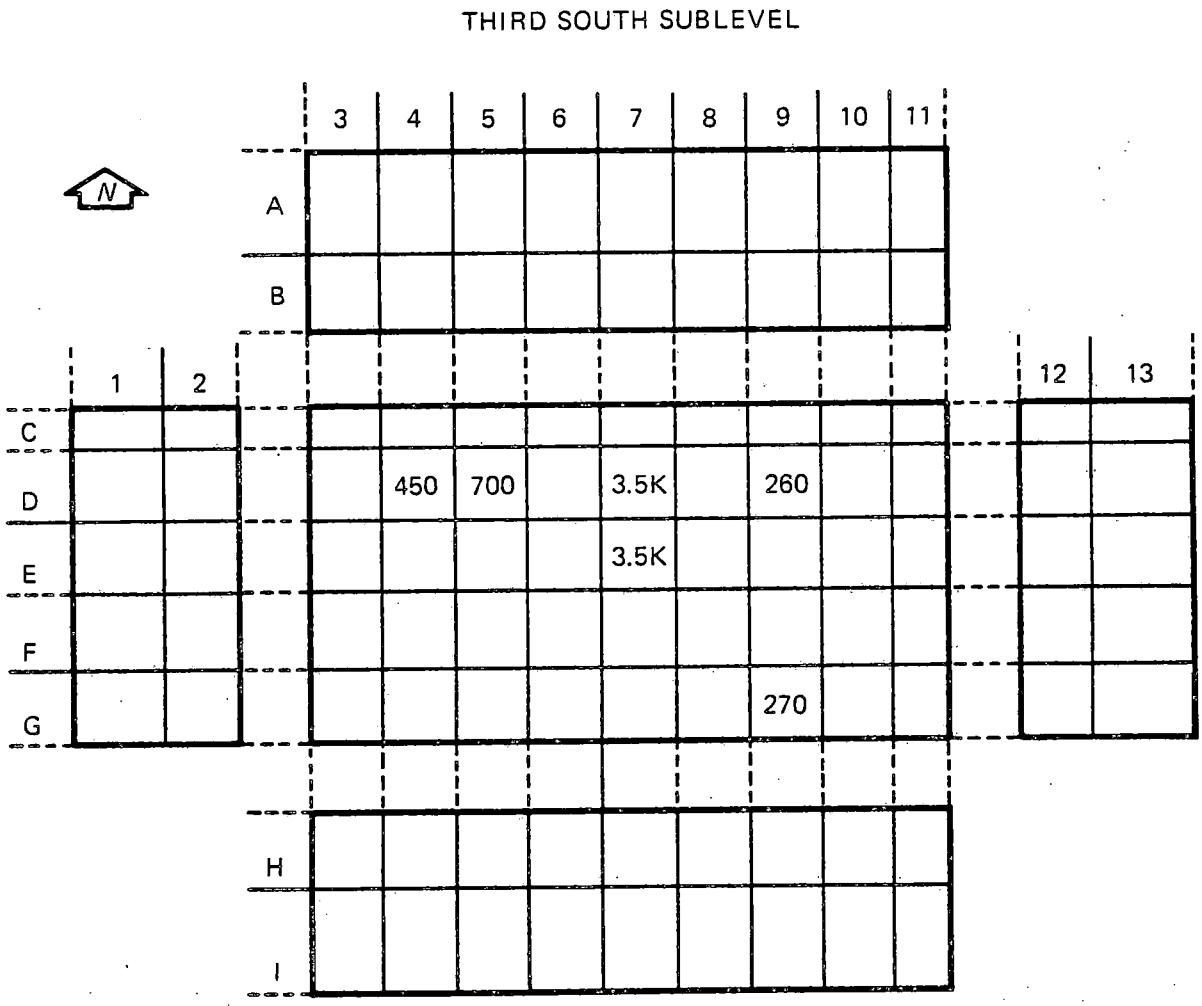

Fig. 18. Beta-gamma transferable contamination (dpm/100 cm^2), from 1-m^2 grid areas, exceeding 200 dpm/100 cm^2 (3.3 Bq/100 cm^2) (Building 7500, third south sublevel). K indicates the value should be multiplied by 1000 (3K = 3000).

