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**Radiological Surveys
of Properties in the
Middlesex, New Jersey, Area**

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RADIOLOGICAL SURVEYS OF PROPERTIES IN THE
MIDDLESEX, NEW JERSEY, AREA

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Work performed
as part of the
Formerly Utilized Sites--
Remedial Action Program

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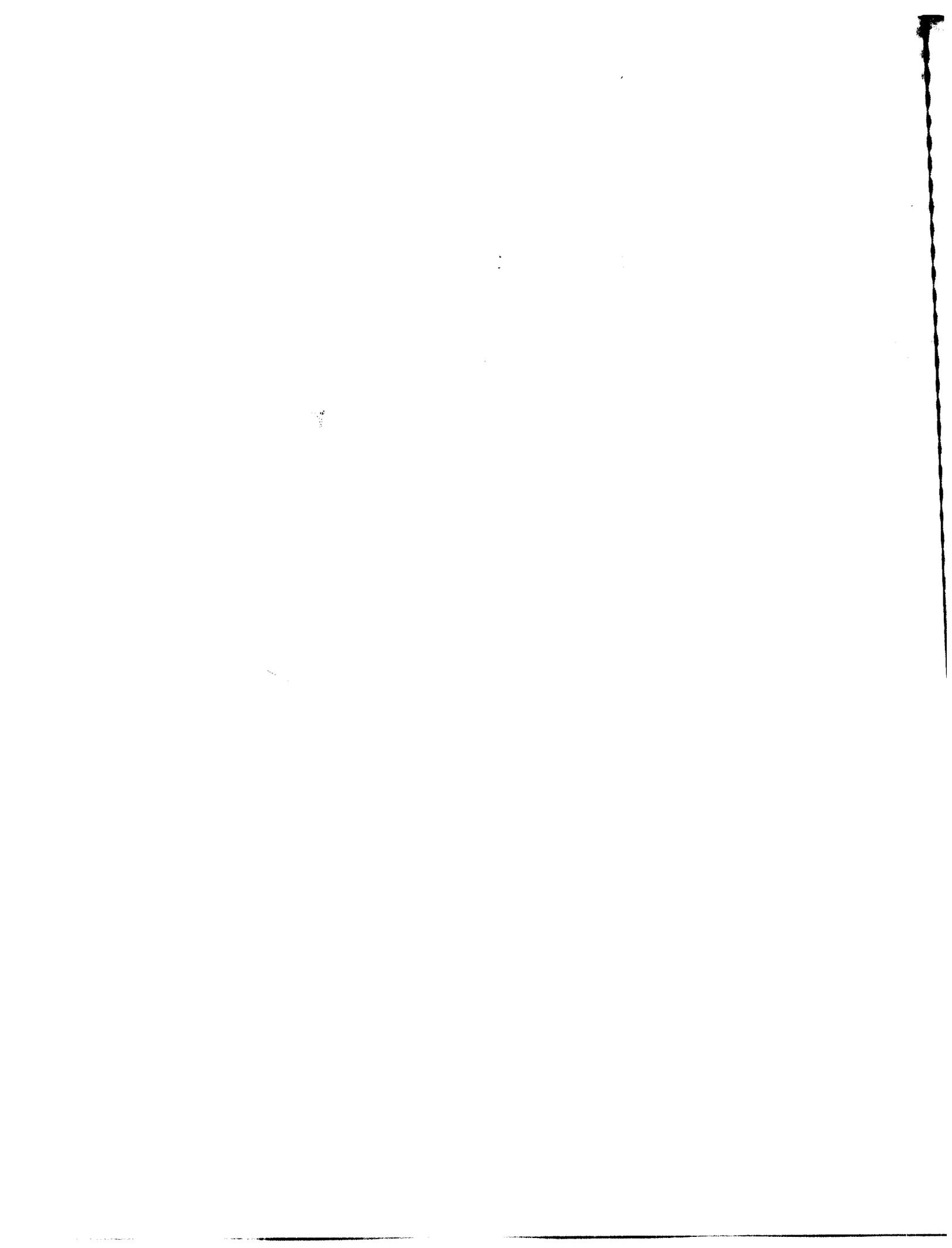
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RADIOLOGICAL SURVEYS OF PROPERTIES IN THE
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FOREWORD

The U.S. Department of Energy (DOE) has determined that the former Middlesex Sampling Plant in Middlesex, New Jersey, and some associated private properties in the Middlesex area are presently contaminated with radioactive residues resulting from previous uses of the sampling plant property. In the 1940s and 1950s, the former Middlesex Sampling Plant facility functioned as a storage depot and sampling plant for Belgian Congo uranium ore. The plant was decommissioned in the mid-1950s, and sampling activities were moved to other locations.

In 1978, an aerial radiological survey of the Middlesex area was conducted to determine whether significant quantities of radium-contaminated material had been transported to off-site areas in the vicinity of the sampling plant. This aerial survey identified 13 areas with above-background radiation levels. These areas included the sampling plant and a former municipal landfill on Mountain Avenue, both of which are the subject of separate DOE reports.¹⁻² The levels at eight of the other 11 areas are attributed to the presence of natural outcroppings of a reddish-brown shale, and the use of granite products. No material from the former sampling plant is present in these locations.

The remaining three areas identified by the aerial survey are private properties which were suspected to contain materials originating from the former sampling plant. The first of these properties is located on Harris Avenue and is the site of the Church of Our Lady of Mount Virgin. It is believed that soil from the sampling plant was moved to the site in about 1947. The second site consists of a small area in a private vehicle parking lot at the north end of the Union Carbide Plant in Bound Brook, New Jersey. Available records fail to indicate any link

between contamination at the parking lot and the sampling plant. The third site is a private residence on William Street in Piscataway, New Jersey. A previous owner of the property notified DOE that soil had been taken from the Middlesex Sampling Plant to use as fill dirt in the yard.

The purpose of this report is to provide the results of the radiological surveys conducted at these three properties, as well as one additional location downstream from the Middlesex Sampling Plant (Willow Lake). These surveys, performed by the Health and Safety Research Division at Oak Ridge National Laboratory, were conducted to characterize the extent of the contamination at each location for input to the decision on what remedial action might be necessary under the Formerly Utilized Sites Remedial Action Program (FUSRAP) of the DOE.

1. RADIOLOGICAL SURVEY OF THE RECTORY OF OUR LADY OF
MOUNT VIRGIN CHURCH, MIDDLESEX, NEW JERSEY

ABSTRACT

A radiological survey was conducted at property owned by the Church of Our Lady of Mount Virgin, located on Harris Avenue in Middlesex, New Jersey. The survey consisted of measurements of the following: surface contamination levels outdoors on the site and indoors on each level of the church rectory; external gamma radiation levels at the surface and at 1 m above the surface outdoors on the site, and external gamma radiation levels at 1 m above the floor in each room of the rectory; radionuclide concentrations in surface soil, subsurface soil, and water on the site; and radon concentrations indoors in the basement and on the first level of the rectory.

The survey revealed that the yard around the church rectory is contaminated with a ^{226}Ra -bearing material, probably pitchblende ore from the former Middlesex Sampling Plant. The elevated ^{226}Ra concentrations around and, to a lesser extent, underneath the rectory are leading to elevated ^{222}Rn concentrations in air in the rectory and elevated alpha contamination levels (from radon daughters) on surfaces inside the rectory. External gamma radiation levels in the rectory yard are well above background levels, and beta-gamma dose rates at many points in the yard are above federal guidelines for the release of property for unrestricted use.

INTRODUCTION

At the request of the Department of Energy (DOE), a radiological survey was conducted at property owned by the Church of Our Lady of Mount Virgin, located on Harris Avenue in Middlesex, New Jersey. A plan view of the surveyed property is shown in Fig. 1-1.

Elevated gamma radiation levels were discovered on this property in the vicinity of the church rectory during an aerial survey by the Washington Aerial Measurements Department of EG&G.³ This aerial survey

was being made of a large area surrounding the former Middlesex Sampling Plant, where pitchblende ores were handled in the 1940s. Some Middlesex residents recall that, in about 1947, soil was moved from the Middlesex Sampling Plant and was used as fill dirt for what is presently the rectory lawn. Records kept by the Church of Our Lady of Mount Virgin indicate that a resolution to build the rectory was passed in September, 1947. However, there are apparently no available records stating when the rectory was built, where the fill dirt was collected, or whether the fill dirt had been placed on the property before the construction of the rectory.

The radiological survey was conducted by members of the Health and Safety Research Division of the Oak Ridge National Laboratory (ORNL) during the period June 6-17, 1978. The survey included the following measurements:

1. gamma radiation levels at the surface and at 1 m above the surface outdoors on the site;
2. beta-gamma dose rates at 1 cm from the surface outdoors on the site;
3. radionuclide concentrations in surface and subsurface soil on the site;
4. gamma radiation levels as a function of depth in auger holes drilled outdoors on the site;
5. radionuclide concentrations in water samples taken from auger holes drilled on the rectory lawn and in a sample of tap water taken from the kitchen of the rectory;
6. radon-222 concentrations in air in the rectory basement and in a bedroom on the first level of the rectory;
7. alpha and beta-gamma contamination levels (by direct reading) on the floor, walls, and ceiling of each room of the rectory;
8. transferable alpha and beta contamination levels in each room of the rectory;
9. external gamma radiation levels at 1 m above the floor in each room of the rectory.

SURVEY METHODS

Methods Used for the Survey Outdoors

The outdoor area of the site was divided into "survey blocks" by the rectangular grid system shown in Fig. 1-1. In the area surrounding the rectory and the old church, survey blocks measuring 25 ft x 25 ft were used. On the remainder of the site, larger survey blocks (50 ft x 50 ft or larger) were used. At the center of each survey block, the external gamma radiation level was measured 1 m above the ground with a NaI scintillation survey meter (see Appendix I), and at 1 cm from the surface, open- and closed-window Geiger-Mueller (G-M) survey meter measurements were made. (The Geiger-Mueller survey meter is described in Appendix I.) Additionally, each of the 25 ft x 25 ft survey blocks and each survey block adjacent to Drake Avenue across the street from the rectory was scanned with a NaI scintillation meter held near the ground. At the point showing the maximum gamma radiation level, the same types of measurements made at the center point of the survey block were repeated.

Surface soil samples were collected at nine of the points on the site showing highest beta-gamma dose rates. These samples were returned to ORNL for analysis of ^{226}Ra and ^{238}U .

Subsurface soil analysis was conducted in holes drilled with a motorized rig (equipped with an 8-in.-diam auger) to depths well below the natural shale formation at the locations shown in Fig. 1-2. A plastic pipe with a 4-in. inner diam was placed in each hole, and a NaI scintillation probe was lowered inside the pipe. The probe was encased in a lead shield with a narrow opening on the side. This arrangement allowed measurements of gamma radiation intensities resulting from contamination within small fractions of the hole depth. Measurements were usually made at 6-in. intervals in very contaminated regions and at 1-ft intervals in relatively uncontaminated regions. At two locations (holes 7 and 8 shown in Fig. 1-2) a split-spoon sampler with a 3-in. diam was used to collect soil samples at intervals from 6 in. to 1 ft throughout the contaminated zone. At each of these locations, logging

with a NaI scintillation meter was also performed. Comparison of the gamma-ray intensities and ^{226}Ra concentration at corresponding depths at these two locations allows an estimate of ^{226}Ra concentrations from loggings at the locations not sampled. At each auger hole location, a random sample of the contaminated soil brought up by the auger was collected for analysis. This was done only to verify the type of contaminant, and the radionuclide concentrations in these random samples should not be interpreted either as an average or as a maximum for the contaminated region.

In three of the auger holes, water was encountered at a depth of approximately 8 ft. Samples of the water were taken for determination of radionuclide concentrations. Methods used to analyze water and soil samples are discussed in Appendix II.

Methods Used for the Survey Indoors

The rectory consists of four levels, including a basement. On each level the rooms were numbered, and each room was considered as a separate unit for survey purposes. In each room the external gamma radiation level at 1 m above the floor was measured near the center of the room with a NaI scintillation meter and with a scaler-equipped G-M counter which is shielded to provide an estimate of the exposure rate that is nearly independent of photon energy.⁴ Next, near the center of each wall and near the centers of the floor and ceiling in each room, open- and closed-window G-M meter measurements were taken at 1 cm from the surface. A direct measurement was made of the alpha contamination level on the floor and each wall in every room. Finally, a smear sample was taken on the floor in each room and another sample was taken on the walls in each room, for the measurement of transferable alpha and beta contamination levels.

Continuous measurements of radon concentrations in air were made for ten days in the basement and for three days in a bedroom on the street level. These measurements were made using an instrument developed by Wrenn et al.⁵ and referred to as a Wrenn Chamber. This instrument, described in Appendix I, was equipped with a printer which recorded automatically (at intervals of 30 min) numbers proportional to the radon

concentrations. Because some radon and progeny from previous 30-min counts remain in the Wrenn Chamber, each reading actually represents a concentration which has been integrated over a period of 2 to 4 hr.

In one of the basement rooms, a rectangular opening had been left in the concrete floor for access to a clean-out plug in the sewer system. Samples of soil were taken from the ground through this opening at intervals of approximately 5 to 6 in. until the natural shale formation was encountered at approximately 18 in. Subsurface soil samples were also taken at approximately 6-in. intervals to a depth of 30 in. in uncovered dirt found outside the building foundation but inside the enclosed back entrance to the basement at the bottom of the stairs. All soil samples were analyzed for ^{226}Ra , ^{238}U , and ^{232}Th .

A water sample was taken from a faucet in the kitchen of the rectory. The sample was analyzed for ^{226}Ra , ^{230}Th , ^{238}U , and ^{210}Pb .

SURVEY RESULTS

Background Radiation Levels and Radionuclide Concentrations

Background external gamma radiation levels in the Middlesex area generally vary between 5 and 10 $\mu\text{R/hr}$. Concentrations of ^{226}Ra , ^{232}Th , and ^{238}U in background soil in the Middlesex area are typically near 1 pCi/g.

Background beta-gamma dose rates, as measured with G-M survey meters used on the site, generally average less than 0.03 mrad/hr. Background direct alpha readings for the type of alpha meter used on this site are negligible. All direct meter readings reported in this document represent gross readings (background radiation levels have not been subtracted). Similarly, background levels have not been subtracted from radionuclide concentrations measured in environmental samples. For the measurement of transferable alpha and beta contamination levels, average background counts were determined for the smear counters (at the place of counting), and these background counts were subtracted from gross counts.

Results of the Survey Outdoors

Gamma and Beta-Gamma Measurements

External gamma measurements at 1 m and beta-gamma dose-rate measurements at 1 cm above the ground over the site indicated that nearly all the radioactive contamination on the site could be found within the triangular area bounded by Harris Avenue, Drake Avenue, and the grid line between rows 10 and 11 of the survey blocks (see Fig. 1-2). This area consists principally of the rectory lawn and the rectory itself, but includes part of the lawn more naturally associated with the old Catholic Church. In addition, gamma and beta-gamma measurements revealed the existence of small, contaminated spots on the ground in the playground across Drake Avenue from the rectory (see Fig. 1-1).

External gamma levels at 1 m above the lawn around the rectory and the old Catholic Church, and in the playground are shown in Fig. 1-3. Measurements in Fig. 1-3 are reported in $\mu\text{R/hr}$ and are given in the form A/B , where A is the external gamma level at 1 m above the center of the indicated survey block, and B is the highest external gamma level at 1 m in the entire survey block. The average external gamma level at 1 m in the area around the rectory indicated in Fig. 1-3 was approximately $33 \mu\text{R/hr}$, and the maximum external gamma level at 1 m in the same area was approximately $220 \mu\text{R/hr}$.

Beta-gamma dose rates at 1 cm above the lawn in the contaminated area around the rectory and the old Catholic Church, and in the playground are shown in Figs. 1-4 and 1-5. Figure 1-4 shows the beta-gamma dose rates at 1 cm at the center of the survey block, and Fig. 1-5 shows the beta-gamma dose rates at 1 cm at the maximum gamma point in the survey block. All measurements in Figs. 1-4 and 1-5 are reported in mrad/hr . The average beta-gamma dose rate at 1 cm in the contaminated area around the rectory and the old Catholic Church as shown in Figs. 1-4 and 1-5 was approximately 0.04 to 0.05 mrad/hr , and the maximum observed beta-gamma dose rate at 1 cm in this area was 1.3 mrad/hr .

In the playground across Drake Avenue from the rectory, some contamination was found in isolated spots. External gamma radiation levels at 1 m in this area (see Fig. 1-3) were generally in the range

of 6 to 9 $\mu\text{R/hr}$, and at isolated spots were as high as 16 $\mu\text{R/hr}$. Beta-gamma dose rates at 1 cm from the surface were as high as 0.19 mrad/hr at isolated spots (see Figs. 1-4 and 1-5).

Surface Contamination Outdoors on the Site

Surface soil samples were taken at the locations shown in Fig. 1-6. These sampling locations were chosen because of elevated gamma radiation levels at the surface. Concentrations of ^{226}Ra and ^{238}U in these samples and the external gamma radiation levels at the surface at sampling points are reported in Table 1-1. All of the samples showed more than 100 pCi/g of ^{226}Ra , and some of the samples showed licensable concentrations of uranium (0.05% by weight, corresponding to 172 pCi/g of ^{238}U ; see 10 CFR 40). A particularly noteworthy sample listed in Table 1-1, sample 8, is not actually a surface sample, but was a small rock taken a few inches beneath the surface in the playground across Drake Avenue from the rectory (see Fig. 1-6). This sample showed a ^{226}Ra concentration of 20,000 pCi/g and a ^{238}U concentration of 21,000 pCi/g (6.1% uranium by weight).

Subsurface Contamination Outdoors on the Site

Holes were drilled outdoors at the locations shown in Fig. 1-2. Core samples were taken at known depths from holes 7, 8, and 13, and randomly selected samples of soil were taken from holes 1 through 6. Concentrations of ^{226}Ra , ^{238}U , and ^{232}Th in subsurface samples taken at these locations are given in Table 1-2. Estimates of ^{226}Ra concentrations made from gamma scintillator loggings for the holes where no core samples were taken are given in Table 1-3. It appears from the results in Tables 1-1, 1-2, and 1-3 that an area bounded by Drake Avenue, Harris Avenue, and an imaginary line possibly 25 ft or more west of the west side of the rectory is contaminated in most places from near the surface to a depth of 2 ft to 4 ft. The contaminated soil shows, on the average, approximately equal activities of ^{226}Ra and ^{238}U . This fact, together with the suspected source of the contaminant, strongly suggests that the radioactive material is pitchblende ore. Furthermore, the survey results indicate that there may be as much as 2,000 yd^3 of contaminated

soil around the rectory containing from 5 to 9,800 pCi/g of ^{226}Ra and comparable concentrations of ^{238}U .

It appears from survey results that the contamination on the playground across Drake Avenue from the rectory exists only in small, isolated spots near the surface. However, as indicated earlier, ^{226}Ra and ^{238}U concentrations in soil at those contaminated spots may be extremely high. As an example, one sample (a rock) taken a few inches beneath the surface showed 20,000 pCi/g of ^{226}Ra and 21,000 pCi/g of ^{238}U . Logging of auger holes drilled within 1 ft of contaminated surface locations indicated no subsurface contamination at these locations (see Table 1-3).

Water was encountered at a depth of approximately 8 ft in three of the auger holes. Samples of the water were taken for analyses of ^{238}U , ^{210}Pb , ^{230}Th , and ^{226}Ra concentrations. Results are reported in Table 1-4.

Results of the Survey Inside the Rectory

Radon Measurements

Radon is apparently entering the rectory through a rectangular opening ("sump") which was left in the concrete floor in Room 7 in the basement for access to a clean-out plug in the sewer system (see Fig. 1-7).

Continuous radon measurements were made for ten days in Rooms 2 and 9 in the basement (see Fig. 1-7) and for three days in Room 9 on the street level (see Fig. 1-8). Results are reported in Tables 1-5 and 1-6. Radon concentrations in Room 2 of the basement averaged approximately 20 pCi/liter and were as high as 48 pCi/liter, while those in Room 9 of the basement averaged approximately 30 pCi/liter and ranged up to 92 pCi/liter. Radon concentrations in Room 9 on the street level ranged from 0.05 to 2.5 pCi/liter and averaged approximately 0.8 pCi/liter.

These short-term radon measurements may not be representative of radon concentrations in air in the rectory over the period of a year, and further radon sampling would be desirable. In particular, the first level of the rectory was very well ventilated during the period of radon

measurements; hence, the measured radon concentrations on that level may have been far below the average annual concentration. The radon measurements do indicate, however, that a potential hazard from radon and its progeny may exist in this structure.

Direct Measurements of Alpha Contamination and Measurements of Transferable Alpha and Beta Contamination Levels

Direct alpha measurements taken at the centers of the floors and walls in individual rooms in the rectory are shown in Figs. 1-7 through 1-10. Direct alpha measurements in the basement were as high as 840 dpm/100 cm². On the street level, second level, and third level of the rectory, the maximum direct alpha measurements were 200, 80, and 20 dpm/100 cm², respectively. It appears that alpha contamination in this structure is principally (and perhaps entirely) the result of radon daughters which settle out of the air and become attached to surfaces. An experiment was performed in the basement to determine how large this contribution from radon daughters was to the total measured alpha contamination. At two locations in Room 9 and at two locations in Room 7 in the basement, new (uncontaminated) materials were placed on the floor and were left for 24 hr. Then direct alpha measurements were taken on these materials and on the floor nearby. At each of the four locations, the direct alpha measurements on the floor (which were 200 dpm/100 cm² or more in every case) were no higher than those on the new materials. This experiment indicates that the elevated direct alpha measurements on the floor (at least at these locations) were due to airborne alpha emitters settling out onto the floor.

Two smear samples were taken in each room of the rectory, one on the floor and a second on the walls. Essentially all of the radon daughters which settle out on surfaces are easily removable. Hence, in order to determine whether removable long-lived alpha or beta emitters exist on the floor or wall surfaces, the smears were counted after a sufficient period had elapsed to allow essentially all radon daughter products on the smear samples to decay. It was found that there was no distinguishable activity of long-lived alpha or beta emitters on the samples.

Gamma and Beta-Gamma Measurements

External gamma radiation levels measured at 1 m above the floors at the centers of the various rooms in the rectory are shown in Figs. 1-11 through 1-14. Measurements ranged from 9 to 44 $\mu\text{R/hr}$ in the basement, from 8 to 22 $\mu\text{R/hr}$ on the street level, and from 7 to 12 $\mu\text{R/hr}$ on the upper two levels.

Geiger-Mueller survey meter measurements were made on the floors and walls in each room of the rectory. Maximum beta-gamma dose rates measured in each room are reported in Table 1-7. There was no significant difference between open- and closed-window G-M meter measurements, indicating that there was no significant beta radiation at the points of measurement. Beta-gamma dose rates generally followed the same pattern as the external gamma levels shown in Figs. 1-11 through 1-14, with the highest beta-gamma dose rate (0.06 mrad/hr) being measured on the north wall of Room 7 in the basement. It is probable that the elevated beta-gamma dose rate at this point was due principally to gamma radiation from the contaminated soil near the outside wall.

Contamination Levels Beneath the Rectory

Soil samples were taken beneath the rectory at the locations shown in Fig. 1-15. Samples S1, S2, and S3 are surface samples; subsurface samples were taken at hole locations 11 and 12. Location S2 is beneath the steps leading to the rectory kitchen and is outside the rectory walls. The other locations shown in Fig. 1-15 are within the walls of the rectory, although the "sump" in Room 7 of the basement is the only soil sampling location within the concrete foundation of the rectory.

Concentrations of ^{226}Ra , ^{238}U , and ^{232}Th in soil samples S1, S2, and S3 are given in Table 1-8. Concentrations of these radionuclides in subsurface samples taken at hole locations 11 and 12 are reported in Table 1-2. The results show that there are significantly higher concentrations of ^{238}U (up to 43 pCi/g) than ^{226}Ra (at most 14 pCi/g) in soil samples taken beneath the rectory. This marked disequilibrium between ^{226}Ra and ^{238}U suggests that at least some of the radioactive contamination beneath the rectory could be due to selective leaching of the radioactive materials adjacent to the house, since soil contaminated directly with

the radioactive materials placed on this property would probably show more nearly equal activities of ^{226}Ra and ^{238}U . Whatever the source of the contamination beneath the house, there are elevated ^{238}U and/or ^{226}Ra concentrations in soil at some points beneath the rectory, at least near the walls.

A water sample was taken from a faucet in the rectory kitchen. The sample was analyzed for ^{238}U , ^{210}Pb , ^{230}Th , and ^{226}Ra . Results are listed in Table 1-4.

SUMMARY AND CONCLUSIONS

Property owned by the Church of Our Lady of Mount Virgin, Middlesex, New Jersey, is contaminated in some places with what appears to be pitchblende ore. Nearly all the radioactive contamination on the site lies within the triangular area bounded by Harris Avenue, Drake Avenue, and the grid line between Rows 10 and 11 of the survey blocks (see Fig. 1-2). In this area the soil outdoors is contaminated from the surface to depths of up to 4 ft. Survey results indicate that there may be up to 2000 yd³ of contaminated surface and subsurface soil around the rectory containing from 5 to 9,800 pCi/g of ^{226}Ra . External gamma radiation levels at 1 m above the ground in the contaminated area around the rectory averaged approximately 33 $\mu\text{R/hr}$ and were as high as 220 $\mu\text{R/hr}$. Beta-gamma dose rates at 1 cm from the surface in this same area averaged approximately 0.04 to 0.05 mrad/hr and were above 0.2 mrad/hr in some areas of 1 m² or more. According to Nuclear Regulatory Commission (NRC) guidelines for the release of property for unrestricted use (see Appendix III), beta-gamma dose rates averaged over an area of 1 m² should not exceed 0.20 mrad/hr, and dose rates should not exceed 1 mrad/hr over any area of 100 cm².

Small contaminated areas (nearly "point sources") were found in the playground across Drake Avenue from the rectory. These contaminated spots are generally within 20 ft of Drake Avenue. Holes were augered within 1 ft of each of the two spots showing highest contamination. No subsurface contamination was found at these locations. A search for the source of elevated gamma radiation readings at the surface at one

contaminated spot on the playground revealed a contaminated "rock" a few inches beneath the surface. The ^{226}Ra and ^{238}U concentrations in this small sample were 20,000 pCi/g and 21,000 pCi/g (6.1% uranium by weight), respectively. The uranium concentration in this and several other samples taken on the site (particularly around the rectory) exceed the licensable level (0.05% uranium by weight, corresponding to 172 pCi/g of ^{238}U). On the playground, the highest external gamma radiation level at 1 m above the surface was 16 $\mu\text{R/hr}$, and the highest beta-gamma dose rate at 1 cm from the surface was 0.19 mrad/hr.

It is not known whether the rectory was built over contaminated soil. However, there is contaminated soil around the outside walls of the building, and analysis of soil samples taken beneath the rectory (near the outside walls) revealed ^{226}Ra concentrations up to 14 pCi/g and ^{238}U concentrations up to 43 pCi/g. (The concentrations of each of these radionuclides in background soil is typically near 1 pCi/g.) It is possible that the elevated ^{226}Ra and ^{238}U concentrations beneath the rectory are the result of leaching of the radionuclides from the contaminated soil beside the rectory. Thorium-232 concentrations in soil samples were all within the normal background range.

Radon-222 concentrations as high as 92 pCi/liter were measured in the rectory basement. Radon concentrations measured on the street level of the house did not exceed 2.6 pCi/liter. These concentrations were measured during a warm season when the house was well ventilated. Hence, it is likely that radon concentrations are much higher during the colder seasons when the house is less well ventilated. The radon measurements indicate that a potential hazard from radon and its progeny could exist in the structure.

It appears that much of the radon in the rectory is entering through a small rectangular opening near the outside wall in the rectory basement. It is also likely that significant quantities of radon are diffusing through the basement walls.

Alpha contamination levels in the rectory were as high as 840 dpm/100 cm^2 (by direct reading) in the basement. On the street level, second level, and third level of the rectory, the maximum direct alpha measurements were 200, 80, and 20 dpm/100 cm^2 , respectively. It

appears that the alpha contamination in this structure is principally (and perhaps entirely) the result of radon daughters which settle out of the air and become attached to surfaces. There was no distinguishable activity of long-lived alpha or beta emitters on smear samples taken in the rectory. Maximum external gamma radiation levels at 1 m in the basement, street level, second level, and third level of the rectory were 44, 22, 12, and 9 $\mu\text{R/hr}$, respectively.

An evaluation of the radiation exposures that could result from the conditions present at the rectory is provided in Appendix IV. This evaluation provides a comparison with present standards and gives an indication of the level of risk associated with the contamination at this site.

Appendix V provides a table of factors for use in the conversion of the units of measurement utilized in this report to the newly adopted International System of Units (SI). This table can be consulted when comparison of survey data and results in SI units is required.

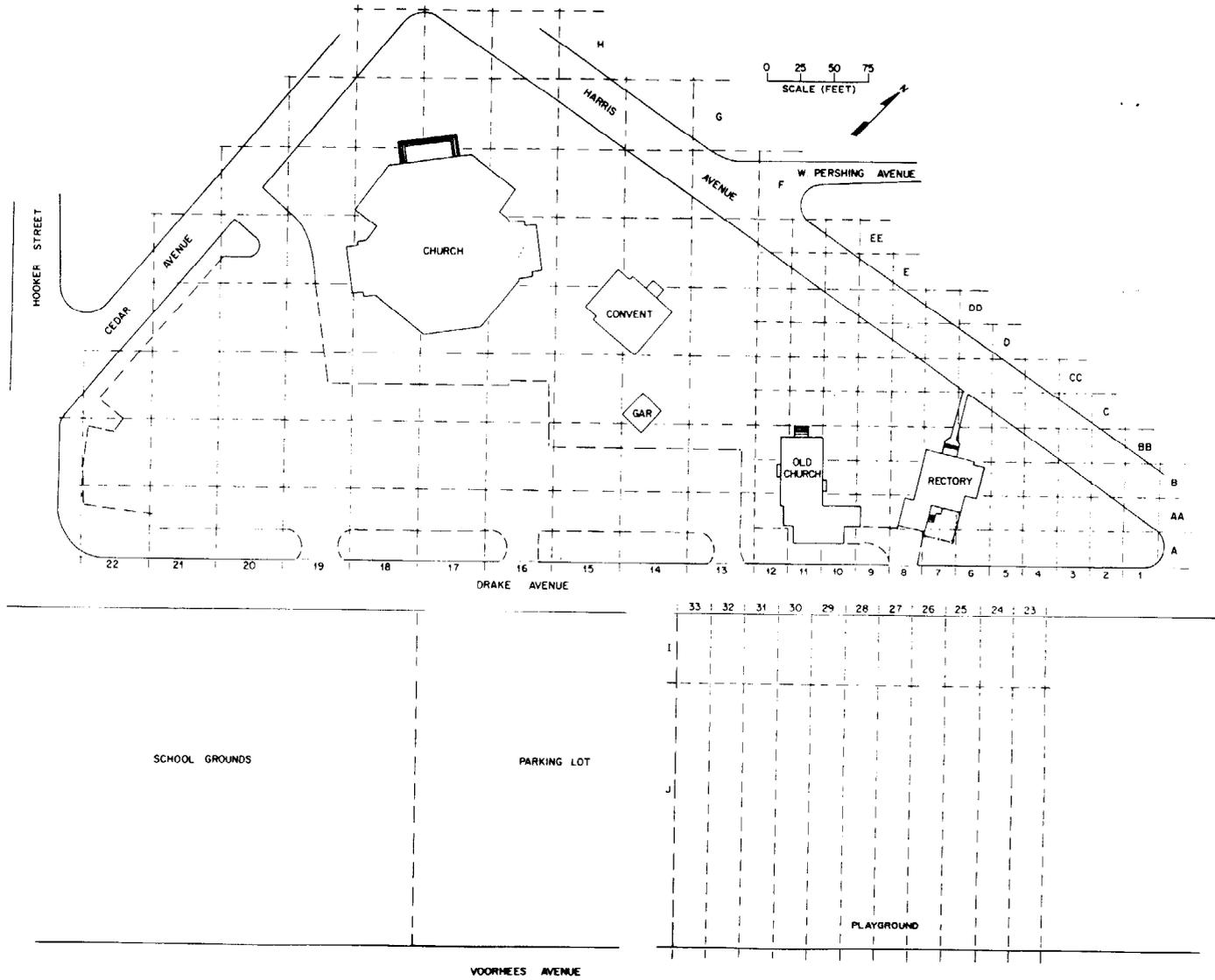


Fig. 1-1. Scaled drawing of rectory site (grid area).

