# COMPREHENSIVE RADIOLOGICAL SURVEY

## OFF-SITE PROPERTY N/N' SOUTH
## NIAGARA FALLS STORAGE SITE
## LEWISTON, NEW YORK

Prepared for

U.S. Department of Energy
as part of the
Formerly Utilized Sites — Remedial Action Program

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FINAL REPORT

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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, NY, for storage of radioactive wastes. These 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]

The Department of Labor is the current owner of a tract identified as off-site property N/N' South (see Figure 1). A radiological survey of that tract is the subject of this report.

## SITE DESCRIPTION

### General

Figure 2 is a plot plan of off-site property N/N' South. The property occupies approximately 31 hectares and is bounded on two sides by roads: Castle Garden to the west, and South Patrol Road on the southeast. Town of Lewiston property borders the site on the south and Modern Landfill, Inc., owns the property to the north. Unused railroad tracks cross the property in a southwest to northeast direction. There are major drainage ditches along Track Street and South Track Street, on both sides of the southwestern portion of the railroad

tracks and crossing the northwest corner of the site. The site is heavily wooded with the exception of the Track Street area and the northwest corner of the site.

## Radiological History

Two small areas of property N/N' South were previously used for handling or storing contaminated material and low-level radioactive wastes.[1] An incinerator in the northwest corner of the property was used by Hooker Electrochemical Company to burn low level radioactive waste containers. Aerial photographs indicate the incinerator was present as late as 1963. The Track Street area was a classification yard, used for temporary storage of metal scrap, building rubble, and other miscellaneous material; some of the material stored in this area was contaminated.

Both of these areas were included in the 1971-72 cleanup efforts; however, following decontamination elevated radiation levels were still present at both locations.[2] Scrap and building debris remain in the ditches adjacent to Track Street and small pieces of debris were noted in the incinerator area. The 1980 mobile gamma scan by Oak Ridge National Laboratory indicated elevated radiation levels in both of these areas.[3]

# SURVEY PROCEDURES

The comprehensive survey of NFSS off-site property N/N' South was performed by the Radiological Site Assessment Program of Oak Ridge Associated Universities (ORAU). The survey was in accordance with a plan dated September 27, 1982, approved by the Department of Energy's Office of Occupational Safety. With the exception of shallow borehole drilling, the survey was conducted during the period of October 18-November 3, 1982; the borehole investigations were performed March 24-25, 1983. The objectives and procedures from that plan are presented in this section.

## Objectives

The objective of the survey was to provide a comprehensive assessment of the radiological conditions on property N/N' South and associated potential

health effects, if any. 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, and
4. concentrations of radionuclides in ground water.

## Procedures

1. Site Preparation

   a. Brush and weeds were cleared as needed to provide access for gridding and surveying. This operation was performed under subcontract by Modern Disposal Co., Model City, NY.

   b. An 80 m grid system was established by McIntosh and McIntosh of Lockport, NY, under subcontract. This grid system is shown on Figure 2. The 80 m grid was subdivided into 10 m intervals in the area where the incinerator had been located and in the area bounded by Track Street and South Track Street (see Figures 4 and 5).

2. Gamma exposure rate measurements were performed at the surface and at 1 m above the surface at each accessible grid line intersection. 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 each accessible grid line intersection. 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 containing elevated concentrations of Ra-226.

4. Surface (0-15 cm) soil samples of approximately 1 kg each were collected at each accessible grid line intersection.

5. Walkover surface scans were conducted over all accessible areas of the property. Scanning intervals were at 5-10 m in the heavily wooded regions and at 1-2 m along roads, railroads, and in the old incinerator and Track Street areas. Portable gamma scintillation survey meters were used for these scans. Locations of elevated contact radiation levels were noted and surface exposure rates were measured at these locations.

6. At locations of elevated surface radiation levels, beta-gamma dose rates and exposure rates at 1 m above the surface were measured. Surface soil samples were obtained from these locations, and, following sampling, the surface exposure levels were remeasured to evaluate the effectiveness of shallow sampling on the removal of the radiation source. The locations where these additional measurements and samples were obtained are indicated on Figures 4, 5, and 6.

7. Detection Sciences Group of Carlisle, MA, performed ground-penetrating radar surveys in the old incinerator and Track Street areas, where elevated direct radiation levels were noted, to identify subsurface objects or anomalies which might be indicative of waste burials on the site. Ground radar scans were also conducted at locations of proposed boreholes to identify the presence of underground piping or utilities which would preclude drilling.

8. Boreholes were drilled to provide a mechanism for logging subsurface direct radiation profiles and collecting subsurface soil and water samples. Fourteen boreholes to ground water depth (2-6 m) were drilled by Site Engineers, Inc., of Voorhees, NJ, using a truck-mounted 20 cm diameter hollow-stem auger. These holes were drilled at systematic locations throughout the property as shown on Figure 7.

