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Radiological Survey Results for the R. P. Adams Company Property, Tonawanda, New York (TNY003)

S. P. McKenzie
M. S. Uziel
R. F. Carrier

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ORNL/RASA-97/1

Prepared for the U.S. ARMY CORPS OF ENGINEERS, Buffalo District
(Budget and Reporting Code 43WM11202; Agency Code DAG)

Radiological Survey Results for the R. P. Adams Company Property, Tonawanda, New York (TNY003)

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Date Issued—November 1998

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OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee 37831-6285
managed by
LOCKHEED MARTIN ENERGY RESEARCH CORP.
for the
U.S. DEPARTMENT OF ENERGY
under contract DE-AC05-96OR22464

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ACKNOWLEDGMENTS

The portion of this project completed after October 1, 1997, was sponsored by the U.S. Army Corps of Engineers, Buffalo District. Prior to that date, the project was sponsored by the Office of Environmental Restoration, U.S. Department of Energy, under contract DE-AC05-84OR21400 with Martin Marietta Energy Systems, Inc., and DE-AC05-96OR22464 with Lockheed Martin Energy Research Corp.

The authors wish to acknowledge the contributions of J. P. Abston, G. H. Cofer, R. L. Coleman, R. C. Gosslee, M. E. Murray, D. E. Rice, D. A. Roberts, R. E. Rodriguez, D. A. Rose, J. Wade, W. Winton, and J. K. Williams of the Measurement Applications and Development Group, Oak Ridge National Laboratory, for sample preparation and participation in the analyses, editing, and reporting of data for this survey. The authors also wish to thank David Henning and Donald Felt of the R. P. Adams Company, Inc.

ABSTRACT

At the request of the U.S. Department of Energy (DOE), a team from Oak Ridge National Laboratory conducted a radiological survey of property belonging to the R. P. Adams Company, Inc., Tonawanda, New York. The survey was performed in November 1995 and May and July 1996. The purpose of the survey was to determine if radioactive residuals had migrated, or been redistributed, from the former Linde property to the south onto the R. P. Adams property. The Linde Air Products Division of Union Carbide Corporation, Tonawanda, New York, had used radioactive materials at that location for work performed under government contract from 1942 through 1948.

The survey was performed in response to Formerly Utilized Sites Remedial Action Program (FUSRAP) requirements. These requirements dictate that the radiological status of certain vicinity properties shall be assessed and documented according to prescribed procedures prior to certification of the property for release for unrestricted use. Such release can only be granted if the property is found to be within current applicable authorized limits.

The survey included a gamma scan of accessible areas in both the developed and the undeveloped portions of the property and the collection and radionuclide analysis of soil samples. A comparison of these data to the current DOE guidelines shows that all radionuclide concentrations and radioactivity levels found on the property are below the current guidelines. Therefore, this property should not be included in the FUSRAP program for remediation.

Radiological Survey Results for the R. P. Adams Company Property, Tonawanda, New York (TNY003)*

INTRODUCTION

From 1942 through approximately 1948, the Linde Air Products Division of Union Carbide Corporation, Tonawanda, New York, was one of many companies performing work associated with the development of nuclear energy for defense-related projects. This work was conducted under government contract to the Manhattan Engineer District (MED) and the Atomic Energy Commission (AEC). During the first 3 years, pitchblende ore from the Belgian Congo and concentrates from the Colorado Plateau ore were converted to U_3O_8. A second process yielding UO_2 was conducted for about a year, and a third process, converting UO_2 to green salt (UF_4), operated during World War II and the following 2 years. Linde also developed and produced barrier material for the Oak Ridge Gaseous Diffusion Plant. Other contracts have been identified, but the exact nature of the work involved is unknown.[1]

As a result of these and similar activities, equipment, buildings, and land at some of the sites became radiologically contaminated resulting in low levels of contamination on the properties. At contract termination, sites used by contractors were decontaminated in accordance with the standards and survey methods in use at that time. Since the original assessments, radiological criteria and guidelines for the release of such sites for unrestricted use have become more stringent. In some instances, records documenting decontamination efforts cannot be found, and the final radiological conditions of the site cannot be adequately determined. As a result, the Formerly Utilized Sites Remedial Action Program (FUSRAP) was established in 1974 to identify these formerly used sites and to reevaluate their radiological status.[1] The radiological assessment showing the presence of radioactive residuals at the Linde site was performed in 1978.[2]

Occasionally, nearby private and commercial properties also became contaminated through migration or redistribution of the radioactive residuals from the original site.[3] The radiological survey detailed in this report was performed under the FUSRAP program as a follow-up to earlier investigations and as a precaution to insure that no residual radioactive materials exceeding current DOE guidelines were present on the R. P. Adams property. The purpose of the survey was to determine if any contamination may have been transferred from the Linde site onto adjacent property belonging the R. P. Adams Company, Inc. The relative locations of the two properties are diagramed on Fig. 1.

The R. P. Adams site lies adjacent to the northern border of the former Linde Plant and extends from East Park Drive to the Niagara Mohawk Power Corporation right-of-way (Fig. 1). The development, production, and management activities of R. P. Adams are conducted in the buildings at the western end of the surveyed property. The eastern half of the site remained undeveloped at the time of the survey (Fig. 2). Most of the data presented in this report was obtained in May and July 1996. The original walkover on the developed portion of the property was conducted in November 1995.

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*The survey was performed by members of the Measurement Applications and Development Group of the Life Sciences Division at Oak Ridge National Laboratory.

SCOPE OF THE SURVEY

The radiological survey included (1) a surface gamma scan of accessible areas of the property, (2) measurement of 1-m gamma exposure rates at soil sampling locations, and (3) collection and radionuclide analysis of systematic and biased soil samples. Systematic samples were collected in a systematic order without regard to radiation level; biased soil samples were collected at locations of slightly elevated gamma levels.

SURVEY METHODS

A comprehensive description of the methods and instrumentation used in this survey and in the laboratory analyses is given in *Procedures Manual for the ORNL Radiological Survey Activities (RASA) Program*, ORNL/TM-8600 (April 1987)[4] and *Measurement Applications and Development Group Guidelines*, ORNL-6782 (January 1995).[5]

Separate grids were established over the developed and the undeveloped portions of the property to enable the precise location of measurements and samples (Figs. 3 and 4). The southwestern corner of each property was designated as 0N, 0E. A sample was then located by number of feet directly north and then directly east of the southwest corner. For example, sample S70 (Fig. 3 and Table 3; 70N, 200E) on the developed west portion of the R. P. Adams property was collected 70 feet north and 200 feet east of the southwest corner (0N, 0E) of the developed part. Sample S16 (Fig. 4 and Table 4; 50N, 840E) on the undeveloped east potion of the R. P. Adams property was collected 50 ft north and 840 feet east of southwest corner (0N, 0E) of the undeveloped area.