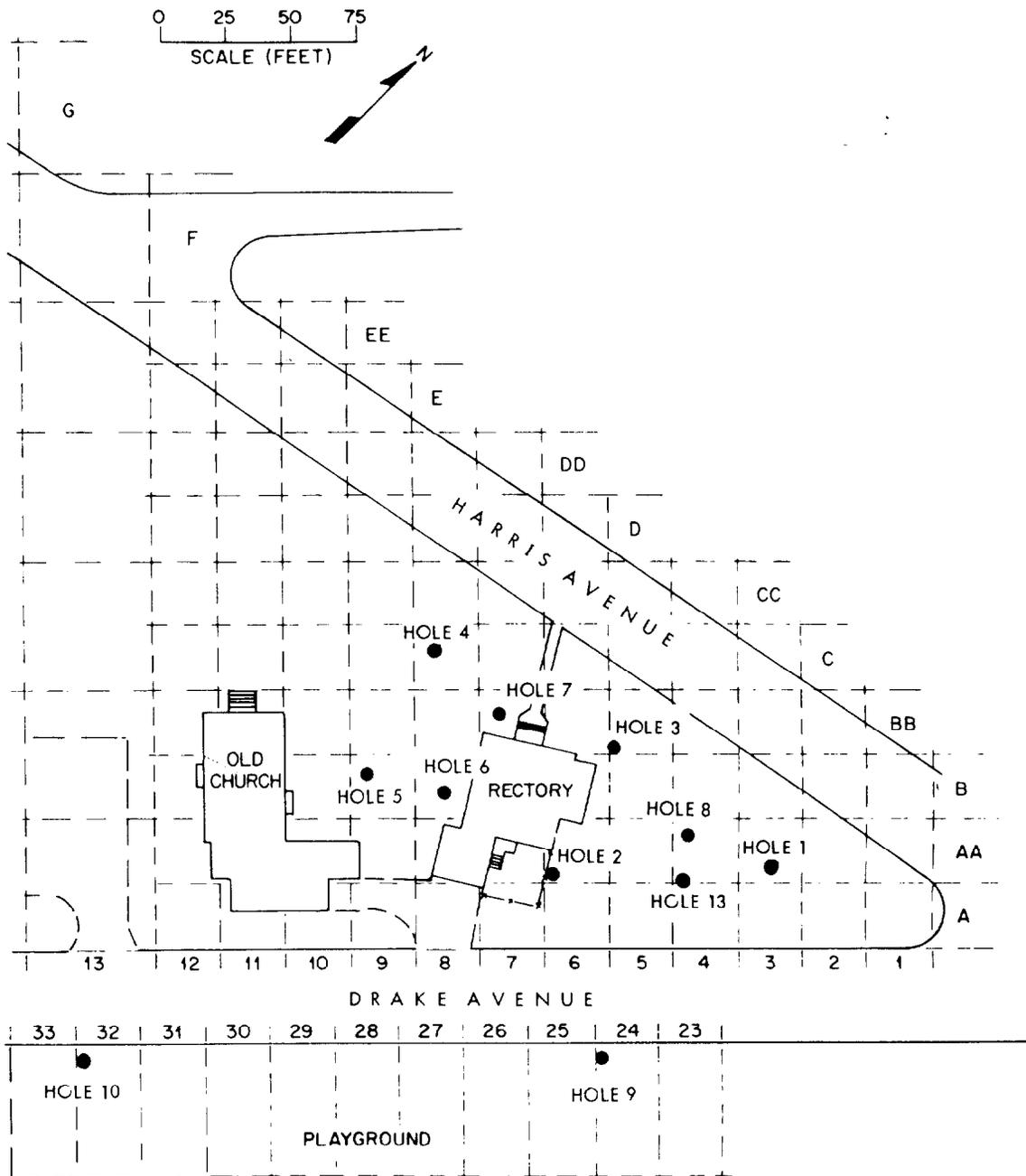


Fig. 1-2. Subsurface sampling locations outdoors on the rectory site.

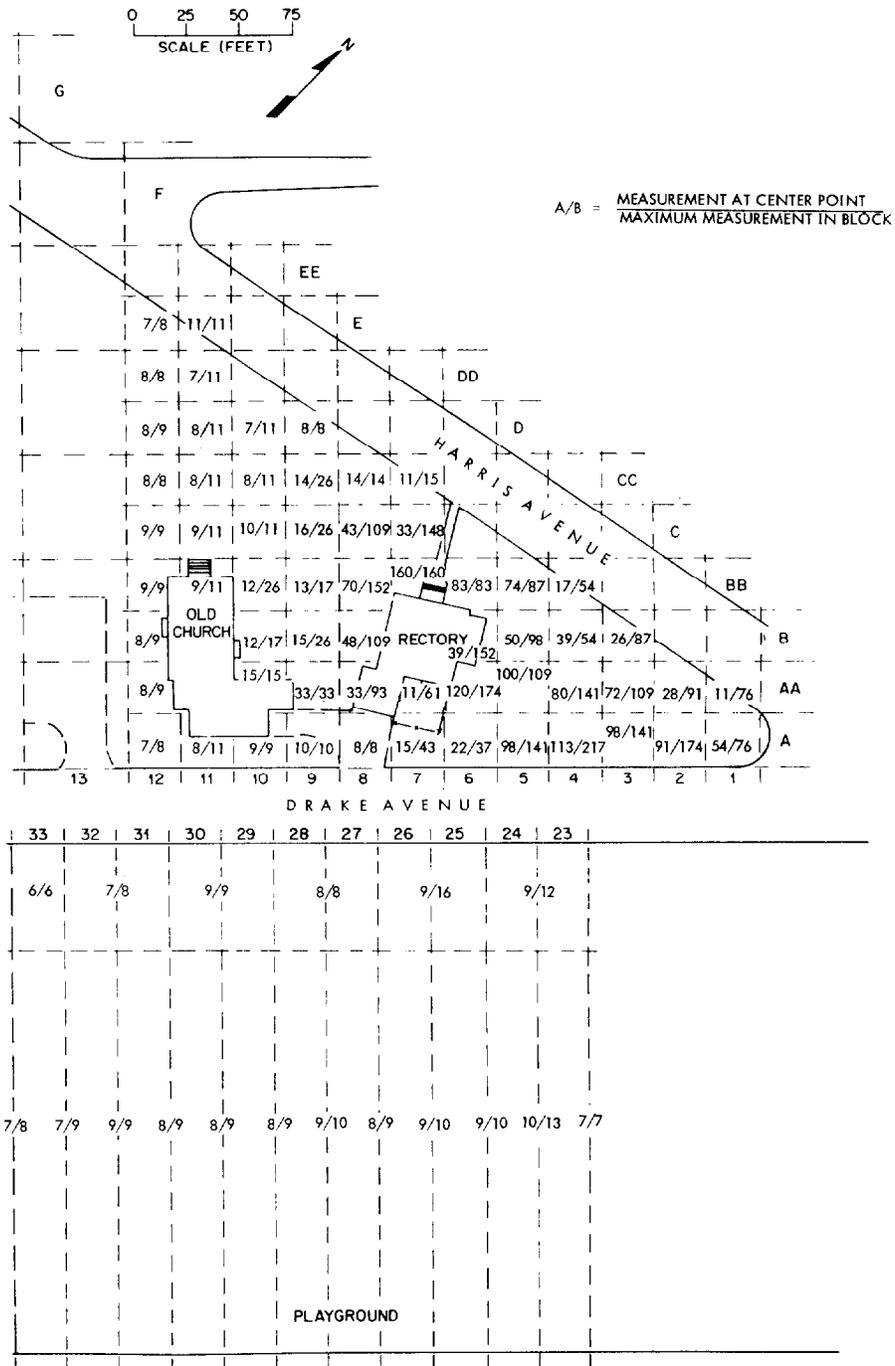


Fig. 1-3. Maximum and center-point measurements of the external gamma radiation level ($\mu\text{R/hr}$) at 1 m in survey blocks.

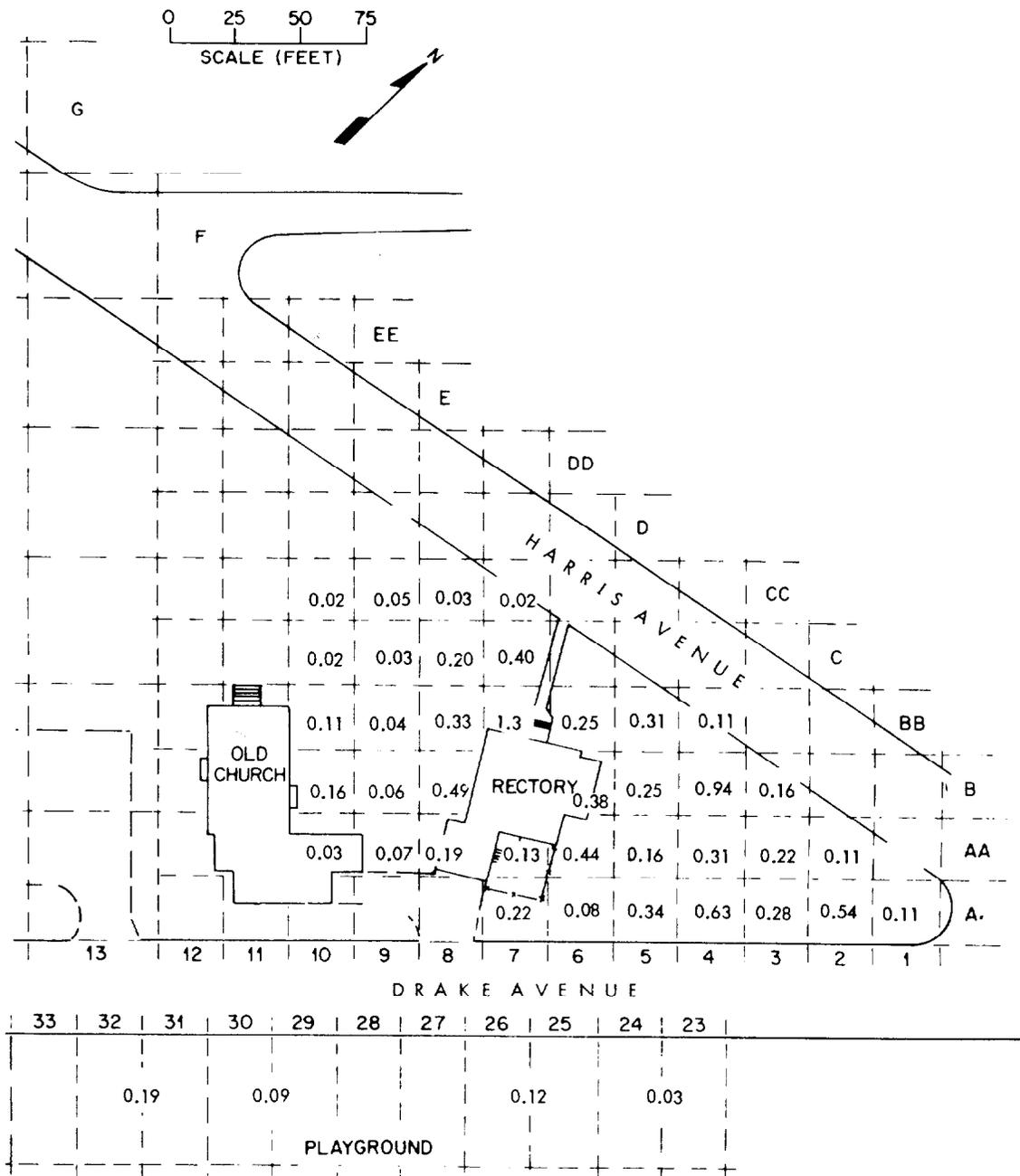


Fig. 1-5. Maximum measured beta-gamma dose rates (mrad/hr) at 1 cm in survey blocks showing nonuniform radiation levels.

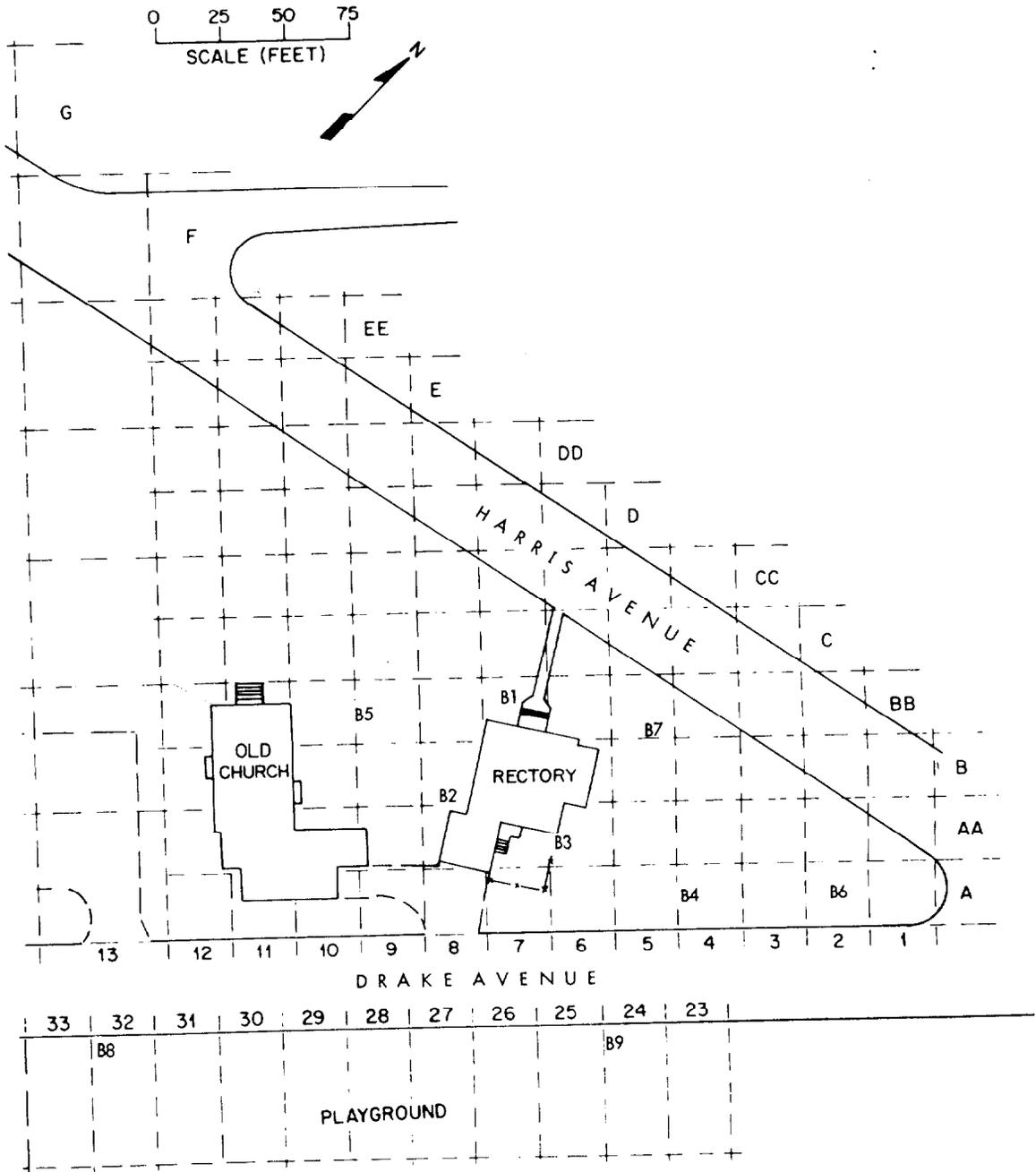


Fig. 1-6. Surface soil sampling locations outdoors on the rectory site.

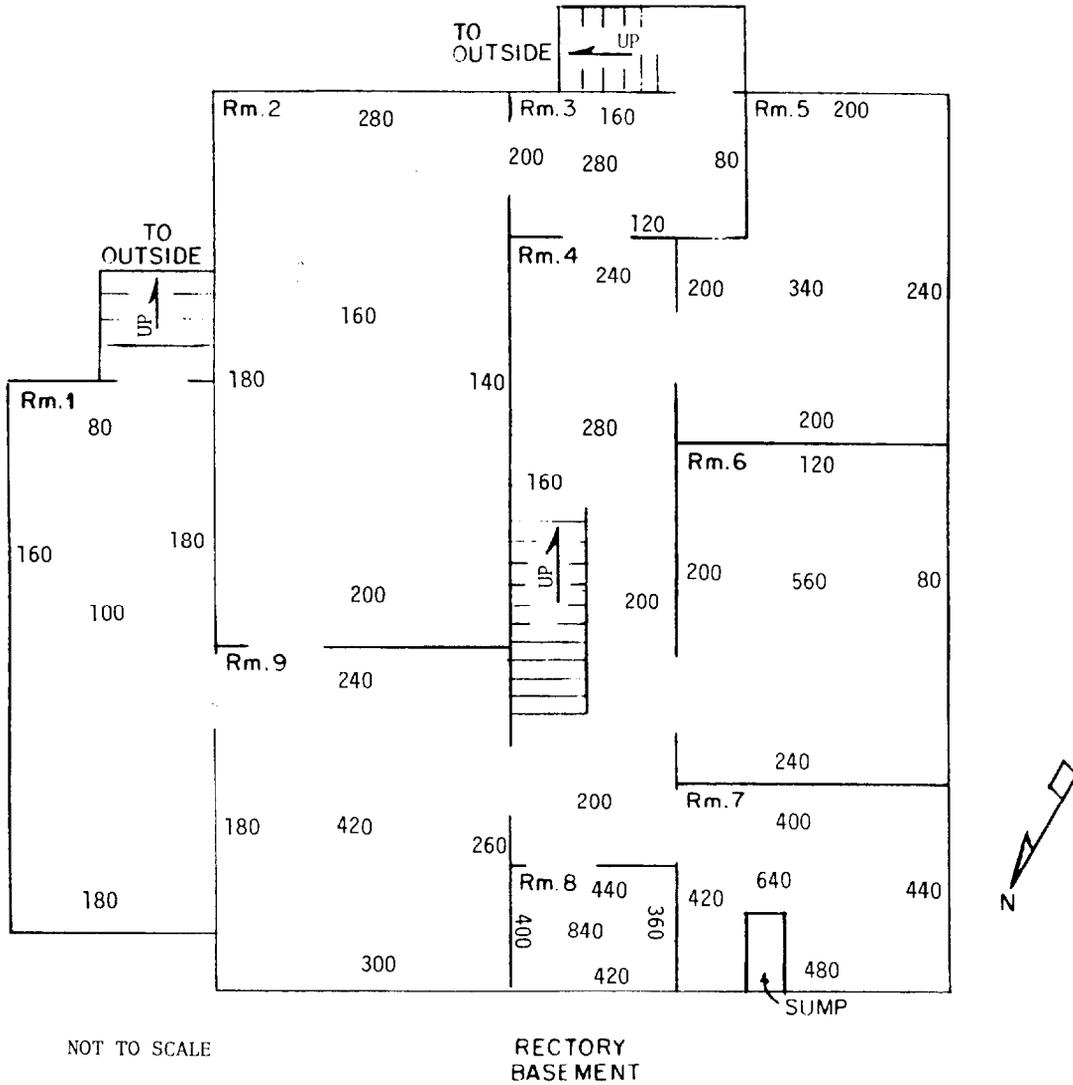


Fig. 1-7. Directly measured alpha contamination (dpm/100 cm²) on floors and walls in rectory basement.

ORNL-DWG 78-21251

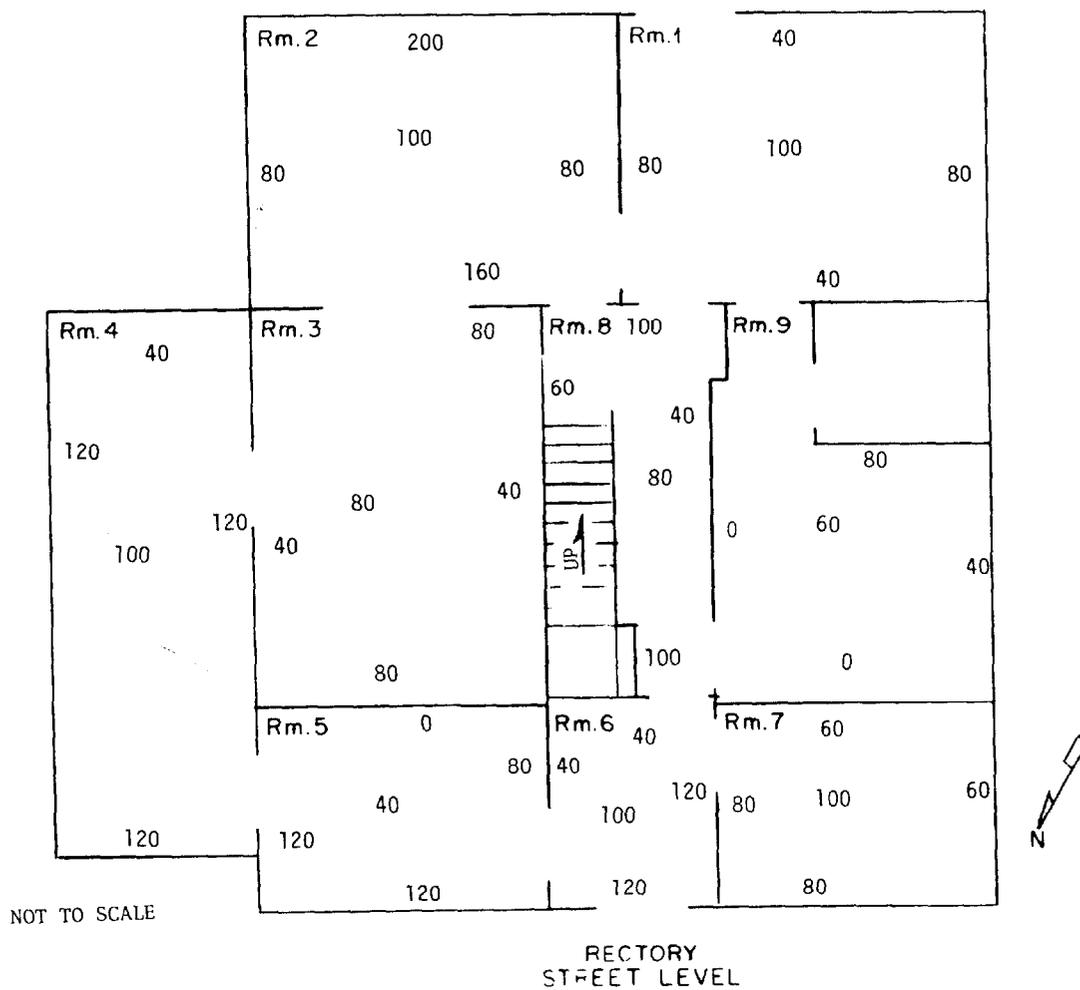
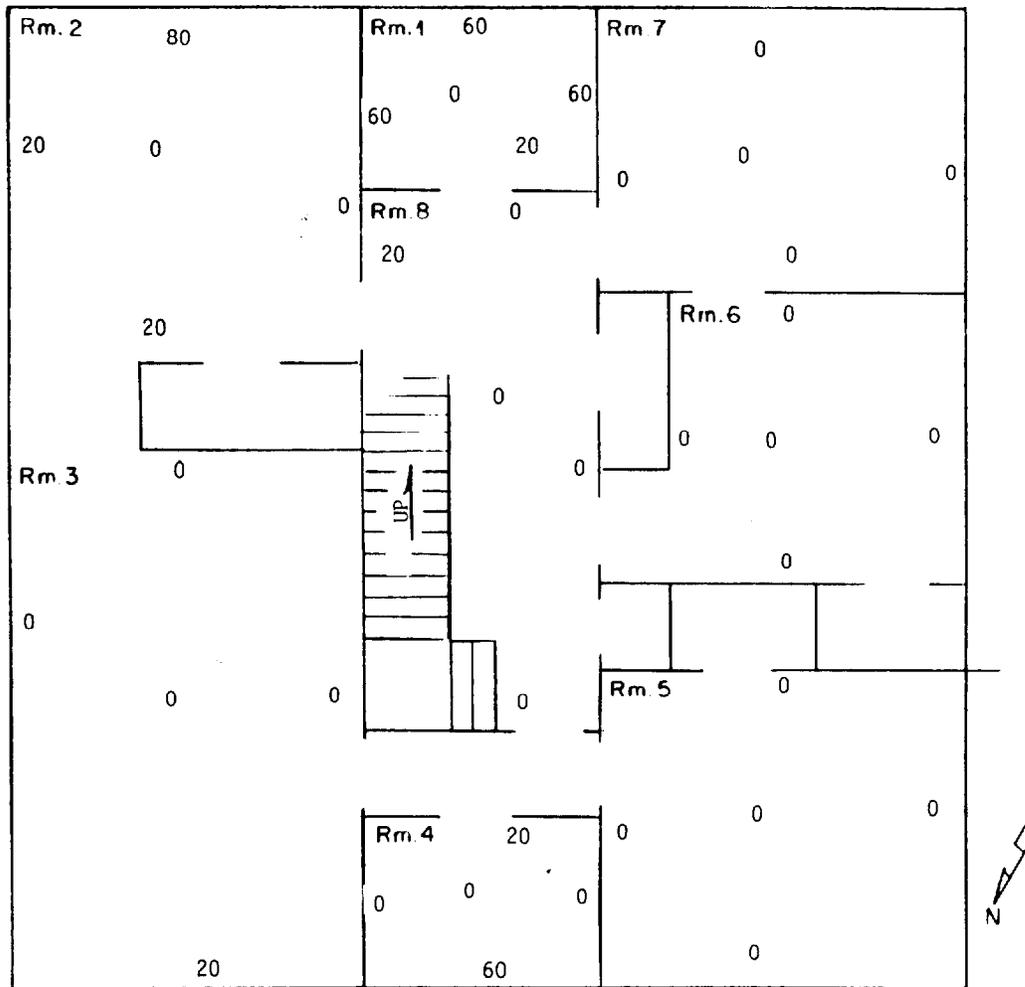


Fig. 1-8. Directly measured alpha contamination (dpm/100 cm²) on floors and walls on street level of rectory.

ORNL-DWG 78-21250

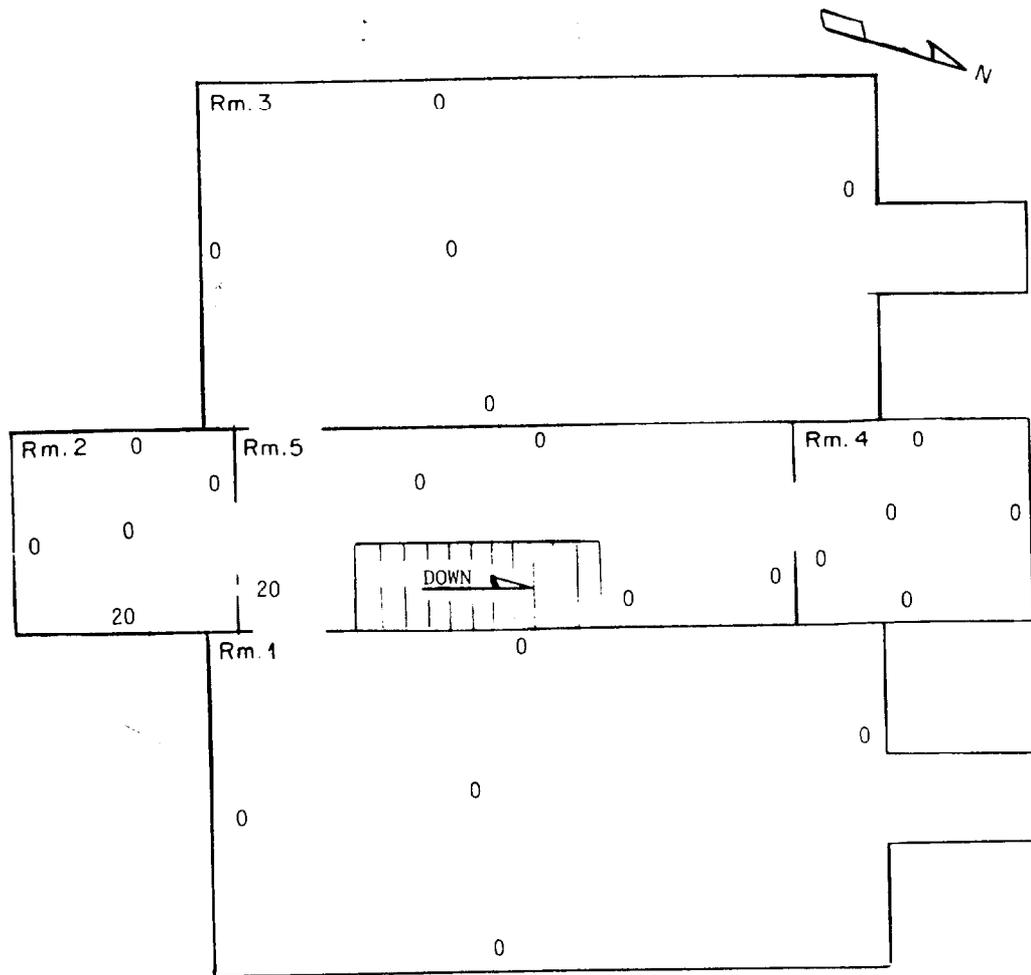


NOT TO SCALE

RECTORY
SECOND LEVEL

Fig. 1-9. Directly measured alpha contamination (dpm/100 cm²) on floors and walls on second level of rectory.

ORNL-DWG 78-21249

RECTORY
THIRD LEVEL

NOT TO SCALE

Fig. 1-10. Directly measured alpha contamination (dpm/100 cm²) on floors and walls on third level of rectory.

