COMPREHENSIVE RADIOLOGICAL SURVEY

OFF-SITE PROPERTY P
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 (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. is the current owner of a tract identified as off-site property P (see Figure 1). A radiological survey of that tract, conducted in June and July 1983, is the subject of this report.

SITE DESCRIPTION

Figure 2 is a plot plan of off-site property P. The property is roughly rectangular in shape, measuring 490 m long and varying in width from about 128 m at the south end to 185 m along the northern boundary. Property P occupies a total area of approximately 6.6 hectares. The site is bounded on the north by Balmer Road, on the south by I Street, and along the western perimeter by Lutts Road. The Central Drainage Ditch easement forms the eastern boundary.

There are three buildings on the property: 1) a one-story building occupied by SCA administrative offices; 2) a one-story building used for miscellaneous storage and maintenance; and 3) an unoccupied two-story structure. There are several access roads and paved parking areas in the vicinity of these buildings. With the exception of several small stands of undergrowth along the Central Drainage Ditch and Balmer Road the property is cleared and maintained.

Radiological History

There is no evidence of storage or burial of contaminated material on property P. One small area exceeding 20 μR/h was identified by the 1972 survey.[2] This area was in the vicinity of the north parking lot. The mobile scan by ORNL in 1980, indicated elevated radiation levels along Lutts Road.[3] Portions of the Central Drainage Ditch are also contaminated.[1,2]

SURVEY PROCEDURES

The comprehensive survey of NFSS off-site property P was performed by the Radiological Site Assessment Program of Oak Ridge Associated Universities (ORAU), during the period of June and July, 1983. The survey was in accordance with a plan dated December 1, 1982, approved by the Department of Energy. The objectives and procedures from that plan are presented in this section. It should be noted that the Central Drainage Ditch and its easement are being surveyed and cleaned by Bechtel National, Inc.; this portion of the property was, therefore, excluded from the ORAU survey.

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 P. 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 buildings on the site.

Procedures

1. A 20 m system was established by McIntosh and McIntosh of Lockport, NY, under subcontract. This grid system is shown on Figure 3.

2. Gamma exposure rate measurements were made at the surface and at 1 m above the surface at 20 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.

3. Beta-gamma dose rate measurements were performed 1 cm above the surface at 20 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 using soil samples from NFSS off-site properties.

4. Surface (0.15 cm) soil samples of approximately 1 kg each were collected at approximately 20 intervals.

5. Walkover surface scans were conducted at 1-2 m intervals over all accessible areas of the property. Portable gamma scintillation survey meters were used for these scans. Locations of elevated contact radiation levels were noted.

6. At selected locations of elevated surface radiation levels, gamma exposure rates at 1 m above the surface and beta-gamma dose rates at

1 cm above the surface were measured. Surface samples were obtained at several of these locations and, following sampling, the surface exposure levels were remeasured to evaluate the effectiveness of shallow sampling on removal of the radiation source.

7. Detection Sciences Group of Carlisle, MA, performed ground-penetrating radar surveys at locations selected for subsurface investigations to identify the presence of underground piping or utilities which would preclude borehole drilling. Several boreholes were relocated slightly to avoid possible underground objects.

8. Five boreholes were drilled to a depth of 5-6 m to provide a mechanism for logging subsurface direct radiation profiles and collecting subsurface soil samples. Drilling was performed by Site Engineers, Inc., of Cherry Hill, NJ, using a truck mounted 20 cm diameter hollow-stem auger. Locations of the boreholes are indicated on Figure 4.

   The boreholes were gamma scanned over their entire length for the presence of subsurface residues. Radiation profiles in the boreholes were determined by measurements of 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 water sample of approximately 3.5 liters was collected from one of the holes (water was not available in the other boreholes). Collection was performed using a hand bailer. Soil samples of approximately 1 kg each were collected from various depths in the holes by scraping the sides of the borehole with an ORAU designed sampling tool.

9. Exploratory direct radiation and surface contamination measurements were performed in all buildings. The building surveys 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 walls, and
d. smear samples to determine levels of removable alpha and beta contamination.

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 5.

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. The water sample was analyzed for gross alpha and gross beta concentrations. Smears of building surfaces were counted for gross alpha and gross beta contamination. 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 5) in the vicinity of the Niagara Falls Storage Site, 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, systematically measured at 20 m grid intervals are presented in Table 2. The gamma exposure rates at 1 m above the surface ranged from 5 to 8 μR/h. Surface contact exposure rates also ranged from 5 to 8 μR/h. Beta-gamma dose rates at the surface ranged from 5 to 28 μrad/h. 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 numerous small isolated areas of elevated surface radiation levels. With the exception of one area at grid point 497N, 181W, these elevated areas were located in the paved parking lot north of the unused two-story structure, i.e. between 640-680N and 140-220W. The locations of these areas are indicated on Figure 6 and the associated radiation levels are presented in Table 3. Exposure rates at surface contact with these areas ranged up to 48 μR/h. Exposure rates at 1 m above the surface and beta-gamma dose rates at the surface were measured at several of these locations, considered to be representative of the general conditions. The maximum 1 m exposure rate was 17 μR/h and the highest contact dose rate was 60 μrad/h. There was no difference between the shielded and unshielded dose rate measurements, indicating negligible beta contributions. At the three locations where samples were collected, there was no change in the surface radiation level after sampling.

Radionuclide Concentrations in Surface Soil

Table 4 presents the concentrations of radionuclides measured in surface soil samples, systematically collected at approximately 20 m intervals. These samples contained the following ranges of concentrations: Ra-226, 0.31 to 2.56 pCi/g; U-235, <0.14 to 0.57 pCi/g; U-238, 0.47 to 6.11 pCi/g; Cs-137, <0.04 to 4.16 pCi/g; and Th-232, 0.20 to 1.62 pCi/g. Several of the samples contained levels of the Ra-226, Cs-137 and Th-232 higher than the ranges noted in baseline samples; however, average concentrations were comparable to the baseline levels. Other gamma emitting radionuclides were not detected in significant concentrations in these samples.

Radionuclide concentrations in samples collected at selected locations of elevated contact radiation levels are presented in Table 5. Sample B1 from an isolated area at grid point 497N,181W, contained 14.9 pCi/g of Ra-226, but no significant concentrations of additional radionuclides. Sampling in the vicinity of the north parking lot indicated that the elevated radiation levels were associated with rock (possibly slag) used as a base for the asphalt paving. Two samples of this paving base material, B2B and B3B, contained high concentrations of Th-232-931 pCi/g and 944 pCi/g, respectively. These samples also contained elevated levels of Ra-226 and U-238. Sample B2B contained 199 pCi/g of Ra-226 and 192 pCi/g of U-238; sample B3B contained 172 pCi/g of Ra-226 and 189 pCi/g of U-238. The presence of Ra-226 and U-238 at equilibrium concentrations, suggest that this material is a naturally occurring ore or slag from operations not concerned with separation of uranium. Sample B3A, containing a mixture of soil and gravel, had lower concentrations of Th-232, Ra-226, and U-238; however, the ratios of these nuclides were similar to those in the paving base material. A sample of the aphalt paving (B2A) did not contain significant radionuclide levels.

Borehole Gamma-Logging Measurements

Gamma measurements in the boreholes did not identify any evidence of elevated subsurface radionuclide levels. The gamma-logging data was not used to quantifying radionuclide concentrations in the subsurface soil because of the varying ratios of Ra-226, U-235, Th-232, U-238, and Cs-137 occurring in soils from the NFSS.

Radionuclide Concentrations in Borehole Soil

Table 6 presents radionuclide concentrations measured in soil samples from boreholes. None of the samples contained radionuclide levels differing from those in the baseline soil samples.

Radionuclide Concentrations in Water

The gross alpha and gross beta concentrations measured in water from borehole H4 (the only borehole where water was available) were 2.27 pci/l and 2.42 pCi/l, respectively (see Table 7). No additional analyses were required on this sample, because the levels were well within the EPA criteria for drinking water systems.

Building Surveys

The results of "exploratory" surveys conducted in the buildings on property P are summarized in Table 8. No areas of elevated direct radiation or surface contamination were noted. 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. Radionuclide concentrations associated with small surface or near-surface areas of contamination and materials, exceed these guideline levels for Ra-226 (5 pCi/g), U-238 (150 pCi/g), and Th-232 (15 pCi/g). Most of these areas are associated with the material used as a paving base for one of the parking lots on property P. This rock contains Th-232 concentrations up to 944 pCi/g and U-238 concentra-tions up to 192 pCi/g. Ra-226 is in equilibrium with U-238. The equilibrium condition suggests that the elevated radionuclide levels in this material are of natural origin and are not the result of previous federal government activities on this property or the NFSS.

One small isolated area at grid location 497N,181W has a surface soil concentration of Ra-226 of 14.9 pCi/g, but no significant levels of other radionuclides. The concentration averaged over 100 m^2 in this area would not exceed the criteria of 5 pCi/g above background.

Direct radiation levels on the property are well below the guideline of 60 μR/h for open land areas. The maximum exposure rate measured was 48 μR/h at surface contact with a small area in the parking lot. At a height of 1 m above the surface, the highest exposure rate measured on the property was 17 μR/h. There was no indication of contamination in subsurface soil or water samples. Measurements in buildings indicated levels are within the guidelines for unrestricted use by the general public.