Twelve shallower (0.5-1.5 m) boreholes were drilled by Earth Dimensions of East Aurora, NY, using a special augering rig able to negotiate swampy and muddy areas. The shallow boreholes were primarily at locations where direct radiation measurements and ground-penetrating radar had indicated possible residues (old incinerator and Track Street areas). The locations of these boreholes are shown on Figures 8 and 9.

Gamma scans of boreholes were performed to identify elevated radiation levels, which would indicate subsurface residues. Radiation profiles in the boreholes were then determined by measurements of gamma radiation at 30-50 cm intervals between the surface and ground water (deep holes) or the hole bottom (shallow holes). A collimated gamma scintillation detector and portable scaler were used for these measurements.

Ground water samples of approximately 3.5 liters each were collected from deep 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 a specially constructed sampling tool.

9. Twenty soil samples and seven water samples were collected from the Lewiston area (but not the 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 10.

## Sample Analysis and Interpretation of Results

Soil and sediment samples were analyzed by gamma spectrometry. Radium-226 was the major radionuclide of concern, although spectra were reviewed for Cs-137, U-235, U-238, and other gamma emitters. Radiochemical analysis for Sr-90 was conducted on several samples with elevated levels of Cs-137.

Water samples were analyzed for gross alpha and beta concentrations. Additional information concerning analytical equipment and procedures is contained in Appendix A.

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

## RESULTS

### Background Levels and Baseline Concentrations

Background exposure rates and baseline radionuclide concentrations in soil, determined for 20 locations (Figure 10) 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, systematically measured at 80 m grid line intersections, are presented in Table 2. Radiation levels measured at 10 m intervals in the old incinerator and Track Street areas are presented in Tables 3 and 4 respectively. The gamma exposure rates at 1 m above the surface ranged from 9.5 to 15 μR/h at the 80 m intervals; contact gamma exposure rates and beta-gamma dose rates at these locations ranged from 8.7 to 16 μR/h and 42 to 140 μrad/h, respectively. In the incinerator area these ranges were exposure rate at 1 m, 10 to 39 μR/h; exposure rate at contact, 10 to 93 μR/h; and beta-gamma dose rate, 42-320 μrad/h. Direct radiation levels in the Track

Street area were exposure rate at 1 m, 9.8 to 18 μR/h; exposure rate at contact, 8.7 to 20 μR/h; and beta-gamma dose rate, 34 to 160 μrad/h.

Beta-gamma measurements performed with the G-M 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 several areas with elevated surface radiation levels in the incinerator and Track Street areas. These locations are indicated on Figures 4, 5, and 6. Direct radiation levels at these locations are presented in Table 5. Gamma exposure rates at contact and at 1 m above the surface at these locations ranged from 20 to 410 μR/h and from 15 to 39 μR/h, respectively. Contact beta-gamma dose rates ranged from 140 to 3770 μrad/h. The maximum contact radiation levels were at grid location 668E,30S - in the Track Street area. Sampling reduced the radiation level significantly at only one location (109E,210S). At other locations, direct radiation levels were not reduced by sampling; at some points levels actually increased following removal of soil samples. This suggests that the contamination at most locations extends greater than 15 cm below the surface and/or is diffused rather than in discrete particles.

Radionuclides Concentrations in the Surface Soil

Tables 6, 7, and 8 list the concentrations of radionuclides measured in surface soil from 80 m grid line intersections and from 10 m grid intersections in the incinerator and Track Street areas. The systematic samples from 80 m grid line intersections (see Table 6) contained Ra-226 concentrations ranging from <0.13 to 2.60 pCi/g. With the exception of the sample from location 740E,0S, the Ra-226 levels were not significantly different from baseline levels. Other radionuclide concentrations in these samples were also in the ranges of baseline levels.

In the old incinerator area, systematic Ra-226 and U-238 levels ranged from <0.13 to 12.8 pCi/g and <0.64 to 20.2 pCi/g, respectively (see Table 7). The highest levels of both Ra-226 and U-238 were in the sample from grid point

170E,30S. Concentrations in systematic soil samples from the Track Street area were: Ra-226, 0.16 to 9.74 pCi/g and U-238, 0.69 to 9.29 pCi/g (see Table 8). The locations with the highest levels of Ra-226 and U-238 were 660E,20S and 700E,80S respectively. Concentrations of U-235 and Cs-137 in systematic samples from both the Incinerator and Track Street areas were not significantly different from those in baseline samples.

Radionuclide concentrations in surface soil samples, collected from locations of elevated radiation levels are presented in Table 9. Samples B1 through B9 were collected from the old incinerator area. All samples obtained from that area contained Ra-226 and U-238 concentrations above those in baseline samples. The highest Ra-226 concentration (141 pCi/g) was in sample B4 from grid location 163E,31S. Sample B3, at grid point 153E,36S, contained the highest U-238 levels (68.5 pCi/g). Several samples from this area also contained slightly elevated levels of U-235 and Cs-137.