ORNL-DWG 78-21248

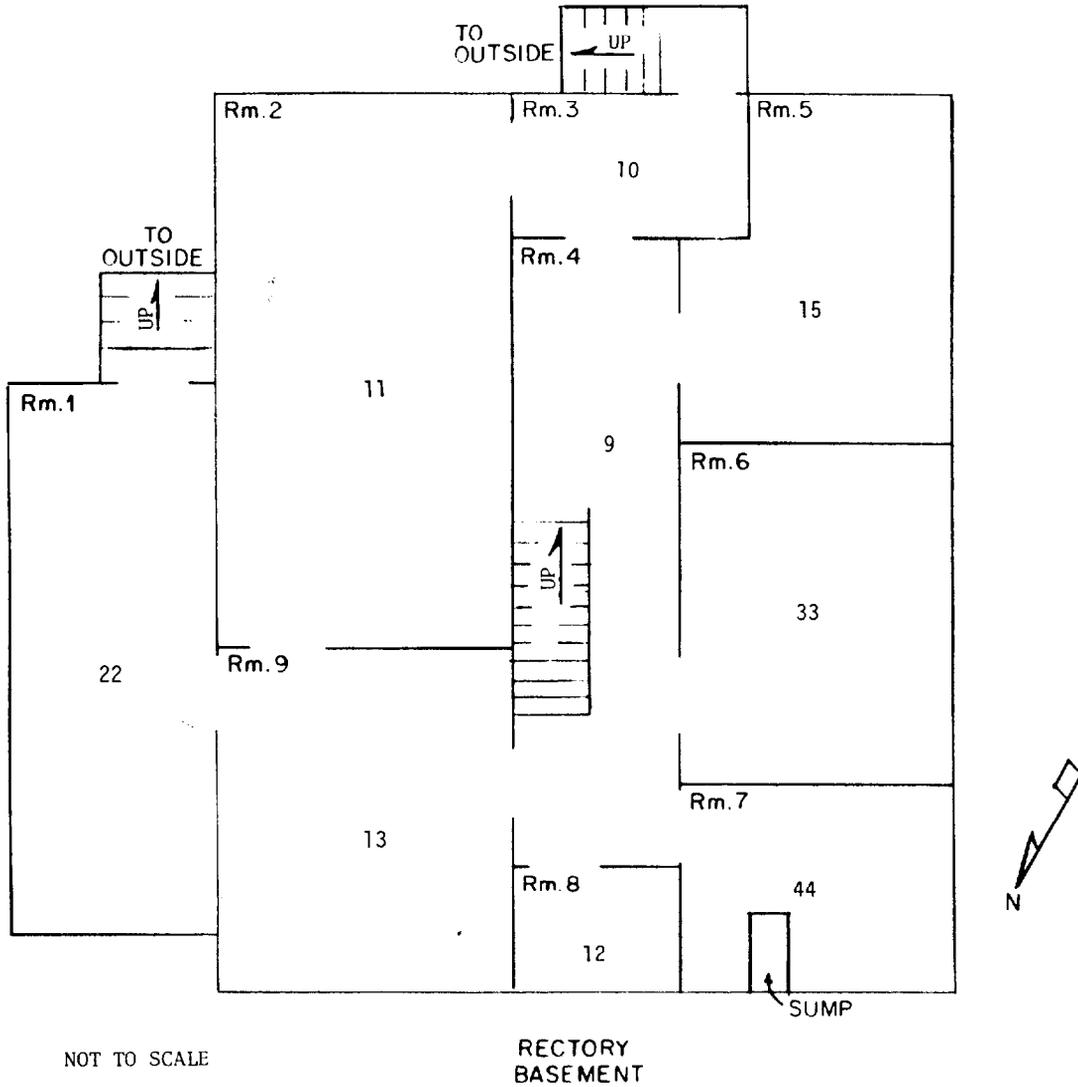


Fig. 1-11. External gamma radiation levels ($\mu\text{R/hr}$) at 1 m in center of rooms in rectory basement.

ORNL-DWG 78-21247

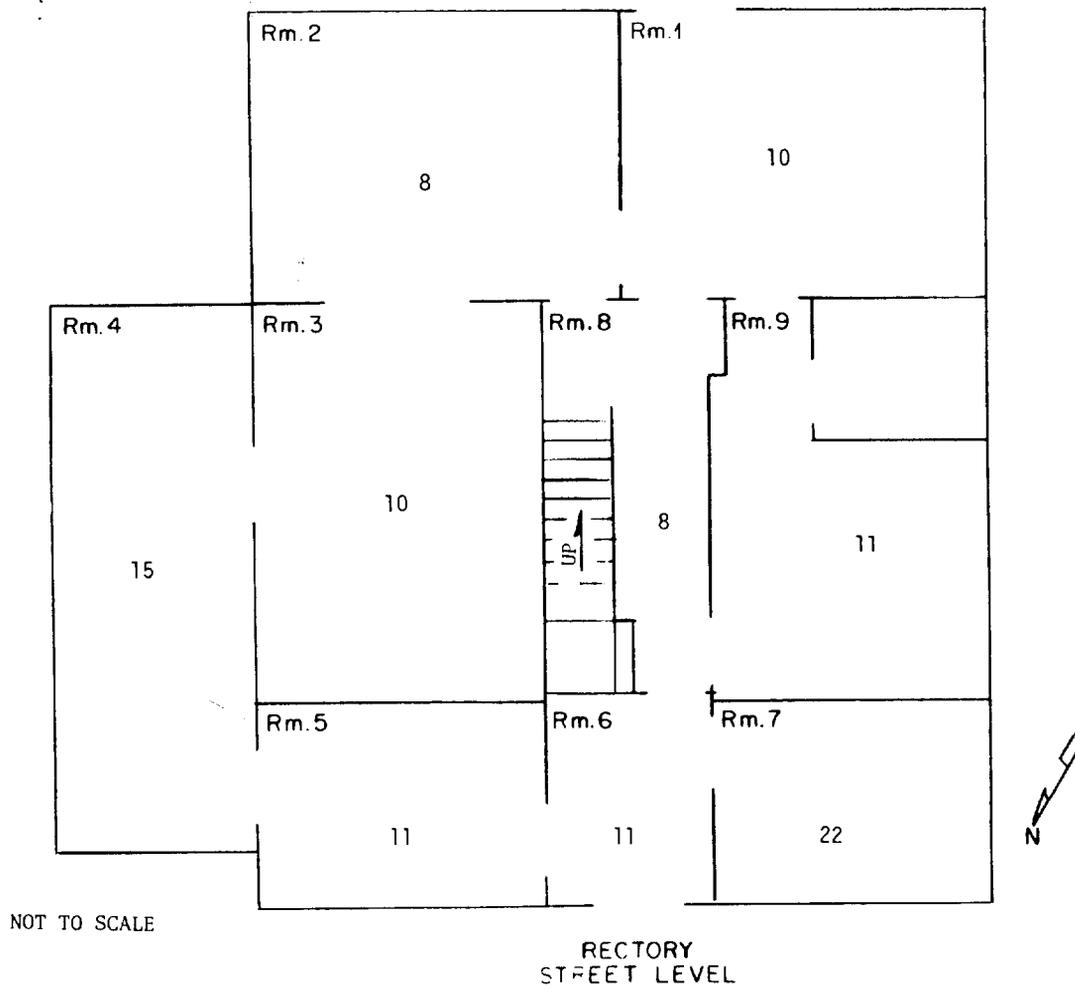
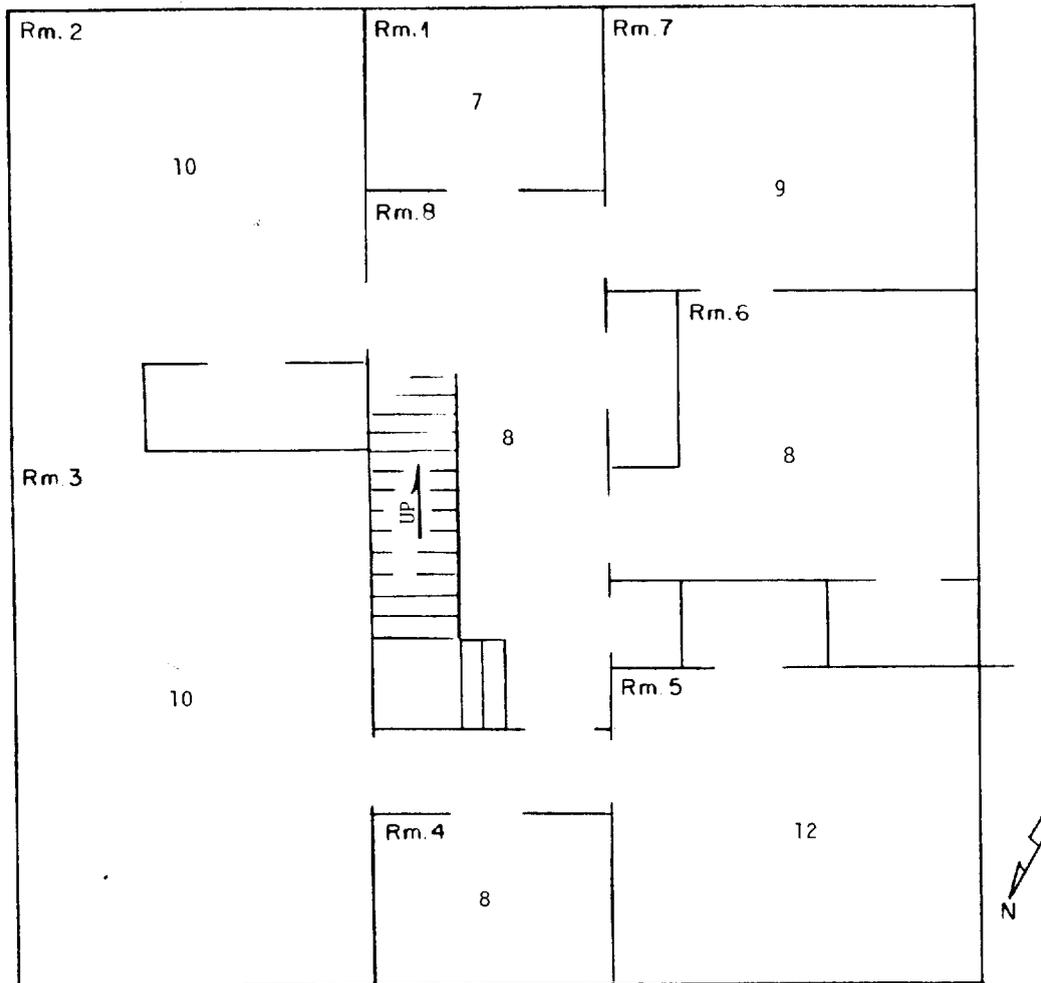


Fig. 1-12. External gamma radiation levels ($\mu\text{R/hr}$) at 1 m in center of rooms on street level of rectory.

ORNL-DWG 78-21246



NOT TO SCALE

RECTORY
SECOND LEVEL

Fig. 1-13. External gamma radiation levels ($\mu\text{R/hr}$) at 1 m in center of rooms on second level of rectory.

ORNL-DWG 78-21245

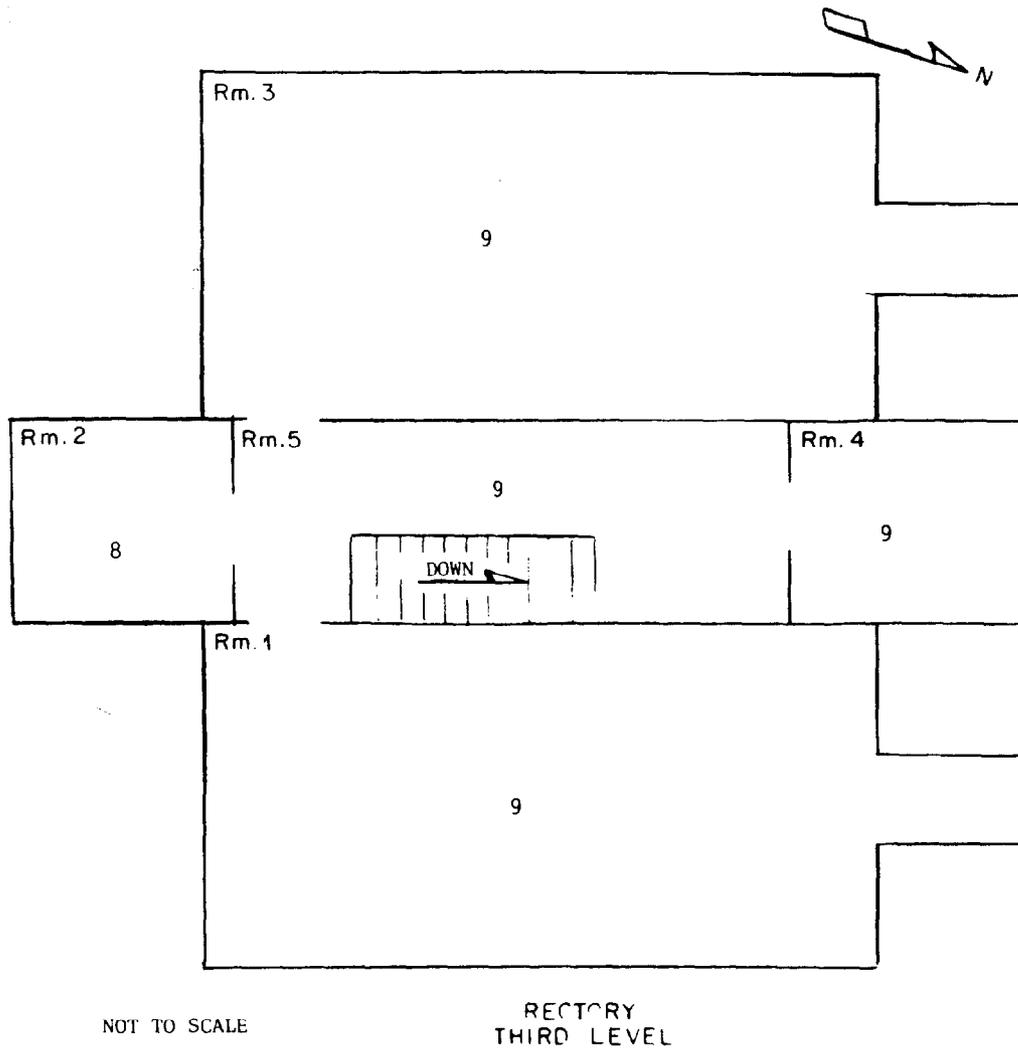


Fig. 1-14. External gamma radiation levels ($\mu\text{R/hr}$) at 1 m in center of rooms on third level of rectory.

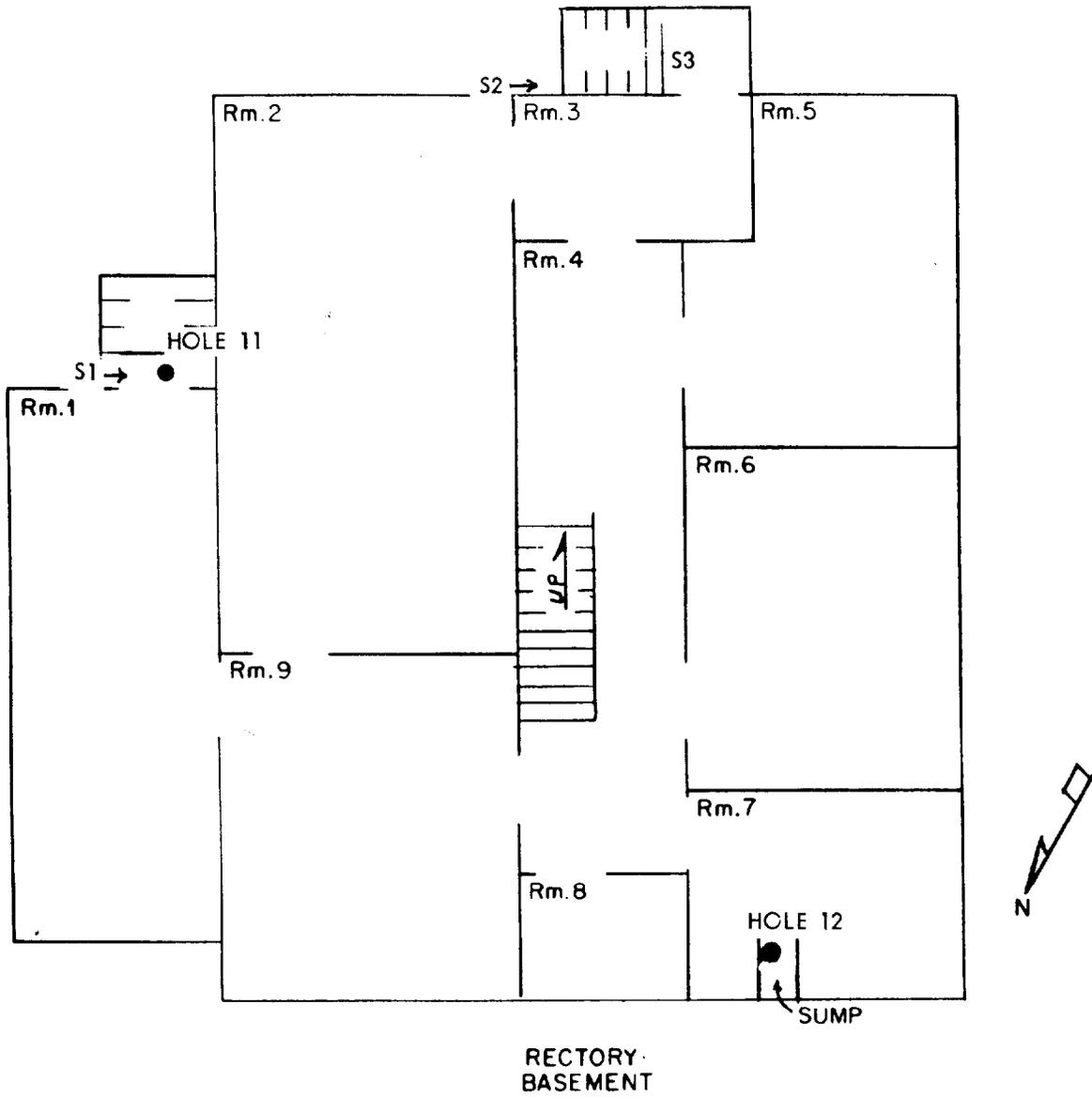


Fig. 1-15. Soil sampling points beneath rectory.

Table 1-1. Radium and uranium concentrations in surface^a soil samples taken on the rectory site at points showing high gamma radiation levels

Location shown Fig. 1-6	²²⁶ Ra (pCi/g)	²³⁸ U (pCi/g)	External gamma level at surface at sampling point (μR/hr)
B1	620	380	760
B2	870	1,200	490
B3	110	180	370
B4	140	140	540
B5	470	950	87
B6	160	270	540
B7	110	120	220
B8	20,000	21,000	120
B9	830	6.5	76

^aAll samples were taken at approximately 0 to 2 in. except sample B8, which was a small rock found nearly 6 in. beneath the surface. Hence, sample B8 was actually not a surface sample.

Table 1-2. Radium, uranium, and thorium concentrations in subsurface soil on the rectory site

Hole no. shown in Figs. 1-2 and 1-15	Depth (ft)	^{226}Ra (pCi/g)	^{238}U (pCi/g)	^{232}Th (pCi/g)
1	Random sample	25	130	1.0
2	Random sample	64	59	1.1
3	Random sample	80	87	1.3
4	Random sample	3.5	4.1	1.4
5	Random sample	1.4	1.2	0.99
6	Random sample	27	29	1.2
7	0 -0.5	270	290	1.7
	0.5-1.0	710	490	NF ^a
	1.0-1.5	45	170	1.7
	1.5-2.0	12	7.8	1.3
	2.0-2.5	9.3	11	1.2
	2.5-3.0	1.2	1.5	1.1
	3.0-3.5	1.3	1.3	1.4
8	0 -0.5	63	68	1.6
	0.5-1.0	140	150	2.6
	1.0-1.5	34	60	1.2
	1.5-2.0	100	76	2.6
	2.0-2.5	7.6	89	1.1
	2.5-3.0	<1.0	14	NF
	3.0-3.5	1.2	2.3	0.99
	4.2-4.7	1.1	2.4	0.74
	4.7-5.2	0.53	0.7	0.78
	5.2-5.7	0.88	1.0	0.91
	5.7-6.3	3.7	3.2	0.81
	6.3-6.8	1.2	1.0	0.87
	6.8-7.3	0.91	1.3	1.3
9	No sample taken			
10	No sample taken			
11	0 -0.5	2.2	31	0.81
	0.5-1.0	1.0	14	0.93
	1.0-1.5	0.78	22	0.98
	1.5-2.0	0.75	39	0.96
	2.0-2.5	0.68	27	0.83
12	0 -0.5	14	43	1.5
	0.5-0.9	1.5	7	1.4
	0.9-1.3	0.96	4.2	1.5
	1.3-1.5	1.3	3	1.8
13	0 -0.5	330	280	NF
	0.5-1.0	110	110	NF
	1.0-1.5	5,900	6,600	NF
	1.5-2.0	7,500	5,200	NF
	2.0-2.3	1,600	1,700	NF
	2.3-2.5	1,800	1,900	NF
	2.5-2.7	9,800	15,000	NF

^aNF - nuclide not found.

Table 1-3. Estimates of subsurface ^{226}Ra contamination on the rectory site based on scintillation probe loggings

Location shown in Figs. 1-2 and 1-15	Estimated extent of contaminated soil (ft)	Depth of maximum contamination (ft)	Maximum reading with shielded scintillator (1,000 cpm)	Estimated above-background ^{226}Ra concentration at point of maximum contamination (pCi/g)	Estimated average above-background ^{226}Ra concentration in contaminated region (pCi/g)
1	0-4.0	1.5	75	470	130
2	0-4.0	1.0	80	500	190
3	0-4.0	1.0	36	220	90
4	0-1.0	0.5	2.5	6	3
5	None				
6	0-3.5	1.5	21	120	50
7	0-3.8	0.5		740 ^a	140 ^a
8	0-3.5	1.0		120 ^a	38 ^a
9	None				
10	None				
11	0-2.5	0 -0.5	No logging	<i>b</i>	<i>b</i>
12	0-1.0	0 -0.5	No logging	11 ^a	5 ^a
13	<i>a</i>	2.5 ^c	No logging	9,800 ^c	3,900 ^c

^aCore samples were taken in these holes and sample results are used here (measured concentrations) rather than estimated concentrations of radium.

^bNo ^{226}Ra contamination found. Soil was contaminated with ^{238}U , averaging 26 pCi/g, from 0 to 2.5 ft.

^cHole dug by hand; did not reach uncontaminated soil.

Table 1-4. Radionuclide concentrations in water samples taken indoors and outdoors at the rectory

Sample designation	Radionuclides in water (pCi/ml)			
	^{210}Pb	^{230}Th	^{226}Ra	^{238}U
MW1 ^a	~0.001	<0.001	~0.001	background
MVCW8 ^b			<0.001	0.0002
MVCW9			<0.001	0.0001
MVCW10			<0.001	background
CG _w ^c (soluble)	0.1	2	0.03	40

^aThis water sample was taken from a faucet in the rectory kitchen.

^bThis water sample was taken from core hole 8 on the rectory lawn.

^cConcentration guide for water in unrestricted areas, as specified in 10 CFR 20.

Table 1-5. Concentration of radon (pCi/liter) in rectory basement

Date	Room	Lowest measurement	Time of lowest measurement	Highest measurement	Time of highest measurement	Average measurement
6/ 2/78	9	2.8	14:36	11.5	23:38	7.8
	2	2.0	15:37	9.2	11:36	5.5
6/ 3/78	9	11.6	0:08	23.4	20:41	16.7
	2	6.1	4:39	14.0	13:40	9.1
6/ 4/78	9	19.7	15:13	62.7	12:13	30.9
	2	11.1	0:41	31.2	12:43	19.7
6/ 5/78	9	13.9	7:16	33.8	23:48	19.2
	2	11.6	18:47	22.7	23:48	15.5
6/ 6/78	9	24.1	15:20	73.3	20:51	53.2
	2	25.5	4:19	47.9	21:21	34.8
6/ 7/78	9	4.9	18:24	61.4	5:52	36.4
	2	3.8	18:24	38.6	23:24	23.5
6/ 8/78	9	16.1	4:55	55.9	9:26	38.9
	2	11.7	20:27	37.2	9:56	27.0
6/ 9/78	9	9.9	11:29	41.8	21:31	27.4
	2	4.5	1:58	28.9	0:28	18.9
6/10/78	9	14.2	17:03	78.3	22:34	33.7
	2	8.4	17:03	32.9	23:34	19.8
6/11/78	9	10.4	11:06	92.4	0:34	49.3
	2	2.4 ^b	11:06 ^b	42.7 ^b	20:07 ^b	25.4 ^b
6/12/78	9	WCM ^b	WCM ^b	WCM ^b	WCM ^b	WCM ^b
(0:00 to 11:05)	2	21.4	8:39	37.7	0:08	28.4

^aSee Fig. 1-7.

^bWrenn Chamber malfunctioned.

Table 1-6. Concentration of radon (pCi/liter) in
rectory, first level, room 9^a

Date	Lowest measurement	Time of lowest measurement	Highest measurement	Time of highest measurement	Average measurement
6/13/78 start 10:03	0.1	10:33	1.3	20:34	0.5
6/14/78	0.03	5:36	1.2	19:07	0.5
6/15/78	0.1	15:24	1.5	0:38	1.0
6/16/78 until 15:58	0.3	8:57	2.5	1:56	1.2

^aSee Fig. 1-8.

Table 1-7. Maximum measured beta-gamma dose rates inside the rectory

Level	Room shown in Figs. 1-7 through 1-10	Maximum beta-gamma dose rate (mrad/hr)	Location of maximum measurement ^a
Basement	1	<0.03	U
	2	<0.03	U
	3	<0.02	U
	4	<0.03	U
	5	<0.03	F
	6	0.03	N
	7	0.06	N
	8	<0.03	U
	9	<0.02	U
Street level	1	<0.02	U
	2	<0.02	U
	3	<0.02	U
	4	0.05	N
	5	<0.03	U
	6	<0.02	U
	7	0.04	N
	8	0.03	F
	9	<0.02	U
Second level	1	<0.02	U
	2	<0.02	U
	3	<0.02	U
	4	<0.02	U
	5	<0.02	U
	6	<0.03	U
	7	<0.03	U
	8	<0.03	U
Third level	1	<0.03	U
	2	<0.03	U
	3	<0.02	U
	4	<0.03	U
	5	<0.02	U

^aU - uniform readings; F - floor; N - north wall.

Table 1-8. Radium-226, ^{238}U , and ^{232}Th concentrations in special surface soil samples at the rectory site

Sample designation	Location	^{226}Ra (pCi/g)	^{238}U (pCi/g)	^{232}Th (pCi/g)	External gamma level at surface sampling point ($\mu\text{R/hr}$)
S1	Bottom of steps at south side of rectory at iron gate leading to basement	5.3	13	0.65	13
S2	Under steps leading to kitchen at rear entrance	2.1	4.0	0.55	22
S3	Bottom of steps to basement at iron door at rear of rectory	2.4	12	0.82	54

2. RADIOLOGICAL SURVEY OF A PARKING LOT AT THE UNION CARBIDE PLANT IN BOUND BROOK, NEW JERSEY

ABSTRACT

A radiological survey was conducted of a parking lot at the Union Carbide plant in Bound Brook, New Jersey. Elevated gamma radiation levels had been observed in this lot during an EG&G aerial survey of a large area surrounding the former ore sampling plant in Middlesex, New Jersey. The present radiological survey consisted of gamma and beta-gamma measurements in the parking lot and determination of radionuclide concentrations in surface and subsurface soil in the lot. A nearly circular region of 50-ft diam in the lot showed above-background external gamma radiation levels. Two isolated spots within this region showed concentrations of uranium in soil above the licensable level stated in 10 CFR 40. Soil samples taken in the area of elevated gamma radiation levels generally showed nearly equal activities of ^{226}Ra and ^{238}U .

INTRODUCTION

At the request of the Department of Energy (DOE), a radiological survey was conducted of a parking lot at the Union Carbide plant in Bound Brook, New Jersey. A scaled drawing of the parking lot is given in Fig. 2-1. The lot, which is covered with gravel and cinders, is well removed from dwellings and other occupied structures.

Elevated gamma radiation levels were discovered above this parking lot during an aerial survey by the Washington Aerial Measurements Department of EG&G.³ This aerial survey encompassed a large area surrounding the former Middlesex Sampling Plant, where pitchblende ores were handled in the 1940s. It should be pointed out that there are no available records linking radioactive materials on the Union Carbide parking lot with the Middlesex Sampling Plant.

The radiological survey was conducted by members of the Health and Safety Research Division of the Oak Ridge National Laboratory (ORNL) on June 12 and 17, 1978. The survey consisted of measurements of the following:

1. external gamma radiation levels at 1 m above the surface throughout the parking lot,
2. external gamma radiation levels at the surface in a 50-ft-diam circular area showing above-background gamma levels at 1 m,
3. beta-gamma dose rates at 1 cm in areas of highest gamma radiation,
4. concentrations of ^{226}Ra , ^{238}U , and ^{232}Th in soil in areas showing elevated gamma radiation and at randomly selected points.

SURVEY METHODS

A NaI scintillation meter (see Appendix I) was used to measure external gamma radiation levels at a height of 1 m throughout the parking lot and to locate possibly contaminated areas. In the region found to show above-background gamma radiation levels at 1 m, the NaI scintillation meter was used to measure gamma levels both at 1 m and at the surface. At points showing highest gamma radiation levels, beta-gamma dose rates at 1 cm above the ground were measured with a Geiger-Mueller (G-M) survey meter (see Appendix I).

At the two locations showing highest beta-gamma dose rates and at one randomly selected location in the region showing above-background external gamma radiation levels at 1 m, a split-spoon sampler with a 3-in. diam was used to take soil samples at intervals of approximately 6 in. from the surface to a depth of 2 ft. The soil samples were returned to ORNL for analysis of ^{226}Ra , ^{238}U , and ^{232}Th . (Methods of analysis are described in Appendix II.) After soil samples were collected, the core holes were augered to a depth of 8 ft using a motorized drilling rig equipped with an 8-in.-diam auger. A plastic pipe with a 4-in. i.d. was placed in each hole, and a scintillation probe encased in a lead shield with a narrow opening on the side was lowered inside this pipe. This arrangement allowed measurements of gamma radiation intensities resulting from contamination within small fractions of the hole depth. The gamma-ray "loggings" were used to examine how far beneath the surface the radioactive contamination extended.

SURVEY RESULTS

External Gamma Radiation Levels

Background external gamma radiation levels at 1 m in the Middlesex area typically range from 5 to 10 $\mu\text{R/hr}$. On this site, a nearly circular area with a diameter of approximately 50 ft showed external gamma radiation levels at 1 m ranging from 11 to 110 $\mu\text{R/hr}$ (see Figs. 2-1 and 2-2). On the remainder of the site, external gamma radiation levels at 1 m were generally near 9 $\mu\text{R/hr}$.

Beta-Gamma Dose Rates

There were two small areas (locations 1 and 2) shown in Fig. 2-3 which showed radiation levels significantly higher than elsewhere on the site. Beta-gamma dose rates at 1 cm at location 1 exceeded 0.20 mrad/hr in an area of nearly 1 m² and were in the range 0.50 to 1.0 mrad/hr in one spot where soil had been removed by Union Carbide (Bound Brook) personnel, who had already found the contamination at location 1. Beta-gamma dose rates at 1 cm from the surface at location 2 were approximately 0.30 mrad/hr in an area no greater than 100 cm². At other randomly selected locations in the area showing elevated gamma radiation levels, beta-gamma dose rates ranged from 0.02 to 0.05 mrad/hr. Background beta-gamma dose rates, as measured with the G-M survey meter used on this site, typically average less than 0.03 mrad/hr.

Results of Soil Analyses and
Gamma Loggings of Auger Holes

Soil samples were taken at the locations shown in Fig. 2-3. Surface samples were taken at each of the seven locations shown, and subsurface samples were taken at locations 1, 2, and 7. As indicated earlier, locations 1 and 2 were chosen for sampling because of elevated beta-gamma dose rates at those points; the other locations were chosen at random. Concentrations of ²³⁸U, ²²⁶Ra, and ²³²Th in the soil samples are reported in Table 2-1. Samples MUC1, MUC1A, and MUC1B were taken at 0 to 3 in., 3 to 6 in., and 6 to 10 in., respectively, in the area

showing highest beta-gamma dose rates. Sample MUC1, which was taken by Union Carbide (Bound Brook) personnel prior to the ORNL survey, showed a ^{226}Ra concentration of 1,500 pCi/g and a ^{238}U concentration of 1,600 pCi/g. This ^{238}U concentration corresponds to approximately 0.5% natural uranium by weight, which exceeds the licensable level of 0.05% natural uranium by weight stated in 10 CFR 40. Samples MUCC1A, MUCC1B, MUCC1C, and MUCC1D, also listed in Table 2-1 as being taken at location 1, were actually taken approximately 18 in. from the points where samples MUC1, MUC1A, and MUC1B were taken. It appears that the contamination level at these two adjacent locations are approximately the same as that at location 2 (1,500 pCi/g ^{226}Ra and 3,000 pCi/g ^{238}U).