SUMMARY

A comprehensive survey of off-site property P at the Niagara Falls Storage Site was conducted during June and July, 1983. The survey included: surface radiation scans, measurements of direct radiation levels, analyses for radionuclide concentrations in surface and subsurface soil and in one subsurface water sample, and measurements of contamination levels in buildings.

The results of the survey indicate the presence of rock-like material, containing elevated levels of the thorium and uranium decay series. This material has been used as a paving base in one of the parking areas. The composition of this material and the history of development of property P suggest that this material is not attributable to previous waste handling and storage activities at NFSS. There is one isolated area of Ra-226 contamination which could be eliminated by the removal of a very small (less than 1 m^3) amount of surface soil. Locations of these areas of elevated radionuclide levels are indicated on Figure 7. Contamination was not noted in subsurface soil and water or on interior building surfaces.

Radionuclide levels on this property do not pose potential health risks and there is no evidence that migration of the radioactive materials is adversely affecting adjacent properties or the ground water.

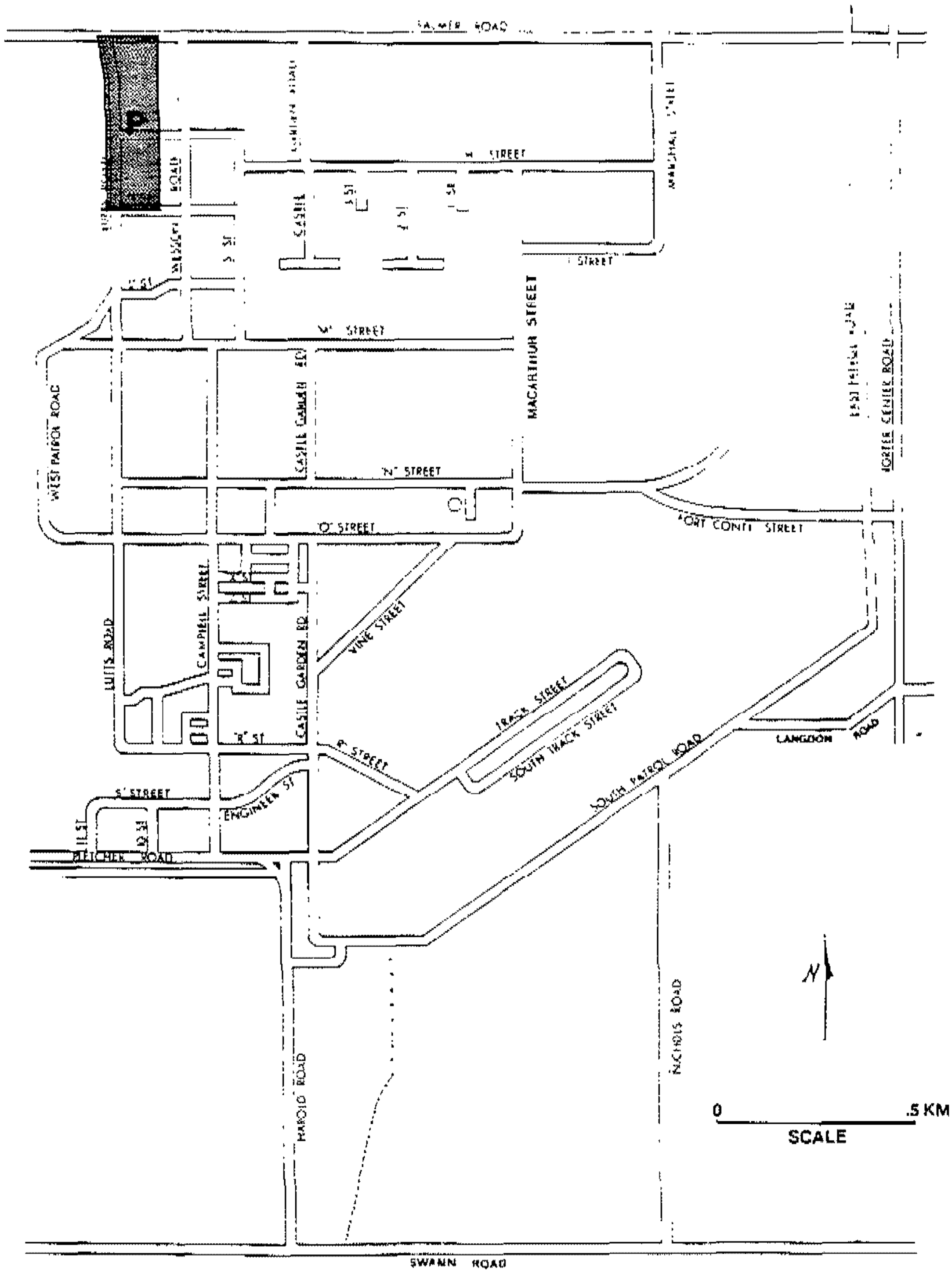

FIGURE 1. Map of the Niagara Falls Storage Site and Off-Site Properties, Lewiston, New York, Indicating the Location of Property F.

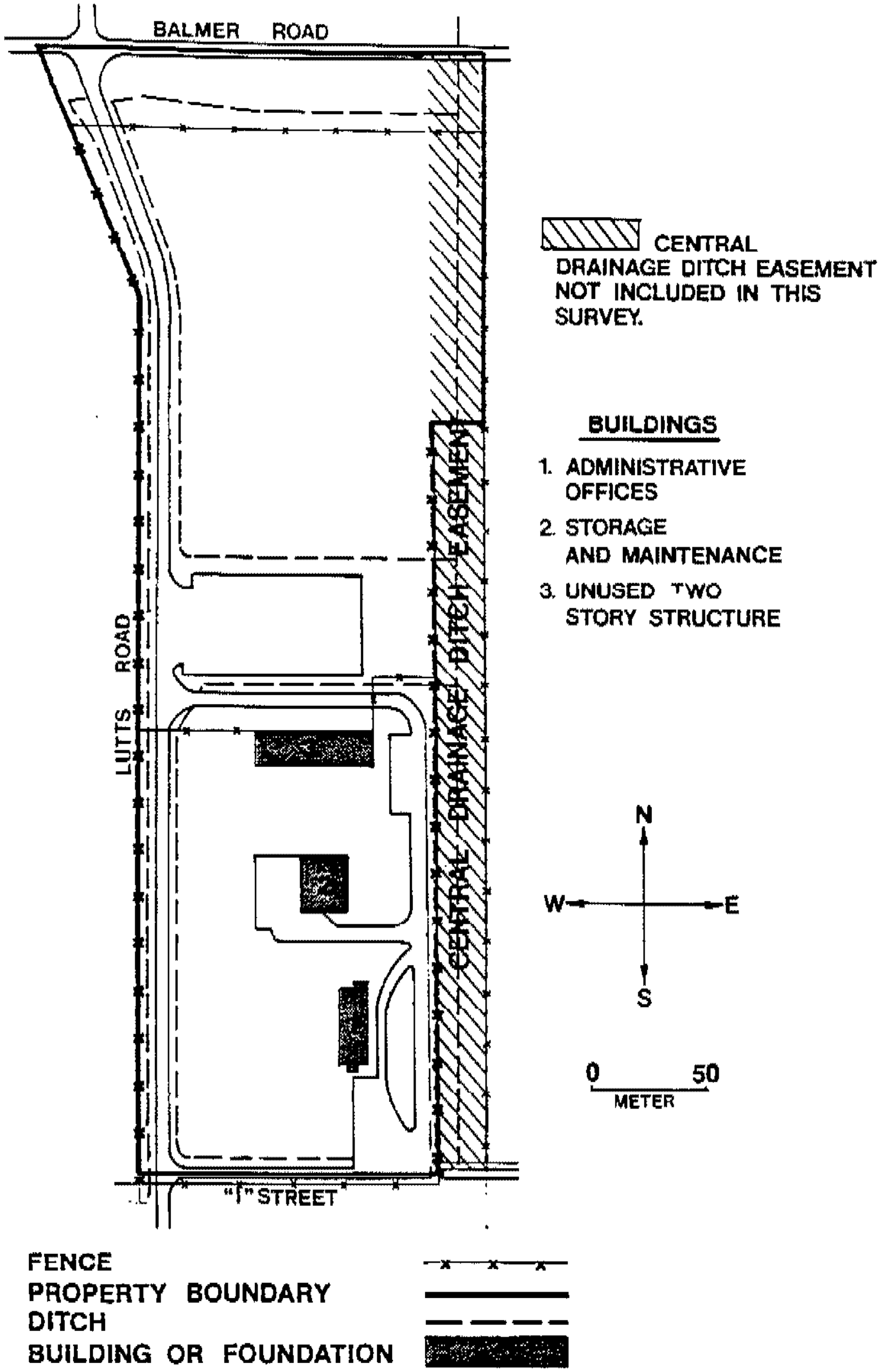

FIGURE 2. Plan View of NFSS Off-Site Property P, Indicating Prominent Surface Features.

