COMPREHENSIVE RADIOLOGICAL SURVEY

OFF-SITE PROPERTY R
NIAGARA FALLS STORAGE SITE
LEWISTON, NEW YORK

Prepared for

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Formerly Utilized Sites -- Remedial Action Program

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INTRODUCTION

Beginning in 1944, the Manhattan Engineer District and its successor, the Atomic Energy Commission (AEC), used portions of the Lake Ontario Ordnance Works (now known as the Niagara Falls Storage Site (NFSS) and associated off-site properties) approximately 3 km northeast of Lewiston, New York, for storage of radioactive wastes. These wastes were primarily residues from uranium processing operations; however, they also included: contaminated rubble and scrap from decommissioning activities, biological and miscellaneous wastes from the University of Rochester, and low-level fission-product waste from contaminated-liquid evaporators at the Knolls Atomic Power Laboratory (KAPL). Receipt of radioactive waste was discontinued in 1954, and following cleanup activities by Hooker Chemical Co., 525 hectares of the original 612-hectare site were declared surplus. This property was eventually sold by the General Services Administration to various private, commercial, and governmental agencies.[1]

SCA Chemical Services, Inc. (SCA) is the current owner of a tract identified as off-site property B (see Figure 1). A radiological survey of that tract, conducted June through September 1983, is the subject of this report.

SITE DESCRIPTION

Figure 2 is a plot plan of off-site property B. The property is rectangular in shape and measures approximately 500 m long by 495 m wide. It occupies a total area of 25 hectares. MacArthur Street delineates the west boundary and "M" Street, the north boundary; a haul road, along what was previously a railroad track, is the south boundary. The eastern boundary is a chain link fence. An out-of-service railroad track parallels the eastern perimeter. There are two interior roads, "J" Street and Marshall Street. A warehouse having a floor area of approximately 1800 m^2

is located between Marshall Street and the railroad tracks, in the northeast portion of the property. There is a paved parking area at the intersection of "M" and Marshall Streets.

SCA is constructing a new landfill on the northwest portion of the site and the warehouse is currently used for temporary storage of chemical wastes. The remainder of the property is not in use and is heavily overgrown with brush and trees. The southeastern portion is swampy and some small areas are inaccessible due to surface water.

Radiological History

There is no evidence of contaminated material burials on off-site property B; however, the 1971-72 AEC survey identified elevated radiation levels near the warehouse - possibly the result of previous storage of contaminated materials in this building.[1,2] Soil samples from this property have indicated elevated concentrations of uranium, radium, and cesium.[1] Decontamination efforts following the 1971-72 survey were not successful in completely eliminating the elevated radiation levels near the warehouse. The 1980 mobile scan by Oak Ridge National Laboratory revealed above background conditions still present along Marshall Street in the vicinity of the warehouse building.[3]

SURVEY PROCEDURES

The comprehensive survey of NFSS off-site property B was performed by the Radiological Site Assessment Program of Oak Ridge Associated Universities (ORAU), during June-September 1983. The survey was in accordance with a plan dated February 3, 1983, approved by the Department of Energy. The objective and procedures from that plan are presented in this section.

Objective

The objective of the survey was to provide a comprehensive assessment of the radiological conditions and associated potential health effects, if any, on property B. Radiological information collected included:

1. direct radiation exposure rates and surface beta-gamma dose rates,
2. locations of elevated surface residues,
3. concentrations of radionuclides in surface and subsurface soil,
4. concentrations of radionuclides in ground water, and
5. surface contamination levels in the warehouse.

Procedures

1. Brush and weeds were cleared as needed to provide access for gridding and surveying and a 40 m grid system was established by McIntosh and McIntosh of Lockport, NY, under subcontract. The grid system is shown on Figure 3.

2. Walkover surface scans were conducted over all accessible areas of the property. Scanning intervals were 1-2 m along all roads, in areas previously identified as having elevated radiation levels, and in other areas where direct radiation measurements suggested possible contaminated residues. Traverses were at 2-5 m intervals on those areas that were relatively inaccessible and had no history of radioactive use. Portable gamma NaI(Tl) scintillation survey meters were used for the scans. Locations of elevated contact radiation levels were noted and surface exposure rates were measured at these locations.

3. Gamma exposure rate measurements were made at the surface and at 1 m above the surface at 40 m grid intervals. Measurements were performed using portable gamma NaI(Tl) scintillation survey

meters. Conversion of these measurements to exposure rates in microroentgens per hour (μR/h) was in accordance with cross calibration with a pressurized ionization chamber.

4. Beta-gamma dose rate measurements were performed 1 cm above the surface at 40 m grid intervals. These measurements were conducted using thin-window (<7 mg/cm^2) G-M detectors and portable scaler/ratemeters. Measurements were also obtained with the detector shielded to evaluate contributions of nonpenetrating beta and low-energy gamma radiations. Meter readings were converted to dose rates in microrads per hour (μrad/h) based on cross calibration with a thin-window ionization chamber.

5. Surface (0-15 cm) soil samples of approximately 1 kg each were collected at each accessible 40 m grid interval.

6. At locations of elevated surface radiation levels, beta-gamma dose rates and exposure rates at 1 m above the surface were also measured. Surface samples were obtained from these locations and, following sampling, the surface exposure levels were remeasured for comparison with presampling levels.

7. Detection Sciences Group of Carlisle, MA, performed ground-penetrating radar surveys at proposed borehole locations to assure that subsurface piping and utilities were not damaged during drilling. In some cases, boreholes were relocated slightly.

8. Boreholes were drilled to provide a mechanism for logging subsurface direct radiation profiles and collecting subsurface soil and water samples. Thirteen boreholes were drilled by Site Engineers, Inc., of Cherry Hill, NJ, using a truck mounted 20 cm diameter hollow-stem auger. The locations of these boreholes are shown on Figure 4.

Gamma radiation scans were performed in the boreholes to identify the locations of elevated direct radiation levels which might indicate subsurface residues. Radiation profiles were determined by measuring gamma radiation at 15-30 cm intervals between the surface and ground water or the hole bottom. A collimated gamma scintillation detector and portable scaler were used for these measurements.

Ground water samples of approximately 3.5 liters were collected from six borehole locations. The samples were collected using a hand bailer. Soil samples of approximately 1 kg each were collected from various depths in the boreholes by scraping the sides of the hole with a specially constructed sampling tool.

9. Surface gamma scans and exploratory alpha and beta-gamma measurements were conducted in the warehouse. Results indicated nonuniform contamination of interior surfaces, requiring a thorough survey of the building. The floor and lower walls (to 2 m) were gridded at 2 m intervals. Gamma scans were performed and locations of elevated contact radiation levels were noted. Gamma exposure rates at 1 m above the floor were measured throughout each room. Total alpha and beta-gamma contamination levels and transferable alpha and beta contamination were measured using portable detectors and smears, respectively. Measurements were at approximately 1 m intervals on all gridded lower surfaces; on upper walls and ceiling surfaces a minimum of one set of measurements per 10 m^2 was performed. Samples of scrapings from several floor cracks were obtained for analysis. Figure 5 is a plot plan of the warehouse facility, indicating reference designations assigned to various rooms.

10. Twenty soil samples and seven water samples were collected from the Lewiston area (but not on NFSS or associated off-site properties) to provide baseline concentrations of radionuclides for comparison purposes. Direct background radiation levels were

measured at locations where baseline soil samples were collected. The locations of the baseline samples and background measurements are shown on Figure 6.

Sample Analysis and Interpretation of Results

Soil samples were analyzed by gamma spectrometry. Radium-226 was the major radionuclide of concern, although spectra were reviewed for U-235, U-238, Th-232, Cs-137, and other gamma emitters. Water samples and building smears were analyzed for gross alpha and gross beta concentrations.

Additional information concerning analytical equipment and procedures is in Appendix A.

Results of this survey were compared to the applicable guidelines for formerly utilized radioactive materials handling sites, which are presented in Appendix B.

RESULTS

Background Levels and Baseline Concentrations

Background exposure rates and baseline radionuclide concentrations in soil, determined for 20 locations (Figure 6) in the vicinity of the NFSS, are presented in Table 1-A. Exposure rates ranged from 6.8 to 8.8 μR/h (typical levels for this area of New York). Concentrations of radionuclides in soil were: Ra-226, <0.09 to 1.22 pCi/g (picocuries per gram); U-235, <0.14 to 0.46 pCi/g; U-238, <2.20 to 6.26 pCi/g; Th-232, 0.32 to 1.18 pCi/g; and Cs-137, <0.02 to 1.05 pCi/g. These concentrations are typical of the radionuclide levels normally encountered in surface soils.

Radioactivity levels in baseline water samples are presented in Table 1-B. The gross alpha and gross beta concentrations ranged from 0.55 to 1.87 pCi/l (picocuries per liter) and <0.63 to 14.3 pCi/l, respectively. These are typical of concentrations normally occurring in surface water.

Direct Radiation Levels

Direct radiation levels, measured at 40 m grid intervals, are presented in Table 2. The gamma exposure rates at 1 m above the surface at these grid points ranged from 4 to 12 μR/h (average 7 μR/h). Surface contact gamma exposure rates and beta-gamma dose rates were 4 to 14 μR/h (average 7 μR/h) and 4 to 44 μrad/h (average 14 μrad/h), respectively. At most locations, measurements performed with the detector shielded averaged approximately 20% less than those with the unshielded detector. This indicates only a small portion of the surface dose rate is due to nonpenetrating beta or low-energy photon radiations.

The walkover survey identified isolated spots of elevated contact radiation levels in the vicinity of the warehouse. These locations are indicated on Figure 7 and associated radiation levels are presented in Table 3. Surface contact gamma exposure rates at these locations ranged from 12-190 μR/h; the maximum was measured at grid point 412N, 1465E. Exposure rates at 1 m above the surface ranged from 12 to 40 μR/h. Beta-gamma dose rates ranged from 29-1350 μrad/h. The maximum dose rate was recorded at grid coordinate 425N, 1498E. Contact exposure rates were not reduced by sampling at most locations; at some locations radiation levels were increased after sample removal.

Radionuclide Concentrations in Surface Soil

Table 4 lists the concentrations of radionuclides measured in surface soil from 40 m grid intervals. These samples contained Ra-226 concentrations ranging from <0.29 to 3.43 pCi/g. The highest level was in the sample collected at grid point 429N, 1486E, near the warehouse. A few additional samples contained Ra-226 concentrations exceeding those in the baseline soil, but none exceeded 5 pCi/g above the baseline level. Concentrations of U-238, U-235, Th-232, and Cs-137 were not significantly different from those in baseline samples. No other gamma emitting radionuclides were noted in these samples.

Radionuclide concentrations in samples from locations of elevated contact radiation levels are presented in Table 5. Concentrations of Ra-226 in these samples ranged from 9.53 to 828 pCi/g; the maximum concentration was measured in sample B3 from grid point 397N, 1503E. Several of these samples also contained elevated U-238 levels; the highest was 156 pCi/g in sample B3.

Borehole Gamma-Logging Measurements

The results of gamma scintillation measurements in boreholes indicated elevated levels only at borehole H13; at that location the contamination is limited to the upper 15 cm. The gamma count rates determined by the borehole measurements were reliable indicators of elevated radionuclide levels. However, the gamma logging data was not useful in quantifying radionuclide concentrations in the subsurface soil, because of the varying ratios of Ra-226, U-235, U-238, Th-232, and Cs-137 occurring in soils from this site.

Radionuclide Concentrations in Borehole Soil Samples

Table 6 presents the radionuclide concentrations measured in soil samples from boreholes. Boreholes H1-H12 did not contain radionuclide concentrations differing from the ranges in baseline samples. Borehole H13, in the vicinity of isolated hot spots near the warehouse, contained 57.4 pCi/g of Ra-226 at the surface but only 9.74 pCi/g at 15 cm deep.

Radionuclide Concentrations in Water

Water samples collected from boreholes contained from 1.72 to 8.15 pCi/l of gross alpha and 2.78 to 9.99 pCi/l of gross beta (see Table 7). The alpha concentrations are above the baseline range but all concentrations are within the EPA Interim Drinking Water Standards.

Building Contamination Levels

The gamma scan of the warehouse identified cracks and expansion joints in the concrete floor with contact radiation levels up to 130 μR/h. The majority of these cracks and joints were located in rooms 1, 2, and 12. Samples of residue from these cracks were analyzed and the contaminant identified as Ra-226. Exposure rates at 1 m above the floor throughout the building ranged from 6 to 14 μR/h.

Total alpha contamination ranged up to 18,700 dpm/100 cm^2 on the floor, 520 dpm/100 cm^2 on lower walls, and 7040 dpm/100 cm^2 on the upper wall and ceiling surfaces. Beta-gamma contamination levels reached 135,000 dpm/100 cm^2 on the floor, 7140 dpm/100 cm^2 on lower walls, and 19,300 dpm/100 cm^2 on the upper walls and ceiling. Rooms 1, 2, 3, and 12 have the highest levels of contamination, although all rooms except 10 and 11 contain areas which exceed the residual contamination criteria. Horizontal ceiling surfaces such as beams, HVAC ducts, pipes, and ledges generally have elevated total alpha and beta-gamma contamination levels. Removable (transferable) contamination was relatively low; the maximum alpha and beta levels measured were 70 dpm/100 cm^2 and 48 dpm/100 cm^2. Ceilings and upper walls were the locations where most removable contamination was noted.

Radon measurements were not conducted in this building, because of the low occupancy factor, the lack of building HVAC systems and general weatherizing, and the usual practice of leaving main doors open for natural ventilation during waste handling activities.

COMPARISON OF SURVEY RESULTS WITH GUIDELINES

The guidelines applicable to cleanup of off-site properties at the Niagara Falls Storage Site are presented in Appendix B. Radiation levels and radionuclide concentrations, at small, isolated spots of surface or near-surface contamination, exceed these guideline values.

Exposure rates in contact with some of the areas of surface contamination near the warehouse exceed the guideline of 60 μR/h; small surface areas inside the warehouse exceed 20 μR/h. Exposure rates at 1 m above the surface are well within these direct radiation guidelines.

Areas of surface contamination outside the warehouse contain Ra-226 concentrations exceeding 5 pCi/g above background levels. These areas are shown on Figure 8 and summarized in Table 9. Several of these areas (394-400N, 1462-1466E; 397N, 1503E; and 412N, 1465E) would exceed the criteria even if averaged over an area of 100 m^2; the other areas are small and isolated and averaging over 100 cm^2 would reduce the Ra-226 level to less than 5 pCi/g above background.

No subsurface contamination was identified and subsurface water samples are within the EPA Interim Drinking Water Standards of 15 pCi/l gross alpha and 50 pCi/l gross beta.

Warehouse building surfaces are contaminated with Ra-226 in excess of the total alpha limits of 100 dpm/100 cm^2 average and 300 dpm/100 cm^2 maximum. Approximately 1000 m^2 of the floor area exceed these limits. In addition to the floor, the entire upper walls and ceiling areas of rooms 1, 2, 3, 12, and 14 and small portions of the lower walls in rooms 1, 2, 3, 8, and 9 exceed these limits. With the exception of loose residues in floor cracks, the contamination on building surfaces is primarily fixed. Only several small isolated areas were noted to have removable contamination levels exceeding 20 alpha dpm/100 cm^2. Floor and lower wall areas exceeding contamination guidelines are indicated on Figures 9 and 10. It should be noted that some of the floor and wall areas in this building were inaccessible for surveying due to stored waste containers.