GAMMA RADIATION MEASUREMENTS

Gamma radiation levels were determined using portable NaI gamma scintillation meters. Because NaI gamma scintillators are energy dependent, measurements of gamma radiation levels in counts per minute are normalized to pressurized ionization chamber (PIC) measurements to estimate gamma exposure rates in μR/h.

SOIL SAMPLING AND ANALYSES

Surface and subsurface soil samples were systematically collected (i.e., without regard to gamma radiation levels) at grid locations shown on Figs. 3 and 4. Additional samples were collected at locations with elevated gamma radiation levels and designated as "biased" (Figs. 3 and 4).

A gradient approach was applied to the soil sampling operations with the highest concentration of samples taken along the fence line nearest the former Linde plant site; fewer samples were collected as sampling operations were moved north away from the Linde site. Work involving uranium at the Linde site was conducted in the southeast quadrant and, since the land is fairly level, it was assumed that any contamination entering the R. P. Adams property would most probably have come from the south.

SURVEY RESULTS

DOE guidelines are summarized in Table 1. Typical background radiation levels for the Tonawanda, New York, area are presented in Table 2. These data are provided for comparison with survey results presented in this section. All direct measurement results presented in this report are gross readings; background radiation levels have not been subtracted. Similarly, background concentrations have not been subtracted from radionuclide concentrations measured in soil samples.

GAMMA EXPOSURE RATE MEASUREMENTS

Developed West End of the Property

Gamma exposure rates in accessible areas of the developed portion of the property ranged from 7 to 11 μR/h at the surface and from 7 to 10 μR/h at 1 m above the ground surface (Fig. 5). The highest gamma exposure measurements found at four biased sampling locations ranged from 11 to 13 μR/h at the ground surface and from 9 to 11 μR/h at 1 m above the surface. These values are at or near background levels typically found in the Tonawanda area (Table 2).

Undeveloped East End of the Property

The undeveloped east end of the R. P. Adams property is approximately 3/8 mile long and 100 yd wide. Scanning was very difficult or impossible in some parts, which contained low-lying swampy, marshy areas with some standing water. More than one-half of the undeveloped area was cleared of trees and covered with grass although parts of the grassy area contained thorny bushes and brush (Fig. 2). Approximately 90% of the cleared area was accessible. The eastern most half was heavily woody and also contained marshy places and standing water. Approximately 50% of the wooded area was accessible.

The gamma scan of accessible areas in the east end revealed general exposure rates ranging from 8 to 12 μR/h at the surface and 7 to 12 μR/h at 1 m (Fig. 6). Higher surface measurements of 13 and 18 μR/h at the surface and 13μR/h at 1-m can probably be attributed to natural radioactive substances present in the outcroppings of slag. Slag was most evident in a ~300-ft-long area at the eastern end of the property near the southern fence.

SOIL SAMPLE ANALYSES

Developed West End of the Property

The results of the soil sample analyses on 33 systematic and 4 biased surface soil samples (0–15 cm) from the developed section of the property are given in Table 3. Sample locations are shown on Fig. 3. Concentrations of ^{238}U ranged from 0.95 to 3.0 pCi/g in 32 systematic samples and 3 biased samples. One systematic sample (S61) contained 4.3 ± 0.5 pCi/g ^{238}U; one biased sample (B15) contained 9.7 ± 3 pCi/g. All samples were well below the DOE guideline values for ^{238}U at this site (see Table 1). Concentrations of ^{226}Ra ranged from 0.90 to 2.2 pCi/g and concentrations of ^{232}Th ranged from 0.65 to 1.3 pCi/g in all samples, systematic and biased. These concentrations are similar to normal background soil concentrations of ^{226}Ra and ^{232}Th for the Tonawanda area (Table 2) and well below the DOE guideline value of 5 pCi/g over the first 15 cm (Table 1).

Undeveloped East End of the Property

The results of the soil sample analyses on 71 samples, systematic plus biased, from the undeveloped portion of the property are given in Table 4. Sample locations are shown on Fig. 4. Samples were collected from both surface (0–15 cm) and subsurface (15–45 cm) areas. Concentrations of ^{238}U ranged from 0.74 to 6.6 pCi/g in 66 samples. Samples S10, B8A, B8B, B10, and B11B, collected in the southeast corner (Fig. 4), ranged from 8.5 to 16 pCi/g. All samples were well below the DOE guideline values for ^{238}U at this site (see Table 1). Concentrations of ^{226}Ra ranged from 0.80 to 3.9 pCi/g and concentrations of ^{232}Th ranged from 0.34 to 3.5 pCi/g in all samples, systematic and biased, surface and subsurface. Some of these concentrations are greater than normal background soil concentrations of ^{226}Ra and ^{232}Th for the Tonawanda area (Table 2), but all are well below the DOE guideline value of 5 pCi/g averaged over the first 15 cm and 15 pCi/g averaged over 15-cm-thick soil layers more than 15 cm below the surface (Table 1).

SIGNIFICANCE OF FINDINGS

Results of this radiological survey indicate that no significant material originating at the Linde plant is located on the developed or undeveloped portions of the R. P. Adams Company property. Although some soil samples contained ^{238}U in concentrations greater than typical background levels found in the Tonawanda area, maximum ^{238}U levels of 16 ± 1 pCi/g were well below the DOE guideline value of 30 pCi/g for this site. All measured gamma exposure rates were similar to normal background levels in the Tonawanda area. Therefore, this property should not be included in the FUSRAP program for remediation.

REFERENCES

1. U. S. Department of Energy, *A Background Report for the Formerly Utilized Manhattan Engineer District/Atomic Energy Commission Sites Program*, DOE/EV-0097, September 1980.
2. Oak Ridge Natl. Lab., *Radiological Survey of the Former Linde Uranium Refinery, Tonawanda, New York*, DOE/EV-005/5, UC-70, U.S. Department of Energy, Division of Environmental Control Technology, Formerly Utilized MED/AEC Sites Remedial Action Program, May 1978.
3. R. E. Rodriguez, M. E. Murray, and M. S. Uziel, *Results of the Radiological Survey at the Town of Tonawanda Landfill, Tonawanda, New York (TNY001)*, ORNL/RASA-92/12, Martin Marietta Energy Systems, Inc., Oak Ridge Natl. Lab., October 1992.
4. T. E. Myrick, B. A. Berven, W. D. Cottrell, W. A. Goldsmith, and F. F. Haywood, *Procedures Manual for the ORNL Radiological Survey Activities (RASA) Program*, ORNL/TM-8600, Martin Marietta Energy Systems, Inc., Oak Ridge Natl. Lab., April 1987.
5. *Measurement Applications and Development Group Guidelines*, ORNL-6782, Martin Marietta Energy Systems, Inc., Oak Ridge Natl. Lab., January, 1995.