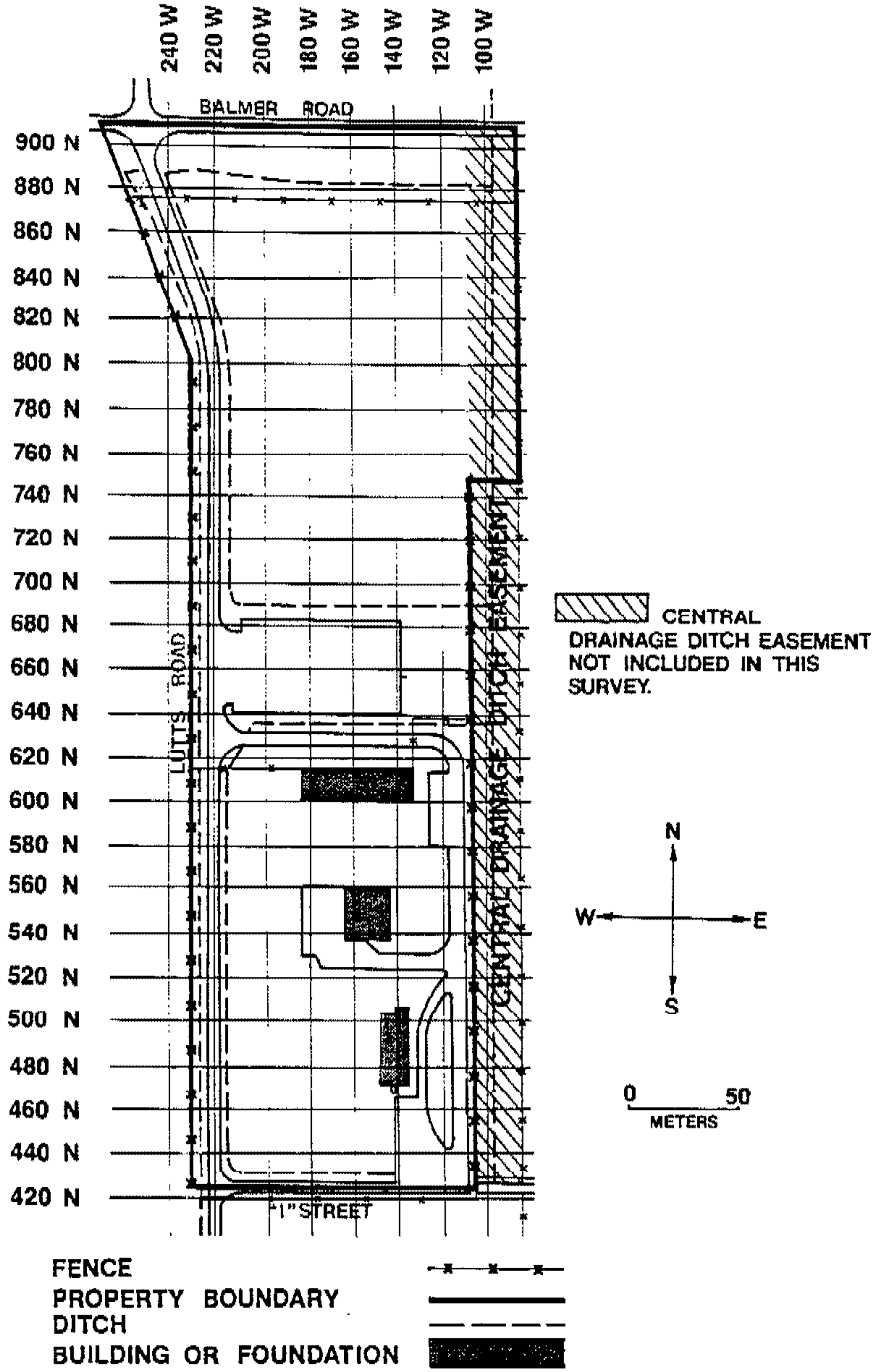

FIGURE 3. Map of Property P, Indicating the 20 Meter Reference Grid System.

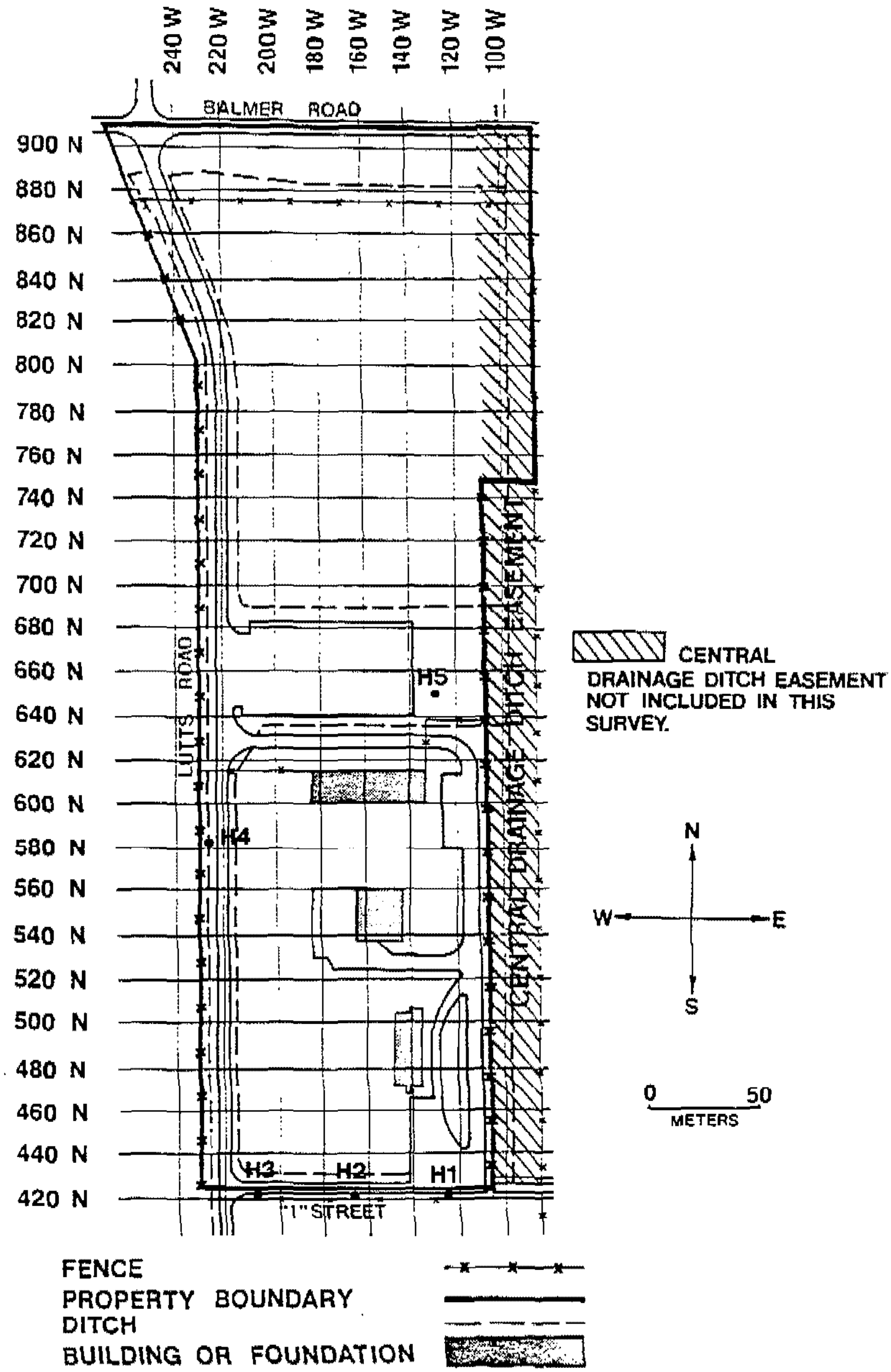

FIGURE 4. Locations of Boreholes on Property P.