SUMMARY

A comprehensive survey of off-site property B at the Niagara Falls Storage Site was conducted during June-September 1983. The survey included: surface radiation scans, measurements of direct radiation

levels, analyses for radionuclide concentrations in surface and subsurface soil and subsurface water samples, and measurements of surface contamination in a warehouse.

The results of the survey indicate small isolated areas of elevated direct radiation and Ra-226 contamination in surface soil and on paving outside the warehouse building. Fixed Ra-226 contamination is also present on interior warehouse surfaces.

Although the contaminated residues on portions of this property exceed the guidelines established for unrestricted release to the general public the contaminants are not migrating from the property and, under present conditions of land and facility use, do not pose potential health risks to the public or site workers.

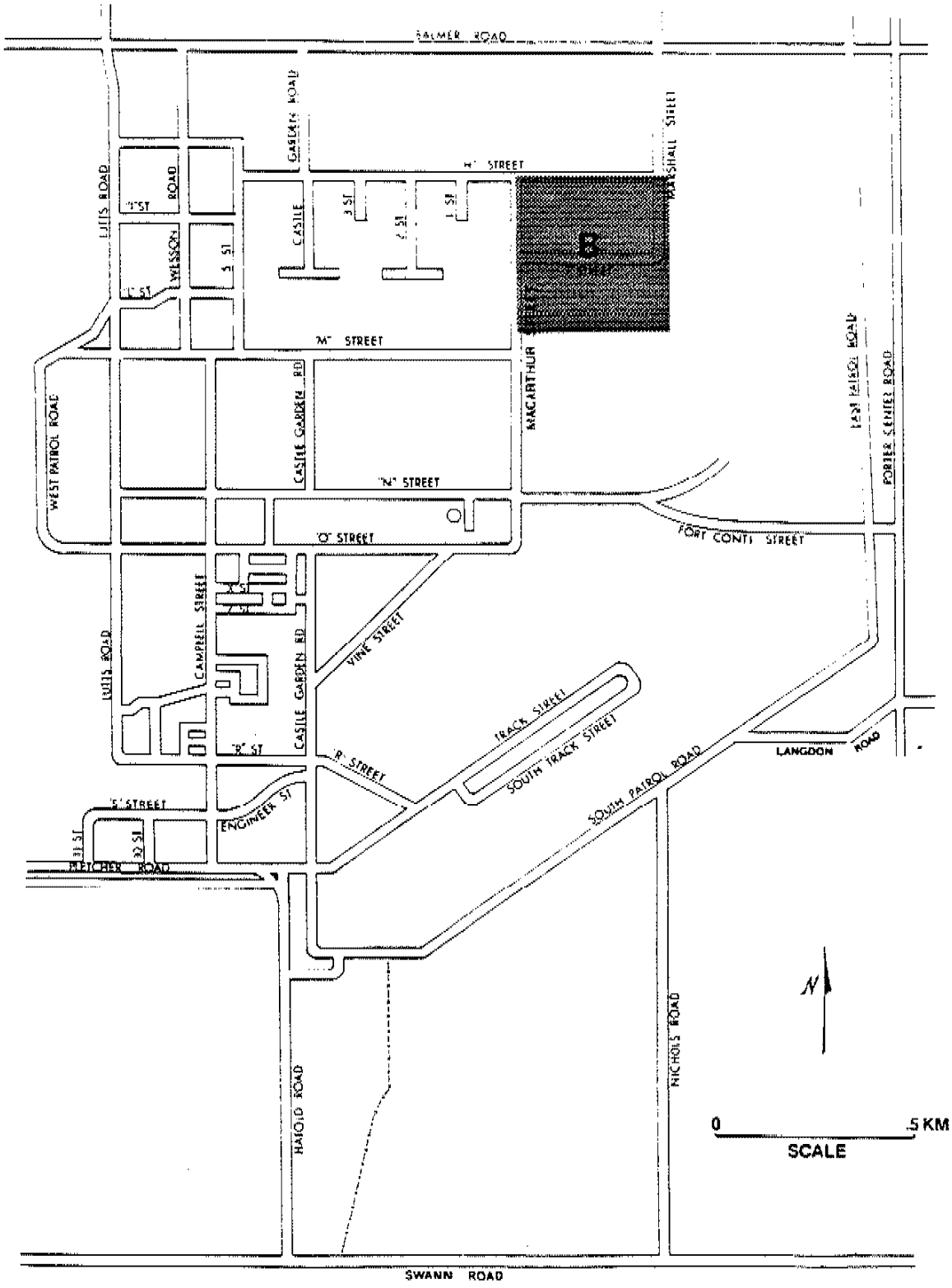

FIGURE 1. Map of Niagara Falls Storage Site and Off-Site Properties, Lewiston, New York, Indicating the Location of Off-Site Property B.

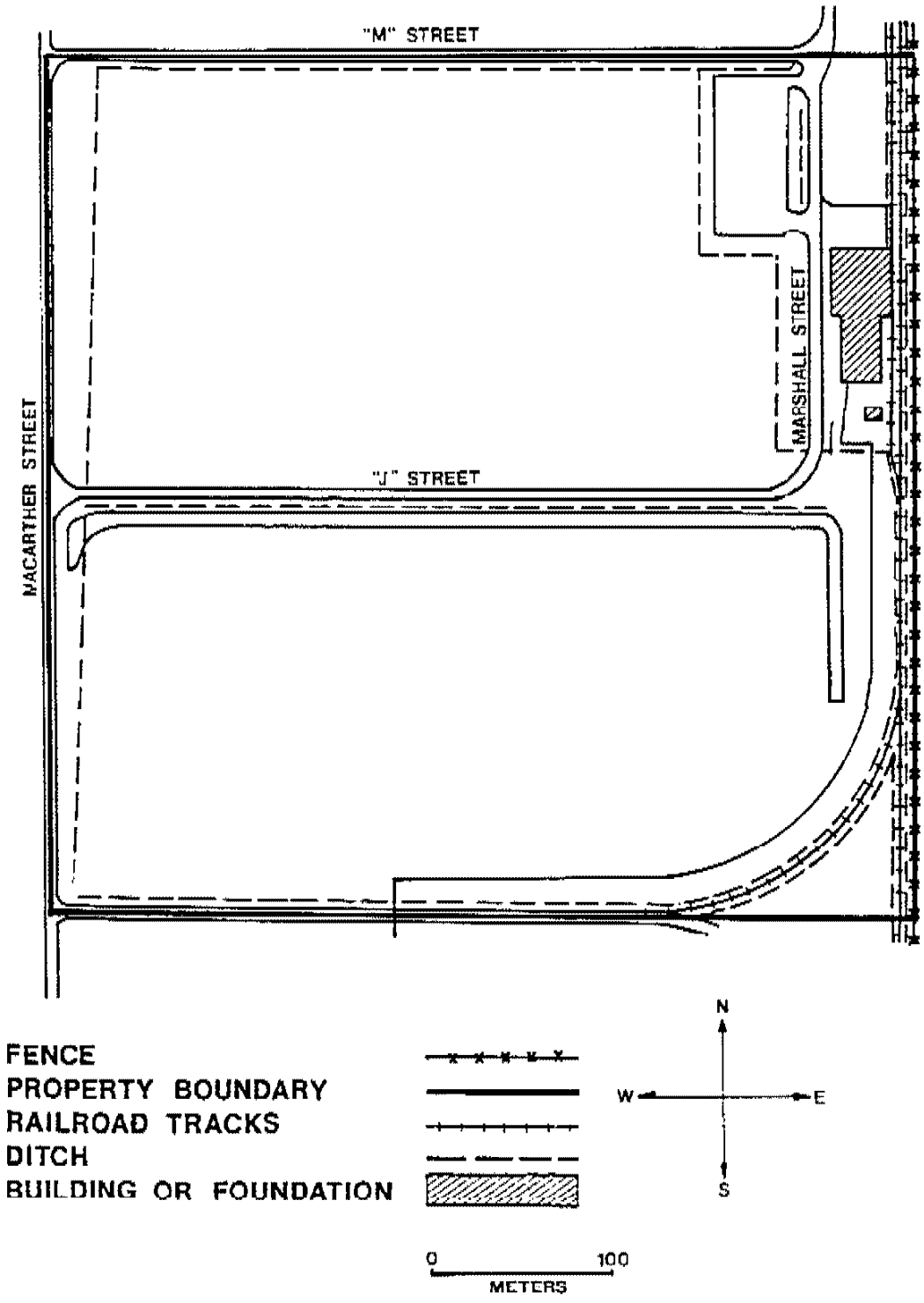

FIGURE 2. Plan View of NFSS Off-Site Property B Indicating Prominent Surface Features.

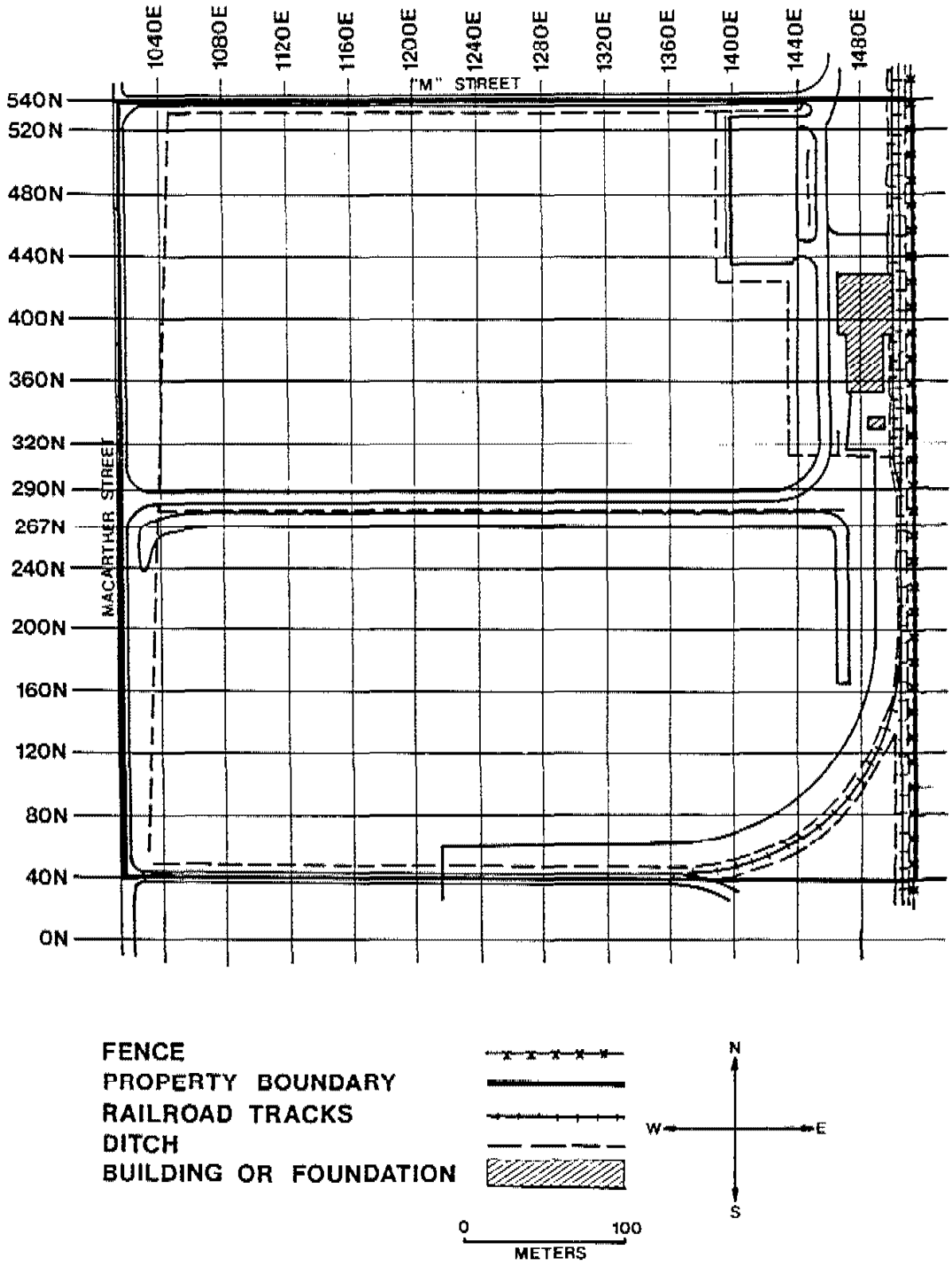

FIGURE 3. Plan View of NFSS Off-Site Property B Indicating the Grid System Established for Survey Reference.

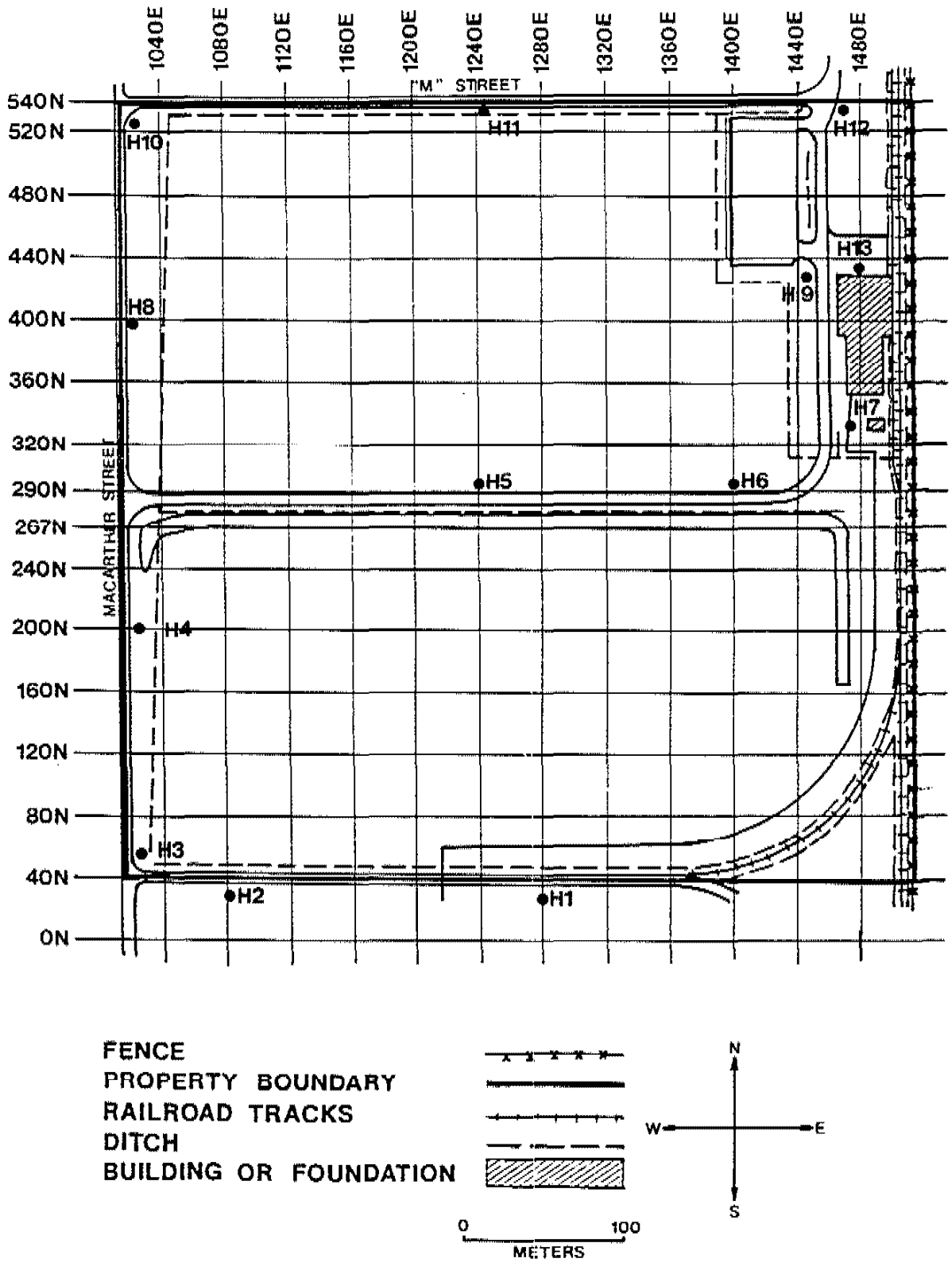

FIGURE 4. Locations of Boreholes for Subsurface Investigations.

