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Formerly Utilized MED/AEC Sites Remedial Action Program

Radiological Survey of the Middlesex Municipal Landfill, Middlesex, New Jersey

April 1980

Final Report

Prepared for

U.S. Department of Energy
Assistant Secretary for Environment
Office of Environmental Compliance and Overview
Division of Environmental Control Technology

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PREFACE

This series of reports results from a program initiated in 1974 by the Atomic Energy Commission (AEC) for determination of the condition of sites formerly utilized by the Manhattan Engineer District (MED) and the AEC for work involving the handling of radioactive materials. Since the early 1940's, the control of over 100 sites that were no longer required for nuclear programs has been returned to private industry or the public for unrestricted use. A search of MED and AEC records indicated that for some of these sites, documentation was insufficient to determine whether or not the decontamination work done at the time nuclear activities ceased is adequate by current guidelines.

This report contains the results of a survey of the current radiological condition of the Middlesex Municipal Landfill, Middlesex, New Jersey. Based upon the findings of the survey, there are low levels of radioactivity at various locations at this site and some type of remedial measures should be considered to preclude any future concern of inadvertent radiation exposure to people.

The work reported in this document was conducted by the following members of the Health and Safety Research Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee:

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RADIOLOGICAL SURVEY OF THE MIDDLESEX MUNICIPAL LANDFILL, MIDDLESEX, NEW JERSEY*

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ABSTRACT

A radiological survey was conducted at the Middlesex Municipal Landfill in Middlesex, New Jersey. In 1948, dirt contaminated with pitchblende ores was brought to this site from a former ore sampling plant in Middlesex. This survey was conducted in order to characterize the present radiological condition of the site and to determine the extent to which contamination is being transported from the site by natural means such as by drainage. The survey included measurement of (1) radionuclide concentrations in surface and subsurface soil on the site; (2) radionuclide concentrations in surface and subsurface water on the site and in Bound Brook; (3) beta-gamma dose rates and external gamma radiation levels on and near the site; and (4) the rate of ^{222}Rn emanation from the soil on the site.

It was found that most of the contamination on the site is in the top 14 ft of soil; however, there is little contamination of surface soil on the site. Average radon emanation rates, average external gamma radiation levels, and average beta-gamma dose rates on the site do not appear to be significantly higher than background levels. Furthermore, radionuclide concentrations in water taken from Bound Brook near the site were far below guide values stated in federal guidelines.

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*Research sponsored by the Division of Environmental Control Technology, U.S. Department of Energy, under contract W-7405-eng-26 with the Union Carbide Corporation.

SECTION I
1978 RADIOLOGICAL SURVEY OF THE MIDDLESEX MUNICIPAL LANDFILL

INTRODUCTION

At the request of the Department of Energy (DOE), a radiological survey was conducted at the Middlesex Municipal Landfill in Middlesex, New Jersey. The surveyed area included the outdoor region shown in Fig. 1, as well as points located along Bound Brook both upstream and downstream from this region.

During the 1940s, a poorly drained field on the grounds of the Middlesex Sampling Plant had been used as an ore storage area. Drums and ore containers were stored on this open ground. Occasionally, handling and transfer operations would result in spillage of small amounts of ore. Consequently, this area became contaminated by small pieces of pitchblende interspersed with the muddy soil. Recovery of this small amount of ore was not feasible under the conditions that existed.

In 1948, the Atomic Energy Commission (AEC) decided that this storage area should be paved. The area was graded smooth prior to black topping. The excess soil from the grading operation was transported to the Middlesex Municipal Landfill. This soil, contaminated by previous ore spillage, was dispersed over approximately 5 acres of the landfill and was used as fill or cover material for sanitary landfill operations.

In 1960, elevated gamma radiation levels were detected on this site by civil defense monitors during a local civil defense exercise. A radiological survey of the site was made at that time by the AEC, and it was found that external gamma radiation levels over an area of approximately 1/2 acre were 20 to 50 times the background levels found in the surrounding area. The elevated gamma radiation could be directly attributed to contamination in the soil transported from the Sampling Plant. After discussions with Borough of Middlesex officials, the AEC removed approximately 650 yd^3 of the contaminated material nearest the surface and covered the area with about 2 ft of uncontaminated dirt. This action reportedly lowered the external gamma radiation levels to no more than 50 μR/hr. The contaminated material was redeposited at an AEC-owned site in New Brunswick, New Jersey.

In 1963, a parcel of approximately 5 acres of the landfill site (originally owned by the Borough of Middlesex) was sold to the Middlesex Presbyterian Church; a church was subsequently constructed on that parcel. It was determined from discussions with local people that both the church and the Middlesex Municipal Building were constructed on "nonfill" or solid ground. This fact was confirmed during a survey of the landfill by the AEC in 1974 (results of this 1974 survey are presented in Section II of this report). The landfill site is surrounded by residences which approach to within 1/4 mile to the south and west and to the edge of Bound Brook on the eastern and northern edges. Results of the 1974 AEC survey indicate that contamination remaining on the property was in an area (See Fig. 1) of approximately 3 acres centered 400 ft northeast of the church.

The present radiological survey was conducted during June, 1978, by members of the Health and Safety Research Division of the Oak Ridge National Laboratory (ORNL). The survey was designed to provide additional data needed to supplement the 1974 survey and to provide a basis for comparison between site conditions in 1974 and the present. The survey included the following measurements: (1) beta-gamma dose rates at 1 cm from the surface and external gamma radiation levels at the surface and at 1 m above the surface throughout the site; (2) concentrations of ^{226}Ra and ^{238}U in surface and subsurface soil on the site; (3) concentrations of ^{226}Ra, ^{238}U, ^{230}Th, and ^{210}Pb in surface and groundwater on the site and in Bound Brook; (4) gamma radiation levels at various depths in auger holes drilled on the site as a means of estimating the ^{226}Ra concentrations at these locations; and (5) rate of emanation of ^{222}Rn from the ground surface.

SURVEY METHODS

Instrumentation

Measurement of Beta-Gamma Dose Rates and External Gamma Radiation Levels

Beta-gamma dose rates were measured with Geiger-Mueller (G-M) survey meters described in Appendix I. The meters were calibrated at ORNL using sealed isotopic sources and by comparison with a Victoreen Model 440 portable ionization chamber. It was determined that, for surfaces contaminated with ^{226}Ra in approximate equilibrium with ^{238}U and other radionuclides in the ^{238}U chain, an open-window reading of 2000 cpm is equivalent to approximately 1 mrad/hr.

Beta radiation cannot penetrate the closed window on the G-M probe; hence, only gamma radiation levels can be measured with the window closed. A significant difference in the open-window and closed-window readings on the G-M survey meter at some point indicates the presence of beta-emitting surface contamination, since most beta particles can penetrate only a few millimeters of dense materials such as soil.

External gamma radiation levels were measured with closed-window G-M survey meters, with the NaI scintillation meters described in Appendix I, and with the Phil gamma-ray dosimeter.[1] The scintillation detectors were standardized daily on the site through the use of sealed isotopic sources. The observed meter responses were standardized by comparison with the closed-window G-M survey meters at gamma radiation levels high enough that the rate meters on the instruments could be read accurately.

Methods Used to Analyze Samples

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 diam (35 mesh). Next, aliquots from each sample were transferred to plastic bottles, weighed, and counted using a Ge(Li) detection system to obtain the ^{226}Ra concentration. This system is coupled with a multichannel analyzer, which sorts pulses corresponding to different gamma-ray energies. The ^{226}Ra concentration is obtained through the use of a computer program which integrates under photon peaks corresponding to 352, 609, 1120, and 1764 keV; these are gamma-ray energies associated with daughters of ^{226}Ra. Because these photopeaks are used, counting is normally done about 30 days after grinding to allow equilibration of radon with ^{226}Ra. These estimates of ^{226}Ra concentrations are presented in this report. A description of the Ge(Li) detector and soil counting techniques is given in Appendix II.

A measurement of the ^{238}U concentration in each sample was obtained by neutron absorption analysis techniques.[2]

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 the neutron absorption techniques previously mentioned.[2] The activity reported for each radionuclide (except ^{238}U) in the water sediment samples represents only that percentage of the activity (normally between 50 and 100%) available by hot HNO_3 leaching.

All direct survey 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.

Survey Procedures

An area considered large enough to encompass all of the radioactive material on the site was divided into 100 ft x 100 ft "survey blocks" by the rectangular grid system shown in Fig. 1. Next, the area was subdivided into 50 ft x 50 ft survey blocks by dividing each 100 ft x 100 ft survey block in this area into four equal parts. At each grid point (i.e., at the intersection of mutually perpendicular grid lines) open- and closed-window G-M survey meter readings were taken at 1 cm from the surface, and a gamma scintillation survey meter reading was taken at 1 m above the surface. Then, each survey block in the area of suspected contamination was scanned with a gamma scintillation survey meter held near the surface. The maximum observed gamma radiation level in the block was recorded; and at the maximum gamma point, open- and closed-window G-M measurements were taken at 1 cm from the surface.

Holes were drilled with a motorized rig equipped with an 8-in.-diam auger, usually to depths of 10 to 20 ft., at the locations shown in Fig. 2. (Holes 1 through 9 were drilled and tested by ORNL in February, 1978, in conjunction with an engineering assessment of the site made by Ford, Bacon and Davis Utah.) A plastic pipe with a 4-in. inside 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 collimating slot 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. or 1-ft intervals. This "logging" of the core holes was done in order to define the profile of radioactivity underground and as a first step in determining the extent of subsurface contamination at each location. Moreover, the loggings were used to estimate the ^{226}Ra concentration in contaminated regions. The procedure used for these estimates is described in Appendix III. For each hole showing elevated gamma levels, a sample of the potentially contaminated material brought up by the auger was collected for analysis of ^{226}Ra and ^{238}U.

The results of auger hole loggings were used to select locations where further soil sampling would be useful. At points as close as practical to selected auger holes, a split-spoon sampler was used to collect soil at intervals of 6 in. throughout the contaminated zone. The concentrations of ^{226}Ra and ^{238}U were determined for these samples.

Surface samples were collected at the locations shown in Fig. 3. Most of the surface sampling locations (as well as the drilling locations) were chosen to provide random and representative sampling. However, those locations labeled "B" in Fig. 3 are "biased" in that they were chosen for sampling because of high radiation levels at these points.

Water samples were taken from each auger hole in which water was found. In addition, water samples were taken from Bound Brook at the locations described in Table 1. Most samples were analyzed for ^{226}Ra, ^{238}U, ^{230}Th, and ^{210}Pb.

Measurement of the Flux of ^{222}Rn

Since activated charcoal readily adsorbs ^{222}Rn, an estimate of the radon flux from ground surfaces was obtained by placing canisters containing charcoal in direct contact with the ground (see Ref. 3). After a period of exposure which ranged from 1 to 2 days, the canisters were removed, and the radon daughters were allowed to achieve equilibrium. The amount of radon adsorbed on the activated charcoal canister was determined by counting the gamma emissions from ^{214}Pb and ^{214}Bi using a 3 x 3-in. NaI scintillation detector coupled to a multichannel pulse height analyzer.

The canisters were distributed uniformly over the site. These modified U.S. Army M-11 gas mask canisters were twisted into the soil to a depth of 1 cm and sealed with additional soil. A total of 41 canisters was used (see Fig. 4). These individual readings were then used to estimate the average rate of emanation of ^{222}Rn over the entire site.

SURVEY RESULTS

Background Measurements

Background external gamma radiation levels at 1 m above the ground in the Middlesex vicinity range from 5 to 10 μR/hr; the average rate is 8 μR/hr. Concentrations of ^{226}Ra and ^{238}U in background soil in the Middlesex area are typically near 1 pCi/g. Background beta-gamma dose rates, as measured with the G-M survey meters used on the site, average approximately 0.01 or 0.02 mrad/hr.

Measurement of Beta-Gamma Dose Rates and External Gamma Radiation Levels

Grid point measurements of gamma radiation levels at 1 m are shown in Fig. 5. The value shown in each 100 x 100-ft survey block is the average of nine measurements taken at points uniformly spaced over the block. This same reporting scheme is used in Fig. 6, which shows the average measurements of the beta-gamma dose rate at 1 cm from the ground. It appears from these results that the area designated by the 1974 AEC survey as containing the bulk of the contamination did not display average radiation exposures which are significantly higher than the rest of the landfill site. However, there are isolated spots in this area which do show elevated levels of radiation exposure. The results of a scan of the area thought to be contaminated are shown in Fig. 7. Highly elevated readings were obtained in only three of the 50 ft x 50 ft survey blocks. The highest readings (1.1 mR/hr gamma ray only and 7.3 mrad/hr beta plus gamma ray) were taken directly on the surface and were associated with a small rock which was subsequently removed from the soil and returned to ORNL for analysis. Removal of this rock resulted in only a slight reduction in the gamma-ray exposure rate at the surface.

It should be emphasized that this radiation profile reflects only average external gamma radiation levels at 1 m and should not be interpreted as showing point-by-point radiation levels. It should also be pointed out that since the highest background external gamma radiation level measured in the vicinity of the site was 10 μR/hr, all measurements of 10 μR/hr and below should not be used to indicate contamination. As may be noted from Fig. 5, all survey blocks had average gamma radiation levels less than 10 μR/hr. Thus, the data indicate that the site has an average external gamma exposure rate which cannot be distinguished from the background level.

Only one area had external gamma radiation levels which exceeded the limits of background. This area of approximately 500 ft^2, located near grid point 4+0, 200R, shows an average external gamma exposure level at 1 m of 30 μR/hr.

According to Nuclear Regulatory Commission (NRC) guidelines given in Appendix IV for the release of property for unrestricted use, average and maximum beta-gamma dose rates measured at 1 cm should not exceed 0.2 mrad/hr and 1.0 mrad/hr, respectively. Only one reading on the site, in the general area of the maximum external gamma area mentioned above, exceeded this NRC limit. This elevated beta-gamma reading was associated with the previously mentioned rock which was removed for analysis. All other beta-gamma readings obtained on site were below NRC guidelines.

Results of Surface Soil Sample Analyses

Surface soil samples were collected at various points throughout the site. As discussed earlier, most sampling locations were chosen according to a scheme devised to provide random, unbiased sampling. Those samples which were taken at spots chosen because of high radiation levels are "biased" and are labeled with a "B" in Table 2. Concentrations of ^{226}Ra and ^{238}U in random surface samples are also listed in Table 2. Radium-226 concentrations in these random samples ranged up to 1.8 pCi/g, and ^{238}U concentrations ranged up to 2.3 pCi/g. The average concentration of ^{226}Ra and ^{238}U for all random surface samples was less than 1.0 pCi/g and 1.22 pCi/g, respectively. These values may be considered to be "background." The biased sample taken at location B2 (Fig. 3) showed a ^{226}Ra concentration of 150 pCi/g; this location coincided with the maximum observed gamma and beta-gamma radiation levels mentioned above. A small rock taken at location B4B (Fig. 3) a few inches beneath the surface showed a ^{238}U concentration of 1100 pCi/g.

Results of Subsurface Soil Sample Analyses

Holes were augered to depths of up to 25 ft at the locations shown in Fig. 2. At most of these locations, the material brought up by the auger was probed with an open-window G-M survey meter, and a sample of material showing elevated readings (or a sample taken at random, if no elevated readings were observed) was taken for analysis of ^{226}Ra and ^{238}U. The concentrations of these radionuclides in the "grab" samples are shown in Table 3.

At locations 12, 17, and 29, holes were "cored" rather than "augered." That is, a split-spoon sampler was used to collect subsurface samples at known depths. Concentrations of ^{226}Ra and ^{238}U in these core samples are shown in Table 3, along with results for "composite" samples (those for which the depth was not determined). It was impossible to take samples at certain depths due to the presence of buried tires, rags, and other rubbish.

Each of the auger holes and core holes was logged with a gamma scintillation probe as described in the section "Survey Methods." By comparison of the subsurface gamma radiation levels and the ^{226}Ra concentrations at the core hole locations, a procedure for estimating ^{226}Ra concentrations in subsurface soil from auger hole "loggings" was developed (see Appendix III). Estimates concerning the extent of the contaminated soil, as determined by the auger hole logging, are given in Table 4.

The general region in which the bulk of the subsurface contamination was found agrees with the region designated by the AEC report as containing the bulk of the contamination. This region is indicated in Fig. 8, along with a larger region where there is some scattered subsurface contamination or low-level contamination possibly due to leaching of radioactive materials. While the contaminated material appears to be very nonuniformly distributed, some generalizations concerning the extent of the contaminated material are indicated in Fig. 9.

Results of Radon Emanation Study

The rate of emanation of ^{222}Rn was measured by the technique described in the section "Survey Methods." Canister locations and results of radon emanation measurements are indicated in Fig. 4. It may be seen from these results that the average rate of emanation for the landfill site is approximately 0.23 pCi/m^2 per sec. The highest values were located in the area that has been designated in previous sections as containing the bulk of the contamination. In addition, some higher-than-average readings were obtained near the banks of the former path of Bound Brook. The rate at which ^{222}Rn emanates from soils containing background concentrations of ^{226}Ra has been measured by other investigators, and these values may be compared with the average rate found here. Wilkening[4] found ^{222}Rn emanation rates which averaged 0.42 pCi/m^2 per sec. Furthermore, background radon flux measurements previously taken in the Middlesex area[5] averaged 0.45 pCi/m^2 per sec. Thus, radon emanation from the landfill is less than the average rate found at background locations in the Middlesex area.

Radon and Radon Daughters

The results of the radon emanation studies at this site were used to estimate the probable maximum concentration of radon and radon daughters in air on the site. It is estimated that the maximum ^{222}Rn concentration at the site is less than 0.01 pCi/liter above the background concentration in the Middlesex area. This estimate employs an empirical relation developed by Schiager[6] and assumes conservative meteorological conditions. Furthermore, the radon concentration measured[7] on the roof of the Middlesex Municipal Building averaged 0.04 pCi/liter. The average concentration measured at two other Middlesex locations which could be considered as background was 0.06 pCi/liter.[7] It may be stated that the concentration of ^{222}Rn resulting from contamination at the site is indistinguishable from background.