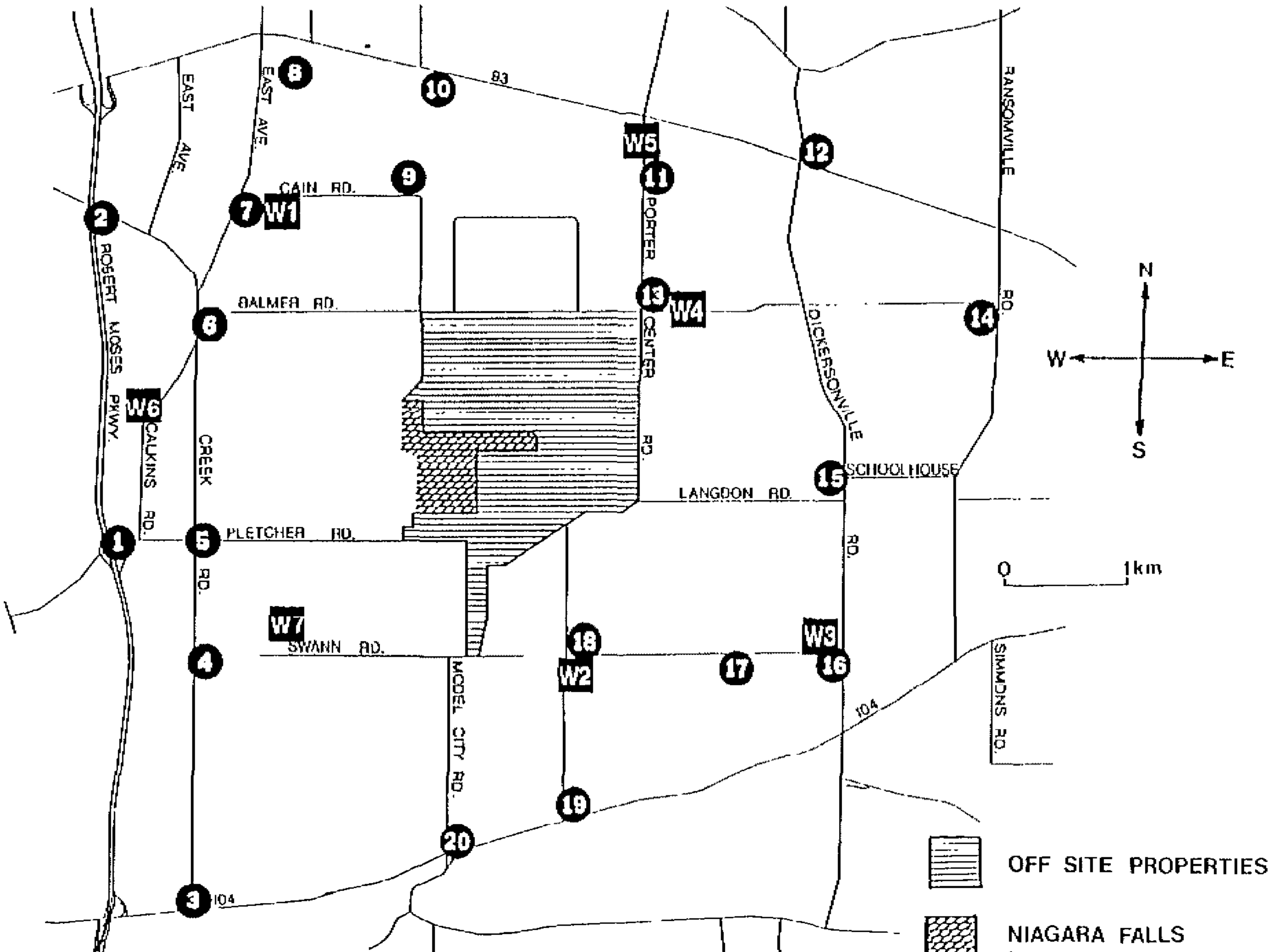

FIGURE 5. Map of Northern Niagara County, New York, Showing Locations of Background Measurements and Baseline Samples. (#1-20: soil samples and direct measurements; W1-W7: water samples.)

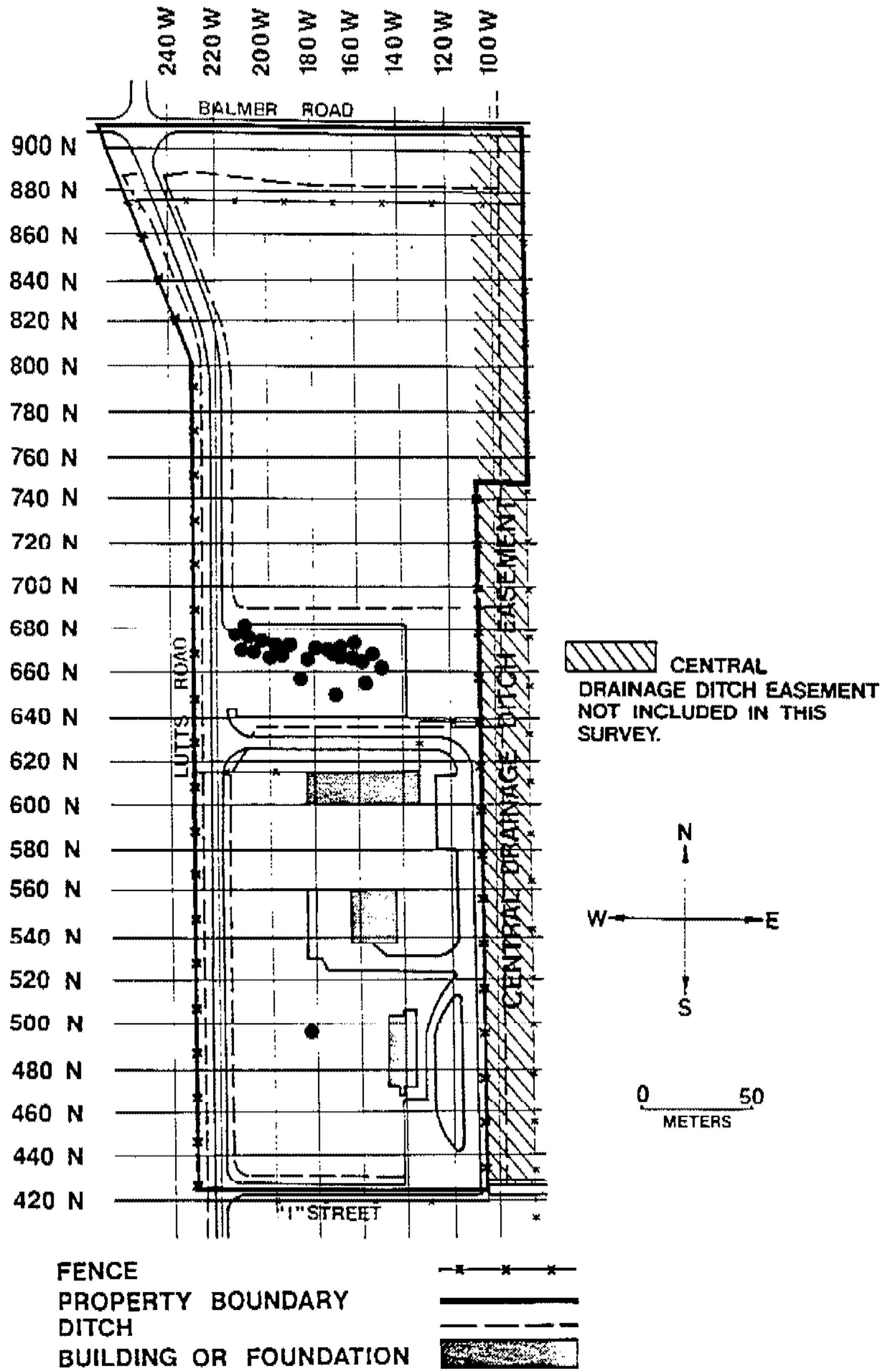

FIGURE 6. Locations of Elevated Surface Radiation Levels, Identified by the Walkover Scan.

