COMPREHENSIVE RADIOLOGICAL SURVEY

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

Prepared for

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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 (presently referred to as the Niagara Falls Storage Site (NFSS) and 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 activties, 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., is the current owner of a tract from the NFSS, identified as off-site property E (see Figure 1). A radiological survey of that tract, conducted May and June 1983, is the subject of this report.

SITE DESCRIPTION

Figure 2 is a plot plan of off-site property E. The property is approximately 832 m long and varies in width from 165 m at the western boundary to 205 m at the eastern boundary. The site occupies a total of about 13.3 hectares. It is bounded on the west by "5" Street and on the east by MacArthur Street. A fence runs parallel to "5" Street along the length of the property. The west-central portion also contains several waste treatment lagoons and ponds which are accessed by unpaved roads. A drainage ditch occupies a major portion on the southern boundary and also encloses much of the waste treatment area. Part of the eastern boundary and the southwest corner are overgrown with brush and trees. Remanents of three wooden buildings stand on the western portion. They were once used for munitions production and were present on this site prior to use of the area for radioactive waste storage by MED/AEC. There is one occupied building, a warehouse recently constructed for storage of chemical waste, located on the eastern section.

Radiological History

There is no history of contaminated material burials on property E. Previous surveys have identified a few small areas of elevated radiation levels in the northeast section (landfill activities may have disturbed these areas) and above-background levels along the railroad tracks near the southwest boundary.[1-3]

SURVEY PROCEDURES

The comprehensive survey of off-site property E was performed by the Radiological Site Assessment Program of Oak Ridge Associated Universities (ORAU), during the period of May-June, 1983. The survey was in accordance with a plan dated February 3, 1983, approved by the Department of Energy's Office of Nuclear Energy. The objectives 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 E. 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,
5. concentrations of radionuclides in water and sediment from drainage ditches on the property, and
6. surface contamination levels in the warehouse building.

Procedures

1. Brush and weeds were cleared as needed to provide access for gridding and surveying and a 40 m system was established. These operations were performed 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 meters along roads, ditches, in areas previously identified as having elevated radiation levels, along railroad tracks, 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 material 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. The scan identified an area along a retention pond berm in the west-central portion of the site as having generally higher direct radiation levels and numerous isolated "hot spots." This area was subdivided into 5 m x 3 m grid intervals.

3. Gamma exposure rate measurements were made at the surface and at 1 m above the surface at 40 m grid line 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 non-penetrating beta and low-energy gamma radiations. Meter readings were converted to dose rate 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 selected locations of elevated surface radiation levels (see Figures 4 and 5), beta-gamma dose rates and exposure rates at 1 m above the surface were also measured. Surface soil 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 in the area along the retention pond berm for evidence of contaminated buried materials. In addition, ground radar surveys were also conducted at proposed borehole locations to identify the presence of subsurface piping or other obstacles, which would preclude borehole drilling.

8. Boreholes were drilled to provide a mechanism for logging subsurface direct radiation profiles and collecting subsurface soil and water samples. Eleven 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 6. It was not possible to drill along the retention pond berm due to the inaccessibility of the area and the possibility of damaging the integrity of the berm.

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

A sample of the ground water was collected from three of the boreholes using a hand bailer. Soil samples of approximately 1 kg each were collected from various depths in the holes by scraping the sides of each borehole with an ORAU designed sampling tool.

9. Four water samples were collected from two areas of standing (surface) water (see Figure 7).

10. Seven sediment samples were collected from ditches along the southern boundary and west-central portion of the site (see Figure 7).

11. Exploratory direct radiation and surface contamination measurements were peformed in the warehouse. The building survey included:

    a. walkover surface scans using NaI gamma scintillation detectors,
    b. exposure rate measurements at 1 m above the floor,
    c. measurements of total alpha and beta-gamma levels on floors and,
    d. smear samples to determine levels of removable alpha and beta contamination.

12. 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 8.

Sample Analyses 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 were analyzed for gross alpha and gross beta concentrations. Selected samples, including those which exceeded the EPA Interim Drinking Water Standard of 15 pCi/l gross alpha, were also analyzed for Ra-226.

Additional information concerning analytical equipment and procedures is contained 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 8) 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 ranged from 5 to 9 μR/h (average 6 μR/h). Surface contact gamma exposure rates and beta-gamma dose rates were 5 to 12 μR/h (average 6 μR/h) and 5 to 38 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 non-penetrating beta or low-energy photon radiations.

The walkover survey identified two areas of generally elevated surface radiation levels and several additional isolated "hot spots." These locations are indicated on Figures 4 and 5. The two general locations were along a retention pond berm (103-112N, 385-450E) and on a small graveled area near "5" Street (220-238N, 182-204E). Contact gamma exposure rates, systematically measured at 5 m intervals along the retention pond berm, ranged from 8-21 μR/h (see Table 3). Gamma exposure rates at 1 m above the surface and contact beta-gamma dose rates in this area ranged from 8-18 μR/h and 8-190 μrad/h respectively. There were numerous isolated "hot spots" noted on the berm. Surface contact gamma exposure rates at these locations ranged from 27-1150 μR/h (refer to Table 4). Beta-gamma dose rates ranged from 27-110,000 μrad/h. The maximum contact level (before sampling) was measured at grid point 105N, 403E.

At several locations of elevated surface radiation, e.g., 105N,403E, 105N,436E, and 106N,445E, the shielded detector measurements were 3-30% of the unshielded measurements, suggesting that a large fraction of the radiation at these locations is due to beta particles. Contact exposure rates were reduced by soil sampling at many of the "hot spot" locations; however, at some of the points, exposure rates were unchanged following sampling. These results indicate the contamination at some locations extends greater than 15 cm below the surface and/or is diffused rather than in small, discrete pieces of material. In the general area adjacent to "5" Street contact gamma exposure rates ranged from 14-35 μR/h. Beta-gamma dose rates at selected sampling locations were recorded up to 48 μrad/h.

Radionuclide Concentrations in Surface Soil

Table 5 lists the concentrations of radionuclides measured in surface soil from 40 m grid intervals. These samples contained Ra-226 concentrations ranging from 0.34 to 3.03 pCi/g; the highest level was in the sample from grid point 240E, 400E. In general, Ra-226 concentrations did not differ from those in baseline samples. Concentrations of U-235, U-238, Cs-137, and Th-232 also are comparable to those in baseline samples. No significant concentrations of other radionuclides were present.

Radionuclide concentrations in surface samples from locations of elevated contact radiation levels are presented in Table 6. Each of the samples contained Ra-226 concentrations exceeding baseline levels. Concentrations ranged from 4.23 to 514 pCi/g. The highest Ra-226 concentration was contained in the sample from grid point 15N, 315E. Elevated uranium concentrations were also measured in several samples; sample B15A, contained 22,600 pCi/g of U-238. Levels of Cs-137 were comparable with baseline concentrations and Th-232 concentrations were below the minimum activity or in the range of baseline samples.

Small pieces of debris, each weighing less than a few grams, were separated from some of the samples collected at locations of elevated direct radiation. These pieces of debris contained levels of Ra-226 activity that were too high to permit analysis by the routine gamma spectrometry procedures. Activity levels determined in these samples by comparison with a known quantity of Ra-226, are presented in Table 7. These samples were pieces of plaster-like chips (probably lead cake) and contained 0.55 to 11.6 µCi of Ra-226. Sample 15A contained small pieces of processed natural uranium (i.e. separated from the longer lived daughter products but with the U-235 and U-238 isotopes in their naturally occurring ratios).

Sampling along the southern portion of the retention pond berm identified the presence of metal containers 20 to 30 cm below the surface. Direct measurements indicate that these containers are contaminated or contain contaminated residues. The possibility of damaging the berm precluded further investigations in this area.

The generally elevated area adjacent to "5" Street was covered with about 15 cm of crushed rock containing approximately 10-12 pCi/g of U-238 and Ra-226. This material is typical of that used as fill or paving base in the Niagra Falls area; similar rock has been identified on other NFSS off-site properties (e.g. property S). The radionuclides in this material are believed to be of natural origin and not attributable to radioactive waste handling and storage operations at this site.

Ground-Penetrating Radar Findings

The subcontractor's report summarizing ground-penetrating radar survey results for property E is provided in Appendix C. A ground radar survey of the south bank of the retention pond berm bounded by 103N, 112N, 385E, and 450E indicated the presence of 22 buried targets. Ground radar also identified possible utility services at several proposed borehole drilling locations, requiring slight relocation of these boreholes.

Borehole Gamma-Logging Measurements

The results of gamma scintillation measurements in boreholes indicate that contamination, with one exception, is confined to the upper 15-30 cm of soil. Borehole H8, drilled along the west end of the retention pond berm, had elevated radiation levels at a depth of 90 cm. It should be reiterated that additional borehole drilling in the retention pond berm area was not possible for reasons previously stated in the procedures section.

The gamma count rates determined by the borehole measurements were reliable indicators of elevated subsurface 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 Subsurface Soil

Table 8 presents the radionuclide concentrations measured in soil samples from boreholes. None of the seven boreholes (H1-H7), located to provide a representative coverage of the property, contained elevated subsurface radionuclide concentrations. Boreholes H9-H11 were drilled along "5" Street on the western edge of the property. Ra-226 concentrations ranged from 0.88 to 4.88 pCi/g. The highest level was found at borehole H11 (235N,190E). This borehole also contained 7.07 pCi/g of U-238 at a depth of .15 m. At .9 m, the level decreased to 1.31 pCi/g. Borehole H10 contained a surface concentration of 5.05 pCi/g of U-238 but less than the minimum detectable activity at a depth of .15 m. Other radionuclide concentrations from these boreholes were in the ranges of baseline soil measurements.

Borehole H8, drilled along the west end of the retention pond berm, had a U-238 concentration of 3.93 pCi/g at a depth of 0.9 m. All other values were within the range of baseline soil levels.

Radionuclide Concentrations in Water

Surface Water

Samples W1-W4 from standing water on property E (refer to Table 9) contained elevated gross alpha and beta concentrations. Samples W2 and W3, collected along the southern boundary, had gross alpha concentrations of 21.6 and 33.3 pCi/l, respectively; sample W3 also contained 117 pCi/l, gross beta. Ra-226 concentrations in these two samples were (W2) <0.17 pCi/l and (W3) <0.16 pCi/l. Samples W1 and W4, also contained higher than background gross alpha and beta concentrations.

Subsurface Water

Two of the three subsurface water samples from the property interior contained elevated gross alpha and gross beta concentrations (see Table 9); however, only sample W6, collected from borehole H8 exceeded 50 pCi/l for gross beta. This sample was from grid loca-tion 105N, 380E, along the west end of the retention pond berm, and contained a gross beta concentration of 63.5 pCi/l. It should be noted that these samples contained high concentrations of dissolved solids. This necessitated the use of smaller volumes of water for gross alpha analysis, thus resulting in larger relative errors than usually obtained by this procedure.

Radionuclide Concentrations in Drainage Ditch Sediments

Concentrations in sediment samples, collected from site drainage ditchsare presented in Table 10. Sediment sample SD1, collected from the west-central portion of the property, did not contain radionuclide levels significantly different from the levels in baseline soil. Sediment samples collected along the southern edge of the property at grid points 102N, 320E (sample SD2), 102N, 440E(SD5), and 102N, 480E (SD6) contained concentrations of U-238 ranging from 3.69 to 5.68 pCi/g. Ra-226 concentrations ranging from 0.85 to 2.25 pCi/g were present in these samples. The highest level was noted at grid location 102N, 380E. Levels of Cs-137, Th-232,and U-235 were comparable with baseline concentrations.

Building Surveys

The results of an "exploratory" survey conducted in the warehouse on property E are summarized in Table 11. No areas of elevated direct radiation or surface contamination were noted with the exception of several drums containing chemical waste which had slightly elevated contact exposure rates of up to 24 μR/h. Further building measurements were therefore not necessary.

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, associated with small, isolated spots of surface or near-surface contamination, exceed these guideline values. However, when considered in terms of potential exposures or averaged over larger surface areas, many of these levels and concentrations meet the cleanup criteria.