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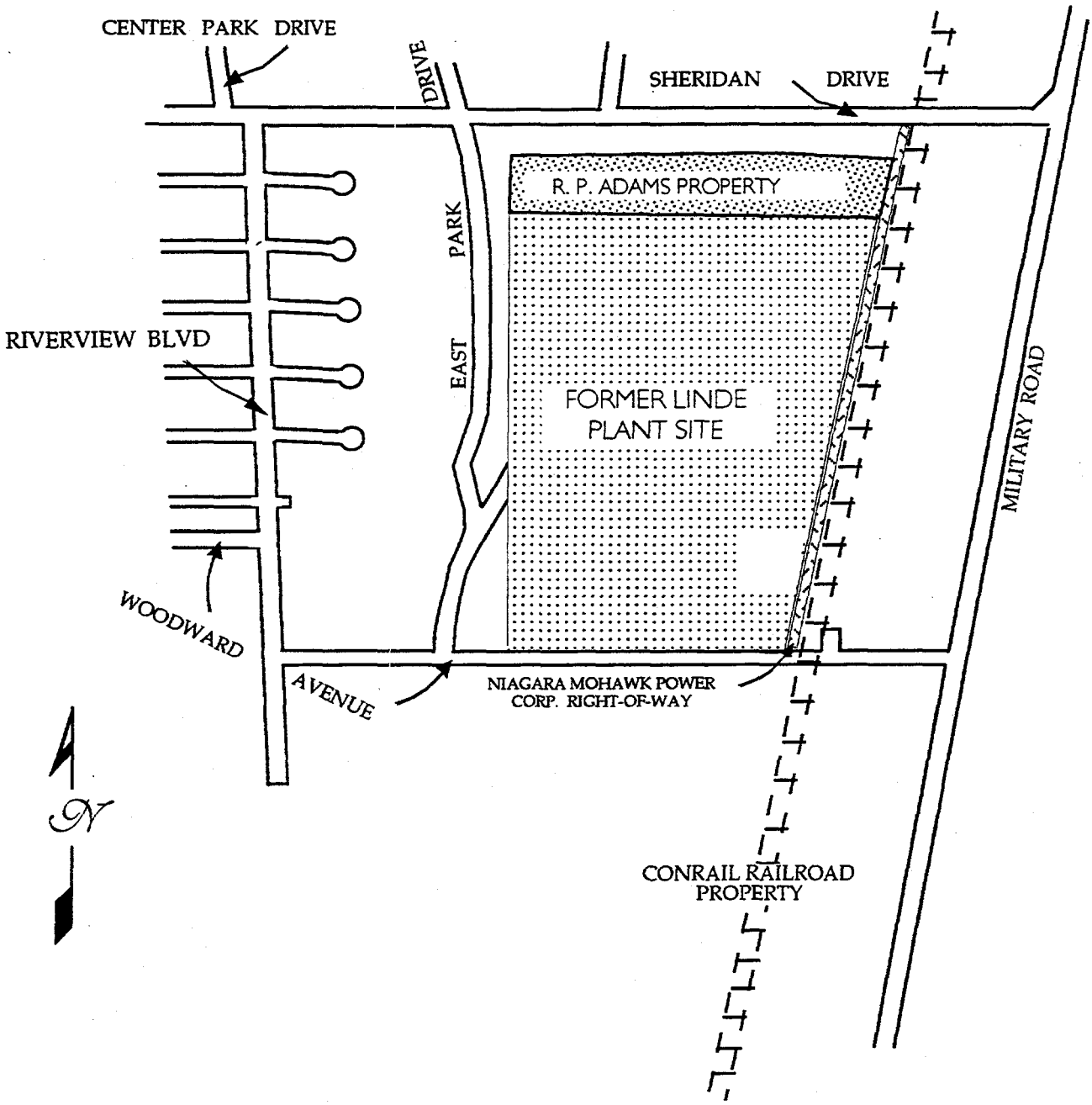

Fig. 1. Diagram showing general location of the R. P. Adams property in relation to the former Linde plant site in Tonawanda, New York. (Not to scale.)

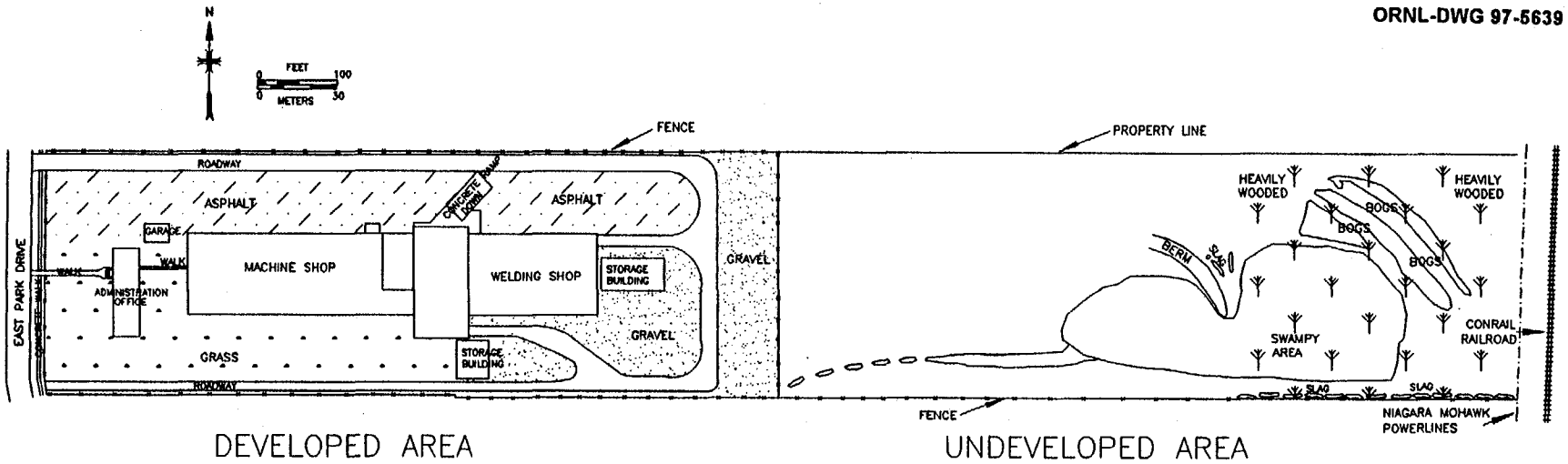

Fig. 2. Diagram showing developed and undeveloped parts of the R. P. Adams property.