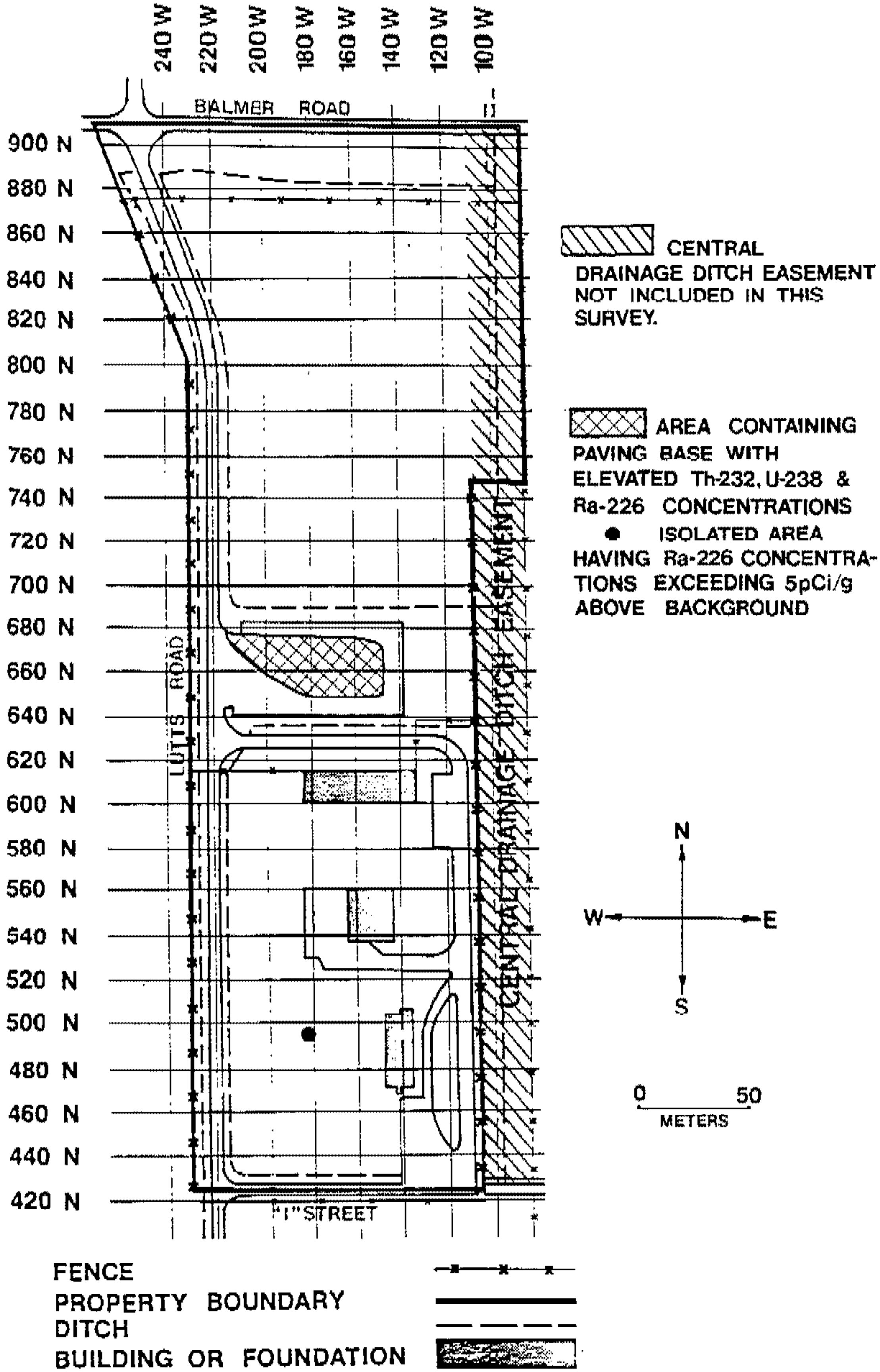

FIGURE 7. Surface Areas of Property P, Where Radionuclide Levels Exceed Criteria and Where Isolated "Hot Spots" Have Been Identified.

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 5.
[b] Measured at 1 m above the surface.
[c] Errors are 2σ based on counting statistics.

TABLE 1-3

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 5.
[b] Errors are 2σ based on counting statistics.

TABLE 2

DIRECT RADIATION LEVELS SYSTEMATICALLY MEASURED
AT 20 M GRID INTERVALS

Grid Location N	Grid Location W	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)
900	240	7	7	20
900	220	8	8	8
900	200	7	8	12
900	180	7	8	21
900	160	8	7	14
900	140	7	7	27
900	120	6	7	10
888	240	7	8	27
880	220	8	8	15
880	200	7	8	19
880	180	7	7	13
880	160	8	8	8
880	140	7	8	25
880	120	7	8	28
860	240	5	5	5
860	220	8	8	14
860	200	7	8	21
860	180	8	8	24
860	160	8	7	18
860	140	7	8	22
860	120	7	7	17
840	240	7	7	27
840	220	7	7	7
840	200	8	8	18
840	180	7	8	12
840	160	8	8	18
840	140	8	8	21
840	120	8	8	22
820	240	7	8	21
820	220	8	7	7
820	200	7	7	18
820	180	8	8	18
820	160	7	7	14
820	140	7	7	7
820	120	8	8	16
800	236	7	7	16
800	220	6	7	10
800	200	7	7	11
800	180	7	7	10
800	160	7	7	14

TABLE 2, cont.

DIRECT RADIATION LEVELS SYSTEMATICALLY MEASURED
AT 20 M GRID INTERVALS

Grid Location N	Grid Location W	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)
800	140	7	7	8
800	120	7	7	23
780	236	7	7	11
780	220	6	6	6
780	200	6	7	10
780	180	7	7	7
780	160	7	7	8
780	140	7	7	10
780	120	8	8	12
760	236	7	7	11
760	220	6	6	6
760	200	6	7	10
760	180	7	7	7
760	160	7	7	8
760	140	7	7	7
760	120	7	7	7
740	236	7	7	7
740	220	7	6	6
740	200	7	7	14
740	180	7	7	10
740	160	7	7	7
740	140	7	7	10
740	120	7	8	14
720	236	7	7	14
720	220	6	7	17
720	200	7	7	11
720	180	7	7	10
720	160	7	7	7
720	140	7	6	7
720	120	7	7	13
700	236	7	7	16
700	220	6	6	6
700	200	6	7	14
700	180	7	7	7
700	160	7	7	7
700	140	7	7	13
700	120	7	7	8
680	236	7	7	8
680	220	5	8	14
680	200	7	7	10

TABLE 2, cont.

DIRECT RADIATION LEVELS SYSTEMATICALLY MEASURED
AT 20 M GRID INTERVALS

Grid Location N	Grid Location W	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)
680	180	7	7	7
680	160	7	8	15
680	140	6	6	19
680	120	7	8	8
660	236	7	7	7
660	220	5	5	5
660	200	5	5	6
660	180	5	5	5
660	160	5	5	5
660	140	5	5	5
660	120	7	8	8
640	236	7	7	7
640	220	5	5	5
640	200	5	5	15
640	180	5	5	5
640	160	5	5	5
640	140	5	5	5
640	120	6	7	18
620	236	7	7	7
620	220	6	7	8
620	200	6	6	6
620	180	6	7	10
620	140	5	5	5
620	120	7	7	8
620	107	6	6	6
600	236	7	7	8
600	220	7	7	7
600	200	6	7	18
600	180	6	6	6
600	160	5	5	5
600	140	6	6	6
600	120	5	5	5
600	107	8	8	22
580	236	7	7	11
580	220	6	6	12
580	200	7	7	7
580	180	6	7	7
580	160	7	7	10
580	140	7	7	7
580	120	6	6	6

TABLE 2, cont.

DIRECT RADIATION LEVELS SYSTEMATICALLY MEASURED AT 20 M GRID INTERVALS

Grid Location N	Grid Location W	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)
580	107	8	7	10
560	236	7	7	7
560	220	6	7	8
560	200	7	7	13
560	180	5	5	5
562	160	5	6	6
560	140	7	7	7
560	120	7	7	10
560	107	8	8	17
540	236	7	7	7
540	220	6	7	17
540	200	6	7	7
540	180	5	5	5
538	160	5	5	5
583	140	7	7	7
583	120	7	7	7
583	107	8	8	18
520	236	6	7	10
520	220	6	7	14
520	200	6	6	6
520	180	6	7	7
520	160	6	7	8
520	140	6	7	7
520	120	6	7	13
520	107	7	7	14
500	236	7	7	8
500	220	6	7	11
500	200	7	7	10
500	180	7	7	7
500	160	6	7	7
500	140	a	a	a
500	120	7	7	14
500	107	8	7	20
480	235	6	7	21
480	220	6	6	6
480	200	7	7	16
480	180	7	7	14
480	160	7	7	13
480	140	a	a	a
480	120	7	7	7

TABLE 2, cont.

DIRECT RADIATION LEVELS SYSTEMATICALLY MEASURED
AT 20 M GRID INTERVALS

Grid Location N	Grid Location W	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	107	8	7	10
460	235	6	6	16
460	220	6	6	6
460	200	7	7	16
460	180	7	7	11
460	160	7	7	27
460	140	6	5	18
460	120	8	8	17
460	107	7	7	10
440	235	6	7	14
440	220	7	7	7
440	200	7	7	7
440	180	7	7	7
440	160	7	7	11
440	140	5	5	5
440	120	5	5	11
440	107	8	8	19
420	235	6	6	9
420	220	6	5	12
420	200	6	7	18
420	180	7	7	8
420	160	6	7	13
420	140	6	7	17
420	120	6	7	7
420	107	8	8	11

[a]Grid point not accessible due to presence of building.

TABLE 3

DIRECT RADIATION LEVELS AT LOCATIONS
IDENTIFIED BY THE WALKOVER SURFACE SCAN

Grid Location N	Grid Location W	Exposure Rate (μR/h) Contact	Exposure Rate (μR/h) 1 m Above Surface	Surface Dose Rate (μrad/h)	Sample[a] Identification	Contact Exposure Rate After Sample Removal (μR/h)
497	181	20	9	29	B1	20
647	173	20	---[b]	---	---	---
648	172	29	---	---	---	---
654	157	38	10	71	---	---
658	186	17	---	---	---	---
662	148	17	---	---	---	---
665	160	32	---	---	---	---
665	182	14	---	---	---	---
666	157	37	---	---	---	---
666	166	17	---	---	---	---
668	199	38	---	---	---	---
670	157	23	---	---	---	---
670	172	31	---	---	---	---
670	196	36	---	---	---	---
670	210	48	17	48	B2(A+B)	48
671	176	26	10	26	---	---
672	174	33	---	---	---	---
672	180	18	---	---	---	---
673	165	18	---	---	---	---
673	175	14	---	---	---	---
673	208	21	10	25	---	---
673	209	26	10	67	---	---
674	188	27	---	---	---	---
674	190	21	---	---	---	---
674	195	23	---	---	---	---
675	164	16	1---	---	---	---
676	179	26	10	60	---	---
677	161	14	---	---	---	---

TABLE 3, 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	W	Contact	1 m Above Surface			
677	203	27	13	27	---	---
678	163	20	20	25	---	---
679	204	24	12	28	---	---
680	205	16	---	---	---	---
680	211	26	12	47	B3(A+B)	26
681	210	17	---	---	---	---
681	211	35	---	---	---	---

[a]Radionuclide analyses are presented in Table 5.
[b]Dash indicates measurement or sampling not performed.