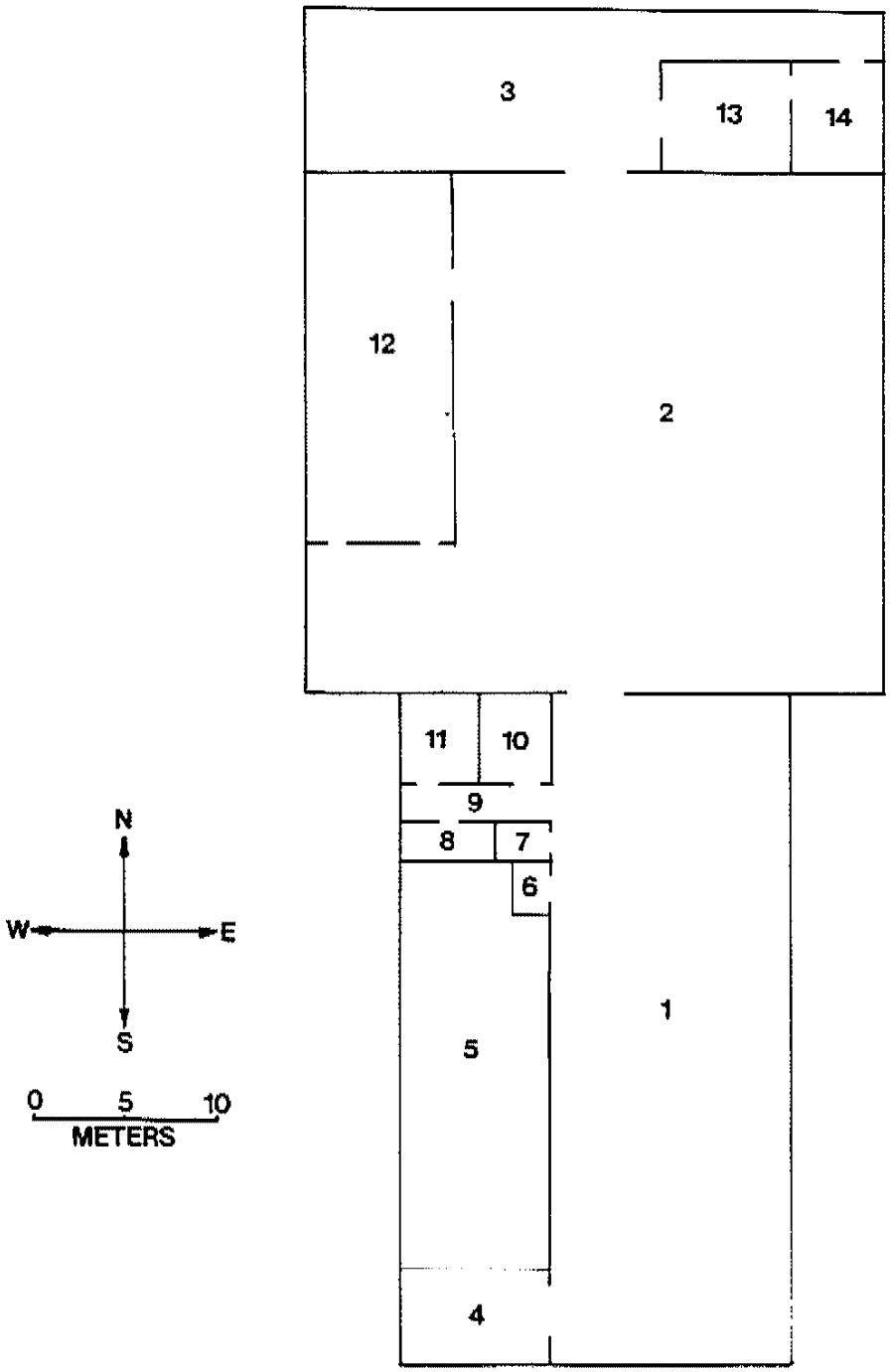

FIGURE 5. Plan of Warehouse Indicating Room Designations for Survey Reference.

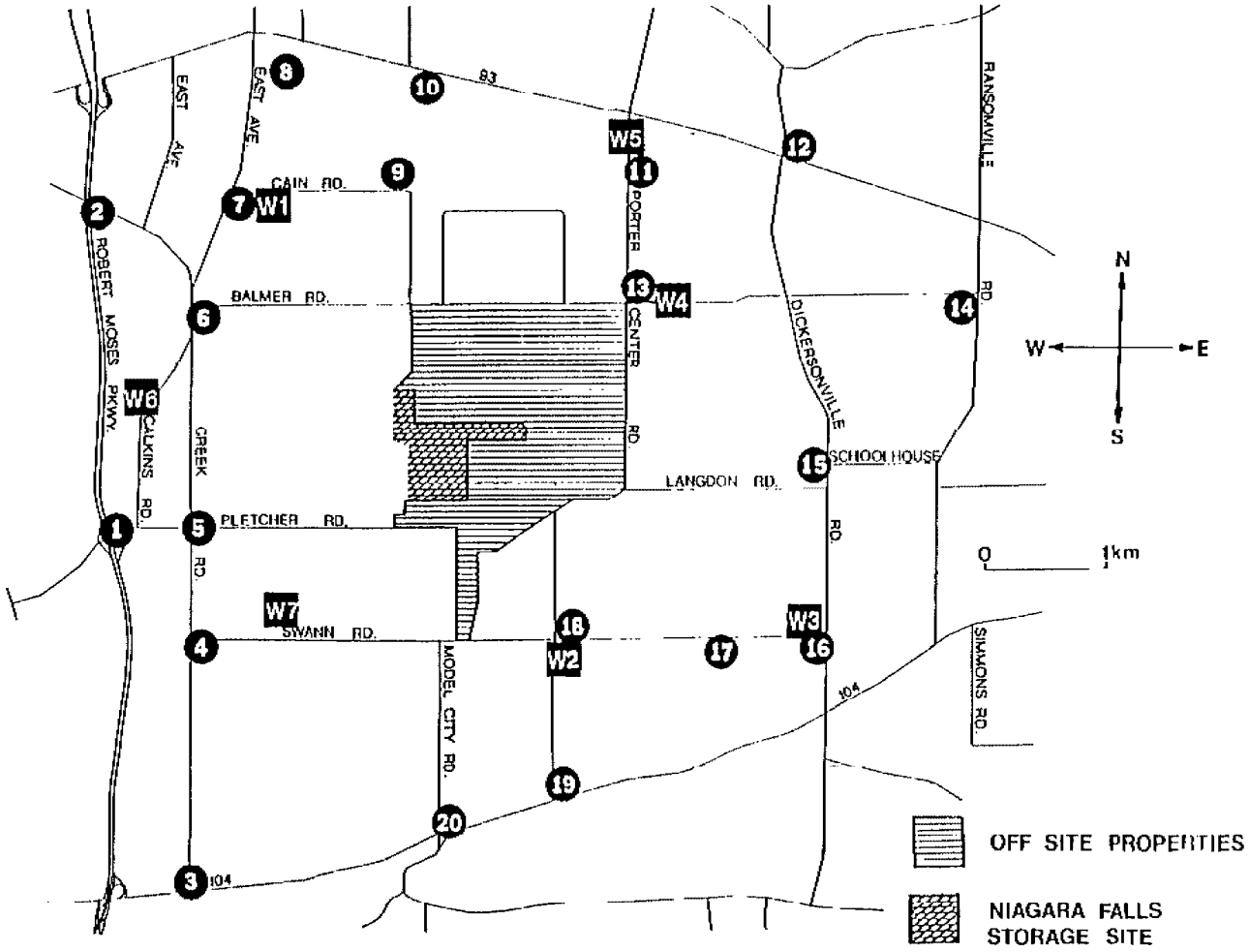

FIGURE 6. Map of Northern Niagara County, New York, Showing Locations of Background Measurements and Baseline Samples. (#1-20: soil samples and direct measurements; W1-W7: water samples.)

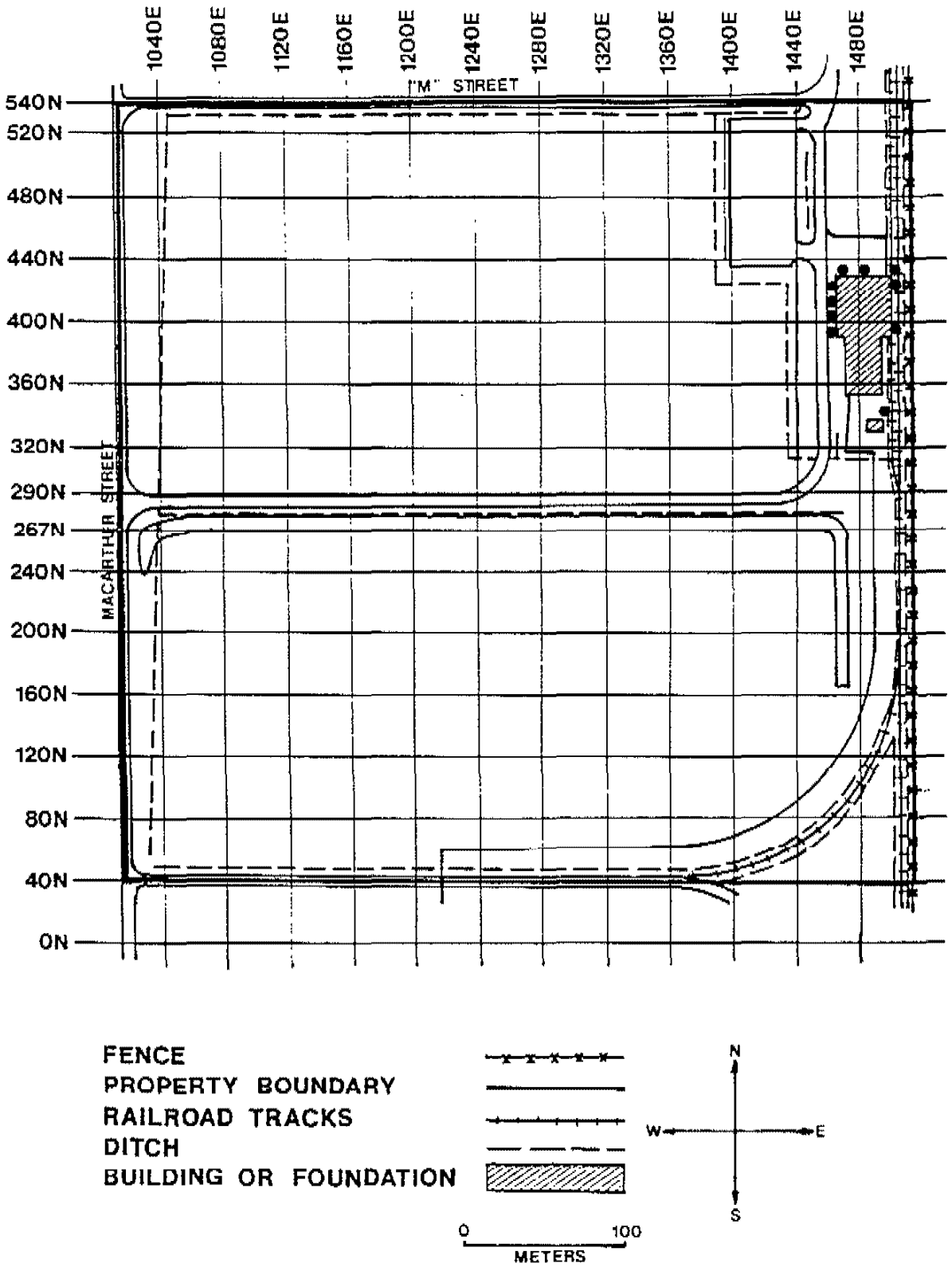

FIGURE 7. Locations of Areas of Elevated Direct Radiation.