It should be noted that the sample taken from the surface to 6 in. at location 7 (which was chosen at random in the area of elevated gamma radiation) showed a ^{226}Ra concentration of 6.3 pCi/g. Surface samples taken at locations 3, 4, 5, and 6 (see Fig. 2-3) showed ^{226}Ra and ^{238}U concentrations ranging from 1.6 to 2.5 pCi/g. By comparison, concentrations of ^{226}Ra and ^{238}U in background soil in the Middlesex-Bound Brook area are typically near 1 pCi/g. However, it is not unusual for some types of background soils to show ^{226}Ra and ^{238}U concentrations as high as 2.5 pCi/g. Thorium concentrations in all samples were in the range of normal background.

The results in Table 2-1, together with gamma measurements made on the site, suggest that the soil in the area outlined with dotted lines in Fig. 2-3 contains above-background concentrations of ^{226}Ra and ^{238}U . The soil analyses indicate that the contamination extends from the surface to a depth of 6 to 12 in., and the gamma loggings of the auger holes indicated that there was no deeply buried contamination. It is estimated that there are only a few cubic yards of soil (perhaps only two or three) showing ^{226}Ra and ^{238}U concentrations more than an order of magnitude above the background level.

SUMMARY AND CONCLUSIONS

The area enclosed by dotted lines in Fig. 2-3 shows above-background radiation levels and at soil sampling locations showed above-background

^{226}Ra and ^{238}U concentrations. Since the contaminated soil showed, in some cases, nearly equal activities of ^{226}Ra and ^{238}U it is possible that the contaminating material is pitchblende ore from the former Middlesex Sampling Plant. However, there are no available records linking the contamination in the Union Carbide parking lot with the plant.

The highest external gamma radiation level at 1 m on the site was 110 $\mu\text{R/hr}$. Concentrations of ^{226}Ra were as high as 1,500 pCi/g, and ^{238}U concentrations were as high as 3,000 pCi/g. A ^{238}U concentration of 3,000 pCi/g corresponds to approximately 1.0% uranium by weight, which exceeds the licensable level of 0.05% uranium in soil stated in 10 CFR 40. There may be as few as 2 or 3 yd^3 of soil on the site showing ^{226}Ra and ^{238}U concentrations more than an order of magnitude above the background level. However, there are probably at least 30 to 40 yd^3 of soil on the site showing above-background concentrations of ^{226}Ra and ^{238}U .

Beta-gamma dose rates at 1 cm exceeded 0.20 mrad/hr in an area of nearly 1 m^2 . According to Nuclear Regulatory Commission guidelines for the release of property for unrestricted use, beta-gamma dose rates should not exceed 0.20 mrad/hr when averaged over 1 m^2 (see Appendix III).

An evaluation of the radiation exposures that could result from the conditions present at the parking lot is provided in Appendix IV. This evaluation provides a comparison with present standards and gives an indication of the level of risk associated with the contamination at this site.

Appendix V provides a table of factors for use in the conversion of the units of measurement utilized in this report to the newly adopted International System of Units (SI). This table can be consulted when comparison of survey data and results in SI units is required.

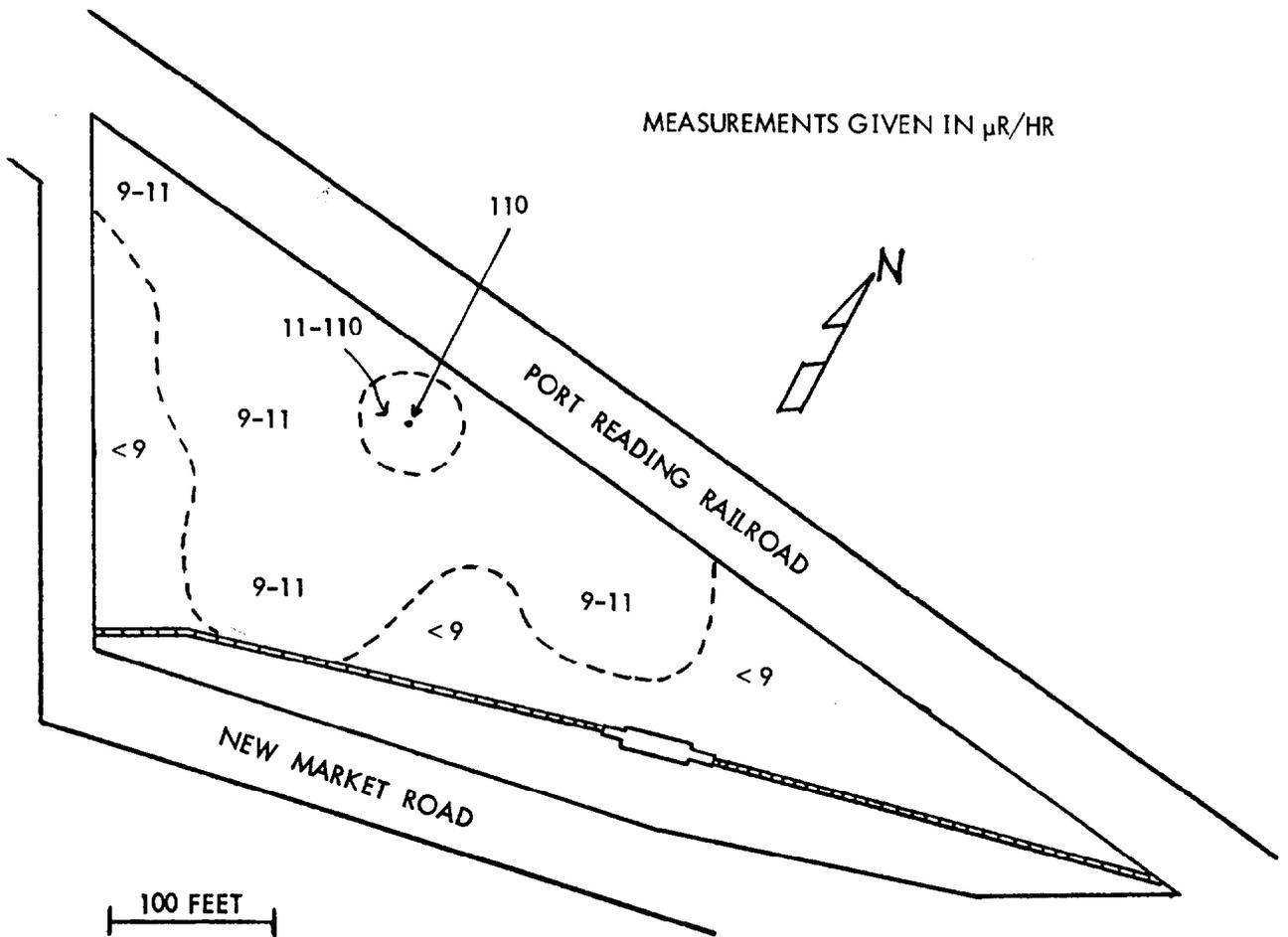


Fig. 2-1. External gamma radiation levels at 1 m ($\mu\text{R}/\text{hr}$) in Union Carbide parking lot.

$$A/B = \frac{\text{gamma level at 1 m}}{\text{gamma level at surface}}$$

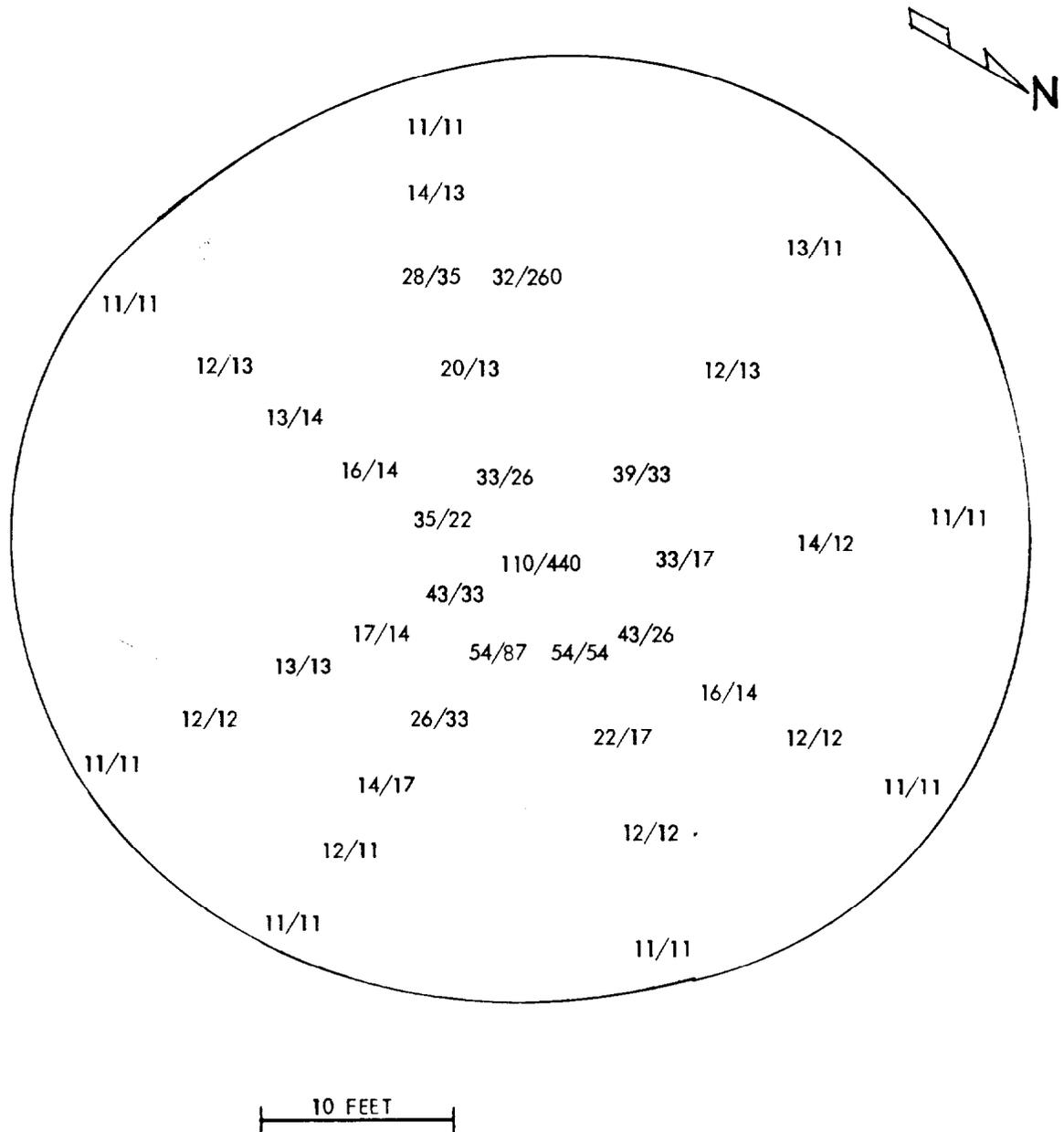


Fig. 2-2. External gamma radiation levels at 1 m ($\mu\text{R/hr}$) in nearly circular area in parking lot showing above-background radiation levels.

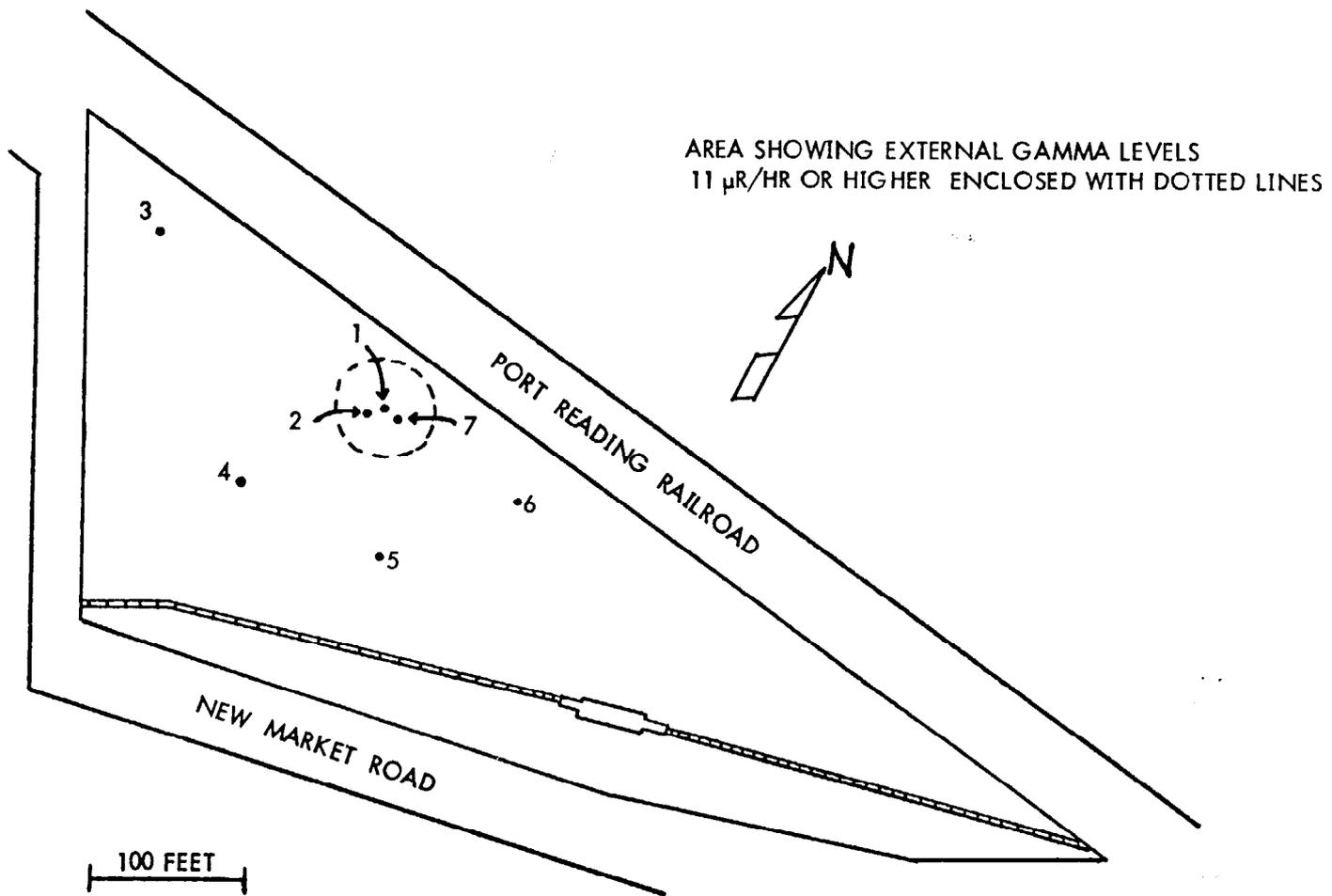


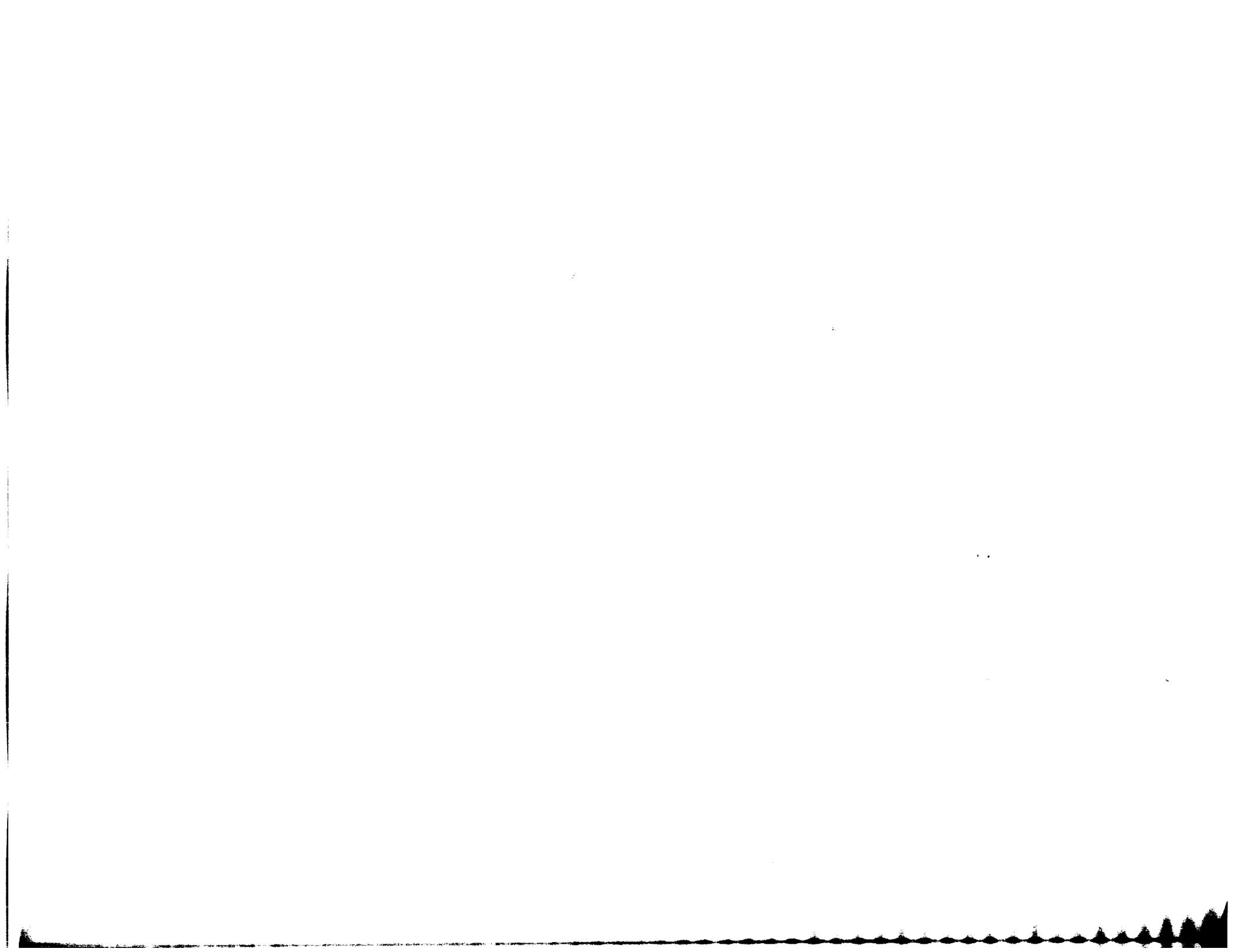
Fig. 2-3. Soil sampling locations in parking lot.

Table 2-1. Radium-226, ^{238}U , and ^{232}Th in soil samples from the Union Carbide parking lot

Sample identification	Location shown in Fig. 2-3	Depth (in.)	^{226}Ra (pCi/g)	^{238}U (pCi/g)	^{232}Th (pCi/g)
MUC1	1	0- 3	1,500	1,600	<i>a</i>
MUC1A	1	3- 6	240	200	<i>a</i>
MUC1B	1	6-10	17	12	2.8
MUCC1A	1 ^{<i>b</i>}	0- 6	1,500	3,000	<i>a</i>
MUCC1B	1 ^{<i>b</i>}	6-12	13	7.8	2.6
MUCC1C	1 ^{<i>b</i>}	12-18	1.3	1.5	1.3
MUCC1D	1 ^{<i>b</i>}	18-24	0.86	1.3	1.4
MUC2	2	0- 2	790	1,600	<i>a</i>
MUCC2A	2	2- 6	6.3	6.4	2.4
MUCC2B	2	6-12	1.2	1.9	<i>a</i>
MUCC2C	2	12-18	1.0	1.3	1.3
MUCC2D	2	18-24	1.0	1.4	1.4
MUCC3A	3	0- 6	7.4	2.9	<i>a</i>
MUCC3B	3	6-12	1.1	1.4	1.4
MUCC3C	3	12-18	0.89	1.4	1.4
MUCC3D	3	18-24	1.0	1.5	1.5
MUC3	3	0- 2	2.5	2.4	2.0
MUC4	4	0- 2	1.8	1.6	1.6
MUC5	5	0- 2	1.8	1.6	1.8
MUC6	6	0- 2	2.1	2.1	1.9
MUC7	7	0- 2	1.3	1.4	1.1
MUC8	Bound Brook not shown	0- 2	2.0	2.0	1.3

^{*a*} Nuclide not found.

^{*b*} These core samples were taken approximately 18 in. from the location where samples MUC1, MUC1A, and MUC1B were taken.



3. RADIOLOGICAL SURVEY OF THE PROPERTY AT 432 WILLIAM STREET,
PISCATAWAY, NEW JERSEY

ABSTRACT

A brief radiological survey was made at the residence at 432 William Street in Piscataway, New Jersey. It had been learned from a previous owner of the property that radioactive material from the former Middlesex Sampling Plant had been used as fill dirt in the yard. The survey revealed that the front yard is generally contaminated from near the surface to a depth of 1.5 to 2.5 ft with ^{226}Ra -bearing material, possibly pitchblende ore. The remainder of the yard shows scattered contamination. External gamma radiation levels inside the house are above the background level near some outside walls.

INTRODUCTION

At the request of the Department of Energy (DOE), a radiological survey was conducted at the residence at 432 William Street in Piscataway, New Jersey. This site consists of a five-room, wood-frame house, a garage, and an 0.2-acre yard (see Fig. 3-1). There is one person (a male in his mid-20s) living in the house. A previous owner of this property notified the DOE that he (the previous owner) had taken soil from the former Middlesex Sampling Plant to use as fill dirt in the yard at this residence. Since pitchblende ores had been handled at the Middlesex Sampling Plant, it was decided that a radiological survey was appropriate for the William Street property.

The survey was conducted on June 15-16 by members of the Health and Safety Research Division of the Oak Ridge National Laboratory (ORNL). The survey consisted of the following on-site measurements:

1. external gamma measurements at 1 m both indoors and outdoors,
2. beta-gamma and gamma measurements at 1 cm from surfaces indoors and outdoors,
3. alpha contamination levels indoors,
4. radionuclide concentrations in surface and subsurface soil outdoors and in water found in the crawl space under the house.

SURVEY METHODS

The Outdoor Survey

The outdoor area was divided into rectangular "survey blocks" as indicated in Fig. 3-1. The blocks in the front yard (along William Street) measured approximately 20 ft x 20 ft, and the survey blocks beside and behind the house were irregular sizes which were determined by natural boundaries such as fences, the house, and a garage.

Each survey block was scanned with a NaI scintillation meter held near the surface for the measurement of gamma radiation levels. (This meter is described in Appendix I.) At that point in the survey block showing the highest external gamma radiation level near the surface, measurements of beta-gamma and gamma radiation levels were made at 1 cm from the ground with the Geiger-Mueller (G-M) survey meter (see Appendix I). At 1 m above the same point, the external gamma radiation level was measured with a NaI scintillation meter. Next, at the center of each survey block, the external gamma radiation level was measured at 1 m above the ground. These center-point readings were used to estimate an average gamma radiation level at 1 m for the entire yard.

At the outdoor locations shown in Fig. 3-2, soil samples were taken (using a posthole digger) at intervals of 6 in. from the surface to depths of up to 2.5 ft. The samples were analyzed for ^{226}Ra and ^{238}U by the methods described in Appendix II. After the samples had been collected, the open holes were "logged" by lowering a gamma scintillation probe into the holes. The probe was encased in a lead shield with a narrow horizontal opening on the side, and measurements of the gamma radiation levels were made at intervals of 6 in. This logging was done as a second method of determining the spatial distribution of the sub-surface contamination in the yard.

The Indoor Survey

Inside the house, external gamma radiation levels at 1 m above the floor were measured with a NaI scintillation meter at the points shown in Fig. 3-1. Furthermore, direct measurements of alpha contamination

levels were made at several points on the floors and walls of each room with the alpha scintillation meters described in Appendix I. Measurements similar to those made inside the house were made in the crawl space under the house. In addition, a sample of water found in the crawl space was taken for the determination of radionuclide concentrations.

SURVEY RESULTS

Results of the Outdoor Survey

Measurements of gamma and beta-gamma radiation levels and of radionuclide concentrations in soil indicate that the shaded area shown in Fig. 3-3 is generally contaminated with ^{226}Ra - and ^{238}U -bearing materials from near the surface to a depth of 1.5 to 2.5 ft. In addition, there is some scattered contamination in the unshaded area of the property shown in Fig. 3-3.

It should be pointed out that results reported in this section have not been adjusted for background. That is, background levels have not been subtracted from radiation levels or radionuclide concentrations.

Gamma and Beta-Gamma Radiation Levels

External gamma radiation levels at 1 m above the ground in the centers of the survey blocks are shown in Fig. 3-1. It is estimated from these center-point measurements that the average external gamma radiation level at 1 m is approximately 75 $\mu\text{R/hr}$ in the front yard and is approximately 50 $\mu\text{R/hr}$ in the entire yard. By comparison, background gamma radiation levels in the Middlesex area typically range from 5 to 10 $\mu\text{R/hr}$.

Maximum measured external gamma radiation levels at 1 m and at the surface within survey blocks and beta-gamma dose rates at 1 cm above the surface at the maximum gamma points are shown in Fig. 3-4. (The shaded circles in Fig. 3-4 indicate the points of highest gamma radiation in the individual survey blocks.) External gamma radiation levels were as high as 330 $\mu\text{R/hr}$ at 1 m and as high as 2,500 $\mu\text{R/hr}$ at the surface. The maximum measured beta-gamma dose rate at 1 cm from the surface outdoors

was 2.5 mrad/hr. The ratios of the closed-window readings to the open-window readings on the G-M survey meter were generally 0.8 or higher, indicating that the elevated beta-gamma dose rates were due principally to gamma radiation.

Measurement of Radionuclide Concentrations in Soil

At the six locations shown in Fig. 3-2, soil samples were taken at intervals of 6 in. from the surface to a depth of 1.5 to 2.5 ft. Locations 1 and 6 were biased in that they were chosen for sampling because of elevated gamma radiation levels at those points. The other four locations were chosen at random. Radium-226 concentrations in the samples are given in Fig. 3-2, and ^{238}U concentrations are given in Fig. 3-5. Concentrations of ^{226}Ra in soil below 1.4 ft at location 2 were estimated from the gamma scintillation loggings; the concentrations of radionuclides in the other samples were determined by actual soil analyses. It is evident from the results in Fig. 3-2 that ^{226}Ra concentrations well above the background level (which is typically near 1 pCi/g) and ranging up to 4,500 pCi/g are present in soil from the surface to depths of at least 2.5 ft in some places. It is estimated that disposal of all soil showing higher than 5 pCi/g of ^{226}Ra would necessitate the removal of approximately 800 yd³ of dirt.

It should be noted that activities of ^{226}Ra and ^{238}U are nearly in equilibrium in samples showing highest contamination levels. This near-equilibrium condition is to be expected with pitchblende ores.

Results of the Survey Indoors

External gamma radiation levels at 1 m above the floor in the house are shown in Fig. 3-1. Measurements were generally in the background range (5 to 10 $\mu\text{R/hr}$) except at the front (northeast) wall in the living room, where a measurement of 13 $\mu\text{R/hr}$ was recorded, and in a small, empty room at the back of the house, where a measurement of 17 $\mu\text{R/hr}$ was observed. The measurement of 13 $\mu\text{R/hr}$ in the front of the house could be expected from the elevated gamma levels in the front yard. The measurement of 17 $\mu\text{R/hr}$ in the back of the house appears to be the

result of contamination just outside, and possibly extending beneath, the southeast corner of the house. This hypothesis is supported by the fact that gamma measurements of 20 to 25 $\mu\text{R/hr}$ were observed against the southeast wall in the crawl space beneath the house. The crawl space does not extend to the outside wall of the house on the southeast side; hence, there may be contamination in the soil between the southeast wall of the crawl space and the outside southeast wall of the house. In the remainder of the crawl space, gamma levels were generally near 10 $\mu\text{R/hr}$.

Direct measurements of alpha contamination were made at several points on the floor and walls in each room. It was concluded that there was no detectable surface contamination inside the house.

In the crawl space, direct alpha measurements were in the range 100 to 150 dpm/100 cm^2 at the base of the concrete wall at points on the northeast side of the crawl space where the wall had become soiled by water drainage from outdoors. Although essentially all contamination on the wall surfaces in the crawl space would be easily removable, the crawl space is apparently seldom entered.

A water sample was taken from a sump in the southern corner of the crawl space; radionuclide concentrations in this sample are reported in Table 3-1. A sample of silt from the sump showed 2.9 pCi/g of ^{226}Ra and 5.8 pCi/g of ^{238}U , respectively.

SUMMARY AND CONCLUSIONS

Measurements of gamma and beta-gamma levels and of radionuclide concentrations in soil indicate that the shaded area shown in Fig. 3-3 is generally contaminated with ^{226}Ra - and ^{238}U -bearing materials from near the surface to a depth of 1.5 to 2.5 ft. In addition, there is some scattered contamination in the unshaded area in Fig. 3-3. The soil in the yard shows ^{226}Ra and ^{238}U concentrations as high as 4,500 pCi/g and 5,800 pCi/g, respectively. A ^{238}U concentration of 5,800 pCi/g corresponds to 1.7% uranium by weight, which is well above the licensable level (0.05% uranium by weight corresponding to 172 pCi/g of ^{238}U) given in 10 CFR 40.

External gamma levels at 1 m averaged approximately 50 $\mu\text{R/hr}$ over the entire yard and approximately 75 $\mu\text{R/hr}$ in the front yard. Beta-gamma dose rates at 1 cm from the ground were as high as 2.5 mrad/hr and exceeded 0.20 mrad/hr over large areas (often much greater than 1 m^2) in the front yard. According to Nuclear Regulatory Commission (NRC) guidelines for the release of property for unrestricted use, beta-gamma dose rates at 1 cm from a surface should not exceed 1 mrad/hr over any area of 100 cm^2 and should not exceed 0.20 mrad/hr when averaged over 1 m^2 (see Appendix III).

Inside the house, external gamma radiation levels at 1 m were within the background range in most areas but were slightly elevated in the living room near the front wall of the house (13 $\mu\text{R/hr}$) and in an empty room in the back of the house (17 $\mu\text{R/hr}$). There is apparently no contamination on the surfaces inside the house; these elevated gamma levels appear to arise from contamination outside the house and possibly beneath the southeast corner of the house. There was some loose, easily removable "dust" at the base of the northeast concrete wall in the crawl space beneath the house showing alpha contamination levels of 100 to 150 cpm/100 cm^2 over an area larger than 1 m^2 . According to NRC guidelines (see Appendix III), direct alpha measurements on surfaces contaminated with ^{226}Ra or ^{230}Th (among other nuclides) should not exceed 100 dpm/100 cm^2 when averaged over an area of 1 m^2 .

An evaluation of the radiation exposures that could result from the conditions present at the William Street property site is provided in Appendix IV. This evaluation provides a comparison with present standards and gives an indication of the level of risk associated with the contamination at this site.

Appendix V provides a table of factors for use in the conversion of the units of measurement utilized in this report to the newly adopted International System of Units (SI). This table can be consulted when comparison of survey data and results in SI units is required.

