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Health and Safety Research Division

RESULTS OF THE RADIOLOGICAL SURVEY AT 467 LATHAM STREET, MAYWOOD, NEW JERSEY

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Work performed
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REMEDIAL ACTION SURVEY AND
CERTIFICATION ACTIVITIES

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operated by
UNION CARBIDE CORPORATION
for the
DEPARTMENT OF ENERGY

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INTRODUCTION

A comprehensive radiological survey at 467 Latham Street, Maywood, New Jersey, was conducted by Oak Ridge National Laboratory (ORNL) from June 3 to 10, 1981 with assistance from Oak Ridge Associated Universities (ORAU). Contaminated material was discovered in the area during an EG&G aerial radiological survey,[1] and confirmed by a ground-level radiological survey by the Nuclear Regulatory Commission.[2] This contaminated material is believed to have originated from the former Maywood Chemical Company (now the Stepan Chemical Company).

The Maywood Chemical Company was founded in 1895. From about 1916 until 1957, the Maywood Chemical Company processed thorium for use in the manufacture of gas mantles for various lighting devices.[1] In 1932, Route 17 was built to the west of the main plant through an area that was used for disposal of process wastes. Although access to the site was probably restricted, the waste disposal area had no access restrictions. In 1959, Maywood Chemical Company was purchased by the Stepan Chemical Company.

During an aerial survey of the Stepan Chemical Company and the surrounding area in Maywood, New Jersey, by EG&G[1] on January 26, 1981, anomalously high gamma-ray exposure rates (principally ^{232}Th daughter radionuclides) were observed in a residential area close to the Stepan Chemical site. Seven private homes in Maywood, New Jersey, were later identified in a follow-up ground survey by the Nuclear Regulatory Commission[2] (NRC) as having external gamma radiation levels significantly above background. Gamma-ray exposure rates up to 3 mR/h were observed on these properties during NRC surveys.

Additional historical information about the seven private properties was obtained from John Tripuka, owner of the property at 461 Latham Street. Mr. Tripuka related that his father moved into 461 Latham in

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*The survey was performed by members of the Off-Site Pollutant Measurements Group of the Health and Safety Research Division at Oak Ridge National Laboratory, under DOE contract W-7405-eng-26.

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1928, the same year the house was built. The father was employed at the Maywood Chemical Plant. The plant at that time allowed removal of processing waste by-products from their operations, charging only a minimal fee for transportation. Much of the by-product material from other operations in the plant was in the form of tea and cocoa leaves mixed with other fill material. In many instances, this material was used as a rich organic mulch for topsoil for gardens, flowers, and shrubbery and as general fill material for lawns. The elder Mr. Tripuka owned a vacant lot that is now 464 Davison Avenue, and between approximately 1944-1946 had many truck loads of this material deposited at the vacant lot. This material was used primarily for fill in a ditch that laterally traversed the back of several lots between Davison Avenue and Latham Street. Apparently, some of this mulch material contained thorium process wastes. Several neighbors in the area used this material for vegetable and flower gardens as well as for low spots in their lawns. The remaining unused material was pushed out and spread over the 464 Davison lot. The lot was sold and a house was built on the vacant lot in 1967.

The present owners of the 467 Latham Street, the Joe Hughes family, have lived there all their lives. The house was constructed in 1925 and has been in the same family since that time. Front and rear views of the property are provided in Figs. 1 and 2, respectively. The layout of the property, depicting the survey grid pattern and approximate property boundaries, is shown in Fig. 3. The dimensions of the lot are approximately 15 m wide by 37.5 m deep.

SURVEY METHODS

The survey measurements performed as part of the radiological survey at 467 Latham Street were done according to the survey plan of May 27, 1981.[3] This action and survey plan for Maywood, New Jersey, are provided in Appendix I. A comprehensive description of the survey methods and instrumentation, as well as the radiation guidelines used in evaluating the data, have been provided in other reports (e.g., reference 4).

SURVEY RESULTS

Applicable federal guidelines have been summarized in Table 1. The normal background levels for the northern New Jersey area are presented in Table 2. These data are provided for comparison with the survey results presented in this section.

With the exception of measurements of transferable activity which represent net count rates, all direct measurement results presented in this report are gross readings; background radiation levels have not been subtracted. Similarly, background concentrations have not been subtracted from radionuclide concentrations measured in environmental samples.

Outdoor Survey Results

External gamma-ray and beta-gamma measurements. The results of the grid point measurements and grid block scans are presented in Table 3. Analysis of this data indicates that only two small isolated areas of contaminated soil are present on the property. These areas have been highlighted with shading on Fig. 4. The larger area located behind the garage is part of a garden plot, where the contaminated mulch material was probably placed in the past. The contamination in the front yard was placed there as fill for a low area.

The average external gamma-ray exposure rate at 1 m above the surface on this property was determined to be 16 μR/h, a value twice the normal background for the Maywood area. These elevated gamma radiation levels are due primarily to direct and scattered radiation from the contamination on bordering properties (461 Latham and 464 Davison). Grid point readings on the property ranged from 7 μR/h to 110 μR/h, with the highest level being recorded at the rear of the lot, nearest to the adjacent properties.

In the two contaminated areas on the property, the maximum measured surface external gamma-ray exposure rate was 86 μR/h, with an associated 1 m exposure rate of 23 μR/h. The maximum measured beta-gamma dose rate on the surface of the contaminated areas was 0.08 mrad/h.

Surface soil samples. Surface soil samples were collected at fourteen systematic locations (MJ samples) and six biased locations (MJB samples) on the property. These sample locations are depicted in Fig. 5. Results of the laboratory analysis for ^{232}Th, ^{238}U, and ^{226}Ra in these samples are presented in Table 4.

The average concentrations of ^{232}Th, ^{238}U, and ^{226}Ra in surface soil from across the yard were approximately 1.1, 0.76, and 0.78 pCi/g, respectively. These values are within the normal background range for the Maywood area. In the two contaminated areas on the property, ^{232}Th concentrations were measured ranging from 10 pCi/g (MJB36) to 26 pCi/g (MJB32). The maximum level is approximately thirty times the normal background concentration for the area. No other biased soil samples contained radionuclide concentrations significantly above background.

Indoor Survey Results

Alpha, beta-gamma, and gamma-ray measurements. The results of the indoor measurements made at 467 Latham Street are provided in Table 5. Schematic views of the floor plans of the house are given in Figs. 6-9 for use in correlation with the data presented in the table.

The average gamma-ray exposure rate at 1 m above the floor surface in the house was determined to be 10 μR/h, a value only slightly above the normal background level for the area. Based on the results of the scan survey of the house and garage, there is no indication of the presence of contaminated materials inside either structure. The maximum surface gamma-ray exposure rate was found to be 18 μR/h, and the maximum observed beta-gamma dose rate was 0.04 mrad/h. Surface alpha activity throughout both structures was found to be negligible (<60 dpm/100 cm^2). No radiation levels in the house or garage exceeded the applicable radiation guidelines.

Radon and radon daughter sampling. Preliminary radon and radon daughter measurements were made in the basement of the house to determine the approximate magnitude of the exposure pathway. The measurements are indicative of radon levels only at the instant of sampling and do not represent daily or annual averages. Further sampling would be required to determine the levels in the house for comparison with applicable guidelines.

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The results of the radon and radon daughter measurements are presented in Table 6. Concentrations of radon in air were measured at 0.68 pCi/L with an associated radon daughter concentration of 0.00017 WL. Both measured levels are in the normal range of background for the Maywood area.

SUMMARY

Summaries of the outdoor and indoor measurement results of the radiological survey conducted at 467 Latham Street are provided in Tables 7 and 8, respectively. These results indicate that at only two locations on the property were contaminated materials found (see Fig. 4). Both locations were outdoors and were found to contain soil primarily contaminated with radionuclides of the ^{232}Th decay chain. The total estimated volume of the contaminated material on the property is approximately 1 m^3, based on an average assumed depth of 15 cm in the suspect areas. A breakdown of this volume by area is provided in Table 9.

Outdoors on the property, the average external gamma-ray exposure rate at 1 m above the surface was approximately two times the normal background for the Maywood area. This increased activity is due to direct and scattered radiation from adjacent contaminated properties, not from the small areas of contamination on this lot. However, in the areas of contamination, surface external gamma-ray exposure rates approached or exceeded the NRC guidelines for continuous exposure (10 CFR 20). Surface soil in these areas contained ^{232}Th in concentrations up to thirty times background.

Inside the house, radiation levels were found to be in the normal background range for homes in the Maywood area. There was no evidence of the presence of contaminated materials present inside either structure on this property. No measured radiation levels approached the applicable guidelines for exposure to the general population.

Using the results of this radiological survey, a preliminary evaluation of the potential exposure pathways for radiation exposures to residents at this location has been conducted. The four primary pathways from the type of contaminated materials found on the property are: (1) direct radiation exposure, (2) inhalation of radon and radon daughter

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8. J. W. Healy and W. J. Bair, "Preliminary Report - Radiological Appraisal of Houses in Maywood, New Jersey". Attachment to letter from W. J. Bair, Battelle Pacific Northwest Laboratories to W. E. Mott, Department of Energy, Washington, D.C., July 17, 1981.