Generally, the accessible areas of Building 7500 appear to have low levels of contamination. The lowest sublevels are contaminated to some extent but should not present any unusual health physics problems. Prior to any extensive work in the north sublevel, it is recommended that a safety inspection be made to verify that no hazards exist because of the deteriorating conditions of the walls and floor.

On the main floor, contamination exists only at the storage pool, around the exhaust stack, in the loading pit, and in a few isolated areas elsewhere. All of this contamination, with the exception of the water in the storage pool, is nontransferable.

Many lines and pipes penetrate the walls of the north sublevels into the reactor cell. Consideration should be given to how these lines are to be removed since they may contain small amounts of liquid contamination trapped in low areas.

5. SUMMARY OF OUTDOOR AND INDOOR AREAS

5.1 OUTDOOR AREAS

5.1.1 Surface Contamination

Eight contaminated surface areas where elevated (above background) direct beta-gamma readings were found had been identified using walk-over survey techniques. All eight areas were located in the southeast yard of HRE-2. From the middle of each contaminated area, a surface soil sample was collected from a layer of earth 0 to 0.3 m below the ground surface.

The major radionuclides that were detected in these eight samples that might cause environmental concerns were ^{137}Cs and ^{90}Sr. All eight soil samples contained significant concentrations of ^{137}Cs. The highest and lowest ^{137}Cs concentrations were detected in samples 12J (160 Bq/g) and 9H (1.6 Bq/g), respectively. A significant concentration of ^{90}Sr was detected in five samples from grid cells 6H (10 Bq/g), 9H (14 Bq/g), 12J (8.4 Bq/g), 13Q (8.2 Bq/g), and 11S (24 Bq/g).

Trace amounts of the following radionuclides were also detected: ^{154}Eu ($\leq$0.3 Bq/g), ^{226}Ra ($\leq$0.04 Bq/g), ^{238}Pu ($\leq$0.011 Bq/g), ^{239}Pu ($\leq 0.6 \times 10^{-2}$ Bq/g), ^{241}Am ($\leq 0.7 \times 10^{-2}$ Bq/g), and ^{244}Cm ($\leq 0.58 \times 10^{-2}$ Bq/g). One sample, 3K, contained a trace amount of ^{134}Cs (0.04 Bq/g). These radionuclide concentrations were insignificant when compared with the average radioactivity in soil samples from perimeter and remote monitoring stations for ORNL (Table 2).[18]

The highest concentration of ^{137}Cs was detected in sample 12J (160 Bq/g). The highest concentration of ^{90}Sr (24 Bq/g) was detected in sample 11S.

Also in the survey of the decontamination pad, a surface area where a direct beta-gamma reading exceeded 0.1 mrad/h was identified. The highest direct reading was 8.0 mrad/h. The lack of transferable contamination was probably the result of weathering because the pad is roofed but has open sides. The readings were highest on the outside of the curb, indicating that contamination may have leached into the ground at that point. This finding was in agreement with the results from the independently performed walk-over survey in which a contaminated surface area adjacent to the curb was also found.

The ^{137}Cs contamination found in sample 9H could come from the decontamination pad. Contamination found in sample 3K was probably introduced by the nearby storm sewer. Sample 3K also contained a trace amount (0.04 Bq/g) of ^{134}Cs.

Samples 12J and 11S were collected from swampish areas located downslope from the site of the previous pond. Radionuclides found in these samples could have leached out of the previous pond.

5.1.2 Subsurface Contamination

The major radionuclide found in subsurface soil samples was ^{90}Sr. Trace amounts of the following radionuclides were also detected: ^{137}Cs ($\leq$5.9 Bq/g), ^{60}Co ($\leq$0.007 Bq/g), ^{226}Ra ($\leq$0.04 Bq/g), ^{235}U ($\leq$0.03 ppm or 0.003 Bq/g), ^{238}U ($\leq$4.8 ppm or 0.06 Bq/g), ^{239}Pu ($\leq 0.8 \times 10^{-3}$ Bq/g), ^{238}Pu ($\leq 0.72 \times 10^{-3}$ Bq/g), ^{241}Am ($\leq 0.84 \times 10^{-2}$ Bq/g), and ^{244}Cm ($\leq 0.36 \times 10^{-2}$ Bq/g). The majority of ^{137}Cs was found in samples collected from core site 17, from the earth layer 0 to 2.4 m into the ground. The ^{137}Cs concentrations decreased drastically with increasing depth. Below 1.2 m, only a trace amount ($\leq$0.3 Bq/g) of ^{137}Cs was detected.