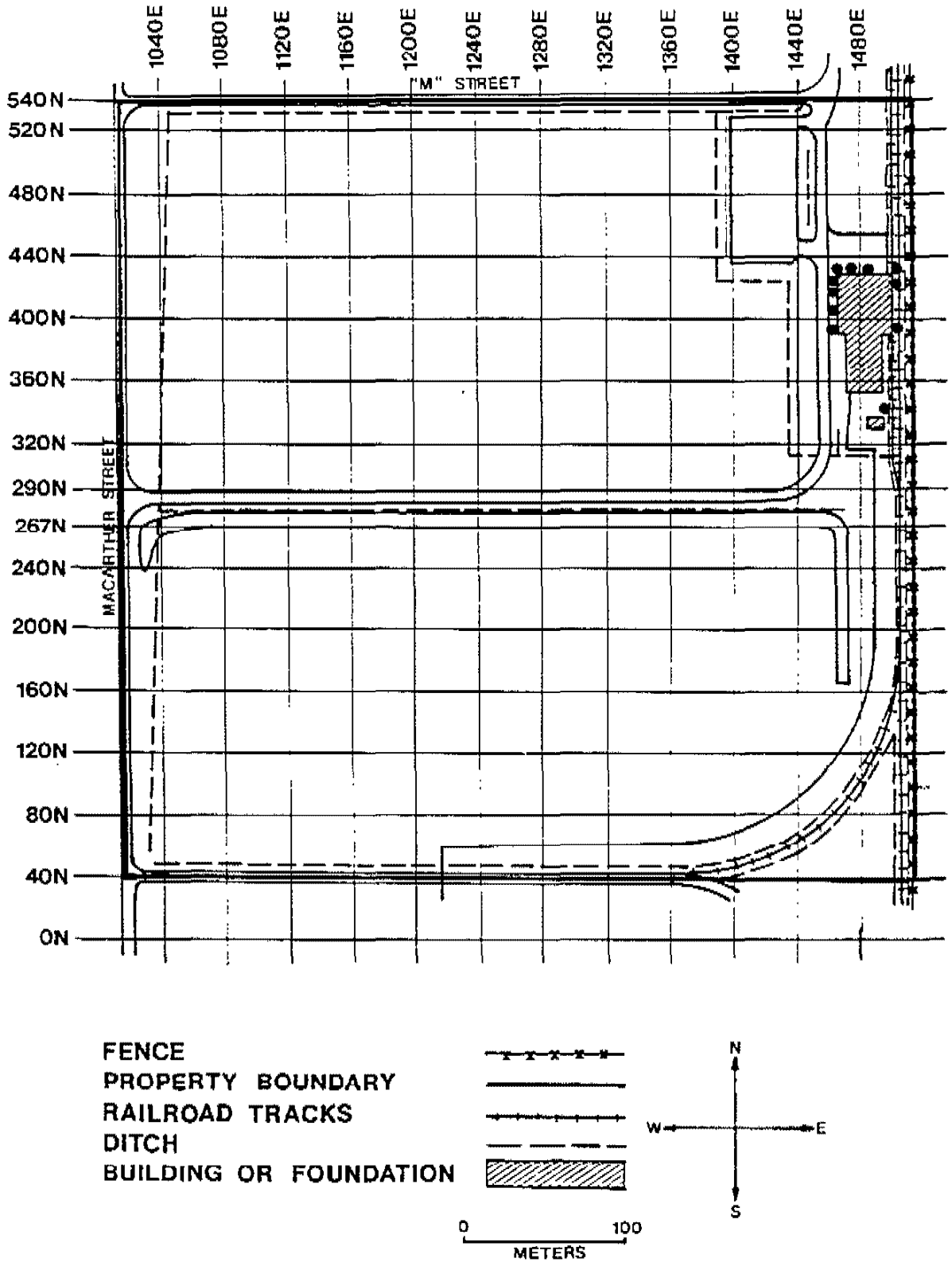

FIGURE 8. Map of NFSS Off-Site Property B Indicating Areas Where Radionuclide Concentrations in Soil Exceed Guideline Levels.

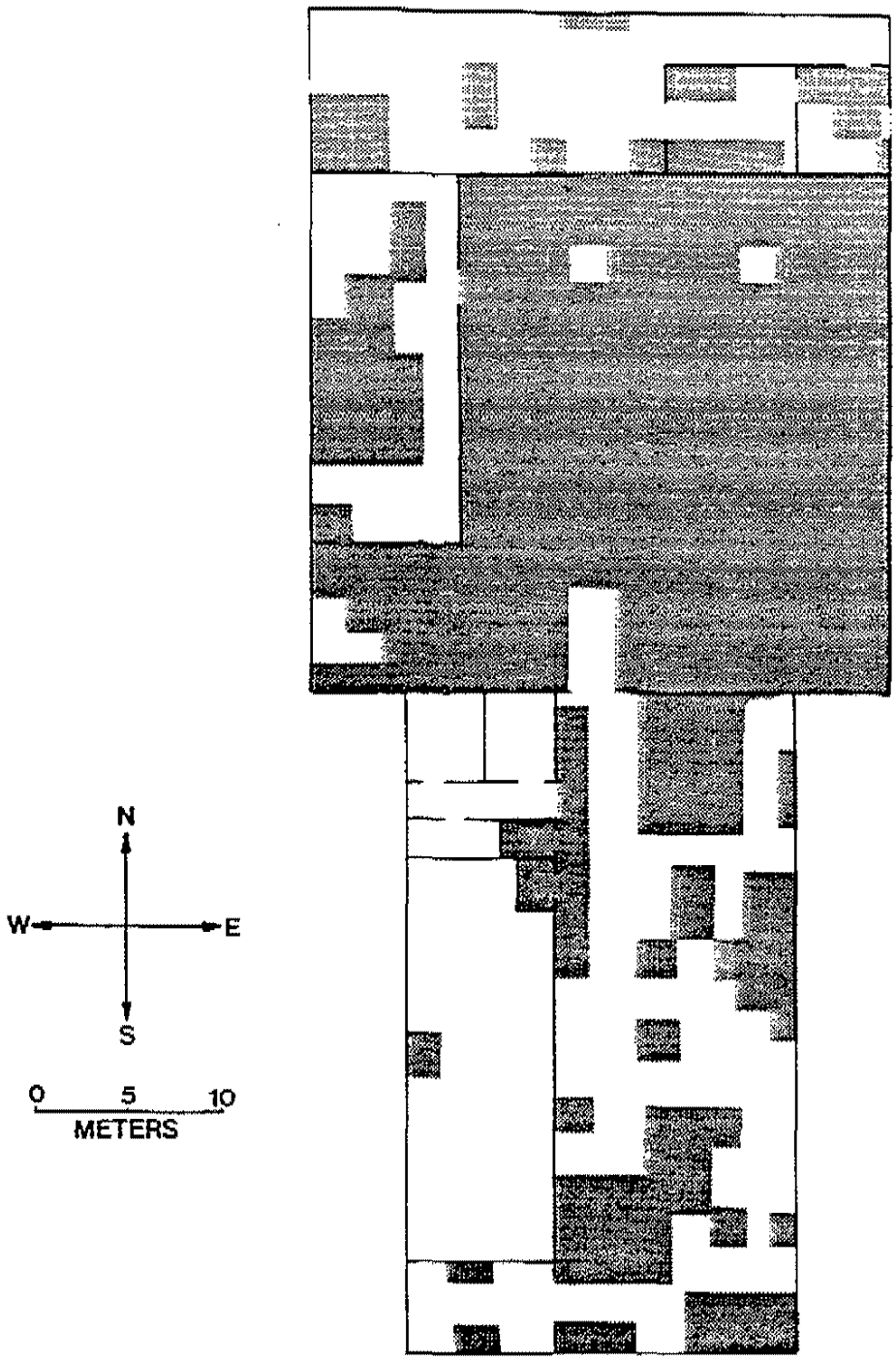

FIGURE 9. Plan of Warehouse Indicating Floor Areas (shaded) Where Contamination Exceeds Criteria.

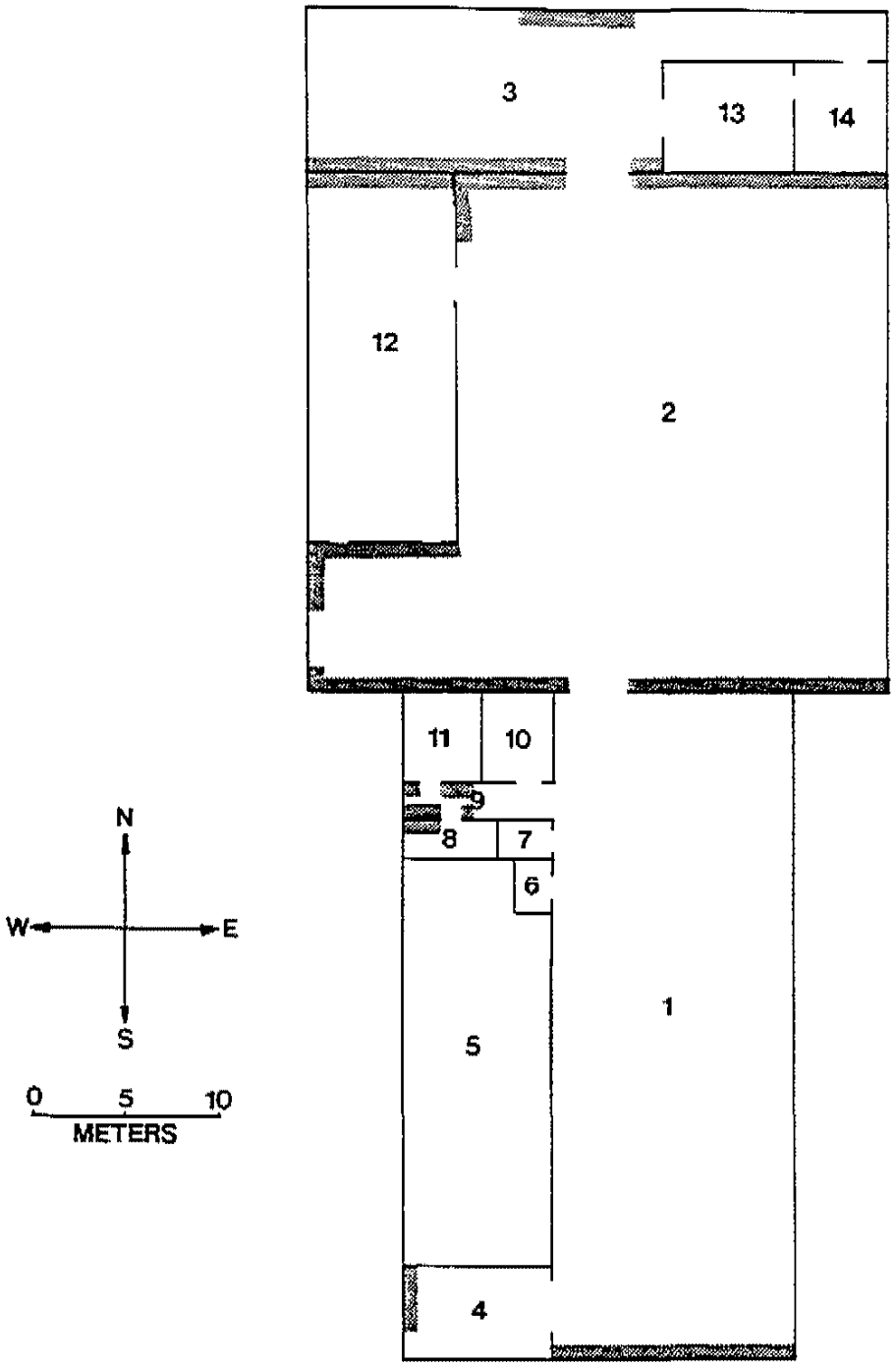

FIGURE 10. Plan of Warehouse Indicating Lower Wall Areas (shaded) Where Contamination Exceeds Criteria.

TABLE 1-A

BACKGROUND EXPOSURE RATES
AND
RADIONUCLIDE CONCENTRATIONS IN BASELINE SOIL SAMPLES

Location [a]	Exposure Rate [b] (μR/h)	Radionuclide Concentrations (pCi/g)				
		Ra-226	U-235	U-238	Th-232	Cs-137
1	6.8	0.74 ± 0.16 [c]	<0.19	<2.89	0.70 ± 0.46	0.29 ± 0.08
2	6.8	0.75 ± 0.19	<0.19	<3.35	0.86 ± 0.24	0.24 ± 0.08
3	8.3	0.71 ± 0.18	0.46 ± 0.41	<3.72	0.88 ± 0.33	0.34 ± 0.09
4	7.9	0.67 ± 0.18	<0.22	<4.10	1.18 ± 0.35	0.12 ± 0.07
5	7.3	0.70 ± 0.16	<0.17	<3.34	0.68 ± 0.24	0.14 ± 0.07
6	7.7	0.50 ± 0.15	<0.16	<2.33	0.52 ± 0.38	0.17 ± 0.09
7	7.7	0.63 ± 0.13	<0.17	<2.73	0.83 ± 0.24	0.35 ± 0.08
8	7.6	0.59 ± 0.12	<0.14	<2.20	0.54 ± 0.23	<0.02
9	7.1	0.63 ± 0.20	<0.23	<4.16	0.83 ± 0.38	0.69 ± 0.11
10	7.1	0.70 ± 0.16	<0.19	<2.98	0.59 ± 0.25	0.69 ± 0.10
11	6.7	<0.09	<0.19	<2.83	0.49 ± 0.31	0.48 ± 0.14
12	7.1	0.48 ± 0.13	<0.16	<2.84	0.65 ± 0.26	0.68 ± 0.10
13	6.7	0.57 ± 0.14	<0.17	<2.36	0.49 ± 0.26	0.41 ± 0.08
14	6.8	0.68 ± 0.17	<0.19	<3.24	0.67 ± 0.25	0.70 ± 0.10
15	8.2	0.65 ± 0.14	<0.17	<3.20	0.72 ± 0.35	0.23 ± 0.08
16	7.4	0.91 ± 0.17	<0.71	<3.58	0.83 ± 0.28	0.61 ± 0.09
17	7.0	0.48 ± 0.14	<0.16	<2.73	0.32 ± 0.22	0.38 ± 0.08
18	7.7	0.73 ± 0.16	<0.18	6.26 ± 9.23	1.01 ± 0.44	0.32 ± 0.12
19	8.8	1.22 ± 0.22	<0.23	<3.79	1.08 ± 0.49	1.05 ± 0.13
20	8.6	0.83 ± 0.17	<0.21	<3.59	0.84 ± 0.29	0.08 ± 0.07
Range	6.8 to 8.8	<0.09 to 1.22	<0.14 to 0.46	<2.20 to 6.26	0.32 to 1.18	<0.02 to 1.05

[a] Refer to Figure 6.
[b] Measured at 1 m above the surface.
[c] Errors are 2σ based on counting statistics.

TABLE 1-B

RADIONUCLIDE CONCENTRATIONS IN BASELINE WATER SAMPLES

Location[a]	Radionuclide Concentrations (pCi/l)	
	Gross Alpha	Gross Beta
W1	0.95 ± 0.93 [b]	4.79 ± 1.15
W2	0.95 ± 0.94	9.17 ± 1.31
W3	0.55 ± 0.78	2.73 ± 1.05
W4	0.63 ± 0.89	5.37 ± 1.17
W5	0.73 ± 0.68	<0.64
W6	1.87 ± 1.84	14.3 ± 2.4
W7	1.16 ± 0.66	<0.63
Range	0.55 to 1.87	<0.63 to 14.3

[a] Refer to Figure 6.
[b] Errors are 2σ based on counting statistics.

TABLE 2

DIRECT RADIATION LEVELS MEASURED
AT 40 M GRID INTERVALS

Grid Location N	Grid Location E	Gamma Exposure Rates at 1 m Above the Surface (μR/h)	Gamma Exposure Rates at the Surface (μR/h)	Beta-Gamma Dose Rates at 1 cm Above the Surface (μrad/h)
40	1015	7	8	8
40	1040	7	7	9
40	1080	7	8	8
40	1120	7	7	7
40	1160	7	8	22
40	1200	8	8	42
40	1240	8	8	15
40	1280	8	8	10
40	1320	8	8	21
40	1360	9	13	30
40	1400	9	9	22
40	1440	8	8	15
40	1480	7	7	16
40	1505	9	9	19
80	1015	7	8	8
80	1040	7	7	7
80	1080	7	7	13
80	1120	7	7	16
80	1160	7	7	17
80	1200	7	7	20
80	1240	7	7	13
80	1280	7	7	9
80	1320	7	7	7
80	1354	7	7	7
80	1400	7	8	28
80	1440	8	8	17
80	1480	8	8	9
80	1507	12	10	17
120	1015	7	7	12
120	1040	7	7	7
120	1080	7	7	17
120	1120	7	7	30
120	1160	6	7	24
120	1200	7	7	7
120	1240	7	7	12
120	1280	7	7	16
120	1320	7	7	21
120	1354	7	7	16
120	1400	7	7	18

TABLE 2, cont.