Sample B10, collected near Castle Garden Road, consisted of a metallic-like rock. Due to its high activity and irregular geometry only qualitative gamma spectroscopy was performed; the major radionuclide was found to be Ra-226. A total Ra-226 activity of 3.73 μCi was determined by comparison of direct radiation levels with those from a standard encapsulated radium source.

Samples B11 through B19 were collected from the Track Street area. All except samples B11 and B21 had elevated Ra-226 levels. The highest Ra-226 level (430 pCi/g) was in sample B17 from grid location 668E,30S. Radionuclide concentrations in samples B11 and B12 consisted mainly of U-238; however, there were also elevated levels of U-235 and Th-232 in these samples. Other samples collected in the Track Street area also had elevated levels of U-235, U-238, and Cs-137.

Samples B6, B7, and B14 were also analyzed for Sr-90; levels were low, ranging from 0.16 to 0.85 pCi/g.

## Ground-Penetrating Radar Findings

The subcontractor report summarizing the ground-penetrating radar survey results for property N/N' South is provided as Appendix C. (This report also includes the findings on property Q, since the two properties were surveyed simultaneously.) At locations where surface contamination was noted in the old incinerator area, radar signatures indicative of non-ionic liquids were present. These anomalies are most likely due to the presence of petroleum solvents or oils that do not readily disperse in the ground. There is no evidence of buried residues in this area. The Track Street area survey indicated no evidence of subsurface objects. No pipes or other subsurface interferences were detected at proposed borehole locations.

## Borehole Gamma-logging Measurements

Gamma scintillation measurements performed in boreholes indicated that contamination is confined to the upper 25-50 cm of soil. As evidenced by soil sample analysis, the gamma count rates determined by the borehole measurements were reliable indicators of elevated subsurface radionuclide levels. However, the gamma-logging data were not useful in quantifying radionuclide concentrations in the subsurface soil, because of the varying ratios of Ra-226, U-235, U-238, and Cs-137 occurring in soils from this site.

## Radionuclide Concentrations in Subsurface Soil

Table 1C presents the radionuclide concentrations measured in soil samples from boreholes. The locations of the fourteen boreholes (H1-H14), selected to provide a representative coverage of the property, had subsurface radionuclide concentrations either in the range of baseline samples or less than the minimum detectable activity (MDA).

Boreholes H15-H21 were at locations where the walkover scan had identified possible surface contamination. Only one subsurface sample collected from the old incinerator area (H19 at 0.3 meters) had an elevated level of Ra-226 (11.6 pCi/g). The sample collected at 0.1 meter from borehole H-21 (also in the

the old incinerator area) had U-235 and U-238 concentrations of 2.36 and 28.6 pCi/g respectively. Other subsurface samples from the incinerator area and all subsurface samples obtained from the Track Street area had radionuclide concentrations either in the range of baseline samples or less than the minimum detectable activity (MDA).

Radionuclide Concentrations in Water

Water collected from the systematic boreholes had gross alpha and gross beta concentrations within the EPA drinking water criteria of 15 pCi/l and 50 pCi/l, respectively (see Table 11). High concentrations of dissolved solids in several samples resulted in residues, which adversely affected the detection sensitivities of the gross alpha and gross beta procedure.

## COMPARISON OF SURVEY RESULTS WITH GUIDELINES

The guidelines applicable to cleanup of the Niagara Falls Storge Site off-site properties are presented in Appendix B. All exposure rates at 1 m above the ground surface on property N/N' South are well below the 60 μR/h criteria established by the NRC for open land areas.

There are two surface areas where the Ra-226 soil concentrations, averaged over 100 $m^2$, exceed the level of 5 pCi/g above background. One of these is near grid point 160E,30S in the old incinerator area. The average concentration, based on biased and systematic samples, is 37.5 pCi/g. The contaminated area, shown on Figure 11, covers approximately 200 $m^2$ and is limited to the top 25 cm of soil. The second area is along a ditch in the vicinity of Track Street and covers approximately 800 $m^2$ to a depth of 25 cm (see Figure 12). The average concentration of Ra-226 in this area is about 122 pCi/g. Although many samples from both these areas had elevated levels of U-238, the criteria level of 40 pCi/g was not exceeded as averaged over 100 $m^2$. Other locations of Ra-226 and U-238 surface soil contamination, indicated on Figures 11 and 12, are small and isolated. At these locations the concentrations, averaged over 100 $m^2$, would be below the criteria level.

Ground penetrating radar identified anomalies in the incinerator area but did not indicate the presence of subsurface objects which would suggest buried materials. Borehole measurements and sampling indicate all subsurface soil concentrations are within the applicable guidelines of 15 pCi/g for Ra-226.

Radionuclide concentrations in surface and subsurface water are within the EPA Interim Drinking Water Standards.

An evaluation of the potential health effects associated with radiation levels and residual contamination on property N/N' South is presented in Appendix D. That section compares the radiation levels with background exposures in the Niagara, New York, area and the scientifically based guidelines established for the protection of radiation workers and the general public.

