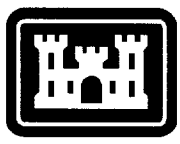
M-633

Formerly Utilized Sites Remedial Action Program (FUSRAP)

ADMINISTRATIVE RECORD

for the Maywood Site, New Jersey



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HEALTH SCIENCES RESEARCH DIVISION

Environmental Restoration and Waste Management Non-Defense Programs
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Radiological Re-Survey Results at 130 West Central Avenue, Maywood, New Jersey (MJ029)

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ACKNOWLEDGMENTS

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ABSTRACT

Maywood Chemical Works (MCW) of Maywood, New Jersey, generated process wastes and residues associated with the production and refining of thorium and thorium compounds from 1916 to 1959. During the early years of operation, MCW stored wastes and residues in low-lying areas west of the processing facilities and consequently some of the residuals containing radioactive materials migrated offsite to the surrounding area. Subsequently, the U.S. Department of Energy (DOE), designated for remedial action the old MCW property and several vicinity properties. Additionally, in 1984, the property at 130 West Central Ave., Maywood, New Jersey and properties in its vicinity were included as a decontamination research and development project under the DOE Formerly Utilized Sites Remedial Action Program. In 1987 and 1988, at the request of DOE, ORNL conducted a radiological survey on this property. A report describing this survey was published in 1989. Results of the survey indicated that while some radionuclide measurements were greater than typical background levels in the northern New Jersey area, no radionuclide concentrations were in excess of the DOE Formerly Utilized Sites Remedial Action Program criteria.

A second radiological survey by ORNL was conducted on this property in May, 1993 at the request of DOE after an ad hoc radiological survey, requested by a new property owner and conducted by Bechtel National, Inc. (BNI), identified some contamination not previously found by ORNL. The purpose of the survey was to determine if residuals from the old MCW were present on the property, and if so, if any radiological elements present were above guidelines. A certified civil survey was requisitioned by ORNL to determine actual property boundaries before beginning the radiological survey. The radiological re-survey included a surface gamma scan and the collection of a large number of soil samples for radionuclide analyses.

Results of this survey demonstrated that although elevated residual thorium-232 contamination was present in a few isolated spots on the southern end of the backyard, it did not exceed DOE guidelines. This part of the property is adjacent to the railroad property, which is scheduled for future remediation. Most of the spotty contamination on the residential property was removed with the extensive soil sampling.

RADIOLOGICAL RE-SURVEY RESULTS AT 130 WEST CENTRAL AVENUE, MAYWOOD, NEW JERSEY (MJ029)*

INTRODUCTION

Processing of thorium ores was performed in Maywood New Jersey, between 1916 and 1959 by the Maywood Chemical Works (MCW).[1] The MCW ceased thorium processing in 1959 and the 30-acre property was sold that same year to Stepan Chemical Company. During the early years of operation, MCW stored wastes and residues in low-lying areas west of the processing facilities. Subsequently, residuals containing radioactive materials migrated off-site to the surrounding area, and the Stepan property and several vicinity properties were designated for remedial action by the U.S. Department of Energy (DOE).

The waste produced by the thorium extraction process was a sand-like material containing residual amounts of thorium and its decay products, with smaller quantities of uranium and its decay products. Because some of the wastes had been carried downstream by Lodi Brook, and some area residents had also used the sand-like wastes as mulch in their yards, the property at 130 West Central Ave., Maywood, New Jersey, and properties in its vicinity were included as a decontamination research and development project under the DOE Formerly Utilized Sites Remedial Action Program. Figure 1 shows the location of Central Avenue relative to the former processing plant.

At the request of the U.S. Department of Energy (DOE), ORNL conducted investigative radiological surveys of several properties surrounding the former processing plant. During 1987 and 1988 a radiological survey was conducted by ORNL on the property at 130 W. Central Ave. The survey and sampling of the ground surface were carried out in April 1987, and the follow-up subsurface investigation was performed in June, 1988. The principal radionuclide of interest was ^{232}Th. A report describing this survey was issued in 1989.[2] Results of this survey indicated that the property contained no significant radioactive contamination above guideline values. Though elevated gamma radiation levels were found on the property, these readings decreased in a northeasterly direction (towards the house). The elevated gamma measurements on this site were considered to be the result of scattered radiation, or "shine" emanating from the MCW interim storage area just south of the property. It was further stated that visual signs of coal ash, which has an elevated natural radionuclide content, were present in all the soil samples. Radiological assessment of the property and investigation of the coal ash suggested that all soil analyses were below DOE Formerly Utilized Sites Remedial Action Program criteria.

In 1992, Bechtel National, Inc. (BNI), the project management contractor

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*The survey was performed by members of the Measurement Applications and Development Group of the Health Sciences Research Division of Oak Ridge National Laboratory under DOE contract DE-AC05-84OR21400.

designated by DOE, conducted an ad hoc radiological survey at the request of a new owner of the property who had uncovered what was thought to be waste vials from the back yard. Three soil samples were collected and analyzed for radionuclide concentrations. Two of the samples were below or only slightly above DOE guideline levels, but the third had elevated thorium concentrations. Bechtel's survey of the property covered all areas maintained by the property owner; however, the survey encompassed several feet further south than the original ORNL radiological survey, and in fact included the adjacent railroad property according to a property boundary civil survey done at the request of ORNL. It was on this part of the property where elevated thorium concentrations were found by Bechtel. Although the data from Bechtel's ad hoc survey as well as ORNL's earlier survey, when evaluated against the hot spot criteria (Table 1), indicated that the values were below criteria for remedial action, it was decided that if contamination had indeed extended onto the private property at 130 W. Central Ave. from the adjacent railroad property (which has already been designated for remediation), it could be addressed during the remediation of the railroad property.