TABLE 4

RADIONUCLIDE CONCENTRATIONS IN SURFACE SOIL SAMPLES
COLLECTED FROM 20 M GRID INTERVALS

Grid Location		Radionuclide Concentrations (pCi/g)				
N	W	Ra-226	U-235	U-238	Cs-137	Th-232
900	240	0.85 ± 0.34[a]	0.49 ± 0.48	1.21 ± 1.30	0.05 ± 0.09	0.92 ± 0.33
900	220	0.96 ± 0.31	<0.28	3.33 ± 1.57	0.15 ± 0.08	0.85 ± 0.41
900	200	0.87 ± 0.20	<0.23	1.59 ± 1.05	0.62 ± 0.11	1.08 ± 0.35
900	180	0.87 ± 0.21	<0.22	1.38 ± 1.64	0.34 ± 0.12	1.13 ± 0.37
900	160	0.86 ± 0.18	<0.26	1.63 ± 1.45	0.30 ± 0.13	0.69 ± 0.33
900	140	0.97 ± 0.32	<0.30	1.83 ± 1.08	0.36 ± 0.13	1.12 ± 0.35
900	120	0.74 ± 0.25	<0.22	1.23 ± 1.35	0.30 ± 0.13	0.88 ± 0.35
880	240	0.95 ± 0.31	<0.22	1.41 ± 2.16	0.28 ± 0.11	0.88 ± 0.39
880	220	0.91 ± 0.20	<0.30	1.65 ± 1.08	0.70 ± 0.13	1.41 ± 0.38
880	200	0.77 ± 0.29	0.34 ± 0.47	3.36 ± 1.20	0.45 ± 0.13	1.07 ± 0.54
880	180	1.08 ± 0.24	<0.31	<0.90	0.53 ± 0.17	1.21 ± 0.40
880	160	1.04 ± 0.23	<0.20	0.86 ± 1.46	0.61 ± 0.14	0.91 ± 0.35
880	140	1.09 ± 0.36	<0.20	<0.75	0.31 ± 0.13	1.08 ± 0.34
880	120	0.86 ± 0.21	<0.33	1.72 ± 2.06	0.43 ± 0.12	1.14 ± 0.40
860	238	0.90 ± 0.26	<0.31	1.44 ± 1.68	1.03 ± 0.16	0.61 ± 0.26
860	220	0.96 ± 0.21	<0.21	0.75 ± 0.86	0.51 ± 0.10	0.84 ± 0.33
860	200	0.91 ± 0.23	<0.29	0.84 ± 1.57	0.49 ± 0.10	1.25 ± 0.42
860	180	0.96 ± 0.23	<0.29	<0.98	0.43 ± 0.08	1.36 ± 0.36
860	160	0.90 ± 0.23	<0.27	4.79 ± 1.55	0.59 ± 0.16	0.87 ± 0.38
860	140	0.90 ± 0.27	<0.23	2.22 ± 2.24	0.73 ± 0.15	1.17 ± 0.39
860	120	1.20 ± 0.27	<0.30	2.08 ± 1.63	0.59 ± 0.14	1.04 ± 0.30
840	240	0.87 ± 0.23	<0.20	<0.65	0.13 ± 0.09	0.98 ± 0.28
840	220	0.97 ± 0.27	<0.28	<0.99	0.55 ± 0.11	1.18 ± 0.39
840	200	2.56 ± 0.40	<0.27	1.63 ± 2.00	0.62 ± 0.17	0.65 ± 0.42
840	180	0.87 ± 0.20	<0.29	3.08 ± 1.68	0.55 ± 0.11	1.10 ± 0.45
840	160	0.83 ± 0.29	<0.25	<0.84	0.72 ± 0.17	1.16 ± 0.50
840	140	0.66 ± 0.35	<0.25	<0.94	0.85 ± 0.17	0.58 ± 0.43
840	120	0.68 ± 0.20	<0.31	3.45 ± 1.47	1.01 ± 0.16	1.47 ± 0.41

TABLE 4, cont.

RADIONUCLIDE CONCENTRATIONS IN SURFACE SOIL SAMPLES
COLLECTED FROM 20 M GRID INTERVALS

Grid Location		Radionuclide Concentrations (pCi/g)				
N	W	Ra-226	U-235	U-238	Cs-137	Th-232
820	240	0.92 ± 0.22	<0.20	<0.73	0.13 ± 0.05	0.93 ± 0.31
820	220	0.96 ± 0.20	<0.30	<0.91	0.74 ± 0.13	0.62 ± 0.23
820	200	0.84 ± 0.23	<0.21	1.92 ± 1.12	0.64 ± 0.13	0.78 ± 0.37
820	180	1.12 ± 0.31	<0.32	2.72 ± 1.06	0.55 ± 0.13	0.92 ± 0.44
820	160	0.84 ± 0.19	<0.20	<0.72	0.49 ± 0.11	1.25 ± 0.50
820	140	0.97 ± 0.22	<0.29	<0.84	0.78 ± 0.14	1.12 ± 0.34
820	120	0.76 ± 0.26	<0.22	<0.69	0.45 ± 0.11	1.41 ± 0.44
800	233	1.08 ± 0.26	<0.28	4.52 ± 1.71	0.17 ± 0.06	1.35 ± 0.35
800	220	0.73 ± 0.20	<0.31	<0.89	0.70 ± 0.15	0.77 ± 0.30
800	200	0.74 ± 0.29	<0.21	<0.82	0.66 ± 0.11	0.64 ± 0.42
800	180	0.69 ± 0.18	<0.19	1.34 ± 1.37	0.48 ± 0.12	0.70 ± 0.26
800	160	0.88 ± 0.25	<0.28	2.19 ± 1.76	0.71 ± 0.12	0.93 ± 0.35
800	140	0.99 ± 0.22	<0.23	1.32 ± 1.43	0.26 ± 0.11	0.90 ± 0.27
800	118	0.93 ± 0.29	<0.29	0.73 ± 3.27	0.54 ± 0.17	0.80 ± 0.41
780	233	0.92 ± 0.27	<0.19	<0.71	0.23 ± 0.09	0.93 ± 0.34
780	220	1.13 ± 0.33	<0.33	<0.99	0.91 ± 0.14	1.48 ± 0.39
780	200	0.93 ± 0.24	<0.23	6.06 ± 1.78	0.70 ± 0.16	0.78 ± 0.34
780	180	0.83 ± 0.21	<0.21	<0.80	0.59 ± 0.13	0.85 ± 0.38
780	160	0.73 ± 0.28	<0.21	1.16 ± 2.48	0.83 ± 0.16	0.91 ± 0.55
780	140	0.79 ± 0.29	<0.34	3.45 ± 2.12	1.26 ± 0.18	1.20 ± 0.44
780	119	0.71 ± 0.17	<0.28	3.08 ± 1.03	0.54 ± 0.11	0.85 ± 0.31
760	233	0.80 ± 0.26	<0.18	<0.68	0.16 ± 0.09	1.05 ± 0.31
760	220	0.95 ± 0.31	<0.22	1.09 ± 1.09	0.41 ± 0.09	0.52 ± 0.24
760	200	0.82 ± 0.42	<0.24	<1.02	1.38 ± 0.23	1.33 ± 0.52
760	180	0.86 ± 0.29	<0.28	1.98 ± 1.88	0.58 ± 0.12	1.49 ± 0.28
760	160	0.86 ± 0.21	<0.31	<0.99	0.95 ± 0.15	1.07 ± 0.39
760	140	0.85 ± 0.39	0.24 ± 0.11	1.17 ± 1.70	1.06 ± 0.15	0.89 ± 0.15

TABLE 4, cont.