DIRECT RADIATION LEVELS MEASURED
AT 40 M GRID INTERVALS

Grid Location N	Grid Location E	Gamma Exposure Rates at 1 m Above the Surface (μR/h)	Gamma Exposure Rates at the Surface (μR/h)	Beta-Gamma Dose Rates at 1 cm Above the Surface (μrad/h)
120	1440	8	8	14
120	1480	8	8	14
120	1507	11	11	18
160	1015	6	7	16
160	1040	7	8	18
160	1080	7	7	12
160	1120	7	7	7
160	1160	7	8	14
160	1200	7	7	12
160	1240	7	8	8
160	1280	7	7	14
160	1320	6	7	9
160	1354	7	8	12
160	1400	7	7	7
160	1440	8	8	11
160	1480	7	7	7
160	1507	10	9	16
200	1015	7	7	24
200	1040	7	7	12
200	1080	7	8	8
200	1120	7	7	10
200	1160	7	7	13
200	1200	7	7	13
200	1240	7	7	7
200	1280	7	8	9
200	1320	8	7	17
200	1354	6	7	15
200	1400	7	8	8
200	1440	8	7	10
200	1480	8	8	8
200	1507	8	8	17
240	1015	7	8	32
240	1040	8	8	18
240	1080	7	7	12
240	1120	7	7	17
240	1160	7	8	11
240	1200	7	7	7
240	1240	7	7	20

TABLE 2, cont.

DIRECT RADIATION LEVELS MEASURED
AT 40 M GRID INTERVALS

Grid Location N	Grid Location E	Gamma Exposure Rates at 1 m Above the Surface (μR/h)	Gamma Exposure Rates at the Surface (μR/h)	Beta-Gamma Dose Rates at 1 cm Above the Surface (μrad/h)
240	1280	7	7	7
240	1320	7	7	15
240	1354	6	7	7
240	1400	7	7	16
240	1440	7	7	13
240	1480	7	7	9
240	1507	8	9	9
280	1015	6	6	9
280	1040	6	6	13
280	1080	7	8	11
280	1120	6	7	7
280	1160	7	7	7
280	1200	6	6	8
280	1240	7	8	15
280	1280	7	7	14
280	1320	7	8	13
280	1360	6	7	7
280	1400	7	6	19
280	1440	6	6	6
280	1480	7	7	7
280	1507	8	8	8
320	1040	8	8	19
320	1080	8	8	27
320	1120	8	8	42
320	1160	7	7	7
320	1200	7	7	12
320	1240	6	7	7
320	1280	6	6	11
320	1320	6	7	7
320	1360	7	7	16
320	1400	7	7	9
320	1440	7	7	10
320	1480	7	8	16
320	1507	8	9	9
360	1040	8	8	41
360	1080	7	7	7
360	1120	7	8	22
360	1160	7	7	7

TABLE 2, cont.

DIRECT RADIATION LEVELS MEASURED
AT 40 M GRID INTERVALS

Grid Location N	Grid Location E	Gamma Exposure Rates at 1 m Above the Surface (μR/h)	Gamma Exposure Rates at the Surface (μR/h)	Beta-Gamma Dose Rates at 1 cm Above the Surface (μrad/h)
360	1200	7	7	21
360	1240	6	6	6
360	1280	6	7	7
360	1320	7	7	7
360	1360	7	8	22
352	1400	6	7	17
360	1440	8	8	24
360	1480	6	6	6
360	1507	8	8	21
400	1040	7	7	7
400	1080	7	9	18
400	1120	8	8	16
400	1160	7	8	17
400	1200	7	8	13
400	1240	7	7	15
400	1280	6	7	7
400	1320	7	7	18
400	1360	7	7	7
400	1400	7	7	18
400	1440	7	8	14
427	1480	10	14	33
400	1507	9	9	10
440	1040	8	8	44
440	1080	7	8	19
440	1120	8	8	21
440	1160	8	8	14
440	1200	7	8	9
440	1240	8	8	21
440	1280	6	7	13
440	1320	6	6	9
440	1360	6	7	7
440	1400	4	5	5
440	1440	5	5	5
440	1480	5	6	6
440	1507	9	8	8
480	1040	8	8	25
480	1080	7	8	16
480	1120	8	9	25

TABLE 2, cont.

DIRECT RADIATION LEVELS MEASURED
AT 40 M GRID INTERVALS

Grid Location N	Grid Location E	Gamma Exposure Rates at 1 m Above the Surface (μR/h)	Gamma Exposure Rates at the Surface (μR/h)	Beta-Gamma Dose Rates at 1 cm Above the Surface (μrad/h)
480	1160	8	8	24
480	1200	8	8	28
480	1240	7	8	12
480	1280	6	7	7
480	1320	6	7	7
480	1360	6	7	17
480	1400	4	4	14
480	1440	6	5	7
480	1480	6	7	7
480	1507	7	8	8
520	1040	8	8	12
520	1080	8	8	10
520	1120	8	8	9
520	1160	7	8	16
520	1200	7	7	7
520	1240	8	7	7
520	1280	7	7	7
520	1320	6	7	8
520	1360	7	7	9
520	1400	4	5	9
520	1440	5	5	5
520	1480	7	8	8
520	1507	7	8	8
540	1040	8	8	25
540	1080	7	8	11
540	1120	7	8	8
540	1160	7	8	14
540	1200	7	8	19
540	1240	7	8	11
540	1280	7	7	7
540	1320	7	6	6
540	1360	6	6	10
540	1400	7	7	7
540	1440	9	9	15
540	1480	6	7	17
540	1507	7	7	7

TABLE 3

DIRECT RADIATION LEVELS AT LOCATIONS
IDENTIFIED BY THE WALKOVER SURFACE SCAN

Grid Location[a] N	Grid Location[a] E	Exposure Rate (μR/h) Contact	Exposure Rate (μR/h) 1 m Above Surface	Surface Dose Rate (μrad/h)	Sample Identification[b]	Contact Exposure Rate After Sample Removal (μR/h)
339-342	1489-1493	14-28	---[c]	---	---	---
341	1492	28	17	29	B1	67
394-400	1462-1466	12-67	---	---	---	---
398	1465	67	20	160	B2	110
397	1503	130	27	390	B3	160
412	1465	190	40	450	B4	310
420	1464	50	22	290	B5	30
422	1493	130	---	---	---	---
423	1464	33	17	400	B6	29
425	1498	67	17	1350	B7	67
426	1465	39	17	75	---	---
426	1481	31	12	74	B8	67

[a] Refer to Figure 7.
[b] Radionuclide analyses of samples presented in Table 5.
[c] Dash indicates measurement or sampling not performed.

TABLE 4

RADIONUCLIDE CONCENTRATIONS IN SURFACE SOIL SAMPLES
FROM 40 M GRID INTERVALS

Grid Location[a]		Radionuclide Concentrations (pCi/g)				
N	E	Ra-226	U-235	U-238	Cs-137	Th-232
40	1016	1.13 ± 0.24	<0.20	1.43 ± 1.28	<0.04	0.63 ± 0.32
40	1040	0.80 ± 0.22	<0.29	<4.51	<0.04	1.07 ± 0.37
40	1080	0.79 ± 0.23	<0.14	0.95 ± 0.45	0.03 ± 0.30	0.82 ± 0.30
40	1120	0.75 ± 0.24	<0.18	0.30 ± 0.48	0.90 ± 0.07	0.91 ± 0.35
40	1160	2.71 ± 0.29	<0.17	0.82 ± 0.98	0.05 ± 0.04	0.78 ± 0.35
40	1200	0.81 ± 0.23	<0.24	1.09 ± 1.48	0.06 ± 0.08	0.92 ± 0.38
40	1240	0.79 ± 0.24	<0.20	1.88 ± 1.30	0.07 ± 0.06	0.86 ± 0.67
40	1280	0.79 ± 0.26	<0.20	1.91 ± 1.45	0.15 ± 0.10	0.87 ± 0.37
40	1320	0.81 ± 0.24	<0.27	<0.85	<0.03	1.07 ± 0.30
40	1360	1.03 ± 0.33	<0.28	1.61 ± 0.90	<0.04	1.11 ± 0.37
40	1400	1.21 ± 0.30	<0.35	<1.14	<0.07	1.09 ± 0.47
40	1440	1.06 ± 0.31	<0.21	<0.79	0.67 ± 0.14	0.64 ± 0.36
40	1480	0.68 ± 0.25	<0.23	1.35 ± 1.61	0.67 ± 0.15	0.86 ± 0.57
40	1507	0.65 ± 0.18	<0.14	<0.38	0.36 ± 0.10	0.74 ± 0.30
80	1015	1.69 ± 0.26	<0.23	0.92 ± 0.69	0.15 ± 0.06	0.50 ± 0.23
80	1040	0.84 ± 0.19	<0.13	0.61 ± 0.68	0.26 ± 0.10	1.01 ± 0.39
80	1080	0.95 ± 0.30	<0.22	1.38 ± 1.78	0.73 ± 0.15	0.78 ± 0.34
80	1120	0.74 ± 0.21	<0.14	0.30 ± 1.27	0.04 ± 0.03	0.65 ± 0.35
80	1160	1.29 ± 0.35	<0.20	1.18 ± 0.91	0.64 ± 0.14	1.68 ± 0.45
80	1200	0.70 ± 0.24	<0.15	1.68 ± 0.62	0.49 ± 0.12	0.70 ± 0.29
80	1240	0.29 ± 0.25	<0.23	<0.76	<0.10	0.43 ± 0.23
80	1280	0.95 ± 0.28	<0.30	0.88 ± 1.97	0.52 ± 0.12	1.22 ± 0.46
80	1320	1.01 ± 0.24	0.14 ± 0.67	1.03 ± 0.63	0.28 ± 0.10	0.95 ± 0.56
80	1360	0.63 ± 0.23	<0.28	<0.90	0.36 ± 0.10	0.80 ± 0.38
80	1400	0.76 ± 0.36	<0.22	<0.69	0.28 ± 0.14	0.88 ± 0.55
80	1440	0.69 ± 0.31	<0.19	<0.77	0.52 ± 0.14	0.49 ± 0.44
80	1480	0.91 ± 0.23	<0.32	1.50 ± 1.06	0.53 ± 0.14	1.23 ± 0.42
80	1507	0.96 ± 0.29	<0.29	<0.99	0.21 ± 0.11	1.64 ± 0.58
120	1015	1.23 ± 0.30	<0.26	<0.77	0.19 ± 0.05	0.85 ± 0.28
120	1040	0.88 ± 0.26	<0.27	3.24 ± 1.87	0.08 ± 0.09	0.83 ± 0.25

TABLE 4, cont.

RADIONUCLIDE CONCENTRATIONS IN SURFACE SOIL SAMPLES
FROM 40 M GRID INTERVALS

Grid Location		Radionuclide Concentrations (pCi/g)				
N	E	Ra-226	U-235	U-238	Cs-137	Th-232
120	1080	0.73 ± 0.21	<0.29	1.86 ± 2.99	0.62 ± 0.12	0.96 ± 0.40
120	1120	0.81 ± 0.20	<0.24	0.96 ± 1.75	0.58 ± 0.11	1.05 ± 0.40
120	1160	1.10 ± 0.26	<0.24	0.54 ± 1.71	0.51 ± 0.13	0.66 ± 0.51
120	1200	0.66 ± 0.19	<0.30	<0.89	0.80 ± 0.16	0.90 ± 0.30
120	1240	0.85 ± 0.24	<0.17	1.23 ± 0.56	0.67 ± 0.15	0.77 ± 0.55
120	1280	0.63 ± 0.25	<0.14	1.11 ± 0.43	<0.02	0.67 ± 0.36
120	1320	0.61 ± 0.34	<0.20	<0.73	0.57 ± 0.12	0.75 ± 0.56
120	1360	0.83 ± 0.21	<0.14	0.94 ± 0.73	0.21 ± 0.07	1.03 ± 0.40
120	1400	0.65 ± 0.21	<0.33	<1.04	0.89 ± 0.15	1.13 ± 0.43
120	1440	1.00 ± 0.26	<0.18	0.35 ± 1.95	0.77 ± 0.16	0.87 ± 0.36
120	1480	0.64 ± 0.30	<0.17	0.58 ± 0.94	0.43 ± 0.13	0.59 ± 0.55
120	1507	0.74 ± 0.29	<0.28	<0.91	0.37 ± 0.09	0.81 ± 0.40
160	1015	1.06 ± 0.23	<0.19	0.72 ± 1.20	0.14 ± 0.08	0.46 ± 0.21
160	1040	0.60 ± 0.24	<0.24	<0.69	<0.04	0.97 ± 0.29
160	1080	0.78 ± 0.28	<0.20	1.58 ± 0.80	0.75 ± 0.14	0.74 ± 0.28
160	1120	0.76 ± 0.24	<0.17	1.36 ± 0.81	0.64 ± 0.11	0.66 ± 0.32
160	1160	0.65 ± 0.24	<0.23	<0.71	0.41 ± 0.12	0.61 ± 0.27
160	1200	0.91 ± 0.33	<0.24	<0.77	0.74 ± 0.15	0.79 ± 0.55
160	1240	0.74 ± 0.28	<0.18	<0.44	0.48 ± 0.13	0.95 ± 0.45
160	1280	1.15 ± 0.24	<0.16	<0.53	0.60 ± 0.13	0.74 ± 0.26
160	1320	0.94 ± 0.26	<0.17	0.74 ± 0.92	0.96 ± 0.17	0.47 ± 0.42
160	1360	0.79 ± 0.30	<0.22	0.79 ± 2.48	0.36 ± 0.09	0.87 ± 0.36
160	1400	0.76 ± 0.19	0.58 ± 0.49	1.04 ± 2.56	0.50 ± 0.12	0.97 ± 0.56
160	1440	1.14 ± 0.24	<0.18	1.42 ± 0.67	0.96 ± 0.17	1.56 ± 0.66
160	1480	1.13 ± 0.19	<0.17	1.02 ± 0.95	0.66 ± 0.10	0.88 ± 0.29
160	1507	0.84 ± 0.23	<0.25	1.43 ± 1.71	0.31 ± 0.12	0.72 ± 0.38
200	1015	0.80 ± 0.16	<0.10	0.45 ± 0.63	0.09 ± 0.07	0.52 ± 0.20
200	1040	1.15 ± 0.26	<0.27	1.44 ± 1.68	0.20 ± 0.08	0.97 ± 0.32
200	1080	0.80 ± 0.25	<0.21	0.71 ± 1.74	0.63 ± 0.11	0.87 ± 0.50
200	1120	0.80 ± 0.20	<0.15	0.74 ± 0.52	0.60 ± 0.12	0.70 ± 0.32

TABLE 4, cont.