The maximum exposure rate of 1150 μR/h, in contact with one of the isolated areas of surface contamination, exceeds the guideline of 60 μR/h for open land areas accessible by the general public. Exposure rates at 1 m above the surface are well below that value. The highest level at this distance above the surface is 26 μR/h - well within the 60 μR/h criteria.

Areas of surface contamination, identified by the walkover scan, contained Ra-226 concentrations in excess of 5 pCi/g; one of the samples, B15A, also contained 22,600 pCi/g of U-238 - a value well above the 156 pCi/g criterion. Many of the isolated "hot spots" are in the area of a retention pond berm; this area is approximately 9 m wide (grid lines 103N to 112N) and 65 m long (grid lines 385E to 450E).

Borehole measurements and sampling did not identify the presence of subsurface contamination exceeding criteria. However, subsurface investigations were not possible in the retention pond berm, where ground-penetrating radar, visual inspection, and direct measurements identified buried contaminated metal containers.

Results of the survey along "5" Street indicated areas of crushed rock containing Ra-226 and U-238. This material is believed to be natural rock or slag, commonly used for fill and as a paving base in the Niagara Falls area. It is not attributable to previous radioactive waste handling and storage activities at this site.

Surface water from two locations along the southern boundary contained gross alpha concentrations above the EPA limits of 15 pCi/l; one of these samples also exceeded the EPA guideline of 50 pCi/l for gross beta. None of the subsurface water samples contained gross alpha levels exceeding 15 pCi/l. One of the samples collected along the west end of the retention pond berm did, however, contain a gross beta concentration of 63.5 pCi/l - a value in excess of the EPA limits. Although some of these samples exceed the EPA Interim Drinking Water Standards, other borehole water samples indicate that residues on the property are not producing general ground water contamination. It should be noted that the EPA standards apply only to community drinking water systems; they are not applicable to sources of water such as those on property E and have been used here only for comparison purposes.

Levels of direct radiation and surface contamination within the warehouse building on this property are not significantly different from background levels and are well below the guidelines for unrestricted use.

SUMMARY

A comprehensive survey of off-site property E at the Niagara Falls Storage Site was conducted during May and June 1983. The survey included: surface radiation scans, measurements of direct radiation levels, and analyses for radionuclide concentrations in soil and water samples, both surface and subsurface. Analyses of sediment samples collected from several drainage ditches were also performed. Ground-penetrating radar was used to identify subsurface anomalies which might suggest buried radioactive residues.

The results of the survey indicate the presence of two general areas and one small, isolated areas of elevated direct radiation and surface soil contamination. Those areas exceeding the cleanup criteria are indicated on Figure 9 and listed in Table 12. The major contaminant is Ra-226; however, a few samples also contained high U-238 concentrations. One of the general areas is the retention pond berm which covers an area of approximately 580 m^2 (about 9 m x 65 m). Numerous surface "hot spots" were noted in this area and ground penetrating radar identified buried metal drums (visually conformed) in the berm. The upper bound of these buried containers could not be determined because of the presence of the retention pond. Also, further subsurface investigations were not possible due to the area's inaccessibility and potential for damaging the pond berm or liner during drilling. It is estimated that the buried containers average 1-2 m below the surface.

The other general area is adjacent to "5" Street and consists of surface (about 15 cm) layer of crush rock or slag with elevted U-238 and Ra-226 concentrations. The area covered by this material is about 400 m^2. This material is believed to be a common construction type fill and not attributable to previous MED/AEC operations at the site.

At some locations of elevated surface radiation, Ra-226 contamination was present in the form of small white chips, similar to those that have been noted on other NFSS off-site properties. The chemical composition of these chips suggest they may be lead cake residues. Although the concentrations of Ra-226 in these small areas are well above the criteria of 5 pCi/g, in most situations averaging the levels of contamination over contiguous surface areas

of 100 m^2, results in levels below these concentration guidelines. Each of these isolated spots occupies less than 1 m^3 of soil.

Several samples of both surface and subsurface water contained radionuclide concentrations exceeding the EPA Interim Drinking Water Standards for gross alpha and/or gross beta. The Ra-226 levels were less than the criteria and additional sampling indicates that contamination of the ground water system is not occurring.

No significant radiation levels or surface contamination were detected in the warehouse on this property.

Although the contaminated residues on small portions of this property exceed the guidelines established for release of the site for unrestricted use by the general public, under present conditions of usage the contaminants do not pose potential health risks to the public or site workers. There is no evidence that migration of the radioactive materials is adversely affecting adjacent properties or the ground water.

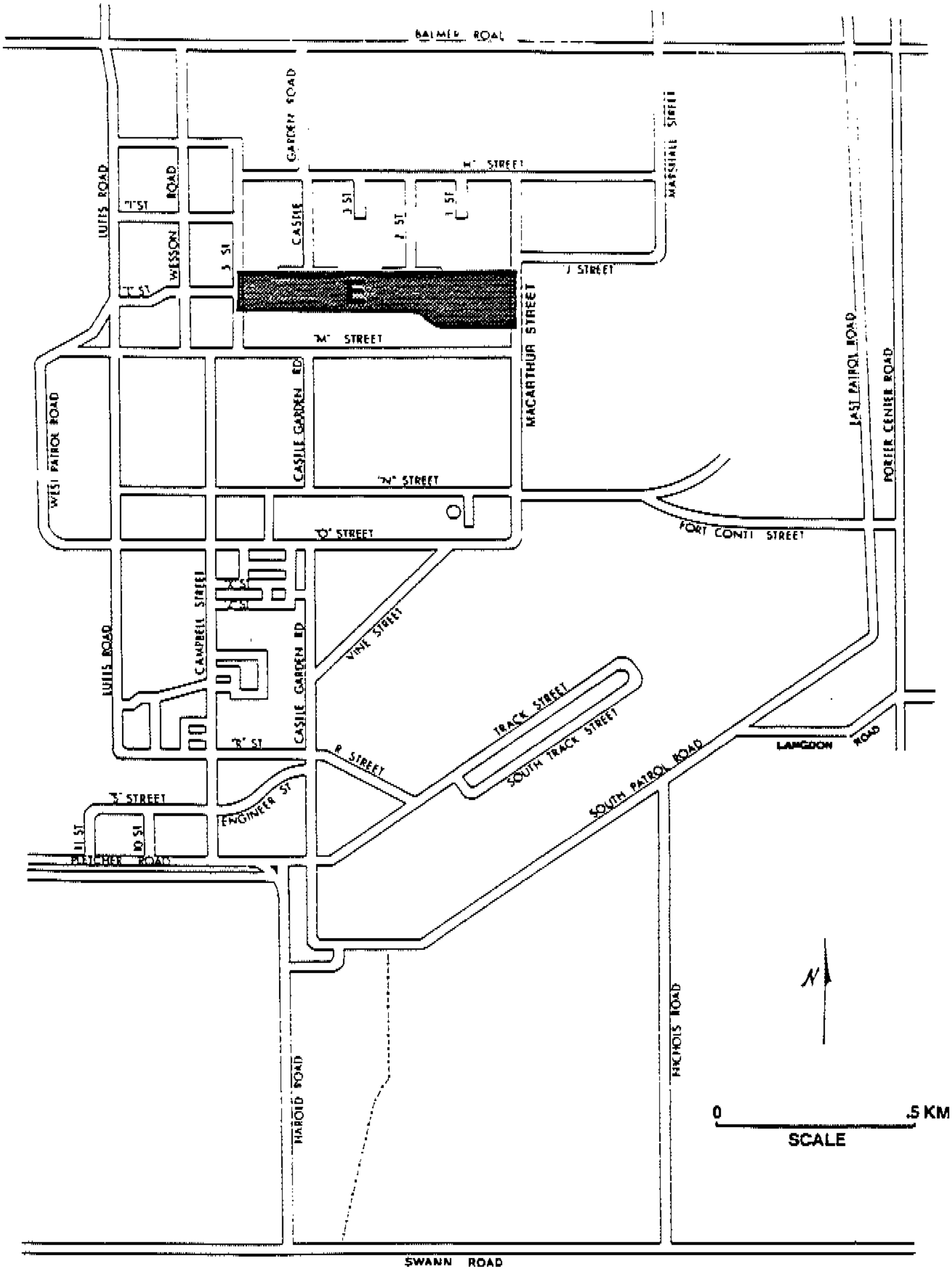

FIGURE 1. Map of the Niagara Falls Storage Site and Off-Site Properties, Lewiston, New York, Indicating the Location of Property E.

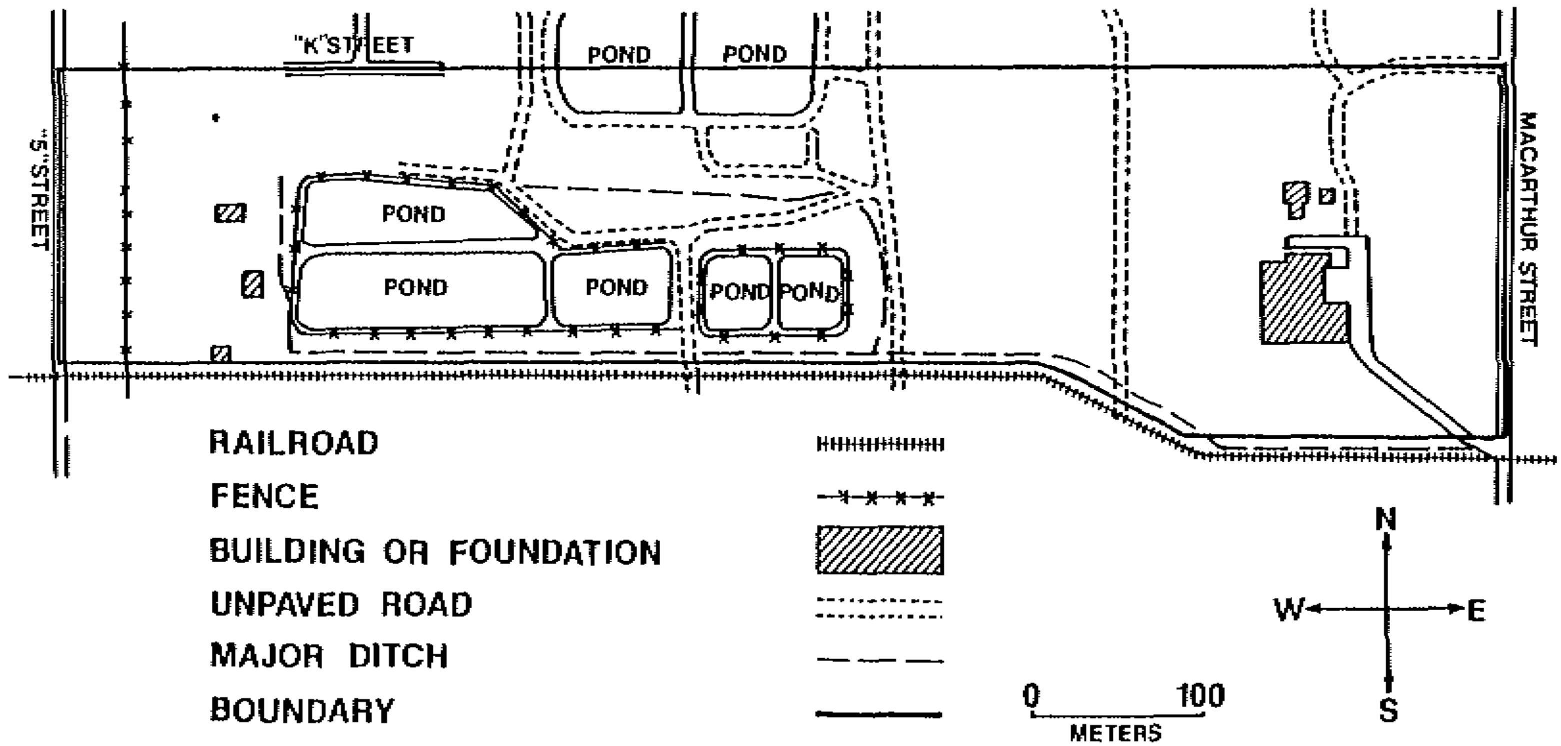

FIGURE 2. Plan View of NFSS Off-Site Property E Indicating Prominent Surface Features.