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Fig. 1. Front view of property at 467 Latham Street in Maywood, NJ

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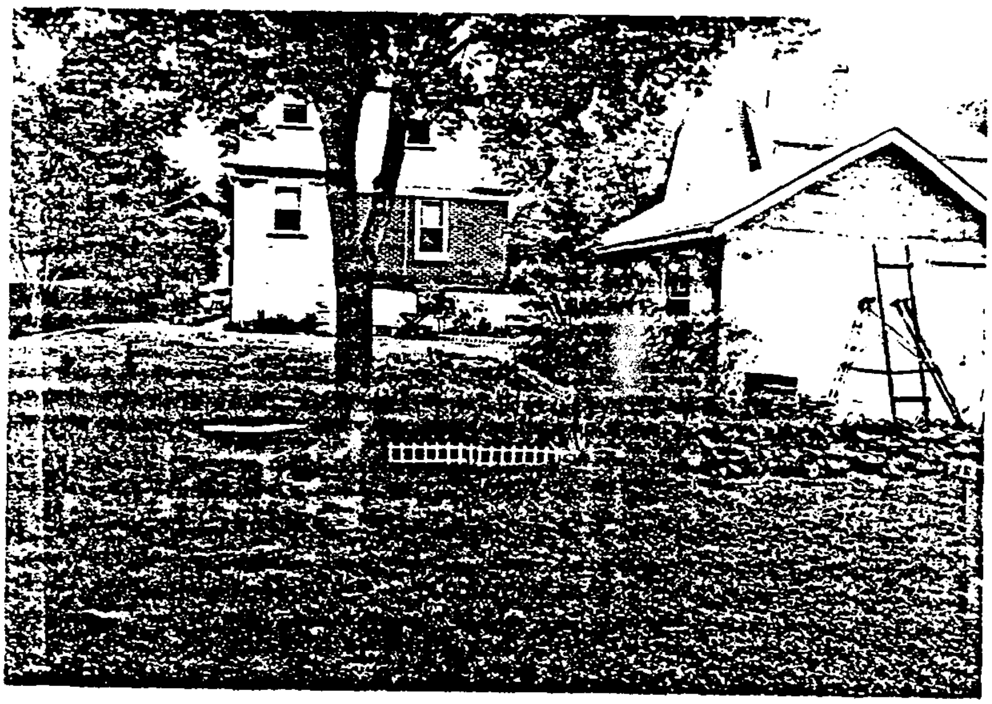

Fig. 2. Rear view of property at 467 Latham Street in Maywood, NJ

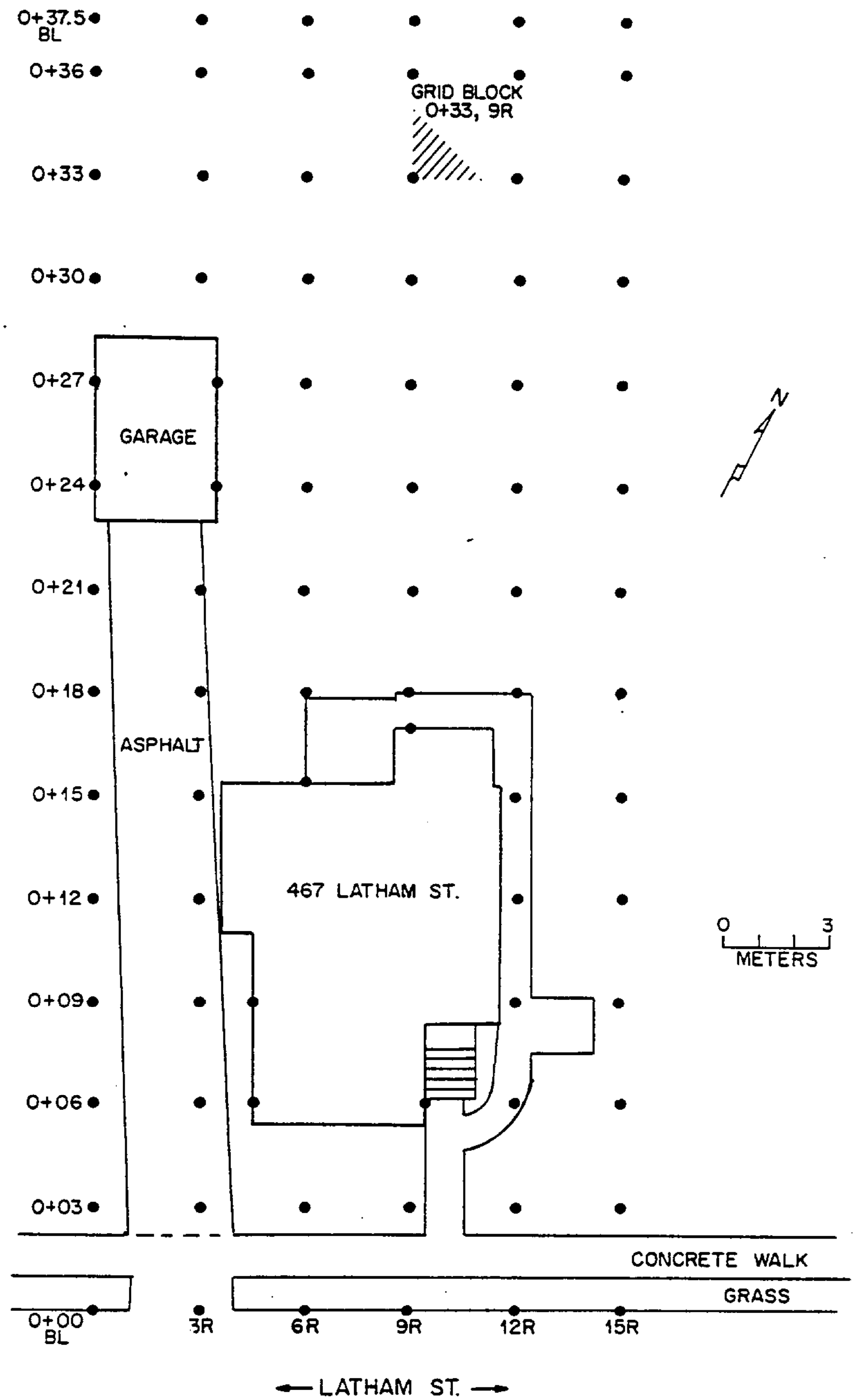

Fig. 3. Grid point and grid block locations at 467 Latham Street.

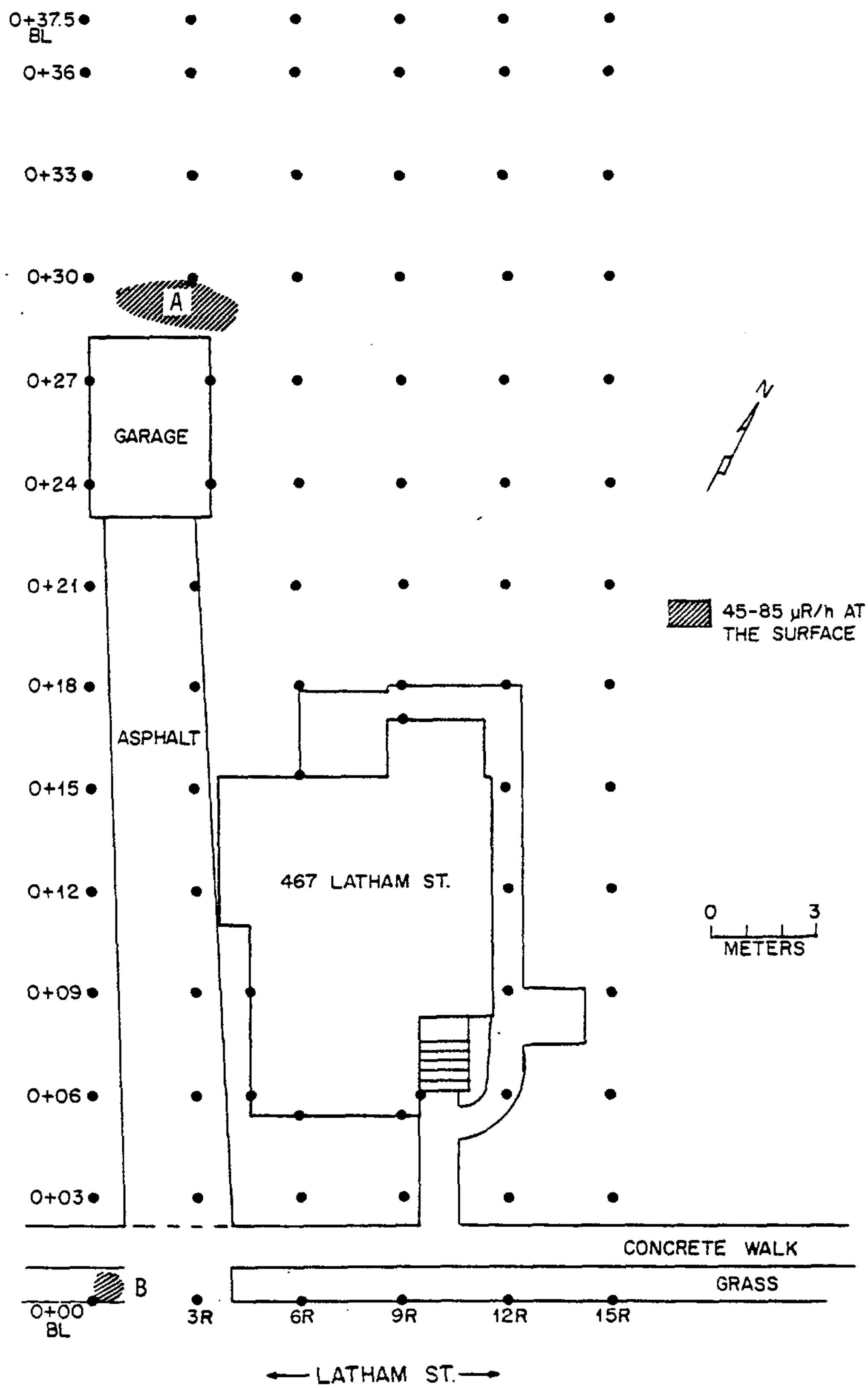

Fig. 4. Estimated extent of contamination at 467 Latham Street, based on the results of the surface gamma-ray scan.