Based on the fact that contamination could have migrated onto the property at 130 W. Central Ave. from the adjacent railroad property, it was decided to take, in addition to the confirmatory samples at the sites where elevated gamma levels were identified, a larger number of samples: (1) to define the nature and extent of the thorium, uranium, and radium present on the property, and (2) to determine whether radioactive elements present were above guidelines, and if so, whether they resulted from the operation of the Maywood Chemical Works. The MAD Group of ORNL was assigned this responsibility, and in May 1993, conducted a second radiological survey of this property. This report describes the methods and results of ORNL's re-survey of the property at 130 W. Central Avenue, Maywood, New Jersey.

SCOPE OF THE SURVEY

At the request of ORNL, a certified civil survey was conducted by the Azzolina & Feury Engineering Company of Paramus, New Jersey to determine the actual property boundaries, corners, and dimensions of this property. The radiological survey included a meticulous and detailed surface gamma scan of the southern quarter of the backyard of the property within the certified property boundaries, and the collection and radionuclide analysis of a large number of soil samples. Additional confirmatory samples were taken at sites in the backyard where elevated gamma levels had been identified. The area of this re-survey of the property at 130 W. Central Ave. is shown as the soil sampling area in Figs. 2 and 3.

SURVEY METHODS

A comprehensive description of the survey methods and instrumentation used in this survey is given in *Procedures Manual for the ORNL Radiological Survey Activities (RASA) Program*, ORNL/TM-8600 (April 1987).[3]

SURFACE RADIATION MEASUREMENTS

Gamma radiation levels were determined using a portable NaI gamma scintillation probe connected to a Victoreen ratemeter. Measurements were recorded and converted to μR/h. Because NaI gamma scintillators are energy dependent, measurements of gamma radiation levels in counts per minute (cpm) are normalized to pressurized ionization chamber (PIC) measurements to estimate gamma exposure rates in μR/h.

SOIL SAMPLING AND ANALYSIS

Surface and subsurface soil samples were systematically collected over the southern part of the backyard of the property at one- and five-meter grid points. Surface and subsurface soil samples were also collected in the areas of known elevated radionuclide levels within the property lines. Such samples are referred to as biased samples and are more likely to contain elevated concentrations of radionuclides than are systematically chosen samples.

SURVEY RESULTS

Current DOE guidelines for sites included within the FUSRAP are summarized in Table 1.[4,5] Typical background radiation levels for the northern New Jersey area are given in Table 2.[6,7] These data are provided for comparison with survey results presented in this section. 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 in soil samples.

A photograph of the portion of the property at 130 W. Central Ave. where sampling took place, taken in May 1993, is shown in Fig. 4.

SURFACE RADIATION MEASUREMENTS

A careful gamma scan was conducted over the backyard of the property. Gamma measurements generally ranged from 18-22 μR/h at one meter above the surface in the southern quadrant (Fig. 3). In addition, surface radiation measurements were taken at the soil surface at each sampling site, both unshielded and shielded (to block out the "shine"*). At the surface, unshielded gamma activities generally ranged from 14 μR/h in the center of the backyard, increasing to 29 μR/h near the southern boundary, and measuring 33 μR/h at the site of the biased sample B1. A reading of 31 μR/h was measured on contact with a large exposed rock in the middle of the backyard. In addition to the normal walk-over gamma scan, a special NaI detector with a cone-shield was deployed to assist in detection

*Under certain conditions, extraneous radiation emanating from a source outside the area (in this case from the Maywood Interim Storage site (MISS) south of the property) is called "shine" or scattered radiation, which will result in elevated gamma measurements.

of hot spots. This detector/shield is mounted on a lightweight metal frame resembling a wheel barrow.

SOIL SAMPLES

Systematic

Systematic soil samples were collected at 1- and 5-meter grid points over the southern quadrant of the backyard, beginning within 1.3 ft of the southern boundary line of the property. Samples were taken beginning at this point , continuing north towards the house, beginning at one meter apart in both directions and then in five-meter sections as gamma levels dropped nearer to the house. Almost all the samples contained ash, metal, and glass, which contain concentrations of natural radionuclides.

All samples were analyzed for uranium, radium and thorium concentrations. Ranges for these radionuclides (for both surface and surface soil) were from 0.89 to 5.6 pCi/g for ^{238}U, 0.72 to 3.4 pCi/g for ^{226}Ra, and 0.83 to 9.8 pCi/g for ^{232}Th. The average concentration (above background) of ^{232}Th is 2.9 pCi/g in surface soil and 2.0 pCi/g in subsurface soil. The maximum concentrations of 5.6 pCi/g (^{238}U) and 9.8 pCi/g (^{232}Th) were found in the surface soil in sample S17 near the southern-most boundary of the property. Radionuclide concentrations decreased generally with depth of soil and in either direction from this sample. Soil sample locations are shown in Fig. 3 and results of analyses are listed in Table 3.

Biased

Biased soil samples were taken in the areas of elevated gamma readings in the backyard at the southern end of the property.

Analyses showed that concentrations of ^{238}U, ^{226}Ra and ^{232}Th ranged from 2.8 to 4.0 pCi/g, from 1.8 to 3.2 pCi/g and from 3.8 to 41 pCi/g, respectively, in both surface and subsurface soil. The maximum of 41 pCi/g ^{232}Th was measured in the B4 sample, which was taken next to the B1 sample (maximum ^{232}Th concentration 25 pCi/g) as shown in Fig. 3 and Table 3. The area represented by the elevated concentrations of radioactive nuclides is very small (less than 1 m^2) and most of the thorium was removed by sampling.

SIGNIFICANCE OF FINDINGS

The measurements taken during the radiological survey at 130 W. Central Avenue, Maywood, New Jersey, indicate results that are within DOE guidelines. These guidelines ensure that unrestricted use will not result in significant exposures to anyone on the site. Isolated spots of contamination, in large part removed with the extensive sampling, were identified in surface and subsurface soil in areas where materials from the former MCW may have migrated. These areas were located in the southern quadrant of the backyard (Fig. 2).