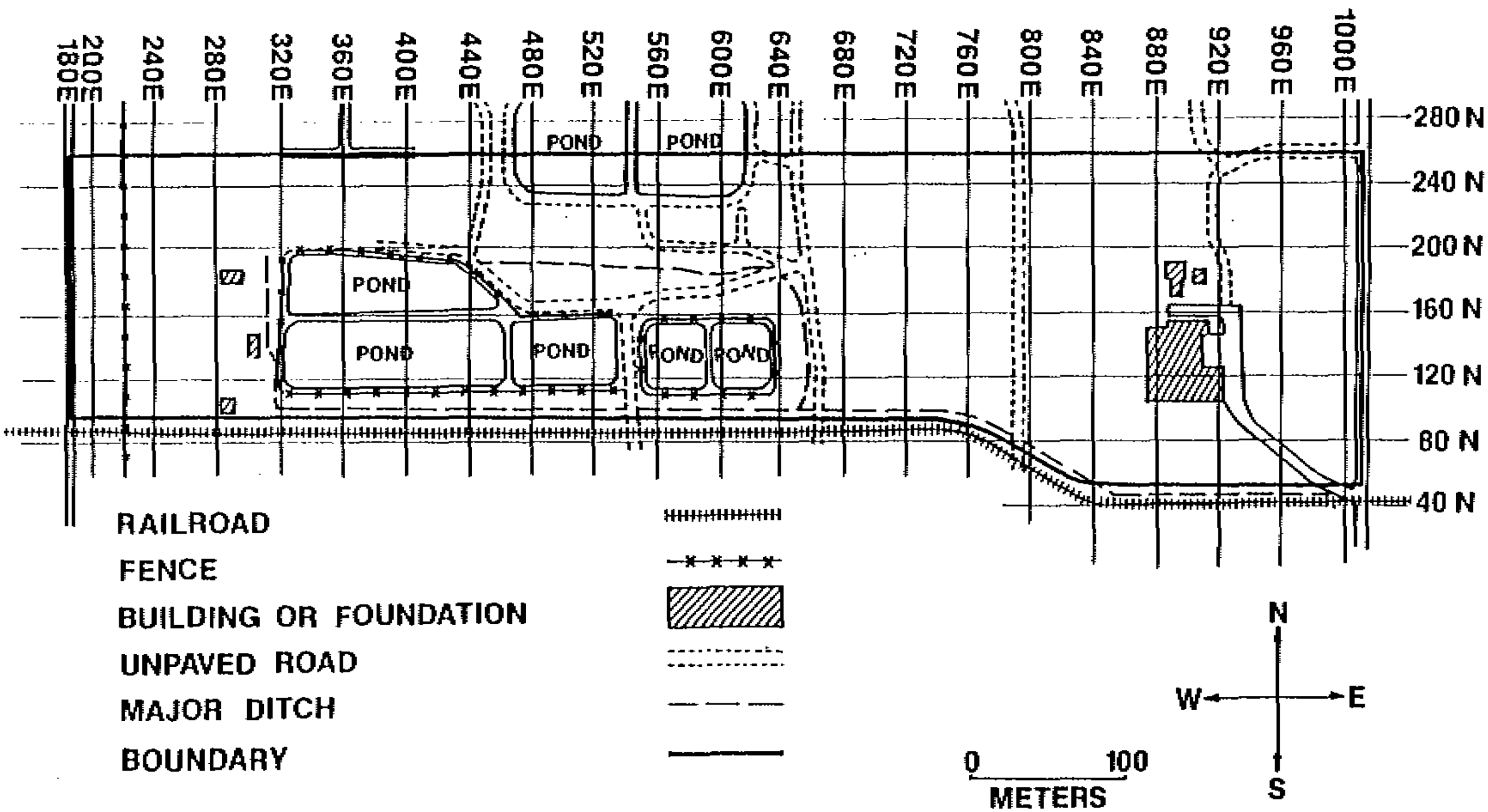

FIGURE 3. Plan View of NFSS Off-Site Property E Indicating the Grid System Established for Survey Reference.

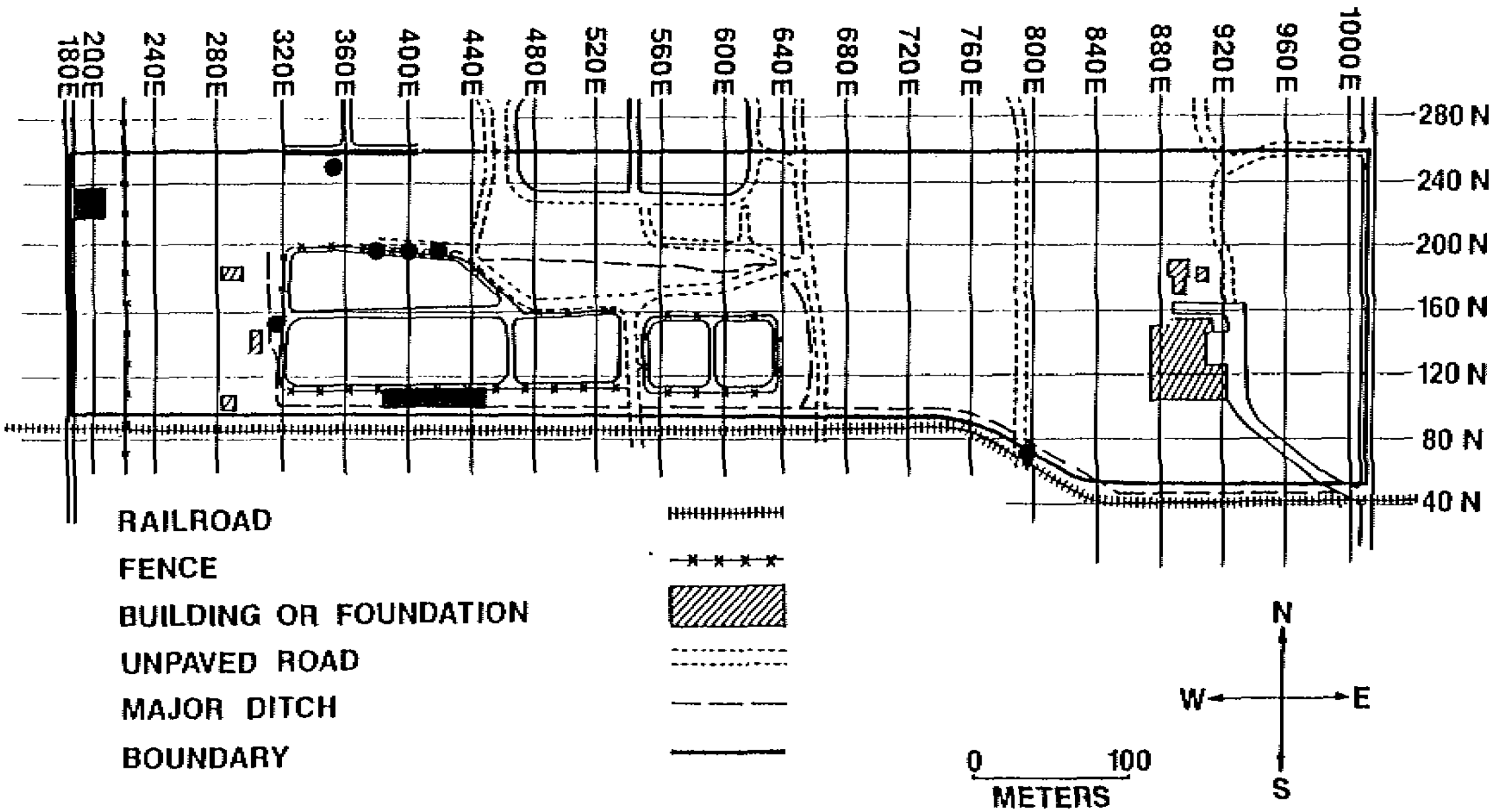

FIGURE 4. Locations of Areas of Elevated Direct Radiation.(Darkly shaded areas represent regions of generally elevated radiation levels. Dots indicate isolated "hot spots.")

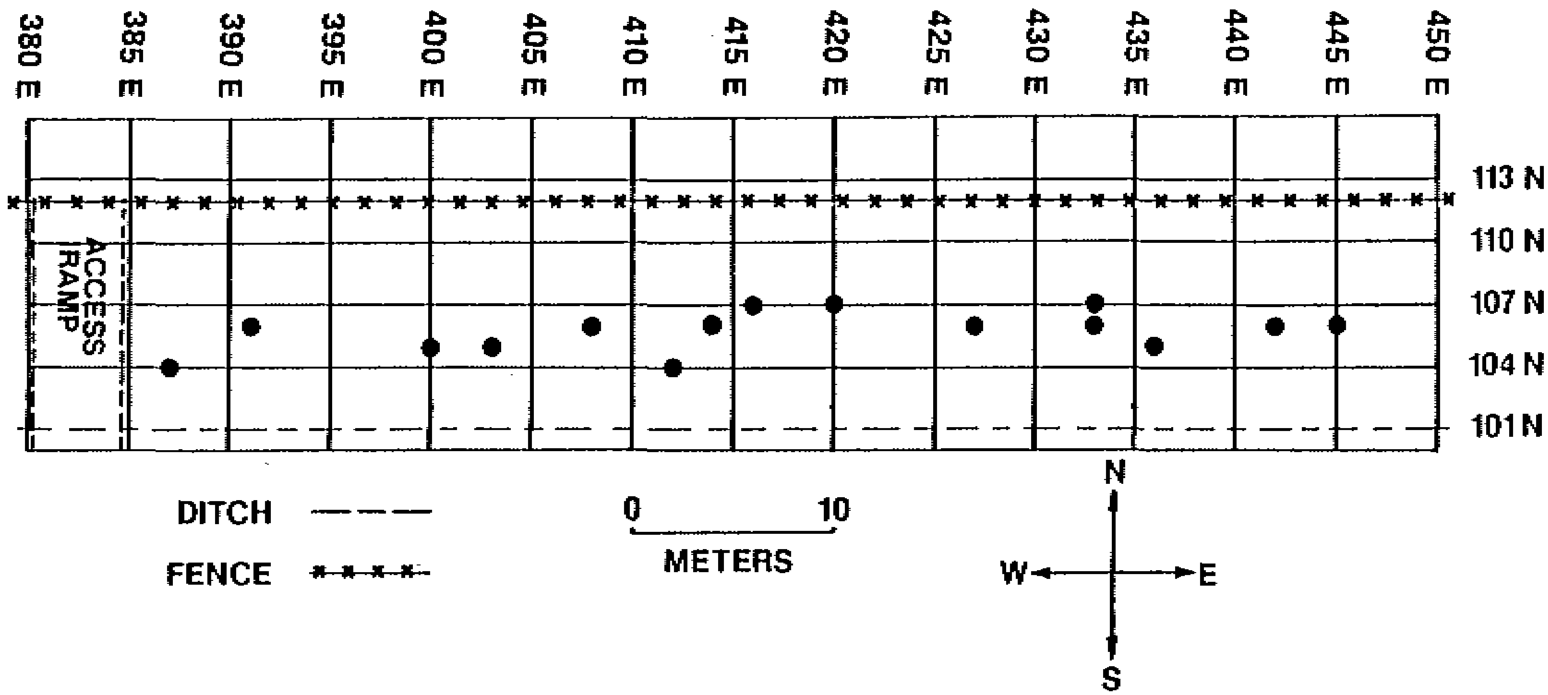

FIGURE 5. Section of Retention Pond Berm Containing Numerous Areas of Surface Contamination. (Dots indicate "hot spots.")