RADIONUCLIDE CONCENTRATIONS IN SURFACE SOIL SAMPLES
COLLECTED FROM 20 M GRID INTERVALS

Grid Location		Radionuclide Concentrations (pCi/g)				
N	W	Ra-226	U-235	U-238	Cs-137	Th-232
760	118	0.99 ± 0.21	<0.28	<0.89	0.61 ± 0.14	1.17 ± 0.42
740	233	0.98 ± 0.30	<0.27	2.00 ± 1.56	0.40 ± 0.09	1.07 ± 0.32
740	220	0.84 ± 0.23	<0.20	1.65 ± 1.49	0.73 ± 0.15	0.66 ± 0.40
740	200	0.84 ± 0.22	<0.24	1.11 ± 2.16	0.56 ± 0.13	1.11 ± 0.49
740	180	0.79 ± 0.27	<0.22	<0.73	0.32 ± 0.08	0.50 ± 0.24
740	160	1.03 ± 0.28	<0.28	1.17 ± 0.87	0.77 ± 0.15	0.99 ± 0.40
740	140	0.78 ± 0.23	<0.21	<0.70	0.39 ± 0.09	1.05 ± 0.33
740	110	0.60 ± 0.28	0.38 ± 0.62	2.05 ± 1.95	0.91 ± 0.18	0.52 ± 0.79
720	233	0.76 ± 0.19	<0.25	<0.85	<0.05	0.99 ± 0.30
720	220	0.84 ± 0.25	<0.19	1.06 ± 2.07	0.60 ± 0.12	0.63 ± 0.29
720	200	0.90 ± 0.24	<0.21	<0.88	0.30 ± 0.11	0.75 ± 0.35
720	180	1.14 ± 0.26	<0.31	2.71 ± 1.07	0.61 ± 0.15	0.82 ± 0.41
720	160	0.36 ± 0.28	<0.19	<0.77	0.52 ± 0.18	0.67 ± 0.61
720	140	0.92 ± 0.32	<0.33	1.96 ± 1.07	0.92 ± 0.16	1.12 ± 0.43
720	120	0.77 ± 0.35	0.49 ± 0.14	<1.02	0.65 ± 0.12	0.68 ± 0.40
700	233	0.76 ± 0.25	<0.21	0.67 ± 1.70	0.14 ± 0.07	0.92 ± 0.37
700	220	0.63 ± 0.25	<0.20	1.99 ± 1.95	0.71 ± 0.13	0.77 ± 0.49
700	200	0.28 ± 0.29	<0.19	<0.74	0.46 ± 0.16	1.34 ± 0.40
700	180	1.10 ± 0.32	<0.35	4.79 ± 1.82	0.69 ± 0.16	1.33 ± 0.72
700	160	0.76 ± 0.24	<0.28	4.21 ± 1.79	0.77 ± 0.14	1.32 ± 0.40
700	140	0.73 ± 0.23	<0.23	1.54 ± 0.95	0.66 ± 0.14	0.85 ± 0.44
700	119	1.01 ± 0.36	0.52 ± 0.13	2.87 ± 1.79	0.63 ± 0.15	1.00 ± 0.51
680	233	0.89 ± 0.24	<0.28	1.58 ± 0.86	0.18 ± 0.07	1.29 ± 0.28
680	220	0.67 ± 0.17	<0.15	0.55 ± 1.14	0.18 ± 0.09	0.38 ± 0.19
682	200	0.87 ± 0.45	<0.29	<1.00	3.26 ± 0.30	0.65 ± 0.50
680	180	0.75 ± 0.32	<0.28	<1.08	3.25 ± 0.34	0.41 ± 0.44
680	160	0.60 ± 0.28	<0.23	1.48 ± 1.80	0.86 ± 0.14	0.75 ± 0.41

TABLE 4, cont.

RADIONUCLIDE CONCENTRATIONS IN SURFACE SOIL SAMPLES COLLECTED FROM 20 M GRID INTERVALS

Grid Location		Radionuclide Concentrations (pCi/g)				
N	W	Ra-226	U-235	U-238	Cs-137	Th-232
680	140	0.70 ± 0.40	<0.45	2.35 ± 2.46	1.57 ± 0.25	<0.27
680	120	0.66 ± 0.25	<0.19	2.04 ± 2.06	0.45 ± 0.11	1.07 ± 0.42
660	233	0.97 ± 0.27	<0.28	3.00 ± 1.07	0.22 ± 0.08	1.52 ± 0.38
660	220	b	b	b	b	b
660	200	b	b	b	b	b
660	180	b	b	b	b	b
660	160	b	b	b	b	b
660	140	b	b	b	b	b
660	120	0.90 ± 0.26	<0.21	0.94 ± 2.01	0.42 ± 0.10	0.88 ± 0.47
640	233	0.97 ± 0.25	<0.22	2.31 ± 1.03	0.22 ± 0.12	0.78 ± 0.37
640	218	1.04 ± 0.22	0.25 ± 0.11	2.61 ± 1.37	0.43 ± 0.08	0.59 ± 0.22
637	200	0.70 ± 0.30	<0.25	<0.90	1.15 ± 0.18	0.71 ± 0.33
638	180	0.91 ± 0.27	<0.20	<0.83	2.82 ± 0.27	0.68 ± 0.40
640	160	1.00 ± 0.38	<0.25	1.62 ± 2.68	4.16 ± 0.37	0.87 ± 0.35
640	140	0.60 ± 0.41	<0.43	<1.32	3.84 ± 0.47	<0.35
640	135	0.56 ± 0.25	<0.20	1.46 ± 1.72	0.24 ± 0.10	0.50 ± 0.37
640	120	1.04 ± 0.29	<0.20	6.11 ± 1.93	0.50 ± 0.14	0.74 ± 0.37
620	233	0.78 ± 0.23	<0.18	2.24 ± 1.48	0.15 ± 0.07	0.60 ± 0.31
620	220	0.95 ± 0.24	<0.27	1.51 ± 1.01	1.04 ± 0.14	0.70 ± 0.36
620	200	0.80 ± 0.33	<0.23	<0.82	0.69 ± 0.19	1.01 ± 0.49
620	180	0.86 ± 0.22	<0.21	1.46 ± 1.69	0.53 ± 0.11	0.42 ± 0.25
620	160	1.04 ± 0.30	<0.30	<0.87	0.62 ± 0.13	0.87 ± 0.48
623	140	0.86 ± 0.21	<0.27	0.69 ± 1.59	0.68 ± 0.11	0.72 ± 0.26
620	120	0.74 ± 0.19	0.24 ± 0.11	<1.00	0.62 ± 0.12	1.07 ± 0.33
620	109	0.39 ± 0.19	<0.16	1.28 ± 1.23	0.27 ± 0.11	0.40 ± 0.30
600	236	0.84 ± 0.27	<0.25	<0.83	0.42 ± 0.10	0.77 ± 0.44
600	220	0.96 ± 0.21	0.20 ± 0.10	1.57 ± 1.99	0.76 ± 0.13	0.98 ± 0.45

TABLE 4, cont.

RADIONUCLIDE CONCENTRATIONS IN SURFACE SOIL SAMPLES
COLLECTED FROM 20 M GRID INTERVALS

Grid Location		Radionuclide Concentrations (pCi/g)				
N	W	Ra-226	U-235	U-238	Cs-137	Th-232
600	200	0.86 ± 0.23	<0.34	3.06 ± 2.14	0.52 ± 0.16	0.87 ± 0.45
600	180	1.21 ± 0.29	<0.25	<1.03	1.03 ± 0.17	0.85 ± 0.31
600	160	0.49 ± 0.24	<0.23	3.23 ± 1.36	0.84 ± 0.16	0.77 ± 0.35
600	140	0.85 ± 0.24	0.19 ± 0.13	3.29 ± 1.60	0.62 ± 0.14	1.10 ± 0.39
600	120	b	b	b	b	b
600	107	0.93 ± 0.24	0.55 + 0.49	<0.76	0.56 ± 0.123	0.30 ± 0.41
580	236	0.67 ± 0.24	<0.18	1.40 ± 1.53	<0.04	0.72 ± 0.24
580	220	0.82 ± 0.28	<0.26	0.82 ± 1.55	0.59 ± 0.12	0.53 ± 0.30
580	200	0.77 ± 0.35	<0.27	2.60 ± 2.41	0.68 ± 0.15	0.99 ± 0.74
580	180	0.56 ± 0.41	<0.26	<1.15	0.89 ± 0.23	0.64 ± 0.54
580	160	0.76 ± 0.26	<0.19	<0.84	0.26 ± 0.08	0.66 ± 0.48
580	140	0.97 ± 0.26	<0.31	<1.08	0.44 ± 0.12	1.14 ± 0.50
580	120	0.61 ± 0.34	<0.23	1.08 ± 1.53	1.58 ± 0.19	0.87 ± 0.31
580	107	0.82 ± 0.28	0.34 ± 0.51	<0.83	0.63 ± 0.15	0.86 ± 0.62
560	236	0.74 ± 0.32	<0.21	<0.81	0.12 ± 0.12	0.97 ± 0.37
560	220	b	b	b	b	b
560	200	1.12 ± 0.29	<0.24	2.13 ± 1.79	0.64 ± 0.17	0.74 ± 0.32
562	180	0.64 ± 0.21	<0.14	<0.60	0.98 ± 0.17	0.28 ± 0.20
560	160	0.92 ± 0.25	<0.20	0.50 ± 1.50	0.87 ± 0.15	0.47 ± 0.26
560	140	0.92 ± 0.24	0.16 ± 0.15	1.15 ± 1.79	0.55 ± 0.13	1.57 ± 0.54
560	120	0.78 ± 0.25	0.15 ± 0.13	1.66 ± 2.09	0.96 ± 0.15	0.99 ± 0.52
560	107	0.73 ± 0.28	<0.21	1.07 ± 1.55	0.51 ± 0.13	0.66 ± 0.35
540	236	0.91 ± 0.30	<0.22	<0.86	0.10 ± 0.05	0.97 ± 0.32
540	220	0.54 ± 0.19	<0.17	<0.61	0.68 ± 0.14	0.48 ± 0.21
540	200	0.70 ± 0.28	<0.20	2.10 ± 1.93	0.97 ± 0.20	0.85 ± 0.57
540	184	0.62 ± 0.23	<0.17	0.95 ± 1.29	0.48 ± 0.12	0.49 ± 0.36
540	160	b	b	b	b	b

TABLE 4, cont.