## SUMMARY

A comprehensive survey of off-site property N/N' South at the Niagara Falls Storage site (former Lake Ontario Ordnance Works) was conducted by Oak Ridge Associated Universities. The survey included surface radiation scans, measurements of direct radiation levels, and analyses of radionuclide concentrations in surface and subsurface soil samples and in subsurface water samples. Ground penetrating radar was also used to identify subsurface anomalies, which might suggest buried radioactive residues or objects.

The results of the survey indicate general and isolated areas of surface soil contamination in the vicinity of the old incinerator and in the Track Street area of the property. The major contaminant is Ra-226, although elevated levels of U-238 were also noted in many of the samples. Smaller amounts of Cs-137, U-235, and Th-232 were also detected in several samples. Subsurface sampling and measurements indicate that this contamination is limited to the top 25 cm of soil. Soil concentrations exceed the criteria in a 800 $m^2$ area in the Track Street area and a 200 $m^2$ area in the vicinity of the old incinerator. These two areas could be brought into compliance with the removal of approximately 200 $m^3$ and 50 $m^3$ of soil, respectively. Other isolated areas of contamination could be eliminated by removal of much smaller amounts of surface soil.

Although there were small areas of contaminated residues on portions of this property, under present conditions of property use, these contaminants do not pose potential health risks. There is no evidence that migration of the radioactive materials is adversely affecting adjacent properties or the ground water.

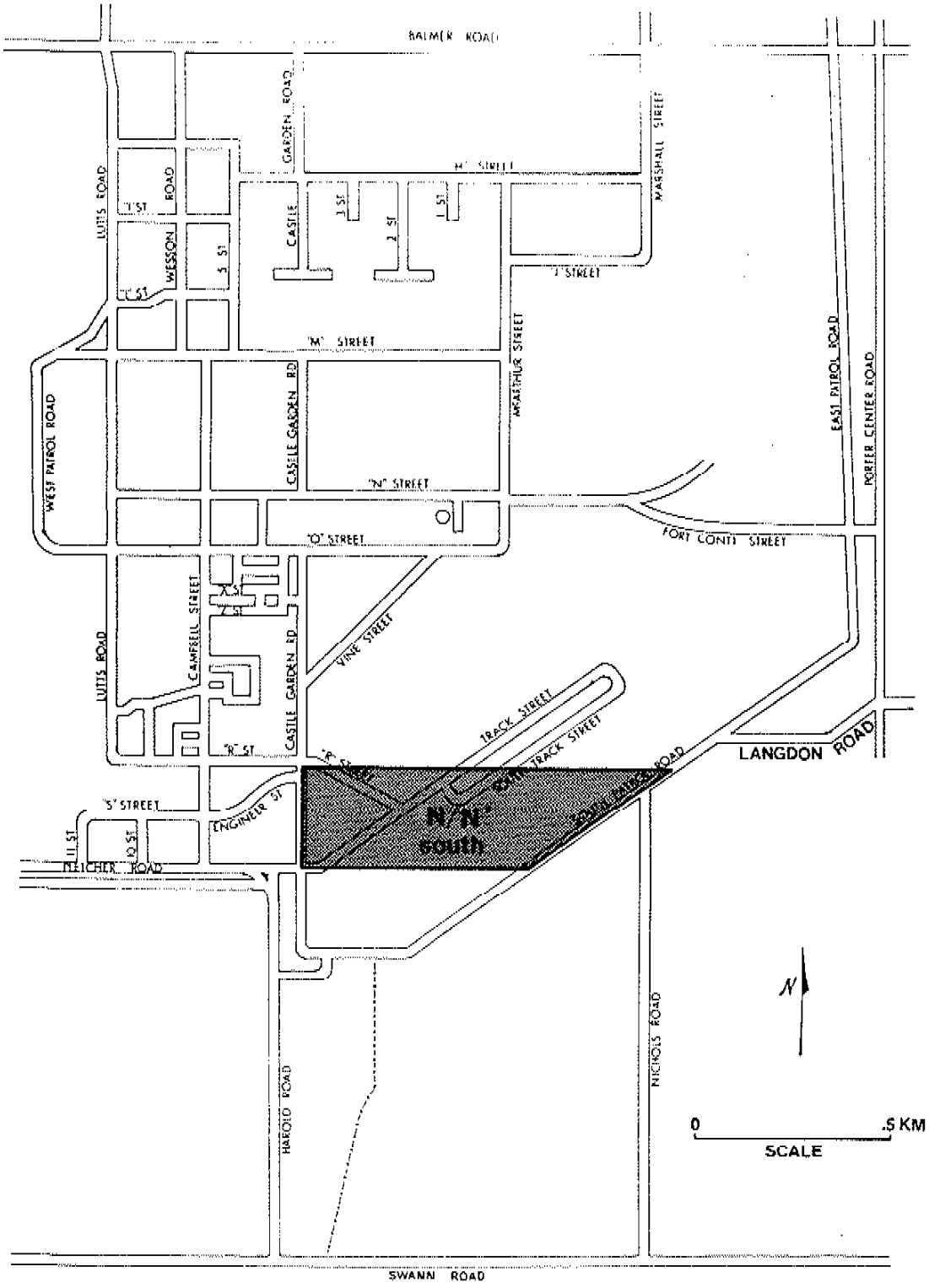



FIGURE 1. Map of Niagara Falls Storage Site and Off-Site Properties, Lewiston, New York, Indicating the Location of Property N/N' South.