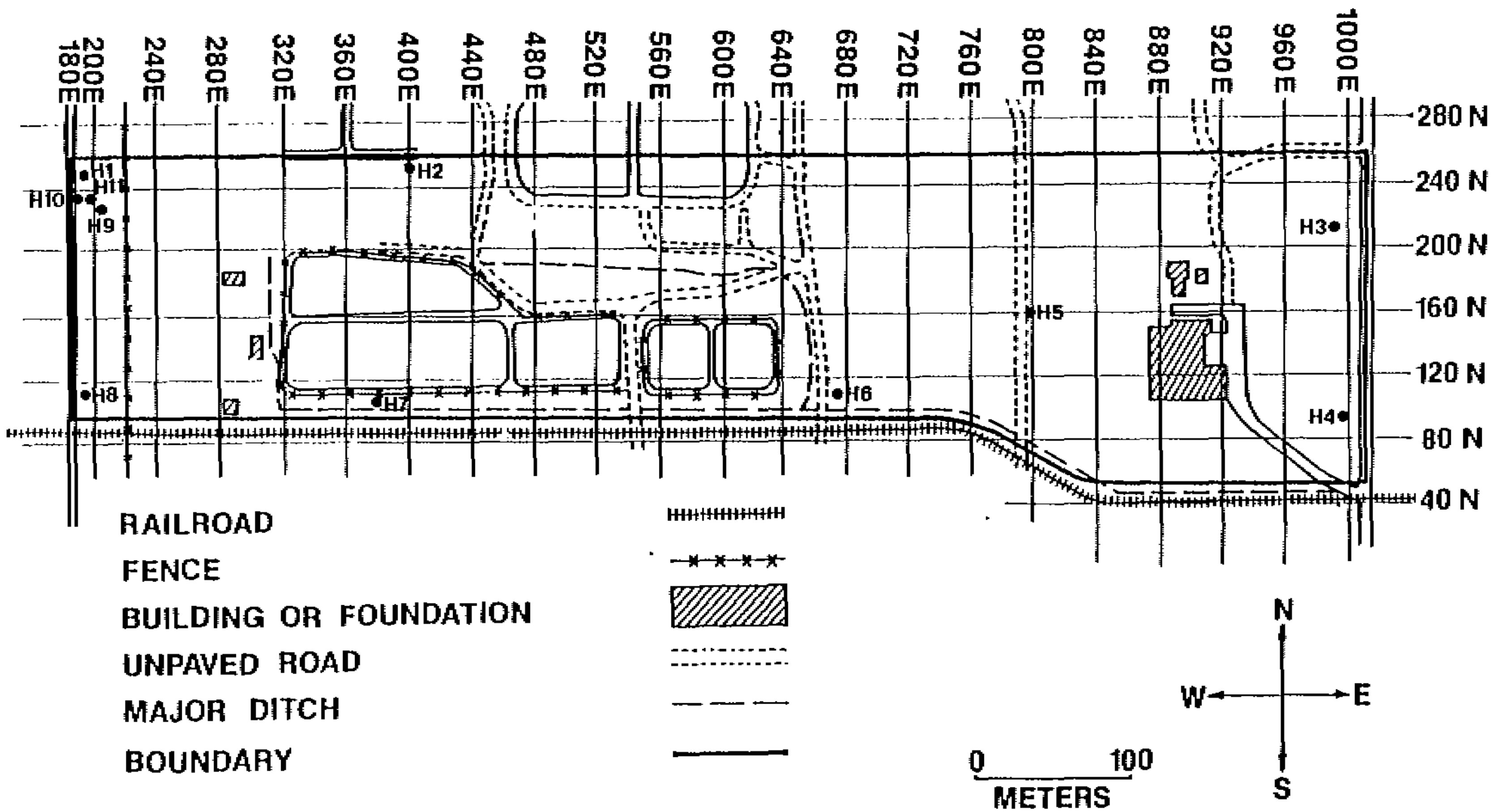

FIGURE 6. Locations of Boreholes for Subsurface Investigations.

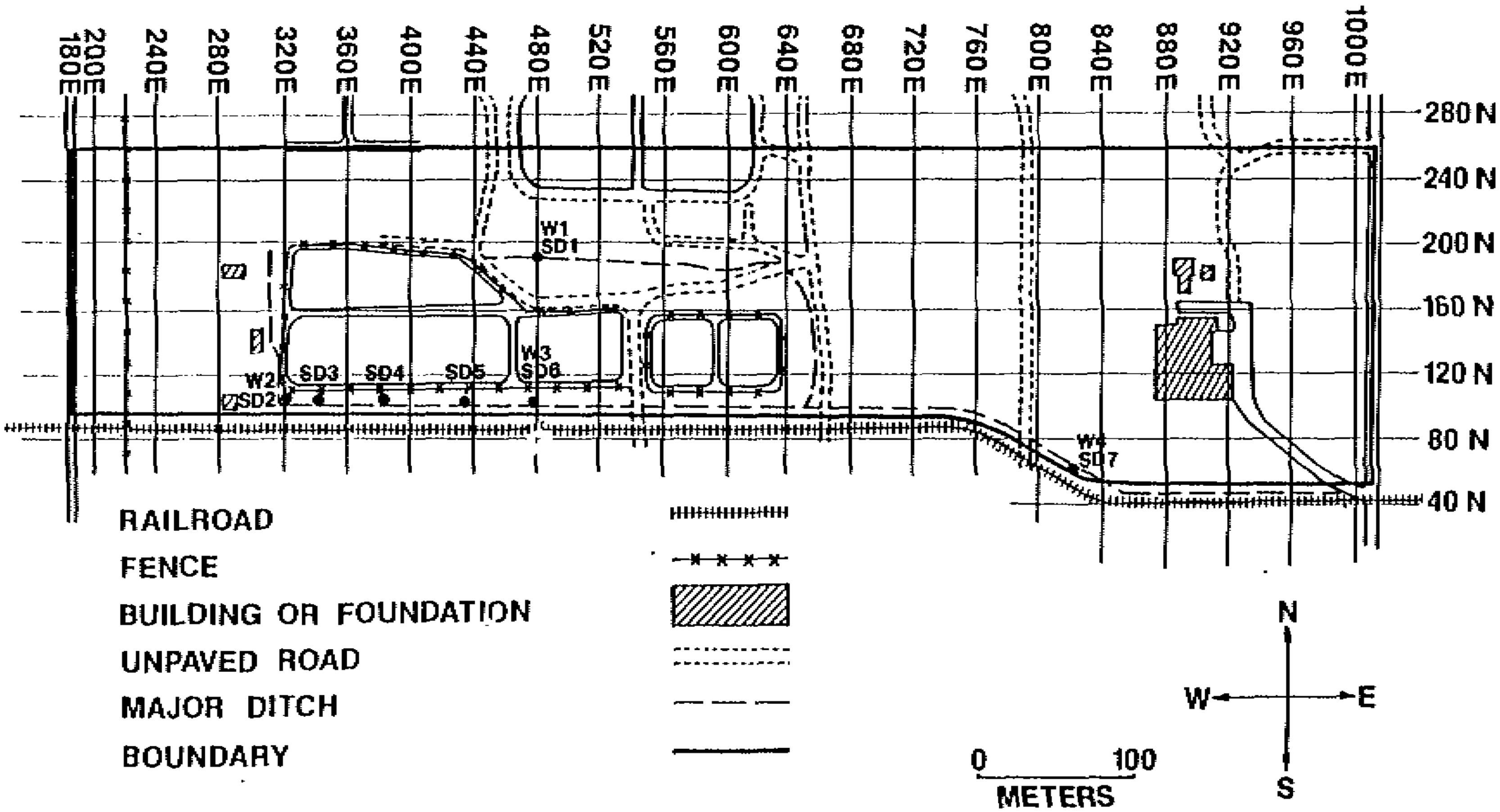

FIGURE 7. Locations of Sediment and Water Samples from Ditches.

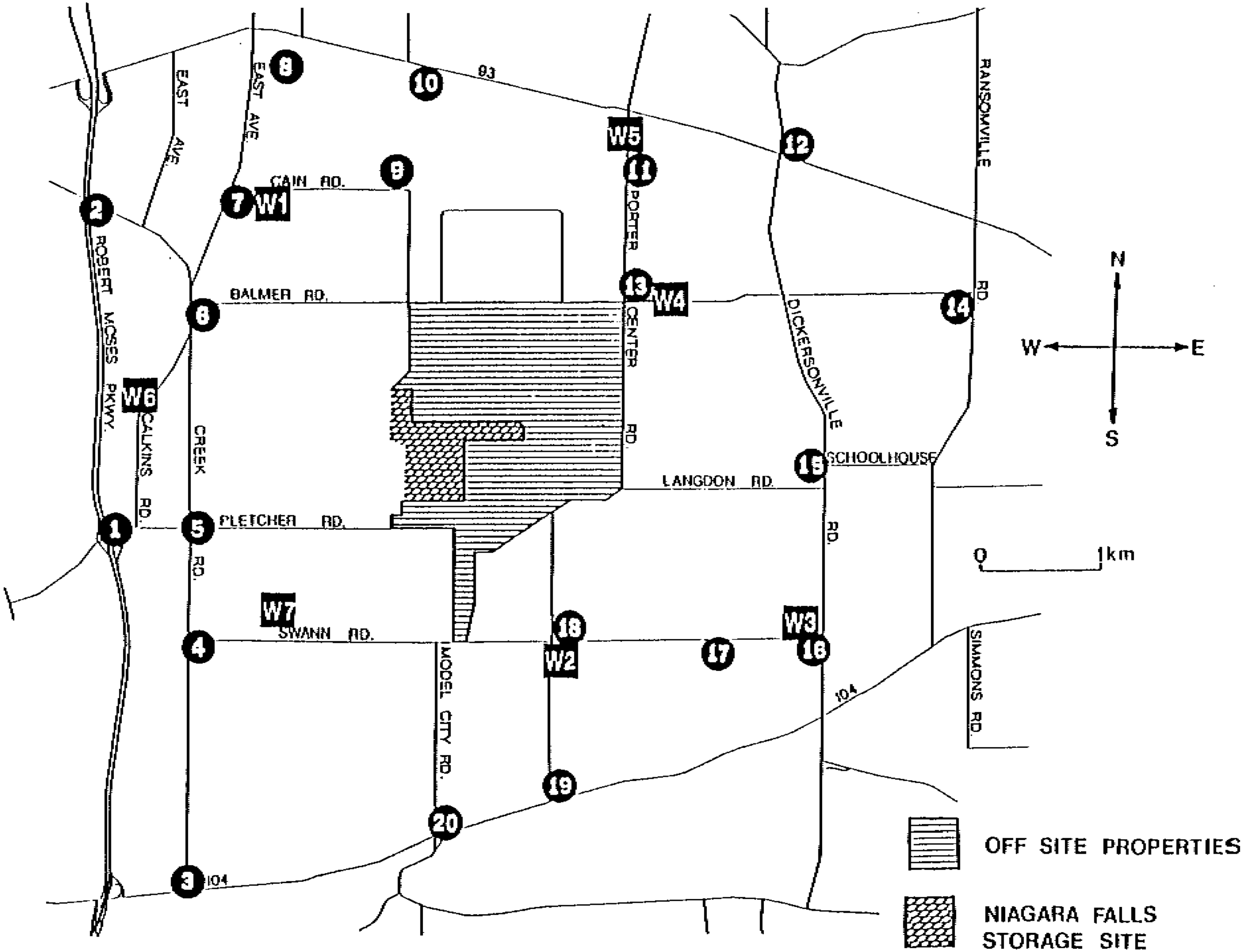

FIGURE 8. Map of Northern Niagara County, New York, Showing Locations of Background Measurements and Baseline Samples. (#1-20: soil samples and direct measurements; W1-W7: water samples)