The concentration of short-lived ^{222}Rn daughters is estimated to be less than 0.0001 working level.* The average radon daughter concentration measured in the parking lot of the Middlesex Municipal Building[7] was less than 0.001 working level. This may be compared with the average radon daughter concentration in the Middlesex area, which is typically 0.002 working level.[5]

Results of Water Sample Analyses

Concentrations of ^{210}Pb, ^{230}Th, ^{226}Ra, and ^{238}U in water samples taken from streams near the site that receive water from the site (directly or indirectly) are given in Table 1. In all cases, concentrations of these radionuclides were well below the concentration guides for water (RCG_w) stated in 10 CFR 20, Appendix B.[8] These radionuclide concentrations appear to be reasonably typical of background values.

Samples of groundwater which was encountered in drilling were taken from 11 holes. The results of analyses are found in Table 5. It may be noted that no sample had ^{226}Ra or ^{238}U concentrations which exceeded the concentration guides of 10 CFR 20.[8] The low concentrations of these

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*A working level is defined as any combination of short-lived radon daughters in 1 liter of air that will result in the ultimate emission of 1.3×10^5 MeV of alpha particle energy.

radionuclides indicate that leaching into groundwater and subsequent migration may not be very extensive at this site.

SUMMARY

In 1948, dirt contaminated with pitchblende ore was dumped on this site. A combination of analysis of subsurface soil samples and gamma scintillation probe "loggings" of 18 holes augered on this site to depths of 25 ft reveal the general location of the bulk of this contamination (see Figs. 8 and 9). Most of the contamination is in the top 14 ft of soil in an area covering 400 x 300 ft in the center of the site. There is little contamination in the surface soil. Average radon emanation rates, average external gamma radiation levels, and average beta-gamma dose rates do not appear to be significantly different from background levels. There may be some leaching of subsurface contaminants toward Bound Brook (see Fig. 8 and 9). However, available data indicate that the amount of leached material is very small at present. Furthermore, the spread of scattered activity into these areas may be attributable to previous landfill operations. Concentrations of ^{210}Pb, ^{230}Th, ^{226}Ra, and ^{238}U in water samples taken from Bound Brook near the site were far below guide values stated in 10 CFR 20, Appendix B, and were within the normal range of background concentrations.

An evaluation has been made of current radiation exposures at the Middlesex Municipal Landfill and is presented in Appendix V (page 67) of this report. The purpose of this evaluation is to present information which will permit the reader to compare current radiation exposures from the site to normal background exposures for that part of New Jersey, as well as to scientifically based guideline values established for the protection of radiation workers and members of the general public.

REFERENCES

1. G. S. Hurst and E. B. Wagner, "A Geiger-Mueller Gamma Ray Dosimeter with Low Neutron Sensitivity," *Health Phys.* 5, 20-26 (1960).
2. F. F. Dyer, J. F. Emery, and G. W. Leddicotte, *Comprehensive Study of the Neutron Activation Analysis of Uranium by Delayed Neutron Counting*, Oak Ridge National Laboratory Report ORNL-3342 (October, 1962).
3. R. J. Countess, "Measurement of Radon Flux with Charcoal Canisters," presented at the Workshop on Methods for Measuring Radiation In and Around Uranium Mills, Albuquerque, New Mexico, May 23-26, 1977.
4. M. H. Wilkening, W. E. Clements, and D. Stanley, "Radon-222 Flux Measurements in Widely Separated Regions," pp. 717-730 in *Proceedings of Natural Radiation Environment II* (John A. S. Adams, ed.), USERDA Report CONF-720805-P1, August 7-11, 1972.
5. *Radiological Survey of the Middlesex Sampling Plant, Middlesex, New Jersey*, Final Report, DOE/EV-0005/1 (November, 1977).
6. K. J. Schiager, "Analysis of Radiation Exposures on or Near Uranium Mill Tailings Piles," *Radiat. Data Rep.* 15, 411-425 (1974).
7. F. F. Haywood, P. T. Perdue, D. J. Christian, R. W. Leggett, and H. W. Dickson, *Radon and Radon Daughter Measurements At and Near the Former Middlesex Sampling Plant, Middlesex, New Jersey*, Oak Ridge National Laboratory Report ORNL-5489 (March, 1980).
8. Code of Federal Regulations, Title 10, Part 20.2, "Standards for Protection Against Radiation," Appendix B.

ORNL-DWG 78-20830

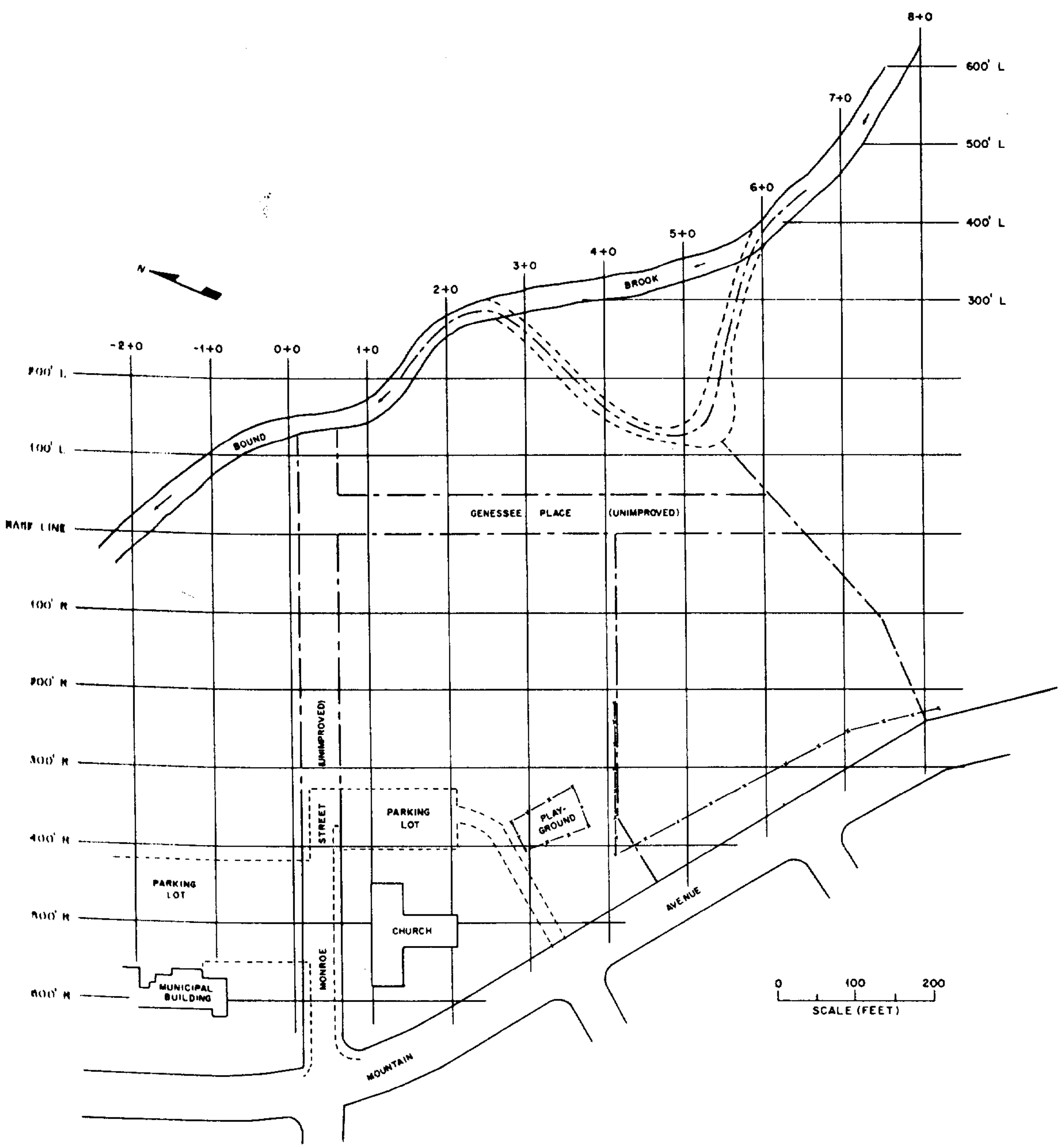

Fig. 1. Scaled drawing of surveyed area and grid systems needed for survey.

ORNL-DWG 78-20831

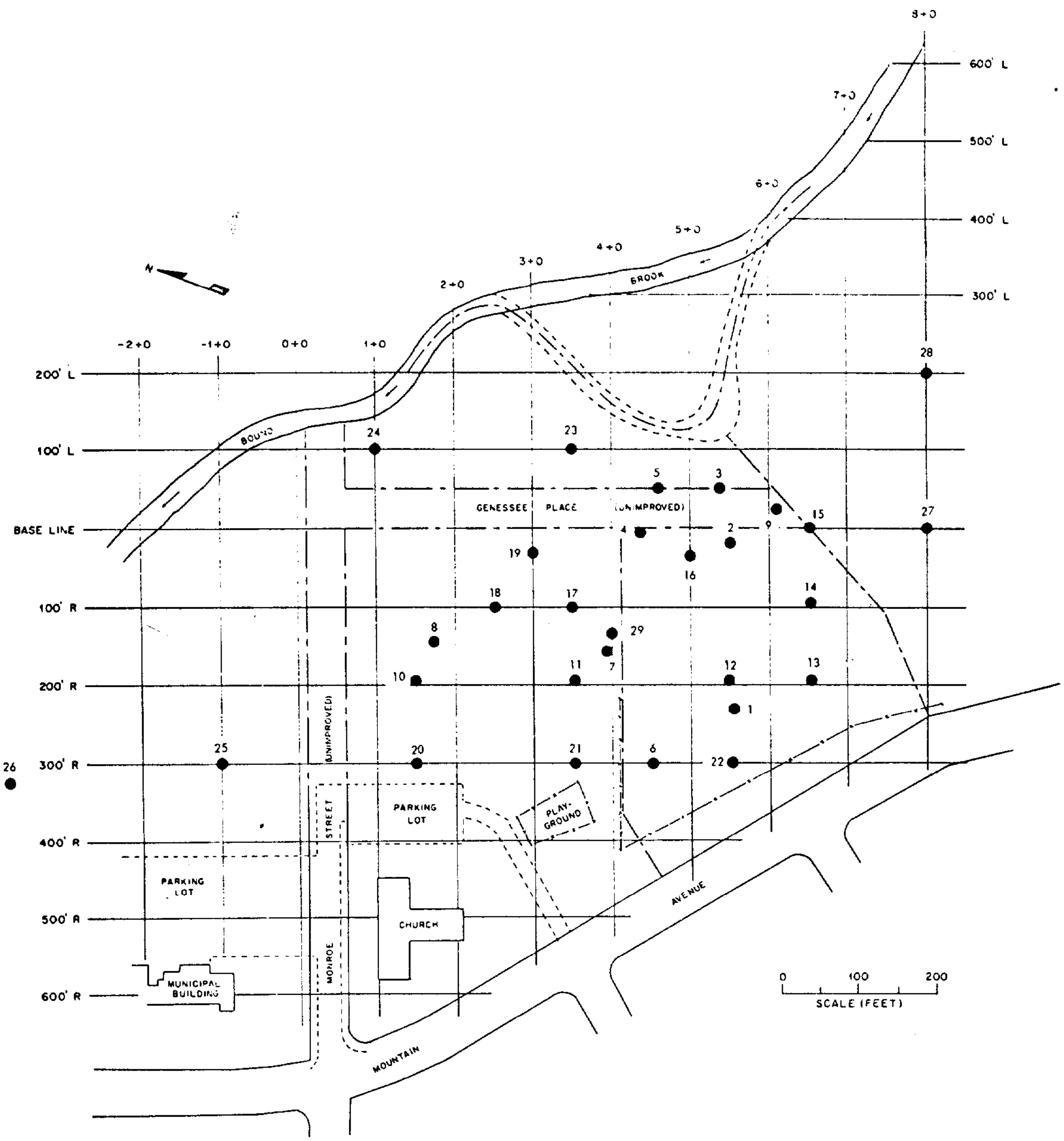

Fig. 2. Drill hole locations.

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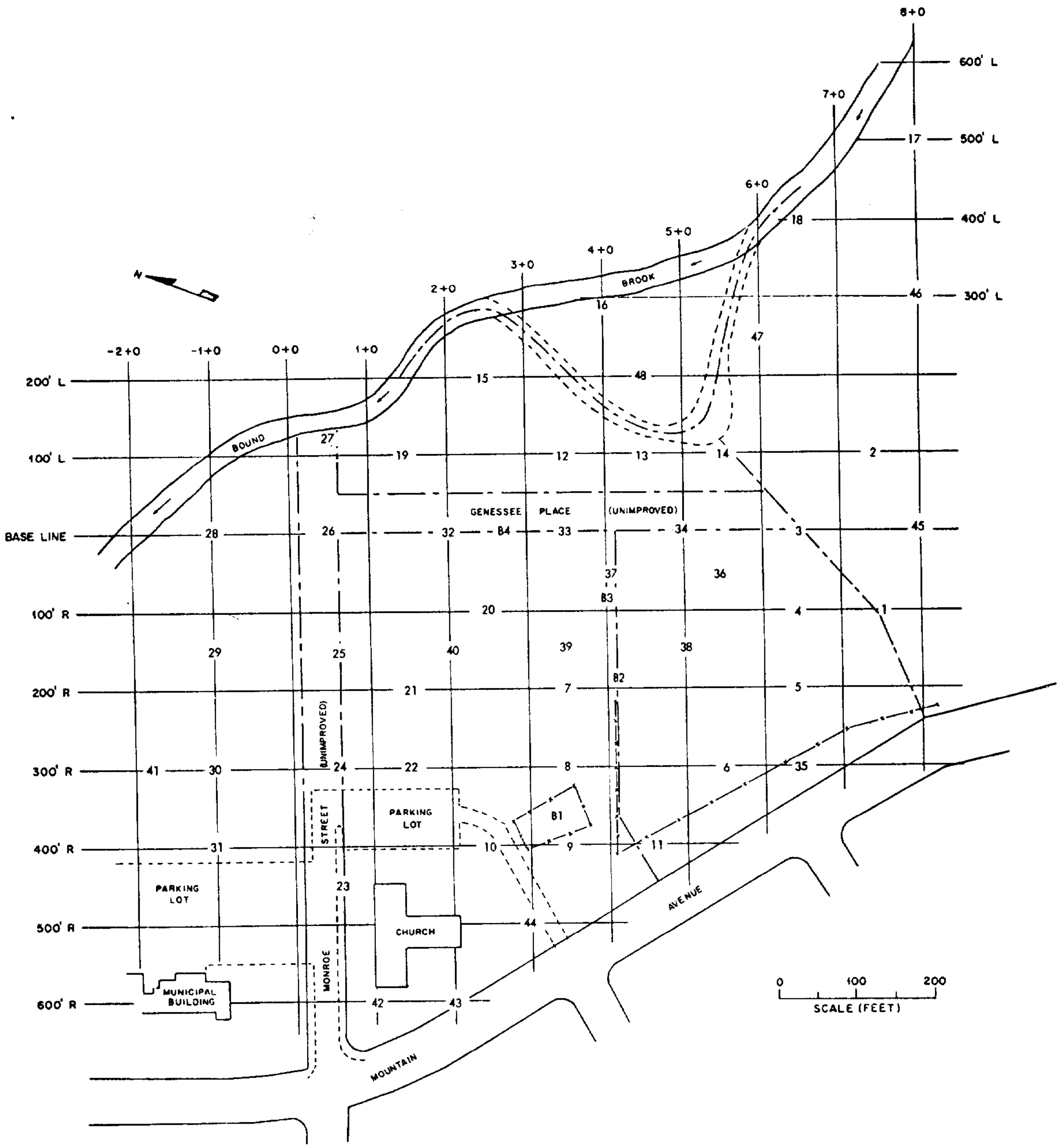

Fig. 3. Surface soil sampling locations.

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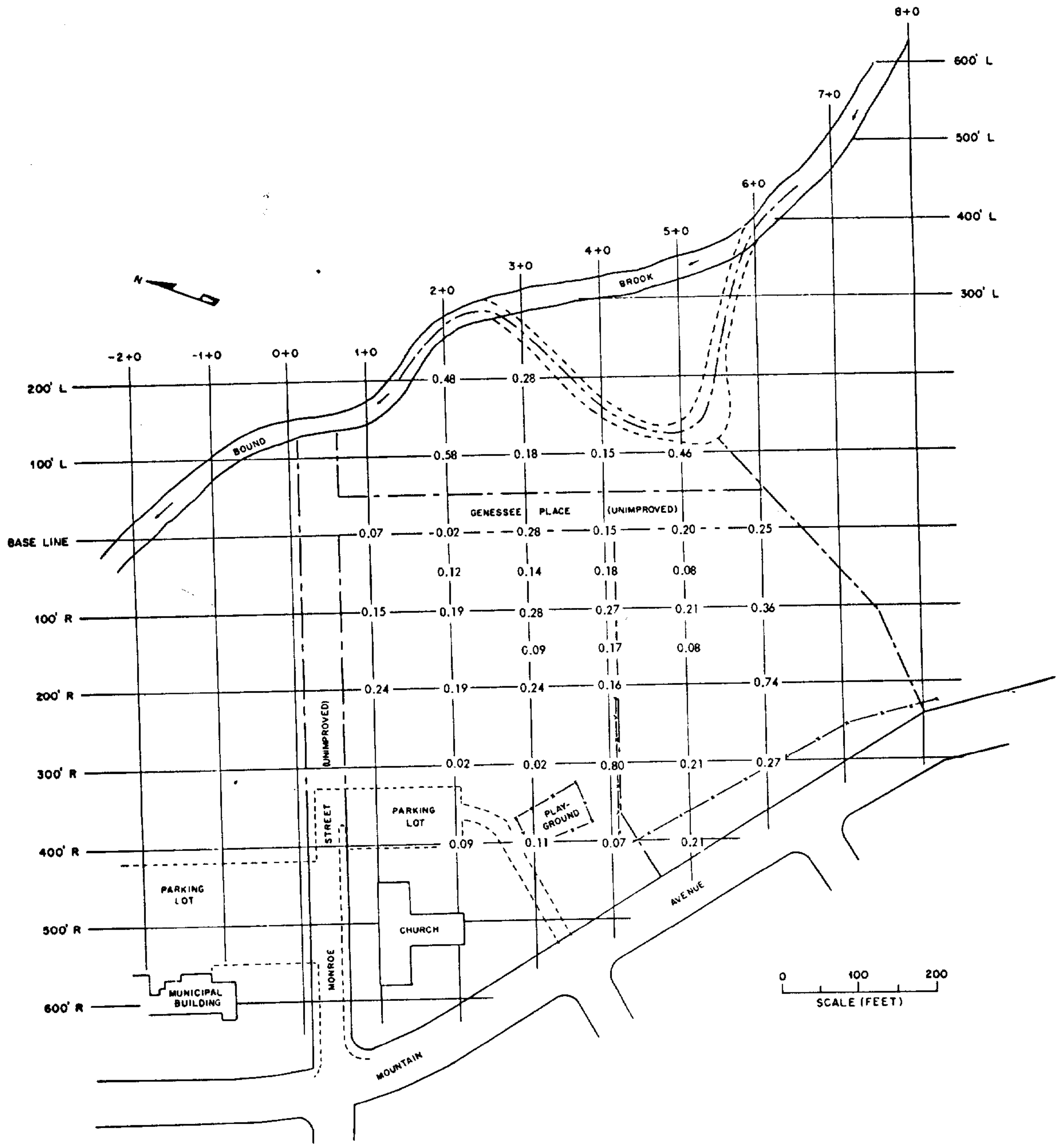

Fig. 4. Radon emanation rates (pCi/m^2 per sec) measured on the site.