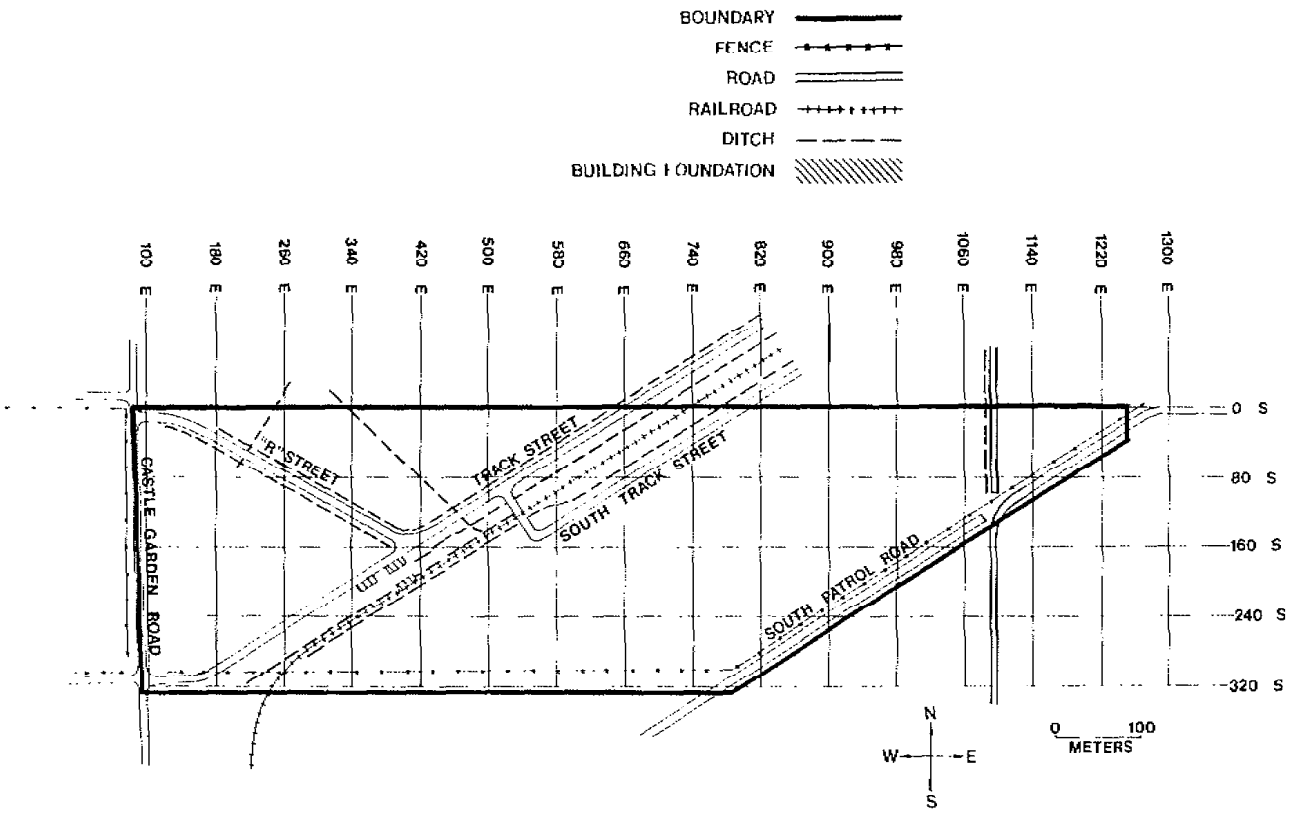



FIGURE 2. Plan View of Off-Site Property N/N' South, Indicating Prominent Surface Features and the Grid System Established for Survey Reference.