RADIONUCLIDE CONCENTRATIONS IN SURFACE SOIL SAMPLES
COLLECTED FROM 20 M GRID INTERVALS

Grid Location		Radionuclide Concentrations (pCi/g)				
N	W	Ra-226	U-235	U-238	Cs-137	Th-232
540	140	0.93 ± 0.33	<0.22	1.40 ± 2.23	0.67 ± 0.15	0.65 ± 0.38
540	120	0.69 ± 0.30	<0.20	<0.77	0.51 ± 0.36	1.14 ± 0.49
540	107	0.70 ± 0.29	<0.16	1.22 ± 1.23	0.31 ± 0.10	0.77 ± 0.32
520	236	0.88 ± 0.20	<0.28	1.23 ± 1.25	0.09 ± 0.12	0.73 ± 0.44
520	220	0.83 ± 0.24	<0.18	<0.70	0.48 ± 0.09	0.51 ± 0.20
520	200	0.93 ± 0.32	<0.38	3.92 ± 2.50	0.66 ± 0.15	0.20 ± 0.26
520	180	1.07 ± 0.33	<0.32	6.97 ± 1.97	0.79 ± 0.15	1.03 ± 0.40
520	160	0.97 ± 0.24	<0.18	2.10 ± 1.80	0.69 ± 0.13	0.69 ± 0.34
520	140	0.82 ± 0.25	<0.21	1.75 ± 1.56	0.62 ± 0.16	0.64 ± 0.31
520	120	0.98 ± 0.25	<0.20	<0.74	0.28 ± 0.15	0.99 ± 0.42
520	107	0.63 ± 0.20	<0.24	<0.75	0.43 ± 0.10	0.53 ± 0.25
500	236	0.86 ± 0.22	<0.22	<0.85	0.11 ± 0.09	0.94 ± 0.35
500	220	0.50 ± 0.23	<0.18	<0.79	0.41 ± 0.11	0.57 ± 0.30
500	200	0.99 ± 0.30	<0.35	3.54 ± 2.59	0.74 ± 0.16	0.89 ± 0.37
500	180	0.89 ± 0.26	<0.30	<1.05	0.77 ± 0.16	0.97 ± 0.59
500	160	0.78 ± 0.34	0.57 ± 0.16	1.86 ± 1.75	1.18 ± 0.19	0.83 ± 0.35
500	140	b	b	b	b	b
500	120	0.84 ± 0.29	<0.29	<0.88	0.55 ± 0.20	1.19 ± 0.88
500	107	1.02 ± 0.27	<0.21	<0.85	0.55 ± 0.13	0.75 ± 0.48
480	236	0.59 ± 0.20	<0.22	1.07 ± 1.63	0.54 ± 0.08	0.76 ± 0.42
480	220	0.62 ± 0.16	<0.13	<0.60	0.44 ± 0.11	0.23 ± 0.17
480	200	0.70 ± 0.23	<0.25	2.00 ± 2.12	0.68 ± 0.15	0.48 ± 0.35
480	180	0.88 ± 0.33	0.26 ± 0.11	6.06 ± 1.91	0.36 ± 0.13	1.38 ± 0.37
480	160	0.72 ± 0.20	<0.33	1.80 ± 1.64	0.66 ± 0.18	0.73 ± 0.30
480	140	b	b	b	b	b
480	120	0.97 ± 0.35	<0.40	2.30 ± 2.79	0.82 ± 0.19	1.62 ± 0.53
480	107	0.76 ± 0.29	<0.21	<0.92	0.44 ± 0.13	0.99 ± 0.32

TABLE 5

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

Sample	Grid Location		Radionuclide Concentrations (pCi/g)[a,b]				
	N	W	Ra-226	U-235	U-238	Cs-137	Th-232
B1	497	181	14.9 ± 1.1[c]	0.95 ± 1.31	9.87 ± 2.39	0.37 ± 0.19	0.69 ± 0.41
B2A (Asphalt)	670	210	0.68 ± 0.12	<0.10	0.74 ± 0.42	0.03 ± 0.05	0.89 ± 0.36
B2B (Rock)	670	210	199 ± 1	15.7 ± 0.8	192 ± 14	<0.11	931 ± 1
B3A (Soil & Gravel)	680	211	49.3 ± 3.9	2.39 ± 3.04	44.9 ± 5.0	1.14 ± 0.33	193 ± 8
B3B (Rock)	680	211	172 ± 17	29.6 ± 29.1	189 ± 14	<2.9	944 ± 41

[a]Refer to Table 3 for direct radiation levels.
[b]Large relative errors and minimum detectable activities for some samples are the result of high continuum count rates caused by high U-238 and Th-232 levels.
[c]Errors are 2σ based on counting statistics.

TABLE 6

RADIONUCLIDE CONCENTRATIONS IN BOREHOLE SOIL

Borehole[a] No.	Grid Location N	Grid Location W	Depth (m)	Radionuclide Concentrations (pCi/g) Ra-226	U-235	U-238	Cs-137
H1	420	125	Surface	0.98 ± 0.32[b]	<0.16	0.67 ± 2.36	0.05 ± 0.04
			0.5	1.02 ± 0.22	<0.26	3.07 ± 1.15	<0.03
			1.0	1.08 ± 0.28	<0.18	1.65 ± 0.64	<0.03
H2	420	167	Surface	0.83 ± 0.28	<0.17	<0.66	<0.03
			0.5	1.05 ± 0.27	<0.29	1.39 ± 2.58	<0.03
			1.0	0.91 ± 0.23	<0.15	1.10 ± 0.66	<0.03
H3	420	210	Surface	0.80 ± 0.24	<0.17	1.72 ± 0.87	<0.04
			0.5	0.76 ± 0.16	<0.24	1.92 ± 1.33	0.04 ± 0.05
			1.0	0.85 ± 0.21	0.19 ± 0.35	0.80 ± 0.64	0.05 ± 0.08
			2.0	0.81 ± 0.28	<0.24	<0.79	<0.03
H4	580	226	Surface	0.71 ± 0.17	<0.23	<0.75	<0.03
			0.5	0.76 ± 0.19	0.23 ± 0.32	<0.32	<0.03
			1.0	0.82 ± 0.18	<0.19	1.18 ± 1.43	<0.03
			2.0	0.79 ± 0.24	<0.25	2.80 ± 1.52	<0.04
H5	650	127	Surface	0.94 ± 0.23	<0.15	0.51 ± 0.99	<0.03
			0.5	1.01 ± 0.20	<0.25	<0.81	<0.04
			1.0	0.87 ± 0.23	<0.29	<0.86	<0.04
			2.0	0.99 ± 0.24	<0.17	0.45 ± 1.77	<0.04

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

TABLE 7

RADIONUCLIDE CONCENTRATIONS IN BOREHOLE WATER

Sample No.	Sample Type	Grid Location		Radionuclide Concentrations (pCi/l)	
		N	W	Gross Alpha	Gross Beta
1	Subsurface (Borehole B4)	580	230	2.27 ± 1.47[a]	2.42 ± 1.64

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

TABLE 8

SUMMARY OF RESULTS OF BUILDING SURVEYS

Building	Gamma Exposure[a] Rates 1 Meter Above the Floor (μR/h)	Surface Contamination Levels: Direct Measurement: Alpha (d/m/100cm^2)	Direct Measurement: Beta-Gamma (d/m/100cm^2)	Direct Measurement: Beta-Gamma Dose Rate (mrad/h)	Transferable: Alpha (d/m/1100cm^2)	Transferable: Beta-Gamma (d/m/1100cm^2)
1 Administration	5–7	<54	<526	<0.02	0–1.4	2.3–32
2 Storage and Maintenance	6–12	<54	<526–1610	<0.02–0.06	0–2.9	2.3–18
3 Unused two – story structure	4–6	<54	<526	<0.02	0–5.7	1.4–14

[a]No areas of elevated gamma radiation were identified by walkover scans of building surfaces.

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 Measurements

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) crystals. Count rates were converted to exposure rates (uR/h) using factors determined by comparing the response of the scintillation detectors with that of a Reuter Stokes Model RSS-111 pressurized ionization chamber at locations on the Niagara Falls Storage Site.

Beta-Gamma Dose Rate Measurements

Measurements were performed using Eberline "Rascal," Model PRS-1, scaler/ratemeters with Model HP-260 thin-window, pancake G-M, beta probes. Dose rates (μrad/h) were determined by comparing 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 mm x 7 mm holes evenly spaced around the region of the scintillation detector. The probe was lowered into each hole using a tripod holder with a small winch. The borehole was scanned and measurements were performed at intervals of 15-30 cm 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 on NFSS properties 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 and Sediment Sample Analysis

Soil and sediment samples were dried, mixed, and a portion placed in a 0.5-liter 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 samples counted using solid state Ge(Li) and intrinsic germanium 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 (equilibrium corrections applied)
U-235 - 0.143 MeV
U-238 - 92.3 and 92.8 keV from Th-234 (secular equilibrium assumed)
Cs-137 - 0.662 MeV
Th-232 - 0.911 MeV from Ac-228 (secular equilibrium assumed)

Several samples with high concentrations were subsequently analyzed for U-238 by neutron activation. Approximately 19-20 g of soil were irradiated for 15 minutes in a neutron flux of 10^8 $n/cm^2/sec$. After a one minute wait time, the U-239 peak (74.6 keV) was counted for 10 minutes and the U-238 concentration calculated.

Water Sample Analysis

Water was 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 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 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

	Allowable Surface Residual Contamination[+1] (dpm/100 cm^2)		
Radionuclides[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.