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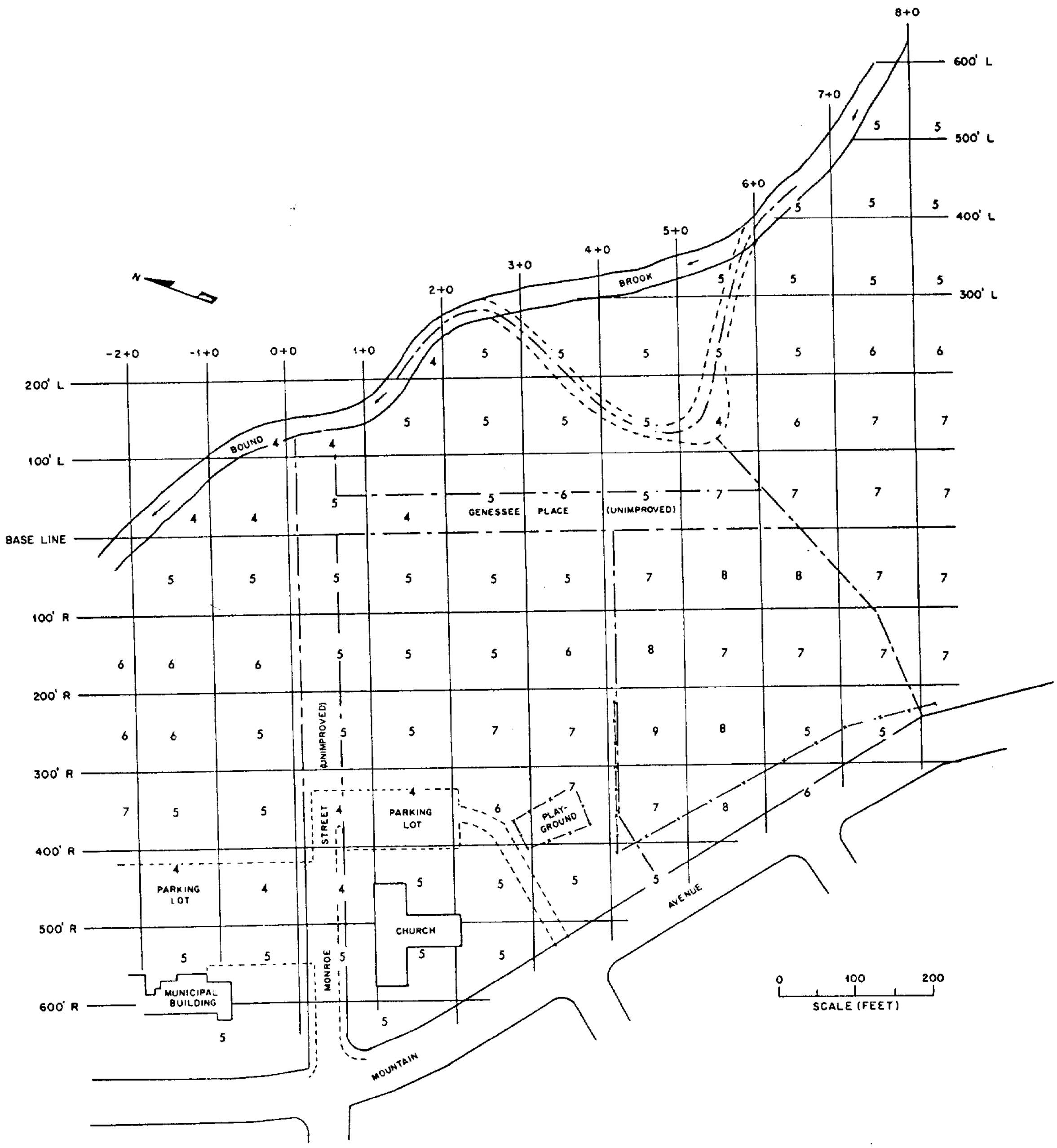

Fig. 5. Average external gamma radiation levels (μR/hr) in survey blocks.

ORNL-DWG 78-21412

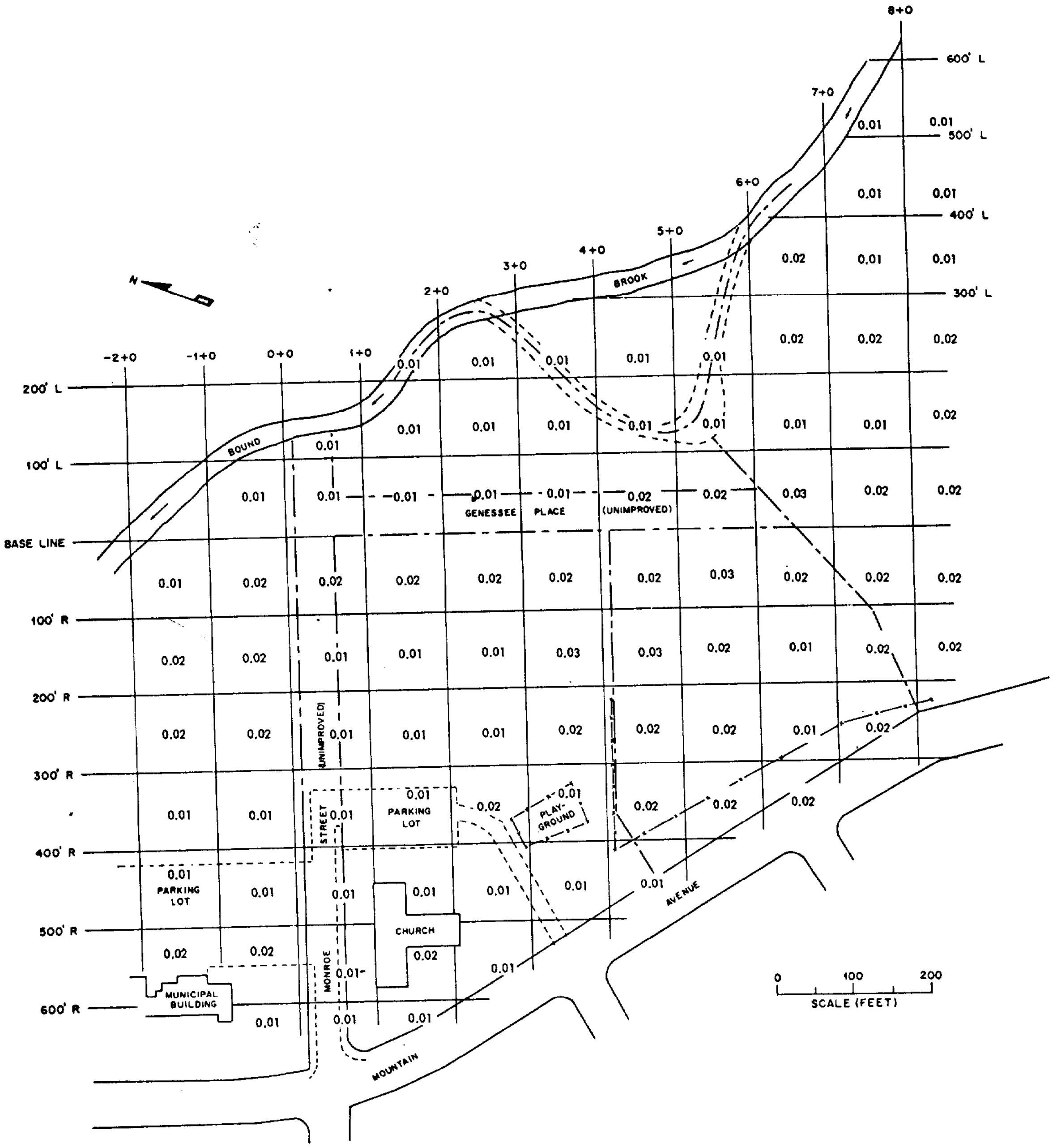

Fig. 6. Average beta-gamma dose rates (mrad/hr) at 1 cm in survey blocks.

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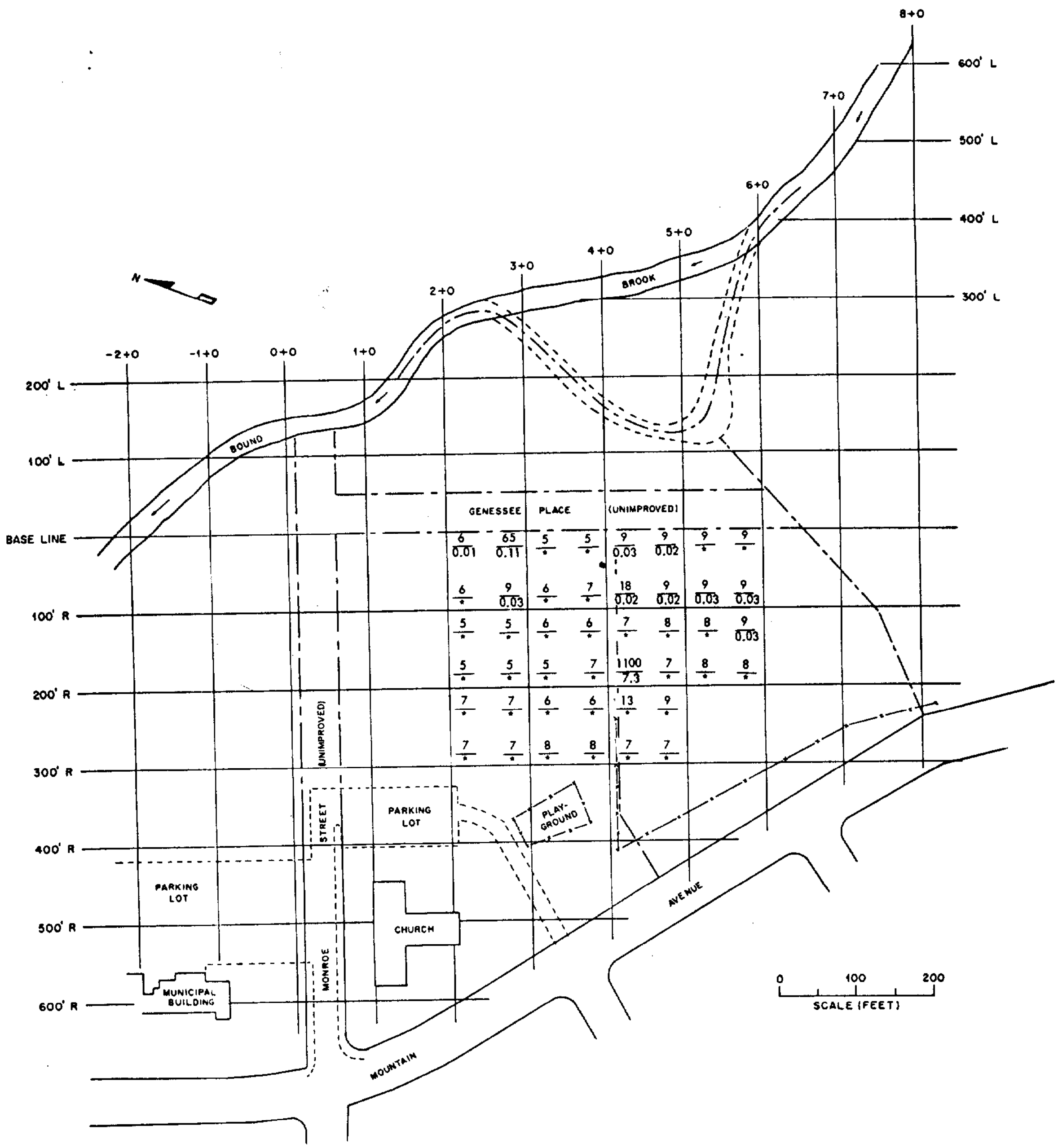

Fig. 7. Maximum measured external gamma radiation levels at surface (numerator, in μR/hr) and beta-gamma dose rate at 1 cm (denominator, in mrad/hr) in 50 ft x 50 ft survey blocks, with asterisks indicating uniform readings (see Fig. 6 for the uniform reading).

ORNL-DWG 78-21414

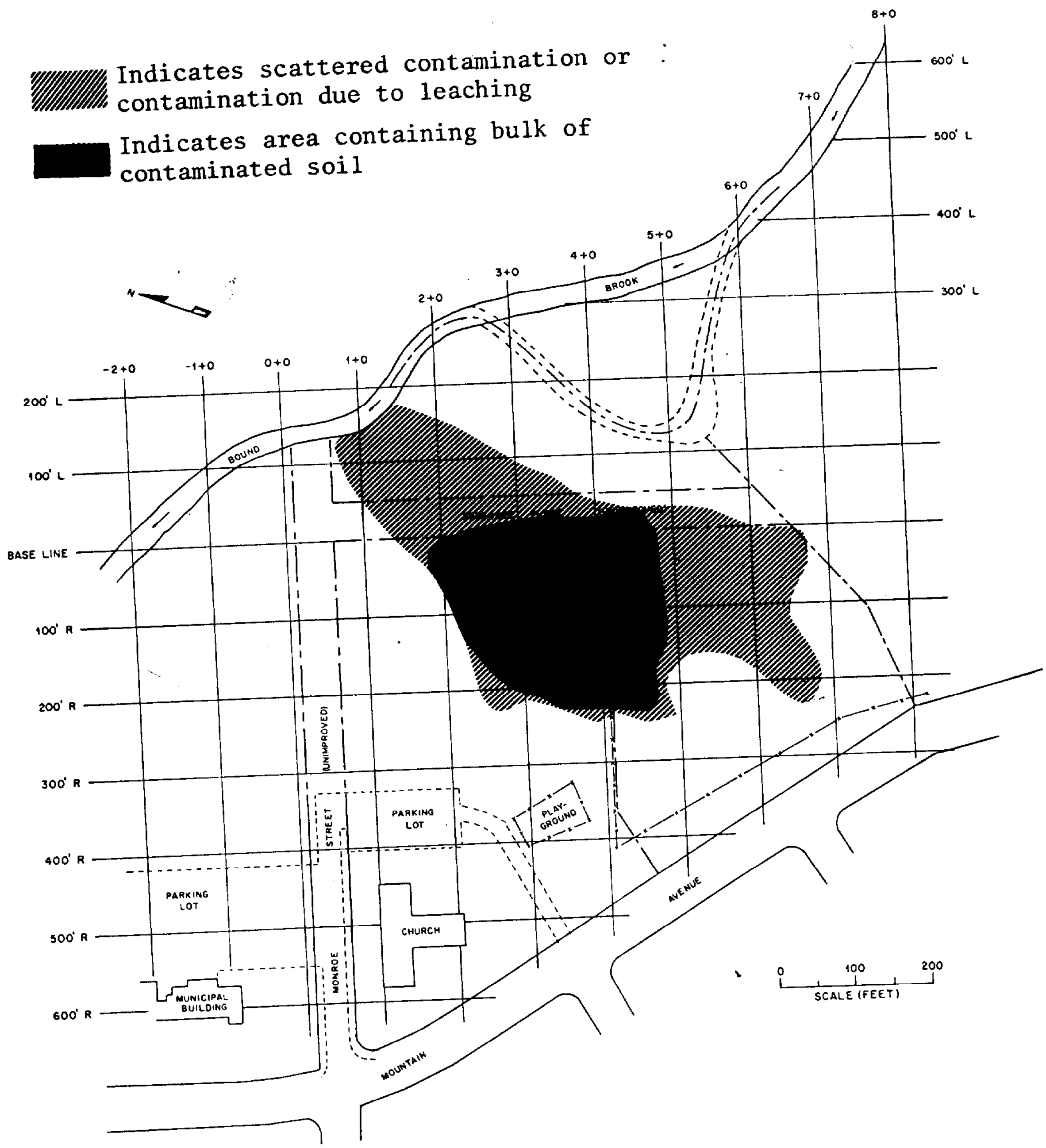

Fig. 8. Area containing contaminated soil.