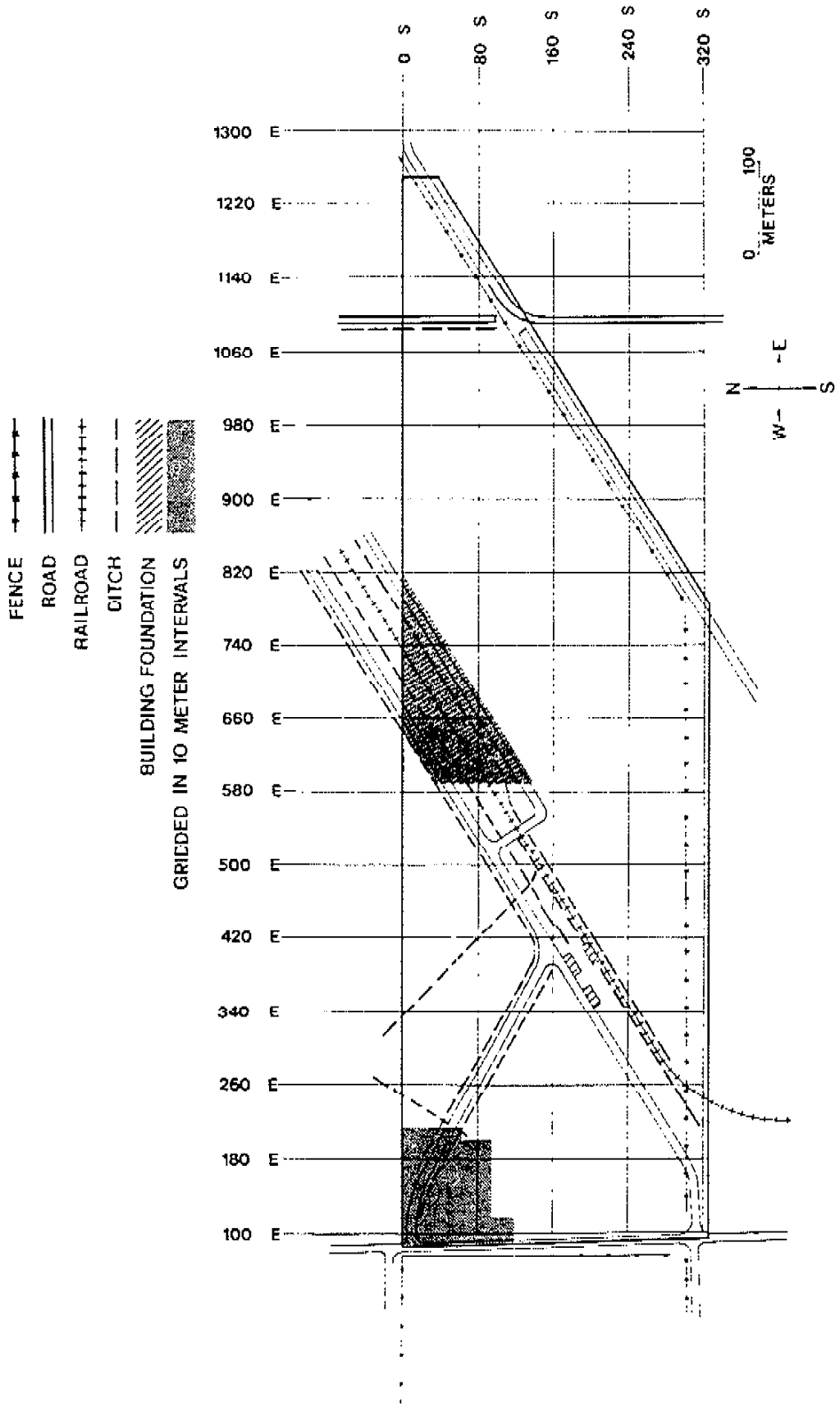



FIGURE 3. Map of Property N/N' South Indicating Areas Gridded in 10 Meter Intervals.