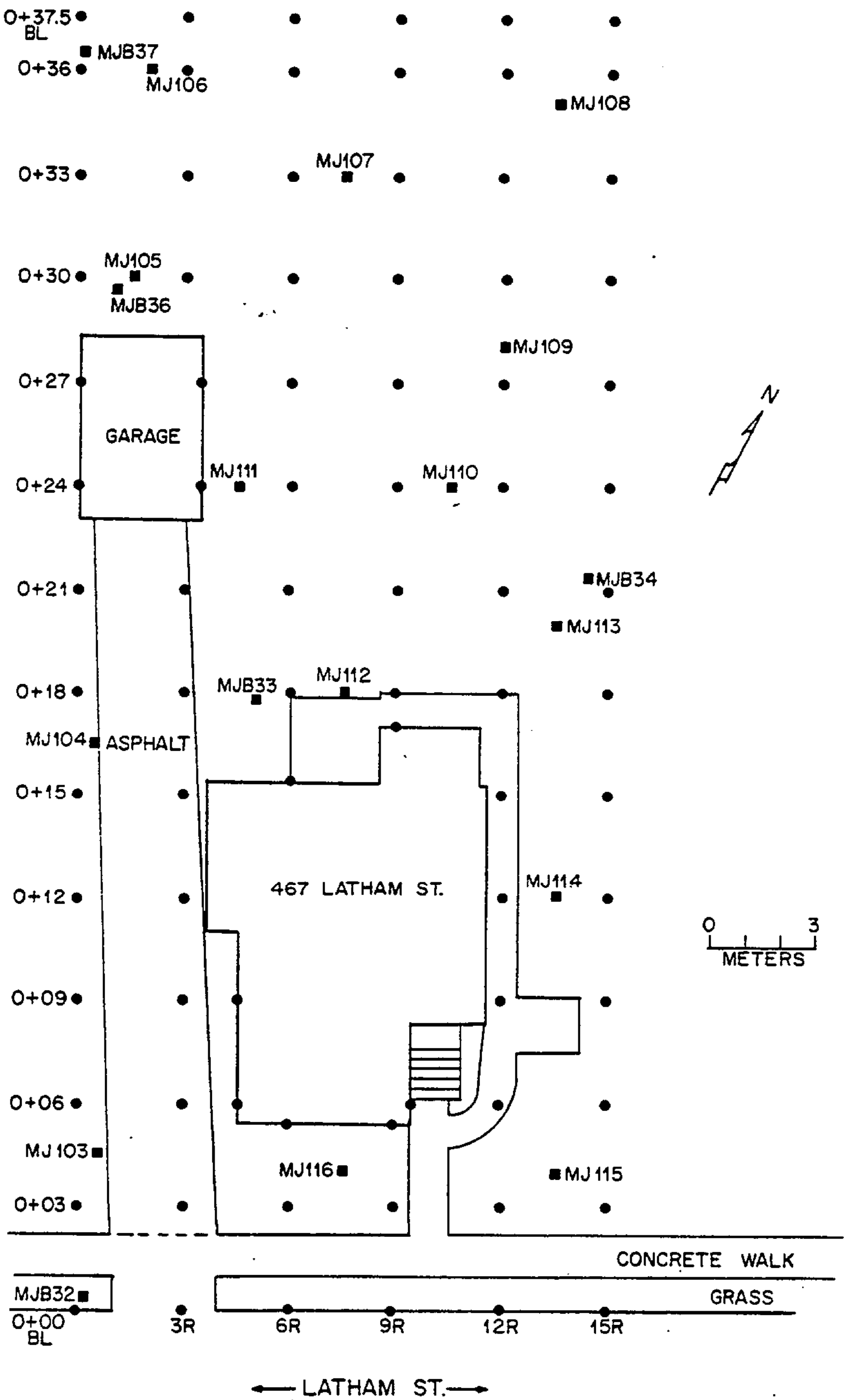

Fig. 5. Location of systematic and biased surface soil samples at 467 Latham Street.

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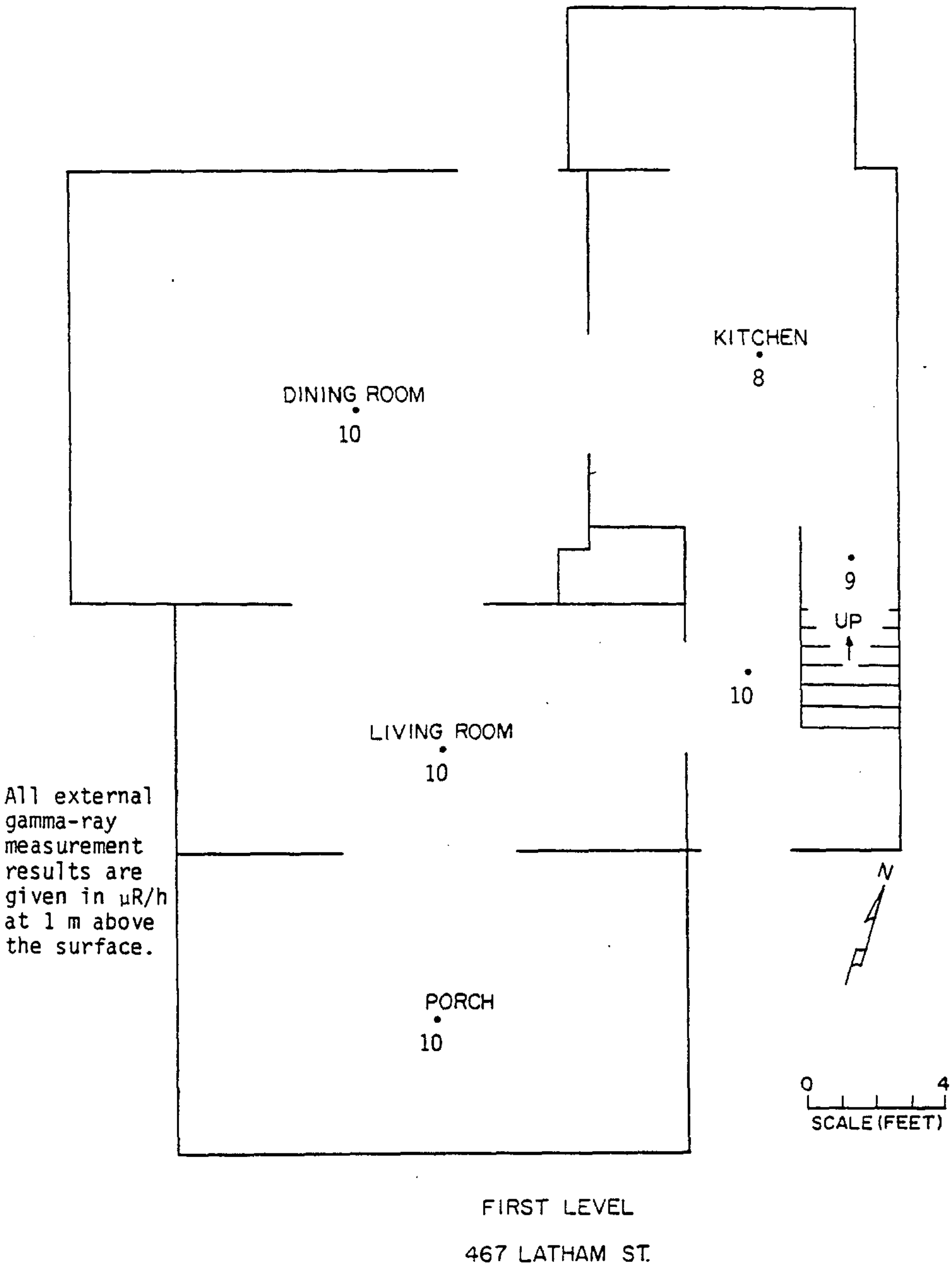


Fig. 6. Schematic of the first level floor plan at 467 Latham Street showing external gamma-ray measurement results at 1 m.

All external gamma-ray measurement results
are given in μR/h at 1 m above the surface.