ORNL-DWG 78-21415

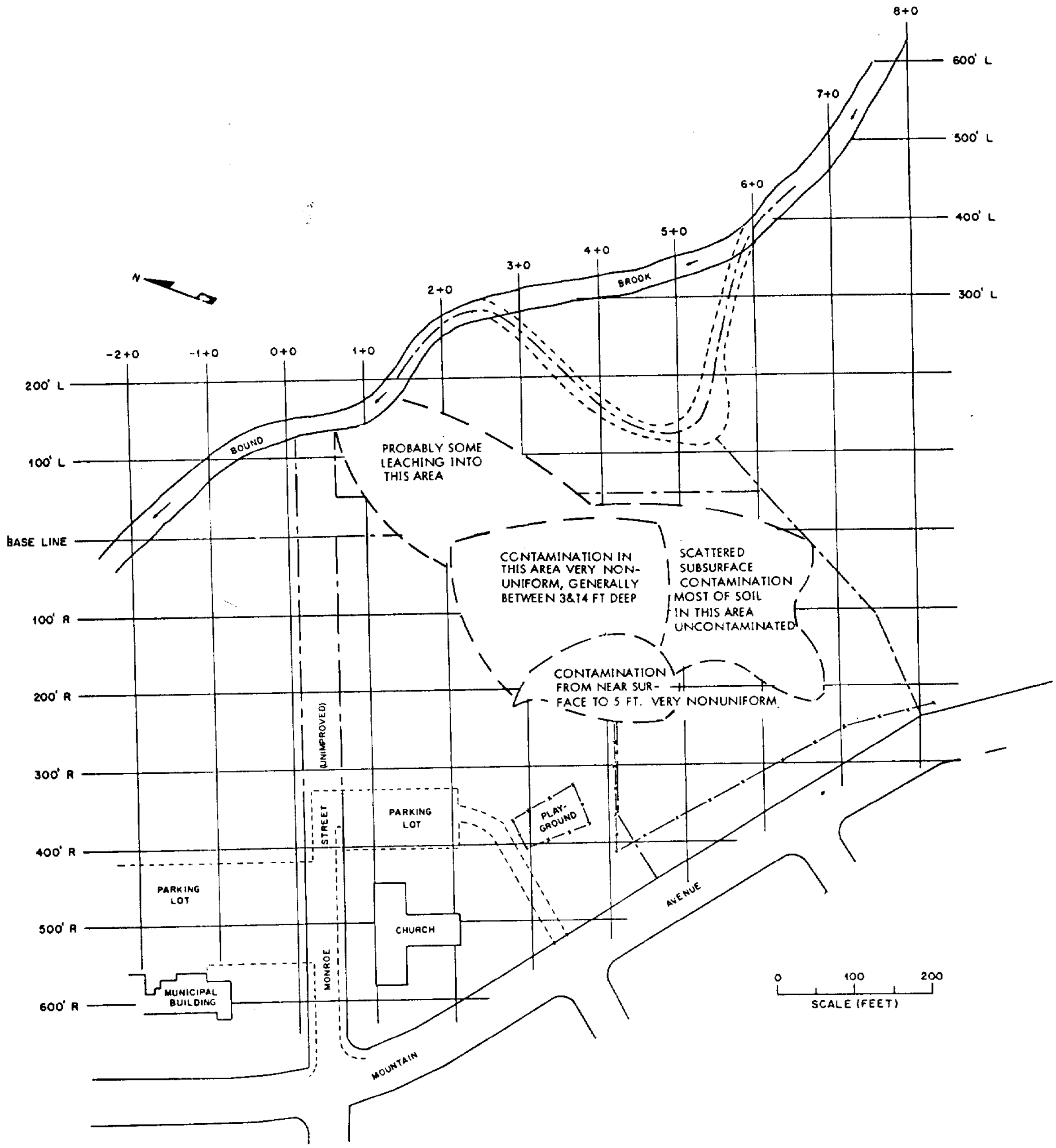

Fig. 9. Possible extent of contamination in various areas.

Table 1. Concentrations of ^{210}Pb, ^{230}Th, ^{226}Ra, and ^{238}U (pCi/ml) in water samples from streams receiving water from site

Sample designation	Location	^{210}Pb	^{230}Th	^{226}Ra	^{238}U
MOW20	Ambrose Brook at Raritan Avenue	<0.005	<0.0005	<0.0005	Background[a]
MOW21	Bound Brook at Union Avenue	<0.003	<0.0005	<0.0005	0.002
MOW22	Bound Brook at Bound Brook Road	<0.004	<0.0005	<0.0005	0.002
MOW23	Bound Brook 450 ft downstream from grid line 0+0 (Fig. 1)	<0.003	<0.001	<0.0005	0.004
MOW24	Bound Brook at grid line -1+0 (Fig. 1)	<0.004	<0.001	<0.0005	0.017
MOW25	Bound Brook at grid line 1+0 (Fig. 1)	<0.003	<0.0005	<0.0005	Background
MOW26	Bound Brook at grid line 3+0 (Fig. 1)	<0.003	<0.0005	<0.0005	0.0003
MOW27	Bound Brook at grid line 5+0 (Fig. 1)	<0.003	<0.0005	<0.0005	Background
MOW28	Bound Brook at grid line 7+0 (Fig. 1)	<0.004	<0.0005	<0.0005	0.0005
MOW29	Bound Brook at South Lincoln Avenue	<0.004	<0.0005	<0.0005	0.003
RCG_w (soluble)[b]		0.1	2	0.03	40

[a]"Background" is less than 0.02 ppm.

[b]10 CFR 20, Appendix B.

Table 2. Concentrations of ^{226}Ra and ^{238}U (pCi/g) in surface soil samples

Sample location shown in Fig. 3	^{226}Ra	^{238}U
1	0.9	1.1
2	1.2	1.4
3	1.0	1.2
4	0.9	1.2
5	0.2	0.2
6	0.8	1.1
7	0.7	0.9
8	0.7	1.6
9	0.9	0.9
10	0.6	0.6
11	1.1	1.3
12	1.4	1.1
13	0.8	1.1
14	0.3	0.4
15	0.7	1.5
16	1.0	1.7
17	0.9	1.0
18	0.5	0.9
19	1.0	1.3
20	0.4	0.6
21	0.9	0.6
22	0.6	0.7
23	0.7	0.9
24	1.4	1.8
25	0.8	1.1
26	1.2	2.3
27	0.5	0.9
28	0.6	1.0
29	0.6	0.7
30	0.9	1.3
31	0.5	0.7
32	0.7	0.9
33	0.4	0.6
34	1.0	1.2
35	0.7	0.7
36	0.7	1.0
37	0.6	0.8
38	0.4	0.5
39	0.9	1.3
40	0.8	0.7
41	0.8	1.3
42	0.5	1.2
43	0.6	0.6
44	0.6	0.4
45	0.7	1.0

Table 2 (cont.). Concentrations of ^{226}Ra and ^{238}U (pCi/g) in surface soil samples

Sample location shown in Fig. 3	^{226}Ra	^{238}U
46	0.7	1.1
47	0.5	0.8
48	0.8	2.0
B1	0.6	1.0
B2	150	93
B3	1.1	1.6
B4A	3.6	1.0
B2B[a]	--	1100

[a]This sample was actually a small rock taken a few inches beneath the surface; not enough sample was present for ^{226}Ra determination.

Table 3. Concentrations of ^{226}Ra and ^{238}U (pCi/g) in subsurface soil on the landfill site

Sample designation[a]	Depth (ft)	^{226}Ra	^{238}U
MCD1	--[b]	0.7	1.0
1A	0 - 2.0	1.0	1.2
1C	5.0- 7.0	0.8	0.9
1E	10.0-12.0	2.9	3.0
MCD2	--	0.6	0.7
2A	0 - 2.0	0.6	0.6
MCD3	--	1.5	2.0
3A	1.0- 2.0	2.8	2.4
3B	3.0- 5.0	1.0	2.5
3C	5.0- 7.0	0.7	1.5
3D	7.0- 9.0	0.7	0.7
MCD4	--	1.8	2.5
MCD5	--	1.1	2.8
5A	9.0-11.0	0.4	0.7
MCD6	--	0.6	0.6
6A	0 - 2.0	0.9	1.2
6C	5.0- 6.0	0.8	0.8
6D	6.0- 8.0	0.6	0.6
6E	8.0-10.0	0.6	0.6
6F	10.0-12.0	0.5	0.5
6G	12.0-14.0	0.5	0.8
MCD7	--	2.7	3.7
7A	0 - 2.0	12	0.7
7B	2.0- 3.0	1.5	1.2
7C	3.0- 4.0	5.5	5.5
MCD8	--	1.2	1.4
MCD9	--	0.7	0.9
9A	15.0-17.0	0.5	0.9
9B	20.0-22.0	1.0	1.0
MCD10	--	3.2	1.1
MCD11	--	2.2	2.3
MCD12	--	7.0	1.0
12A	0 - 1.0	0.9	1.2
12B	1.0- 2.0	1.0	1.3
12C	2.0- 3.0	0.9	1.2
12D	3.0- 4.0	0.7	1.0
12E	4.0- 5.0	0.6	1.3
12F	5.0- 6.0	0.6	0.7
12G	6.0- 7.0	0.6	0.9
12H	7.0- 7.5	0.5	0.7
12K	10.0-11.0	0.5	0.8
12L	11.0-12.0	0.6	0.7
12M	12.0-13.0	0.5	0.6
12N	13.0-14.0	0.4	0.5
MCD13	--	1.2	0.6

Table 3 (cont.). Concentrations of ^{226}Ra and ^{238}U (pCi/g) in subsurface soil on the landfill site

Sample designation[a]	Depth (ft)	^{226}Ra	^{238}U
MCD14	--	1.9	1.7
MCD15	--	170	140
MCD16	--	2.0	2.3
16A	0 - 1.0	0.8	1.1
16B	1.0- 2.0	0.8	1.3
MCD17	--	1000	630
17A	0 - 1.0	0.6	0.8
17B	1.0- 2.0	0.5	0.7
17C	2.0- 4.0	1.1	1.4
17E	4.0- 5.0	4.8	7.1
17F	5.0- 6.0	25	28
17G	6.0- 7.0	19	19
17H	7.0- 8.0	6.2	8.2
17I	8.0- 9.0	6.1	4.1
17J	9.0-10.0	2.0	2.1
MCD18	--	9.4	8.4
MCD19	--	12	11
MCD20	--	1.5	2.5
MCD21	--	0.7	1.1
MCD22	--	0.7	0.8
MCD23	--	1.4	2.3
MCD24	--	1.1	1.7
MCD25	--	1.6	1.4
MCD26	--	1.1	1.1
MCD27	--	1.1	1.1
MCD29A[c]	0 - 1.0	1.1	1.2
29B	1.0- 2.0	5.8	8.8
29C	2.0- 3.0	54	58
29D	3.0- 4.0	40	49
29F	5.0- 6.0	16	22
29G	6.0- 7.0	1.0	1.4
29J	8.0-10.0	2.0	3.0

[a]Number refers to hole locations as shown in Fig. 2.

[b]Samples for which no depth is given were taken from auger turnings while the hole was being drilled.

[c]Hole 28 collapsed before any samples could be taken.

Table 4. Estimated[a] concentrations of ^{226}Ra (pCi/g) in subsurface soil on the landfill site

Location shown in Fig. 2	Depth (ft)	^{226}Ra
10	0 -19.0	<1.0
11	0	9.0
	1.0	10
	2.0	21
	3.0	11
	4.0	9.0
	5.0	6.0
	6.0	7.0
	7.0	6.0
	8.0	5.0
	9.0	5.0
	10.0-12.0	<1.0
13	0	<1.0
	1.0	<1.0
	2.0	2.0
	3.0	<1.0
	4.0	4.0
	5.0	3.0
	6.0	4.0
	7.0	5.0
	8.0	4.0
	9.0	3.0
	10.0	4.0
	11.0	4.0
	12.0	5.0
	13.0	9.0
	14.0	10
	15.0	12
	16.0	4.0
	17.0	1.0
14	0-25.0	<1.0
15	0- 6.0	<1.0
	7.0	2.0
	8.0	3.0
	9.0	3.0
	10.0	5.0
	11.0	5.0
	12.0	5.0
	13.0	9.0
	14.0	27
	15.0	16
	16.0	6.0
	17.0	4.0
	18.0	3.0

Table 4 (cont.). Estimated[a] concentrations of ^{226}Ra (pCi/g) in subsurface soil on the landfill site

Location shown in Fig. 2	Depth (ft)	^{226}Ra
16	0-22.0	<1.0
18	0- 5.0	<1.0
	6.0	4.0
	7.0	12
	8.0	2
	9.0	<1.0
	10.0	2.0
	11.0-19.0	<1.0
19	0- 4.0	<1.0
	5.0	9.0
	6.0	21
	7.0	9.0
	8.0	47
	9.0	36
	10.0	8.0
	11.0	8.0
20	0-17.0	<1.0
21	0-18.0	<1.0
22	hole fell in	
23	0-10.0	<1.0
24	0-12.0	<1.0
	12.0-19.0	4.0
25	0-13.0	<1.0
26	0-12.0	<1.0
27	0-22.0	<1.0
28	hole fell in; no log	

[a]Estimated from gamma radiation intensities in auger holes.

Table 5. Concentrations of radionuclides in groundwater samples

Sample no.[a]	^{226}Ra (pCi/liter)	^{238}U (pCi/liter)
MCD10	<0.5	0.3
MCD15	0.9	4.1
MCD16	<0.5	<3[b]
MCD17	1.4	11
MCD18	<0.5	<3[b]
MCD20	1.4	<3[b]
MCD23	<0.5	10
MCD24	<0.5	3.2
MCD25	<0.5	<3[b]
MCD26	<0.5	5.0
MCD27	5.5	0.05

[a]Identification numbers refer to augered hole locations shown in Fig. 2

[b]For these samples, 3 pCi/liter of ^{238}U was the minimum measurable activity.

APPENDIX I

DESCRIPTION OF RADIATION SURVEY METERS

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 precalibrated Victoreen Model 440 ionization chamber (Fig. I-B). The open-window calibration factor was found to be 2000 cpm per mrad/hr for surfaces contaminated with ^{226}Ra in equilibrium with ^{238}U and 2300 cpm per mrad/hr for surfaces contaminated with initially pure uranium. The closed-window (gamma) calibration factor, determined by use of a National Bureau of Standards (NBS) standard ^{226}Ra source, was 3200 cpm per mrad/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 x 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 μR/hr to several hundred μR/hr. This instrument is calibrated at ORNL with an NBS standard ^{226}Ra source. Typical calibration factors are of the order of 300 cpm/μR per hr.

The mobile laboratories shown in Fig. I-D are used during each formal survey to serve as a control center and to house instruments and other equipment needed during the survey. Each lab is equipped with its own electric generator and mobile radio-telephone as well as its own set of calibrated survey instruments. One of the mobile labs has its own microcomputer for data reduction in remote locations.

ORNL-Photo 6704-76

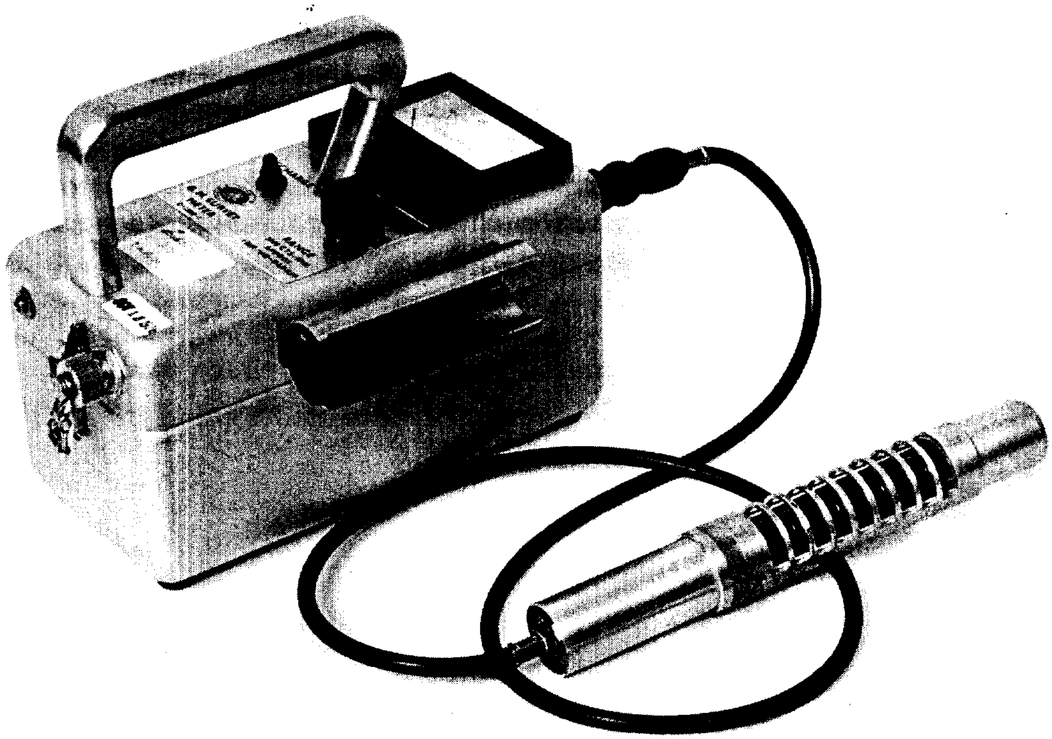

Fig. I-A. Geiger-Mueller survey meter.