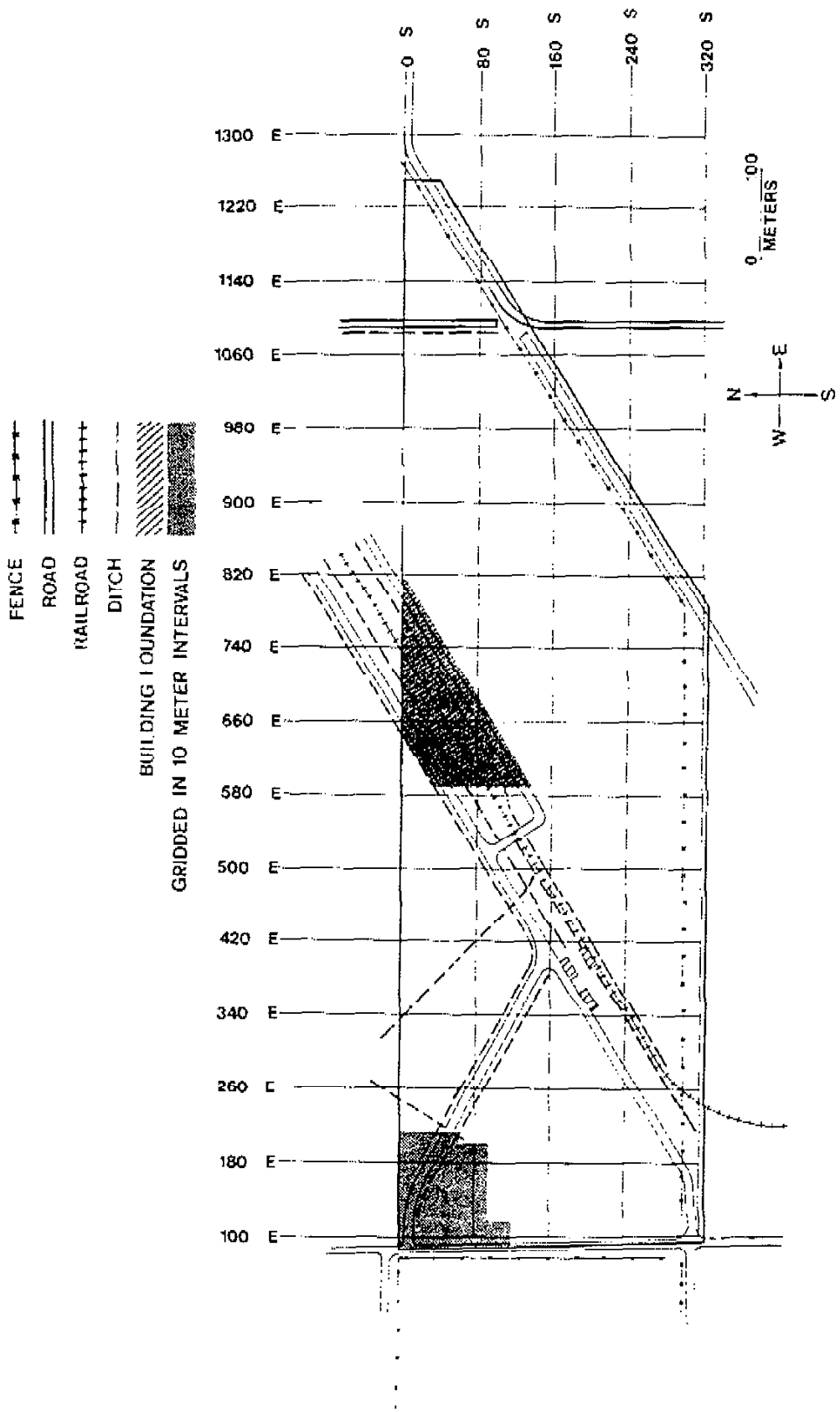
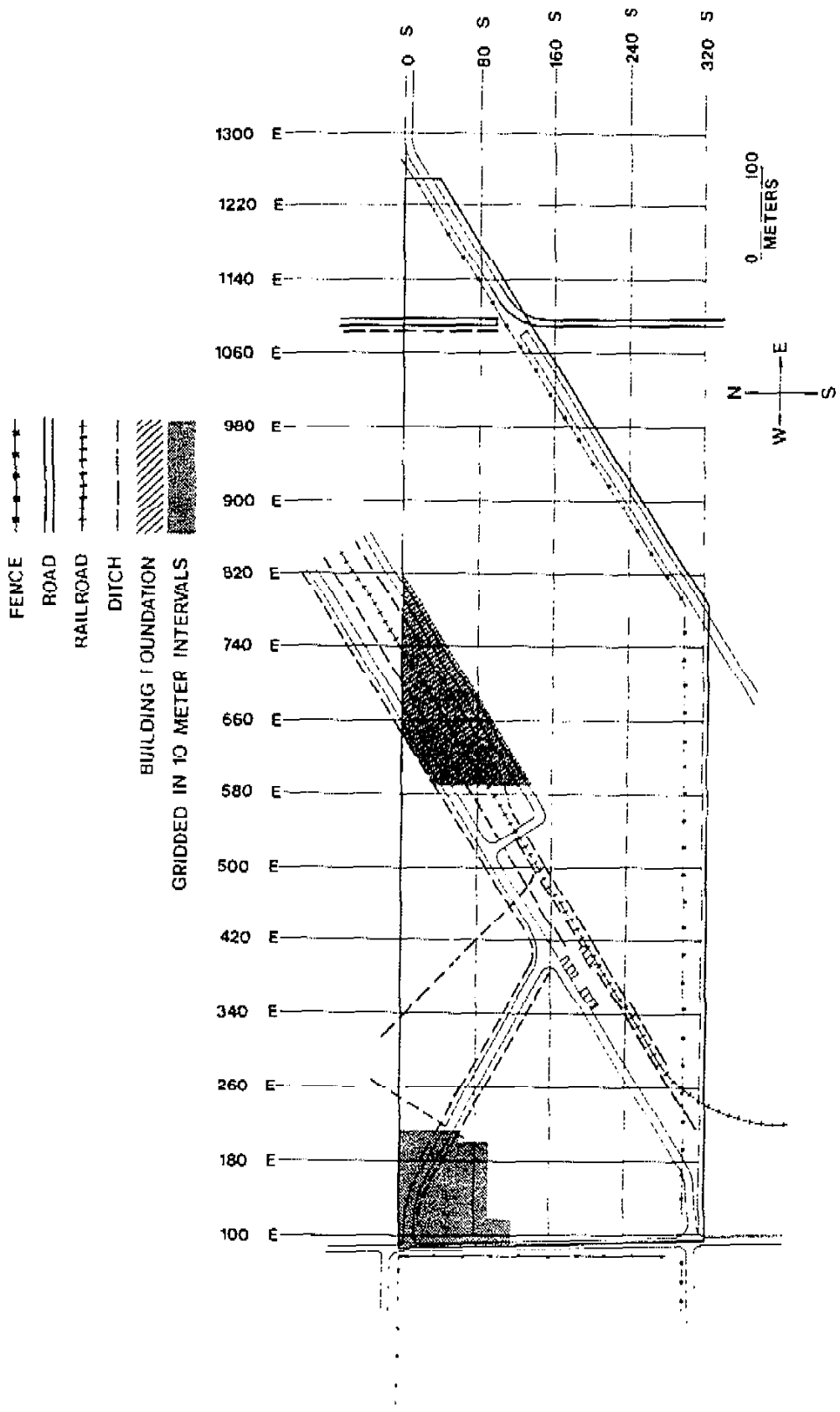