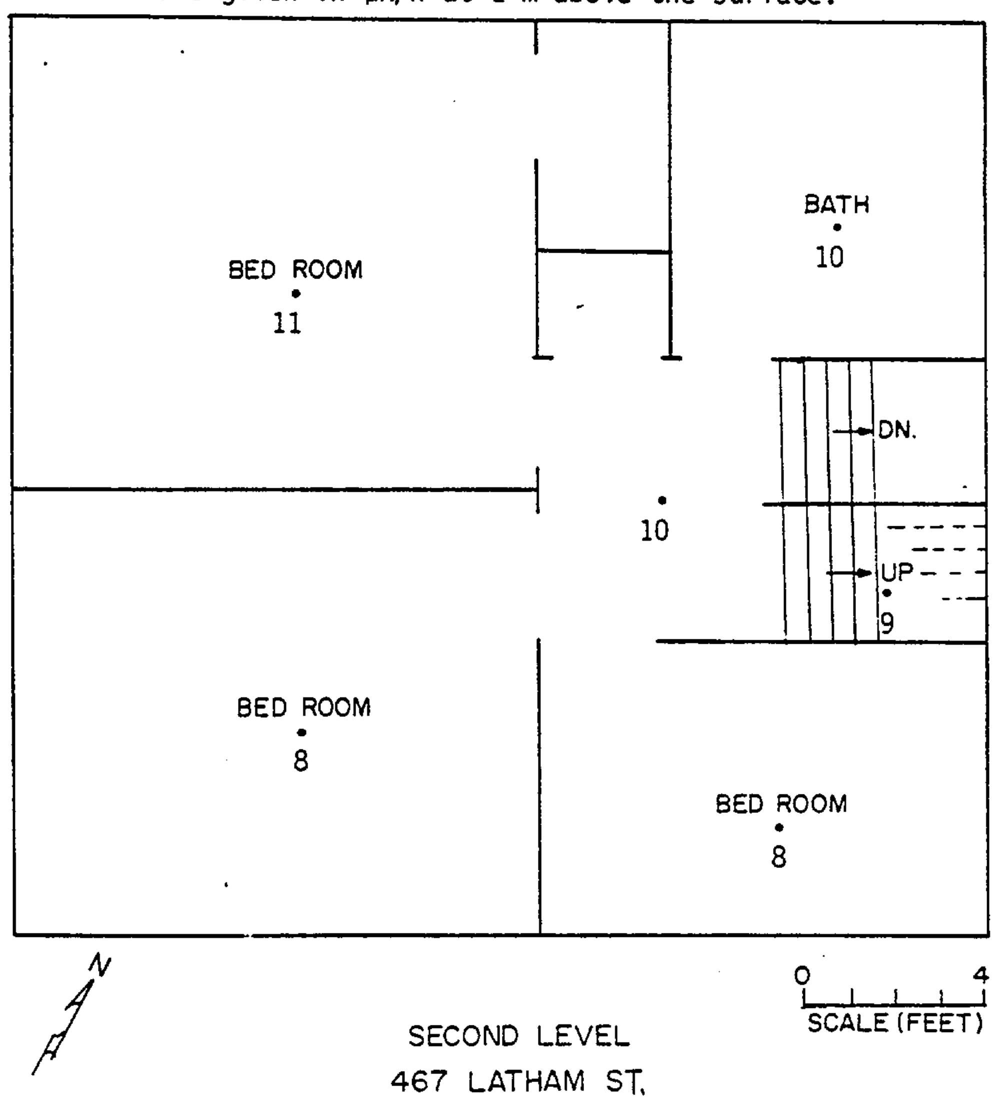
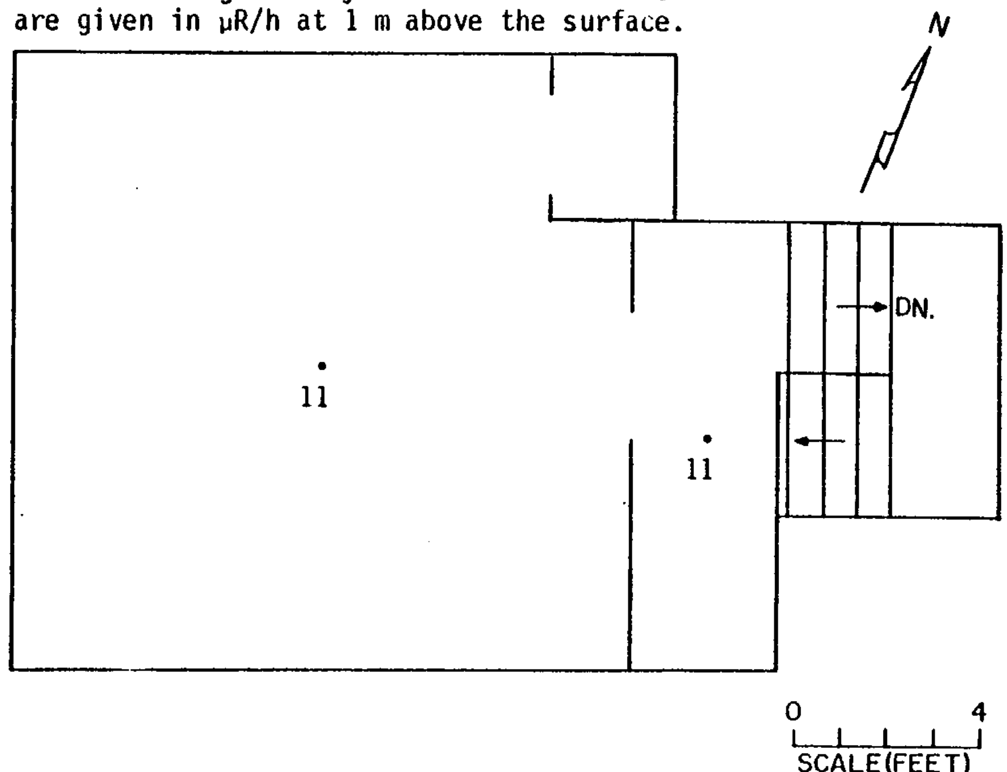


Fig. 7. Schematic of the second level floor plan at 467 Latham Street showing external gamma-ray measurement results at 1 m.

All external gamma-ray measurement results
are given in μR/h at 1 m above the surface.



THIRD LEVEL

467 LATHAM ST.

Fig. 8. Schematic of the third level floor plan at 467 Latham Street showing external gamma-ray measurement results at 1 m.

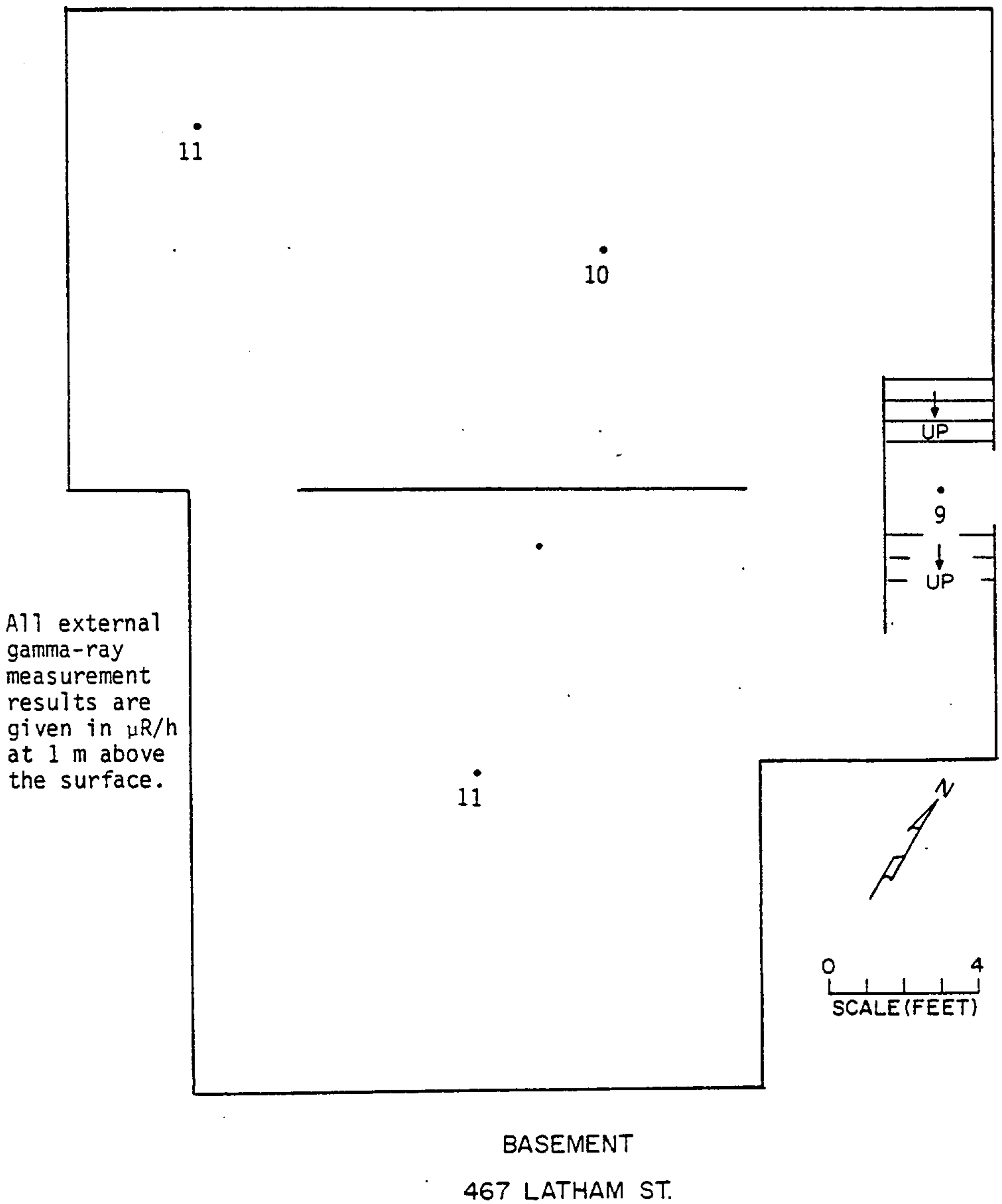


Fig. 9. Schematic of the basement floor plan at 467 Latham Street showing external gamma-ray measurement results at 1 m.