The highest gamma readings were in the section of the property in the backyard nearest to the southern boundary which is the area adjacent to the railroad property and closest to the MISS where"shine" influences gamma readings. In addition, the soil contained glass, coal ash, and metal, which accounts for a certain amount of natural elevation in the radionuclide content of some samples.

Concentrations of uranium and radium found in the majority of the soil samples taken from the backyard of the property were generally below DOE guidelines for these radionuclides. Although some of the soil samples from isolated spots near the southern boundary of the property contained elevated concentrations of ^{232}Th (Table 3), when averaged over 100 m^2 the concentration of ^{232}Th is less than 3.5 pCi/g for surface soil and less than 2.1 pCi/g in subsurface soil. Guidelines set by DOE are 5 pCi/g above background, averaged over 100 m^2 in surface soil (0-15 cm), and 15 pCi/g in subsurface soil (15-30 cm). Therefore, based on these findings, this property should not be considered for inclusion under FUSRAP.

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1. L. W. Cole, J. Berger, P. Cotten, R. Gosslee, L. Sowell, and C. Weaver, *Radiological Assessment of Ballod Associates Property (Stepan Chemical Company), Maywood, New Jersey*, Oak Ridge Associated Universities, Oak Ridge, Tenn., July 30, 1981.

2. R. D. Foley, L. M. Floyd, and R. F. Carrier, *Results of the Radiological Survey at 130 West Central Avenue, Maywood, New Jersey (MJ029)*, ORNL/RASA-88/90, Martin Marietta Energy Systems, Inc., Oak Ridge Natl Lab, October 1989.

3. T. E. Myrick, B.A. Berven, W. D. Cottrell, W.A. Goldsmith, and F.F. Haywood, *Procedures Manual for the ORNL Radiological Survey Activities (RASA Program*, ORNL/TM-8600, Martin Marietta Energy Systems, Inc., Oak Ridge Natl Lab., April 1987.

4. U. S. Department of Energy, *Guidelines for Residual Radioactive Material at Formerly Utilized Sites Remedial Action Program and Remote Surplus Facilities Management Program Sites* , Rev. 2, March 1987.

5. U. S. Department of Energy, *Radiation Protection of the Public and the Environment,* DOE Order 5400.5, April 1990.

6. T. E. Myrick, B. A. Berven, and F. F. Haywood, *State Background Radiation Levels: Results of Measurements Taken During 1975-1979*, ORNL/TM-7343, Martin Marietta Energy Systems, Inc., Oak Ridge Natl Lab., November 1981.

7. S. GLevin, R. K. Stoms, E. Kuerze, and W. Huskisson, "Summary of Natural Environmental Gamma Radiation Using a Calibrated Portable Scintillation Counter," *Radiological Health Data Report* 9:679-695 (1968).

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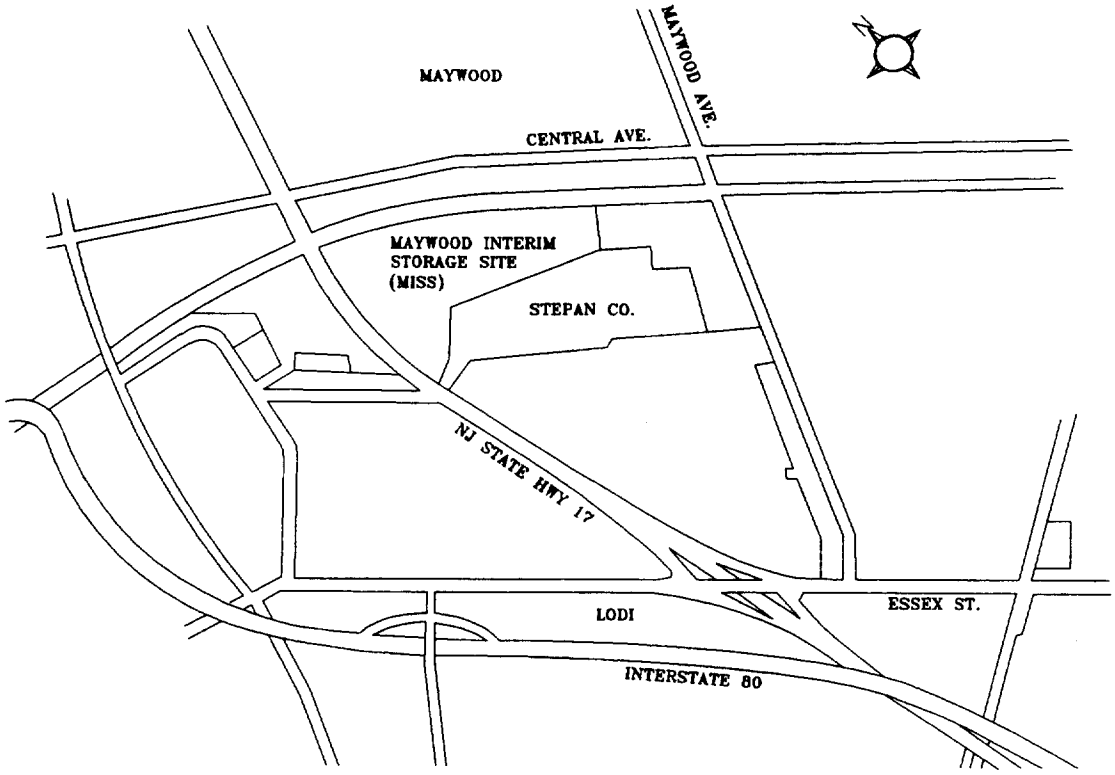

Fig. 1. Diagram showing the general location of the property at 130 W. Central Ave., Maywood, New Jersey relative to the Maywood Interim Storage Site (MISS) Maywood, New Jersey.