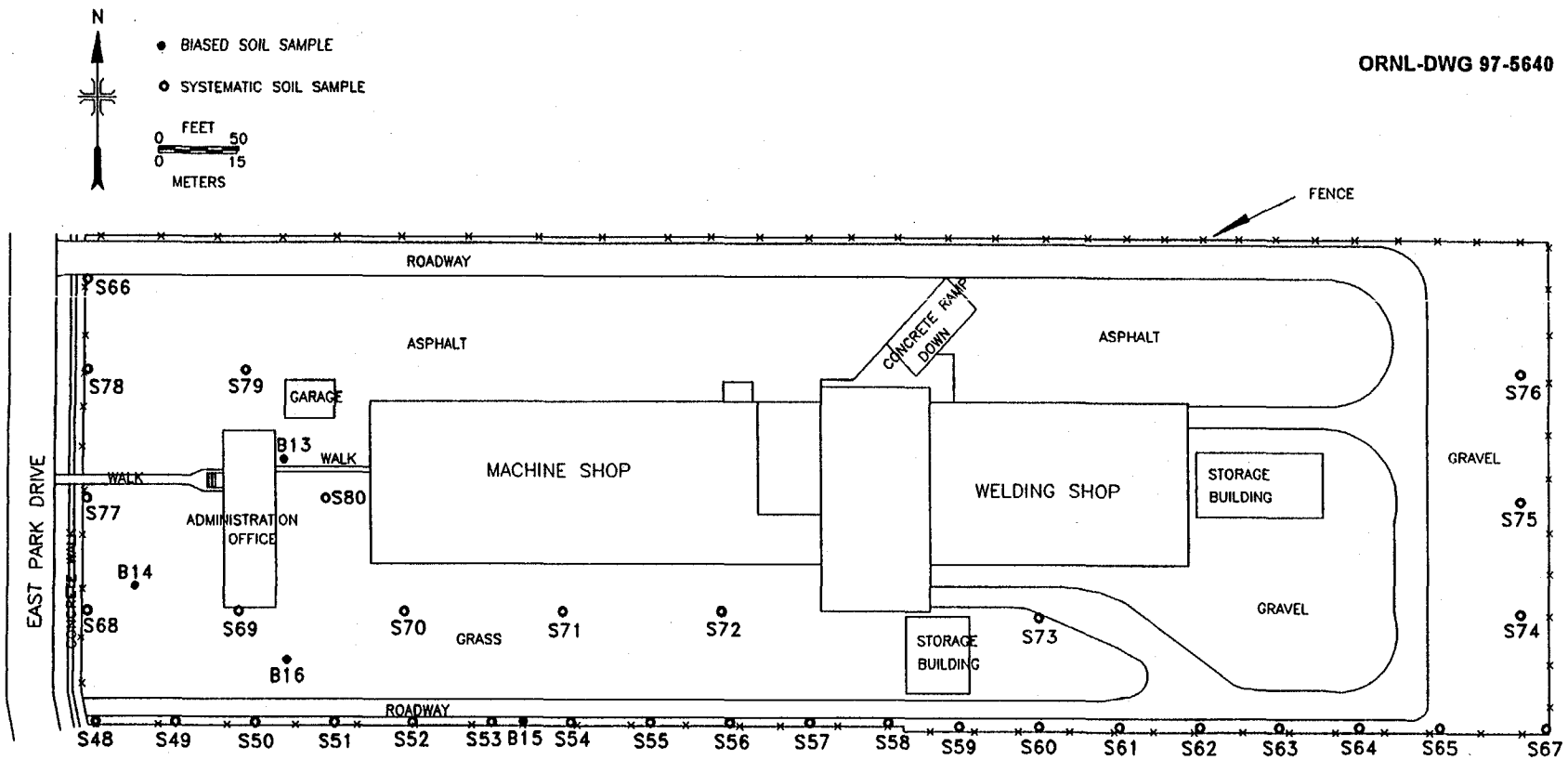

Fig. 3. Diagram showing systematic and biased soil sampling locations on the developed portion of the R. P. Adams property.

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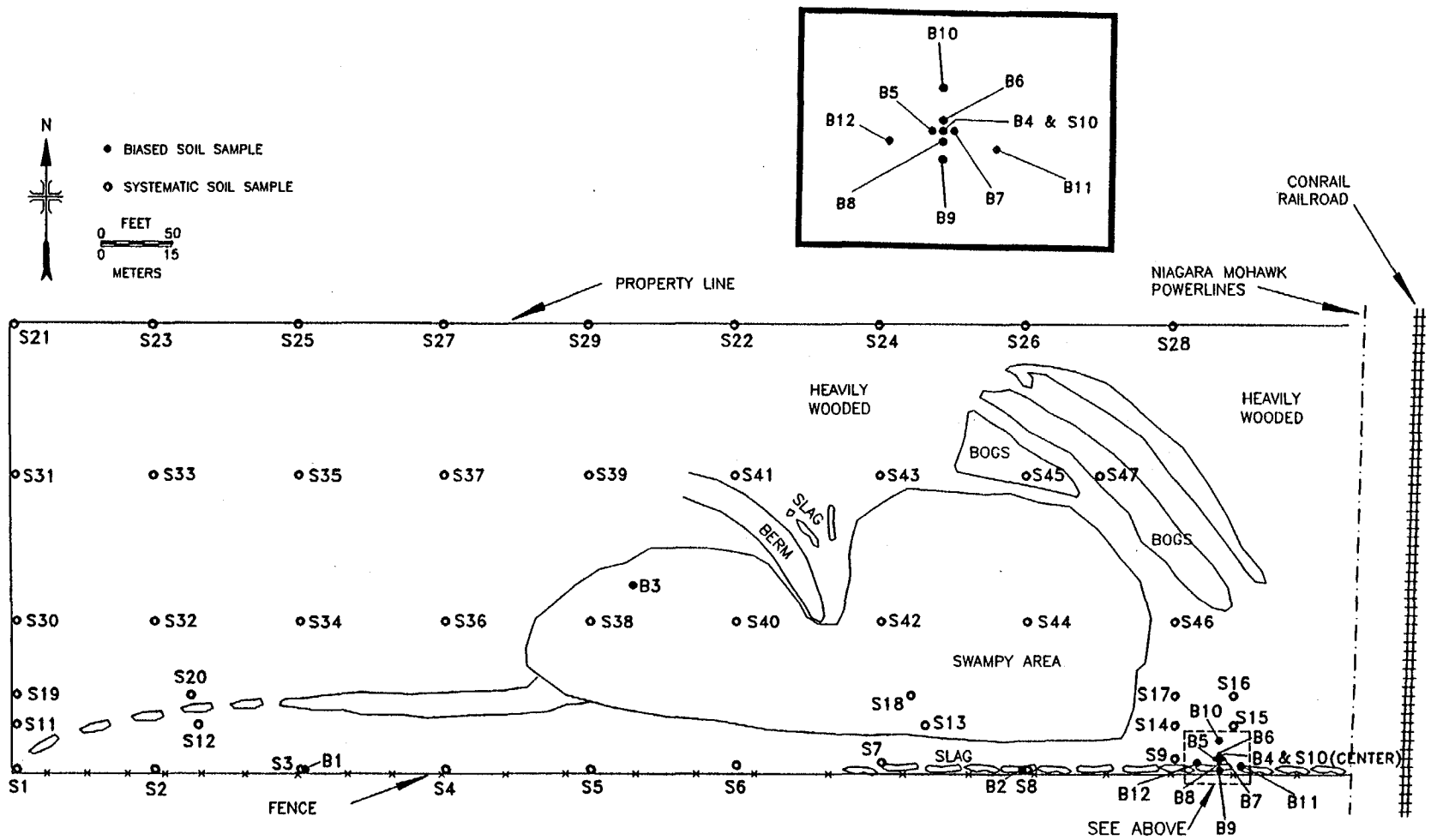