Table 1. A summary of applicable radiation guidelines

Mode of exposure	Exposure conditions	Guideline value	Guideline source
1. External gamma radiation	Continuous exposure to individual in general population (whole body)	60 μR/h	Nuclear Regulatory Commission (NRC) - Standards for Protection Against Radiation (10 CFR 20.105)
2. Surface alpha contamination	^{226}Ra contamination fixed on surfaces	100 dpm/100 cm^2	NRC 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 (Adapted from NRC Reg. Guide 1.86
	Removable ^{226}Ra contamination	20 dpm/100 cm^2	
3. Surface beta contamination	Removable beta-gamma emitters	1000 dpm/100 cm^2	Same as number 2
4. Beta-gamma dose rates	Average dose rate on an area no greater than 1 m^2	0.20 mrad/h	Same as number 2
	Maximum dose rate in any 100 cm^2 area	1.0 mrad/h	Same as number 2
5. Exposure to radon	Maximum permissible concentration of ^{222}Rn in air in unrestricted areas	3.0 pCi/L	NRC 10 CFR 20.103, Appendix B, Table II
6. Radionuclides in water	Maximum contaminant level for combined ^{226}Ra and ^{228}Ra in drinking water	5 pCi/L	EPA Interim Standards 40 CFR 141.15
	Maximum permissible concentration of the following radionuclides in water for unrestricted areas		NRC 10 CFR 20.103 Appendix B, Table II
	^{226}Ra	30 pCi/L	
	^{238}U	40,000 pCi/L	
	^{230}Th	2,000 pCi/L	
	^{210}Pb	100 pCi/L	
7. Airborne ^{222}Rn progeny	Remedial action indicated if ^{222}Rn progeny exceed this concentration because of uranium mill tailings under or around the structure	0.01 WL	10 CFR 712.7

Table 2. Background radiation levels for the northern New Jersey area.

Type of radiation measurement or sample	Radiation level or radionuclide concentration
Gamma-ray exposure rate at 1 m above floor or ground surface (μR/h)	8[a]
Direct alpha activity on indoor floor or wall surface (dpm/100 cm^2)	26
Transferable alpha activity on indoor floor or wall surface (dpm/100 cm^2)	10
Transferable beta-gamma activity on indoor floor or wall surface (dpm/100 cm^2)	20
Beta-gamma dose rate activity on ground, floor and wall surfaces (mrad/h)	0.01 - 0.03
Indoor radon concentration (pCi/L)	
Basement	1.7[b]
Upstairs	0.8[b]
Indoor radon daughter concentration (WL)	
Basement	0.008[b]
Upstairs	0.004[b]
Concentration of radionuclides in soil (pCi/g)	
^{232}Th	0.9[c]
^{238}U	0.9[c]
^{226}Ra	0.9[c]

[a]Reference 5.
[b]Reference 6.
[c]Reference 7.

Table 3. Outdoor measurements at 467 Latham Street

Grid[a] location	Grid point measurements[b]			Grid block measurements[c]		
	Gamma exposure at 1 m (μR/h)	Gamma exposure at the surface (μR/h)	Beta-gamma dose rate at 1 cm above the surface[d] (mrad/h)	Maximum gamma exposure at 1 m[d] (μR/h)	Maximum gamma exposure at the surface[d] (μR/h)	Beta-gamma dose rate at maximum 1 cm above the surface[d] (mrad/h)
0+00, BL	15	10		11	47	0.08
0+03, BL	9	9			13	
0+06, BL	12	12			14	
0+09, BL	14	13			14	
0+12, BL	14	13			14	
0+15, BL	13	13			14	
0+18, BL	13	16		23	19	
0+21, BL	20	17		35	21	
0+24, BL	49	47	0.05			
0+27, BL	47	58	0.08	33	56	0.05
0+30, BL	40	28		51	35	
0+33, BL	35	30			35	
0+36, BL	56	30		86	51	0.04
0+37.5, BL	110	47	0.04		11	
0+00, 3R	7	7			11	
0+03, 3R	8	9			11	
0+06, 3R	8	8			12	
0+09, 3R	9	11			12	
0+12, 3R	11	11			15	
0+15, 3R	9	10		14	23	
0+18, 3R	9	10			15	
0+21, 3R	11	11			12	
0+24, 3R	9	9			14	
0+27, 3R	11	9		23	86	0.03
0+30, 3R	18	16			11	
0+33, 3R	23	17			28	
0+36, 3R	35	28	0.04		28	
0+37.5, 3R	47	26				
0+06, 4.5R	11	8				
0+09, 4.5R	11	9				
0+12, 3.5R	11	10				
0+15, 3.5R	10	9				

Table 3. (continued)

Grid[a] location	Grid point measurements[b] Gamma exposure at 1 m (μR/h)	Gamma exposure at the surface (μR/h)	Beta-gamma dose rate at 1 cm above the surface[d] (mrad/h)	Grid block measurements[c] Maximum gamma exposure at 1 m[d] (μR/h)	Maximum gamma exposure at the surface[d] (μR/h)	Beta-gamma dose rate at maximum 1 cm above the surface[d] (mrad/h)
0+00, 6R	8	7			10	
0+03, 6R	8	8			11	
0+5.5, 6R	10	9				
0+15.5, 6R	10	12			13	
0+18, 6R	11	12			13	
0+21, 6R	11	11			14	
0+24, 6R	12	11			15	
0+27, 6R	15	13			18	
0+30, 6R	16	15			19	
0+33, 6R	19	16			23	
0+36, 6R	26	23	0.03		23	
0+37.5, 6R	30	23				
0+00, 9R	7	7			10	
0+03, 9R	8	8			10	
0+5.5, 9R	9	8			14	
0+17, 9R	11	9			12	
0+18, 9R	10	9			12	
0+21, 9R	11	11			14	
0+24, 9R	12	11			16	
0+27, 9R	15	12			17	
0+30, 9R	13	13			18	
0+33, 9R	15	14			18	
0+36, 9R	19	17			19	
0+37.5, 9R	21	15			19	
0+00, 12R	7	6			11	
0+03, 12R	8	8			12	
0+06, 12R	9	9			14	
0+09, 12R	10	11			12	
0+12, 12R	8	9			12	
0+15, 12R	9	9			13	
0+18, 12R	12	11			13	
0+21, 12R	11	11		12	23	0.02

Table 3. (continued)

Grid[a] location	Grid point measurements[b]			Grid block measurements[c]		
	Gamma exposure at 1 m (μR/h)	Gamma exposure at the surface (μR/h)	Beta-gamma dose rate at 1 cm above the surface[d] (mrad/h)	Maximum gamma exposure at 1 m[d] (μR/h)	Maximum gamma exposure at the surface[d] (μR/h)	Beta-gamma dose rate at maximum 1 cm above the surface[d] (mrad/h)
0+24, 12R	12	12			15	
0+27, 12R	14	12			18	
0+30, 12R	15	15			18	
0+33, 12R	16	14			18	
0+36, 12R	19	16			19	
0+37.5, 12R	23	14			21	
0+00, 15R	8	7				
0+03, 15R	8	9				
0+06, 15R	8	8				
0+09, 15R	8	9				
0+12, 15R	8	10				
0+15, 15R	9	10				
0+18, 15R	9	10				
0+21, 15R	11	11				
0+24, 15R	12	11				
0+27, 15R	11	12				
0+30, 15R	12	13				
0+33, 15R	12	14				
0+36, 15R	14	14				
0+37.5, 15R	18	12				

[a] Grid location is shown in Fig. 3.
[b] Grid point measurements are discrete measurements at each grid point.
[c] Grid block measurements are obtained by gamma-ray scan of entire block.
[d] Absence of a value indicates no measurement was taken.

Table 4. Results of radionuclide analyses of surface soil samples from 467 Latham Street

Sample[a]	Location[b]	Radionuclide concentration (pCi/g)		
		^{232}Th[c]	^{238}U[d]	^{226}Ra[c]
MJ103	0+4.5, 0.5R	0.96 ± 0.04	0.71	0.77 ± 0.02
MJ104	0+16.5, 0.5R	1.6 ± 0.2	0.73	0.90 ± 0.05
MJ105	0+30, 1.5R	1.1 ± 0.2	0.68	0.70 ± 0.09
MJ106	0+36, 2R	1.5 ± 0.03	0.68	0.90 ± 0.04
MJ107	0+33, 7.5R	1.1 ± 0.02	0.79	0.83 ± 0.03
MJ108	0+35, 13.5R	1.9 ± 0.06	0.89	1.0 ± 0.04
MJ109	0+28, 12R	1.0 ± 0.2	0.77	0.70 ± 0.05
MJ110	0+24, 10.5R	0.83 ± 0.04	0.72	0.67 ± 0.02
MJ111	0+24, 4.5R	0.95 ± 0.04	0.71	0.71 ± 0.03
MJ112	0+18, 7.5R	1.1 ± 0.2	0.77	0.80 ± 0.02
MJ113	0+20, 13.5R	0.90 ± 0.04	0.77	0.70 ± 0.04
MJ114	0+12, 13.5R	1.3 ± 0.04	0.79	0.75 ± 0.04
MJ115	0+04, 13.5R	0.77 ± 0.02	0.85	0.76 ± 0.02
MJ116	0+04, 7.5R	0.90 ± 0.04	0.76	0.66 ± 0.03
MJB32	0+0.2, 0.2R	26 ± 2	2.3	3.7 ± 0.2
MJB33	0+17.8, 5R	1.9 ± 0.03	1.1	1.3 ± 0.03
MJB34	0+21.5, 14.5R	0.95 ± 0.06	0.68	0.63 ± 0.04
MJB36	0+29.5, 1R	10 ± 0.2	0.72	2.4 ± 1.0
MJB37A	0+36.5, BL	3.6 ± 0.08	0.95	1.2 ± 0.05
MJB37B[e]	0+36.5, BL	1.5 ± 0.05	0.90	0.85 ± 0.03

[a]MJ is a systematic surface soil sample; MJB is a biased surface soil sample. All samples are taken from the top 15 cm of soil surface.

[b]Location is shown on Fig. 5.

[c]Indicated error is at the 95% confidence interval (±2σ).

[d]Total error on measurement results is less than ±3% error (95% confidence level).

[e]Sample was obtained at a depth of 41-46 cm.