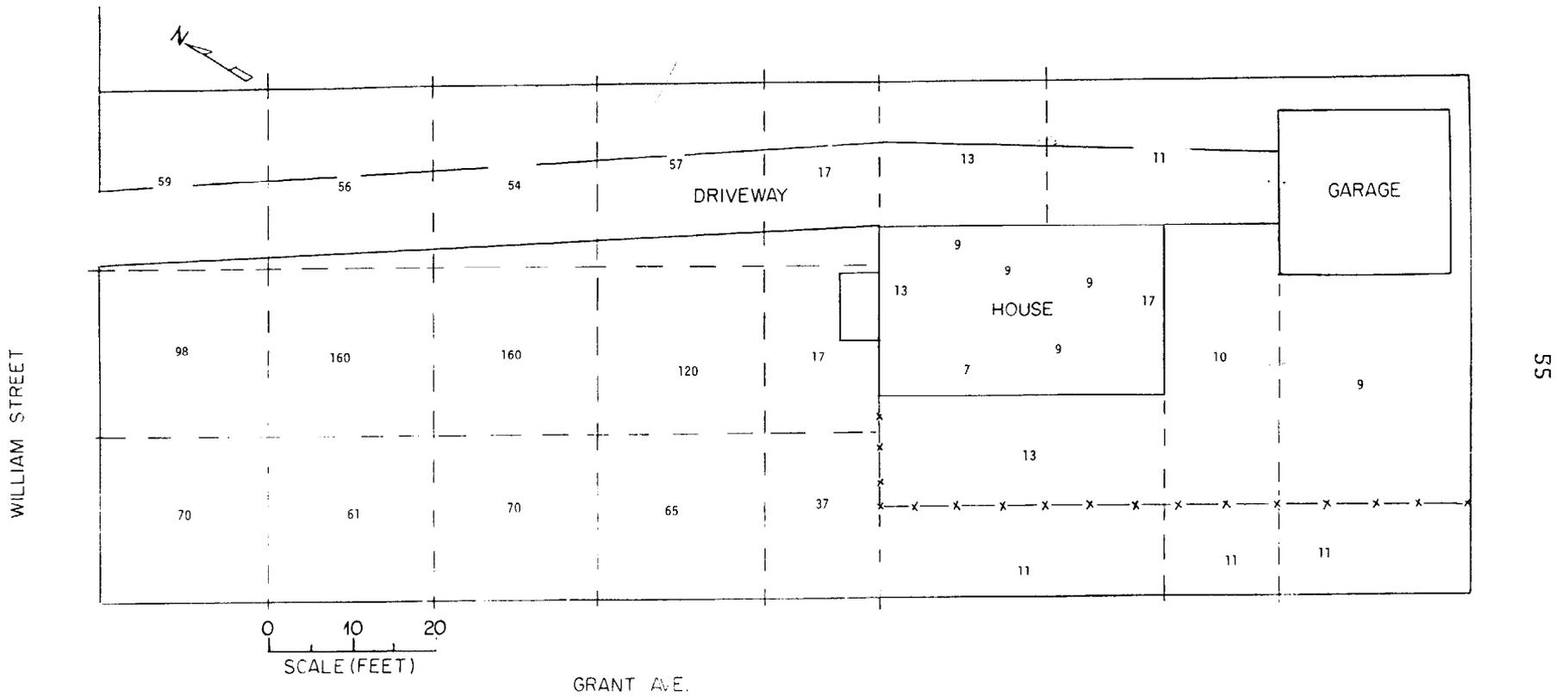


Fig. 3-1. External gamma radiation levels ($\mu\text{R/hr}$) at 1 m at center of survey blocks, 432 William Street site.

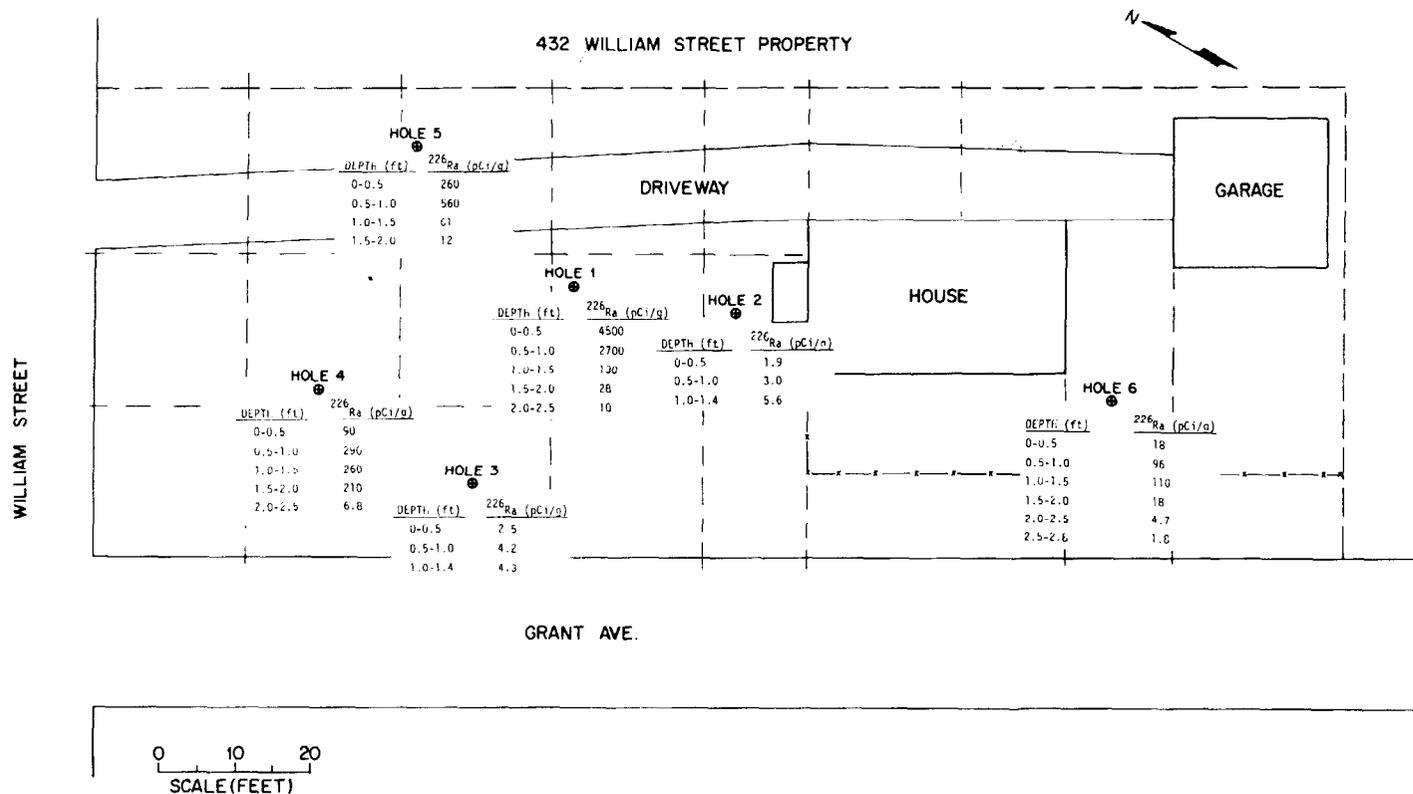


Fig. 3-2. Soil sampling locations and ^{226}Ra concentrations (pCi/g) in soil samples at 432 William Street.

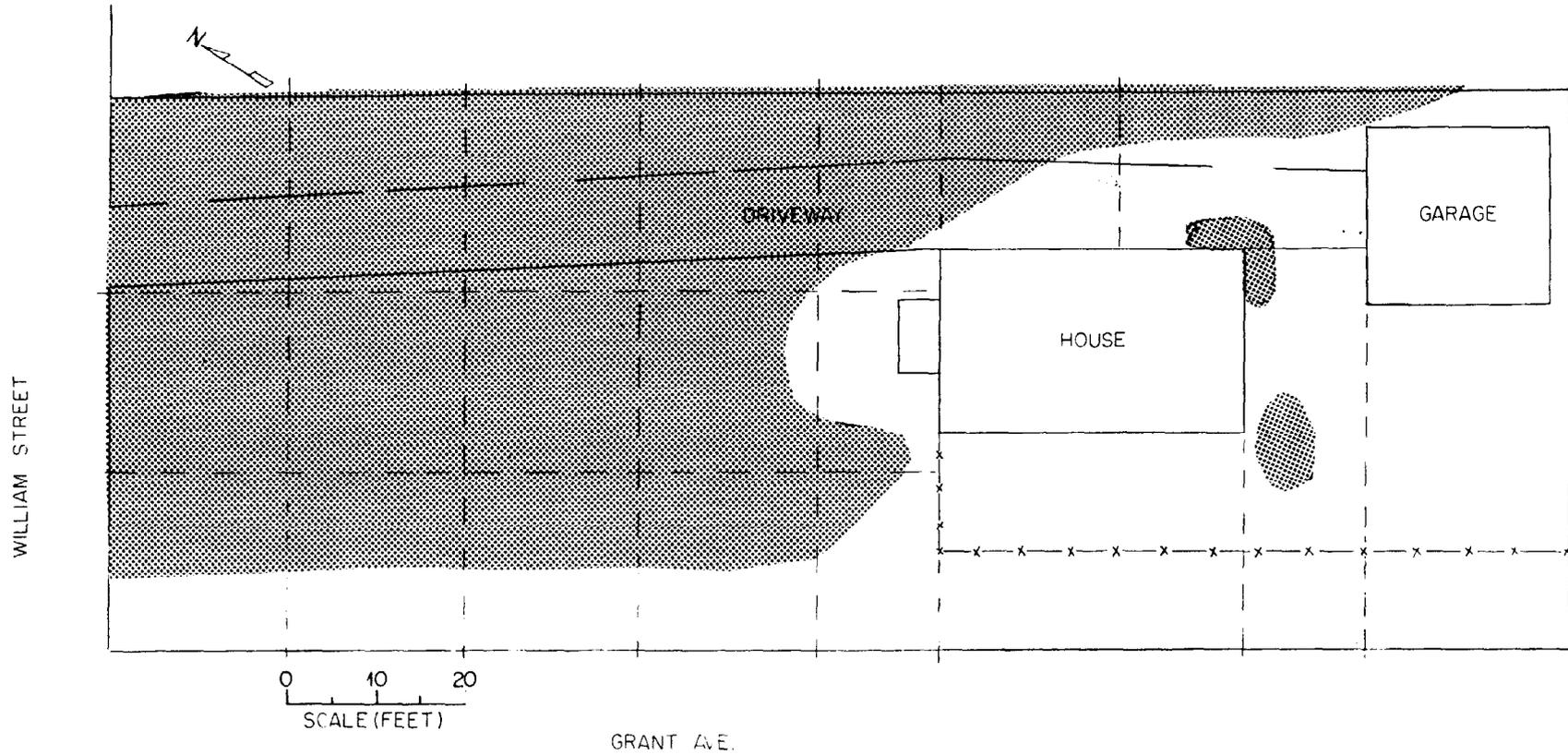
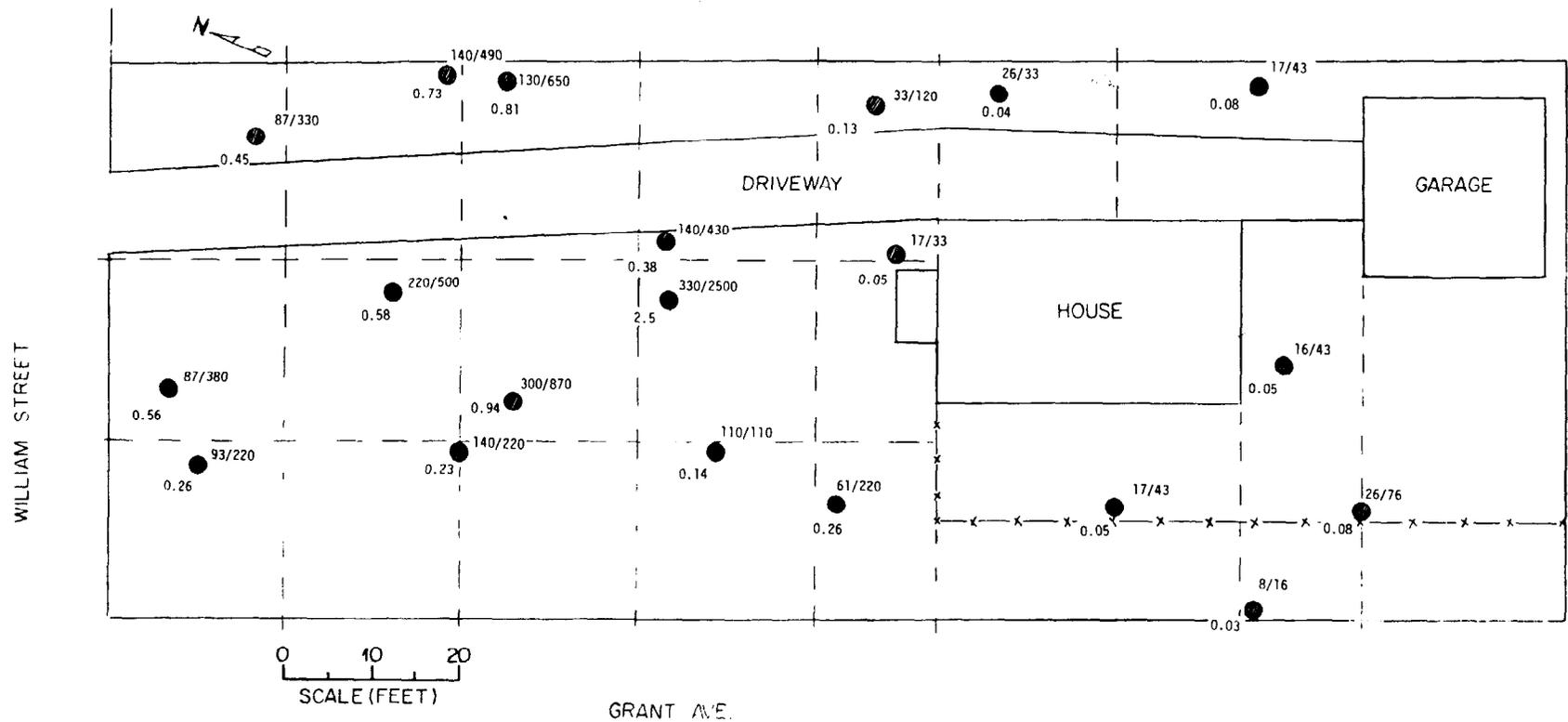


Fig. 3-3. Area on William Street property showing general contamination (the unshaded area showed scattered contamination).



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Fig. 3-4. Maximum measured external gamma radiation levels at 1 m and at the surface within survey blocks and beta-gamma dose rate at 1 cm at maximum gamma points.

Example of notation:

87/330 external gamma at 1 m = 87 μ R/hr
 external gamma at surface = 330 μ R/hr

0.45 beta-gamma dose rate at 1 cm = 0.45 mrad/hr

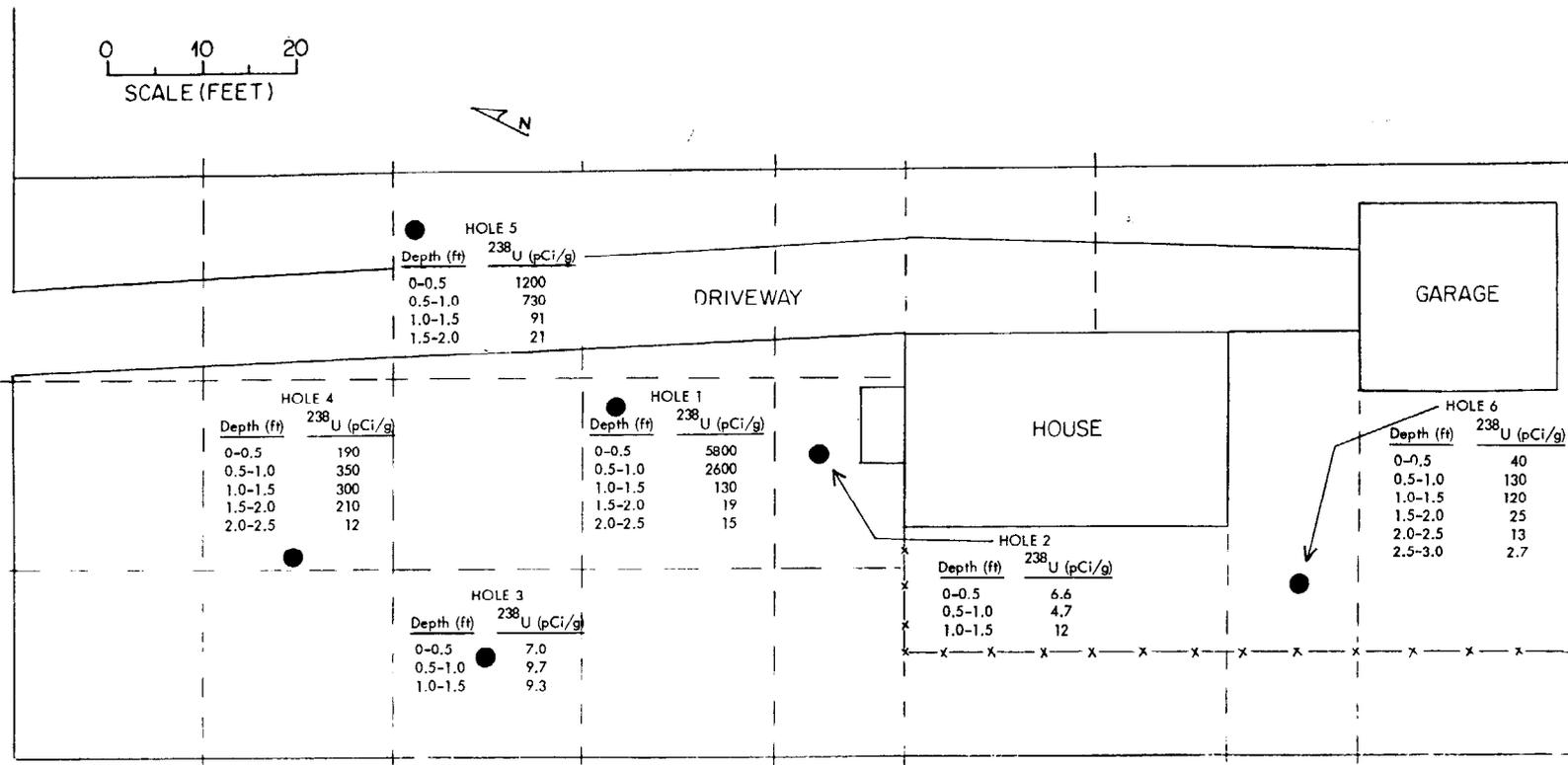


Fig. 3-5. Concentrations of ²³⁸U in soil samples on William Street property.

Table 3-1. Radionuclide concentrations (pCi/ml) in water samples taken from crawl space beneath house on William Street property

	^{226}Ra	^{238}U	^{230}Th	^{210}Pb
	0.002	0.009	0.0036	0.001
CG ^a	0.03	40	2	0.1

^aConcentration guide for water in unrestricted areas, as specified in 10 CFR 20.

4. RADIOLOGICAL SURVEY OF THE FLOOR OF WILLOW LAKE, MIDDLESEX, NEW JERSEY

ABSTRACT

A radiological survey was made of the floor of Willow Lake in Middlesex, New Jersey, to determine whether ^{226}Ra -bearing materials from the former Middlesex Sampling Plant had drained into this lake via Ambrose Brook. The survey consisted of (1) measurement of ^{226}Ra , ^{238}U , and ^{232}Th in samples taken from the lake floor and (2) measurement of gamma radiation levels on the lake floor for comparison with background measurements made in Ambrose Brook upstream from the former ore sampling plant. It was found that ^{226}Ra , ^{238}U , and ^{232}Th concentrations in sediment and gamma radiation levels on the lake floor were not significantly higher than background.

INTRODUCTION

At the request of the Department of Energy (DOE), a radiological survey was made of the floor of Willow Lake in Middlesex, New Jersey. This lake is fed by Ambrose Brook, which receives drainage water through other drainage pathways from the former Middlesex Sampling Plant (see Fig. 4-1). The purpose of the radiological survey of Willow Lake was to determine whether the ^{226}Ra -bearing materials from the former pitchblende ore sampling plant had reached the lake and accumulated there.

Willow Lake is approximately 457 m long, and its width varies from a few meters to approximately 69 m. At the time of the survey (June, 1978), there were approximately 1.8 m of water at the deepest measured point. Silt on the lake floor varied from a few centimeters in thickness to nearly a meter. At the western end of the lake is an earthen dam with a concrete spillway approximately 6 m wide (see Fig. 4-1).

The radiological survey of the lake floor was conducted on June 8 and 16, 1978, by members of the Health and Safety Research Division of the Oak Ridge National Laboratory (ORNL). The survey consisted of (1) collection of samples of sediment from the lake floor for analysis

of ^{226}Ra , ^{238}U , and ^{232}Th and (2) measurement of gamma radiation levels on the lake floor for comparison with background measurements made in Ambrose Brook upstream from the former ore sampling plant.

SURVEY METHODS

Samples of sediment were taken by driving a 5-cm electrical conduit through the silt and into the shale at the bottom of the lake. After the conduit was removed from the lake, the length containing the sediment was cut off and sealed. The shale in the lake bottom served as a sealing plug in the bottom of the sample tube. The samples were returned to ORNL where they were divided into 15-cm segments. The samples were analyzed for ^{226}Ra and ^{238}U by the methods described in Appendix II.

Gamma radiation at the bottom of the lake was measured using a "flounder," which consists of 12 Geiger-Mueller (G-M) tubes in a water-proof lucite container. The G-M tubes are shielded to provide an estimate of the gamma radiation that is nearly independent of photon energy. The flounder is lowered by wires to the bottom of the lake, and the total counts (in this case, 5-min counts) from the G-M tubes are read from an attached scaler kept above the water surface. A judgment is made concerning potential contamination on the lake bottom by comparison with similar readings made at background locations, in this case in Ambrose Brook far upstream from the former sampling plant.

SURVEY RESULTS

Concentrations of ^{226}Ra , ^{238}U , and ^{232}Th in sediment samples taken from the bottom of the lake are reported in Table 4-1; sampling locations are indicated in Fig. 4-2. The concentrations of ^{226}Ra , ^{238}U , and ^{232}Th in background soil in the Middlesex area are typically near 1 pCi/g, although these concentrations may be 2 pCi/g or higher in some types of soil. In the sediment samples taken from the lake floor, the ^{226}Ra concentration ranged from less 0.71 pCi/g to 2.5 pCi/g. It is suggested by the results in Table 4-1 that no significant quantities of ^{226}Ra from the former ore sampling plant have reached Willow Lake. This hypothesis

is supported by the results of the gamma survey made at the bottom of the lake. Statistical analysis of the data in Tables 4-1 and 4-2 determined that gamma radiation levels at the points of measurement in Willow Lake were not significantly higher than background levels. (It should be pointed out that gamma radiation levels can easily vary 50% or more over different types of background soil.)

CONCLUSIONS

While it is possible that small quantities of ^{226}Ra from the former ore sampling plant have reached Willow Lake, there apparently has been no significant buildup of ^{226}Ra in the lake. This conclusion is based on measurements of ^{226}Ra in sediment from the lake floor and gamma radiation levels on the lake floor, neither of which varied beyond limits which could be expected under background conditions.

Appendix V provides a table of factors for use in the conversion of the units of measurement utilized in this report to the newly adopted International System of Units (SI). This table can be consulted when comparison of survey data and results in SI units is required.

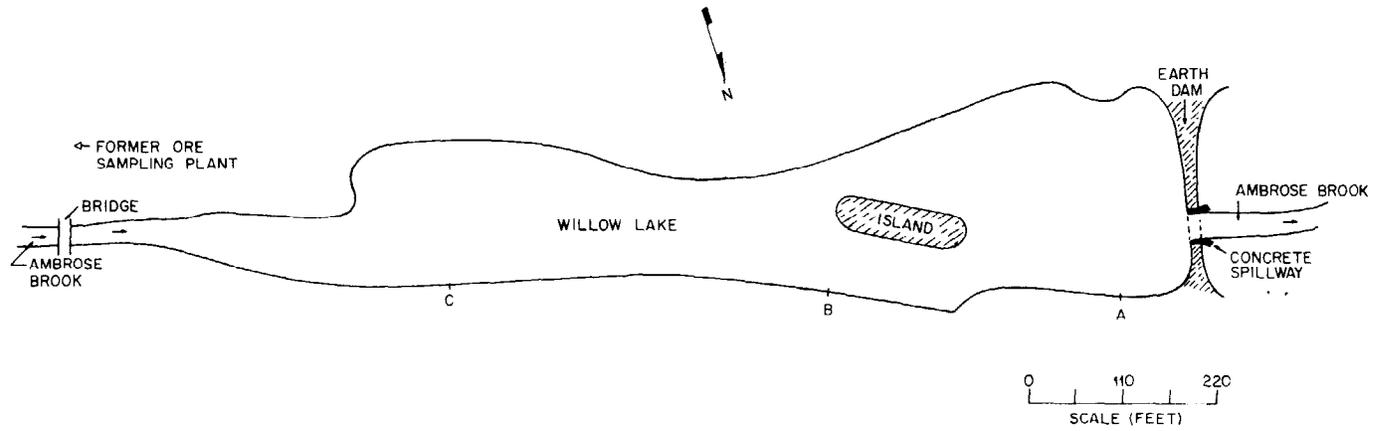


Fig. 4-1. Scaled drawing of Willow Lake and a portion of Ambrose Brook.

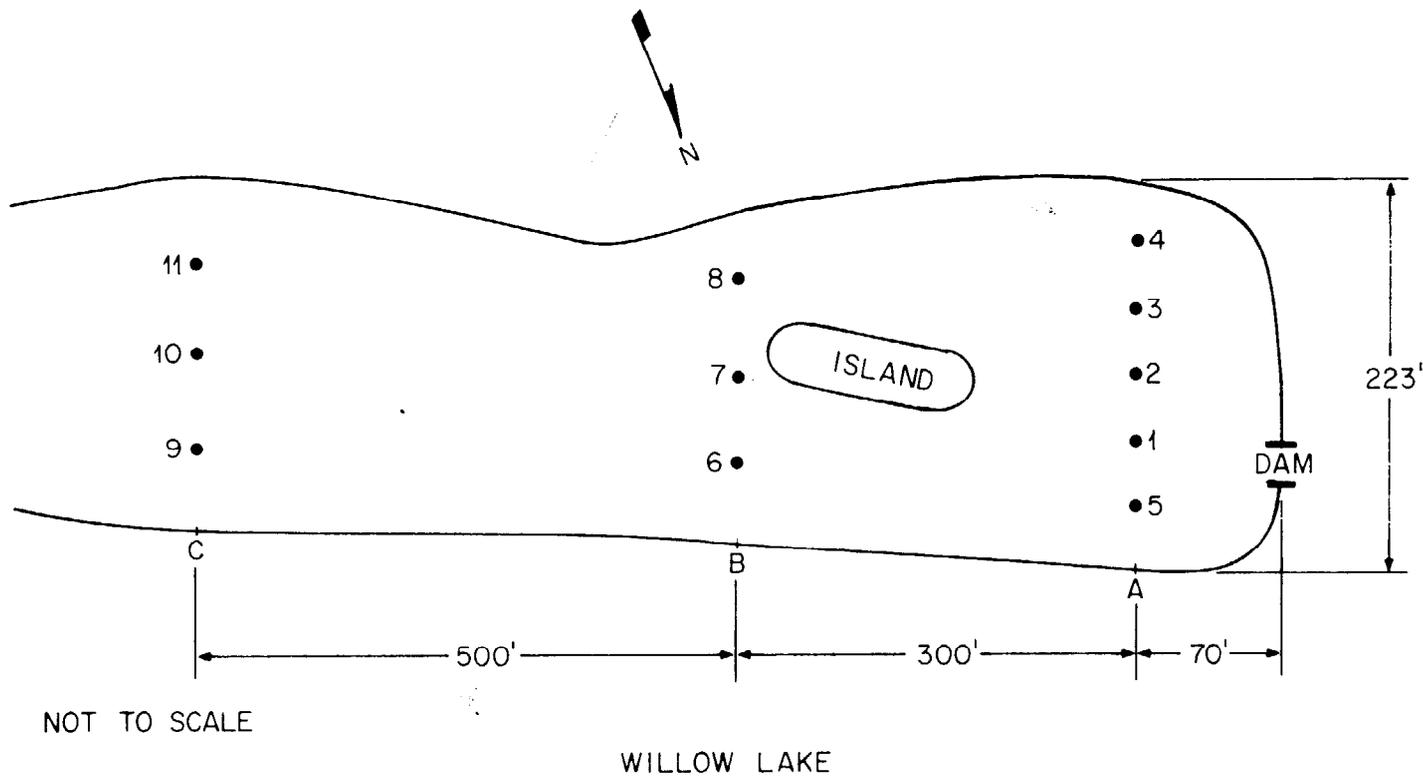


Fig. 4-2. Points where mud samples were taken from Willow Lake and traverse lines (A and C) used for gamma survey.

Table 4-1. Concentration of ^{226}Ra , ^{238}U , and ^{232}Th (pCi/g) in sediment samples taken from the floor in Willow Lake

Location shown in Fig. 4-2	Depth (ft)	^{226}Ra	^{238}U	^{232}Th
1	0 -0.5	1.9	1.2	1.6
	0.5-1.0	1.6	1.0	1.2
	1.0-1.4	0.90	0.84	1.3
2	0 -0.5	1.9	1.4	1.9
	0.5-1.0	1.7	0.6	1.6
	1.0-1.5	1.1	0.8	1.4
3	0 -0.5	2.5	1.4	1.7
	0.5-1.0	1.8	α	1.7
	1.0-1.6	1.0	0.84	1.2
4	0 -0.5	2.1	1.4	1.8
	0.5-1.0	1.6	1.1	1.6
	1.0-1.5	1.3	1.0	1.4
	1.5-2.0	1.3	0.90	1.4
	2.0-2.4	1.0	0.83	1.4
5	0 -0.5	2.0	1.4	1.6
	0.5-1.0	1.2	1.0	1.5
6	0 -0.5	1.8	1.5	1.4
	0.5-1.0	1.4	1.1	1.5
	1.0-1.4	1.3	0.95	1.4
7	0 -0.5	0.91	0.99	1.2
	0.5-1.3	1.3	α	1.4
8	0 -0.5	1.9	1.4	1.6
	0.5-1.0	1.0	0.97	1.3
	1.0-1.5	1.0	0.78	1.3
	1.5-1.9	1.1	1.0	1.4
9	0 -0.5	2.3	2.0	1.5
	0.5-0.9	0.75	0.70	1.2
10	0 -0.5	1.2	1.1	1.1
	0.5-1.0	0.71	0.61	0.97
	1.0-1.5	0.89	0.84	1.4
11	0 -0.5	2.4	1.8	1.7
	0.5-1.0	1.7	1.2	1.5
	1.0-1.6	1.3	0.95	1.5

α No data obtained.