Fig. 4. Diagram showing systematic and biased soil sampling locations on the undeveloped portion of the R. P. Adams property. Inset at top is an enlarged view of sampling locations B4 through B12 and S10.

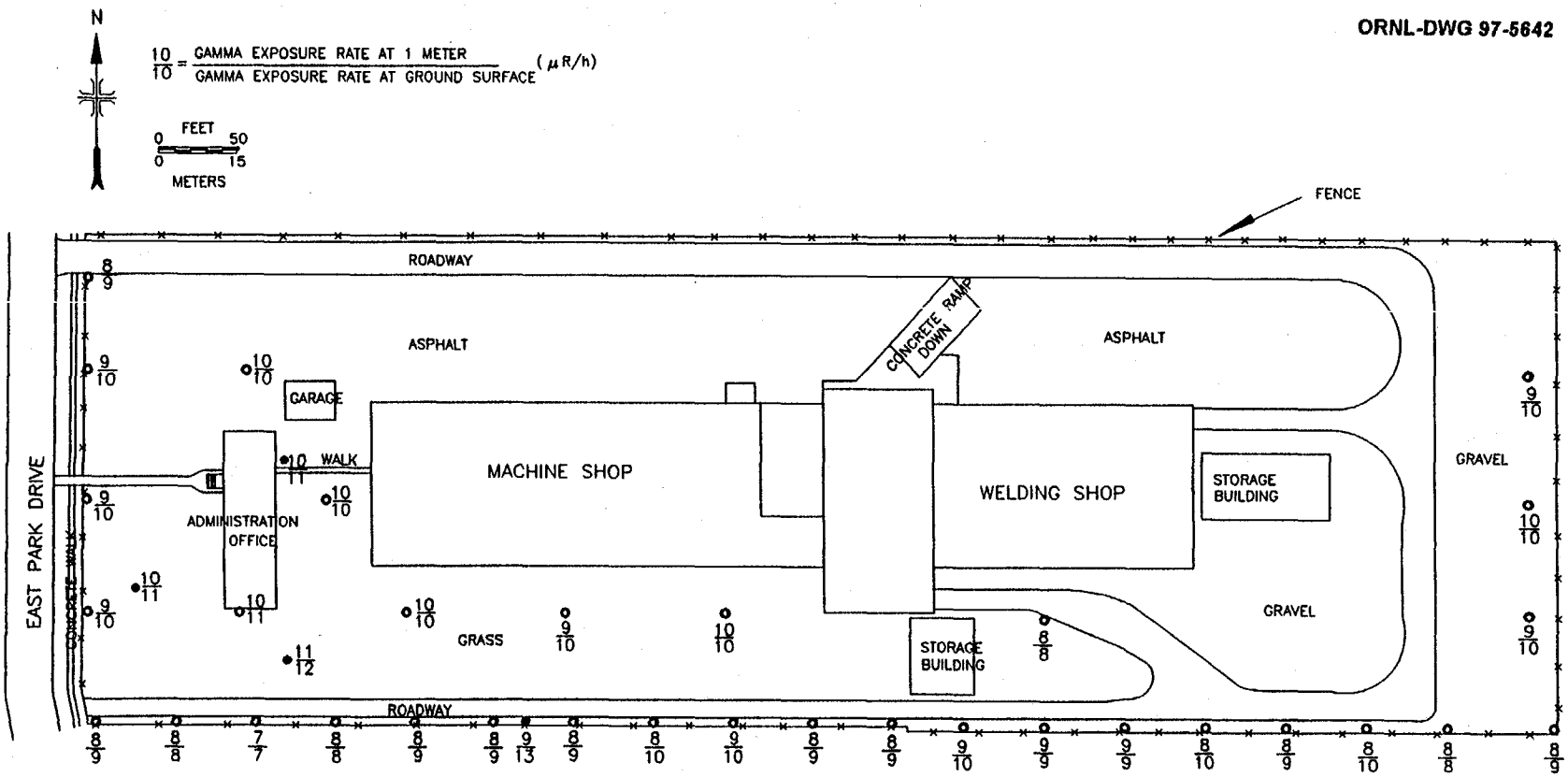

Fig. 5. Diagram showing surface and 1-m gamma exposure rates on the developed portion of the R. P. Adams property.