ORNL-Photo 6710-76

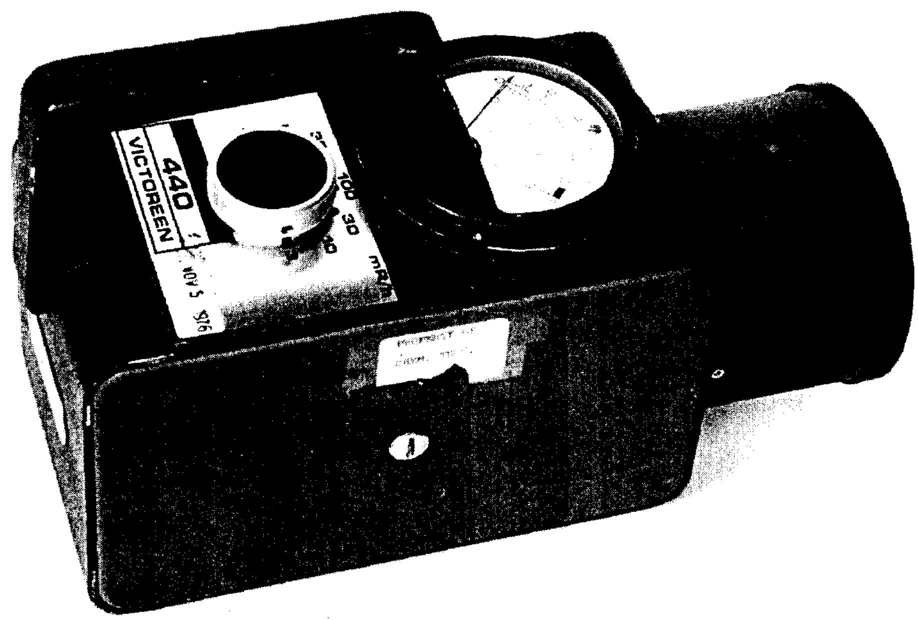

Fig. I-B. Victoreen Model 440 ionization chamber.

ORNL-Photo 6707-76

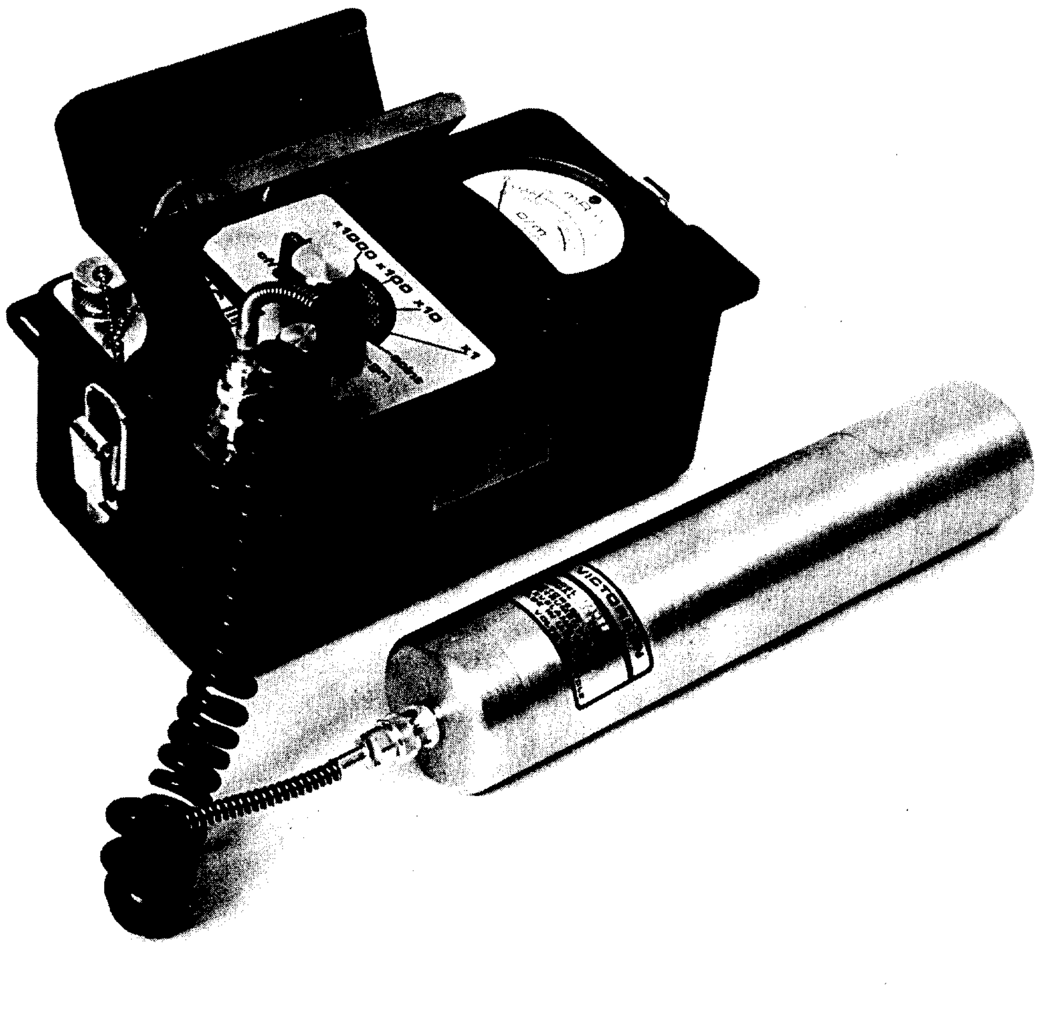

Fig. I-C. Gamma scintillation survey meter.

ORNL-Photo 1068-78

Fig. I-D. Mobile labs used for logistic support during surveys.

APPENDIX II

DESCRIPTION OF GE(LI) DETECTOR AND SOIL COUNTING PROCEDURES

DESCRIPTION OF Ge(Li) DETECTOR SYSTEM

A holder for twelve 30-cm^3 polyethylene bottles (standard containers for liquid scintillation samples) and a background shield have been designed for use with a 50-cm^3 Ge(Li) detector system (see Fig. II-A). 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-cm^3 sample and a graded shield developed for use with the system, it is possible to measure 1 pCi/g of ^{232}Th or ^{226}Ra with an error of ±10% or less.

Pulses are sorted by a 4096-channel analyzer (see Fig. II-B), 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 2500 gamma rays and which runs continuously on the IBM-360 system at ORNL. In identifying and quantifying ^{226}Ra, six principal gamma-ray lines are analyzed. Most of these are from ^{214}Bi and correspond to 295, 352, 609, 1120, 1765, and 2204 keV. An estimate of the concentration of ^{238}U is obtained from an analysis of the 93 keV line from its daughter ^{234}Th.

ORNL-Photo 2172-75

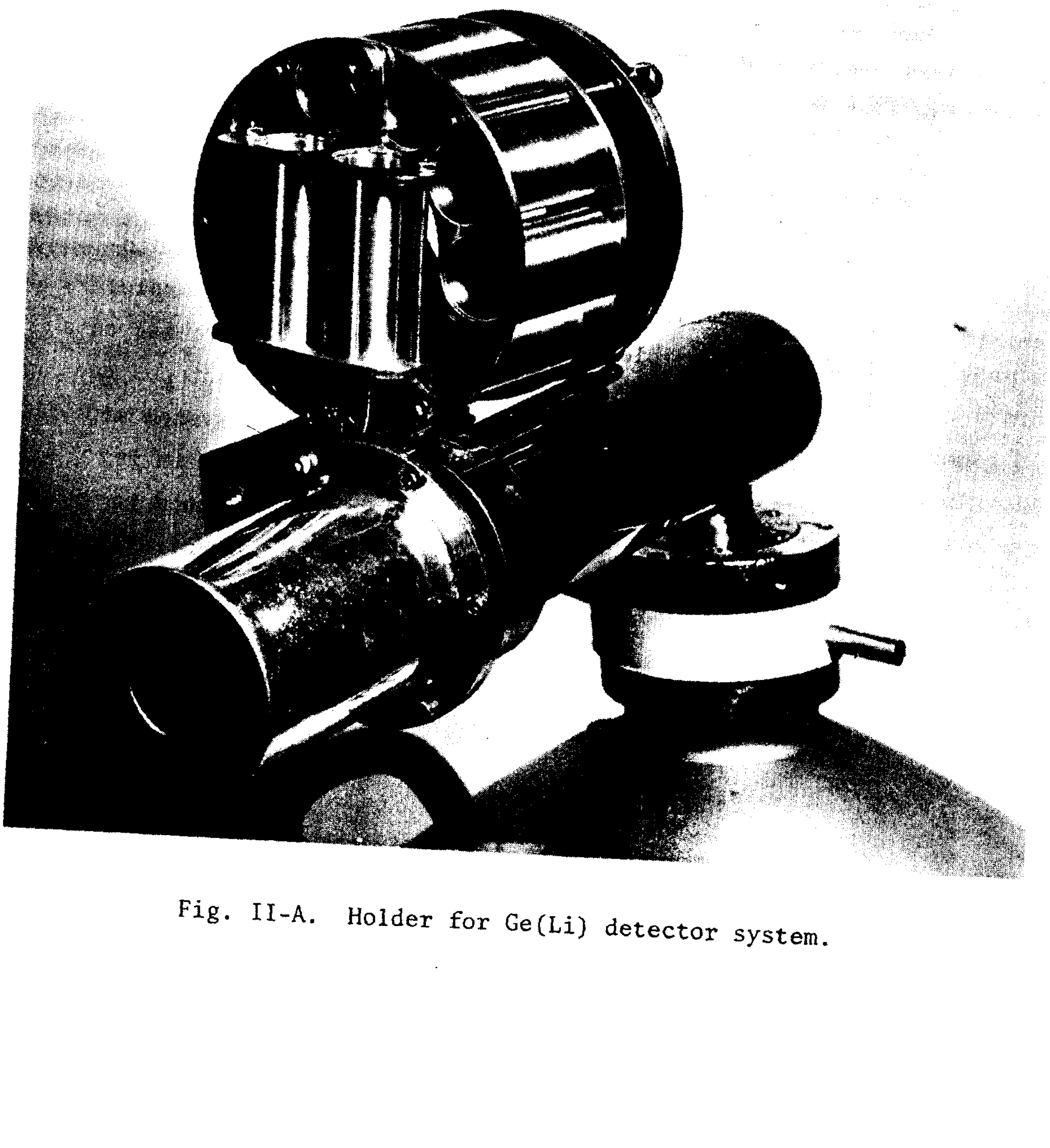

Fig. II-A. Holder for Ge(Li) detector system.

ORNL-Photo 6719-76

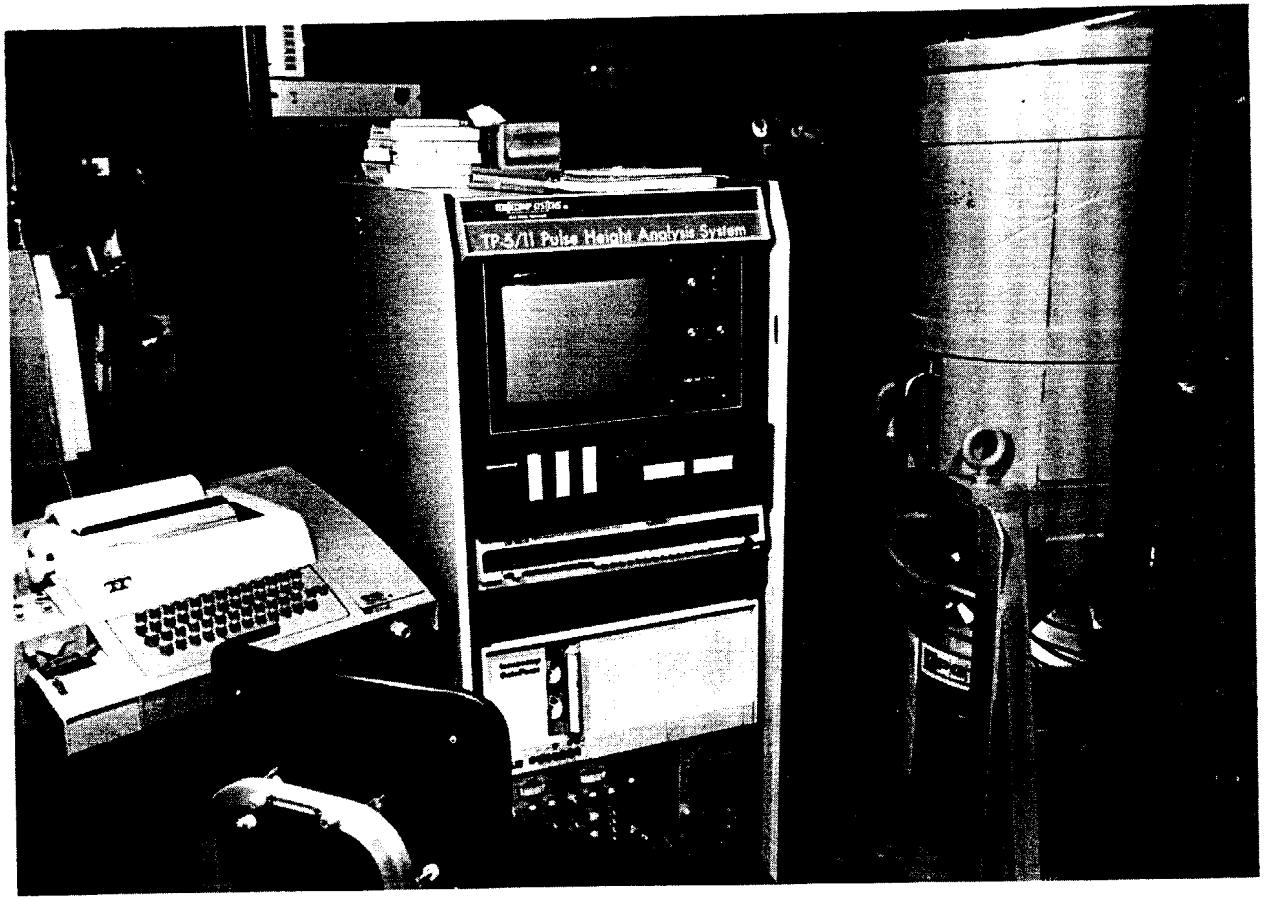

Fig. II-B. Computer-based multichannel analyzer and one of three Ge(Li) counting systems.

APPENDIX III

PROCEDURE FOR ESTIMATING ^{226}RA CONCENTRATIONS FROM GAMMA SCINTILLATION PROBE LOGGINGS

Since the gamma radiation intensity of subsurface soil contaminated with ^{226}Ra and other radionuclides from the ^{238}U chain depends chiefly on the concentrations of ^{226}Ra and daughters present, gamma scintillation probe loggings in auger holes can be used to estimate ^{226}Ra concentrations in subsurface soil. In the case of the Middlesex site, 29 auger holes were logged. At two of these holes, soil samples were extracted at intervals of approximately 6 in. By comparison with scintillation probe readings at corresponding depths, a "best-fitting" curve, $y = 11x - 12.8$, was obtained, where y is the ^{226}Ra concentration in pCi/g and x is the meter reading in thousand counts per min. Using this conversion, the ^{226}Ra concentration was estimated from gamma radiation levels measured in auger holes.

APPENDIX IV

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 IV-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 IV-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 IV-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 or 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 IV-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 IV-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

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

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

[c]Measurements 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.

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

[e]The amount of removable radioactive material per 100 cm^2 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.

[f]The 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 IV-2 or Table IV-3. (Table IV-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 IV-2. Surface contamination limits

The levels may be averaged[a] over the 1 m^2 provided the maximum activity in any area of 100 cm^2 is less than 3 times the limit value.

Nuclide	Limit (activity) dpm/100 cm^2 Total	Limit (activity) dpm/100 cm^2 Removable
Group 1: Nuclides for which the nonoccupational MPC_a[b] is 2 x 10^{-13} Ci/m^3 or less or for which the nonoccupational MPC_w[c] is 2 x 10^{-7} Ci/m^3 or less; includes Ac-227; Am-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_a[b] is 1 x 10^{-12} Ci/m^3 or less or for which the nonoccupational MPC_w[c] is 1 x 10^{-6} Ci/m^3 or less; includes Es-254; Fm-256; I-126, -131, -133; Po-210; Ra-223; Sr-90; Th-232; U-232.[d]	1000	200
Group 3: Those nuclides not in Group 1 or Group 2.	5000	1000

[a]See note following table on applications of limits.

[b]MPC_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).

[c]MPC_w: Maximum Permissible Concentration in Water applicable to members of the public.

[d]Values 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 IV-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 m^2[a] provided the maximum activity in any area of 100 cm^2 is less than 3 times the limit value.

Nuclide	Limit (activity) dpm/100 cm^2 Total	Removable
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

---

[a]Note on application of Tables IV-2 and IV-3 to isolated spots or activity:

For purposes of averaging, any m^2 of surface shall be considered to be contaminated above the limit, L, applicable to 100 cm^2 if:

a. From measurements of a representative number, n, of sections, it is determined that $1/n \sum_{n} Si \geq L$, where Si is the dpm/100 cm^2 determined from measurement of section i; or

b. On surfaces less than 1 m^2, it is determined that $1/n \sum_{n} Si \geq AL$, where A is the area of the surface in units of m^2; or

c. It is determined that the activity of all isolated spots or particles in any area less than 100 cm^2 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 seasonable 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*
Vol. 41, No. 133, p. 28404, Friday, July 9, 1976

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 V

EVALUATION OF RADIATION EXPOSURES AT THE MIDDLESEX MUNICIPAL LANDFILL, MIDDLESEX, NEW JERSEY

EVALUATION OF RADIATION EXPOSURES AT THE MIDDLESEX MUNICIPAL LANDFILL, MIDDLESEX, NEW JERSEY

The U.S. Department of Energy (DOE) has determined that the Middlesex Municipal Landfill in Middlesex, New Jersey, is presently contaminated with naturally occurring radioactive residues. In 1948, this 23-acre site was used to deposit about 6000 cubic yards of soil contaminated with pitchblende ore (a naturally occurring mineral containing a high percentage of uranium). This contaminated soil had been moved to the landfill from the former Middlesex Sampling Plant by an authorized contractor. Results of an Atomic Energy Commission (AEC) survey in 1960 revealed some higher-than-normal external gamma radiation levels over an area of approximately 1/2 acre. This finding resulted in the removal of about 600 cubic yards of contaminated material. This cleaned area was subsequently covered with about 2 feet of clean fill dirt, thus lowering the external gamma radiation to approximately normal levels.

During the period between 1960 and 1974, a tract of land of approximately 5 acres was sold to the Middlesex Presbyterian Church and a building was constructed on the land. During weekdays, part of the building and grounds is currently used as a day care center for local children. The church and the Middlesex Municipal Building are located on the western edge of the site, and Bound Brook forms a border along the northern and northeastern edges of the site. The closest residence to the center of the area where contaminated material exists is approximately 500 feet toward the south.