Table 5. Indoor measurements at 467 Latham Street

Location[a]	External gamma exposure rate (μR/h): Center of room at 1 m	External gamma exposure rate (μR/h): Surface maximum	Beta-gamma dose rate at 1 cm in the center of room (mrad/h)	Average direct alpha activity on surface (dpm/100 cm²)	Transferable alpha activity/Transferable beta-gamma activity (dpm/100 cm²)
Street level					
Porch	10	12	0.02	<26	b
Living room	10	11	0.02	<26	b
Dining room	10	12	0.03	<26	b
Kitchen	8	11	0.02	<26	<10/<20
Hallway	10	11	0.02	<26	b
Stairway to second level	9	11	0.02	<26	b
Second level					
Hall	10	10	0.01	<26	<10/<20
Southeast bedroom	8	9	0.01	<26	b
Southwest bedroom	8	9	0.01	<26	b
Northwest bedroom	11	12	0.02	<26	b
Bathroom	10	10	0.01	<26	b
Stairway to third level	9	9	0.02	<26	b
Third level					
Hallway	11	10	0.02	<26	b
Bedroom	11	11	0.01	<26	<10/<20
Basement					
Stairway to basement	9	11	0.01	<26	b
Furnace room	11	14	0.02	<26	b
Study	10	13	0.04	<26	<10/<20
South room	11	13	0.02	<26	b
Unattached garage					
Garage	16	18	0.02	52	b

[a]Location is shown on Figs. 6-9.

[b]No measurement taken.

Table 6. Radon and radon daughter measurements at 467 Latham Street

Location	Concentration of ^{222}Rn in air (pCi/L)	Radon daughter concentration in air (WL)	Concentration of radionuclides in air (pCi/L)				
			^{218}Po (Ra A)	^{214}Pb (Ra B)	^{214}Bi (Ra C)	^{212}Pb (Th B)	^{212}Bi (Th C)
Basement	0.68	0.00017	0.12	0.0027	0.0090	0.014	0.0071

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Table 7. Summary of outdoor measurements and survey results at 46 Latham Street.

Measurement or sample type	Number of measurements/samples	Range	Mean	Biased readings[a]
Grid Point Measurements				
External gamma-ray exposure rate at 1 m (μR/h)	84	7-110	16	
External gamma-ray exposure rate at surface (μR/h)	84	6-58	14	
Systematic surface soil samples				
^{232}Th concentration (pCi/g)	14	0.77-1.5	1.1	
^{238}U concentration (pCi/g)	14	0.68-0.89	0.76	
^{226}Ra concentration (pCi/g)	14	0.66-1.0	0.78	
Biased Measurements[a]				
Maximum external gamma-ray exposure rate at 1 m (μR/h)				86
Maximum external gamma-ray exposure rate at surface (μR/h)				86
Maximum concentration of ^{232}Th in surface soil (pCi/g)				26

[a]Biased measurements included gamma-ray scanning of the entire yard and surface soil sampling at biased locations.

Table 8. Summary of indoor measurements and survey results at 467 Latham Street

Measurement or sample type	Number of measurements/samples	Range	Mean	Biased Readings[a]
Systematic room surveys				
External gamma-ray exposure rate at 1m (μR/h)	19	8-16	10	
Beta-gamma dose rate at 1 cm above surface (mrad/h)	19	0.01-0.04	0.02	
Direct alpha activity on surface (dpm/100 cm^2)	19	<26-52	<26	
Biased Measurements[a]				
Maximum external gamma-ray exposure rate at surface (μR/h)				18
Maximum beta-gamma dose rate at 1cm (mrad/h)				0.04
^{222}Rn concentration in air (pCi/L)				0.68
^{222}Rn daughter concentration in air (WL)				0.00017

[a]Biased measurements included gamma-ray scanning of each room, measurement of the beta-gamma dose rates at locations of elevated gamma levels, and measurements of indoor radon and radon daughter concentrations.

Table 9. Summary of measurements results in contaminated areas at 467 Latham Street

Location[a]	Measurement type	Measurement result
Area A	Maximum external gamma-ray exposure rate at surface (μR/h)	86
	^{232}Th concentrations measured in surface soil (pCi/g)	10
	Estimated areal extent of contamination (m^2)	4.5
	Estimated average depth of contamination (m)	0.15
	Estimated total volume of contaminated material[b] (m^3)	0.7
Area B	Maximum external gamma-ray exposure rate at surface (μR/h)	47
	^{232}Th concentration measured in surface soil (pCi/g)	26
	Estimated areal extent of contamination (m^2)	1.0
	Estimated average depth of contamination (m)	0.15
	Estimated total volume of contaminated material[b] (m^3)	0.2

[a]For area designation see Fig. 4.

[b]Volume estimates are based on a correlation of surface measurements and subsurface investigations using a reasonable number of drill holes. The exact shape of the contaminated regions cannot be precisely determined by this type of investigation. Actual irregular shapes have therefore been approximated by the most reasonable regular geometric shape (e.g., cylinder, or rectangular prism).

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APPENDIX I

ACTION AND SURVEY PLAN, MAYWOOD, NEW JERSEY

ACTION PLAN FOR PRIVATE PROPERTY SURVEYS IN MAYWOOD, NEW JERSEY

Purpose

This plan defines the ORNL activities to survey private properties in Maywood, New Jersey, which are believed to be contaminated with residues from thorium processing operations at the former Maywood Chemical Company. There are three objectives of these surveys: (1) define the current radiological status of each property, (2) define the sources of radiation exposures on each property and estimate the volume of material involved, and (3) prepare an exposure evaluation, comparing radiation exposures with guidelines.

Approach

Initially, ORNL will review all available data relevant to the properties involved. A generic survey plan will then be developed for conduct of private property surveys and will be modified in the field as needed to characterize the properties and radiation sources. Following approval of this approach, ORNL will conduct the radiological surveys at each private property for which consent can be obtained. The findings of each field survey will be prepared and submitted to DOE as a preliminary report; a final report on each property will be submitted after environmental samples are analyzed. The required work is separated into individual tasks which may be summarized as follows:

Task 1. Review of Available Data

Data provided by ESED have been reviewed and incorporated in the survey planning process. Other data have been volunteered by ORAU, and by the New Jersey Department of Environmental Protection. It is anticipated that additional contacts will be made with NRC Region I personnel. Historical information about each property will be obtained from brief home owner/occupant interviews.

Task 2. Preparation of Survey Plan

The radiological survey plan for private properties will be developed after the available data are reviewed. Ordinarily, a site visit would precede this task. However, due to the immediate need for the surveys, a general plan will be prepared based on prior experience. This plan will be modified in the field as needed to fully characterize any property.

Task 3. Implementation of Radiological Surveys

Radiological surveys of private properties will be conducted according to the approved survey plan. Surveys will only be conducted on properties for which consent can be obtained. Outdoor drilling will be done on an as-needed basis. Drilling or coring through basement floors will only be done as a last resort for obtaining necessary data about subsurface radioactivity profiles.

Task 4. Gamma-Ray Scans of Adjacent Properties

Because of the crescent shapes of the isopleths in the EG&G aerial survey and the possibility of spill-over contamination, it is recommended that gamma-ray scans be conducted on adjacent properties along Latham and Davidson Streets. These scans would be conducted by survey personnel walking on the property. The ground would be scanned with an NaI(Tl) scintillation survey meter at the surface; building foundation walls would also be scanned. If any anomalies were found during this scan, a full radiological survey of the property would be conducted. A scanning survey of a property would be done only with the property owner's consent.

Task 5. Radiological Survey Reporting

The radiological survey findings for each property will be reported in two separate reports. One report will contain all field measurement data obtained at each property. These preliminary letter reports will be submitted to DOE within five days following the completion of the survey. Conclusions in these letter reports will relate the radiation exposures found on each site to established guidelines for members of the public. Sources of radiation exposures will be identified and the quantity of radioactive material involved will be estimated. An evaluation of radiation exposure will be prepared for each property. The second letter report for each property will contain all analytical results for environmental samples taken during the survey. These analytical results will be related to on-site measurements. Comments received on the preliminary report will be incorporated in preparation of the second report. Any properties for which access was denied will be identified as will any property which had no anomalies on the surface gamma-ray scan. These identifications will be made in the cover letter transmitting the first series of reports.

Schedule

Task 1 and Task 2.

These tasks will be completed during the week ending May 20, 1981.

Task 3 and Task 4.

These tasks will be performed concurrently. Task 3 is scheduled to begin June 3, 1981.

Task 5.

Preliminary reports will be transmitted during the week of June 19, 1981. Target date for transmittal is June 15, 1981. Draft final letter reports will be transmitted approximately six weeks following the preliminary report transmittal.

RADIOLOGICAL SURVEY PLAN FOR PRIVATE PROPERTIES IN MAYWOOD, NEW JERSEY

INTRODUCTION

The Stepan Chemical Company (formerly Maywood Chemical Company) was developed in 1895. From about 1916 until 1957 the Maywood Chemical Company processed thorium for use in the manufacture of gas mantles for various lighting devices.[1] In 1932, Route 17 was built to the west of the main plant through an area that was used for disposal of process wastes. Although access to the site was probably restricted, the waste disposal area had no access restrictions. In 1959, Maywood Chemical Company was purchased by the Stepan Chemical Company. A federally supervised cleanup of a portion of the waste dump was conducted in 1960. Presently, Stepan Chemical Company owns a 30-acre site east of N.J. Route 17, just south of the New York, Susquehanna and Western Railroad right of ay. On the west side of N.J. Route 17, SWS Industries owns a vacant 8. acre site (formerly a portion of the waste disposal area); plans have been made to locate a warehouse/office complex on this site.