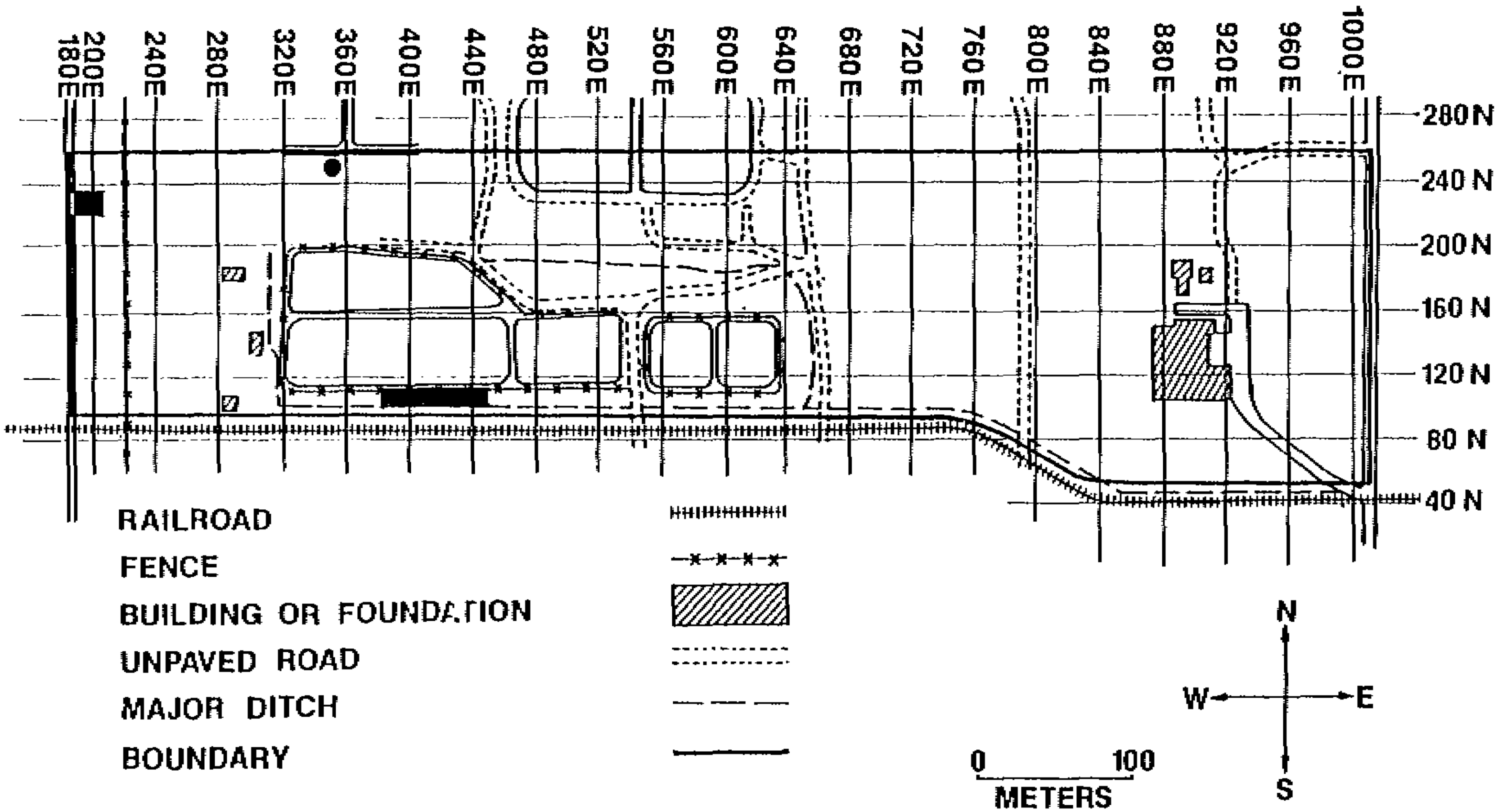

FIGURE 9. Map of NFSS Off-Site Property E Indicating Areas Where Radionuclide Concentrations in Soil Exceed Criteria. (Darkly shaded areas represent regions of generally elevated radiation levels. Dots indicate isolated "hot spots".)

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	0.35 ± 0.08
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	<0.21	<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 8.
[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 8.
[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)
240	180	8	8	17
240	200	8	8	8
240	240	7	8	24
240	280	8	7	15
240	320	7	7	13
240	360	7	7	11
240	400	7	7	38
240	440	8	7	26
240	480	6	7	9
240	520	7	7	31
240	560	7	7	16
240	600	7	7	21
240	640	8	8	21
240	680	8	8	25
240	720	8	8	21
240	760	8	8	17
240	800	8	8	24
240	840	7	8	28
240	880	7	8	27
240	920	7	7	10
240	960	7	7	16
240	1000	7	6	22
240	1008	6	6	8
200	180	5	6	6
200	200	7	7	13
200	240	7	7	30
200	280	7	7	18
200	320	8	8	19
200	360	9	12	23
200	400	7	8	29
200	440	8	8	18
200	480	7	7	7
200	520	6	6	15
200	560	7	7	23
200	600	7	7	20
200	640	7	7	17
200	680	8	8	22
200	720	7	8	12
200	760	8	8	8
200	800	7	7	30
200	840	7	7	28

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)
200	880	7	8	25
200	920	7	7	31
200	960	7	7	8
200	1000	7	7	10
200	1008	7	7	7
160	180	5	5	7
160	200	7	7	7
160	240	7	7	14
160	280	7	7	7
160	320	8	9	22
160	360	a	a	a
160	400	a	a	a
160	440	a	a	a
160	480	a	a	a
160	520	a	a	a
160	560	5	5	6
160	600	5	5	5
160	640	7	7	17
160	680	8	8	8
160	720	8	8	17
160	760	8	8	19
160	800	8	8	19
160	840	8	8	25
160	880	7	7	14
160	920	5	5	10
160	960	7	7	16
160	1000	7	7	14
160	1008	6	6	8
120	180	7	7	7
120	200	7	7	7
120	240	7	7	16
120	280	6	6	9
120	320	6	7	11
120	360	a	a	a
120	400	a	a	a
120	440	a	a	a
120	480	a	a	a
120	520	a	a	a
120	560	a	a	a
120	600	a	a	a
120	640	7	7	11

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	680	7	7	10
120	720	7	7	16
120	760	7	7	7
120	800	7	7	16
120	840	7	7	14
120	870	6	6	6
120	925	4	5	6
120	960	6	7	7
120	1000	6	7	15
120	1008	7	7	7
110	360	7	7	9
110	400	8	9	12
110	440	9	9	13
110	480	6	6	6
110	520	6	6	6
110	560	6	7	20
110	600	6	6	16
80	760	7	8	19
80	800	8	8	27
80	840	7	8	12
80	880	8	8	14
80	920	8	8	21
80	960	7	7	9
80	1000	7	7	20
80	1017	7	7	18

[a]Grid point not accessible due to presence of waste treatment lagoon.

TABLE 3

DIRECT RADIATION LEVELS
MEASURED ON THE RETENTION POND BERM

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)
110	385	8	8	11
110	390	10	10	36
110	395	9	10	23
110	400	8	9	12
110	405	9	12	19
110	410	9	8	17
110	415	11	10	36
110	420	11	8	22
110	425	9	8	8
110	430	10	10	24
110	435	9	8	15
110	440	9	9	13
110	445	9	8	39
110	450	8	8	8
107	385	8	9	23
107	390	11	11	28
107	395	12	12	32
107	400	10	12	32
107	405	12	13	22
107	410	17	17	26
107	415	8	10	44
107	420	18	20	190
107	425	17	20	150
107	430	16	21	92
107	435	14	16	60
107	440	12	12	36
107	445	12	12	33
107	450	9	9	12
104	385	12	12	32
104	390	16	17	130
104	395	15	16	140
104	400	14	14	51
104	405	13	14	75
104	410	16	16	63
104	415	17	17	100
104	420	17	18	150
104	425	17	17	76

TABLE 3, cont.

DIRECT RADIATION LEVELS
MEASURED ON THE RETENTION POND BERM

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)
104	430	14	17	96
104	435	14	12	39
104	440	8	8	11
104	445	8	8	35
104	450	9	9	30

TABLE 4

DIRECT RADIATION LEVELS AT LOCATIONS IDENTIFIED BY THE WALKOVER SURFACE SCAN

Grid Location[a]		Exposure Rate (μR/h)		Surface Dose Rate (μrad/h)	Sample Identification[b]	Contact Exposure Rate After Sample Removal (μR/h)
N	E	Contact	1 m Above Surface			
251	359	79	8	79	-----[c]	-----
220-238	182-204	14-35	13-26	-----	-----	-----
235	185	35	26	36	B1	35
234	185	31	22	48	B2	31
197	376	37	9	41	B3	12
197	400	14	8	38	B4	14
197	416	31	11	51	B5	12
155	315	18	8	35	B6	10
103-112	385-450	8-1150	8-21	-----	-----	-----
107	416	170	21	370	B7	21
107	420	37	17	77	B8	20
107	433	82	16	92	B9	82
106	391	510	17	510	B10	14
106	408	120	17	120	B11	18
106	414	160	20	220	B12	160
106	427	45	17	49	B13	26
106	433	80	17	140	-----	-----
106	442	410	14	470	B14	14
106	445	160	16	6880	-----	-----
105	400	34	15	50	-----	-----

TABLE 4, cont.

DIRECT RADIATION LEVELS AT LOCATIONS
IDENTIFIED BY THE WALKOVER SURFACE SCAN

Grid Location		Exposure Rate (μR/h)		Surface Dose Rate (μrad/h)	Sample Identification	Contact Exposure Rate After Sample Removal (μR/h)
N	E	Contact	1 m Above Surface			
105	403	1150	17	110,000	B15	27
105	436	110	14	7,550	-----	-----
104	387	27	12	27	B16	27
104	412	84	17	180	B17	17
66	798	190	10	290	B18	11

[a]Refer to Figures 4 and 5.
[b]Radionuclide analyses of samples presented in Table 6 and 7.
[c]Dash indicates measurement or sampling not performed.

TABLE 5

RADIONUCLIDE CONCENTRATIONS IN SURFACE SOIL SAMPLES
COLLECTED FROM 40 M GRID INTERVALS

Grid Location		Radionuclide Concentrations (pCi/g)				
N	W	Ra-226	U-235	U-238	Cs-137	Th-232
240	183	2.51 ± 0.41[a]	<0.26	3.08 ± 1.19	0.86 ± 0.15	0.43 ± 0.35
240	200	0.85 ± 0.20	<0.20	1.45 ± 0.89	0.49 ± 0.11	0.73 ± 0.63
240	240	0.89 ± 0.23	<0.22	1.89 ± 1.52	0.56 ± 0.13	0.57 ± 0.24
240	280	0.98 ± 0.30	<0.33	0.34 ± 2.13	1.09 ± 0.17	1.08 ± 0.42
240	320	0.90 ± 0.26	<0.27	1.89 ± 1.45	0.43 ± 0.11	1.19 ± 0.35
240	360	1.60 ± 0.25	<0.28	<0.86	0.35 ± 0.10	0.86 ± 0.27
240	400	3.03 ± 0.40	<0.19	1.25 ± 1.71	0.06 ± 0.07	1.14 ± 0.37
240	440	0.94 ± 0.25	0.35 ± 0.11	2.41 ± 1.54	0.20 ± 0.07	0.95 ± 0.27
240	480	b	b	b	b	b
240	520	b	b	b	b	b
240	545	0.78 ± 0.24	<0.29	1.80 ± 1.69	0.07 ± 0.12	1.85 ± 0.47
240	600	b	b	b	b	b
240	640	0.85 ± 0.33	<0.20	<0.72	0.15 ± 0.10	0.80 ± 0.33
240	680	0.99 ± 0.25	<0.19	1.33 ± 1.24	<0.03	1.29 ± 0.36
240	720	0.60 ± 0.21	<0.17	<0.75	<0.04	0.99 ± 0.45
240	760	0.85 ± 0.21	<0.17	<0.62	<0.03	0.98 ± 0.30
240	800	0.79 ± 0.23	<0.19	1.00 ± 1.61	<0.03	0.85 ± 0.28
240	840	0.78 ± 0.26	<0.19	1.29 ± 1.43	<0.03	0.93 ± 0.43
240	880	0.84 ± 0.24	<0.20	1.26 ± 1.58	<0.03	0.91 ± 0.55
240	920	0.34 ± 0.23	<0.19	<0.65	<0.04	0.96 ± 0.36
240	960	1.14 ± 0.29	<0.27	4.49 ± 1.33	0.33 ± 0.13	1.03 ± 0.52
240	1000	0.83 ± 0.26	<0.22	1.52 ± 1.70	0.54 ± 0.12	1.10 ± 0.38
240	1005	0.69 ± 0.15	<0.15	<0.51	0.05 ± 0.03	0.60 ± 0.30
200	183	1.29 ± 0.25	<0.19	1.52 ± 1.41	0.54 ± 0.09	1.40 ± 0.36
200	200	0.90 ± 0.25	<0.23	1.17 ± 1.93	0.42 ± 0.16	0.86 ± 0.33
200	240	0.94 ± 0.25	<0.26	0.99 ± 2.05	0.39 ± 0.08	1.16 ± 0.36
200	280	0.66 ± 0.19	<0.17	<0.65	0.07 ± 0.04	0.92 ± 0.33

TABLE 5, cont.