Table 4-2. Gamma radiation measurements made on Willow Lake floor compared with background measurements

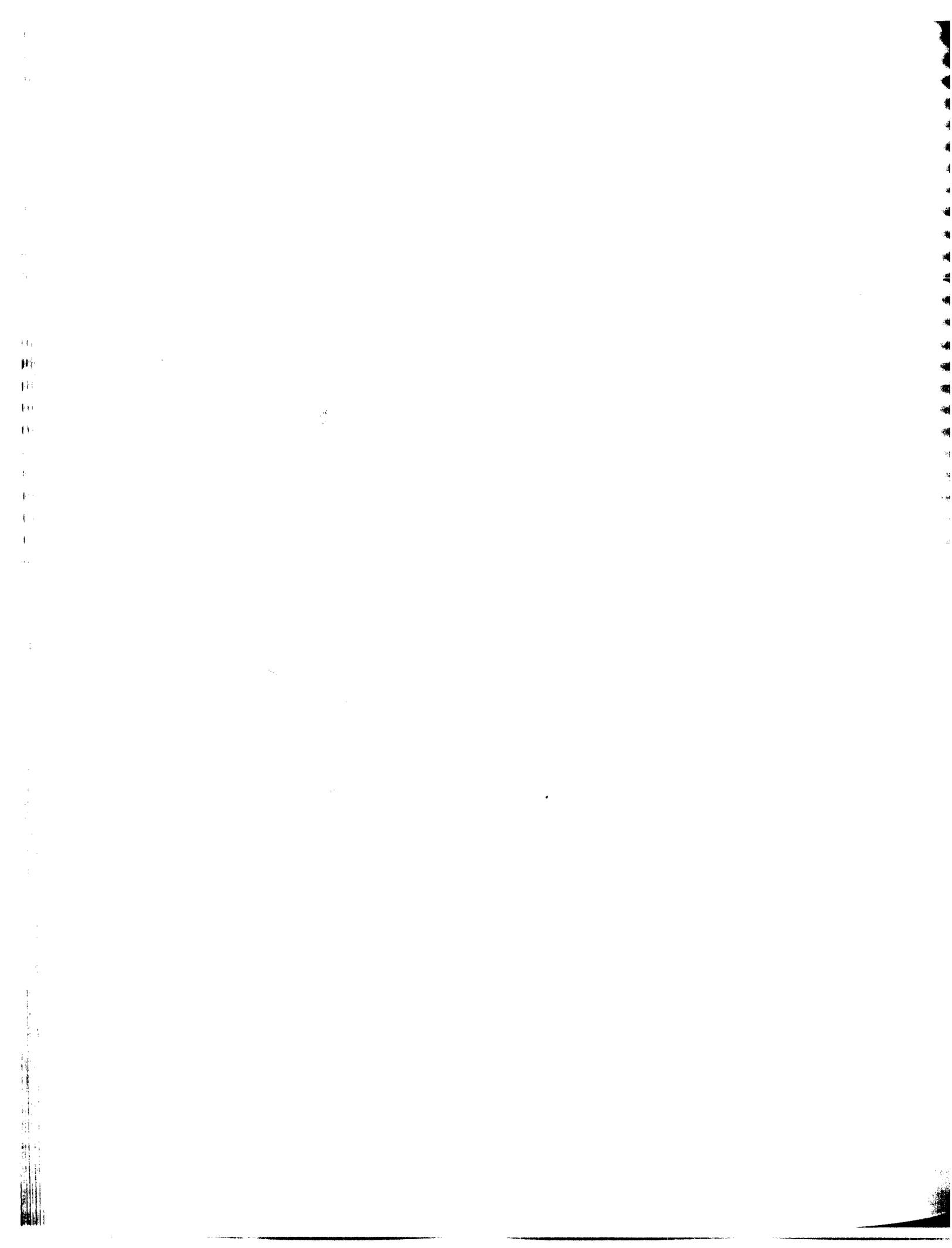
Background measurements	Counts per minute
Background location 1	826
Background location 2	815
Background location 3	872
<u>Traverse line A (Fig. 4-2)</u>	
Distance from north bank (ft)	
5	744
25	824
50	863
75	833
100	908
125	842
150	835
175	837
200	880
223	1,033
<u>Traverse line C (Fig. 4-2)</u>	
Distance from north bank	
2	1,058
25	916
50	925
75	877
100	902
125	880
150	908
168	1,053

5. REFERENCES

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2. U.S. Department of Energy, *Radiological Survey of the Middlesex Municipal Landfill, Middlesex, New Jersey*, Formerly Utilized MED/AEC Sites Remedial Action Program, Division of Environmental Control Technology (to be published).
3. "Preliminary Results of Aerial Radiological Survey, Middlesex, New Jersey, May, 1978," EG&G Energy Measurements Group for the U.S. Department of Energy (to be prepared as a DOE report).
4. E. B. Wagner and G. S. Hurst, "A Geiger-Mueller Gamma-Ray Dosimeter with Low Neutron Sensitivity," *Health Phys.* 5, 20 (1961).
5. M. E. Wrenn, H. Spitz, and N. Cohen, *IEEE Trans. Nucl. Sci.* 22, 645 (1975).

APPENDIX I

DESCRIPTION OF RADIATION SURVEY METERS, WRENN CHAMBERS,
AND TECHNIQUE FOR THE MEASUREMENT OF
RADON DAUGHTER CONCENTRATIONS



RADIATION SURVEY METERS

Beta-Gamma Survey Meter

A portable Geiger-Mueller (G-M) survey meter is the primary instrument for measuring beta-gamma radioactivity. The G-M tube is a halogen-quenched stainless steel tube having a 30 mg/cm^2 wall thickness and presenting a cross-sectional area of approximately 10 cm^2 . Since the G-M tube is sensitive to both beta and gamma radiation, measurements are taken in both an open-window and a closed-window configuration. Beta radiation cannot penetrate the closed window, and thus the beta reading can be determined by taking the difference between the open- and closed-window readings. This meter is shown in Fig. I-A.

The G-M survey meters were calibrated by comparison with a pre-calibrated Victoreen Model 440 ionization chamber (Fig. I-B). The open-window calibration factor was found to be 2,000 cpm per mR/hr for surfaces contaminated with ^{226}Ra in equilibrium with ^{238}U and 2,300 cpm per mR/hr for surfaces contaminated with initially pure uranium. The closed-window (gamma) calibration factor, determined by use of an NBS standard ^{226}Ra source, was 3,200 cpm per mR/hr.

Gamma Scintillation Survey Meter

A portable survey meter using a NaI scintillation probe is used to measure low-level gamma radiation exposure. The scintillation probe is a 3.2×3.8 -cm NaI crystal coupled to a photomultiplier tube. This probe is connected to a Victoreen Model Thyac III ratemeter (see Fig. I-C). This unit is capable of measuring radiation levels from a few $\mu\text{R/hr}$ to several hundred $\mu\text{R/hr}$. This instrument is calibrated at ORNL with an NBS standard ^{226}Ra source. Typical calibration factors are of the order of 300 cpm per $\mu\text{R/hr}$.

TECHNIQUES FOR THE MEASUREMENT OF RADON AND RADON DAUGHTERS IN AIR

Continuous Radon Monitor

Concentrations of radon are measured using a detector developed by Wrenn et al.^{I-1} This detector operates on the principle that most of the RaA ions are positively charged. Radon is allowed to diffuse through a foam-rubber-covered, hemispherically-shaped metal screen, which filters radon daughters. As radon in the chamber decays, after diffusing into the cavity, RaA ions are attracted to a thin aluminized mylar film which is stretched over a zinc sulfide scintillation detector. The potential between this aluminized mylar film and the hemispherically-shaped wire screen creates a strong electric field which serves to attract the charged ions. The ions thus attracted remain on the surface of the mylar film and continue their radioactive decay to other radon daughters. The principal radiation detected by a radon monitor of this type is the alpha particles from RaA and RaC'. Alpha pulses are counted and integrated for a fixed period of time, usually 30 min. At the end of each timed counting period, the total count for each channel is printed automatically, and the system is reset and counting before the next period is initiated.

The radon monitor in use by ORNL is similar to that developed by Wrenn. However, the scintillation detector is larger (2 in. in diam), and a provision has been made to utilize an alpha source in order to standardize the chamber before putting it into service (see Fig. I-D). The alpha standard is inserted through a hole in the top of the chamber and rests in a fixed and repeatable position. During use of the monitor, the source access hole is plugged with a rubber stopper. An overall view of the ORNL radon monitor is shown in Fig. I-E.

Radon Progeny Monitor

An alpha spectrometry technique has been refined by Kerr^{I-2, I-3} for the measurement of ^{222}Rn progeny concentrations in air. From one integral count of the ^{218}Po alpha activity and two integral counts of the ^{214}Po alpha activity, the concentrations in air of ^{218}Po , ^{214}Bi , and ^{214}Pb may be calculated.

Particulate ^{222}Rn daughters attached to airborne dust are collected on a membrane filter with a pore size of 0.4 microns. A sampling time of 5 min and a flow rate of 12 liters/min are used. This filter sample is then placed under a silicon surface barrier detector and counted. The detector and counting system used for radon daughter measurements are shown in Fig. I-F. Usually, counting of this kind is performed with a vacuum between the sample and the detector which requires a complicated sample holder and time-consuming sample-changing methods. Experiments at this laboratory have shown that ease in sample handling is obtained with little loss in resolution when helium is used as a chamber fill gas.¹⁻⁴ In this counter, helium is flowed between the diode and the filter sample, which are separated by a distance of 0.5 cm. One integral count of the ^{218}Po alpha activity is obtained from 2 to 12 min, and two integral counts of the ^{214}Po activity are obtained from 2 to 12 min and 15 to 30 min, respectively. All counting intervals are referenced to $t = 0$ at the end of sampling.

The equations describing the ^{222}Rn progeny atoms collection rates on the filter are of the form

$$\frac{dn_i(t)}{dt} = C_i v + \lambda_{i-1} n_{i-1}(t) - \lambda_i n_i(t), \quad (1)$$

where

n_i = number of the i th species of atom on the filter as a function of time,

λ_i = radioactive decay constant of the i th species (min^{-1}),

C_i = concentration of the i th species (atoms liters^{-1}),

v = air sampling flow rate (liters min^{-1}).

From the general form of Eq. 1, specific equations can be obtained describing the number of each ^{222}Rn decay product collected on the filter as a function of time. Also, by letting $v = 0$ in Eq. 1, a set of equations describing the decay on the filter of each ^{222}Rn progeny can be obtained. The equations describing the decay of ^{222}Rn progeny on the filter can be integrated and related to the integral counts obtained experimentally. Values for the total activities of ^{218}Po , ^{214}Pb , and ^{214}Bi on the filter at the end of sampling are obtained. The airborne

concentrations are obtained by solving the equations describing the atom collection rates on the filter. A computer program has been written to perform these matrix operations, to calculate the air concentrations of the radon progeny, and to estimate the accuracy of the calculated concentrations.

REFERENCES FOR APPENDIX I

- I-1. M. E. Wrenn, H. Spitz, and N. Cohen, "Design of a Continuous Digital Output Environmental Radon Monitor," *IEEE Trans. Nucl. Sci.* 22, 645 (1975).
- I-2. G. D. Kerr, *Measurement of Radon Progeny Concentrations in Air by Alpha-Particle Spectrometry*, Oak Ridge National Laboratory Report ORNL/TM-4924 (July, 1975).
- I-3. G. D. Kerr, "Measurement of Radon Progeny Concentrations in Air," *Trans. Am. Nucl. Soc.* 17, 541 (1973).
- I-4. P. T. Perdue, W. H. Shinpaugh, J. H. Thorngate, and J. A. Auxier, "A Convenient Counter for Measuring Alpha Activity of Smear and Air Samples," *Health Phys.* 26, 114 (1974).

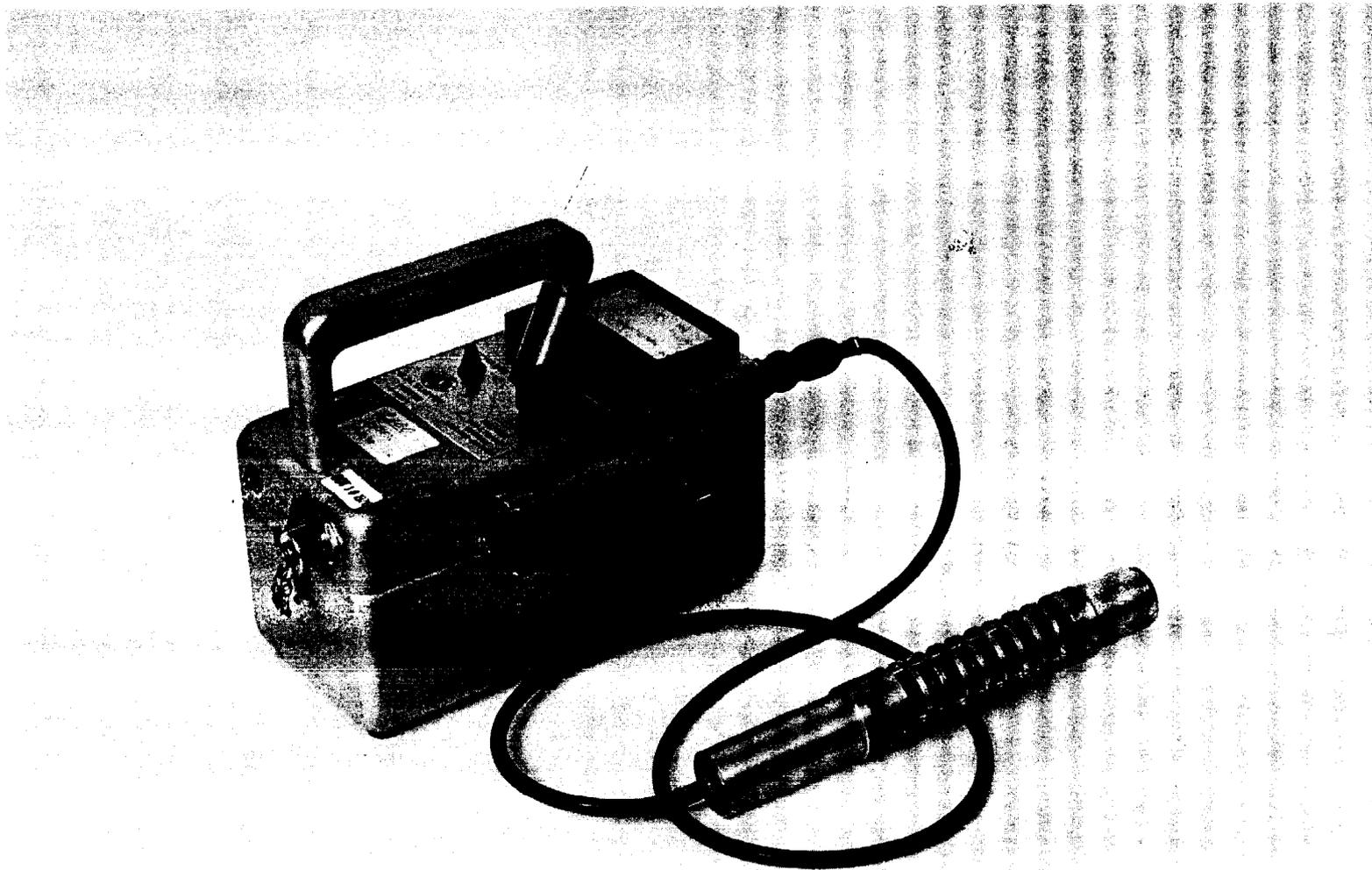


Fig. I-A. Geiger-Mueller survey meter.

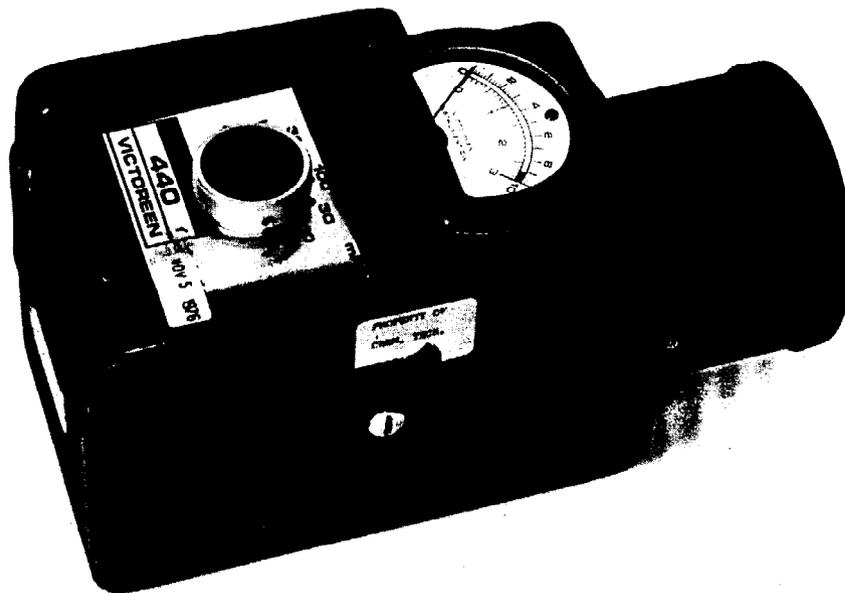


Fig. I-B. Victoreen 440 ionization chamber.

ORNL-Photo 6707-76

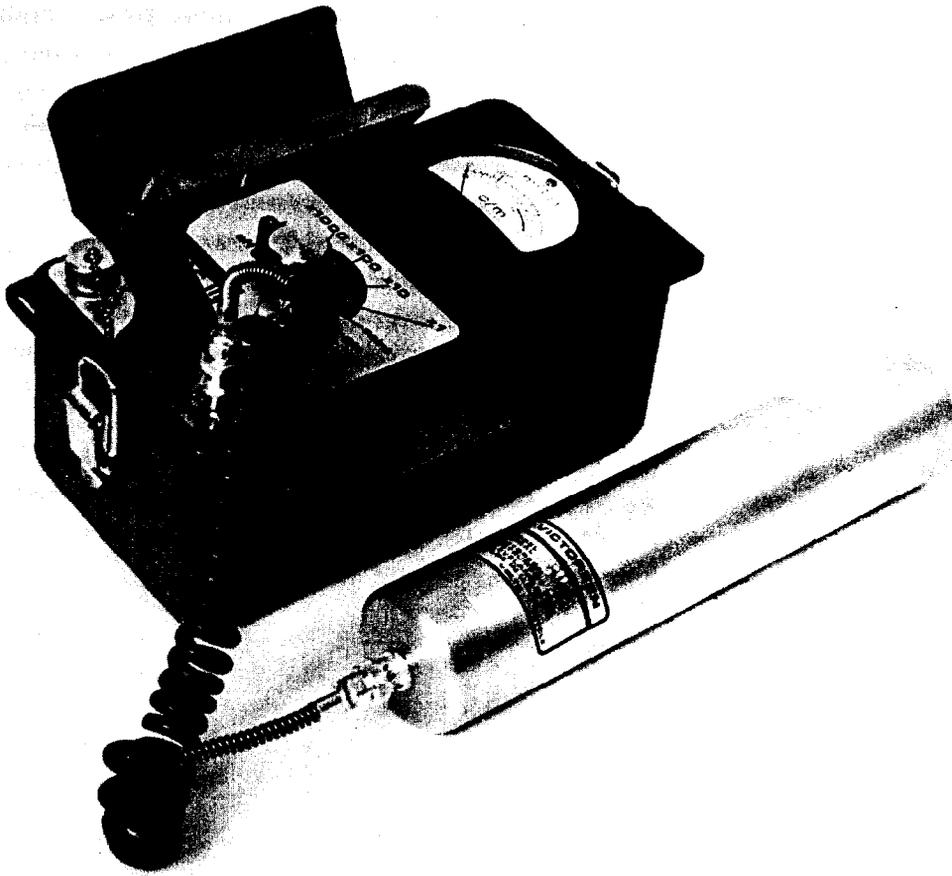


Fig. I-C. Gamma scintillation survey meter.



Fig. I-D. View of ionization chamber utilized in ORNL radon monitor. Shown is the photomultiplier housing, screen mesh hemisphere housing, and aluminized mylar covered ZnS scintillator.



Fig. I-E. Overall view of ORNL continuous radon monitor.

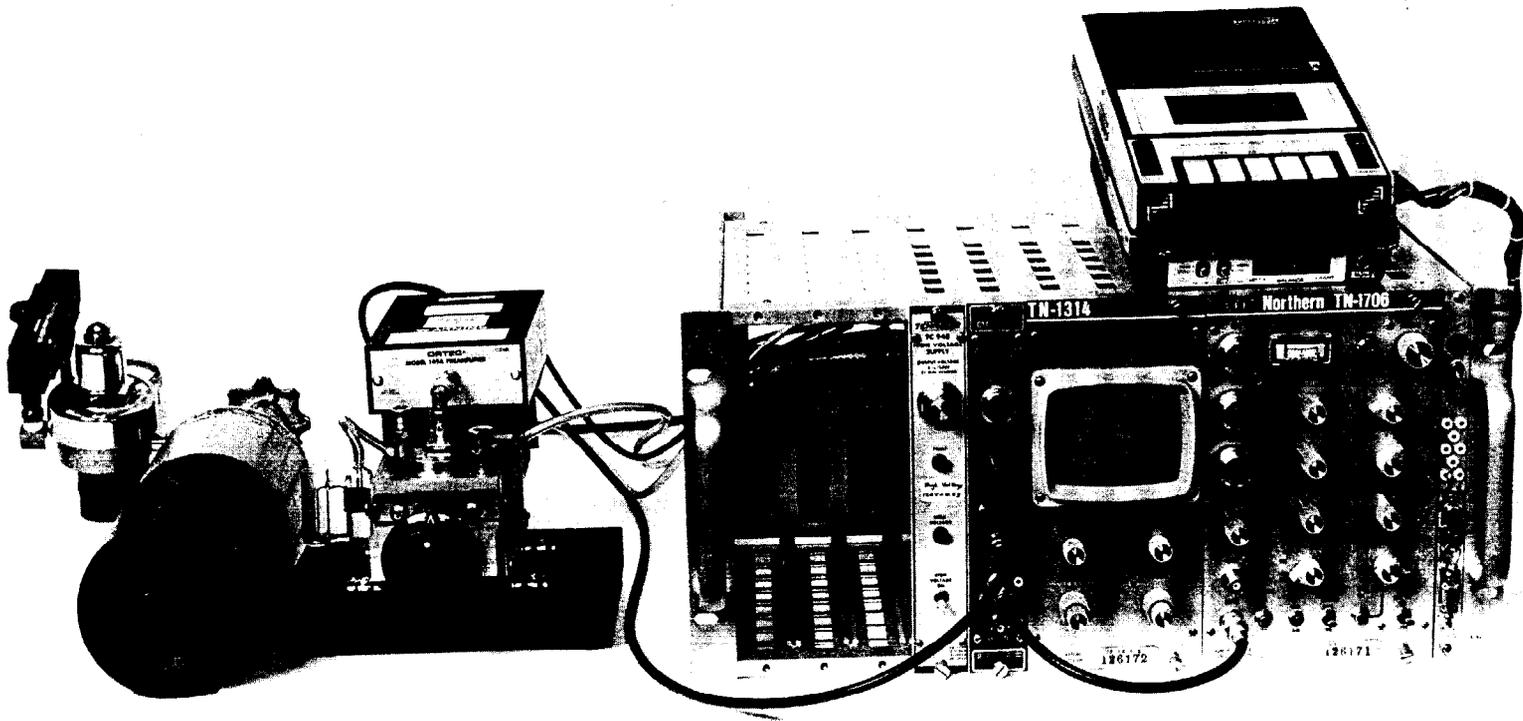


Fig. I-F. Counting system for radon daughter measurements.

APPENDIX II

METHODS USED TO ANALYZE SAMPLES

SOIL SAMPLE ANALYSIS

Samples of soil collected on the site were packed in plastic bags and returned to ORNL where they were dried for 24 hr at 110°C and then pulverized to a particle size no greater than 500 μm in diam (-35 mesh). Next, aliquots from each sample were transferred to plastic bottles or petri dishes, weighed, and counted using a Germanium-Lithium Drifted [Ge(Li)] detector and a multichannel analyzer. The spectra obtained in this way are analyzed by computer techniques. A description of the Ge(Li) detector and soil-counting techniques is given below.

A holder for twelve 30-cm³ polyethylene bottles (standard containers for liquid scintillation samples) and a background shield have been designed for use with a 50-cm³ Ge(Li) detector system (see Figs. II-A and II-B). During counting of the samples, the holder is used to position ten of the sample bottles around the cylindrical surface of the detector, parallel to and symmetric about its axis, and two additional bottles across the end surface of the detector, perpendicular to and symmetric with its axis. With a 300-cm³ sample and a graded shield developed for use with the system, it is possible to measure 1 pCi/g of ²³²Th or ²²⁶Ra with an error of $\pm 10\%$ or less.

Pulses are sorted by a 4096-channel analyzer (see Fig. III-C), stored on magnetic tape, and subsequently entered into a computer program which uses an iterative least-squares method to identify radionuclides corresponding to those gamma-ray lines found in the sample. The program, which is accessible through a remote terminal, relies on a library of radioisotopes which contains approximately 700 isotopes and 2,500 gamma rays and which runs continuously on the IBM-360 system at ORNL. In identifying and quantifying ²²⁶Ra, six principal gamma-ray lines are analyzed. Most of these are from ²¹⁴Pb and correspond to 295, 352, 609, 1,120, 1,765, and 2,204 keV. For analysis of ²³²Th, seven gamma lines of its daughters are analyzed (239, 338, 583, 795, 911, 969, and 2,615 keV).

A measurement of the ²³⁸U concentration in each sample was obtained by neutron absorption techniques.

WATER AND SEDIMENT ANALYSIS

Water and sediment samples collected on and near the site were analyzed by the Analytical Chemistry Division of ORNL for ^{210}Pb , ^{226}Ra , and ^{230}Th using techniques described in Appendices to the ORNL Master Manual. The samples were analyzed for ^{238}U using neutron absorption techniques. The activity reported for each radionuclide in the water sediment samples represents only that percentage of the activity (normally between 50 and 100%) available by hot HNO_3 leaching.

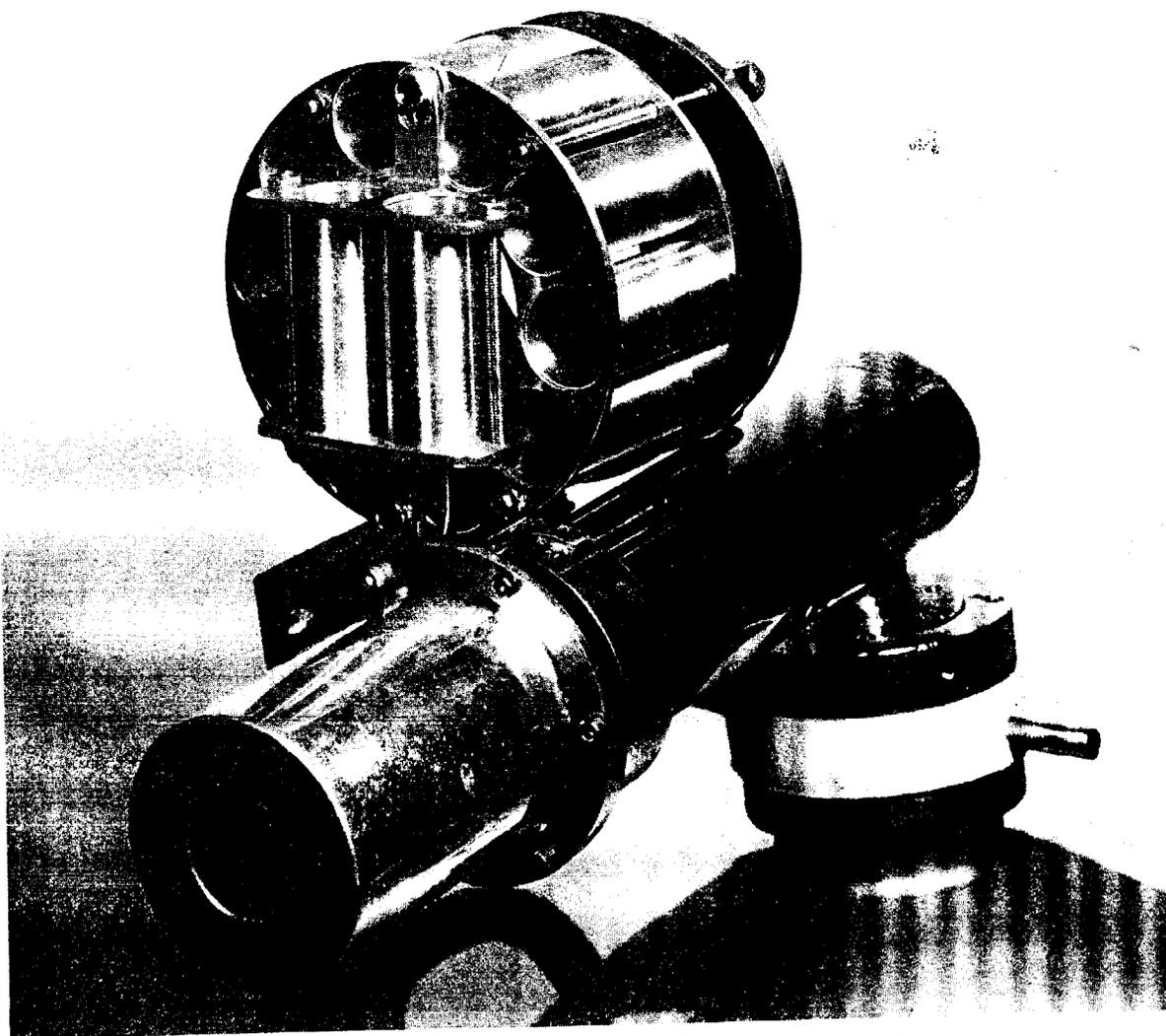


Fig. II-A. Holder for Ge(Li) detector system.

ORNL-Photo 2171-75

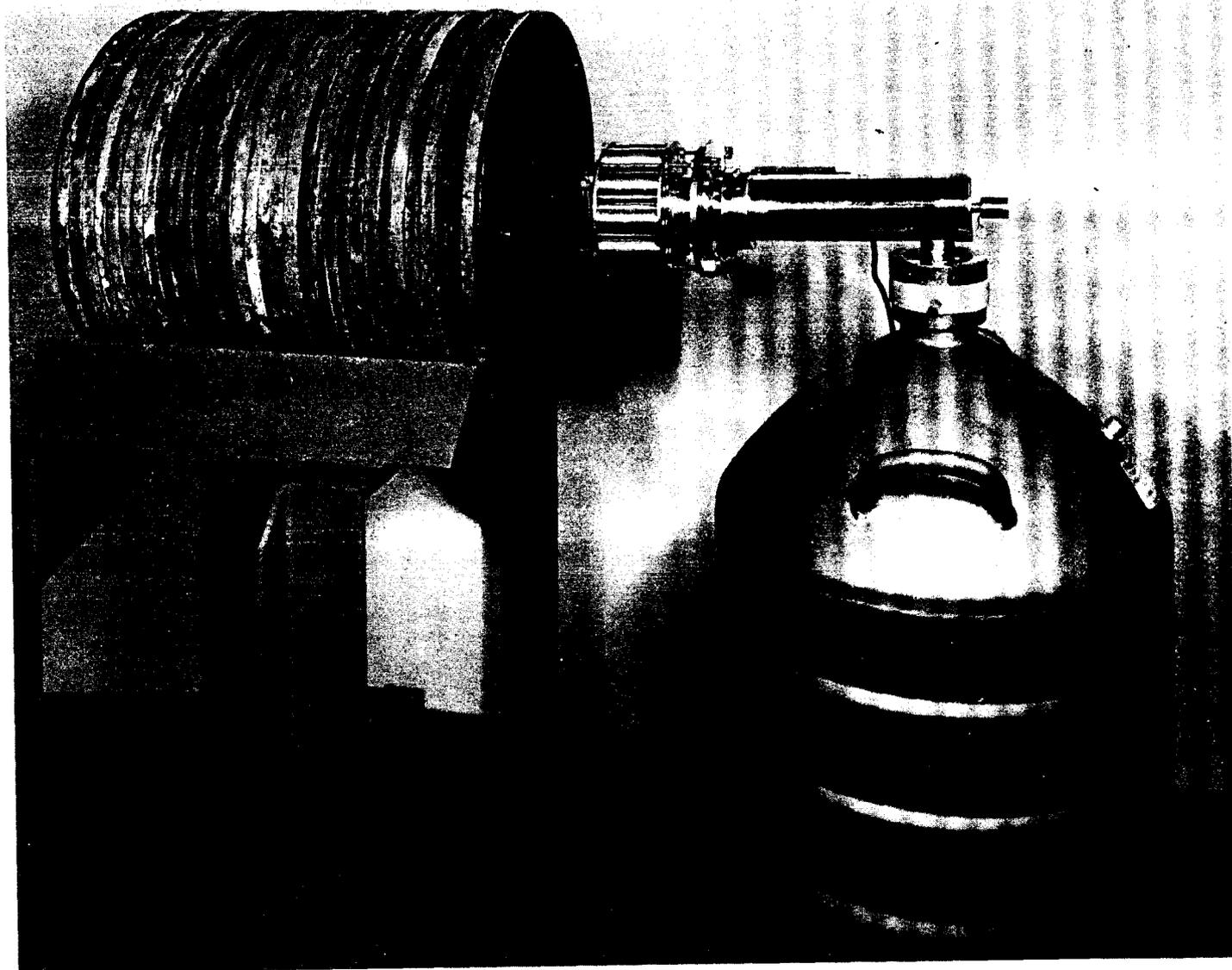


Fig. II-B. Ge(Li) detector system.