During an aerial survey of the Stepan Chemical Company and the surround area in Maywood, New Jersey, by EG&G[1] on January 26, 1981, anamously igh gamma-ray exposure rates (principally ^{232}Th daughter radionuclides were observed in a residential area close to the Stepan Chemical site. Seven private homes in Maywood, New Jersey, were later identified in a follow-up ground survey by the Nuclear Regulatory Commission[2] as having external gamma radiation levels significantly above background. Exposure rates up to 3 mR/h have been observed on these properties. It is surmized that thorium residues were obtained from the Maywood Chemical Waste disposal area and used as fill material on these private properties.

At the request of the Environmental and Safety Engineering Division (ESED) of the Department of Energy, the Off-Site Pollutant Measurements Group, at Oak Ridge National Laboratory (ORNL) will perform a comprehensive radiological survey on seven private properties in Maywood, New Jersey. The survey is scheduled to begin June 3, 1981.

SURVEY METHODS

The following section describes the survey methods to be employed in performing the ORNL radiological survey. Detailed descriptions of instrumentation, measurement procedures and sample analyses are presented in an ORNL/TM report.[3]

Outdoor Survey

Grid system

Prior to radiological measurements, a rectangular grid will be established covering the entire area to be surveyed. The spacing of mutually perpendicular grid lines will be determined by the size of the area involved and by the level of detail required for any given area. At least 30 grid points (intersection of grid lines) will be established for each property. At some locations where significant levels of contamination are observed, a smaller grid system will be superimposed to provide more detailed information as required. The size of the smaller grid system will be determined in the field as conditions dictate.

External gamma radiation measurements

External gamma radiation levels will be measured using a 3.2 cm × 3.8 cm NaI(Tl) probe attached to a ratemeter (calibration for this instrument is performed in the field using a Reuter-Stokes Pressurized Ion Chamber [PIC]). External gamma-ray exposure rates are measured at the ground surface and 1 m above the ground surface at grid points; these measurements will be recorded. Each grid block (square formed by the grid lines) will be scanned at the surface, and the maximum gamma radiation level within each block will be noted.

Beta-gamma dose rates

Beta-gamma dose rate measurements at 1 cm above the ground surface will be performed at those locations where surface gamma radiation levels are significantly above background. The instrument used for these measurements is a Geiger-Mueller (G-M) survey meter with a window thickness of 7 mg/cm^2 and a halogen-quenched GM tube (open and closed window).

Surface deposits of radioactive materials

Samples of surface soil (a 10 cm × 10 cm area soil sample to a 15-cm depth) will be collected at systematic locations and analyzed in order to identify the locations and estimated quantities of surface deposits of radioactivity. In addition, biased surface soil samples will be obtained at representative locations where elevated external gamma radiation levels are observed. Soil samples will be packaged and transported back to ORNL for processing and analyses for concentrations of ^{238}U, ^{226}Ra, ^{232}Th and other radionuclides as appropriate.

Subsurface deposits of radioactive materials

Drillings and/or corings will be made at selected locations throughout any area suspected of having subsurface deposits of contaminated materials. The purpose of drilling and/or coring is to locate and estimate the quantities of subsurface deposits of radioactivity. If subsurface radioactivity is suspected within an area and no surface contamination is evident, a random search technique of drilling and gamma-ray logging within that area will be used to locate and identify the boundaries of any subsurface contamination. Drill holes will be augered to an approximate 15-cm diameter and to a depth where a naturally occurring soil strata is encountered. A plastic pipe with a 10-cm (4-inch) inside diameter will be placed in each hole, and an NaI(Tl) gamma-ray scintillation probe will be lowered inside the pipe. The probe is encased in a lead shield with a narrow collimating slot on the side. This arrangement provides measurement of gamma radiation intensities resulting from contamination within small fractions of the hole depth. Measurements are usually made at 15-cm or 30-cm intervals. This "logging" of the core holes is 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. Samples of subsurface soil from core holes will be collected at random locations and returned to ORNL for analysis for ^{226}Ra, ^{238}U, ^{232}Th and other radionuclides deemed appropriate. The number of locations of core holes will be determined in the field based on the results of auger-hole loggins and surface gamma radiation levels. The core holes will be drilled and split-spoon samples will be taken at 15- to 30-cm intervals as required. After sampling, the core holes will be augered to a 15-cm diameter and logged at 15- to 30-cm intervals (as required) using the lead-shielded gamma-ray scintillator.

Indoor Surveys

External gamma radiation measurements

External gamma radiation levels will be measured at a height of 1 m above the floor in the center of each room using an NaI(Tl) scintillation survey meter. The survey meter will be cross-calibrated with the Reuter-Stokes PIC in the most frequently occupied room of the house. The floor and walls of each room will be scanned for gamma radiation at the surface and the maximum gamma radiation level associated with each surface will be noted.

Beta-gamma dose rates

Beta-gamma dose rates will be measured at those locations where external gamma-ray exposure rates were found to be significantly above background. These measurements will consist of open- and closed-window Geiger-Mueller (G-M) survey meter readings.

Surface alpha radiation levels

Surface alpha radiation levels will be measured at the center of the room as well as several other locations as determined in the field. A ZnS(Ag) detector (covered by a 0.03-mil aluminized mylar sheet) will be used and have an attached photomultiplier tube with a portable scaler/ratemeter.

Removable alpha and beta-gamma activity from surfaces

Removable or transferable surface contamination levels will be measured by taking standard smears. The smears are lightly rubbed over a 100-cm^2 area and counted for removable long-lived alpha and beta-gamma activity. A smear sample will be obtained near the center of the room where a hard surface is accessible. Smear samples will also be taken at locations where elevated gamma, beta-gamma, and/or alpha radiation levels are observed.

Radon and radon progeny measurements

Concentration of radon (^{222}Rn) will be measured indoors at the houses if evidence of indoor contamination is found. Individual radon (radon [^{222}Rn], thoron [^{220}Rn], actinon [^{219}Rn]) progeny concentrations in air will be measured at various locations and times within all houses.

Other samples

During the gamma-ray scanning of the property, building materials such as wood, concrete, or bricks may be found to have elevated gamma radiation levels associated with them. These materials as well as atypical samples from the outdoor survey (e.g., large rocks, vegetation, etc.) may be obtained and returned to ORNL for analyses. The resulting laboratory analysis is sample-specific, dependent on the pattern of contamination (i.e., radionuclide concentration versus measurement of surface contamination).

REFERENCES

1. EG&G, An Aerial Radiological Survey of the Stepan Chemical Company and Surrounding Area, Maywood, New Jersey, EG&G Survey Report NRC-8109 (April 1981).

2. Nuclear Regulatory Commission, memorandum from M. Campbell to J. D. Kinnerman, re: Records of Surveys of Private Homes in Maywood, New Jersey, Docket No. 40-8610, May 15, 1981.

3. B. A. Berven, T. E. Myrick, R. W. Leggett, W. A. Goldsmith, and F. F. Haywood, Generic Radiological Survey and Post Remedial Action Survey Plan for Private and Public Properties Associated with the Department of Energy's Remedial Action Program, ORNL/TM-7850 (in draft).

APPENDIX II

EVALUATION OF RADIATION EXPOSURES AT 467 LATHAM STREET IN MAYWOOD, NEW JERSEY

EVALUATION OF RADIATION EXPOSURES AT 467 LATHAM STREET IN MAYWOOD, NEW JERSEY

INTRODUCTION

Contaminated material was first discovered at this property and several nearby properties during an EG&G aerial radiological survey and subsequent ground-level Nuclear Regulatory Commission radiological survey. Because the contaminated material was similar to waste material that was generated by the Maywood Chemical Company (now Stepan Chemical Company), the material is believed to have originated from that source.

John Tripuka, owner of 461 Latham Street, confirmed that from 1944-1946, material from the former Maywood Chemical Company was transported to 464 Davison (then a vacant lot) by his father and was used for fill and mulching material at both properties. Other neighbors also had access to this material for use in their yards.

In June 1981, on request of the Department of Energy (DOE), Oak Ridge National Laboratory (ORNL) performed a radiological survey of this property. It was determined that radioactive material of the naturally occurring thorium and uranium decay chains was present in two isolated locations outdoors on the property. The contamination is limited to approximately the upper 6 inches (15 cm) of soil. No residual radioactive materials were found inside the house.

BACKGROUND RADIATION EXPOSURES

The naturally occurring radionuclides present at this property are present normally 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 exposures to the general public are much lower than limits established for workers in the nuclear industry.

As described previously, the contaminated materials present on this property consisted of radionuclides of the thorium and the uranium decay chains. Uranium-238 and thorium-232 were created when the earth was formed, and are still present today because they take a very long time to undergo radioactive decay. The half-life is a measure of the time required for radioactive decay; for uranium-238 it is 4.5 billion years. Thus, if 4.5 billion years ago you had a curie* of uranium-238, today you would have one-half curie; 4.5 billion years hence, this would only be one-fourth curie. 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 II-1 until stable lead is formed. The "decay product" listed in Table II-1 is the radiation produced as the parent decays. Radioactive decay started by thorium-232 continues as shown in Table II-2 until stable lead is also formed.

RADIATION EXPOSURES AT 467 LATHAM STREET

There are four primary pathways to humans from the type of contaminated material found on this property. These potential pathways are: (1) direct gamma-ray exposures, (2) inhalation of radon and radon daughters from radon decay, (3) inhalation of airborne radioactive particles, and (4) ingestion of radioactively contaminated foods or water.

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*The curie is a unit used to measure the amount of radioactivity in a substance; one curie represents 37 billion radioactive distintegrations per second.

In the following sections, the magnitude of each of these pathways at 467 Latham Street is described, based on the radiological conditions determined from the recent radiation survey. A summary of this radiation exposure data is given in Table II-3 along with a listing of the normal background levels for this area and the applicable guideline values for comparison.