Contamination at the Middlesex Municipal Landfill is due to underground deposits of naturally occurring radionuclides, principally uranium-238 and its decay products including, but not limited to, thorium-230 and radium-226. This contamination could result in slight radiation exposures to persons playing or working on the site. The area containing most of the contamination is not occupied at present; also, it is located at least 100 feet from both the church playground and a group of waste bins used by the local population for the disposal of refuse. Future plans for the site include its possible use as a municipal park. At the present time, approximately 15 children and several adults use the church building and playground for about 30 hours per week. On Sunday, this building is occupied by approximately 100 persons for about 3 hours. The municipal building, located on the western edge of the site, has an occupancy of approximately 600 man-hours per week by city employees.

Radiation exposures to temporary occupants of the site result from two primary sources: inhalation of radon gas and its decay products which exist in air and gamma radiation emitted by the contamination in the soil. Additional exposures from ingestion (e.g., eating or drinking while occupying one of the contaminated areas) are relatively small as compared with inhalation and direct gamma radiation. However, the presence of small pieces of uranium-bearing ore at or near the ground surface could pose a potential for direct ingestion by small children.

The radionuclides which comprise the contamination at the landfill site 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 exposure 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 exposure to the general public are much lower than the limits established for workers in the nuclear industry.

Temporary occupants of the church and municipal building on the strip of land which borders the Middlesex Municipal Landfill are receiving radiation exposures which are indistinguishable from background exposures. In no case would an exposure in this area approach guidelines for limiting exposure to the general public. Present exposures are summarized and are compared numerically with guidelines and background radiation in the accompanying Table V-1.

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 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-quarter 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 V-2 until stable lead is formed. The "decay product" listed in this table is the radiation produced as the parent decays.

Exposure to External Gamma Radiation

As may be seen in Table V-2, several of the daughters of uranium-238 emit gamma radiation. (Gamma rays are penetrating radiation like X-rays.) Hence, the contaminated areas represent sources of external gamma radiation exposure. Gamma exposure rates measured at 1 meter above the ground ranged from 4 to 32 microRoentgens† per hour. One small area (approximately 500 square feet), located in the center of the site, shows an average external gamma radiation level of 30 microRoentgens per hour at 1 meter above the ground. If this small area were to be occupied for 2000 hours per year (normal working hours), the resulting exposure would be equivalent to 60,000 microRoentgens. For comparison, a typical chest X-ray (according to Department of Health, Education, and Welfare data) might yield an exposure of about 27,000 microRoentgens. The background exposure rate in the Middlesex area ranges from 5 to 10 microRoentgens per hour with an average background

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*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.

†The 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.

rate of 8 microRoentgens per hour. The average exposure rate measured at the Middlesex Municipal Landfill was about 5 microRoentgens per hour.

The National Council on Radiation Protection and Measurements (NCRP) has recommended a maximum annual whole body exposure rate of 500,000 microRoentgens per year to an individual continually exposed in the general population; this corresponds to an exposure rate of 250 microRoentgens per hour for 2000 exposure hours. At the present time, there are no exposures at this site which exceed this guideline value. For an individual in the general public, this guideline is ten times lower than guidelines established for a worker in the nuclear industry.

Inhalation of Radionuclides

Radon-222, the daughter of radium-226 (as shown in Table V-2) is an inert gas which may leave the soil and enter the atmosphere. The average daily concentration of radon-222 was 0.04 picocurie* per liter of air measured at the municipal building over a 7-day period in May, 1978. At approximately the same time, the average daily concentration of radon-222 was 0.06 picocurie per liter of air measured at the Parker School. The Parker School is reasonably representative of area background. Thus, radon-222 concentrations attributable to the landfill site are comparable to those caused by background radioactivity.

Radioactive decay of radon-222 is rapid (days) and its decay gives rise to short-lived daughters as shown in Table V-2. Background concentrations of radon daughters both inside and outside structures are typically less than 0.01 working level† (WL). The average concentration of short-lived radon-222 daughters in air measured at the parking lot of the municipal building was less than 0.001 working level. Consequently, exposures to radon-222 and its daughters (due to material buried at this site) are insignificant as long as use of the site does not change.

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

†The 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.

It is further estimated that radon levels in the air of a structure (concrete slab or with crawl space) built directly over soil containing the bulk of the contamination could approach 0.8 picocuries per liter which is similar to indoor levels of background radon-222. This level would be expected to yield radon daughter concentrations of about 0.004 working level. If structures with basements were built in the same contaminated area, resulting radon daughter concentrations could be significantly greater. Although no such structures exist at the present and none are planned for the immediate future, nothing definitive can be said at this time regarding long-range land-use plans.

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 working level throughout the normal work period of 2000 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.

Other Considerations of Exposure

Both groundwater and water from Bound Brook were sampled and analyzed for a variety of radionuclides. All samples had radionuclide concentrations well below the recommended values set forth in 10 CFR 20* for water consumed by the general public.

Radiation measurements and soil samples taken along Bound Brook on the site indicate that small amounts of contaminated material may have migrated toward the brook from the area containing the highest levels of contamination.

While no crops are currently grown on this site, use of the contaminated soil for such a purpose could produce additional human exposure

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

through consumption of crops which have incorporated radioactive materials (e.g., radium-226). Actions which involve considerable scraping or tilling of dry soil could lead to human exposure through inhalation of airborne radioactive dust.

Use of this site or its residues for residential construction could result in continuous exposures to radon daughters which are in excess of guideline values.

Risk and Radiation Exposures

Risks resulting from radiation exposures should be considered within the context of other risks incurred in normal living. For simplicity, 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 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 estimates of the number of increased cancers in the relatively small population being exposed at the Middlesex Landfill site.

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 rates 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 2000 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 rates 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 microRoentgens 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.

Remedial Measures

The small radiation exposures at the Middlesex Municipal Landfill are attributable to the presence of contaminated soil and materials buried within the soil. Contamination on the surface appears to be confined to a small area of approximately 500 square feet. The small 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. The DOE is now actively evaluating alternatives under a priority program designed to assure adequate public protection.

Summary

The Middlesex Municipal Landfill is contaminated with buried materials containing naturally occurring uranium-238, radium-226, and their daughters. Current radiation exposures are not appreciably different from background exposures. However, the underground contamination poses the potential for producing elevated levels of human exposure if future activities at the site were to uncover pieces of uranium ore at or near the ground surface, or result in the construction of buildings over the contaminated area. The DOE has developed a coordinated plan which addresses the specific problems at the Middlesex Landfill site and other formerly utilized MED/AEC sites. Currently, work is underway to implement the elements of this plan.

Table V-1. Summary of exposure data at the Middlesex Municipal Landfill, Middlesex, New Jersey

Exposure source	Background levels	Guideline value for general public	Guideline value for radiation workers	Average levels at Middlesex Municipal Landfill
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 measured on roof of Municipal Building was 0.04 picocurie 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 concentration measured on parking lot of Municipal Building was less than 0.001 working level
Gamma radiation from decay products of radium and uranium contamination	8 microRoentgens[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 level 1 meter above the ground was about 5 microRoentgens per hour. One small area averaged 30 microRoentgens per hour

[a]The picocurie is a unit which was defined for expressing the amount of radioactivity present in a substance.

[b]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.

[c]The Roentgen is a unit which was defined for radiation protection purposes for people exposed to penetrating gamma radiation. A microRoentgen is one-millionth of a Roentgen.

Table V-2. 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	1600 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

[a]Short-lived radon daughters.

SECTION II

U.S. ATOMIC ENERGY COMMISSION RADIATION SURVEY REPORT FOR THE BOROUGH OF MIDDLESEX MUNICIPAL LANDFILL SITE JUNE, 1974

PREFACE

This radiological survey was conducted by the Atomic Energy Commission (AEC) in 1974, and a limited number of copies were distributed. This printing represents a second edition for wider distribution. This effort was a prelude to the current Department of Energy program for determination of the radiological condition of sites formerly utilized by the Manhattan Engineer District (MED) and the AEC for work involving the handling, storage, or disposal of radioactive materials.

In 1974, the findings of the AEC survey indicated the presence of radioactivity in the landfill site; however, it represented no measurable radiation health or safety problem as the property was being utilized at that time. Major excavation or development of the site in the future could pose a potential for radiation exposure that could, under certain circumstances, exceed radiation protection standards for the general public. Such potential for radiation exposure would be of a low level and could be dealt with at the time of planning and development without risk to the public health or undue interference in development activities. From that long-range point of view, the AEC suggested to the Borough of Middlesex that the property record be appropriately flagged to provide assurance in the future that these considerations are recognized and evaluated in connection with requests for building permits or other possible real property zoning and land use.

SECTION II

U.S. ATOMIC ENERGY COMMISSION RADIATION SURVEY REPORT FOR THE BOROUGH OF MIDDLESEX MUNICIPAL LANDFILL SITE JUNE, 1974

INTRODUCTION AND SUMMARY

At the request of the Division of Operational Safety, Atomic Energy Commission (AEC) Headquarters, a radiological survey of certain adjoining properties belonging to the Borough of Middlesex, New Jersey, and the Middlesex Presbyterian Church was made during the period March 25 to April 4, 1974. The historical background leading to the requested survey is discussed in a later section of the report. An area of approximately 3 acres was found to contain subsurface deposits of radioactivity ranging from about 3 to 60 times naturally occurring gamma background levels. This area is approximately half on Borough property and half on church property. The deposits were found to exist at depths ranging from less than 1 ft to 18 ft. Over 100 soil samples from 39 core holes were taken and analyzed for radium, uranium, and thorium at the New Brunswick Laboratory. An average radium concentration over the 3-acre area was found to be about 11 pCi/g with localized maximum levels up to 140 pCi/g.

Surface gamma measurements were found to be within the range of normal background variations except in a small area (<100 ft^2) where the contaminated residual is located near the surface. This area is on Borough property presently used as a sanitary landfill.

Radon samples were taken over the suspect area and inside the church building and compared with background radon levels from off-site areas. Only those samples taken in the area having elevated surface gamma readings were significantly above background levels (i.e., about an order of magnitude higher). No evidence of elevated radon was found inside the church building.

Preliminary survey findings were discussed by AEC representatives with the Mayor of Middlesex Borough at the time of the on-site survey. No such discussion was held with church representatives. Representatives from the *Middlesex Chronicle* newspaper and radio-TV station *WCTC*, New Brunswick, made inquiries during the initial phases of the on-site survey. In response, it was indicated that survey findings would be made public when the analytical work was completed.

CONCLUSIONS

Findings of this survey appear to support the following conclusions:

1. The contaminated area in its present configuration and use presents no significant radiation exposure potential to the public. This should be the case as long as the area is undisturbed by excavation or the construction of habitable enclosures.
2. The exposure of individuals at or exceeding AEC guide levels cannot be convincingly dismissed as a credible possibility under circumstances which could exist if the area were developed in the future with residences or other habitable structures.

HISTORICAL BACKGROUND

In 1948, dirt contaminated with pitchblende ore was removed from the Middlesex Sampling Plant site to the Middlesex Municipal Landfill by a contractor during construction of an asphalt pad.

In May, 1960, during a local civil defense (CD) exercise, CD monitors detected elevated radiation levels in the landfill and questioned the source of the radioactive material. The matter came to public attention and received newspaper coverage. The AEC noted the issue and upon reviewing its past local activities concluded that AEC operations were the likely source. Upon analytical confirmation of the presence of pitchblende, a further survey of the area was made. Readings taken at that time confirmed gamma radiation levels 20 to 50 times background over a fairly consolidated area of less than 1/2 acre.

Meetings were held with local officials in November, 1960, to discuss the significance of survey findings and to offer remedial assistance. The AEC subsequently removed the part of the material nearest the surface (about 650 yd^3) and covered the area with about 2 ft of clean dirt--sufficient to reduce surface radiation levels to about 50 μR/hr. Upon assurance by the AEC that no health hazard existed, Borough officials agreed the situation was satisfactory. No official record of the residual contamination exists in available Borough records.

On January 30, 1974, a meeting was again held with Middlesex Borough officials to request permission to resurvey the involved area to permit reevaluation of current conditions. It was learned that about 5 acres previously a part of the landfill had been sold to the Middlesex Presbyterian Church and a church building erected thereon. Location of the suspect area, as recollected by "old timers" at the Borough, was near the boundary between church and dump properties. The accuracy of this information has been subsequently confirmed by survey data. At this meeting, the press was informed of AEC survey plans and briefed on the history surrounding the suspected contamination.

Description of the Area Surveyed

The area bounded by Mountain Avenue, Pershing Avenue, Westminister Street, and Bound Brook is shown in Fig. 1. In 1948, the time when it is suspected that contaminated soil was disposed of at the landfill, essentially all of the area was designated as a landfill site for the Borough of Middlesex.

Subsequent to the 1961 AEC cleanup action, a 5-acre plot was sold to the Middlesex Presbyterian Church and a building constructed. It was understood from discussions with local people familiar with the history of the site that the church and municipal building were constructed on "nonfill" or solid ground.

In 1948, the landfill area was essentially a gully from the brook to within 100 to 200 ft of Mountain Avenue. The area is now, for the most part, level to within about 100 ft of the brook--indicating the amount of fill which has been deposited. Bound Brook flood plain elevation is about 15 ft below Mountain Avenue. The surface of the landfill has reportedly risen 8 to 10 ft since 1961. Findings from the gamma scanning of core holes confirm the presence of contaminated material at successively greater depths as one goes away from Mountain Avenue toward the brook.

The current landfill site lies to the south and southeast of the Presbyterian Church property and is expected to reach final elevations and terminate operation in 1974. Borough plans for the site are reportedly contingent on the availability of federal funds. If funds become available, a park-recreation area may be developed in the present landfill area.

SURVEY FINDINGS

Surface Gamma Survey

Figure 2 shows a schematic of the area covered by systematic traverses of areas presently or formerly used for landfill disposal. Other areas around the buildings and parking lots which were not amenable to such systematic traverses were surveyed and found to be generally in the background range of 9 to 11 μR/hr. Asphalt parking areas tended to measure somewhat lower (i.e., 7 to 9 μR/hr).

Core holes 1, 2, and 6 (see Fig. 3) were drilled to explore areas with elevated gamma readings (i.e., 80 μR/hr, 17 μR/hr, and 30 μR/hr, respectively). Drillings confirmed the presence of contaminated material near the surface. Core hole 34 was drilled at the other location of elevated reading (i.e., 20 μR/hr), and no significant subsurface contamination was found. Core holes 7 and 20, with normal background readings at the surface, revealed substantial deposits of radioactive materials at depths from 2 to 4 ft. Hence, it is apparent that surface readings are not a conclusive measurement unless the deposit is very near the surface.

Radon Survey

Radon surveys were conducted by the AEC Health and Safety Laboratory (HASL). The intended purpose of the radon survey was to assist in identifying the location of contaminated material in the dump site. As with the surface gamma survey, the radon data are not conclusively indicative for deeper deposits. Extension of the interpretation of radon survey data for other purposes such as the estimation of potential radon sources affecting future construction in the area is not attempted.

Background radon emanation within a few miles of the dump site as measured by HASL revealed fluctuations up to a factor of six. These measurements are made by sealing a "flux can" to the ground and, after a sampling period of 30 min, transferring the trapped air from the can to a radon scintillation chamber. Radon emanation rate may then be calculated in curies per unit area per unit time. Comparison with similar type measurements made in the suspect area showed some samples to be above the reference off-site background range. All but one of the elevated samples are in the small area with surface radiation levels of 20 to 30 μR/hr and are about 10 to 20 times concurrent off-site radon levels. The other elevated sample, which showed an emanation rate about twice the maximum background levels, was from an area with surface gamma readings of 14 to 15 μR/hr.

Radon and radon daugher measurements made in the church building were indistinguishable from naturally occurring levels.

Subsurface Survey

Thirty-nine core holes were drilled as shown in Fig. 3. Each hole was scanned with a shielded Geiger-Mueller (G-M) probe, and gamma radiation readings are tabulated in Table 1. The maximum radiation level detected was about 0.6 mR/hr. Contaminated material was detected over an area of about 3 acres as shown by the shaded area on Fig. 1. Contamination was found to exist over this area in a layer generally 3 to 5 ft in thickness and at depths from less than 1 ft to about 18 ft. Two typical cross sections through the contaminated area are illustrated in Figs. 4 and 5. It is roughly estimated that between 15-20,000 yd^3 of contaminated material may exist in this area. If so, an obvious dilution of the remaining 6000 yd^3 hauled here in 1948 has occurred. It should be pointed out that in this report "contaminated" refers to areas where gamma radiation readings in core holes exceed 50 cpm. This represents about three times observed background levels in the core holes (i.e., 20 μR/hr). Selection of this criterion is based solely on the fact that the level is sufficiently above field instrument sensitivity and beyond the range of background fluctuations to allow some degree of confidence that the suspect radioactive material is present. The criterion is not selected to suggest that higher levels represent a health hazard.

Soil samples were analyzed by the New Brunswick Laboratory for uranium, thorium, and radium concentrations.

Table 2 is a compilation by core hole of the analytical results. It is noted that radium concentrations over the 3-acre area average about 11 pCi/g with the maximum observed to be 140 pCi/g. Naturally occurring radium in area soil is about 1 pCi/g (NYO-1521). Uranium levels up to 280 ppm were found. This compares with the 10 CFR 40 *de minimus* concentration of 500 ppm. Uranium concentrations appear to track consistently with radium concentrations as one would expect. Thorium concentrations are not appreciably different from general background levels reported to EPA (ORP/SID 72-1).

Soil samples were collected along the brook to assess any run off from the contaminated residual. Grass was also collected in the vicinity of core hole 20 for analysis. These analytical data are included in Table 2.

Evaluation of Data

Two conditions require evaluation to permit an understanding of the health and safety implications of radioactive material remaining in the landfill site.