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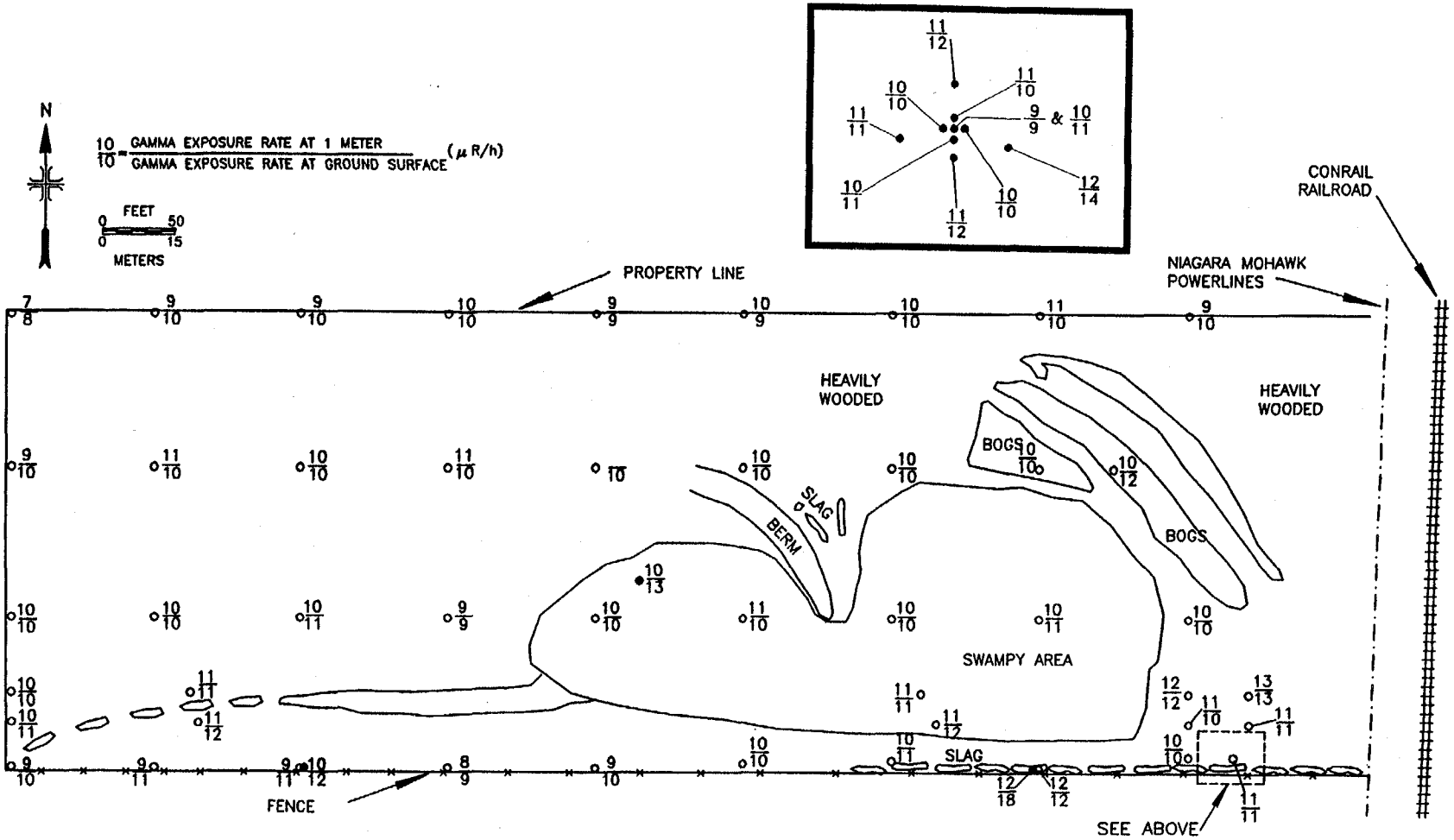

Fig. 6. Diagram showing surface and 1-m gamma exposure rates on the undeveloped portion of the R. P. Adams property. Inset at top corresponds to the inset in Fig. 4.

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

Mode of exposure	Exposure conditions	Guideline value
Gamma radiation	Indoor gamma radiation level (above background)	20 μR/h[a]
Radionuclide concentrations in soil (generic)	Maximum permissible concentration of the following radionuclides in soil above background levels, averaged over a 100-m^2 area ^{226}Ra ^{232}Th ^{230}Th	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
Derived concentrations	Maximum permissible concentration of total uranium in soil above background levels, averaged over a 100-m^2 area.	60 pCi/g[b]
Guideline for non-homogeneous contamination (used in addition to the 100-m^2 guideline)[c]	Applicable to locations with an area ≤ 25 m^2, with significantly elevated concentrations of radionuclides ("hot spots")	$G_A = G_i(100/A)^{1/2}$, where G_A = guideline for "hot spot" of area (A) G_i = guideline averaged over a 100-m^2 area

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

[b]Guidelines for uranium are derived on a site-specific basis. A total uranium guideline of 60 pCi/g will be applied at the R. P. Adams Company site. This corresponds to a ^{238}U concentration of ~30 pCi/g.

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

Sources: Adapted from U.S. Department of Energy, DOE Order 5400.5, April 1990; U.S. Department of Energy, *Guidelines for Residual Radioactive Material at Formerly Utilized Sites Remedial Action Program and Remote Surplus Facilities Management Program Sites*, Rev. 2, March 1987; and U.S. Department of Energy, *Radiological Control Manual*, DOE/EH-0256T, Rev. 1, April 1994.

Table 2. Background radiation levels and concentrations of selected radionuclides in soil near Tonawanda, New York

Type of radiation measurement or sample	Radiation level or radionuclide concentration	
	Range	Average
Gamma exposure rate at ground surface (μR/h)[a]	8–11	9
Concentration of radionuclides in soil (pCi/g)[a]		
^{238}U	0.8–1.1	1.0
^{226}Ra	0.7–1.1	0.9
^{232}Th	0.5–0.9	0.8

[a]Values obtained from four locations in the Tonawanda area.

Source: R. E. Rodriguez, M. E. Murray, and M. S. Uziel, *Results of the Radiological Survey at the Town of Tonawanda Landfill, Tonawanda, New York (TNY001)*, ORNL/RASA-92/12, Martin Marietta Energy Systems, Inc., Oak Ridge Natl. Lab., October 1992.

Table 3. Concentrations of selected radionuclides in soil samples collected from the developed west portion of the R. P. Adams property, Tonawanda, New York