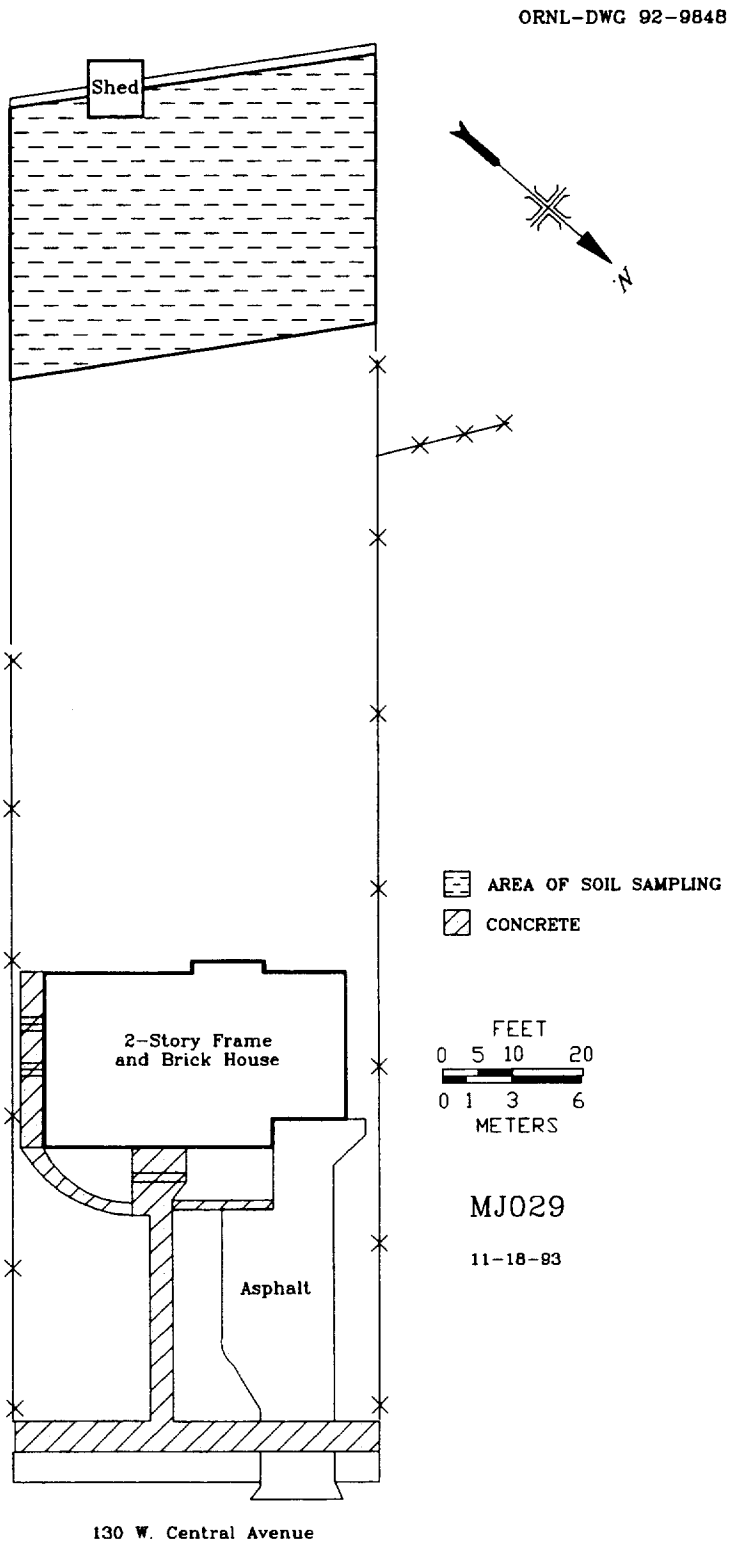

Fig. 2. Diagram of the property at 130 W. Central Ave., Maywood, New Jersey and the southern part of the backyard involved in the re-survey.