RADIONUCLIDE CONCENTRATIONS IN SURFACE SOIL SAMPLES
FROM 40 M GRID INTERVALS

Grid Location		Radionuclide Concentrations (pCi/g)				
N	E	Ra-226	U-235	U-238	Cs-137	Th-232
200	1160	0.96 ± 0.34	<0.21	0.95 ± 1.31	0.53 ± 0.21	0.70 ± 0.42
200	1200	1.09 ± 0.24	<0.30	1.68 ± 1.76	0.59 ± 0.12	1.05 ± 0.44
200	1240	1.10 ± 0.33	<0.35	2.25 ± 2.34	0.60 ± 0.14	1.21 ± 0.49
200	1280	0.64 ± 0.40	<0.16	1.48 ± 0.58	0.49 ± 0.12	1.00 ± 0.33
200	1320	0.78 ± 0.28	<0.23	1.27 ± 1.38	0.57 ± 0.12	0.86 ± 0.51
200	1360	0.51 ± 0.19	<0.20	0.53 ± 0.72	0.41 ± 0.13	0.60 ± 0.27
200	1400	0.89 ± 0.25	<0.18	1.46 ± 1.00	0.76 ± 0.15	0.88 ± 0.66
204	1440	1.09 ± 0.26	<0.15	1.43 ± 0.95	0.43 ± 0.12	0.67 ± 0.27
200	1480	b	b	b	b	b
200	1507	0.86 ± 0.30	<0.15	1.22 ± 0.91	0.73 ± 0.16	1.15 ± 0.46
240	1015	0.84 ± 0.26	<0.16	1.68 ± 1.19	0.19 ± 0.09	0.76 ± 0.30
240	1040	0.75 ± 0.20	<0.19	1.53 ± 1.59	0.14 ± 0.06	0.53 ± 0.57
240	1080	0.84 ± 0.24	<0.20	<0.73	0.24 ± 0.13	0.88 ± 0.35
240	1120	0.56 ± 0.19	<0.19	0.65 ± 1.24	0.46 ± 0.13	0.41 ± 0.27
240	1160	0.83 ± 0.33	<0.32	1.69 ± 1.84	0.59 ± 0.13	0.42 ± 0.27
240	1200	0.69 ± 0.30	<0.26	<0.97	0.72 ± 0.16	1.07 ± 0.69
240	1240	0.91 ± 0.28	<0.22	0.84 ± 1.88	0.63 ± 0.13	0.72 ± 0.48
240	1280	0.76 ± 0.28	<0.27	1.68 ± 1.74	0.66 ± 0.22	0.90 ± 0.53
240	1320	0.85 ± 0.34	<0.36	0.77 ± 1.94	0.77 ± 0.15	0.54 ± 0.27
240	1360	1.00 ± 0.26	<0.13	1.66 ± 0.49	0.42 ± 0.11	1.08 ± 0.34
240	1400	0.68 ± 0.29	<0.34	2.27 ± 2.19	0.75 ± 0.15	1.00 ± 0.44
240	1440	0.83 ± 0.23	<0.22	<0.72	0.45 ± 0.11	0.62 ± 0.49
240	1480	0.70 ± 0.21	<0.22	1.14 ± 1.24	0.20 ± 0.07	0.81 ± 0.35
240	1507	0.49 ± 0.25	<0.22	1.05 ± 1.67	0.35 ± 0.14	1.55 ± 0.45
280	1017	1.11 ± 0.29	<0.18	1.23 ± 1.42	0.64 ± 0.15	0.53 ± 0.23
280	1040	1.29 ± 0.25	<0.30	<0.96	0.75 ± 0.16	1.38 ± 0.36
280	1080	0.70 ± 0.15	<0.13	0.82 ± 0.65	0.07 ± 0.06	0.78 ± 0.33
280	1120	0.85 ± 0.26	<0.21	0.82 ± 1.20	0.27 ± 0.13	0.64 ± 0.46
280	1160	0.75 ± 0.20	0.23 ± 0.30	1.09 ± 0.80	<0.04	0.88 ± 0.28
280	1200	0.68 ± 0.16	<0.23	<0.80	0.29 ± 0.09	0.63 ± 0.36

TABLE 4, cont.

RADIONUCLIDE CONCENTRATIONS IN SURFACE SOIL SAMPLES
FROM 40 M GRID INTERVALS

Grid Location		Radionuclide Concentrations (pCi/g)				
N	E	Ra-226	U-235	U-238	Cs-137	Th-232
280	1240	0.95 ± 0.15	<0.27	1.36 ± 0.74	0.25 ± 0.12	1.31 ± 0.39
280	1280	1.48 ± 0.33	<0.31	1.61 ± 1.87	0.41 ± 0.12	0.75 ± 0.55
280	1320	1.03 ± 0.23	<0.19	0.75 ± 1.46	0.51 ± 0.11	0.72 ± 0.37
280	1360	b	b	b	b	b
280	1400	0.98 ± 0.23	<0.30	1.71 ± 1.37	0.71 ± 0.13	1.24 ± 0.44
280	1440	1.03 ± 0.24	<0.27	3.09 ± 2.02	0.21 ± 0.11	0.76 ± 0.29
280	1480	0.83 ± 0.35	<0.23	<0.75	0.57 ± 0.15	0.96 ± 0.39
280	1510	0.94 ± 0.23	<0.27	<0.90	0.29 ± 0.15	0.70 ± 0.24
320	1015	b	b	b	b	b
320	1040	0.81 ± 0.28	<0.19	<0.81	0.51 ± 0.13	0.74 ± 0.38
320	1080	0.86 ± 0.33	<0.19	1.54 ± 1.12	0.04 ± 0.04	0.69 ± 0.46
320	1120	0.86 ± 0.20	<0.20	<0.66	0.38 ± 0.11	0.63 ± 0.46
320	1160	1.19 ± 0.35	<0.19	<0.66	0.06 ± 0.05	0.81 ± 0.44
320	1200	0.70 ± 0.26	<0.35	1.48 ± 2.11	0.68 ± 0.14	0.99 ± 0.39
320	1240	1.35 ± 0.33	<0.42	2.61 ± 1.18	0.86 ± 0.16	1.30 ± 0.52
320	1280	0.73 ± 0.25	<0.16	<0.65	0.59 ± 0.13	0.58 ± 0.57
320	1320	0.70 ± 0.16	<0.27	<0.86	0.74 ± 0.14	0.95 ± 0.37
320	1360	0.71 ± 0.23	<0.22	<0.69	0.58 ± 0.12	1.04 ± 0.30
320	1400	0.80 ± 0.28	<0.19	<0.68	0.73 ± 0.17	0.51 ± 0.39
320	1440	0.80 ± 0.26	<0.23	1.12 ± 1.52	0.47 ± 0.14	0.57 ± 0.28
320	1482	1.13 ± 0.31	<0.24	<0.78	0.69 ± 0.16	1.13 ± 0.51
320	1510	2.39 ± 0.43	<0.30	1.78 ± 2.13	1.05 ± 0.18	1.29 ± 0.42
360	1015	b	b	b	b	b
360	1040	0.46 ± 0.20	<0.15	<0.69	0.24 ± 0.10	0.56 ± 0.44
360	1080	0.80 ± 0.21	<0.22	0.99 ± 0.18	0.40 ± 0.10	0.54 ± 0.30
360	1120	0.80 ± 0.23	<0.27	2.58 ± 1.10	0.42 ± 0.11	1.12 ± 0.33
360	1160	0.80 ± 0.31	<0.17	1.08 ± 1.42	0.23 ± 0.13	0.83 ± 0.35
360	1200	0.44 ± 0.18	<0.21	1.66 ± 0.70	0.54 ± 0.14	0.35 ± 0.41
360	1240	0.81 ± 0.21	<0.28	3.52 ± 1.56	<0.03	0.76 ± 0.60
360	1280	0.83 ± 0.25	<0.38	<0.88	0.72 ± 0.12	0.76 ± 0.35

TABLE 4, cont.

RADIONUCLIDE CONCENTRATIONS IN SURFACE SOIL SAMPLES
FROM 40 M GRID INTERVALS

Grid Location		Radionuclide Concentrations (pCi/g)				
N	E	Ra-226	U-235	U-238	Cs-137	Th-232
360	1320	0.93 ± 0.36	<0.23	1.43 ± 1.03	0.77 ± 0.17	0.65 ± 0.38
360	1360	0.73 ± 0.31	<0.21	0.80 ± 1.84	0.96 ± 0.15	0.56 ± 0.38
360	1400	0.83 ± 0.31	<0.24	<0.76	0.88 ± 0.17	1.08 ± 0.46
360	1440	1.91 ± 0.49	<0.29	4.99 ± 1.91	1.69 ± 0.26	1.03 ± 0.58
360	1480	b	b	b	b	b
360	1510	1.14 ± 0.30	<0.34	<0.97	0.64 ± 0.15	0.82 ± 0.69
400	1015	b	b	b	b	b
400	1040	0.79 ± 0.28	<0.33	<1.11	0.83 ± 0.15	1.14 ± 0.41
400	1080	1.08 ± 0.26	<0.30	3.37 ± 1.73	0.32 ± 0.13	0.94 ± 0.35
400	1120	0.70 ± 0.19	<0.20	<0.74	0.22 ± 0.07	0.78 ± 0.34
400	1160	0.76 ± 0.19	<0.26	<0.93	0.13 ± 0.05	0.99 ± 0.38
400	1200	0.68 ± 0.28	<0.20	<0.75	0.29 ± 0.11	0.60 ± 0.59
400	1240	0.68 ± 0.29	<0.20	1.43 ± 0.94	0.47 ± 0.11	0.84 ± 0.51
400	1280	0.64 ± 0.16	<0.14	0.60 ± 0.66	0.55 ± 0.11	0.80 ± 0.28
400	1320	0.73 ± 0.19	<0.17	0.45 ± 1.36	0.73 ± 0.13	0.76 ± 0.45
400	1360	0.93 ± 0.23	<0.18	1.08 ± 0.57	0.68 ± 0.13	0.63 ± 0.41
400	1400	b	b	b	b	b
400	1440	1.21 ± 0.35	<0.19	1.43 ± 1.55	0.58 ± 0.12	0.78 ± 0.31
400	1480	b	b	b	b	b
400	1510	1.64 ± 0.30	<0.20	1.23 ± 0.98	0.87 ± 0.14	1.26 ± 0.38
440	1015	b	b	b	b	b
440	1040	0.90 ± 0.26	<0.24	0.63 ± 1.65	0.21 ± 0.11	0.67 ± 0.65
440	1080	1.10 ± 0.29	<0.31	2.13 ± 1.52	0.23 ± 0.10	1.26 ± 0.32
440	1120	0.82 ± 0.35	<0.22	2.50 ± 1.88	0.24 ± 0.13	0.72 ± 0.42
440	1160	0.76 ± 0.30	<0.21	1.68 ± 2.66	0.35 ± 0.14	0.52 ± 0.36
440	1200	0.76 ± 0.25	0.30 ± 0.61	<0.74	0.65 ± 0.15	0.68 ± 0.36
440	1240	0.59 ± 0.25	<0.19	<0.56	0.02 ± 0.03	0.68 ± 0.33
440	1280	0.94 ± 0.33	<0.22	1.60 ± 1.44	1.15 ± 0.20	0.64 ± 0.34
440	1320	0.60 ± 0.33	<0.21	<0.82	0.95 ± 0.19	0.34 ± 0.26
440	1360	0.89 ± 0.27	<0.18	1.22 ± 0.98	0.88 ± 0.14	<0.29

TABLE 4, cont.

RADIONUCLIDE CONCENTRATIONS IN SURFACE SOIL SAMPLES
FROM 40 M GRID INTERVALS

Grid Location		Radionuclide Concentrations (pCi/g)				
N	E	Ra-226	U-235	U-238	Cs-137	Th-232
440	1400	0.55 ± 0.20	<0.16	<0.47	0.74 ± 0.12	0.34 ± 0.20
437	1440	0.64 ± 0.28	<0.15	<0.42	0.11 ± 0.06	0.24 ± 0.24
429	1468	3.43 ± 0.37	<0.27	<0.84	0.10 ± 0.09	0.53 ± 0.33
440	1510	0.88 ± 0.22	<0.17	0.68 ± 1.04	0.59 ± 0.12	1.11 ± 0.32
480	1015	b	b	b	b	b
480	1040	0.73 ± 0.24	<0.18	1.58 ± 1.68	<0.04	0.84 ± 0.17
480	1080	0.49 ± 0.36	<0.22	<0.88	0.35 ± 0.10	1.01 ± 0.37
480	1120	0.72 ± 0.28	<0.20	<0.93	0.34 ± 0.12	0.98 ± 0.39
480	1160	0.89 ± 0.21	<0.28	1.61 ± 0.89	0.46 ± 0.12	1.49 ± 0.42
480	1200	0.88 ± 0.26	<0.28	<0.85	0.28 ± 0.12	0.92 ± 0.15
480	1240	1.00 ± 0.28	0.24 ± 0.11	3.55 ± 1.35	0.78 ± 0.16	1.34 ± 0.34
480	1280	0.74 ± 0.21	<0.24	<0.71	0.54 ± 0.16	0.75 ± 0.34
480	1320	0.94 ± 0.29	0.56 ± 0.51	0.94 ± 1.63	0.98 ± 0.17	<0.28
480	1360	0.84 ± 0.22	<0.20	1.00 ± 2.58	0.42 ± 0.13	1.22 ± 0.39
480	1400	0.46 ± 0.13	0.06 ± 0.33	0.58 ± 0.34	0.03 ± 0.02	<0.08
480	1442	0.98 ± 0.30	<0.27	<0.86	0.45 ± 0.12	0.98 ± 0.38
480	1480	1.07 ± 0.31	<0.21	0.44 ± 1.30	0.28 ± 0.13	1.22 ± 0.47
480	1510	1.39 ± 0.41	<0.29	1.10 ± 1.00	1.64 ± 0.24	1.37 ± 0.76
520	1015	b	b	b	b	b
520	1040	0.06 ± 0.25	<0.16	<0.78	0.09 ± 0.08	0.78 ± 0.34
520	1080	0.79 ± 0.26	<0.21	<0.76	0.24 ± 0.09	0.80 ± 0.29
520	1120	0.71 ± 0.23	<0.16	<0.70	0.19 ± 0.07	<0.24
520	1160	0.71 ± 0.21	<0.19	1.20 ± 2.00	0.27 ± 0.09	0.69 ± 0.24
520	1200	0.58 ± 0.23	<0.23	<0.72	0.27 ± 0.10	0.44 ± 0.35
520	1240	0.83 ± 0.26	0.37 ± 0.47	1.75 ± 1.80	0.29 ± 0.12	0.62 ± 0.27
520	1280	0.88 ± 0.23	<0.17	0.49 ± 1.09	0.58 ± 0.13	0.65 ± 0.33
520	1320	1.29 ± 0.33	<0.36	3.64 ± 1.56	0.85 ± 0.14	1.06 ± 0.32
520	1360	0.44 ± 0.27	<0.29	1.76 ± 1.67	0.62 ± 0.14	0.78 ± 0.41

TABLE 4. cont.