Sample ID[a]	Grid location[a]	Depth (cm)	Radionuclide concentration (pCi/g)[b]		
			^{238}U	^{226}Ra	^{232}Th
		Systematic samples[c]			
S48	0N, 0E	0–15	2.1 ± 0.4	1.2 ± 0.09	0.83 ± 0.1
S49	0N, 50E	0–15	1.3 ± 0.6	1.0 ± 0.07	0.87 ± 0.1
S50	0N, 100E	0–15	0.96 ± 0.5	0.95 ± 0.08	0.90 ± 0.1
S51	0N, 150E	0–15	1.2 ± 0.7	1.2 ± 0.1	0.89 ± 0.1
S52	0N, 200E	0–15	1.8 ± 0.9	1.1 ± 0.1	1.0 ± 0.1
S53	0N, 250E	0–15	2.6 ± 0.4	1.1 ± 0.08	0.90 ± 0.1
S54	0N, 300E	0–15	2.0 ± 0.3	1.1 ± 0.08	0.98 ± 0.1
S55	0N, 350E	0–15	1.8 ± 0.3	1.2 ± 0.1	0.89 ± 0.1
S56	0N, 400E	0–15	1.9 ± 0.3	1.1 ± 0.09	1.2 ± 0.1
S57	0N, 450E	0–15	1.3 ± 0.9	1.0 ± 0.09	1.0 ± 0.1
S58	0N, 500E	0–15	1.8 ± 0.9	1.0 ± 0.09	1.1 ± 0.1
S59	0N, 550E	0–15	3.0 ± 1	1.2 ± 0.09	1.3 ± 0.1
S60	0N, 600E	0–15	1.9 ± 0.2	1.2 ± 0.1	1.1 ± 0.1
S61	0N, 650E	0–15	4.3 ± 0.5	1.2 ± 0.09	1.2 ± 0.1
S62	0N, 700E	0–15	2.8 ± 1	1.5 ± 0.1	1.2 ± 0.1
S63	0N, 750E	0–15	2.6 ± 0.4	1.2 ± 0.09	1.1 ± 0.1
S64	0N, 800E	0–15	3.0 ± 1	1.4 ± 0.09	1.1 ± 0.1
S65	0N, 850E	0–15	1.6 ± 0.7	1.2 ± 0.09	0.70 ± 0.1
S66	280N, 0E	0–15	1.2 ± 0.3	0.96 ± 0.07	0.72 ± 0.09
S67	0N, 920E	0–15	1.9 ± 0.2	1.4 ± 0.09	0.90 ± 0.1
S68	70N, 0E	0–15	1.3 ± 0.3	1.2 ± 0.1	1.1 ± 0.1
S69	70N, 95E	0–15	1.0 ± 0.6	1.1 ± 0.09	1.1 ± 0.1
S70	70N, 200E	0–15	1.8 ± 0.9	1.6 ± 0.1	0.95 ± 0.1
S71	70N, 300E	0–15	1.2 ± 0.3	1.1 ± 0.09	0.83 ± 0.1
S72	70N, 400E	0–15	1.5 ± 0.8	1.0 ± 0.08	1.1 ± 0.1
S73	70N, 600E	0–15	1.7 ± 0.4	1.1 ± 0.1	1.2 ± 0.1
S74	70N, 900E	0–15	1.1 ± 0.3	0.91 ± 0.08	1.2 ± 0.1
S75	140N, 900E	0–15	1.0 ± 0.5	1.0 ± 0.08	1.1 ± 0.1

Table 3 (continued)

Sample ID[a]	Grid location[a]	Depth (cm)	Radionuclide concentration (pCi/g)[b]		
			^{238}U	^{226}Ra	^{232}Th
S76	220N, 900E	0–15	1.1 ± 0.3	1.1 ± 0.09	1.2 ± 0.2
S77	140N, 0E	0–15	1.7 ± 0.8	1.2 ± 0.08	0.92 ± 0.1
S78	220N, 0E	0–15	1.2 ± 0.7	1.3 ± 0.1	0.84 ± 0.1
S79	220N, 100E	0–15	0.95 ± 0.5	0.90 ± 0.07	0.65 ± 0.1
S80	140N, 150E	0–15	2.0 ± 0.3	2.2 ± 0.1	0.87 ± 0.1
		Biased samples[d]			
B13	165N, 125E	0–15	1.9 ± 0.74	1.2 ± 0.08	1.0 ± 0.1
B14	85N, 30E	0–15	1.8 ± 0.8	1.1 ± 0.09	1.0 ± 0.1
B15	0.5N, 270E	0–15	9.7 ± 3	1.2 ± 0.1	1.0 ± 0.2
B16	40N, 125E	0–15	1.6 ± 0.3	1.2 ± 0.08	0.96 ± 0.1

[a]Sample locations are shown on Figs. 4 and 5.
[b]Indicated counting error is at the 95% confidence level (±2σ).
[c]Systematic samples are collected without regard to gamma radiation levels.
[d]Biased samples are taken from areas shown to have elevated gamma exposure rates.

Table 4. Concentrations of selected radionuclides in soil samples collected from the undeveloped east portion of the R. P. Adams property, Tonawanda, New York

Sample ID[a]	Grid location[a]	Depth (cm)	Radionuclide concentration (pCi/g)[b]		
			^{238}U	^{226}Ra	^{232}Th
		Systematic samples[c]			
S1	0N, 0E	0–15	1.6 ± 0.3	1.4 ± 0.2	0.77 ± 0.09
S2	0N, 100E	0–15	0.74 ± 0.4	0.80 ± 0.06	0.65 ± 0.07
S3	0N, 200E	0–15	1.2 ± 0.8	1.9 ± 0.1	0.89 ± 0.1
S4	0N, 300E	0–15	1.9 ± 0.7	1.7 ± 0.1	0.83 ± 0.1
S5	0N, 400E	0–15	0.90 ± 0.6	1.1 ± 0.08	0.63 ± 0.1
S6	3N, 500E	0–15	4.7 ± 2.0	1.1 ± 0.08	0.79 ± 0.2
S7	5N, 600E	0–15	1.8 ± 1	1.7 ± 0.1	1.0 ± 0.2
S8A	0N, 700E	0–15	5.6 ± 2	2.2 ± 0.1	1.2 ± 0.1
S8B	0N, 700E	15–30	6.4 ± 2	2.0 ± 0.1	1.0 ± 0.2
S8C	0N, 700E	30–45	2.8 ± 1	1.1 ± 0.1	1.1 ± 0.1
S9A	8N, 800E	0–15	3.8 ± 0.6	2.6 ± 0.2	1.2 ± 0.2
S9B	8N, 800E	15–30	4.9 ± 1	2.8 ± 0.2	1.1 ± 0.1
S9C	8N, 800E	30–45	4.3 ± 2	2.1 ± 0.1	1.2 ± 0.1
S10	8N, 830E	0–15	16 ± 1	2.3 ± 0.2	1.0 ± 0.2
S11	30N, 0E	0–15	1.2 ± 0.3	1.0 ± 0.08	1.0 ± 0.1
S12	30N, 130E	0–15	1.3 ± 0.3	1.0 ± 0.09	1.0 ± 0.1
S13	30N, 630E	0–15	3.6 ± 0.5	1.3 ± 0.09	0.99 ± 0.1
S14	30N, 800E	0–15	5.0 ± 2	2.2 ± 0.2	0.90 ± 0.2
S15	30N, 840E	0–15	6.6 ± 2	1.9 ± 0.2	1.1 ± 0.2
S16	50N, 840E	0–15	6.1 ± 2	2.2 ± 0.2	1.0 ± 0.2
S17A	50N, 800E	0–15	4.3 ± 0.5	1.5 ± 0.2	1.1 ± 0.1
S17B	50N, 800E	15–30	1.2 ± 0.8	1.0 ± 0.1	1.2 ± 0.1
S17C	50N, 800E	30–45	1.3 ± 0.3	1.0 ± 0.08	1.4 ± 0.1
S18	50N, 620E	0–15	4.5 ± 2	1.2 ± 0.1	1.1 ± 0.2
S19	50N, 0E	0–15	1.2 ± 0.6	1.1 ± 0.08	1.0 ± 0.1
S20	50N, 125E	0–15	1.7 ± 0.3	1.1 ± 0.1	1.1 ± 0.1
S21	295N, 0E	0–15	1.0 ± 0.8	0.85 ± 0.08	0.74 ± 0.1
S22	500 ft E of NW corner of property at perimeter	0–15	3.6 ± 2	1.3 ± 0.09	0.94 ± 0.1
S23	100 ft E of NW corner of property at perimeter	0–15	1.3 ± 0.3	1.0 ± 0.09	0.69 ± 0.1