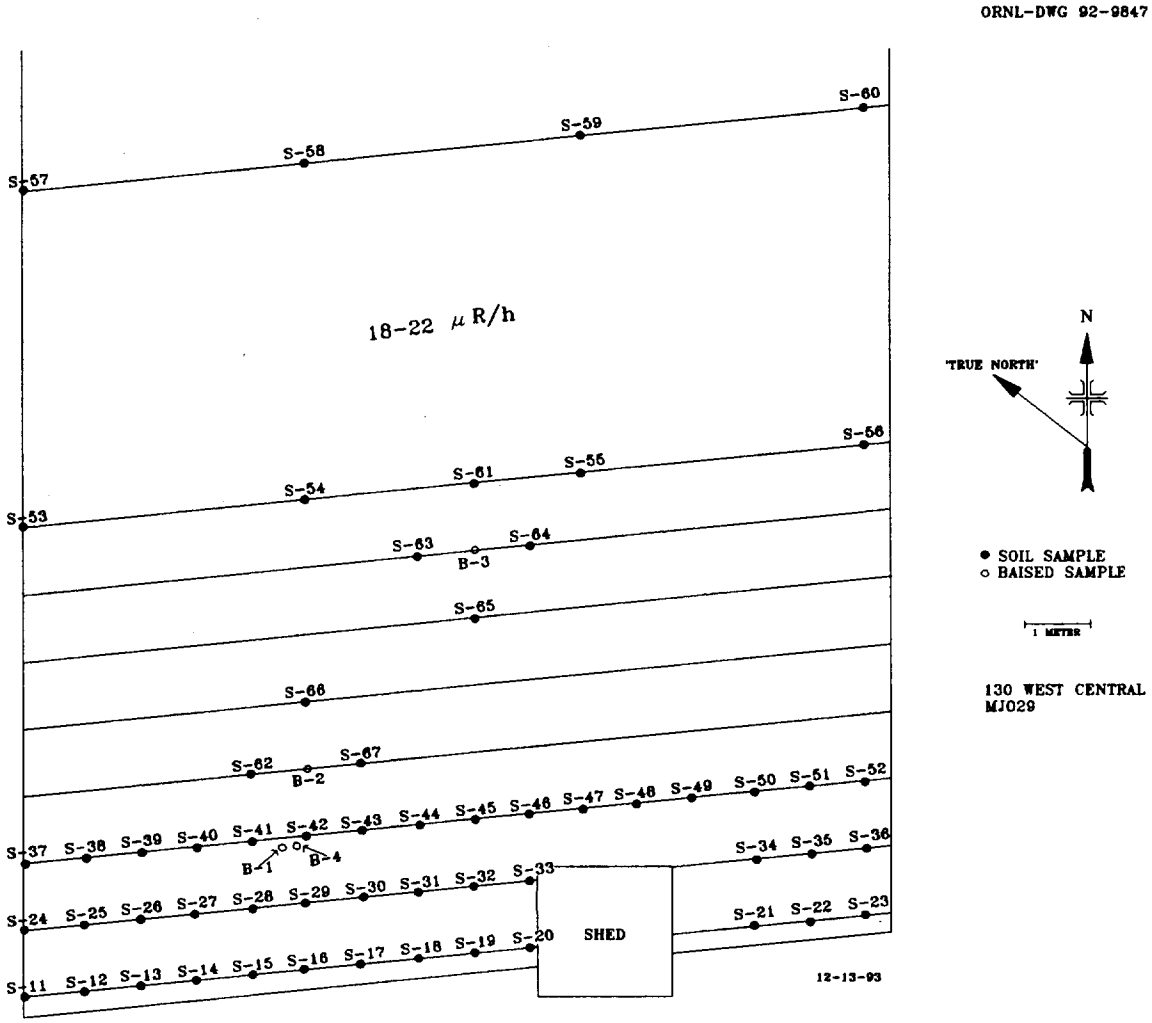

Fig. 3. Surface gamma exposure rates and soil sampling locations on the section of the backyard involved in the re-survey of the property at 130 W. Central Ave., Maywood, New Jersey. Sampling was done at 1- and 5-meter gridpoints.

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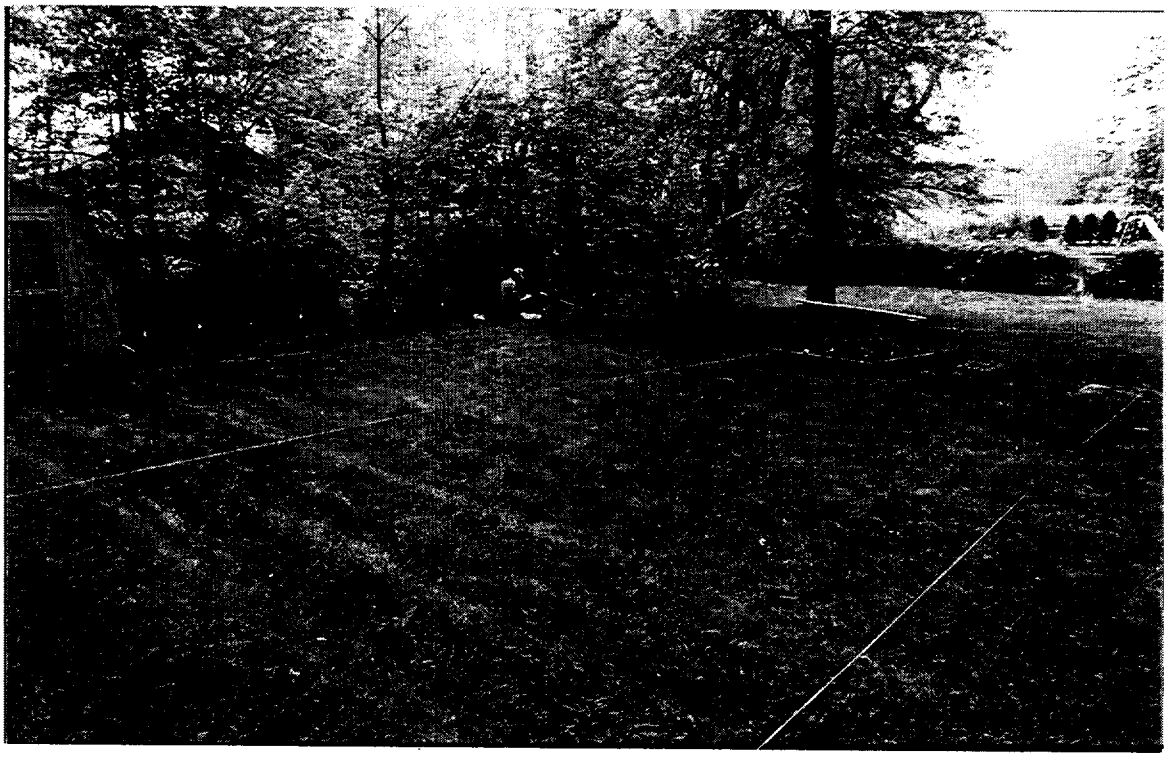

Fig. 4. View of the workers in southwest corner of the backyard of the property at 130 W. Central Ave., Maywood, New Jersey, showing gridlines for soil samples.