RADIONUCLIDE CONCENTRATIONS IN SURFACE SOIL SAMPLES
COLLECTED FROM 40 M GRID INTERVALS

Grid Location		Radionuclide Concentrations (pCi/g)				
N	W	Ra-226	U-235	U-238	Cs-137	Th-232
200	320	1.95 ± 0.33	<0.31	4.00 ± 1.75	0.37 ± 0.09	0.80 ± 0.30
200	360	1.95 ± 0.31	<0.23	2.56 ± 2.10	0.02 ± 0.03	0.97 ± 0.69
200	400	0.99 ± 0.24	<0.28	0.82 ± 1.61	<0.07	1.10 ± 0.33
200	440	0.95 ± 0.24	<0.26	1.89 ± 0.99	<0.06	1.16 ± 0.32
200	480	0.80 ± 0.18	<0.16	<0.61	<0.03	0.68 ± 0.28
200	520	0.69 ± 0.24	<0.18	<0.65	0.11 ± 0.10	0.87 ± 0.36
200	560	0.60 ± 0.24	<0.18	1.56 ± 1.25	0.09 ± 0.04	0.95 ± 0.31
200	600	0.78 ± 0.26	<0.26	1.65 ± 1.52	0.15 ± 0.09	1.05 ± 0.42
200	640	0.64 ± 0.24	0.24 ± 0.40	0.98 ± 1.18	<0.04	0.61 ± 0.35
200	680	0.85 ± 0.28	<0.27	3.18 ± 1.69	0.13 ± 0.06	1.37 ± 0.33
200	720	0.78 ± 0.26	<0.26	2.05 ± 1.42	0.06 ± 0.12	0.89 ± 0.51
200	760	0.89 ± 0.23	<0.23	2.37 ± 1.45	<0.03	1.00 ± 0.28
200	800	0.65 ± 0.21	<0.20	1.17 ± 1.53	<0.03	0.83 ± 0.32
200	840	0.73 ± 0.16	<0.25	<0.75	<0.04	0.90 ± 0.31
200	880	0.83 ± 0.21	<0.17	<0.59	<0.03	0.76 ± 0.27
200	920	0.58 ± 0.18	<0.13	<0.30	<0.02	0.54 ± 0.34
200	960	0.66 ± 0.25	<0.20	<0.80	0.37 ± 0.11	0.78 ± 0.39
200	1000	c	c	c	c	c
200	1005	0.69 ± 0.16	<0.22	<0.68	<0.04	1.08 ± 0.33
160	183	0.73 ± 0.16	<0.22	<0.70	0.44 ± 0.10	0.69 ± 0.27
160	200	0.74 ± 0.21	<0.23	1.03 ± 1.58	0.60 ± 0.12	1.08 ± 0.37
160	240	0.63 ± 0.15	<0.25	2.44 ± 1.25	<0.03	1.18 ± 0.33
160	280	1.10 ± 0.25	<0.27	<0.88	0.36 ± 0.09	1.24 ± 0.56
160	320	1.56 ± 0.25	0.93 ± 0.56	3.33 ± 1.01	<0.04	0.80 ± 0.34
160	360	b	b	b	b	b
160	400	b	b	b	b	b
160	440	b	b	b	b	b

TABLE 5, cont.

RADIONUCLIDE CONCENTRATIONS IN SURFACE SOIL SAMPLES
COLLECTED FROM 40 M GRID INTERVALS

Grid Location		Radionuclide Concentrations (pCi/g)				
N	W	Ra-226	U-235	U-238	Cs-137	Th-232
160	480	b	b	b	b	b
160	520	b	b	b	b	b
160	560	0.99 ± 0.18	<0.23	<0.68	<0.05	0.50 ± 0.22
160	600	0.94 ± 0.28	<0.25	0.84 ± 1.44	<0.04	0.81 ± 0.31
160	640	1.03 ± 0.29	<0.27	2.56 ± 1.62	0.11 ± 0.08	0.78 ± 0.32
160	680	0.70 ± 0.26	<0.26	2.93 ± 1.03	<0.04	1.21 ± 0.32
160	720	0.98 ± 0.20	0.33 ± 0.38	1.64 ± 1.30	0.06 ± 0.05	1.04 ± 0.38
160	760	0.83 ± 0.18	<0.18	1.54 ± 1.43	<0.03	0.80 ± 0.48
160	800	0.79 ± 0.21	<0.20	<0.70	0.08 ± 0.09	0.85 ± 0.32
160	840	0.85 ± 0.23	<0.27	1.27 ± 1.73	<0.04	1.16 ± 0.54
160	880	0.58 ± 0.16	<0.22	<0.66	<0.03	0.72 ± 0.25
160	920	0.74 ± 0.20	<0.16	1.22 ± 1.45	<0.03	0.66 ± 0.32
160	960	0.70 ± 0.25	<0.22	1.24 ± 1.64	0.73 ± 0.14	1.34 ± 0.04
160	1000	0.65 ± 0.23	<0.18	<0.70	0.42 ± 0.10	0.86 ± 0.27
160	1005	0.68 ± 0.16	<0.18	0.86 ± 1.14	0.09 ± 0.04	0.59 ± 0.31
120	183	1.36 ± 0.31	<0.30	0.95 ± 0.84	1.10 ± 0.14	0.60 ± 0.53
120	200	0.93 ± 0.24	0.37 ± 0.30	0.66 ± 1.179	0.69 ± 0.16	1.07 ± 0.45
120	240	0.81 ± 0.18	<0.23	<0.73	<0.03	0.82 ± 0.26
120	280	0.81 ± 0.19	<0.20	1.08 ± 1.57	0.42 ± 0.10	1.14 ± 0.36
120	320	0.95 ± 0.23	<0.20	1.43 ± 1.25	<0.04	0.90 ± 0.27
120	360	b	b	b	b	b
120	400	b	b	b	b	b
120	440	b	b	b	b	b
120	480	b	b	b	b	b
120	520	b	b	b	b	b
120	560	b	b	b	b	b
120	600	b	b	b	b	b

TABLE 5, cont.

RADIONUCLIDE CONCENTRATIONS IN SURFACE SOIL SAMPLES
COLLECTED FROM 40 M GRID INTERVALS

Grid Location		Radionuclide Concentrations (pCi/g)				
N	W	Ra-226	U-235	U-238	Cs-137	Th-232
120	640	0.85 ± 0.25	<0.18	<0.69	<0.04	0.92 ± 0.39
120	680	0.89 ± 0.18	<0.16	1.40 ± 0.80	<0.03	0.88 ± 0.27
120	720	0.88 ± 0.23	<0.24	<0.80	<0.03	0.98 ± 0.27
120	760	0.66 ± 0.26	<0.19	<0.69	<0.03	0.94 ± 0.40
120	800	0.91 ± 0.26	<0.21	0.86 ± 1.90	0.06 ± 0.12	0.76 ± 0.41
120	840	0.73 ± 0.23	<0.18	1.58 ± 1.46	0.05 ± 0.06	0.79 ± 0.31
120	880	b	b	b	b	b
120	920	b	b	b	b	b
120	960	0.96 ± 0.29	<0.33	<1.04	1.03 ± 0.17	1.45 ± 0.45
120	1000	0.91 ± 0.25	<0.29	2.32 ± 1.81	0.72 ± 0.18	1.23 ± 0.41
120	1005	0.89 ± 0.29	<0.17	1.06 ± 1.72	0.06 ± 0.04	0.90 ± 0.27
110	360	1.26 ± 0.28	<0.29	4.47 ± 1.13	0.09 ± 0.07	0.94 ± 0.43
110	400	1.30 ± 0.26	<0.28	2.32 ± 0.92	0.09 ± 0.04	0.75 ± 0.28
110	440	0.91 ± 0.23	<0.19	<0.69	0.10 ± 0.08	1.02 ± 0.36
110	480	0.80 ± 0.20	<0.28	4.49 ± 1.68	<0.04	0.91 ± 0.30
110	520	0.90 ± 0.21	<0.25	1.28 ± 1.17	0.28 ± 0.08	1.02 ± 0.32
110	560	0.80 ± 0.24	<0.20	1.29 ± 1.57	0.04 ± 0.08	0.68 ± 0.32
110	600	0.64 ± 0.18	<0.20	1.07 ± 1.55	<0.04	0.85 ± 0.28
80	760	0.81 ± 0.23	<0.27	2.23 ± 1.05	0.24 ± 0.12	0.98 ± 0.32
80	800	0.85 ± 0.23	<0.18	1.63 ± 0.80	0.05 ± 0.04	0.67 ± 0.28
80	840	1.14 ± 0.26	<0.22	<0.69	0.82 ± 0.12	0.89 ± 0.33

TABLE 5, cont.

RADIONUCLIDE CONCENTRATIONS IN SURFACE SOIL SAMPLES
COLLECTED FROM 40 M GRID INTERVALS

Grid Location		Radionuclide Concentrations (pCi/g)				
N	W	Ra-226	U-235	U-238	Cs-137	Th-232
80	880	1.01 ± 0.33	<0.27	<0.80	0.20 ± 0.12	0.87 ± 0.24
80	920	0.86 ± 0.24	<0.25	1.59 ± 0.86	<0.03	1.26 ± 0.45
80	960	0.80 ± 0.23	<0.23	0.97 ± 1.63	0.90 ± 0.16	0.62 ± 0.40
80	1000	0.96 ± 0.23	<0.16	<0.64	0.22 ± 0.10	0.64 ± 0.23

[a]Errors are 2σ based on counting statistics.
[b]Grid point not accessible due to presence of waste treatment facility or building.
[c]Sample not collected.

TABLE 6

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

Sample No.	Grid Location N	Grid Location E	Radionuclide Concentrations (pCi/g)[a] Ra-226	U-235	U-238	Cs-137	Th-232
B1	235	185	11.9 ± 0.7[b]	0.83 ± 0.13	11.9 ± 3.8	0.79 ± 0.15	<0.32
B2	234	185	9.73 ± 0.67	<0.55	10.3 ± 2.4	0.72 ± 0.14	0.47 ± 0.56
B3	197	376	c	c	c	c	c
B4	197	400	4.23 ± 0.41	0.74 ± 0.65	8.56 ± 1.56	<0.04	1.15 ± 0.48
B5	197	416	c	c	c	c	c
B6	155	315	514 ± 5	<2.57	<8.05	<0.34	<1.40
B7	107	416	c	c	c	c	c
B8	107	420	c	c	c	c	c
B9	107	433	19.3 ± 0.7	<0.83	28.5 ± 2.7	<0.09	1.04 ± 0.65
B10A	106	391	20.6 ± 1.0	1.48 ± 1.27	11.7 ± 2.4	<0.08	1.42 ± 1.25
B10B	106	391	c	c	c	c	c
B11	106	408	c	c	c	c	c
B12	106	414	11.6 ± 0.7	<0.71	70.8 ± 3.5	0.36 ± 0.14	1.06 ± 0.51
B13	106	427	c	c	c	c	c
B14	106	442	c	c	c	c	c
B15A	105	403	51.3 ± 4.9	1120 ± 15	22600 ± 81	<0.90	<2.33
B15B	105	403	c	c	c	c	c
B16	104	387	4.56 ± 0.43	1.02 ± 0.74	18.7 ± 3.0	0.11 ± 0.06	0.89 ± 0.44
B17	104	412	c	c	c	c	c
B18	66	798	c	c	c	c	c

[a]Refer to Table 4 for direct radiation levels.

[b]Errors are 2σ based on counting statistics.

[c]Small sample with Ra-226 activity too high for gamma spectrometry analysis: Refer to Table 7 for total activity.