Table 4 (continued)

Sample ID[a]	Grid location[a]	Depth (cm)	Radionuclide concentration (pCi/g)[b]		
			^{238}U	^{226}Ra	^{232}Th
S24	600 ft E of NW corner of property at perimeter	0–15	3.2 ± 0.5	1.5 ± 0.1	1.1 ± 0.2
S25	200 ft E of NW corner of property at perimeter	0–15	2.1 ± 0.4	1.1 ± 0.1	0.89 ± 0.1
S26	700 ft E of NW corner of property at perimeter	0–15	2.9 ± 0.4	1.5 ± 0.1	0.96 ± 0.1
S27	300 ft E of NW corner of property at perimeter	0–15	1.5 ± 0.3	1.2 ± 0.09	1.1 ± 0.1
S28	800 ft E of NW corner of property at perimeter	0–15	1.9 ± 0.4	1.5 ± 0.1	0.89 ± 0.1
S29	400 ft E of NW corner of property at perimeter	0–15	1.4 ± 0.3	1.2 ± 0.1	1.1 ± 0.1
S30	100N, 0E	0–15	1.2 ± 0.3	1.1 ± 0.08	0.98 ± 0.1
S31	200N, 0E	0–15	1.7 ± 0.7	1.1 ± 0.08	1.0 ± 0.1
S32	100N, 100E	0–15	1.4 ± 0.6	1.1 ± 0.08	1.1 ± 0.1
S33	200N, 100E	0–15	1.4 ± 0.3	1.2 ± 0.09	0.97 ± 0.1
S34	100N, 200E	0–15	1.6 ± 0.4	1.2 ± 0.09	1.0 ± 0.1
S35	200N, 200E	0–15	1.7 ± 1	1.2 ± 0.09	1.1 ± 0.1
S36	100N, 300E	0–15	1.4 ± 0.6	1.2 ± 0.08	0.34 ± 0.08
S37	200N, 300E	0–15	1.3 ± 0.8	1.1 ± 0.1	1.1 ± 0.1
S38	100N, 400E	0–15	5.3 ± 2	1.6 ± 0.1	1.1 ± 0.1
S39	200N, 400E	0–15	1.5 ± 0.4	1.2 ± 0.09	1.1 ± 0.1
S40	100N, 500E	0–15	3.4 ± 0.5	1.4 ± 0.09	1.1 ± 0.1
S41	200N, 500E	0–15	4.1 ± 0.6	1.5 ± 0.1	1.0 ± 0.1
S42	100N, 600E	0–15	3.9 ± 2	1.8 ± 0.1	1.3 ± 0.2
S43	200N, 600E	0–15	5.0 ± 0.6	1.8 ± 0.1	1.0 ± 0.2
S44	100N, 700E	0–15	4.2 ± 1	2.0 ± 0.1	1.2 ± 0.1
S45	200N, 700E	0–15	2.7 ± 0.4	1.6 ± 0.1	1.0 ± 0.1
S46	100N, 800E	0–15	1.5 ± 0.9	1.5 ± 0.1	1.1 ± 0.1
S47	200N, 750E	0–15	1.3 ± 0.7	1.7 ± 0.1	0.97 ± 0.1

Table 4 (continued)

Sample ID[a]	Grid location[a]	Depth (cm)	Radionuclide concentration (pCi/g)[b]		
			^{238}U	^{226}Ra	^{232}Th
			Biased samples[d]		
B1	0N, 203E	0–15	1.7 ± 0.3	1.9 ± 0.1	1.0 ± 0.1
B2A	0N, 696E	0–15	3.0 ± 1	2.4 ± 0.1	2.2 ± 0.2
B2B	0N, 696E	15–30	3.4 ± 1	2.3 ± 0.1	1.7 ± 0.2
B3A	125N, 430E	0–15	5.6 ± 2	2.5 ± 0.1	3.5 ± 0.2
B3B	125N, 430E	15–30	3.0 ± 1	2.5 ± 0.1	3.5 ± 0.3
B4	8N, 830E	0–15	6.6 ± 1	1.8 ± 0.1	1.0 ± 0.2
B5	8N, 827E	0–15	4.2 ± 0.9	1.5 ± 0.1	0.97 ± 0.2
B6	11N, 830E	0–15	3.3 ± 1	1.4 ± 0.1	0.91 ± 0.1
B7	8N, 833E	0–15	6.0 ± 2	2.2 ± 0.2	0.96 ± 0.2
B8A	5N, 830E	0–15	11 ± 4	2.6 ± 0.2	1.1 ± 0.2
B8B	5N, 830E	15–30	10 ± 2	3.4 ± 0.2	1.1 ± 02
B9A	0N, 830E	0–15	2.6 ± 1	1.9 ± 0.1	1.2 ± 0.1
B9B	0N, 830E	15–30	3.3 ± 1	1.9 ± 0.1	1.0 ± 0.1
B9C	0N, 830E	30–45	4.9 ± 2	2.2 ± 0.1	0.87 ± 0.1
B10	20N, 830E	0–15	8.5 ± 2	2.3 ± 0.2	1.0 ± 0.2
B11A	3N, 845E	0–15	6.4 ± 0.6	3.9 ± 0.2	3.1 ± 0.2
B11B	3N, 845E	15–30	8.9 ± 3	3.7 ± 0.2	1.7 ± 0.2
B12	5N, 815E	0–15	4.8 ± 2	3.2 ± 0.2	1.2 ± 0.2

[a]Sample locations are shown on Figs. 4 and 5.
[b]Indicated counting error is at the 95% confidence level (±2σ).
[c]Systematic samples are collected without regard to gamma radiation levels.
[d]Biased samples are taken from areas shown to have elevated gamma exposure rates.