The highest concentration of ^{90}Sr (45 Bq/g) was found at core site 15 from the earth layer 1.2 to 1.8 m into the ground. The majority of ^{90}Sr was found in five subsurface soil samples collected from core sites 14, 15, 16, and 17. These five samples were taken from the earth layer 0.6 to 1.8 m into the ground. This earth layer corresponds to the sediment layer of the filled-in pond. All four core sites were located downslope in the perimeter of the previous pond site. Only low levels of ^{90}Sr ($\leq$0.2 Bq/g) were detected in samples collected from areas upslope from the previous pond site. This indicates that the detected ^{90}Sr probably is coming from the earth layer in which the previous pond sediment is located. The distance from the site of the previous pond is approximately 22 m to core site 17 and approximately 70 m to the creek.

Previous and current studies have shown that ^{90}Sr was found not only in soil samples collected from core site 17 ($\leq$24 Bq/g) but also in water samples from the nearby creek ($\leq$0.04 Bq/mL).

Radionuclides entering the creek are readily transported, causing greater environmental concerns. Actions to prevent ^{90}Sr from leaching into this creek will reduce environmental pollution. Recent monthly radioactive waste disposal operations and effluent monitoring reports indicate that the average combined ^{90}Sr contribution from the HRE-2 and the Molten Salt Reactor Experiment (MSRE) areas is less than 5% of the ^{90}Sr going into White Oak Lake.[25] So that the priorities of the D&D work could be more effectively determined, the HRE-2 (or NSPP) and MSRE should be considered separately.

The inventory of ^{90}Sr in the subsurface earth layer at the perimeter of the previous pond was approximately 3.7×10^{10} Bq (1 Ci) in approximately 1000 metric tons of soil. This was estimated by assuming that the contaminated earth layer was 2600 m^2 in area and 0.9 m deep.

Samples were collected from the perimeter of the previous pond. No drilling was done at the site of the previous pond. Contamination in the area of the pond, especially the bottom, is expected to be much higher because the sediment containing the highest concentration of radionuclides has been fixed on site. Radiological content in this area has not been studied, and it is possible that other long-lived yet less mobile radionuclides may still exist in this area along with ^{90}Sr.

Because of the expected high concentration of radionuclides in the area of the previous pond site, health physics monitoring and protective techniques would probably be required to drill through the previous pond bottom. These precautions may include special work permits, C-zone clothing, respirators, and containment tents.

Although drilling through the previous pond site could be hazardous, it would be necessary in order to take inventory of the radiological content of this earth layer of probable high contamination.

Pipes from the HRE-1 and HRE-2 waste disposal systems probably are still underground and could still contain small amounts of radionuclides. Special precautions may be needed in any future excavation at this facility, especially in the southeast yard, should the excavation option be chosen.

During the HRE-1 era, 1951 to 1953, a large quantity of fuel solution containing enriched ^{235}U was accidentally released into the creek.[26] By now, after 30 years, because of the high water solubility most (if not all) of the fuel solution should be washed away. However, it is possible that some residual radionuclides, especially ^{235}U, are left on the creek bank and in the sediment. To verify this, soil and sediment samples from these areas would be needed.

5.2 INDOOR AREAS

The contamination was almost exclusively ^{137}Cs and ^{90}Sr. No alpha contamination, either direct or transferable, was detected above background level. The actinide levels in these samples were below detection limits. Direct and transferable beta-gamma readings are summarized in Table 9.

The waste evaporator, Building 7502, presented the most serious potential hazard of the accessible indoor areas of the HRE-2 facility. The accessible areas of this building were extensively contaminated. Building 7502 is deteriorating and in need of repair and maintenance. A survey in the blockhouse needs to be done prior to decontamination and decommissioning; however, this will need to be carefully planned because the access on the roof is open to the environment.