- Case 1 - What is the potential for radiation exposure to individuals assuming the area remains undeveloped or otherwise undisturbed by excavation below the existing surface?
- Case 2 - What is the potential radiation exposure to individuals if the area is developed and subsurface deposits are disturbed and/or exposed?

Case 1 suggests a situation which may exist at the site for at most a few years. The present landfill site is expected to terminate operation in the immediate future. The part of the church property which contains radioactive material will likely have a development potential independent of that of the Borough Landfill but equally as unpredictable at this time.

It is clear, however, that for as long as Case 1 conditions exist the credible potential for gamma radiation or radon exposure approaching a fraction of the AEC population guides is negligible. Certainly no health hazard attributable to the radioactive deposit can be imagined for Case 1.

For the conditions anticipated for Case 2, one must consider the additive exposure effect of gamma radiation levels existing at the site and the radon concentrations which emanate from residual radium deposits.

Projected external gamma exposure from maximum residual radiation levels (0.6 mR/hr) could be on the order of 5 rem/year if one assumed continuous occupancy and ignored the practicalities of geometry, attenuation, and radiation field averaging. One may allow at least a factor of 0.1 reduction to account for these parameters and retain some margin of conservatism. Thus, exposure at the 0.5 rem/year level may be considered possible under very limited circumstances. Further reduction of this projected exposure rate is probably possible; however, since no radiological control exists over the use of the site, it is considered inadvisable to rule out those circumstances which are, in fact, theoretically possible.

Projected radon exposure becomes significant only if buildings are constructed in the contaminated area causing a concentration or buildup inside the structures. The following section provides a computation of radon buildup in a house assuming soil concentrations on the order of 100 pCi/g. Based on soil analyses in Table 2, this level must be considered credible.

THEORETICAL IMPACT OF RADIATION RESIDUAL ON RADON LEVELS IN FUTURE CONSTRUCTION AT THE MIDDLESEX MUNICIPAL LANDFILL SITE

Statement of Problem

This section develops a theoretical calculation of the radon levels that would be expected in the baseline of a house constructed on the Middlesex Borough Municipal Landfill site and subject to the effects of a residual concentration such as that which remains in the 3-acre area identified by the 1974 AEC-OR survey of the landfill.

Statement of Basic Assumptions

1. Regarding the prevailing radium concentration: Soil analyses over the 3-acre area containing residual pitchblende contamination indicates an average radium concentration of about 11 pCi/g. This compares to a naturally occurring background level of 1 pCi/g. For this calculation, to assure conservatism, the five highest soil samples have been averaged yielding a radium concentration of about 100 pCi/g. It is assumed that a house could be exposed to soil containing such a radium level.
2. Regarding the hypothetical future house construction: It is assumed that the floor of the baseline is 8 ft below grade and dimensions of the basement are 60 x 30 ft. It is assumed that backfill around the basement wall extends 2 ft in the perpendicular direction out from the four basement walls. The backfill is assumed contaminated to a level of 100 pCi of radium per gram of soil.

Utilizing these basic assumptions, the following calculation is made to attempt to predict radon levels in future housing which might be constructed on the landfill site.

The source, S, of the radon will be the inventory of radium in the volume, V_b, of backfill:

$$
\begin{aligned}
S &= V_b\ (100\ \text{pCi/g}) \\
V_b &= (60' \times 8' \times 2')\ 2\ \text{walls} + (30' \times 8' \times 2')\ 2\ \text{walls} = \\
&\quad 3 \times 10^3\ \text{ft}^3 \qquad (1) \\
\rho &= 100\ \text{lbs/ft}^3 = \text{density of backfill} \\
S &= 3 \times 10^3\ \text{ft}^3 \times 100\ \text{lbs/ft}^3 \times 450\ \text{g/lb} \times 100\ \text{pCi/g} = 13.5\ \text{mCi.}
\end{aligned}
$$

Assuming the radon to be in equilibrium with the radium, there would be a total of 13.5 mCi of radon produced in the backfill. It is crudely estimated from geometrical considerations that about one-third of the radon produced or 4.5 mCi would enter the basement.

Now the question becomes what is the maximum concentration of radon which will occur in the house assuming a minimum ventilation rate of one-half the building volume per hour. This ventilation rate is reported by ORNL to be the lowest observed in their feasibility studies of tritium contaminated natural gas usage in connection with Project Gasbuggy.

Let

N = the number of radon atoms at time, t,

C_1 = a constant source of radon atoms,

= 4.5×10^{-3} Ci x 3.7×10^{10} atoms/sec = 1.7×10^{8} atoms/sec,

C_2 = a rate at which radon atoms are removed via ventilation

= 0.5/hr = 1.4×10^{-4}/sec.

Therefore,

$$\frac{dN}{dt} = C_1 - \lambda N - C_2 N. \tag{2}$$

Where λ is the radon decay constant,

$$\lambda = \frac{0.693}{3.8 \text{ days} \times 24 \text{ hr/day} \times 3600 \text{ sec/hr}} = 2.1 \times 10^{-6}/\text{sec}.$$

Since λ is much less than C_2, for purposes of this calculation, the radiological decay of radon will be neglected and the λN term in equation (2) drops out leaving

$$\frac{dN}{dt} = C_1 - C_2 N. \tag{3}$$

Integrating equation (3) and solving for N gives

$$N = \frac{C_1}{C_2}\,[1 - \exp(-C_2 t)]. \tag{4}$$

Let $t \to \infty$ to represent an equilibrium condition

$$N = \frac{C_1}{C_2} \text{ at equilibrium}$$

$$= \frac{1.7 \times 18^{8} \text{ atoms/sec}}{1.4 \times 10^{-4}/\text{sec}} = 1.2 \times 10^{12} \text{ atoms of radon.} \tag{5}$$

The radon activity at equilibrium in the house will be

$$N = \frac{1.3 \times 10^{12} \text{ atoms} \times 2.1 \times 10^{-6}/\text{sec}}{3.7 \times 10^{10} \text{ atoms/sec - Ci}} = 7 \times 10^{-5} \text{ Ci.} \tag{6}$$

The equilibrium radon concentration, X, in the basement due to the radium inventory in the backfill is therefore

$$X = \frac{70\ \text{Ci}}{\text{volume of basement}} = 1.4 \times 10^{-7}\ \text{Ci/cc}.$$

This equals a working level concentration of 1.3 WL.

It should be pointed out that, if the house were built without a basement upon a concrete slab on top of ground contaminated at the 10 pCi/g concentration, the radon levels in the house may be two to three times below this level.

In the above calculations, no credit is taken for the attenuation of radon as it diffuses through the walls of the structure.

ORNL-DWG 80-8232C

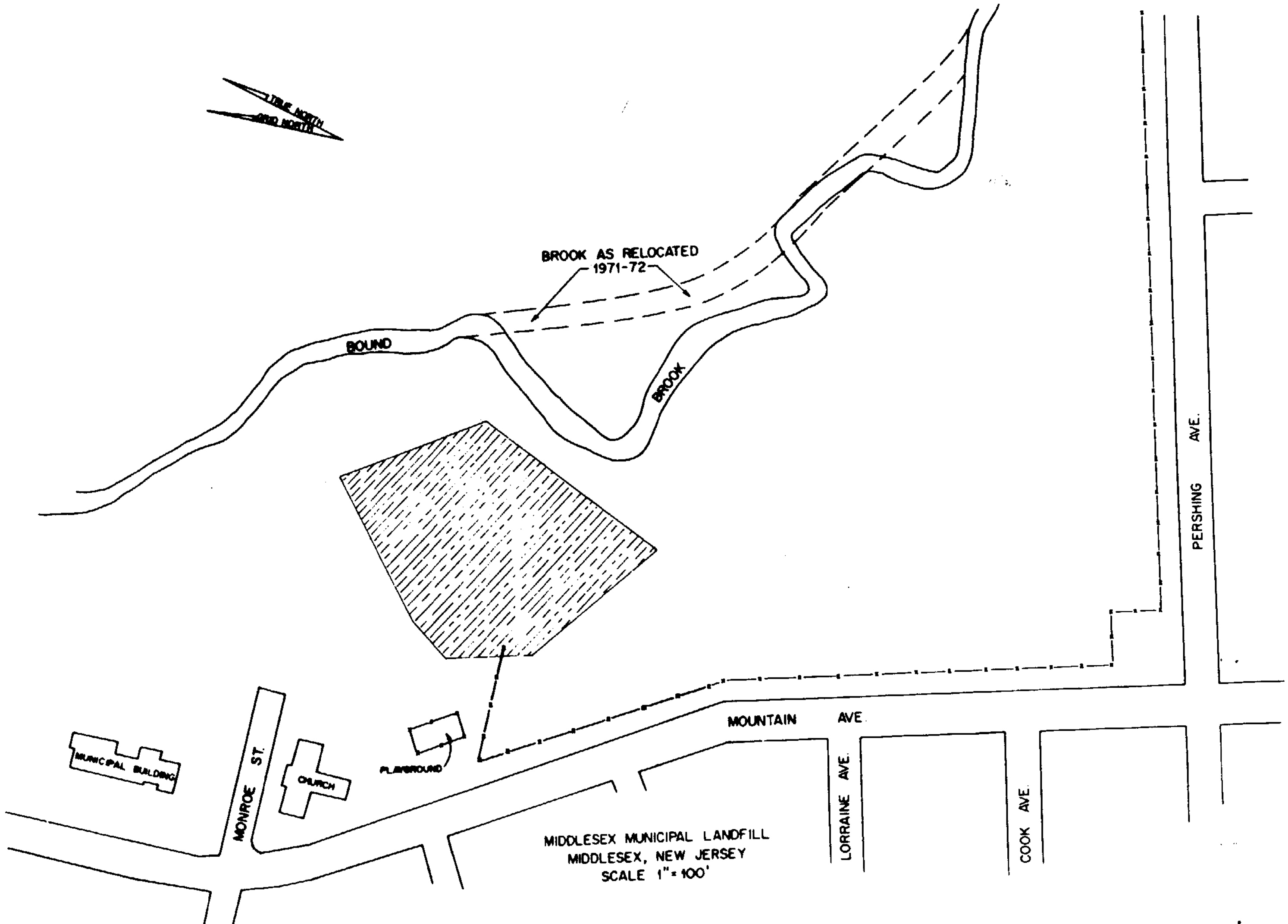

Fig. 1. Middlesex Municipal Landfill site. (Shaded area represents general location where contaminated material was found during the 1974 survey.)

ORNL-DWG 80-8232B

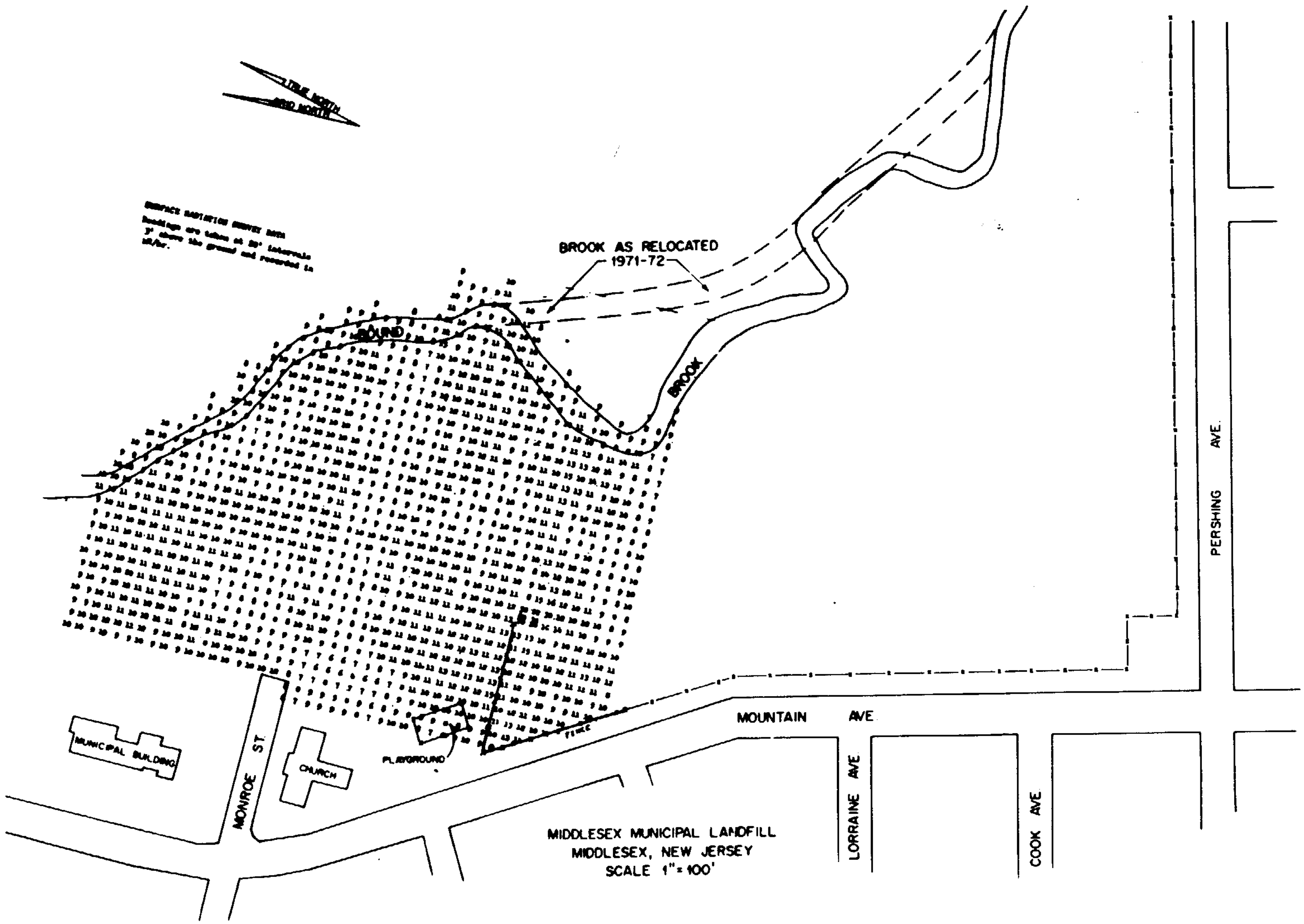

Fig. 2. Gamma radiation traverse of Middlesex Municipal Landfill taken during 1974 survey.

ORNL-DWG 80-8232A

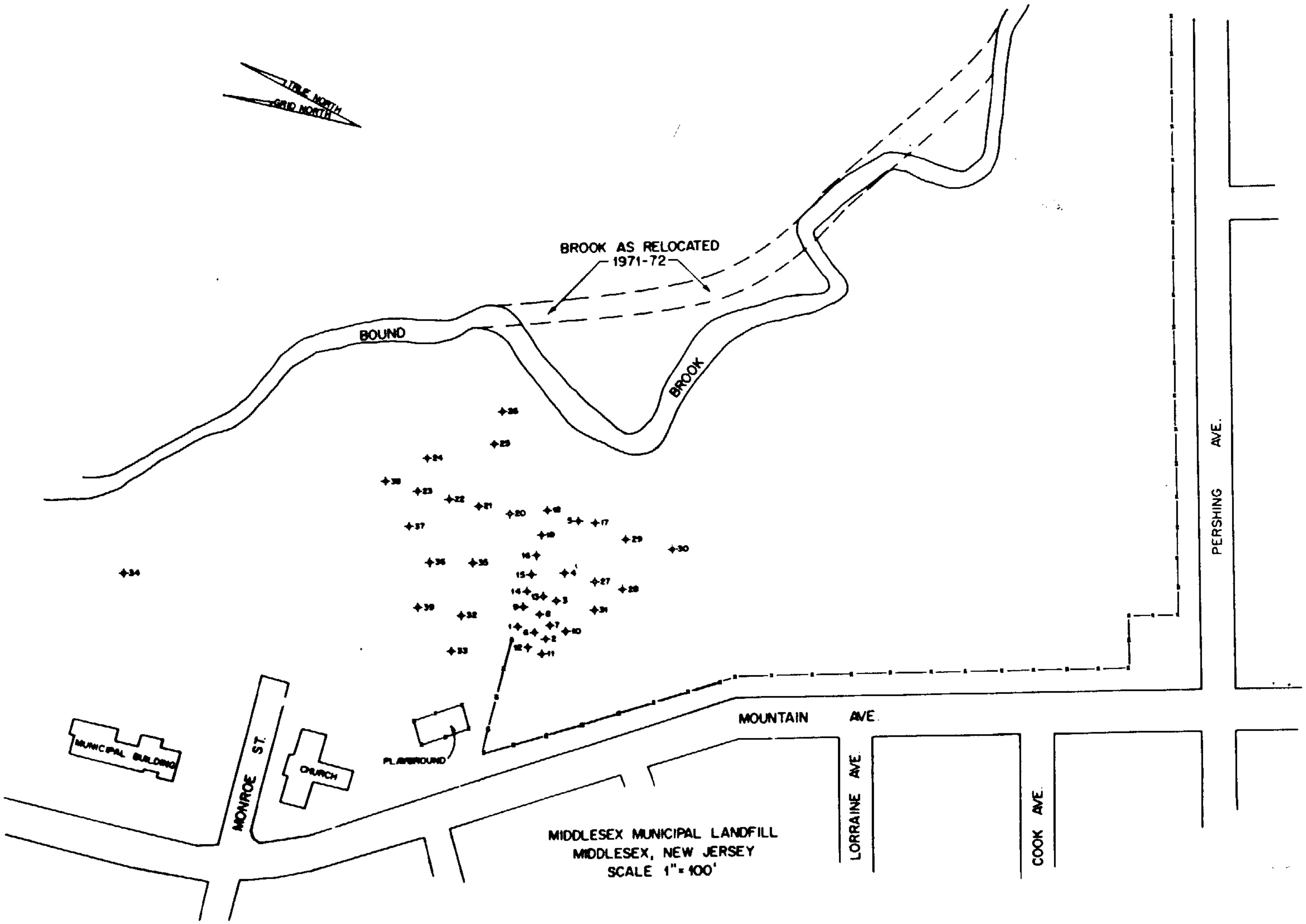

Fig. 3. Location of auger holes during the 1974 survey of the Middlesex Municipal Landfill.