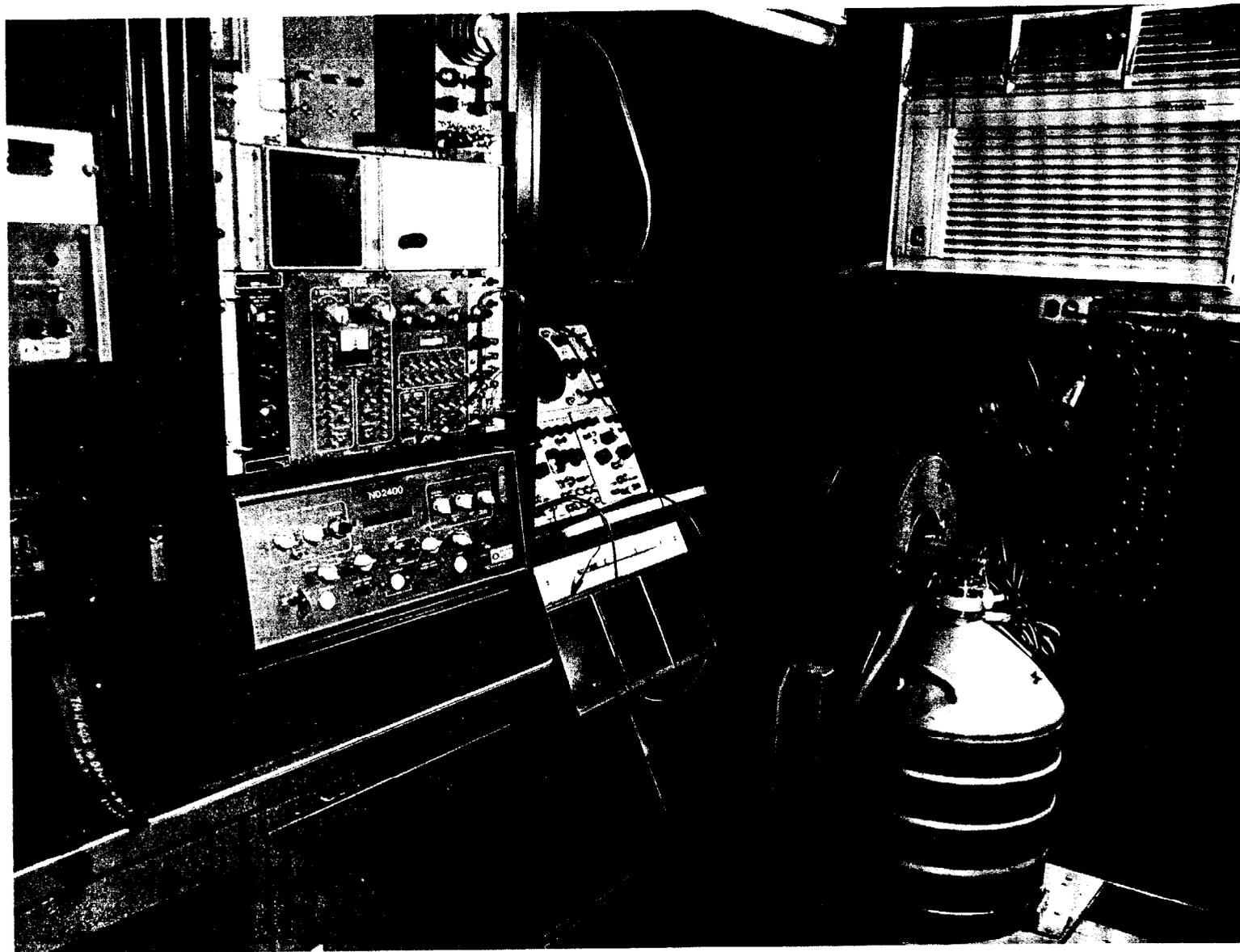
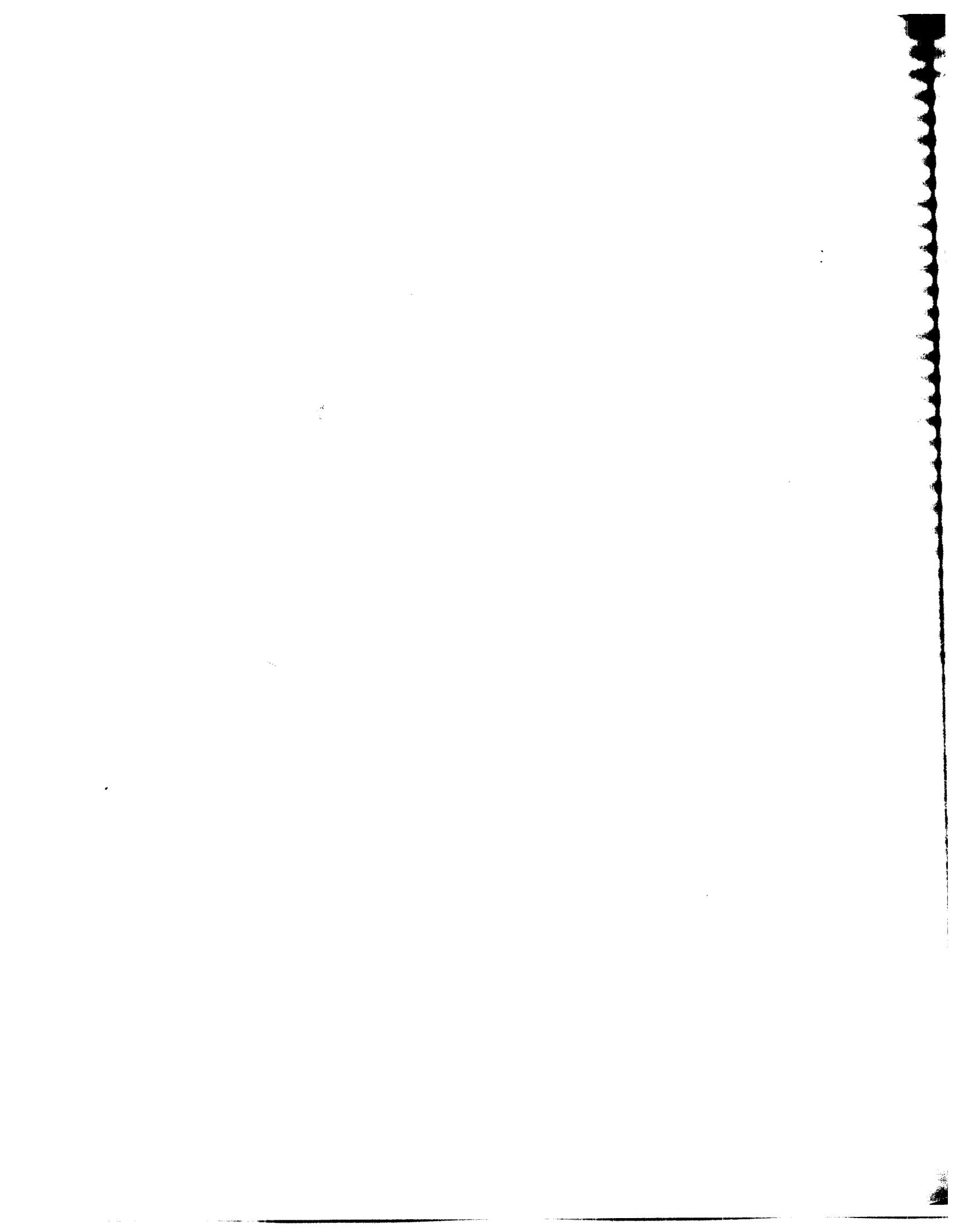
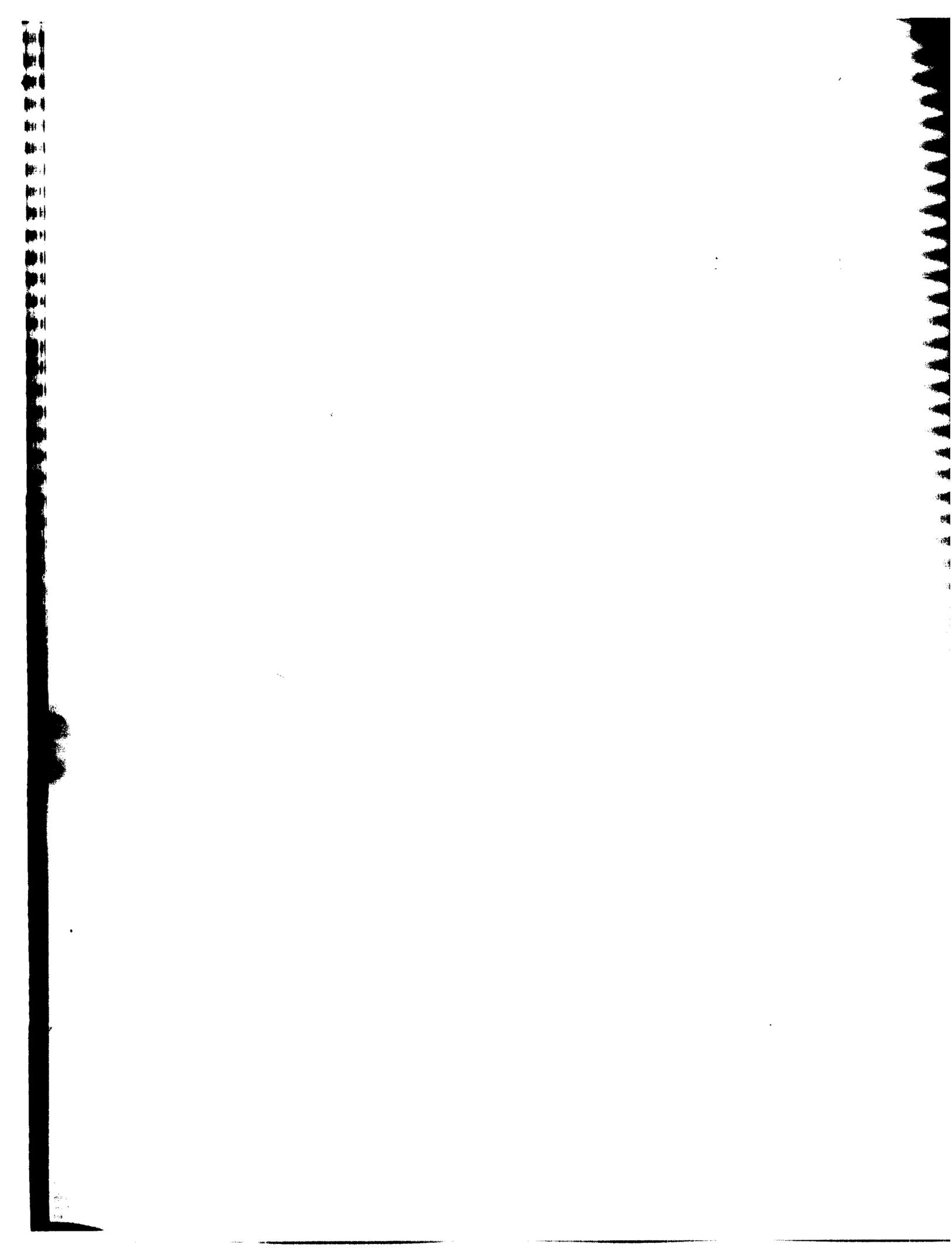


Fig. II-C. 4096-channel analyzer.



APPENDIX III

PERTINENT RADIOLOGICAL REGULATIONS,
STANDARDS, AND GUIDELINES



GUIDELINES FOR DECONTAMINATION OF FACILITIES AND EQUIPMENT PRIOR
TO RELEASE FOR UNRESTRICTED USE OR TERMINATION OF LICENSES FOR
BY-PRODUCT, SOURCE, OR SPECIAL NUCLEAR MATERIAL

U.S. Nuclear Regulatory Commission
Division of Fuel Cycle and Material Safety
Washington, D.C. 20555

November 1976

The instructions in this guide in conjunction with Table III-1 specify the radioactivity and radiation exposure rate limits which should be used in accomplishing the decontamination and survey of surfaces or premises and equipment prior to abandonment or release for unrestricted use. The limits in Table III-1 do not apply to premises, equipment, or scrap containing induced radioactivity for which the radiological considerations pertinent to their use may be different. The release of such facilities or items from regulatory control will be considered on a case-by-case basis.

1. The licensee shall make a reasonable effort to eliminate residual contamination.
2. Radioactivity on equipment or surfaces shall not be covered by paint, plating, or other covering material unless contamination levels, as determined by a survey and documented, are below the limits specified in Table III-1 prior to applying the covering. A reasonable effort must be made to minimize the contamination prior to use of any covering.
3. The radioactivity on the interior surfaces of pipes, drain lines, or ductwork shall be determined by making measurements at all traps, and other appropriate access points, provided that contamination at these locations is likely to be representative of contamination on the interior of the pipes, drain lines, or ductwork. Surfaces of premises, equipment, or scrap which are likely to be contaminated but are of such size, construction, or location as to make the surface inaccessible for purposes of measurement shall be presumed to be contaminated in excess of the limits.
4. Upon request, the Commission may authorize a licensee to relinquish possession or control of premises, equipment, or scrap having surfaces contaminated with material in excess of the limits specified. This may include, but would not be limited to, special circumstances such as razing of buildings, transfer of premises to another organization continuing work with radioactive materials, or conversion of facilities to a long-term storage or standby status. Such request must:

- a. Provide detailed, specific information describing the premises, equipment or scrap, radioactive contaminants, and the nature, extent, and degree of residual surface contamination.
 - b. Provide a detailed health and safety analysis which reflects that the residual amounts of material on surface areas, together with other considerations such as prospective use of the premises, equipment or scrap, are unlikely to result in an unreasonable risk to the health and safety of the public.
5. Prior to release of premises for unrestricted use, the licensee shall make a comprehensive radiation survey which establishes that contamination is within the limits specified in Table III-1. A copy of the survey report shall be filed with the Division of Fuel Cycle and Material Safety, USNRC, Washington, D.C. 20555, and also with the Director of the Regional Office of the Office of Inspection and Enforcement, USNRC, having jurisdiction. The report should be filed at least 30 days prior to the planned date of abandonment. The survey report shall:
- a. Identify the premises.
 - b. Show that reasonable effort has been made to eliminate residual contamination.
 - c. Describe the scope of the survey and general procedures followed.
 - d. State the findings of the survey in units specified in the instruction.

Following review of the report, the NRC will consider visiting the facilities to confirm the survey.

Table III-1. Acceptable surface contamination levels

Nuclides ^a	Average ^{b,c,f}	Maximum ^{b,d,f}	Removable ^{b,e,f}
U-nat, U-235, U-238, and associated decay products	5,000 dpm α /100 cm ²	15,000 dpm α /100 cm ²	1,000 dpm α /100 cm ²
Transuranics, Ra-226, Ra-228, Th-230, Th-228, Pa-231, Ac-227, I-125, I-129	100 dpm/100 cm ²	300 dpm/100 cm ²	20 dpm/100 cm ²
Th-nat, Th-232, Sr-90, Ra-223, Ra-224, U-232, I-126, I-131, I-133	1,000 dpm/100 cm ²	3,000 dpm/100 cm ²	200 dpm/100 cm ²
Beta-gamma emitters (nuclides with decay modes other than alpha emission or spontaneous fission) except Sr-90 and other noted above.	5,000 dpm $\beta\gamma$ /100 cm ²	15,000 dpm $\beta\gamma$ /100 cm ²	1,000 dpm $\beta\gamma$ /100 cm ²

^aWhere surface contamination by both alpha- and beta-gamma-emitting nuclides exists, the limits established for alpha- and beta-gamma-emitting nuclides should apply independently.

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

^cMeasurements of average contaminant should not be averaged over more than 1 square meter. For objects of less surface area, the average should be derived for each such object.

^dThe maximum contamination level applies to an area of not more than 100 cm².

^eThe amount of removable radioactive material per 100 cm² of surface area should be determined by wiping that area with dry filter or soft absorbent paper, applying moderate pressure, and assessing the amount of radioactive material on the wipe with an appropriate instrument of known efficiency. When removable contamination on objects of less surface area is determined, the pertinent levels should be reduced proportionally and the entire surface should be wiped.

^fThe average and maximum radiation levels associated with surface contamination resulting from beta-gamma emitters should not exceed 0.2 mrad/hr at 1 cm and 1.0 mrad/hr at 1 cm, respectively, measured through not more than 7 milligrams per square centimeter of total absorber.

Excerpts from
Proposed
ANSI N328-197

Proposed American National Standard

Control of Radioactive Surface Contamination
on Materials, Equipment, and Facilities to be
Released for Uncontrolled Use

Secretariat
Health Physics Society

Property shall not be released for uncontrolled use unless documented measurements show the total and removable contamination levels to be no greater than the values in Table III-2 or Table III-3. (Table III-3 is easier to apply when the contaminants cannot be individually identified.)

Where potentially contaminated surfaces are not accessible for measurement (as in some pipes, drains, and ductwork), such property shall not be released pursuant to this standard, but made the subject of case-by-case evaluation. Credit shall not be taken for coatings over contamination.

Table III-2. Surface contamination limits

The levels may be averaged^a over the 1 m² provided the maximum activity in any area of 100 cm² is less than 3 times the limit value.

Nuclide	Limit (activity) dpm/100 cm ²	
	Total	Removable
Group 1: Nuclides for which the nonoccupational MPC ^b is 2×10^{-13} Ci/m ³ or less or for which the nonoccupational MPC ^c is 2×10^{-7} Ci/m ³ or less; includes Ac-227; Am ^w -241; -242m, -243; Cf-249; -250, -251, -252; Cm-243, -244, -245, -246, -247, -248; I-125, -129; Np-237; Pa-231; Pb-210; Pu-238, -239, -240, -242, -244; Ra-226, -228; Th-228, -238. ^d	100	20
Group 2: Those nuclides not in Group 1 for which the nonoccupational MPC ^b is 1×10^{-12} Ci/m ³ or less or for which the nonoccupational MPC ^c is 1×10^{-6} Ci/m ³ or less; includes Es-254; ^w Fm-256; I-126, -131, -133; Po-210; Ra-223; Sr-90; Th-232; U-232.	1000	200
Group 3: Those nuclides not in Group 1 or Group 2.	5000	1000

^aSee note following table on applications of limits.

^bMPC^a: Maximum Permissible Concentration in Air applicable to continuous exposure of members of the public as published by or derived from an authoritative source such as NCRP, ICRP, or NRC (10 CFR 20, Appendix B, Table 2, Column 1).

^cMPC^w: Maximum Permissible Concentration in Water applicable to members of the public.

^dValues presented here are obtained from 10 CFR Part 20. The most limiting of all given MPC values (e.g., soluble vs. insoluble) are to be used. In the event of the occurrence of a mixture of radionuclides, the fraction contributed by each constituent of its own limit shall be determined and the sum of the fractions must be less than one.

Table III-3. Alternate surface contamination limits

(All alpha emitters, except U-nat and Th-nat are considered as a group.)
The levels may be averaged over 1 m²^a provided the maximum activity in any area of 100 cm² is less than 3 times the limit value.

<u>Nuclide</u>	<u>Limit (activity)</u> <u>dpm/100 cm²</u>	
	<u>Total</u>	<u>Removable</u>
If the contaminant cannot be identified; or if alpha emitters other than U-nat and Th-nat are present; or if the beta emitters comprise Ac-227, Ra-226, Ra-228, I-125, and I-129.	100	20
If it is known that all alpha emitters are generated from U-nat and Th-nat; and beta emitters are present which, while not identified, do not include Ac-227, I-125, I-129, Ra-226, and Ra-228.	1000	200
If it is known that alpha emitters are generated only from U-nat and Th-nat; and the beta emitters, while not identified, do not include Ac-227, I-125, I-129, Sr-90, Ra-223, Ra-228, I-126, I-131, and I-133.	5000	1000

^aNote on application of Tables III-2 and III-3 to isolated spots or activity:

For purposes of averaging, any m² of surface shall be considered to be contaminated above the limit, L, applicable to 100 cm² if:

- From measurements of a representative number, n, of sections, it is determined that $1/n \sum_{i=1}^n S_i \geq L$, where S_i is the dpm/100 cm² determined from measurement of section i; or
- On surfaces less than 1 m², it is determined that $1/n \sum_{i=1}^n S_i \geq AL$, where A is the area of the surface in units of m²; or
- It is determined that the activity of all isolated spots or particles in any area less than 100 cm² exceeds 3L.

SURGEON GENERAL'S GUIDELINES
Part 712
Grand Junction Remedial Action Criteria

Federal Register, Vol. 41, No. 253, pp. 56777-8, Thursday, December 30, 1976

PART 712 - GRAND JUNCTION
REMEDIAL ACTION CRITERIA

712.1 Purpose

(a) The regulations in this part establish the criteria for determination by ERDA of the need for, priority of, and selection of appropriate remedial action to limit the exposure of individuals in the area of Grand Junction, Colo., to radiation emanating from uranium mill tailings which have been used as construction-related material.

(b) The regulations in this part are issued pursuant to Publ. L. 92-314 (86 Stat. 222) of June 16, 1972.

712.2 Scope

The regulations in this part apply to all structures in the area of Grand Junction, Colo., under or adjacent to which uranium mill tailings have been used as a construction-related material between January 1, 1951, and June 16, 1972, inclusive.

712.3 Definitions

As used in this part:

(a) "Administrator" means the Administrator of the Energy Research and Development Administration or his duly authorized representative.

(b) "Area of Grand Junction, Colo.," means Mesa County, Colo.

(c) "Background" means radiation arising from cosmic rays and radioactive material other than uranium mill tailings.

(d) "ERDA" means the Energy Research and Development Administration or duly authorized representative thereof.

(e) "Construction-related material" means any material used in the construction of a structure.

(f) "External gamma radiation level" means the average gamma radiation exposure rate for the habitable area of a structure as measured near floor level.

(g) "Indoor radon daughter concentration level" means that concentration of radon daughters determined by: (1) averaging the results of 6 air samples, each of at least 100 hours duration, and taken at a minimum of 4-week intervals throughout the year in a habitable area of a structure, or (2) utilizing some other procedure approved by the Commission.

(h) "MilliRoentgen" (mR) means a unit equal to one-thousandth (1/1000) of a Roentgen which Roentgen is defined as an exposure dose of X or gamma radiation such that the associated corpuscular emission per 0.001293 gram of air produces, in air, ions carrying one electrostatic unit of quantity of electricity of either sign.

(i) "Radiation" means the electromagnetic energy (gamma) and the particulate radiation (alpha and beta) which emanate from the radioactive decay of radium and its daughter products.

(j) "Radon daughters" means the consecutive decay products of radon-222. Generally these include Radium A (polonium-218), Radium B (lead-218), Radium C (bismuth-214), and Radium C' (polonium-214).

(k) "Remedial action" means any action taken with a reasonable expectation of reducing the radiation exposure resulting from uranium mill tailings which have been used as construction-related material in and around structures in the area of Grand Junction, Colo.

(l) "Surgeon General's guidelines" means radiation guidelines related to uranium mill tailings prepared and released by the Office of the U.S. Surgeon General, Department of Health, Education and Welfare on July 27, 1970.

(m) "Uranium mill tailings" means tailings from a uranium mill operation involved in the federal uranium procurement program.

(n) "Working Level" (WL) means any combination of short-lived radon daughter products in 1 liter of air that will result in the ultimate emission of 1.3×10^5 MeV of potential alpha energy.

712.4 Interpretations

Except as specifically authorized by the Administrator in writing, no interpretation of the meaning of the regulations in this part by an officer or employee of ERDA other than a written interpretation by the General Counsel will be recognized to be binding upon ERDA.

712.5 Communications

Except where otherwise specified in this part, all communications concerning the regulations in this part should be addressed to the Director, Division of Safety, Standards, and Compliance, U.S. Energy Research and Development Administration, Washington, D.C. 20545.

712.6 General radiation exposure level criteria for remedial action

The basis for undertaking remedial action shall be the applicable guidelines published by the Surgeon General of the United States. These guidelines recommend the following graded action levels for remedial action in terms of external gamma radiation level (EGR) and indoor radon daughter concentration level (RDC) above background found within dwellings constructed on or with uranium mill tailings:

EGR	RDC	Recommendation
Greater than 0.1 mR/hr	Greater than 0.05 WL	Remedial action indicated
From 0.05 to 0.1 mR/hr	From 0.01 to 0.05 WL	Remedial action may be suggested
Less than 0.05 mR/hr	Less than 0.01 WL	No remedial action indicated

712.7 Criteria for determination of possible need for remedial action

Once it is determined that a possible need for remedial action exists, the record owner of a structure shall be notified of that structure's eligibility for an engineering assessment to confirm the need for remedial action and to ascertain the most appropriate remedial

measure, if any. A determination of possible need will be made if as a result of the presence of uranium mill tailings under or adjacent to the structure, one of the following criteria is met:

(a) Where ERDA approved data on indoor radon daughter concentration levels are available:

(1) For dwellings and schoolrooms: An indoor radon daughter concentration level of 0.01 WL or greater above background.

(2) For other structures: An indoor radon daughter concentration level of 0.03 WL or greater above background.

(b) Where ERDA approved data on indoor radon daughter concentration levels are not available:

(1) For dwellings and schoolrooms:

(i) An external gamma radiation level of 0.05 mR/hr or greater above background.

(ii) An indoor radon daughter concentration level of 0.01 WL or greater above background (presumed).

(A) It may be presumed that if the external gamma radiation level is equal to or exceeds 0.02 mR/hr above background, the indoor radon daughter concentration level equals or exceeds 0.01 WL above background.

(B) It should be presumed that if the external gamma radiation level is less than 0.001 mR/hr above background, the indoor radon daughter concentration level is less than 0.01 WL above background and no possible need for remedial action exists.

(C) If the external gamma radiation level is equal to or greater than 0.001 mR/hr above background but is less than 0.02 mR/hr above background, measurements will be required to ascertain the indoor radon daughter concentration level.

(2) For other structures:

(i) An external gamma radiation level of 0.15 mR/hr above background averaged on a room-by-room basis.

(ii) No presumptions shall be made on the external gamma radiation level/indoor radon daughter concentration level relationship. Decisions will be made in individual cases based upon the results of actual measurements.

712.8 Determination of possible need for remedial action where criteria have not been met

The possible need for remedial action may be determined where the criteria in 712.7 have not been met if various other factors are present. Such factors include, but are not necessarily limited to, size of the affected area, distribution of radiation levels in the affected area, amount of tailings, age of individuals occupying affected area, occupancy time, and use of the affected area.

712.9 Factors to be considered in determination of order or priority for remedial action

In determining the order or priority for execution of remedial action, consideration shall be given, but not necessarily limited to, the following factors:

- (a) Classification of structure. Dwellings and schools shall be considered first.
- (b) Availability of data. Those structures for which data on indoor radon daughter concentration levels and/or external gamma radiation levels are available when the program starts and which meet the criteria in 712.7 will be considered first.
- (c) Order of application. Insofar as feasible remedial action will be taken in the order which the application is received.
- (d) Magnitude of radiation level. In general, those structures with the highest radiation levels will be given primary consideration.
- (e) Geographical location of structures. A group of structures located in the same immediate geographical vicinity may be given priority consideration particularly where they involve similar remedial efforts.
- (f) Availability of structures. An attempt will be made to schedule remedial action during those periods when remedial action can be taken with minimum interference.
- (g) Climatic conditions. Climatic conditions or other reasonable considerations may affect the scheduling of certain remedial measures.

712.10 Selection of appropriate remedial action

(a) Tailings will be removed from those structures where the appropriately averaged external gamma radiation level is equal to or greater than 0.05 mR/hr above background in the case of dwellings and schools and 0.15 mR/hr above background in the case of other structures.

(b) Where the criterion in paragraph (a) of this section is not met, other remedial action techniques, including but not limited to sealants, ventilation, and shielding, may be considered in addition to that of tailings removal. ERDA shall select the remedial action technique or combination of techniques, which it determined to be the most appropriate under the circumstances.