In general, the accessible areas of Building 7500 appear to have low levels of contamination. The lowest sublevels are contaminated to some extent but should not present any unusual health physics problems. Prior to any extensive work in the north sublevels, it is recommended that a safety inspection be made to verify that no hazards exist as a result of the deteriorating conditions of the walls and floor.

The reactor cell, the chemical processing cell C, the evaporator cell, and the storage pool present more serious potential hazard then the accessible areas discussed above. Among them, the reactor cell will be the most hazardous when opened. The direct beta-gamma readings in the reactor cell could be as high as 6 Gy/h (600 rad/h). Some alpha contamination resulting from residual fuel would be expected in the reactor cell. Radioactive gases could also exist in the cell.

Many lines and pipes from the reactor cell, cell C, the evaporator cell, and the storage pool might still contain small amount of liquid contamination trapped in low areas. Consideration should be given to how these lines are to be removed.

Table 9. A summary of the highest transferable and direct beta-gamma activities detected in the indoor areas[a]

Surveyed area	Direct radiation		Transferable	Comments
	μGy/h	mrad/h[b]	(Bq/100 cm²)[c]	
Building 7502, Waste evaporator	150	15	530	This is one of the most contaminated indoor accessible areas. The high activities were from the areas of the west and south corridors (as shown in Figs. 7 and 8. The area inside the waste evaporator cell was inaccessible and probably highly contaminated.
Building 7500, Main floor	23	2.3	ND[e]	No transferable contamination was detected. Elevated direct beta-gamma readings were primarily associated with the storage pool, the exhaust stack, and the loading pit, as shown in Fig. 9.
Building 7500, North first sublevel		BG[d]	6.3	Just one spot of low-level transferable contamination was detected, on this sublevel, as shown in Fig. 19.
Building 7500, North second sublevel	650	65	83	Some direct beta-gamma readings were found on the south wall, which is adjacent to the reactor cell, and a few hot spots with transferable contamination were found on the floor near the east wall, as shown in Figs. 11 and 12. Grid cells 14E and 14F show both direct readings and transferable readings.
Building 7500, North third sublevel	64	6.4	12.0	The floor was partially covered with noncontaminated water. This area is in a general state of disrepair. Only low levels of activities were detected as shown in Figs. 13 and 14.
Building 7500 South first sublevel	16	1.6	ND	No transferable activity was detected. Low-level direct reading was detected only in grid cells 10K and 10L, as shown in Fig. 15.
Building 7500, South second sublevel	8	0.8	ND	Only low-level, direct beta-gamma readings were measured on this level (see Fig. 16).
Building 7500, South third sublevel	48	4.8	58	This level showed the strongest indications of fixed and transferable contaminations among south sublevels.

[a]No transferable nor fixed alpha activity was detected above background levels.

[b]1 mrad ≈ 3100 cpm; this conversion could be accurate when only a high energy gamma-ray was present and was only relative otherwise.

[c]1 Bq = 60 dpm.

[d]Bg indicates below background (0.02 mrad/h).

[e]ND indicates nondetectable (<3.3 Bq/100 cm²).

6. REFERENCES

1. J.H. Coobs and T.E. Myrick, *The ORNL Surplus Facilities Management Program Maintenance and Surveillance Plan for Fiscal Year 1984*, ORNL/CF-83/56, Oak Ridge Natl. Lab., 1983.

2. D.R. Simpson and S. De La Garza, *Preliminary Radiological Characterization of the Homogeneous Reactor Experiment No. 2 (HRE-2)*, ORNL/CF-82/288, Oak Ridge Natl. Lab., 1982.

3. C.L. Segaser and F.C. Zapp, *Homogeneous Reactor Experiment Design Manual*, ORNL/CF-52-160, Oak Ridge Natl. Lab., 1952.

4. R.H. Chapman, *HRE-2 Design Manual*, ORNL-TM-348, Oak Ridge Natl. Lab., 1964.

5. A.M. Rom and H.O. Weeren, *Design of Chemical Processing Plant for Homogeneous Reactor Test*, ORNL-2784, Oak Ridge Natl. Lab., 1959.