TABLE 7

RA-226 ACTIVITY IN SAMPLES FROM
LOCATIONS OF ELEVATED DIRECT RADIATION LEVELS

Sample	Grid Location		Nature of Sample	Ra-226 (μCi)
	N	E		
B3	197	376	White Chips	2.09
B5	197	416	" "	2.14
B7	107	416	" "	1.06
B8	107	420	" "	0.55
B10B	106	391	" "	11.6
B11	106	408	" "	1.64
B13	106	427	" "	8.82
B14	106	442	" "	1.18
B15B	105	403	" "	2.06
B17	104	412	" "	2.65
B18	66	798	" "	1.12

TABLE 8

RADIONUCLIDE CONCENTRATIONS IN BOREHOLE SOIL SAMPLES

Borehole[a] No.	Grid Location N	Grid Location E	Depth (m)	Radionuclide Concentrations (pCi/g) Ra-226	U-235	U-238	Cs-137	Th-232
H1	244	187	Surface	0.98 ± 0.19[b]	<0.28	<0.87	0.40 ± 0.09	1.07 ± 0.41
H2	255	400	Surface	1.11 ± 0.20	<0.25	1.69 ± 1.57	<0.04	1.01 ± 0.28
			1	0.96 ± 0.26	<0.19	1.67 ± 1.69	<0.03	0.93 ± 0.50
H3	209	992	Surface	0.99 ± 0.24	<0.29	0.71 ± 1.58	0.30 ± 0.11	0.90 ± 0.34
			0.5	0.83 ± 0.18	<0.18	<0.64	<0.03	1.04 ± 0.44
			1	1.01 ± 0.34	<0.25	1.03 ± 2.34	<0.03	0.86 ± 0.68
			2	0.83 ± 0.25	<0.19	2.17 ± 1.39	<0.02	0.80 ± 0.35
			3	0.74 ± 0.26	<0.21	1.69 ± 1.30	<0.03	0.65 ± 0.37
H4	89	995	Surface	0.60 ± 0.21	<0.18	<0.74	0.36 ± 0.09	0.57 ± 0.26
			0.5	0.98 ± 0.28	<0.19	1.11 ± 0.84	<0.03	0.62 ± 0.48
H5	160	790	Surface	0.76 ± 0.18	<0.20	<0.65	0.07 ± 0.07	0.67 ± 0.25
			0.3	1.13 ± 0.31	<0.34	1.24 ± 2.36	<0.04	1.28 ± 0.40
H6	108	673	Surface	0.78 ± 0.29	<0.20	<0.68	<0.03	0.87 ± 0.26
			0.5	0.86 ± 0.21	<0.20	0.86 ± 1.56	<0.03	0.51 ± 0.54
			1	1.00 ± 0.26	<0.22	<0.82	<0.04	1.07 ± 0.42
			2	0.85 ± 0.26	<0.36	<1.05	<0.05	0.99 ± 0.43
H7	105	380	Surface	0.66 ± 0.20	<0.19	<0.66	<0.03	0.91 ± 0.36
			0.6	0.93 ± 0.24	<0.17	0.73 ± 1.82	0.33 ± 0.09	0.68 ± 0.27
			1.5	0.86 ± 0.20	<0.26	0.57 ± 1.67	<0.03	1.02 ± 0.37

TABLE 8, cont.

RADIONUCLIDE CONCENTRATIONS IN BOREHOLE SOIL SAMPLES

Borehole[a] No.	Grid Location N	Grid Location E	Depth (m)	Radionuclide Concentrations (pCi/g) Ra-226	U-235	U-238	Cs-137	Th-232
H8	111	192	Surface	0.66 ± 0.24	<0.17	<0.57	<0.03	0.64 ± 0.27
			0.9	1.08 ± 0.38	<0.26	3.93 ± 2.81	<0.04	1.18 ± 0.36
H9	233	201	Surface	1.55 ± 0.36	<0.29	<0.98	<0.04	0.80 ± 0.44
			0.3	0.90 ± 0.21	<0.18	0.74 ± 1.41	0.08 ± 0.08	1.00 ± 0.36
H10	235	184	Surface	0.88 ± 0.63	<0.57	5.05 ± 2.85	0.52 ± 0.11	0.98 ± 0.50
			0.15	1.36 ± 0.28	<0.31	<1.06	<0.05	0.96 ± 0.30
			0.6	0.84 ± 0.19	<0.25	0.17 ± 0.46	<0.03	0.81 ± 0.29
H11	235	190	Surface	1.76 ± 0.31	<0.21	2.40 ± 0.95	<0.03	0.48 ± 0.33
			0.15	4.88 ± 0.40	<0.43	7.07 ± 1.40	<0.06	0.85 ± 0.47
			0.9	0.74 ± 0.16	<0.24	1.31 ± 1.24	<0.03	0.77 ± 0.45

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

TABLE 9

RADIONUCLIDE CONCENTRATIONS IN WATER SAMPLES

Sample Identification	Sample Type	Grid Location N	Grid Location E	Radionuclide Concentrations (pCi/l) Gross Alpha	Gross Beta	Ra-226
W1	Surface[a]	190	480	<3.66	22.7 ± 7.9	---[d]
W2	Surface[a]	102	320	21.6 ± 6.8[c]	27.5 ± 6.4	<0.17
W3	Surface[a]	102	480	33.3 ± 12.9	117 ± 14	<0.16
W4	Surface[a]	65	820	11.9 ± 4.2	8.43 ± 5.04	<0.18
W5	Subsurface Borehole H11[b]	235	190	7.53 ± 2.05	15.6 ± 2.7	<0.17
W6	Subsurface Borehole H8[b]	105	380	<8.49	63.5 ± 14.2	<0.17
W7	Subsurface Borehole H4[b]	89	995	3.7 ± 3.0	0.69 ± 4.2	---[d]

[a]Refer to Figure 7.
[b]Refer to Figure 6.
[c]Errors are 2σ based on counting statistics.
[d]Dashes indicated analyses not performed.

TABLE 10

RADIONUCLIDE CONCENTRATIONS IN SEDIMENT SAMPLES FROM DRAINAGE DITCHES

Sample No.	Grid Location[a]		Radionuclide Concentrations (pCi/g)				
	N	W	Ra-226	U-235	U-238	Cs-137	Th-232
SD1	190	480	0.98 ± 0.24[b]	<0.23	0.92 ± 1.62	0.11 ± 0.09	0.82 ± 0.45
SD2	102	320	0.85 ± 0.30	<0.28	4.46 ± 1.47	0.10 ± 0.90	2.14 ± 0.55
SD3	102	340	0.89 ± 0.21	<0.28	1.78 ± 1.27	0.19 ± 0.07	0.71 ± 0.23
SD4	102	380	2.25 ± 0.36	<0.23	<0.86	0.11 ± 0.05	0.90 ± 0.42
SD5	102	440	1.34 ± 0.31	0.76 ± 0.55	5.68 ± 2.20	0.09 ± 0.09	0.84 ± 0.45
SD6	102	480	1.14 ± 0.30	<0.28	3.69 ± 1.70	0.09 ± 0.11	1.19 ± 0.38
SD7	65	820	0.95 ± 0.33	<0.31	1.52 ± 1.40	0.13 ± 0.06	0.93 ± 0.50

[a]Refer to Figure 7.

[b]Errors are 2σ based on counting statistics.

TABLE 11

SUMMARY OF WAREHOUSE SURVEY

Building	Gamma Exposure[a] Rates 1 Meter Above the Floor (μR/h)	Surface Contamination Levels: Direct Measurement			Surface Contamination Levels: Transferable	
		Alpha (d/m/100cm²)	Beta-Gamma (d/m/100cm²)	Beta-Gamma Dose Rate (mrad/h)	Alpha (d/m/100cm²)	Beta-Gamma (d/m/100cm²)
Warehouse	5-6	<27-57	<310-413	0.03 - 0.04	0 - 4.4	<3.7 - 6.5

[a]Three sets of drums (1-4 drums/set) were noted to have slightly elevated levels up to 24 μR/h.

TABLE 12

LISTING OF AREAS ON PROPERTY E WHICH
EXCEED RESIDUAL CONTAMINATION CRITERIA

Grid Location[a]		Radionuclides	Estimated Quantities of Material Exceeding Guidelines			Remarks
N	E		(Area (m^2)	Depth (m)	Volume (m^3)	
251	359	-----[b]	-----	-----	<1	Isolated "hot spot".
220-238	182-204	Ra-226, U-238[c]	400	0.15	60	
103-112	385-450	Ra-226, U-238	580+	1-2	580-1160+	Exact area and depth along the retention pond was unknown because borehole drilling was not possible. The bank was inaccessible and damage to the pond was likely.

[a]Refer to Figure 9.
[b]Dash indicates determination was not made.
[c]Naturally occuring material in rock fill.

REFERENCES

1. E.A. Vierzba and A. Wallo, Background and Resurvey Recommendations for the Atomic Energy Commission Portion of the Lake Ontario Ordnance Works, Aerospace Corp., November 1982.

2. Oak Ridge Operations, U.S. Atomic Energy Commission, Radiation Survey and Decontamination Report of the Lake Ontario Ordnance Works Site, Oak Ridge, TN, January 1973.

3. T.E. Myrick, et al., Preliminary Results of the Ground-Level Gamma-Ray Scan Survey of the Former Lake Ontario Ordnance Works Site - Draft Report, ORNL, Oak Ridge, TN, 1981.

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 rates (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 several locations on the NFSS 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 was 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-233, 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 factors 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 and Sediment Sample Analysis

Gamma Spectrometry

Soil and sediment 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 (Princeton Gamma Tech) 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. Fifty milliliters of each was were evaporated to dryness and counted for gross alpha and gross beta using a Tennelec Model LB 5100 low-background proportional counter.

Analysis for Ra-226 was performed using the standard technique EPA 600/4-80-032 (August 1980).

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 equipment operation within acceptable statistical fluctuations. 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

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

(Review Within DOE Continuing)

Presented here are the residual contamination cleanup and waste control guidelines of general applicability to the FUSRAP project and remote SFMP sites[1/]. A site-specific analysis will be prepared for each FUSRAP and remote SFMP site prior to determining residual contamination guidelines for a specific site. In addition, it is the policy of the DOE to decontaminate sites in a manner consistent with DOE's as-low-as-reasonably-achievable (ALARA) policy. ALARA will be considered in reducing levels of residual contamination below applicable dose limits. ALARA will be implemented using cost/benefit considerations, and applied on a site-specific basis.

The soil residual contamination guidelines 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 radium-226 and thorium-230 guidelines include an additional limitation for buildup of radon-222 decay products in buildings. The aggregate of the contribution from all major pathways, based on scenarios for permanent intrusion, e.g., establishing residences on the site, was assumed. In most circumstances, the probability is low that such an intrusion will occur. Also, conservative assumptions were used in deriving these guidelines to ensure that a particular dose limit would not be exceeded. Use of these guidelines is additionally conservative because the pathways considered in the derivation of the guidelines assume all water intake and most food intake is from the site. Also, the FUSRAP and remote SFMP 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 or remote SFMP sites decontaminated to these guidelines will not be appreciably different from that normally received from natural background radiation.

The residual contamination guidelines for surface contamination of structures were adapted from guidelines developed by the U. S. Nuclear Regulatory Commission (NRC) for decontamination of facilities and equipment prior to release for unrestricted use or termination of licenses for byproduct, source, or special nuclear material[2/]. The waste control guidelines are consistent with applicable DOE Orders and EPA's regulations for inactive uranium milling sites, 40 CFR Part 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/] U. S. Nuclear Regulatory Commission 1982 Guidelines for Decontamination of Facilities and Equipment Prior to Release for Unrestricted Use or Termination of Licenses for Byproduct, Source, or Special Nuclear Material. Division of Fuel Cycle and Material Safety, Washington, DC.

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

The following guidelines 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. A site-specific analysis will be prepared for each site prior to determining residual contamination guidelines for a specific site. 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 on a site-specific basis. Site-specific guidelines and ALARA policy will be determined by DOE on a site-specific basis and an ALARA report filed on completion of remedial action at a site. Existing state and federal standards will be applied for water protection. 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) Guidelines (Maximum Limits for Unrestricted Use)

Radionuclide	Soil Criteria[2/,3/,4/] (pCi/g above background)
U-Natural[5/]	75
U-238[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	60
Pu-241[8/]	2400
Pu-238, 239, 240	300
Cs-137	80

Sr-90	300
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 guideline 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 guidelines 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 guidelines are allowable provided that the average over 100 m^2 is not exceeded. However, DOE ALARA policy will be considered on a site-specific basis when dealing with elevated localized concentrations.

5/ A curie of natural uranium means the sum of 3.7×10^{10} disintegrations per second (dis/s) over any 15cm thick layers from U-238 plus 3.7×10^{10} dis/s from U-234 plus 1.7×10^{9} 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 guideline was derived from the Am-241 concentration.