ENVIRONMENTAL PROTECTION AGENCY
Title 40, Part 141

Drinking Water Regulations--Radionuclides

Interim Primary Drinking Water Regulations
Promulgation of Regulations on Radionuclides

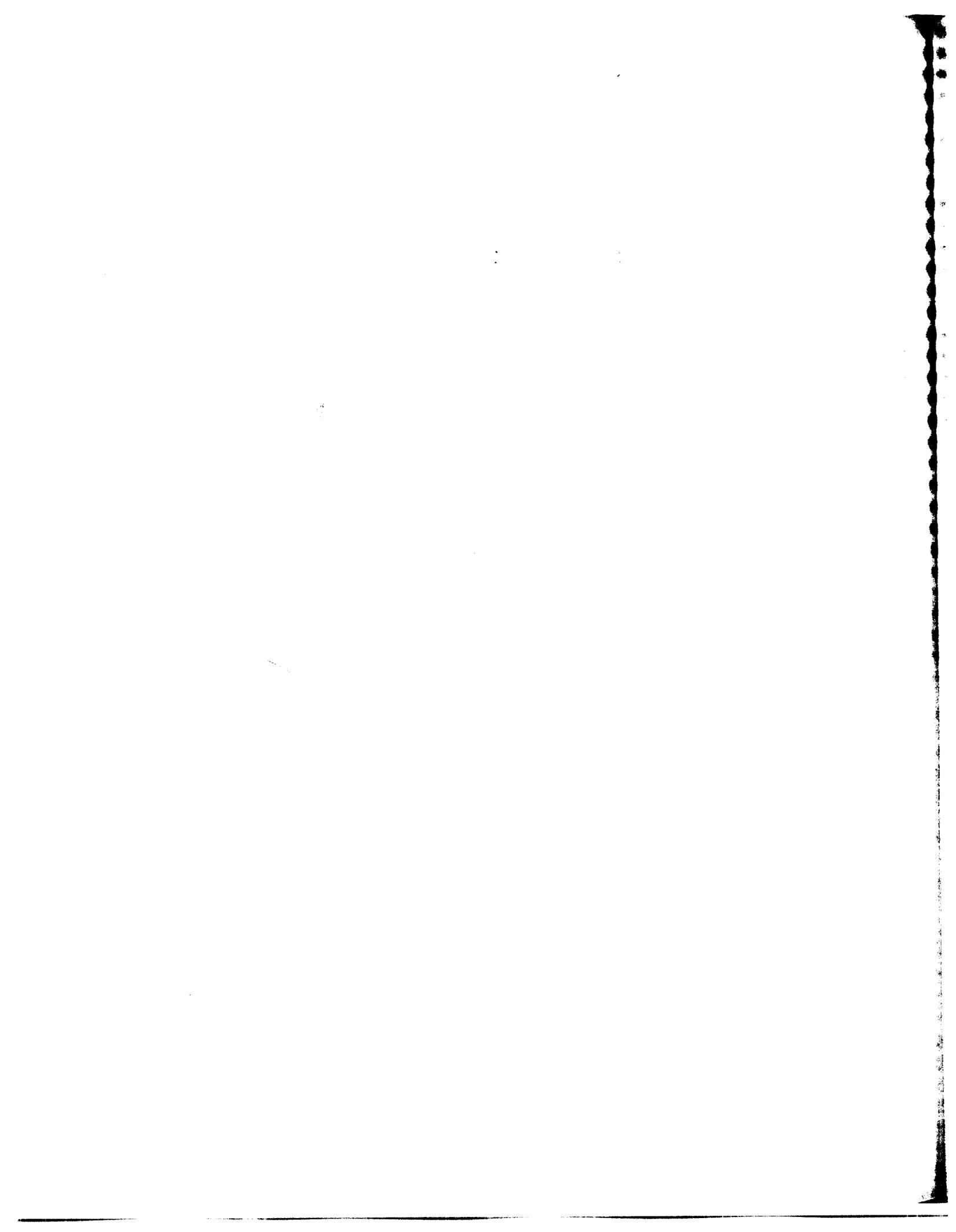
Federal Register, Vol. 41, No. 133, pp. 28402-9, Friday, July 9, 1976

Part 141.15 *Federal Register*

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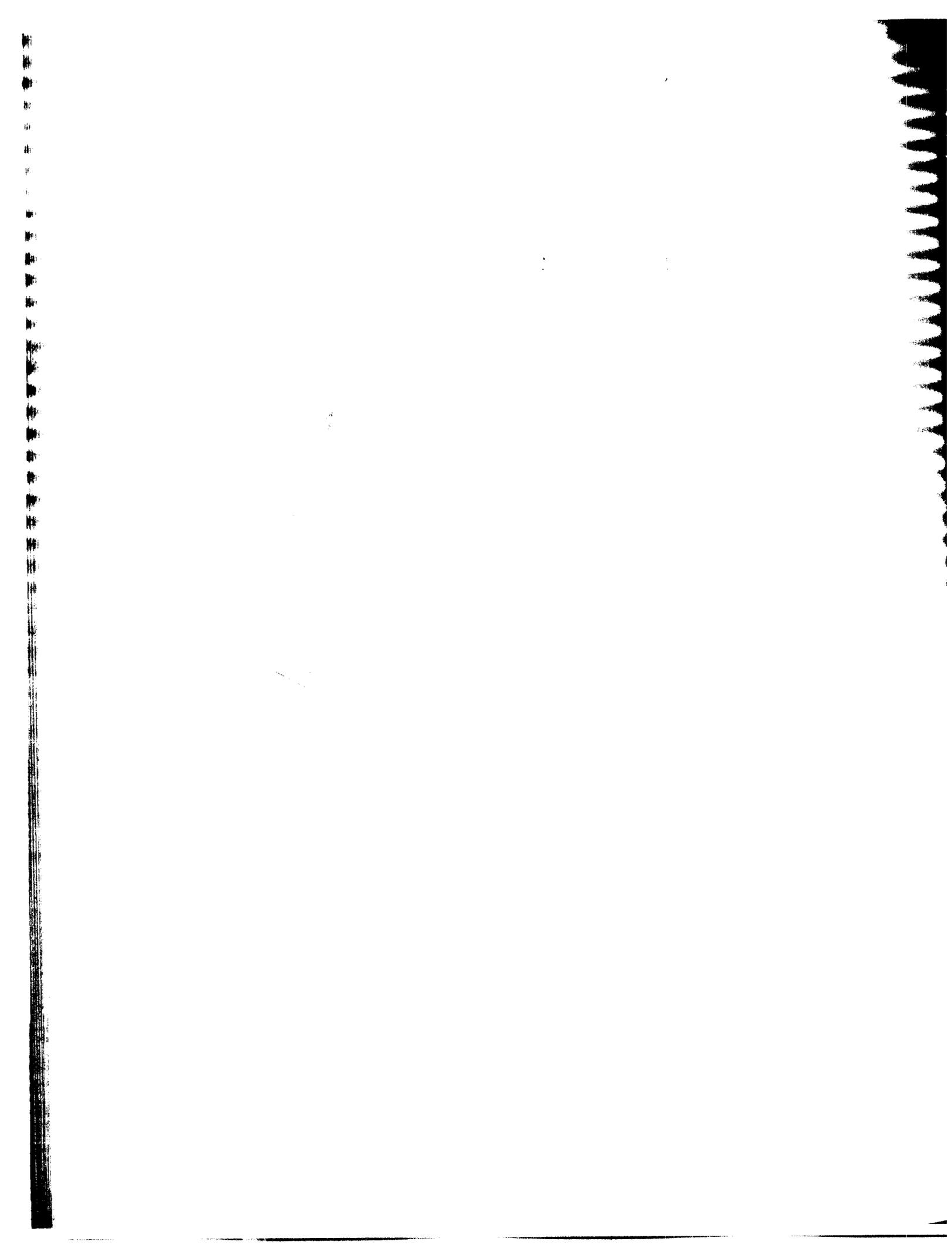
Maximum contamination levels for ^{226}Ra , ^{228}Ra , and gross alpha particle radioactivity.

- (a) Combined ^{226}Ra and ^{228}Ra - 5 pCi/liter.
- (b) Gross alpha particle activity (including ^{226}Ra but excluding radon and uranium) - 15 pCi/liter.



APPENDIX IV

EVALUATION OF RADIATION EXPOSURES AT THE FORMER MIDDLESEX
SAMPLING PLANT AND ASSOCIATED PROPERTIES,
MIDDLESEX, NEW JERSEY



The U.S. Department of Energy (DOE) has determined that the former Middlesex Sampling Plant (owned by the U.S. Government) in Middlesex, New Jersey, and some associated private properties in the Middlesex area are presently contaminated with radioactive residues resulting from previous uses of the sampling plant property. These associated properties consist of land adjacent to the former sampling plant and three parcels remote from the former sampling plant site. This contamination is producing radiation exposures to occupants of the former sampling plant and the associated properties. These exposures are summarized and compared numerically with guidelines and background radiation in Tables IV-1 and IV-2. (The former municipal landfill site is the subject of a separate report and has not been included herein.)

The naturally occurring radionuclides present at the sampling plant and associated sites are present in minute quantities throughout our environment. Concentrations of these radionuclides in normal soils, air, water, food, etc., are referred to as background concentrations. Radiation exposures resulting from this environmental radioactivity are referred to as background exposures. These background exposures are not caused by any human activity and, to a large extent, can be controlled only through man's moving to areas with lower background exposures. Each and every human receives some background exposures daily.

The use of radioactive materials for scientific, industrial, or medical purposes may cause radiation exposures above the background level to be received by workers in the industry and, to a lesser extent, by members of the general public. Scientifically based guidelines have been developed to place an upper limit on these additional exposures. Limits established for exposures to the general public are much lower than the limits established for workers in the nuclear industry.

In the 1940s and 1950s, the former Middlesex Sampling Plant facility functioned as a storage depot and a sampling plant for Belgian Congo uranium ore. The plant was decommissioned in the mid-1950s and sampling activities were moved to other locations. The Atomic Energy Commission (AEC) retained control over the site from 1946 to 1968, at which time it was turned over to the General Services Administration and, subsequently, to the Department of the Navy.

Table IV-1. Summary of exposure data at the former Middlesex Sampling Plant, Middlesex, New Jersey

Exposure source	Background levels	Guideline value for general public	Guideline value for radiation workers	Average levels at former Sampling Plant site
Radon in air	Less than one picocurie ^a per liter of air	Continuous exposure to 3 picocuries per liter of air	Exposure for 40 hours per week and 50 weeks per year to 30 picocuries per liter of air	Average daytime concentration ranged from 0.3 to 13 picocuries per liter of air
Radon daughters in air	Less than 0.01 working level ^b	0.01 working level for residences and school rooms, and 0.03 working level for other structures	0.33 working level for uranium miners exposed for 40 hours per week and 50 weeks per year	Average daytime concentration ranged from 0.003 working level to 0.15 working level
Gamma radiation from decay products of radium and uranium contamination	8 micro-Roentgens ^c per hour in the Middlesex area	250 microRoentgens per hour above natural background for 40 hours per week and 50 weeks per year for an individual in the general public. This is equivalent to 0.5 Roentgen per year	2500 microRoentgens per hour for 40 hours per week and 50 weeks per year. This is equivalent to 5 Roentgens per year	Average gamma radiation levels one meter above the floor or ground ranged from 8 to 340 microRoentgens per hour. Readings of up to 230 microRoentgens per hour were observed in the drainage ditch at the south end of the site

^aThe picocurie is a unit which is defined for expressing the amount of radioactivity present in a substance.

^bThe working level is a unit which is defined for radiation protection purposes for uranium miners. It represents a specific level of energy emitted by the short-lived daughters of radon.

^cThe Roentgen is a unit which is defined for radiation protection purposes for people exposed to penetrating gamma radiation. A microRoentgen is one millionth of a Roentgen.

Table IV-2. Summary of exposure data at property associated with the former Middlesex Sampling Plant, Middlesex, New Jersey, area

Exposure source	Background levels	Guideline value for general public	Guideline value for radiation workers	Average levels at associated properties
Radon in air	Less than one picocurie ^a per liter of air	Continuous exposure to 3 picocuries per liter of air	Exposure for 40 hours per week and 50 weeks per year to 30 picocuries per liter of air	Average concentration in rectory basement was 26.0 picocuries per liter. Average concentrations in first floor of rectory was 0.9 picocurie per liter. In residences on eastern boundary of former Sampling Plant site, average was 0.3 picocurie per liter, in commercial establishment on western boundary, average was 0.55 picocurie per liter
Radon daughters in air	Less than 0.02 working level ^b in basements	0.01 working level for residences and school rooms, and 0.03 working level for other structures	0.33 working level for uranium miners exposed for 40 hours per week and 50 weeks per year	Concentration in rectory basement ranged from 0.009 working level to 0.43 working level. In residences on eastern boundary of former Sampling Plant site, average was 0.004 working level; in commercial establishment on western boundary, average was 0.014 working level
Gamma radiation from decay products of radium and uranium contamination	8 micro-Roentgens ^c per hour in the Middlesex area	250 microRoentgens per hour above natural background for 40 hours per week and 50 weeks per year for an individual in the general public. For continuous exposure, this is equivalent to 60 microRoentgens per hour. Each of these is equivalent to 0.5 Roentgen per year	2500 microRoentgens per hour for 40 hours per week and 50 weeks per year. This is equivalent to 5 Roentgens per year	At rectory, average gamma radiation levels one meter above the ground ranged to 217 microRoentgens per hour; lawn averaged 50 microRoentgens per hour. Union Carbide parking lot ranged to 110 microRoentgens per hour and averaged 24 microRoentgens per hour. William Street property ranged to 350 microRoentgens per hour and averaged 50 microRoentgens per hour over the site. Properties along eastern boundary of former Sampling Plant ranged to 67 microRoentgens per hour with an average of 29 microRoentgens per hour; along the southern boundary ranged to 235 microRoentgens per hour with an average of 37 microRoentgens per hour

^aThe picocurie is a unit which is defined for expressing the amount of radioactivity present in a substance.

^bThe working level is a unit which is defined for radiation protection purposes for uranium miners. It represents a specific level of energy emitted by the short-lived daughters of radon.

^cThe Roentgen is a unit which is defined for radiation protection purposes for people exposed to penetrating gamma radiation. A microRoentgen is one-millionth of a Roentgen.

Until January 1979, the site was occupied by the U.S. Marine Corps, Sixth Motor Transport Battalion. The permanent staff of approximately ten marines spent most of their normal work period (40 hours per week) in the administration building, with no marine spending more than a few hours per week in the former process building. In addition to the regular staff, the site was used on a regular basis as a reserve training center, resulting in an occupation of the process building for an additional ten hours per month by up to 200 marines. At the present, the six buildings on this seven-acre tract are unoccupied.

During the 1976 investigation of radiological conditions at the former sampling plant, it was discovered that several properties adjacent to the site had been contaminated by radioactive materials originating from within the site. These materials were probably moved by natural wind and rain erosion. The contaminated properties along the eastern and southern boundaries are primarily residential and commercial, although many are currently undeveloped.

In 1978, an aerial radiological survey of the Middlesex area was conducted in order to determine whether significant quantities of radium-contaminated material had been transported to other off-site areas in the vicinity of the sampling plant. This aerial survey showed 13 areas where radiation levels were higher than those considered normal for this part of New Jersey. These areas include the sampling plant and a former municipal landfill on Mountain Avenue. Eight of these areas can be explained by the presence of outcroppings of a reddish-brown shale and the use of granite products. (These rocks commonly contain more naturally occurring radionuclides than do other rocks found in New Jersey.) No material from the former sampling plant is present in these eight areas.

The remaining three areas found in the aerial survey are private properties which were suspected to contain materials originating from the former sampling plant. The first of these properties is located on Harris Avenue and is the site of the Church of Our Lady of Mount Virgin. Structures at this site include the rectory, convent, garage, and both the old and new church buildings. It is believed that soil from the sampling plant was moved to the site in about 1947. Available records do not indicate whether the soil was dumped before or after construction of the rectory building.

The second site consists of a small area in a private vehicle parking lot at the north end of the Union Carbide Plant in Bound Brook, New Jersey. Available records fail to indicate any link between the contamination at the parking lot and the sampling plant.

The third site is a private residence on William Street in Piscataway, New Jersey. This 0.2-acre property is the site of a five-room, wood-frame house and a garage. One person lives at this address. A previous owner of the property notified DOE that he had taken soil from the former Middlesex Sampling Plant to use as fill dirt in the yard.

The contamination present at the former sampling plant site and associated properties consists primarily of uranium-238 and radium-226. Uranium-238 is believed to have been created when the earth was formed. It is still present today because it takes a very long time to decay. The half-life is a measure of the time required for radioactive decay; for uranium-238 it is 4.5 billion years. Thus, if you begin with one curie* of uranium-238, one-half curie will remain after 4.5 billion years. After 9 billion years, this would only be one-fourth curie of uranium-238, etc. As the uranium-238 decays, it changes into another substance--thorium-234. Thorium-234 is called the "daughter" of uranium-238. In turn, thorium-234 is the "parent" of protactinium-234. Radioactive decay started by uranium-238 continues as shown in Table IV-3 until stable lead is formed. The "decay product" listed in Table IV-3 is the radiation produced as the parent decays.

There are two principal ways in which people may be exposed to radiation at the former sampling plant and associated properties. These are inhalation of radionuclides in air and exposure to external gamma radiation. Additional exposures may be received in other ways (e.g., by eating foods grown in contaminated gardens). These exposures and their sources will be examined on a case-by-case basis.

*A curie is a unit defined for expressing the amount of radioactivity present in a substance; one curie represents 37 billion radioactive disintegrations per second.

Table IV-3. Uranium-238 decay series

Parent	Half-life	Decay products	Daughter
uranium-238	4.5 billion years	alpha	thorium-234
thorium-234	24 days	beta, gamma	protactinium-234
protactinium-234	1.2 minutes	beta, gamma	uranium-234
uranium-234	250 thousand years	alpha	thorium-230
thorium-230	80 thousand years	alpha	radium-226
radium-226	1,600 years	alpha	radon-222
radon-222	3.8 days	alpha	polonium-218
polonium-218 ^a	3 minutes	alpha	lead-214
lead-214 ^a	27 minutes	beta, gamma	bismuth-214
bismuth-214 ^a	20 minutes	beta, gamma	polonium-214
polonium-214 ^a	$\frac{2}{10,000}$ second	alpha	lead-210
lead-210	22 years	beta	bismuth-210
bismuth-210	5 days	beta	polonium-210
polonium-210	140 days	alpha	lead-206
lead-206	stable	none	none

^aShort-lived radon daughters.

Exposure from the Inhalation of Radionuclides in Air

As may be seen in Table IV-3, radium-226 changes to radon-222 as a result of radioactive decay. Radon-222 is an inert gas which can seep from the ground and enter buildings through floors, cracks, drains, etc., and by the influx of outside air. If not diluted by additional pure ventilation air, the concentration can build up in closed areas of buildings. The background concentration of radon inside buildings is typically less than one picocurie per liter of air.* Outdoor concentrations of radon are generally lower than those indoors.

Radioactive decay of radon is rapid (days) and gives rise to short-lived daughters as shown in Table IV-3. Background concentrations of radon daughters both inside and outside structures are typically less than 0.01 working level (WL).[†] Studies of the health of uranium and other hard-rock miners have established that inhalation of large quantities of radon daughters over long periods of time increases an individual's risk of contracting lung cancer. The present federal guide value for uranium mine workers (given by the Environmental Protection Agency [EPA]), when translated to the units discussed here, would limit mine workers to an exposure of 0.33 WL throughout the normal work period of 2,000 hours per year. This guide value is significantly lower than the exposures received by most of the miners included in the health studies mentioned above.

Former Sampling Plant Site

The deposits of radium-bearing residues in soil, storm drain sediments, and on building surfaces are the indirect sources of most of the radiation exposure to persons who might occupy this site.

As indicated in Table IV-1, occupants of this site could be exposed to average radon concentrations which are higher (four times higher or more) than the level suggested for continuous exposure to the general

*One picocurie is one million-millionth of a curie, previously defined.

[†]The working level is a unit which was defined for radiation protection purposes for uranium miners. It represents a specific level of energy emitted by the short-lived daughters of radon.

population. Guidelines discussed here are those given in Federal Regulation 10 CFR 20.*

The radon daughter concentrations measured in many areas of the process building at the former sampling plant exceed the guide value of 0.03 WL given in Federal Regulation 10 CFR 712.[†] This value is based on a recommendation of the U.S. Surgeon General for exposure to radon daughter products in structures (other than dwellings or schools) built on or with radium-bearing residues from the extraction of uranium from ores such as those sampled at this site. Although long-term air sampling is continuing, results of short-term measurements suggest that any persons employed in the process building could be exposed to radon daughter concentrations in air which exceed the guide value in 10 CFR 712 by as much as a factor of 5 or more.

At the present time, residents in the immediate vicinity of the former sampling plant are subject to a small increase in exposure to radon which emanates from residues on the site and which is transported in the atmosphere to areas off the site. The concentration of radon decreases quickly with distance away from the former sampling plant. For example, at distances of about 200 meters, radon concentrations cannot be distinguished from those considered normal for this part of New Jersey.

Associated Properties

Concentrations of radon measured in two residences along the eastern boundary of the sampling plant site ranged from 0.2 to 0.4 picocurie per liter of air; radon daughter concentrations ranged from 0.003 to 0.004 WL. In a commercial establishment along the western boundary of the sampling plant site, the radon concentration averaged 0.55 picocurie per liter; the radon daughter concentration averaged 0.014 WL. All these measurements were well below guideline values. However, exposures to radon daughter

*Title 10, Code of Federal Regulations, Part 20, is a regulatory document promulgated by the Nuclear Regulatory Commission and may be found in the *Federal Register*.

[†]Title, 10, Code of Federal Regulations, Part 712, is a document promulgated by the Energy Research and Development Administration (now Department of Energy) and may be found in the *Federal Register*.

concentrations in excess of guideline values could occur in residential structures which might subsequently be built over contaminated areas east or south of the former sampling plant site.

Measurements of the concentration of radon in the rectory of Our Lady of Mount Virgin church ranged up to 92.4 picocuries per liter of air in the basement and averaged approximately 26 picocuries per liter. Measurements on the first floor, which was very well ventilated, ranged up to 2.5 picocuries per liter. Many of the readings in the basement exceed the guideline value of 3.0 picocuries per liter for exposure of the general public as set forth in 10 CFR 20. The majority of this radon appears to be emanating through the outside basement walls. This indicates that radium-226 bearing material may have been used as backfill around these walls. Typically, in structures with basements (such as the rectory), the concentrations of radon-222 and its daughters are higher in the basements than they are on upper floors. Concentrations of radon daughters in the rectory basement ranged from 0.009 WL to 0.43 WL. Since these measurements were made during the summer when many doors and windows of the rectory were open, it is possible that annual average exposures to radon daughters in the rectory basement are greater than the guideline values of 10 CFR 712.

Exposure to External Gamma Radiation

As may be seen in Table IV-3, several of the daughters of radium-226 and of uranium-238 emit gamma radiation (gamma rays are penetrating radiation like X-rays). Hence, contaminated areas of the former sampling plant and the associated properties are sources of external gamma radiation exposure. Background external gamma radiation in the Middlesex area ranged from 5-10 microRoentgens* per hour with an average of 8 microRoentgens per hour. A single typical chest X-ray (according to Department of Health, Education, and Welfare data) might yield an exposure of about 27,000 microRoentgens, which is equivalent to 3,400 hours of exposure to the average background level in Middlesex.

*The Roentgen is a unit which was defined for radiation protection purposes for people exposed to penetrating gamma radiation. A micro-Roentgen is one-millionth of a Roentgen.

The National Council on Radiation Protection and Measurement (NCRP) has recommended a maximum annual whole-body exposure of 500,000 microRoentgens per year to an individual continually exposed in the general public. This value corresponds to 250 microRoentgens per hour for 2,000 exposure hours (40 hours per week and 50 weeks per year) or to approximately 60 microRoentgens per hour for continuous exposure. This guideline for exposure of an individual in the general public is ten times lower than the guideline established for a worker in the nuclear industry.

Former Sampling Plant Site

The gamma-radiation level at one meter above the ground ranged from 14 to 340 microRoentgens per hour, with an average over the site of 53 microRoentgens per hour. It appears that all persons who might be employed on this site would receive average gamma exposures that are below the guideline. Also, marines who were stationed at the sampling plant site for short periods of time (ten hours per month) received proportionately less exposure; exposure of these marines would not be considered to be significant compared to normal background gamma exposures.

Associated Properties

The drainage area south of the former sampling plant site showed external gamma readings which ranged from 10 to 150 microRoentgens per hour, with an average of 37 microRoentgens per hour. External gamma radiation levels at one meter above the ground in drainage ditches in this area ranged from 10 to 235 microRoentgens per hour. Where the drainage ditches merge with a main stream which flows to Ambrose Brook, the external gamma exposure level was 48 microRoentgens per hour. Furthermore, gamma radiation levels in the yards of residences along the eastern boundary of the sampling plant site ranged from 11 to 67 microRoentgens per hour, with an average of 29 microRoentgens per hour among these properties. Thus, if the drainage area south of the sampling plant site were to become occupied, external gamma exposures on these properties could exceed the guideline value.

External gamma exposures measured at one meter above the ground near the rectory of Our Lady of Mount Virgin ranged up to 217 microRoentgens per hour and averaged 50 microRoentgens per hour. Gamma

exposures inside the rectory ranged up to 44 microRoentgens per hour in the basement and averaged 10 microRoentgens per hour throughout the rectory. Gamma exposures at the Union Carbide parking lot ranged to 110 microRoentgens per hour and averaged 24 microRoentgens per hour over a circular area of approximately 50 feet in diameter. The remainder of the site averaged 9 microRoentgens per hour. Gamma exposure rates at the William Street property averaged 75 microRoentgens per hour in the front yard and 50 microRoentgens over the entire property. A maximum reading of 330 microRoentgens per hour was obtained in the front yard. Measurements made inside the house averaged 10 microRoentgens per hour, with a maximum reading of 17 microRoentgens per hour. The guideline is exceeded over much of the outdoor areas at both the rectory and the William Street property.

Other Considerations of Exposure

At the sampling plant site and at the associated properties, soil is contaminated with radium-226 to the extent that radon daughter concentrations in air within structures built over this soil would be expected to exceed the guidelines given in 10 CFR 712. In addition, actions which involve considerable scraping or tilling of dry soil, particularly in the areas showing high concentrations of radium in surface soil, could lead to human exposures through inhalation of airborne radioactive dust during the course of these actions.

The concentration of radionuclides in water samples taken at these sites were all well below the concentration guide for water set forth in 10 CFR 20.

Several of the parcels of private property adjacent to and along the eastern boundary of the sampling plant site are used for private gardens. Soil samples taken in these gardens showed radium-226 concentrations as high as 63.5 picocuries per gram (pCi/g), with an average concentration of 18 pCi/g in soil which might be used for gardens. The normal background concentration of radium-226 in soils of this area is approximately 1.0 pCi/g. The amount of radium ingested by eating crops grown in contaminated soil will vary according to the habits of the gardener. However, it appears that this concentration of radium-226 in garden soil could result in ingestion levels which approach or exceed

10 picocuries per day--a level at which the EPA suggests that remedial action be taken. Furthermore, soil at the rectory, Union Carbide parking lot, and Williams Street sites contains high levels of radium-226. Use of this soil in the future for the growth of crops could lead to significant exposures through consumption of crops which have incorporated radium-226.

Risk and Radiation Exposures

Risks resulting from radiation exposures should be considered within the context of other risks incurred in normal living. For simplicity, ordinary risks to health may be classified in four categories:

1. Unacceptable--problems with risk so high as to require immediate action, such as severe diseases where medical treatment is required to save a life.
2. Concerned--problems where people are willing to spend time and money to reduce potential hazards. Examples of this include the maintenance of public highways and signs, signals, fire departments, and rescue squads.
3. Recognized--problems where people may accept some inconvenience to avoid certain activities such as flying in airplanes, swimming alone, etc.
4. No great concern--problems with a low frequency of occurrence. There is an awareness of potential hazard, but an accompanying feeling that these problems occur only to other people.

An individual may be exposed to risks over which he can exercise some control (voluntary), and risks over which he feels he has no personal control or choice (involuntary).

Daily, an individual is confronted with decisions about risk which have an associated benefit--for example, driving a car. This can serve as an illustration that a voluntary, concerned risk may be deemed appropriate due to the desirable perceived benefit. As another example, an individual who smokes cigarettes has subjected himself to a risk of lung cancer which is about ten times higher than that for a nonsmoker.

For purposes of radiation protection, all radiation exposures are assumed to be capable of increasing an individual's risk of contracting cancer. A precise numerical value cannot be assigned with any certainty

to a given individual's increase in risk attributable to radiation exposure. The reasons for this are numerous; they include the individual's age at onset of exposure, variability in latency period (time between exposure and physical evidence of disease), the individual's personal habits and state of health, previous or concurrent exposure to other cancer-causing agents, and the individual's family medical history. Because of these variables, large uncertainties would exist in any estimate of the number of increased cancers in the small population which would occupy the sampling plant site and associated properties.

The normal annual death rate* from lung cancer for all population groups in Middlesex County (as of 1970) was 29.4 deaths per 100,000 population; in Somerset County (as of 1970), the rate was 26.0 deaths per 100,000 population. At the same time, the annual death rate from lung cancer for all population groups in the United States and the state of New Jersey were 21.1 and 25.7 deaths per 100,000 population, respectively. A one-year exposure to the guideline value for uranium miners (0.33 working level for 2,000 hours) might increase the risk of death due to lung cancer by approximately four percent.

The annual death rate from all types of cancer among all population groups in Middlesex County (as of 1970) was 184 deaths per 100,000 population; in Somerset County (as of 1970), the rate was 160 deaths per 100,000 population. At the same time, the death rate from all types of cancer for all population groups in the United States and in the state of New Jersey were 151 and 175 per 100,000 population, respectively. A one-year exposure to penetrating gamma radiation of 500,000 micro-Roentgens might increase the risk of death due to all types of cancer by about one-tenth of a percent. Exposures in excess of these guideline values would be expected to result in proportionately higher increases in risk. Consequently, any action taken to reduce either the rate or the duration of radiation exposures would also reduce the risk attendant to that exposure.

*Mortality statistics were obtained from data in *U.S. Cancer Mortality by County: 1950-1969*, prepared by the National Cancer Institute, 1973, available from U.S. Government Printing Office.

Remedial Measures

Guidelines quoted in this summary which have been established for occupational exposure of radiation workers are based on the philosophy that the benefit to the worker (gainful employment) far outweighs any risk associated with occupational radiation exposure. Radiation exposures to marines who were stationed at the site were unrelated to their normal jobs; no discernable benefits might be attributed to these exposures. Consequently, the small risks associated with the exposures appear to be unwarranted. The exposures which presently exist, as well as more serious potential exposures, could be alleviated by removal of the contaminated material or by covering the contaminated area with several feet of uncontaminated soil. In the latter case, provisions for maintenance of the fill would have to be provided.

Present exposures, and potential exposures due to changes in land use, are associated with radium-226 contamination of properties adjacent to the former sampling plant site. This contamination appears to have been carried to these properties by the runoff of rainfall. Remedial measures could include the removal of contaminated surface soil followed by backfill with uncontaminated soil.

Exposures at both the William Street property and at the rectory result from the presence of contaminated soil containing elevated levels of radium-226 and uranium-238. At each of these locations, the contaminated soil appeared to have been used as landfill. Remedial measures (yet to be determined) could include removal of all soil to a depth of about three feet, followed by backfill with uncontaminated soil. Most of the contamination at this church site is confined to the area immediately surrounding the rectory building. The rectory is currently experiencing elevated levels of radon and its short-lived daughters. This radioactivity appears to be seeping through the outer basement walls. Soil around these walls may need to be removed and replaced with uncontaminated soil.

SUMMARY

In summary, the former sampling plant in Middlesex, New Jersey, is contaminated with residues containing naturally occurring radionuclides. This contamination would produce radiation exposures to employees working at this site. However, the site is currently unoccupied. These exposures would approach and, in the case of radon daughters in the former process building, would exceed scientifically based guidelines. Future employees at the sampling plant site would receive no benefits from any involuntary exposures to radiation; the risk of cancer may be elevated somewhat by these exposures.

Individuals residing on properties adjacent to the former sampling plant are currently receiving radiation exposures from contamination which appears to have been washed onto their property by rainfall runoff. Also contaminated are three other associated properties in the Middlesex area: the Church of Our Lady of Mount Virgin, the parking lot at the Union Carbide Plant in Bound Brook, and a residence on William Street in Piscataway. This contamination is yielding elevated exposures to external gamma radiation. Furthermore, the contamination leads to elevated concentrations of radon and its daughters in the basement of the church rectory; these levels exceed pertinent guidelines. Available documentation supports the contention that the contamination at the church site and Williams Street residence originated at the sampling plant. However, it is not clear as to the origin of the material at the Union Carbide Plant.

Consequently, remedial measures appear to be called for. The Department of Energy has developed a coordinated plan which addresses the specific problems at the former Middlesex Sampling Plant and all associated properties. Currently, work is underway to implement the elements of this plan.

APPENDIX V

STANDARD UNITS OF MEASUREMENT

The following table has been developed for use with this report in the conversion of units of measurement from those utilized in the text to the newly adopted International System of Units (SI). Units used in the text which do not appear in this table are considered as standard under the new system.

Table V-1. Standard units of measurement

To Convert From	Into SI Units	Multiply By
gallons (gal)	liters (l)	3.785
inches (in)	centimeters (cm)	2.540
square inches (in ²)	square centimeters (cm ²)	6.452
feet (ft)	meters (m)	0.3048
square feet (ft ²)	square meters (m ²)	0.0929
acres (a)	hectare (ha)	0.4047
miles (mi)	kilometer (km)	1.61
millirad (mrad)	microgray (μGy)	10.0
microroentgen (μR)	coulomb per kilogram (C/kg)	2.58 x 10 ⁻¹⁰
disintegrations per minute (dpm)	becquerel (Bq)	0.02
picocurie (pCi)	becquerel (Bq)	0.037
microcurie (μCi)	becquerel (Bq)	3.7 x 10 ⁴

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