RADIONUCLIDE CONCENTRATIONS IN SURFACE SOIL SAMPLES
FROM 40 M GRID INTERVALS

Grid Location		Radionuclide Concentrations (pCi/g)				
N	E	Ra-226	U-235	U-238	Cs-137	Th-232
520	1400	0.40 ± 0.17	<0.08	0.42 ± 0.39	<0.02	<0.09
518	1441	0.96 ± 0.23	<0.27	<0.80	0.35 ± 0.10	0.73 ± 0.47
520	1480	0.76 ± 0.26	<0.16	0.67 ± 0.86	0.58 ± 0.12	1.06 ± 0.35
520	1510	0.94 ± 0.25	<0.31	1.67 ± 2.37	0.28 ± 0.07	0.92 ± 0.34

[a] Errors are 2σ based on counting statistics.
[b] Sample not obtained.

TABLE 5

RADIONUCLIDE CONCENTRATIONS IN SURFACE SAMPLES
FROM LOCATIONS IDENTIFIED BY THE WALKOVER SCAN

Sample Identification	Grid Location N	Grid Location E	Radionuclide Concentrations (pCi/g)[a] Ra-226	U-235	U-238	Cs-137	Th-232
B1	341	1492	9.53 ± 0.58[b]	0.40 ± 0.57	5.78 ± 0.92	0.11 ± 0.05	<0.17
B2	398	1465	69.5 ± 1.6	2.92 ± 2.09	7.63 ± 4.87	0.37 ± 0.14	<0.54
B3	397	1503	828 ± 8	26.2 ± 8.4	156 ± 16	<0.70	<2.59
B4	412	1465	324 ± 4	8.90 ± 3.24	<29.9	1.25 ± 0.97	<0.93
B5	420	1464	90.5 ± 3.1	<1.66	<3.92	0.09 ± 0.16	<0.94
B6	423	1464	63.6 ± 2.5	<1.38	<3.17	0.23 ± 0.18	<0.69
B7	425	1498	231 ± 4	4.07 ± 3.79	15.2 ± 9.2	<0.26	1.93 ± 1.75
B8	426	1481	89.6 ± 2.3	2.50 ± 2.48	3.78 ± 5.64	0.74 ± 0.11	<0.57

[a] Refer to Table 3 for direct radiation levels.
[b] Errors are 2σ based on counting statistics.

TABLE 6

RADIONUCLIDE CONCENTRATIONS IN BOREHOLE SOIL SAMPLES

Borehole No.[a]	Grid Location N	Grid Location E	Depth (m)	Radionculide Concentrations (pCi/g) Ra-226	U-235	U-238	Cs-137	Th-232
H1	30	1280	Surface	0.89 ± 0.20[b]	<0.23	3.47 ± 1.42	<0.03	0.60 ± 0.20
			0.5	1.05 ± 0.24	<0.13	0.80 ± 0.73	<0.03	0.82 ± 0.34
			1.2	3.03 ± 0.35	<0.35	6.69 ± 1.96	<0.04	1.14 ± 0.35
			2.0	1.01 ± 0.23	<0.22	<0.83	<0.04	1.12 ± 0.59
H2	30	1080	Surface	1.08 ± 0.19	<0.25	1.26 ± 1.12	<0.03	0.60 ± 0.20
			0.5	0.98 ± 0.24	<0.14	0.93 ± 0.95	<0.03	0.95 ± 0.32
			1.0	0.81 ± 0.28	<0.16	0.86 ± 1.37	<0.03	0.92 ± 0.29
H3	50	1020	Surface	0.98 ± 0.29	<0.25	3.14 ± 1.88	0.17 ± 0.09	1.11 ± 0.33
			0.5	1.08 ± 0.23	<0.17	1.56 ± 0.74	<0.03	1.06 ± 0.38
			2	0.71 ± 0.26	<0.19	0.88 ± 1.97	<0.04	0.87 ± 0.32
H4	200	1020	Surface	0.65 ± 0.18	<0.11	0.72 ± 0.61	0.14 ± 0.07	0.72 ± 0.61
			0.5	0.78 ± 0.23	<0.17	1.08 ± 0.71	0.06 ± 0.04	0.77 ± 0.35
			1	0.61 ± 0.15	<0.22	<0.71	<0.03	0.89 ± 0.31
H5	287	1240	Surface	1.16 ± 0.26	<0.20	1.56 ± 0.78	0.13 ± 0.09	0.80 ± 0.29
			0.5	1.06 ± 0.33	<0.21	1.35 ± 1.32	<0.04	0.80 ± 0.42
			1	1.18 ± 0.34	<0.34	8.03 ± 2.44	<0.05	1.14 ± 0.50
H6	287	1400	Surface	0.61 ± 0.19	<0.12	0.67 ± 0.77	0.22 ± 0.05	0.75 ± 0.24
			0.5	0.85 ± 0.29	<0.19	1.77 ± 0.95	<0.03	0.84 ± 0.36
			2	0.81 ± 0.20	<0.15	0.72 ± 0.72	0.04 ± 0.07	0.94 ± 0.26
H7	330	1470	Surface	0.93 ± 0.24	<0.18	0.98 ± 1.03	0.32 ± 0.11	0.58 ± 0.34
			0.5	0.75 ± 0.18	<0.24	2.17 ± 1.84	0.22 ± 0.08	0.61 ± 0.38
			1	1.21 ± 0.33	<0.36	2.45 ± 3.22	<0.05	1.34 ± 0.36

TABLE 6, cont.

RADIONUCLIDE CONCENTRATIONS IN BOREHOLE SOIL SAMPLES

Borehole No.	Grid Location N	Grid Location E	Depth (m)	Radionculide Concentrations (pCi/g) Ra-226	U-235	U-238	Cs-137	Th-232
H8	400	1015	Surface	0.73 ± 0.23	<0.10	0.53 ± 0.63	0.08 ± 0.06	0.74 ± 0.32
			0.5	1.35 ± 0.29	<0.17	0.87 ± 1.92	<0.03	1.31 ± 0.39
			1	1.03 ± 0.30	<0.31	<0.92	<0.04	1.03 ± 0.54
H9	430	1445	Surface	1.51 ± 0.29	<0.30	5.12 ± 1.43	0.51 ± 0.13	1.16 ± 0.39
			0.5	0.24 ± 0.21	<0.13	<0.37	<0.02	0.71 ± 0.30
			2	0.73 ± 0.21	0.28 ± 0.33	0.44 ± 1.46	<0.03	0.85 ± 0.29
H10	525	1015	Surface	0.86 ± 0.25	<0.26	1.19 ± 1.29	0.33 ± 0.09	0.72 ± 0.26
			0.5	1.75 ± 0.25	<0.16	1.67 ± 0.51	<0.03	0.74 ± 0.30
			1	1.99 ± 0.34	1.62 ± 0.51	1.39 ± 1.36	<0.03	0.91 ± 0.31
			2	0.91 ± 0.23	<0.25	0.89 ± 0.93	<0.04	1.06 ± 0.41
H11	536	1240	Surface	0.69 ± 0.20	<0.13	0.63 ± 1.09	0.13 ± 0.05	0.57 ± 0.33
			0.5	1.35 ± 0.30	<0.30	<0.91	<0.05	1.04 ± 0.32
			2	0.71 ± 0.23	<0.11	0.73 ± 0.65	<0.02	0.89 ± 0.23
H12	537	1463	Surface	0.63 ± 0.25	<0.20	0.83 ± 0.66	0.27 ± 0.08	0.57 ± 0.36
			0.5	0.78 ± 0.20	<0.14	0.64 ± 0.43	<0.03	0.88 ± 0.41
			1	0.93 ± 0.26	<0.19	<0.69	<0.04	1.09 ± 0.37
H13	426	1478	Surface	57.4 ± 1.4	1.81 ± 1.26	<1.10	<0.10	<0.40
			0.15	9.74 ± 0.69	<0.37	<1.04	<0.06	0.38 ± 0.45
			0.5	0.93 ± 0.18	<0.23	1.05 ± 1.62	<0.03	0.80 ± 0.29

[a] Refer to Figure 4.
[b] Errors are 2σ based on counting statistics.

TABLE 7

RADIONUCLIDE CONCENTRATIONS IN WATER SAMPLES

Sample Identification	Sample Type	Grid Location N	Grid Location E	Radionculide Concentrations (pCi/1) Gross Alpha	Radionculide Concentrations (pCi/1) Gross Beta
W1	Subsurface (Borehole H1)[a]	30	1280	3.94 ± 1.21[b]	2.87 ± 0.93
W2	Subsurface (Borehole H2)[a]	32	1080	6.50 ± 2.13	4.71 ± 1.64
W3	Subsurface (Borehole H6)[a]	287	1400	4.85 ± 2.33	3.62 ± 2.00
W4	Subsurface (Borehole H7)[a]	330	1470	8.15 ± 2.33	9.99 ± 2.38
W5	Subsurface (Borehole H10)[a]	525	1015	3.12 ± 2.00	5.99 ± 2.21
W6	Subsurface (Borehole H13)[a]	537	1463	1.72 ± 1.61	3.37 ± 1.53

[a] Refer to Figure 4.
[b] Errors are 2σ based on counting statistics.

TABLE 8

SUMMARY OF WAREHOUSE SURVEY RESULTS

Room[a]	Surface	SURFACE CONTAMINATION LEVELS					Gamma Exposure Rates at 1 Meter Above Floor (μR/h)
		Direct Measurement			Transferable		
		Alpha (dpm/100 cm^2)	Beta-Gamma (dpm/100 cm^2)	Beta-Gamma Dose Rate (mrad/h)	Alpha (dpm/100 cm^2)	Beta-Gamma (dpm/100 cm^2)	
1	Floor	<39-11700	<350-63400	<0.01-1.54	0-4	<3-7	10-13
	Lower Walls	<39-310	<350-4440	<0.01-0.11	0-44	<3-24	
	Upper Walls & Ceilings	<39-5060	<350-19300	<0.01-0.47	0-34	<3-13	
2	Floor	<39-18700	<350-135000	<0.01-3.28	0-33	<3-31	6-13
	Lower Walls	<39-440	<350-3910	<0.01-0.09	0-7	<3-12	
	Upper Walls & Ceilings	<39-7040	<350-14600	<0.01-0.35	0-70	<3-48	
3	Floor	<39-2390	<350-17300	<0.01-0.42	0-7	<3-16	8-14
	Lower Walls	<39-520	<350-7140	<0.01-0.17	0-7	<3-7	
	Upper Walls & Ceilings	<39-1380	<350-3410	<0.01-0.08	0-19	<3-18	
4	Floor	<39-750	<350-1210	<0.01-0.03	0-6	<3-6	6-8
	Lower Walls	<39-230	<350-1380	<0.01-0.03	0-3	<3-7	
	Upper Walls & Ceilings	<39-130	<350-1530	<0.01-0.04	0-4	<3-7	
5	Floor	<39-260	<350-1180	<0.01-0.03	0-2	<3-6	6-8
	Lower Walls	---[b]	---	---	---	---	
	Upper Walls & Ceilings	<39-440	<350-1970	<0.01-0.05	0-4	<3-7	
6	Floor	180-390	760-1290	0.02-0.03	0-3	<3	8-14
	Lower Walls	<39-150	1130-1911	0.03-0.05	0-2	<3	
	Upper Walls & Ceilings	<39-100	<350-2380	<0.01-0.06	0-3	<3	

TABLE 8, cont.

SUMMARY OF WAREHOUSE SURVEY RESULTS

Room	Surface	SURFACE CONTAMINATION LEVELS					Gamma Exposure Rates at 1 Meter Above Floor (μR/h)
		Direct Measurement			Transferable		
		Alpha	Beta-Gamma	Beta-Gamma Dose Rate	Alpha	Beta-Gamma	
		(dpm/100 cm^2)		(mrad/h)	(dpm/100 cm^2)		
7	Floor	260-500	790-1440	0.02-0.03	0-4	<3	8-14
	Lower Walls	<39-150	760-1940	0.02-0.05	0-4	<3	
	Upper Walls & Ceiling	<39-100	560-1970	0.01-0.05	0-2	<3	
8	Floor	<39-100	<350-690	<0.01-0.02	0-2	<3-6	10-14
	Lower Walls	<39-190	<350-1650	<0.01-0.04	0-4	<3-4	
	Upper Walls & Ceiling	<39	<350-2050	<0.01-0.05	0-2	<3	
9	Floor	<39-65	<350-1030	<0.01-0.03	0-3	<3	8-12
	Lower Walls	<39-250	<350-1680	<0.01-0.04	0-3	<3-5	
	Upper Walls & Ceiling	<39-52	<350-650	<0.01-0.02	0-2	<3	
10	Floor	<39-65	1120-1730	0.03-0.04	0-2	<3-5	10-12
	Lower Walls	<39-120	<350-1150	<0.01-0.03	0-3	<3	
	Upper Walls & Ceiling	<39-230	<350-5170	<0.01-0.13	0-3	<3	
11	Floor	<39-100	<350-940	<0.01-0.02	0-3	<3	8-10
	Lower Walls	<39-150	<350-850	<0.01-0.02	0-3	<3-4	
	Upper Walls & Ceiling	<39-150	<350-740	<0.01-0.02	0-3	<3	
12	Floor	<39-7560	1410-96200	0.03-2.34	0-19	<3-22	8-14
	Lower Walls	<39-130	<350-3440	<0.01-0.08	0-6	<3-9	
	Upper Walls & Ceiling	<39-2720	<350-3380	<0.01-0.08	0-53	<3-32	

TABLE 8. cont.

SUMMARY OF WAREHOUSE SURVEY RESULTS

Room	Surface	SURFACE CONTAMINATION LEVELS					Gamma Exposure Rates at 1 Meter Above Floor (μR/h)
		Direct Measurement			Transferable		
		Alpha (dpm/100 cm^2)	Beta-Gamma (dpm/100 cm^2)	Beta-Gamma Dose Rate (mrad/h)	Alpha (dpm/100 cm^2)	Beta-Gamma (dpm/100 cm^2)	
13	Floor	<39-1060	1210-15000	0.03-0.36	0-9	<3-5	6-10
	Lower Walls	<39-150	<350-4620	<0.01-0.11	0-4	<3-9	
	Upper Walls & Ceiling	<39-90	410-2560	0.01-0.06	0-4	<3-4	
14	Floor	<39-520	2030-13300	0.05-0.32	0-13	<3-19	6-12
	Lower Walls	<39-180	<350-3090	<0.01-0.08	0-6	<3-12	
	Upper Walls & Ceiling	65-1600	1590-4700	0.04-0.11	0-43	<3-32	

[a] Refer to Figure 5.

[b] Dash indicates measurement not performed.