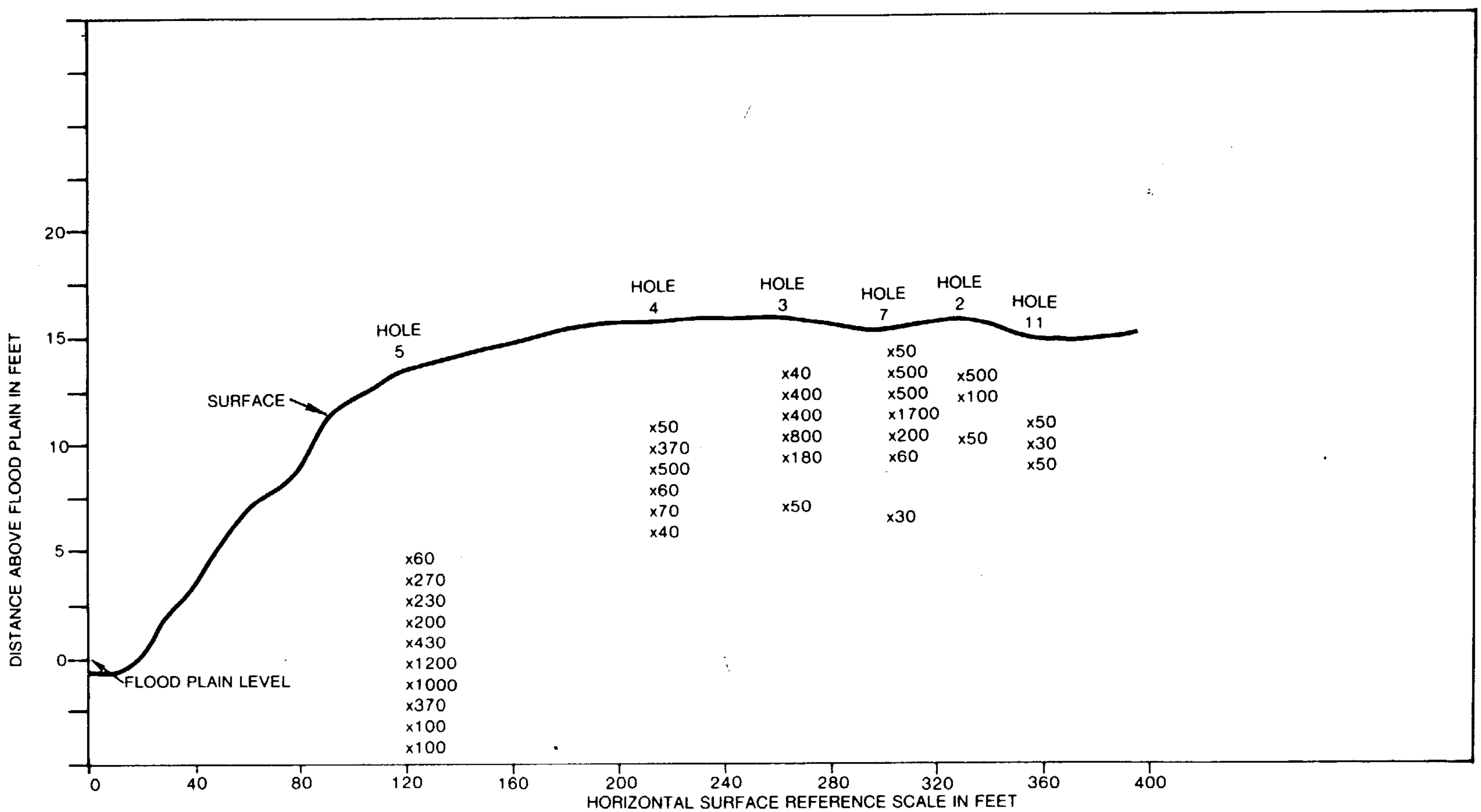

Fig. 4. Surface cross section measurements for holes 5, 4, 3, 7, 2, and 11 (counts/min). (Source: U.S. Atomic Energy Commission, *Radiation Survey Report of the Middlesex Landfill Site*, June, 1974.)

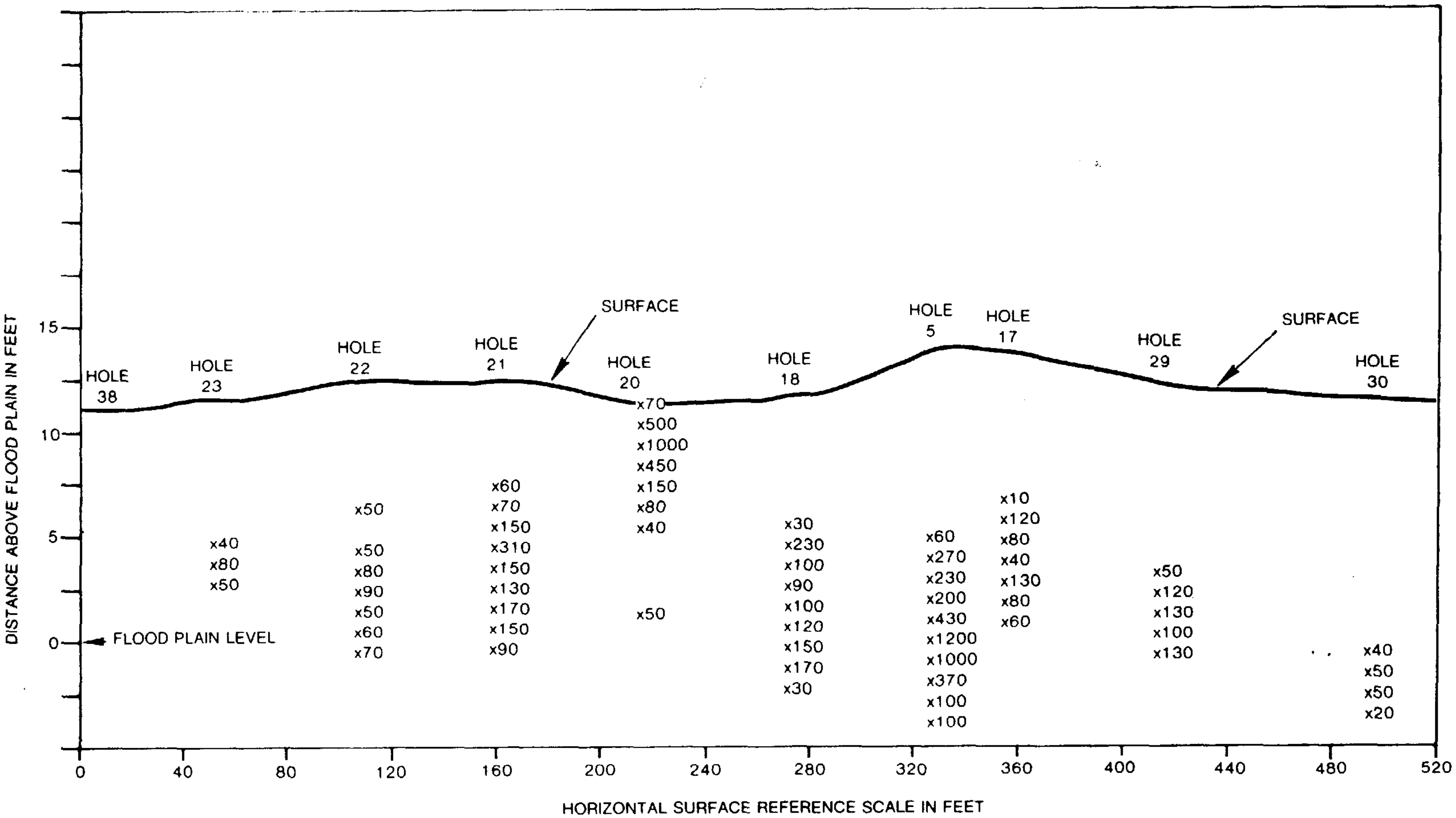

Fig. 5. Cross section and measurements from holes 38, 23, 22, 21, 20, 18, 5, 17, 29, and 30 (counts/min). (Source: U.S. Atomic Energy Commission, *Radiation Survey Report of the Middlesex Landfill Site*, June, 1974.)

Table 1. Radiation profile of core holes, readings in counts per minute (CPM) 2.6 CPM $\approx$ 1 μR/hr

Hole no.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Surface elevation above the floodplain in ft	14.50	15.24	16.26	16.19	14.06	16.25	15.65	15.16	14.17	14.98	15.08	15.00	15.23	14.35	13.44	14.44	13.81
Gamma level, μR/hr, at 3 ft above hole	80	17	13	8	11	30	11	15	10	11	10	12	9	9	9	9	11
Hole - depth in ft																	
0	700			20	30	60	50	20	20	30	20	20	20	20	20	20	20
1				30	20	170	50			20	20	40	30	10	40	20	20
2	270	500	40	10	20		500	150	90	20	40	40	80	70	30	40	10
3	70	100	400	10	10	70	500	110	100	20	20	20	100	60	50	240	10
4			400	10	10		1700		100	50	50	10	220	150	50	800	10
5			800	50	10		200	110	40	20	30	30	120	170	370	480	20
6	40	50	180	370	10	40	60		40	20	50	40	60	70	130	120	20
7				500	10				50	30	30	50	20	30	60	110	10
8				60	10			30	70	10	30	30	10	20	40	120	120
9	25	50	50	70	60	30	30		50	20	30	40	30	20	50	110	80
10			50	40	270				30	10	20	20	20	10	40	90	40
11	40	30		40	230			30	40	10	20	20	30	10	30	100	130
12				50	200	30	30		30		20		30	20	40	70	80
13				50	430			30			20				40	20	60
14					1200		30				30					10	
15					1000	20					30					20	
16					370	30					20						
17					100						20						
18					100						20						

Table 1. Radiation profile of core holes,
readings in counts per minute (CPM)
2.6 CPM $\approx$ 1 μR/hr (cont.)

Hole no.	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34
Surface elevation above the floodplain in ft	11.70	12.55	11.40	12.56	12.34	11.67	10.34	9.91	7.39	16.38	16.99	12.39	12.10	15.96	14.06	14.77	5.55
Gamma level, μR/hr, at 3 ft above hole	10	10	10	9	8	9	10	11	10	8	9	8	9	9	12	12	20
Hole - depth in ft																	
0	20	20	70	10	10	20	20	30	20	20	30	20	20	10	20	20	20
1	30	40	500	10	20	10	30	20	10	20	20	20	20	10	20	20	40
2	20	40	1000	20	20	30	20	20	20	10	20	20	10	10	40	30	30
3	10	20	450	30	10	30	30	20	20	20	30	20	10	10	40	50	30
4	30	30	150	20	10	20	20	20	10	10	20	10	10	20	50	20	20
5	20	120	80	60	10	20	20	20	10	10	20	10	20	10	50	30	20
6	30	270	40	70	50	20	30	20	30	10	20	20	20	60	30	40	30
7	230	70		150	20	40	70	80	40	50	10	20	10	50	30	30	10
8	100	70		310	50	80	70	90	30	120	10	20	10	40	30	30	20
9	90	50		150	80	50	50	90	30	60	60	50	10	20	30	30	
10	100	50	50	130	90	20	50	80	10	40	50	120	20	30	20	20	
11	120	30		170	50	20		80	20	40	40	130	10	30	20	20	
12	150	20		150	60	20				50	40	100	40		30	20	
13	170			90	70	30				50		130	50				
14	30												50				
15													20				

Table 1. Radiation profile of core holes, readings in counts per minute (CPM) 2.6 CPM $\approx$ 1 $\mu R/hr$ (cont.)

Hole no.	35	36	37	38	39
Surface elevation above the floodplain in ft	13.23	13.20	12.83	11.18	13.61
Gamma level, $\mu R/hr$, at 3 ft above hole	10	10	10	10	10
Hole - depth in ft					
0	20	10	10	10	10
1	30	10	10	10	40
2	20	10	20	10	30
3	30	20	30	10	60
4	60	100	20	10	40
5	50	230	20	20	70
6	60	110	10	20	40
7	180	60	20	30	30
8	180	50	40	30	20
9	120	40	40	10	20
10	50			30	20
11	30			20	20
12				20	30
13				20	

Table 2. Core hole soil samples

Sample Location	Ra pCi/g	μg U/g[a]	μg Th/g[a]
Hole 1			
0- 1 ft	23	40	5
6- 8 ft	7	6	7
10-12 ft	3.9	3	8
Hole 2			
3- 5 ft	5.4	5	11
6- 8 ft	1.2	2	8
9-11 ft	0.5	3	7
11-12 ft	0.1	19	9
Hole 3			
6- 8 ft	140	280	9
9-11 ft	28	40	9
11-13 ft	6	11	11
13-18 ft	3	7	11
Hole 4			
6- 8 ft	97	130	10
12 ft	13	15	10
Hole 5			
13-20 ft	26	90	6
Hole 6			
0- 2 ft	13	40	8
2- 5 ft	15	70	6
8-13 ft	5	6	7
13-18 ft	7.1	4	9
18-20 ft	2.5	3	7
Hole 7			
0- 2 ft	0.3	3	9
2- 5 ft	60	60	8
13-20 ft	13	4	8
Hole 8			
0- 2 ft[b]	33	80	11
1- 5 ft	23	40	18
5- 8 ft	9.5	12	10
8-13 ft	4.8	8	19
Hole 9			
0- 2 ft	24	14	7
2- 5 ft	19	30	12
5- 8 ft	3.6	6	14
8-13 ft	4.7	10	25
Hole 10			
0- 2 ft	<0.1	4	11
2- 5 ft	5.8	3	6
5- 8 ft	5.7	3	5
8-13 ft	1.5	1	5
Hole 11			
0- 2 ft	2.4	3	7
5-13 ft	8.0	3	8
Hole 12			
0- 2 ft	7.6	3	8
2- 8 ft	1.8	3	7
8-13 ft	2	4	11
Hole 13			
0- 2 ft	1	3	7
2- 5 ft	6	40	14
5- 8 ft	10	17	20
Hole 14			
0- 2 ft	4.1	3	7
2- 5 ft	9.9	17	25
5-10 ft	3.7	6	20
10-12 ft	3.6	3	6
Hole 15			
0- 2 ft	6.2	8	13
2- 5 ft	9.0	12	10
5- 8 ft	25	30	15
Hole 16			
0- 2 ft	6	3	10
8-12 ft	12	22	9
18-20 ft	8.7	9	8
Hole 17			
0- 1 ft[b]	<1.0	4	12
0- 8 ft	2.8	3	10
8-20 ft	7.3	14	5
Hole 18			
0- 2 ft	3.7	3	12
10-15 ft	4	8	7
15-20 ft	9.3	12	5
Hole 19			
0- 3 ft	7.7	3	13
3- 8 ft	4.2	20	7
8-13 ft	6.1	7	15
13-18 ft	1.2	5	8
Hole 20			
0- 3 ft	4	6	9
3- 8 ft	112	200	8
8-13 ft	5.8	8	9
Hole 21			
0- 5 ft	2.9	4	7
5- 8 ft	5	3	4
8-13 ft	10	15	7
13-18 ft	3.3	7	6
Hole 22			
0- 3 ft	3.5	1.5	3
3- 7 ft	3.4	1.5	5

Table 2. Core hole soil samples (cont.)

Sample Location	Ra pCi/g	μg U/g[a]	μg Th/g[a]	Sample Location	Ra pCi/g	μg U/g[a]	μg Th/g[a]
Hole 23				Hole 34			
0- 3 ft	<1.0	2	5	0- 3 ft	5.1	4	11
3- 8 ft	10	7	5	3- 8 ft	<1.0	4	7
8-13 ft	8.3	4	6	8-13 ft	2.4	4	10
Hole 24				Hole 35			
0- 3 ft	5.0	2	4	0- 3 ft	3.9	2	7
3- 8 ft	5.6	2	4	3- 8 ft	11	16	8
				8-13 ft	5.3	9	5
Hole 25				Hole 36			
0- 3 ft	4.0	4	7	0- 3 ft	3.1	4	5
3- 8 ft	4.2	3	6	3- 8 ft	7.6	17	7
8-11 ft	4.4	2	5	8-13 ft	11	16	10
Hole 26				Hole 37			
0- 3 ft	3.3	5	6	0- 3 ft	3.5	2	4
Hole 27				3- 8 ft	5.8	2	5
0- 3 ft	2.9	3	7	8-13 ft	0.8	2	5
3- 8 ft	4.4	9	9	Hole 38			
Hole 28				0- 7 ft	<0.1	2	6
0- 3 ft	3.4	2	5	7-13 ft	4.1	5	5
3- 8 ft	0.5	1	9	Hole 39			
8-13 ft	5	7	6	0- 8 ft	1.5	3	7
Hole 29				8-13 ft	9.5	4	7
0- 3 ft	4.5	1.5	4	Creek 1			
8-13 ft	4	5	3				
13-18 ft	19	25	7	On flood-plane N of hole 38	3.1	1.5	4
Hole 30				Creek 2			
0- 3 ft	2.8	3	5				
3- 8 ft	1.7	2	5				
8-13 ft	7	3	5				
13-18 ft	3.3	2	4	On flood-plane N of hole 38	3.5	1.5	3
Hole 31				Creek 3			
0- 3 ft	6.7	3	6				
3- 8 ft	<0.1	11	11				
8-13 ft	2.8	3	5	On flood-plane E of hole 26	4.0	2	5
Hole 32				Creek 4			
0- 3 ft	3	4	6				
3- 8 ft	<0.1	4	15				
8-13 ft	4.7	2	7	On flood-plane E of hole 5	4.6	1.5	4
Hole 33							
0- 3 ft	8.7	4	8	Grass at hole 20	3.4	0.4	1.5
3- 8 ft	3.7	2	6				
8-13 ft	5.2	2	6				

[a]Accuracy of these values is estimated to be ±20%.

[b]Sample from the original hole which could not be drilled beyond this depth.

*U.S. GOVERNMENT PRINTING OFFICE : 1980 0-310-912/1017