Table 1. Applicable guidelines for protection against radiation
(Limits for uncontrolled areas)

Mode of exposure	Exposure conditions	Guideline value
Gamma radiation	Indoor gamma radiation level (above background)	20 μR/h[a]
Total residual surface contamination[b]	^{238}U, ^{235}U, U-natural (*alpha emitters*) or Beta-gamma emitters[c]	
	Maximum	15,000 dpm/100 cm^2
	Average	5,000 dpm/100 cm^2
	Removable	1,000 dpm/100 cm^2
	^{232}Th, Th-natural (*alpha emitters*) or ^{90}Sr (*beta-gamma emitter*)	
	Maximum	3,000 dpm/100 cm^2
	Average	1,000 dpm/100 cm^2
	Removable	200 dpm/100 cm^2
	^{226}Ra, ^{230}Th, transuranics	
	Maximum	300 dpm/100 cm^2
	Average	100 dpm/100 cm^2
	Removable	20 dpm/100 cm^2
Beta-gamma dose rates	Surface dose rate averaged over not more than 1 m^2	0.20 mrad/h
	Maximum dose rate in any 100-cm^2 area	1.0 mrad/h
Radionuclide concentrations in soil (generic)	Maximum permissible concentration of the following radionuclides in soil above background levels, averaged over a 100-m^2 area	5 pCi/g averaged over the first 15 cm of soil below the surface; 15 pCi/g when averaged over 15 cm-thick soil layers > 15 cm below the surface
	^{226}Ra	
	^{232}Th	
	^{230}Th	
Derived concentrations	^{238}U	Site specific[d]

Table 1 (continued)

Mode of exposure	Exposure conditions	Guideline value
Guideline for non-homogeneous contamination (used in addition to the 100-m^2 guideline)[e]	Applicable to locations with an area ≤25 m^2, with significantly elevated concentrations of radionuclides ("hot spots")	$G_A = G_i(100/A)^{1/2}$, where G_A = guideline for "hot spot" of area (A) G_i = guideline averaged over a 100-m^2 area

[a]The 20 μR/h shall comply with the basic dose limit (100 mrem/yr) when an appropriate-use scenario is considered.

[b]DOE surface contamination guidelines are consistent with *NRC Guidelines for Decontamination at Facilities and Equipment Prior to Release for Unrestricted Use or Termination of Licenses for By-Product, Source, or Special Nuclear Material*, May 1987.

[c]Beta-gamma emitters (radionuclides with decay modes other than alpha emission or spontaneous fission) except ^{90}Sr, ^{228}Ra, ^{223}Ra, ^{227}Ac, ^{133}I, ^{129}I, ^{126}I, ^{125}I.

[d]DOE guidelines for uranium are derived on a site-specific basis. Guidelines of 35-40 pCi/g have been applied at other FUSRAP sites. *Sources*: J. L. Marley and R. F. Carrier, *Results of the Radiological Survey at 4 Elmhurst Avenue, Colonie, New York (AL219)*, ORNL/RASA-87/117, Martin Marietta Energy Systems, Inc., Oak Ridge Natl. Lab., February 1988; B. A. Berven et. al., *Radiological Survey of the Former Kellex Research Facility, Jersey City, New Jersey*, DOE/EV-0005/29, ORNL-5734, Martin Marietta Energy Systems, Inc., Oak Ridge Natl. Lab., February 1982.

[e]DOE guidelines specify that every reasonable effort shall be made to identify and to remove any source that has a concentration exceeding 30 times the guideline value, irrespective of area (adapted from *Revised Guidelines for Residual Radioactive Material at FUSRAP and Remote SFMP Sites, April 1987).*

Sources: Adapted from U.S. Department of Energy, *Radiation Protection of the Public and the Environment*, DOE Order 5400.5, April 1990, and U.S. Department of Energy, *Guidelines for Residual Radioactive Material at Formerly Utilized Sites Remedial Action Program and Remote Surplus Facilities Management Program Sites*, Rev. 2, March 1987; and *U. S. Department of Energy Radiological Control Manual*, DOE N 5480.6 (DOE/EH-256T), June 1992.

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

Type of radiation measurement or sample	Radiation level or radionuclide concentration[a]
Gamma exposure at 1 m above ground surface (μR/h)	8[b]
Concentration of radionuclides in soil (pCi/g)[c]	
^{226}Ra	0.9
^{232}Th	0.9
^{238}U	0.9

[a] These values represent an average of normal radionuclide concentrations in this part of thc state. Actual values may fluctuate.

[b] Source: U. S. Department of Energy, *Radiological Survey of the Middlesex Municipal Landfill, Middlesex, New Jersey*, DOE/EV-00005/20, April 1980. Values ranging from 8-11 μR/h (average 9 μR/h) were obtained from 35 locations in the Rochelle Park, New Jersey area.[7]

[c] Source: T. E. Myrick, and B. A. Berven, *State Background Radiation Levels: Results of Measurements Taken During 1975-1979*, ORNL/TM-7343, Martin Marietta Energy Systems, Inc., Oak Ridge Natl. Lab., November 1981 (Ref. 6).

Table 3. Concentrations of radionuclides in soil samples from 130 West Central Avenue, Maywood, New Jersey (MJ029)