2. Structure Guidelines (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 R/h) above background in any occupied or habitable building.

c. Indoor/Outdoor Structure Surface Contamination

Radionuclides 2/	Allowable Surface Residual Contamination 1/ ($dpm/100\ cm^2$) Average 3/,4/	Maximum 4/,5/	Removable 4/,6/
Transuranics, Ra-226, Ra-228, Th-230, Th-228, Pa-231, Ac-227, I-125, I-129	100	300	20
U-Natural, Th-232, Sr-90, Fr-223, Ra-224, U-232, I-126, I-131, I-133	1,000	3,000	200
U-Natural, U-235, U-238, and associated decay products	5,000	15,000	1,000
Beta-gamma emitters (radionuclides with decay modes other than alpha emission or spontaneous fission) except Sr-90 and others noted above	5,000	15,000	1,000

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

2/ Where surface contamination by both alpha- and beta-gamma-emitting radionuclides exists, the limits established for alpha- and beta-gamma-emitting radionuclides shall apply independently.

3/ Measurements of average contaminant should not be averaged over more than 1 m^2. For objects of less surface area, the average shall be derived for each such object.

4/ The average and maximum radiation levels associated with surface contamination resulting from beta-gamma emitters should not exceed 0.2 mrad/h at 1 cm and 1.0 mrad/h at 1 cm, respectively, measured through not more than 7 mg/cm^2 of total absorber.

5/ The maximum contamination level applies to an area of not more than 100 cm^2.

6/ The amount of removable radioactive material per 100 cm^2 of surface area should be determined by wiping that area with dry filter or soft absorbent paper, applying moderate pressure, and assessing the amount of radioactive material on the wipe with an appropriate instrument of known efficiency. When removable contamination on objects of less surface area is determined, the pertinent levels shall be reduced proportionately and the entire surface shall be wiped.

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

Specified here are the control requirements for radioactive wastes and residues related to the nuclear fuel cycle at FUSRAP and remote SFMP sites. It is the policy of DOE to store radioactive wastes in a manner representing sound engineering practices consistent with DOE's ALARA policy.

1. Interim Storage

All operational and control requirements specified in the following DOE Orders and other items 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. 5820, Radioactive Waste Management.

g. 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.

h. 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).

i. 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 requirement 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 requirements 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

Exceptions may be made to the guidelines presented herein following analysis of the site-specific aspects of a candidate site. Specific situations that warrant consideration for modifying these guidelines are:

1. Where remedial actions would pose a clear and present risk of injury to workers or members of the public, notwithstanding reasonable measures to avoid or reduce risk.

2. Where remedial actions would produce environmental harm that is clearly excessive compared to the health benefits to persons living on or near affected sites, now or in the future, notwithstanding reasonable measures to limit damage to the environment. A clear excess of environmental harm is harm that is long-term, manifest, and grossly disproportionate to health benefits that may reasonably be anticipated.

3. Where the cost of remedial actions for contaminated soil is unreasonably high relative to long-term benefits and the residual radioactive materials do not pose a clear present or future hazard. The likelihood that buildings will be erected or that people will spend long periods of time at such a site should be considered in evaluating this hazard. Remedial actions will generally not be necessary where residual radioactive materials have been placed semipermanently in a location where site-specific factors limit their hazard and from which they are costly or difficult to remove, or where only minor quantities of residual radioactive materials are involved. Examples are residual radioactive materials under hard surface public roads and sidewalks, around public sewer lines, or in fence-post foundations. Supplemental standards shall not be applied at such sites, however, if individuals are likely to be exposed for long periods of time to radiation from such materials at levels above those that would prevail in Subpart A.

4. Where the cost of cleanup of a contaminated building is clearly unreasonably high relative to the benefits. Factors that shall be included in this judgment are the anticipated period of occupancy, the incremental radiation level that would be affected by remedial actions, the residual useful lifetime of the building, the potential for future construction at the site, and the applicability of less costly remedial methods than removal of residual radioactive materials.

5. Where there is no known remedial action.

D. GUIDELINE SOURCE

Guideline	Source
Residual Contamination Criteria[1/]	
Soil Guideline	DOE Order 5480.1A, 40 CFR Part 192[2/]
Structure Guideline	40 CFR Part 192, NRC Guidelines for Decontamination of Facilities and Equipment Prior to Release for Unrestricted Use or Termination of Licenses for Byproduct, Source, or Special Nuclear Material (July 1982).
Control of Radioactive Wastes and Residues	
Interim Storage	DOE Order 5480.1A
Long-Term Management	40 CFR Part 192

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

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

APPENDIX C

REPORT OF GROUND-PENETRATING RADAR SURVEY
OF OFF-SITE PROPERTY E
AT THE NIAGARA FALLS STORAGE SITE

DETECTION SCIENCES GROUP

496 HEALD ROAD CARLISLE, MASSACHUSETTS 01741 (617)369-7999

FINAL REPORT

GROUND-PENETRATING RADAR SURVEY

AREA E

FORMER LAKE ONTARIO ORDNANCE WORKS

LEWISTON, NEW YORK

Prepared for

OAK RIDGE ASSOCIATED UNIVERSITIES, INC.
Oak Ridge, Tennessee 37830

Purchase Order No. C-29943-002
Letter Release No. 2
Dated May 6, 1983

Report No. J155-83

July 14, 1983

DETECTION SCIENCES GROUP

INTRODUCTION AND SUMMARY

On May 31 and June 1, 1983, Detection Sciences Group performed a ground-penetrating radar survey of the systematic and biased borehole locations on Property E at the former Lake Ontario Ordnance Works, Lewiston, New York. The survey was performed in accordance with Oak Ridge Associated Universities, Inc. Purchase Order No. C-29943-002, Letter Release No. 2, dated May 6, 1983. The survey work was conducted under the field direction and instructions of O.R.A.U personnel.

On Property E, a total of 11 boring locations were inspected. (This procedure has been described in detail in the Final Report on Property G, dated August, 1983, and will not be iterated here.) Potential drilling obstacles were found at 5 of the 11 locations; 4 systematic and 1 biased borings were relocated. The proposed locations for the 11 borings and the final locations of the borings are listed in Table I (attached).

The designations assigned to the borings are E1 through E11. There are 7 systematic borings and 4 biased borings, as listed in Table I. These designations are assigned by Detection Sciences Group in accordance with the sequence in which the borings were inspected, and are not designations assigned by O.R.A.U.

A grid survey was performed on the south bank of the southwestern pond in Area E. The survey ran from 385E to 441E, covering the bank from the chain-link fence at 112N to the edge of the ditch at 103N. There was a buried drum visible at the surface at the western end of the survey grid, at coordinate 103N, 388E. A total of 22 buried targets, whose size and shape appear to be the same as would be observed from a buried drum, are scattered through the survey grid. Some of these targets may be clay balls or other drum-sized objects rather than actual drums; the conservative approach is to identify all such targets, realizing that a certain percentage are likely to be "false alarms". The locations of all drum-sized radar targets are tabulated in Table II. Figure 1 plots the locations of these drum-sized targets.

A separate binding, titled "Radar Graphic Charts", contains all of the radar charts made in Area E. The proposed location of the boring is the centerpoint of each chart, shown by a pair of vertical dashed lines. The final location of each boring is shown by the arrow at the top of each chart. On the radar charts showing the grid survey on the south bank of the pond, the buried targets are highlighted in orange. The vertical scale for all charts is 1 inch = 1 foot. The horizontal scale is in meters, as marked at the top of the charts.

TABLE I

BORING LOCATIONS DETERMINED BY RADAR

AREA E - SYSTEMATIC BORINGS

Boring Number	Direction of Relocation	Proposed Location	Final Location	Notes
E1	Move 1m West	209N, 993E	209N, 992E	Deep Systematic
E2	[Move 1m West Move 1m South	90N, 996E	89N, 995E	Deep Systematic
E3	-	255N, 400E	255N, 400E	Deep Systematic
E4	Move 3m East	108N, 670E	108N, 673E	Deep Systematic
E5	-	160N, 790E	160N, 790E	Deep Systematic
E7	Move 1m South	112N, 192E	111N, 192E	Deep Systematic
E11	-	244N, 187E	244N, 187E	Deep Systematic

AREA E - BIASED BORINGS

Boring Number	Direction of Relocation	Proposed Location	Final Location	Notes
E6	-	107N, 380E	107N, 380E	Deep Bias
E8	-	235N, 190E	235N, 190E	Shallow Bias
E9	Move ½m East	235N, 184E	235N, 184.5E	Shallow Bias
E10	-	233N, 201E	231N, 201E	Shallow Bias*

* The Drillers were cautioned about a possible obstacle below the surface; this boring was not moved because the obstacle could be the cause of the bias reading.

TABLE II.

COORDINATE LOCATIONS OF DRUM-SIZED RADAR TARGETS,
SOUTH BANK OF POND, AREA E

Radar Survey Line	Coordinate Location	Notes
109N	386.5E	Typical depth 3-4 ft.
	415.5E	" "
106N	388.5E	" "
	400.5E	
	402.0E	
	419.0E	
	422.0E	
	434.0E	
103N	386.0E	
	388.0E*	
	393.0E	
	403.5E	
	418.0E	
399E	106.5N	
404E	107.0N	
414E	104.5N	
419E	111.5N	
	107.5N	
424E	111.5N	
429E	112.0N	
434E	105.0N	
439E	109.0N	

* Drum visible at ground surface.

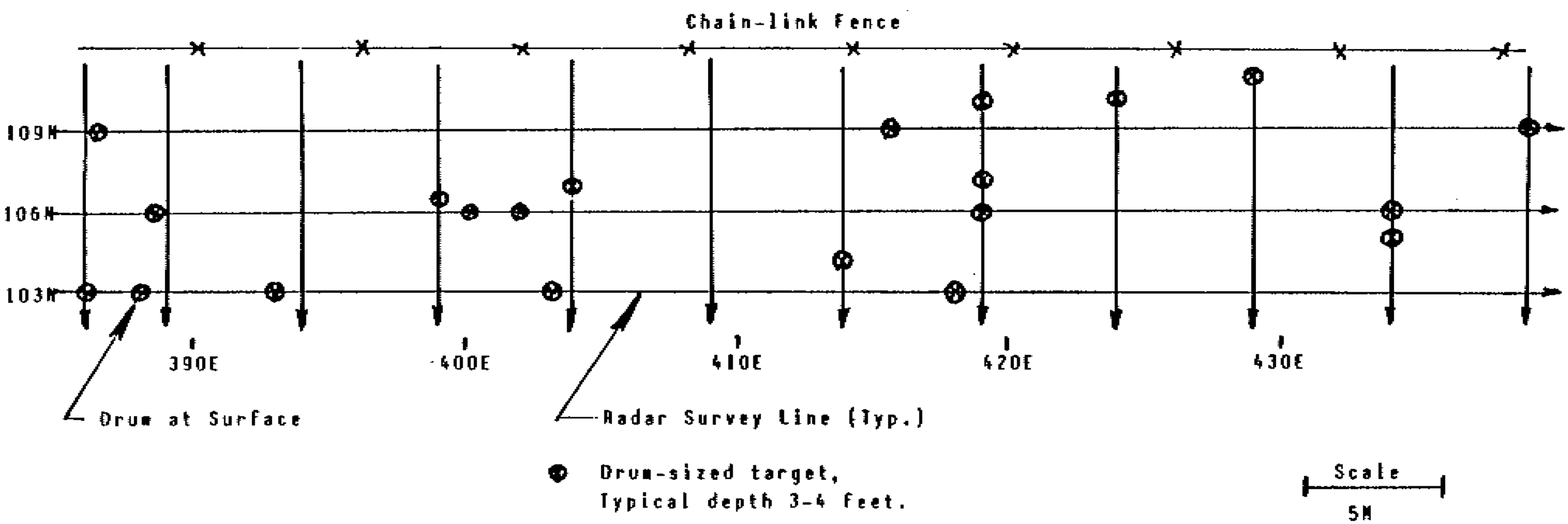

Figure 1.

The locations of the drum-sized targets are plotted on the radar survey grid made in Area E on the south bank of the pond.