6. M.H. Fontana et al., *Proposal for the Nuclear Safety Pilot Plant*, ORNL/CF-61/11-73, Oak Ridge Natl. Lab., 1961.

7. R.E. Adams et al., *Uranium Oxide and Sodium Oxide Aerosol Experiments: NSPP Mixed-Oxide Test 300-307, Data Record Report*, NUREG/CR-2697, Oak Ridge Natl. Lab., 1982.

8. D.O. Campbell, *Decontamination of the Homogeneous Reactor Experiment*, ORNL-1839, Oak Ridge Natl. Lab., 1956.

9. S.E. Beal and S. Visner, *Homogeneous Reactor Test—Summary Report for the Advisory Committee on Reactor Safeguards*, ORNL-1834, Oak Ridge Natl. Lab., 1955.

10. O.O. Yarbro, *HRT Chemical Plant Runs 18 and 19 Summary*, ORNL/CF-60/3-161, Oak Ridge Natl. Lab., 1960.

11. C.D. Cagle and L.P. Pugh, *Decommissioning Study for the Homogeneous Reactor Experiment No. 2 (HRE-2)*, ORNL/CF-76-77, Oak Ridge Natl. Lab., 1976.

12. W.R. Reed, F. J. Peretz, and S. P. Dumont, *Preliminary Decommission Study Reports, Volume 6: Homogeneous Reactor Test*, X-OE-231, Oak Ridge Natl. Lab., 1984.

13. W.R. Reed, F.J. Peretz, and S.P. Dumont, *Preliminary Decommissioning Study Reports, Volume 5: HRT Retention Pond*, X-OE-231, Oak Ridge Natl. Lab., 1984.

14. E.D. Gupton, *Health Physics Instrument Manual*, ORNL/332, Oak Ridge Natl. Lab., 1961.

15. J.S. Eldridge and S.F. Huang, *Radioactivity Determinations in Decontamination and Decommissioning*, Analytical Chemistry Division Annual Report, ORNL/CF-83/91, Oak Ridge Natl. Lab., 1983.

16. W.A. Alexander et al., *Radionuclide Characterization of Subsurface Soil on the Site of Building 3505 at ORNL*, TM-8479, Oak Ridge Natl. Lab., 1982.

17. T.W. Oakes et al., *Methods and Procedures Utilized in Environmental Management Activities at Oak Ridge National Laboratory*, ORNL/TM-7212, Oak Ridge Natl. Lab., 1981.

18. J.A. Auxier and T.W. Oakes, *Industrial Safety and Applied Health Physics Division Annual Report for 1981*, ORNL-5859, Oak Ridge Natl. Lab., 1982.

19. *ORNL Health Physics Manual, Procedures and Practices for Radiation Protection*, Procedure 2.7, Table 2, Oak Ridge Natl. Lab., Oak Ridge, Tenn.

20. *Radiological Health Handbook*, U.S. Department of Health, Education, and Welfare, Washington, DC, 1970.

21. J.S. Eldridge and T.W. Oakes, "Radionuclide Migration from Shallow Land Burial Site," *Health Physics* 45(1),216 (1983).

22. F.T. Binford, *An Analysis of the Potential Hazards Associated with the Disposal of Radioactive Waste in Open Pits at ORNL*, ORNL/CF-60- 5-63, Oak Ridge Natl. Lab., 1960.

23. N. Irving Sax, *Dangerous Properties of Industrial Materials*, Van Nostrand Reinhold Company, New York, 1979.

24. L.E. Boring et al., *Results of the Radiological Survey of the Former Metal Recovery Facility at Oak Ridge National Laboratory*, Evaluation Research Corporation, Oak Ridge, Tenn., 1981.

25. L.C. Lasher and C.B. Scott, *Radioactive Liquid and Gaseous Waste Disposal Operations and Effluent Monitoring Report for the Month of June 1983*, ORNL/CF-83/214, Oak Ridge Natl. Lab., 1983.

26. S.E. Bell, *Summary of Efforts to Recover 235 Spillage at the 7500 Area*, ORNL/CF-52-9-46, 1952.