Sample number[a]	Depth (cm)	Radionuclide concentration (pCi/g)[b]		
		^{238}U	^{226}Ra	^{232}Th
		Systematic samples[c]		
S11A	0-15	1.5± 0.7	1.9 ± 0.1	2.6± 0.2
S11B	15-30	1.4± 0.6	1.5 ± 0.1	1.9± 0.2
S12A	0-15	2.3± 0.6	2.0 ± 0.1	2.6± 0.2
S12B	15-30	1.5± 0.6	1.5 ± 0.1	1.5± 0.2
S13A	0-15	1.8± 0.7	1.7 ± 0.1	3.3± 0.2
S13B	15-31	1.3± 0.7	1.9 ± 0.1	2.6± 0.2
S14A	0-15	1.8± 0.4	1.9 ± 0.1	3.7± 0.2
S14B	15-30	1.9± 0.5	1.9 ± 0.1	3.2± 0.2
S15A	0-15	1.1± 0.6	1.7 ± 0.1	4.2± 0.2
S15B	15-30	1.2± 0.7	1.5 ± 0.1	2.8± 0.2
S16A	0-15	2.6± 0.8	1.9 ± 0.1	4.6± 0.2
S16B	15-30	1.7± 0.7	1.8 ± 0.1	3.3± 0.2
S17A	0-15	5.6± 2	3.0 ± 0.2	9.8± 0.3
S17B	15-30	2.4± 0.9	2.3 ± 0.1	4.4± 0.2
S18A	0-15	3.1± 0.6	1.8 ± 0.1	4.9± 0.4
S18B	15-30	2.8± 0.8	2.1 ± 0.1	3.0± 0.2
S19A	0-15	2.4± 0.9	2.0 ± 0.2	4.8± 0.3
S19B	15-30	1.9± 0.7	2.3 ± 0.1	3.0± 0.2
S20A	0-15	4.8± 0.7	2.7 ± 0.2	4.2± 0.2
S20B	15-30	2.6± 0.8	2.7 ± 0.1	3.0± 0.2
S21A	0-15	3.0± 0.9	2.6 ± 0.1	3.9± 0.2
S21B	15-30	3.3± 0.9	2.7 ± 0.1	3.4± 0.2
S22A	0-15	1.7± 0.4	2.4 ± 0.1	3.7± 0.2
S22B	15-30	2.5± 0.5	2.5 ± 0.1	3.1± 0.2
S23A	0-15	2.4± 0.8	2.0 ± 0.1	3.5± 0.2
S23B	15-30	1.9± 0.8	2.2 ± 0.1	3.2± 0.2
S24A	0-15	1.6± 0.5	1.9 ± 0.1	2.6± 0.1
S24B	15-30	1.2± 0.6	0.98± 0.1	1.2± 0.1
S25A	0-15	1.9± 0.5	1.4 ± 0.1	2.2± 0.2
S25B	15-30	1.8± 0.6	1.0 ± 0.1	1.4± 0.2

Table 3. (continued)

Sample number[a]	Depth (cm)	Radionuclide concentration (pCi/g)[b]		
		^{238}U	^{226}Ra	^{232}Th
S26A	0-15	2.0± 1	1.8 ± 0.1	2.9± 0.2
S26B	15-30	1.2± 0.6	1.1 ± 0.1	1.6± 0.2
S27A	0-15	2.2± 0.9	2.4 ± 0.1	3.6± 0.2
S27B	15-30	2.5± 0.5	2.3 ± 0.1	2.7± 0.3
S28A	0-15	3.4± 0.6	2.3 ± 0.1	3.3± 0.2
S28B	15-30	3.8± 1	2.4 ± 0.1	2.8± 0.2
S29A	0-15	1.5± 0.6	1.4 ± 0.1	2.9 ±0.2
S29B	15-30	1.4± 0.8	1.8 ± 0.1	2.6± 0.2
S30A	0-15	3.3± 0.6	1.8 ± 0.1	6.8± 0.3
S30B	15-30	2.2± 0.7	1.6 ± 0.1	3.2± 0.2
S31A	0-15	3.2± 1.1	1.8 ± 0.1	3.3± 0.2
S31B	15-30	1.9± 0.5	1.6 ± 0.1	2.4± 0.2
S32	0-15	2.6± 0.5	2.1 ± 0.1	3.6± 0.2
S33A	0-15	2.4± 0.6	2.2 ± 0.1	3.2± 0.2
S33B	15-30	2.7± 0.9	2.6 ± 0.2	3.3± 0.3
S34A	0-15	3.4± 0.6	2.5 ± 0.1	4.3± 0.2
S34B	15-30	3.1± 1	1.5 ± 0.1	2.9± 0.1
S35A	0-15	3.1± 1	2.8 ± 0.2	5.2± 0.4
S35B	15-30	1.5± 0.5	1.3 ± 0.1	1.9± 0.2
S36A	0-15	2.4± 0.6	1.5 ± 0.1	2.1± 0.2
S36B	15-30	3.7± 0.8	3.0 ± 0.2	4.7± 0.2
S37A	0-15	3.0± 2	1.7 ± 0.1	2.5± 0.2
S37B	15-30	2.1± 0.6	0.82±0.1	1.1± 0.1
S38A	0-15	3.0± 0.8	1.7 ± 0.1	2.3± 0.2
S38B	15-30	1.5± 0.4	1.1 ± 0.1	1.4± 0.2
S39A	0-15	4.7± 1.0	2.3 ± 0.1	3.2± 0.2
S39B	15-30	1.4± 0.7	1.4 ± 0.1	1.9± 0.2
S40A	0-15	3.1± 0.7	2.3 ± 0.2	3.3± 0.3
S40B	15-30	1.9± 0.6	1.8 ± 0.1	2.3± 0.2

Table 3. (continued)