Direct Gamma-Ray Exposures

As shown in Tables II-1 and II-2, several of the daughters of uranium-238 and of thorium-232 emit gamma radiation (gamma-rays are penetrating radiation like X-rays). Hence, the contamination present on this property is a source of external gamma radiation exposure to persons who reside near or come in contact with this material. Measurements of the gamma radiation levels outdoors on the property determined that the exposure rate at 1 m above the ground ranged from 7 to 110 microroentgens* per hour, with an average of 16 microroentgens per hour. Inside the house, the exposure rates ranged from 8 to 16 microroentgens per hour, with an average value of 10 mircoroentgens per hour. For comparison, the normal background gamma-ray exposure rate for the Maywood area is 8 microroentgens per hour.

The NRC guidelines (found in the Code of Federal Regulations, Title 10, Part 20†) require that the continuous gamma radiation exposure to any individual in the general population not exceed 500 milliroentgens per year. For persons residing at this property, continuous exposure (24 hours a day, 365 days per year) to the average levels found outdoors would result in an annual gamma-ray exposure of 140 milliroentgens, a value well below the guideline limit. Indoors, the continuous annual exposure from the average radiation levels would be 88 milliroentgens. Again, this exposure is below the applicable guideline. For comparison

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*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. A milliroentgen is one-thousandth of a roentgen, or one thousand microroentgens.

†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.

with everyday exposures, these values can be compared to a normal background exposure of 70 milliroentgens per year in New Jersey or a typical chest X-ray exposure of 27 milliroentgens.

Inhalation of Radon and Radon Daughters

Radon-222 (the daughter of radium-226) and radon-220 (the daughter of radium-224) are inert gases produced by decay of their respective parent radionuclides. When produced, this gas can migrate through the soil or other materials and eventually be released to the atmosphere. If the gas enters a structure with poor ventilation, accumulation of the gas and its short-lived daughters in room air can occur. Breathing of this short-lived radon daughter results in exposure of the respiratory tract to radiation.

Since contaminated soil containing the radioactive parents of radon-222 and radon-220 was found on this property, the potential for radon migration into the house was believed to exist. Measurements of the indoor concentrations of radon and its daughters in air were made for comparison with normal background levels, as well as current guidelines. The radon (radon-222 and radon-220) concentration in the basement of the house was determined to be 0.68 picocuries* per liter, a value in the range of normal background for the Maywood area (0.8 to 1.7 picocuries per liter). The NRC guideline value for radon-222 in air is 3 picocuries per liter and for radon-220 is 10 picocuries per liter (10 CFR 20).

The measured average radon daughter concentrations in the basement of the house were determined to be 0.00017 working level.[†] This concentration is within the normal background range for the New Jersey area (0.004 to 0.008 working level), and is well below the guideline values of 0.03 working level suggested in 10 CFR 20 or 0.01 working level given in the Surgeon General's Guidelines.[§]

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

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

§Federal Register, Vol. 41, No. 253, pages 56777-56778, December 30, 1976 (10 CFR 712).

Inhalation of Airborne Radioactive Particles

Radioactive particles associated with soil or similar materials can become airborne due to natural (e.g., wind) or human (scraping) forces. Once airborne, these particles can become inhaled, with subsequent exposure of the respiratory tract. Guidelines for acceptable concentrations of radionuclides in air have been developed and are presented in 10 CFR 20. At 467 Latham, this exposure pathway is of no concern due to the location of the contaminated material under grass and other vegetation. However, if present land use changes and extensive handling or scraping of the contaminated material occurs, the potential for radiation exposure from this pathway would be increased.

Ingestion of Radioactivity

The final pathway of potential radiation exposure for residents at this property is the ingestion of radionuclides through contaminated foods or water. Since the water supply at this residence is the public water system, unaffected by the contamination on the property, ingestion of contaminated water is considered insignificant.

The magnitude of the radiation exposure to an individual ingesting foods grown in contaminated soil is dependent upon a number of factors, including: (1) the concentration of radionuclides in the soil, (2) the amount of uptake of the specific radionuclide by the plant of concern, and (3) the amount of the plant consumed by the individual. At the present time, no guidelines are available listing the acceptable concentrations of radionuclides in the soil or foods for the radionuclides of concern at this property. Due to the small amount of contaminated material on this property and its spotty distribution, this radiation exposure pathway would be negligible in comparison to the direct gamma-ray exposure pathway.

PRELIMINARY ESTIMATE OF RADIATION RISK

For purposes of radiation protection, all radiation exposures are assumed to be capable of increasing an individual's risk of contracting cancer. A precise numerical value cannot be assigned with any certainty to a given individual's increase in risk attributable to radiation exposure. The reasons for this are numerous; they include the individual's age at onset of exposure, variability in latency period (time between exposure and physical evidence of disease), the individual's personal habits and state of health, previous or concurrent exposure to other cancer-causing agents, and the individual's family medical history. Because of these variables, large uncertainties exist in any estimates of the number of increased cancer deaths in the relatively small population exposed at this property.

Using the results of the radiological survey at this property, preliminary estimates of the increased risk of cancer for residents living there have been calculated.* These estimates considered only the two most significant exposure pathways (direct radiation exposure and inhalation of radon and radon daughters) and were based on the following assumptions:

1. The measurements that are reported in Table II-3 are respresentative of the conditions throughout the year and for every year. It is recognized that radon and radon-daughter levels in the homes could be higher in winter because of less ventilation.
2. The inhabitants spend 5% of their time in the basement (or the radon escaping to the upstairs when the door is opened adds an equivalent exposure).
3. The inhabitants live in this house all of their lives, from birth to age 70.
4. Each day the inhabitants spend an average of two hours away from the house and property, four hours outside the house but on the property, and 18 hours inside the house.

The total estimated increased risk due to radiation induced cancer for residents at 467 Latham Street was calculated to be 0.01%.* Thus, for persons living for a lifetime at 467 Latham, instead of an average

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*J. W. Healy and W. J. Bair, "Preliminary Report - Radiological Appraisal of Houses in Maywood, N. J." Attachment to letter from W. J. Bair, Battelle Pacific Northwest Laboratories to W. E. Mott, Department of Energy, Washington, D. C., July 17, 1981.

chance of 24.4% of eventually dying from cancer (the average for Bergen County, New Jersey in 1975)*, they might have a hypothetical average chance of 24.41% of dying from cancer. These values compare with a lifetime average chance of dying from cancer of 21.8% for the state of New Jersey, and a 19.3% for the United States.

SUMMARY

A summary of radiation exposure data at 467 Latham Street is presented in Table II-3. Of the four primary radiation exposure pathways, none are of immediate concern at this site under present conditions of property use. Inhalation of radionuclides is considered a negligible source of radiation exposure at the present since there is no apparent ordinary mechanism to cause contaminated material in the soil to become airborne. It is believed that possible future use of portions of the property for growing food could contribute appreciable radiation exposure to an individual consuming this food as a large fraction of his diet; however, under current conditions of use, this pathway is of no concern. Average exposures to gamma radiation on this property were below the guidelines for exposure to individuals in the general public although elevated levels do exist at two isolated locations. Finally, radon and radon daughter concentrations measured inside the house were in the normal range of background, indicating that exposure from this pathway would be insignificant.

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*Mortality statistics were obtained from data in Vital Statistics of the United States - 1975, Volume II - Mortality, Part B, U. S. Department of Health, Education and Welfare, Public Health Service, National Center for Health Statistics, (PHS) 78-1102, 1977.

Table II-1. Uranium-238 decay series

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

[a]Short-lived radon daughters.

Table II-2. Thorium-232 decay series

Parent	Half-life	Decay products	Daughter
Thorium-232	14 billion years	alpha	radium-228
Radium-228	6.7 years	beta	actinium-228
Actinium-228	6.1 hours	beta, gamma	thorium-228
Thorium-228	1.9 years	alpha, gamma	radium-224
Radium-224	3.6 days	alpha, gamma	radon-220
Radon-220	55 seconds	alpha, gamma	polonium-216
Polonium-216	0.15 seconds	alpha	lead-212
Lead-212	11 hours	beta, gamma	bismuth-212
Bismuth-212	61 minutes	alpha, beta, gamma	polonium-212 (64%) or thallium-208 (36%)
Polonium-212	0.3 millionth of a second $(\frac{3}{1,000,000})$	alpha	lead-208
or			
Thallium-208	3.1 minutes	beta, gamma	lead-208
Lead-208	stable	none	none

Table II-3. Summary of exposure data at 467 Latham Avenue in Maywood, New Jersey

Exposure pathway[a,b]	New Jersey background levels	Guideline value for individual in the general public	Average levels found on property
Gamma radiation	Outdoors: 8 microRoentgens per hour at one meter	Outdoors: 60 microRoentgens per hour	Outdoors: 16 microRoentgens per hour at one meter
	Indoors: 8 microRoentgens per hour at one meter	Indoors: 60 microRoentgens per hour	Indoors: 10 microRoentgens per hour at one meter
Radon in indoor air	Basement: 1.7 picocuries per liter	3 picocuries per liter	Basement: 0.68 picocuries per liter
	Upstairs: 0.8 picocuries per liter		
Radon daughters in indoor air	Basement: 0.008 working level	Basement: 0.01 working level	Basement: 0.00017 working level
	Upstairs: 0.004 working level	Upstairs: 0.01 working level	

[a]Inhalation of radionuclides pathway is not an appreciable source of radiation exposure to individuals living at this property.

[b]Ingestion of vegetables grown in contaminated soil could only be a significant pathway of radiation exposure to individuals living at this property if vegetables grown in contaminated soil constitute a large fraction of their diet.