TABLE 9

LISTING OF AREAS ON PROPERTY B WHERE RADIONUCLIDE CONCENTRATIONS EXCEED GUIDELINE LEVELS

Grid Location[a] N	Grid Location[a] E	Radionuclide	Estimated Quantities of Material Exceeding Guidelines Area (m^2)	Depth (m)	Volume (m^3)	Remarks
339-342	1489-1493	Ra-226	12	0.15	1.8	
394-400	1462-1466	Ra-226	24	0.15	3.6	
397	1503	Ra-226	---[b]	---	---	Isolated surface spots with contaminated area less than 1 m^2.
412	1465	Ra-226	---	---	---	
420	1464	Ra-226	---	---	---	
422	1493	Ra-226	---	---	---	
423	1464	Ra-226	---	---	---	
425	1498	Ra-226	---	---	---	
426	1465	Ra-226	---	---	---	
426	1478	Ra-226	---	---		
426	1481	Ra-226	---	---	---	
Warehouse Building		Ra-226	2500-3000	N/A	N/A	

[a] Refer to Figure 8.

[b] Dash indicates determination was not made.

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APPENDIX A

INSTRUMENTATION AND ANALYTICAL PROCEDURES

APPENDIX A

Instrumentation and Analytical Procedures

Gamma Scintillation Measurement

Walkover surface scans and measurements of gamma exposure rates were performed using Eberline Model PRM-6 portable ratemeters with Victoreen Model 489-55 gamma scintillation probes containing 3.2 cm x 3.8 cm NaI(Tl) scintillation crystals. Count rates were converted to exposure levels (μR/h) using factors determined by comparing the response of the scintillation detector with that of a Reuter Stokes model RSS-111 pressurized ionization chamber at locations on the Niagara Falls Storage Site and off-site properties.

Beta-Gamma Dose Rate Measurements

Measurements were performed using Eberline "Rascal," Model PRS-1, portable scaler/ratemeters with Model HP-260 thin-window, pancake G-M, beta probes. Dose rates (μrad/h) were determined by comparison of the response of a Victoreen Model 440 ionization chamber survey meter to that of the G-M probes.

Borehole Logging

Borehole gamma radiation measurements were performed using a Victoreen Model 489-55 gamma scintillation probe, connected to a Ludlum Model 2200 portable scaler. The scintillation probe was shielded by a 1.25 cm thick lead shield with four 2.5 cm x 7 mm holes evenly spaced around the region of the scintillation crystal. The probe was lowered into each hole using a tripod holder with a small winch. Measurements were performed at 15-30 cm intervals in all holes. The logging data were used to identify regions of possible residues and guide the selection of subsurface soil sampling locations. Due to the varying ratios of Ra-226, U-235, U-238, Th-232, and Cs-137, there was no attempt to estimate soil radionuclide concentrations directly from the logging results.

Building Surface Contamination Measurements

Total alpha and beta-gamma levels on building surfaces were measured using Eberline model AC3-7 ZnS alpha scintillation and Eberline model HP-260 thin-window, pancake G-M detectors, respectively. These probes were coupled to Eberline "Rascal," Model PRS-1, portable scaler/ratemeters. Count rates were corrected for background and appropriate efficiency and probe area facts applied.

Removable contamination levels were determined by wipe (smear) tests of approximately 100 cm^2 of the surface using 5 cm diameter filter paper. These wipe samples were counted for gross alpha and gross beta activity using a Tennelec Model LB-5100 low-background proportional counter, and appropriate background and efficiency corrections were applied.

Soil Sample Analysis

Soil samples were dried, mixed, and a portion placed in a 0.5 l Marinelli beaker. The quantity placed in each beaker was chosen to reproduce the calibrated counting geometry and ranged from 600 to 800 g of soil. Net soil weights were determined and the samples counted using intrinsic germanium and Ge(Li) detectors coupled to a Nuclear Data model ND-680 pulse height analyzer system. Background and Compton stripping, peak search, peak identification, and concentration calculations were performed using the computer capabilities inherent in the analyzer system. Energy peaks used for determination of radionuclides of concern were:

Ra-226 - 0.609 MeV from Bi-214 (corrected for equilibrium conditions)
U-235 - 0.143 MeV
U-238 - 0.094 MeV from Th-234 (secular equilibrium assumed)
Th-232 - 0.911 MeV from Ac-228 (secular equilibrium assumed)
Cs-137 - 0.662 MeV

Water Sample Analysis

Water samples were rough-filtered through Whatman No. 2 filter paper. Remaining suspended solids were removed by subsequent filtration through 0.45 μm membrane filters. The filtrate was acidified by addition of 10 ml of concentrated nitric acid. A known volume of each sample was evaporated to dryness and counted for gross alpha and gross beta using a Tennelec Model LB 5100 low-background proportional counter.

Calibration and Quality Assurance

With the exception of the exposure and dose rate conversion factors for portable survey gamma and beta-gamma meters, all survey and laboratory instruments were calibrated with NBS-traceable standards. The calibration procedures for these portable instruments are described above.

Quality control procedures on all instruments included daily background and check-source measurements to confirm lack of malfunctions and nonstatistical deviations in equipment. The ORAU laboratory participates in the EPA Quality Assurance Program.

APPENDIX B

SUMMARY OF RADIATION GUIDELINES APPLICABLE TO OFF-SITE PROPERTIES AT THE NIAGARA FALLS STORAGE SITE

U. S. DEPARTMENT OF ENERGY

RESIDUAL CONTAMINATION AND WASTE CONTROL CRITERIA FOR FORMERLY UTILIZED SITES REMEDIAL ACTION PROGRAM (FUSRAP) AND REMOTE SURPLUS FACILITIES MANAGEMENT PROGRAM (SFMP) SITES

Presented here are the residual contamination cleanup and waste control criteria of general applicability to the FUSRAP project and remote SFMP sites[1/].

With the exception of limits for radium-226, the soil residual contamination criteria were developed on the basis of limiting maximum individual radiation exposure to DOE limits specified in DOE Order 5480.1A exclusive of exposure from natural background radiation or medical procedures. The aggregate of the contribution from all major pathways, based on scenarios for permanent intrusion, e.g., establishing residences on the site, has been assumed. In most circumstances, the probability is low that such an intrusion will occur. Also, conservative assumptions were used in deriving these criteria to ensure that a particular dose limit would not be exceeded. Use of these criteria is additionally conservative because the pathways considered in the derivation of the criteria assume all water intake and most food intake is from the site. Also, the sites often have limited agricultural capability and the contamination is generally not homogeneous. The combined effect of these factors is such that the probable radiation exposure to the average population on, or in the vicinity of, FUSRAP sites decontaminated to these criteria limits will not be appreciably different from that normally received from natural background radiation.

The residual contamination criteria for surface contamination of structures were developed from a proposed ANSI standard[2/] modified as appropriate to be consistent with DOE Order 5480.1A and the specific needs of FUSRAP for cost-effective, workable guidelines which provide an adequate safety margin. The waste control criteria are consistent with applicable DOE Orders and EPA's regulations for inactive uranium milling sites, 40 CFR 192.

[1/] A remote SFMP site is one that is excess to DOE programmatic needs and is located outside a major operating DOE R&D or production area. Remote sites are more likely to be released to the public or excessed to other government agencies after decontamination than are sites located with major R&D or production areas.

[2/] ANSI N13.12 (proposed) -- an adaptation to be applied, as appropriate.

A. RESIDUAL CONTAMINATION CRITERIA FOR FORMERLY UTILIZED SITES AND REMOTE SURPLUS FACILITIES MANAGEMENT PROGRAM SITES

The following criteria represent the maximum residual contamination limits for unrestricted use of land and structures contaminated with radionuclides related to the nuclear fuel cycle at FUSRAP and remote SFMP sites. It is the policy of DOE to decontaminate sites to contamination levels at or below the limits and in a manner consistent with DOE's as-low-as-is-reasonably-achievable (ALARA) policy. Residual contamination limits for other nuclides will be developed when required using the same methodology[1/] as was used for those represented here.

1. Soil (Land) Criteria (Maximum Limits for Unrestricted Use)

Radionuclide	Soil Criteria[2/,3/,4/] (pCi/g above background)
U-Natural[5/]	75
U-236[6/]	150
U-234[6/]	150
Th-230[7/]	15
Ra-226	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 more than 15 cm below the surface and less than 1.5m below the surface.
U-235[6/]	140
Pa-231	40
Ac-227	190
Th-232	15
Am-241	20
Pu-241[8/]	800
Pu-238, 239, 240	100
Cs-137	80
Sr-90	100
H-3 (pCi/ml soil moisture)	5,200

1/ Described in ORO-831 and ORO-832.

2/ In the event of occurrence of mixtures of radionuclides, the fraction contributed by each radionuclide to its limit shall be determined, and the sum of these fractions shall not exceed 1. There are two special cases for which this rule must be modified:

(a) If Ra-226 is present, then the fraction for Ra-226 should not be included in the sum if the Ra-226 concentration is less than or equal to the Th-230 concentration. If the Ra-226 concentration exceeds the Th-230 concentration, then the sum shall be evaluated by replacing the Ra-226 concentration by the difference between the Ra-226 and Th-230 concentrations.

(b) If Ac-227 is present, then the same rule given in (a) for Ra-226 relative to Th-230 applies for Ac-227 relative to Pa-231.

3/ Except for Ra-226, these criteria represent unrestricted-use residual concentrations above background averaged across any 15 cm thick layer to any depth and over any contiguous 100 m^2 surface area. The same conditions prevail for Ra-226 except for soil layers beneath 1.5 m; beneath 1.5 m, the allowable Ra-226 concentration may be affected by site-specific conditions and must be evaluated accordingly.

4/ Localized concentrations in excess of these limits are allowable provided that the average over 100 m^2 is not exceeded.

5/ A curie of natural uranium means the sum of 3.7×10^{10} disintegrations per second (dis/s) from U-238 plus 3.7×10^{10} dis/s from U-234 plus 1.7×10^{5} dis/s from U-235. One curie of natural uranium is equivalent to 3,000 kilograms or 6,600 pounds of natural uranium.

6/ Assumes no other uranium isotopes are present.

7/ The Th-230 guideline is 15 pCi/g to account for ingrowth of Ra-226 as Th-230 decays. Ra-226 is a limiting radionuclide because its decay product is Rn-222 gas.

8/ The Pu-241 criterion was derived from the Am-241 concentration.

2. Structure Criteria (Maximum Limits for Unrestricted Use)

a. Indoor Radon Decay Products

A structure located on private property and intended for unrestricted use shall be subject to remedial action as necessary to ensure the annual average concentration of radon decay products is less than 0.03 WL within the structure.

b. Indoor Gamma Radiation

The indoor gamma radiation after decontamination shall not exceed 20 microroentgen per hour (20 μR/h) above background.

c. Indoor/Outdoor Structure Surface Contamination

Radionuclides	Allowable Surface Residual Contamination[1] (dpm/100 cm^2) Total	Removable
Group 1:	100	20
Radionuclides for which the uncontrolled area concentration guide in air above background[2] is 2×10^{-13} Ci/m^3 or less or for which the uncontrolled area concentration guide in water above background[2] is 2×10^{-7} Ci/m^3 or less; includes Pa-231, Th-228, Th-230, Ac-227, Ra-226, Ra-228, and Pb-210.		
Group 2:	1,000	200
Radionuclides not in Group 1 for which the uncontrolled area concentration guide in air above background[2] is 1×10^{-12} Ci/m^3 or less or for which the uncontrolled area concentration guide in water above background[2] is 1×10^{-6} Ci/m^3 or less; includes U-232, U-238, Th-232, Ra-223, and Po-210.		
Group 3:	5,000	1,000
Those radionuclides not in Group 1 or Group 2; includes U-234, U-235, and Ra-224 and all other beta-gamma emitters.		

[1] The levels may be averaged over 1 m^2 provided the maximum activity in any area of 100 cm^2 is less than 3 times the limit value; dpm = disintegrations per minute. In the event of occurrence of mixtures of radionuclides, the fraction contributed by each radionuclide to its limit shall be determined, and the sum of these fractions shall not exceed 1.

[2] Given in Attachment 1 to Chapter XI, Table II, DOE Order 5480.1A.

B. CONTROL OF RADIOACTIVE WASTES AND RESIDUES FROM FUSRAP AND REMOTE SFMP SITES

Specified here are the control requirements (criteria) for radioactive wastes and residues related to the nuclear fuel cycle at FUSRAP and remote SFMP sites.

1. Interim Storage

All operational and control requirements specified in the following DOE Orders shall apply:

a. 5480.1A, Environmental Protection, Safety, and Health Protection Program for DOE Operations.

b. 5480.2, Hazardous and Radioactive Mixed Waste Management.

c. 5483.1, Occupational Safety and Health Program for Government-Owned Contractor-Operated Facilities.

d. 5484.1, Environmental Protection, Safety, and Health Protection Information Reporting Requirements.

e. 5484.2, Unusual Occurrence Reporting System.

f. Control and stabilization features will be designed to ensure, to the extent reasonably achievable, an effective life of 50 years, and in any case, at least 25 years.

g. Rn-222 concentrations in the atmosphere above facility surfaces or openings shall not (1) exceed 100 pCi/l at any given point, or an average concentration of 30 pCi/l for the facility site, or (2) exceed an average Rn-222 concentration at or above any location outside the facility site of 3.0 pCi/l (above background).

h. For water protection, use existing state and federal standards; apply site-specific measures where needed.

2. Long-Term Management

a. All operational requirements specified for Interim Storage Facilities (B.1) will apply.

b. Control and stabilization features will be designed to ensure to the extent reasonably achievable, an effective life of 1,000 years and, in any case, at least 200 years. Other disposal site design features shall conform with 40 CFR Part 192 performance guidelines/requirements.

c. Rn-222 emanation to the atmosphere from facility surfaces or opening shall not (1) exceed an average release rate of 20 $pCi/m^2/s$, or (2) increase the annual average Rn-222 concentration at or above any location outside the facility site by more than 0.5 pCi/l.

d. For water protection, use existing state and federal standards; apply site-specific measures where needed.

e. Prior to placement of any potentially biodegradable contaminated wastes in a Long-Term Management Facility, such wastes will be properly conditioned to (1) ensure that the generation and escape of biogenic gases will not cause the criteria in paragraph 2.c. to be exceeded, and (2) ensure that biodegradation within the facility will not result in premature structural failure not in accordance with the criteria in paragraph 2.b.. If biodegradable wastes are conditioned by incineration, incineration operations will be carried out in compliance with all applicable federal, state, and local air emission standards and requirements, including any standards for radionuclides established pursuant to 40 CFR Part 61, National Emission Standards for Hazardous Air Pollutants (NESHAPS).

C. EXCEPTIONS

1. *Procedure* -- *Analysis of site-specific conditions.*

2. Applicability -- Where health and safety would be endangered, or where cost clearly outweighs benefits.

D. CRITERIA SOURCE

Criteria	Source
Residual Contamination Criteria[1/]	
Soil Criteria	DOE Order 5480.1A, 40 CFR Part 192[2/]
Structure Criteria	40 CFR Part 192, proposed ANSI N13.12.
Control of Radioactive Wastes and Residues	
Interim Storage	DOE Order 5480.1A
Long-Term Management	40 CFR Part 192

Exceptions

Procedure	40 CFR Part 192
Applicability	40 CFR Part 192

1/ The bases of the residual contamination criteria are developed in ORO-831 as supplemented and ORO-832.

2/ Based on limiting the concentration of radon-222 decay products to 0.03 WL within structures.