Sample number[a]	Depth (cm)	Radionuclide concentration (pCi/g)[b]		
		^{238}U	^{226}Ra	^{232}Th
S41A	0-15	2.8 ± 0.8	2.5 ± 0.2	3.5 ± 0.2
S41B	15-30	3.2 ± 0.8	2.4 ± 0.1	3.0 ± 0.3
S42A	0-15	3.0 ± 1.0	2.3 ± 0.1	4.6 ± 0.3
S42B	15-30	3.9 ± 1.3	2.0 ± 0.1	3.0 ± 0.3
S43A	0-15	1.9 ± 1.1	1.9 ± 0.1	4.4 ± 0.2
S43B	15-30	3.5 ± 2	1.8 ± 0.1	3.3 ± 0.2
S44A	0-15	2.2 ± 0.6	1.7 ± 0.1	4.1 ± 0.2
S44B	15-30	2.8 ± 1	1.9 ± 0.1	3.1 ± 0.2
S45A	0-15	2.8 ± 0.6	2.5 ± 0.2	3.9 ± 0.3
S45B	15-30	2.3 ± 0.6	2.2 ± 0.2	3.0 ± 0.3
S46A	0-15	4.0 ± 0.7	3.3 ± 0.2	4.4 ± 0.3
S46B	15-30	3.4 ± 0.8	3.2 ± 0.2	3.3 ± 0.3
S47A	0-15	4.0 ± 2	2.9 ± 0.1	4.2 ± 0.3
S47B	15-30	4.2 ± 1	3.3 ± 0.2	3.6 ± 0.3
S48A	0-15	2.7 ± 0.7	2.3 ± 0.1	3.9 ± 0.2
S48B	15-30	3.3 ± 0.6	3.1 ± 0.2	3.9 ± 0.3
S49A	0-15	3.0 ± 1	2.7 ± 0.2	4.8 ± 0.3
S49B	15-30	3.5 ± 0.7	2.7 ± 0.2	3.8 ± 0.3
S50A	0-15	3.4 ± 0.8	3.2 ± 0.2	4.5 ± 0.3
S50B	15-30	3.4 ± 0.6	3.4 ± 0.2	4.1 ± 0.3
S51A	0-15	3.1 ± 0.8	2.9 ± 0.2	5.1 ± 0.3
S51B	15-30	3.1 ± 1	2.6 ± 0.1	3.5 ± 0.2
S52A	0-15	3.7 ± 2	3.2 ± 0.2	4.0 ± 0.2
S52B	15-30	3.1 ± 0.8	2.9 ± 0.1	3.4 ± 0.3
S53A	0-15	2.6 ± 0.6	1.6 ± 0.1	2.5 ± 0.2
S53B	15-30	1.5 ± 0.5	0.90± 0.1	1.1 ± 0.2
S54A	0-15	3.8 ± 0.8	2.8 ± 0.2	3.7 ± 0.3
S54B	15-30	3.7 ± 1	3.1 ± 0.2	3.4 ± 0.3
S55A	0-15	2.8 ± 0.6	1.7 ± 0.1	3.7 ± 0.2
S55B	15-30	2.7 ± 0.6	2.2 ± 0.1	3.6 ± 0.2
S55C	30-45	2.8 ± 1	2.6 ± 0.1	3.2 ± 0.2

Table 3. (continued)

Sample number[a]	Depth (cm)	Radionuclide concentration (pCi/g)[b]		
		^{238}U	^{226}Ra	^{232}Th
S56A	0-15	2.0 ± 1	1.1 ± 0.1	2.4 ± 0.2
S56B	15-30	2.0 ± 0.6	0.98± 0.1	3.3 ± 0.2
S56C	30-45	1.2 ± 0.5	1.4 ± 0.1	2.6 ± 0.2
S57A	0-15	1.2 ± 0.4	0.82± 0.1	1.5 ± 0.2
S57B	15-30	0.89± 0.5	0.72± 0.1	0.83± 0.1
S58	0-15	1.6 ± 5	1.2 ± 0.1	2.7 ± 0.2
S59A	0-15	3.0 ± 0.6	1.2 ± 0.1	2.5 ± 0.2
S59B	15-30	1.6 ±0.6	0.92± 0.1	1.5 ± 0.2
S60A	0-15	1.1 ± 0.5	1.1 ± 0.1	2.6 ± 0.2
S60B	15-30	0.91± 0.3	0.90± 0.1	1.3 ± 0.1
S61A	0-15	4.9 ± 0.6	2.7 ± 0.2	5.6 ± 0.3
S61B	15-30	4.8 ± 1	2.6 ± 0.1	3.9 ± 0.3
S62A	0-15	1.8 ± 0.5	1.4 ± 0.1	3.1 ± 0.2
S62B	15-30	1.9 ± 0.5	1.7 ± 0.1	2.7 ± 0.2
S63A	0-15	3.9 ± 0.5	1.6 ± 0.1	3.2 ± 0.2
S63B	15-30	3.1 ± 2	2.3 ± 0.1	3.8 ± 0.2
S63C	30-45	3.8 ± 0.5	2.0 ± 0.1	2.2 ± 0.2
S64A	0-15	4.2 ± 1	2.3 ± 0.1	3.2 ± 0.2
S64B	15-30	3.9 ± 2	3.3 ± 0.2	3.7 ± 0.3
S64C	30-45	3.2 ± 1	2.3 ± 0.1	2.3 ± 0.2
S65A	0-15	2.1 ± 0.9	2.2 ± 0.1	2.9 ± 0.2
S65B	15-30	2.7 ± 1	2.4 ± 0.1	2.9 ± 0.2
S65C	30-45	2.9 ± 0.6	2.6 ± 0.1	3.2 ± 0.3
S66A	0-15	2.9 ± 0.8	2.8 ± 0.2	8.3 ± 0.4
S66B	15-30	5.2 ± 2	3.0 ± 0.2	6.3 ± 0.3
S67A	0-15	2.8 ± 0.7	2.5 ± 0.2	4.0 ± 0.3
S67B	15-30	3.4 ± 1	2.7 ± 0.2	3.5 ± 0.4

Table 3. (continued)

Sample number[a]	Depth (cm)	Radionuclide concentration (pCi/g)[b]		
		^{238}U	^{226}Ra	^{232}Th
		Biased samples[d]		
B1A	0-15	3.5± 1	2.4± 0.3	25± 2
B1B	15-30	2.8± 0.8	1.8± 0.1	8.2± 0.2
B2A	0-15	4.0± 2	2.4± 0.2	11± 0.4
B2B	15-30	2.9± 0.6	2.4± 0.1	4.1± 0.3
B3A	0-15	3.6± 1	2.4± 0.1	3.8± 0.2
B3B	15-30	3.1± 0.7	3.2± 0.1	3.8± 0.2
B4	0-15	4.0± 2	2.5± 0.6	41 ± 3

[a]Samples begin at number S11; soil samples from first survey were numbered S1-S10. Locations of soil samples from this survey are shown on Fig. 3.

[b]Indicated counting error is at the 95% confidence level (± 2σ).

[c]Systematic samples are taken at locations irrespective of gamma exposure rates.

[d]Biased samples are taken from areas with elevated gamma exposure rates.

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