FIGURE 5. Map of Property N/N' South Indicating Areas Gridded in 10 Meter Intervals.

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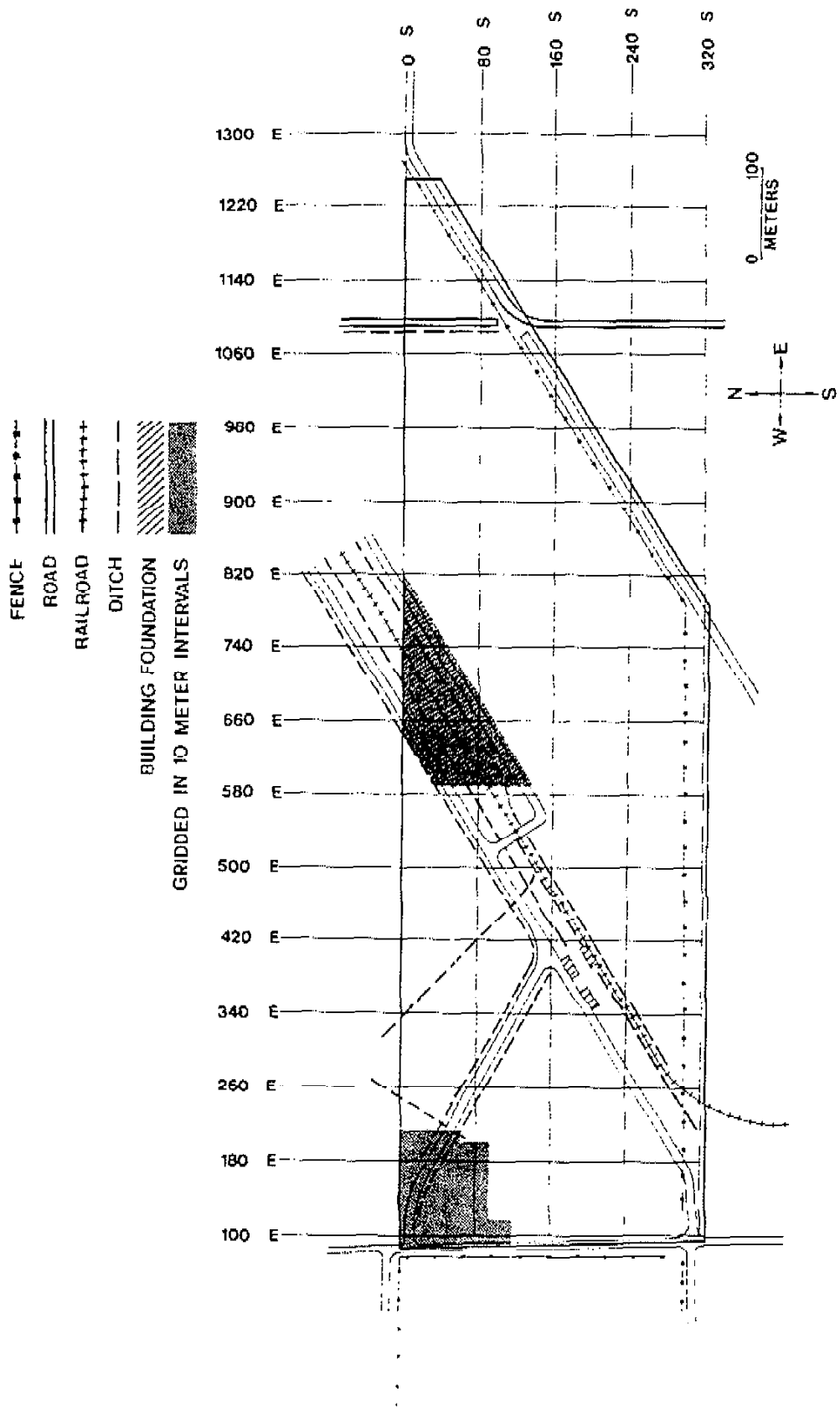


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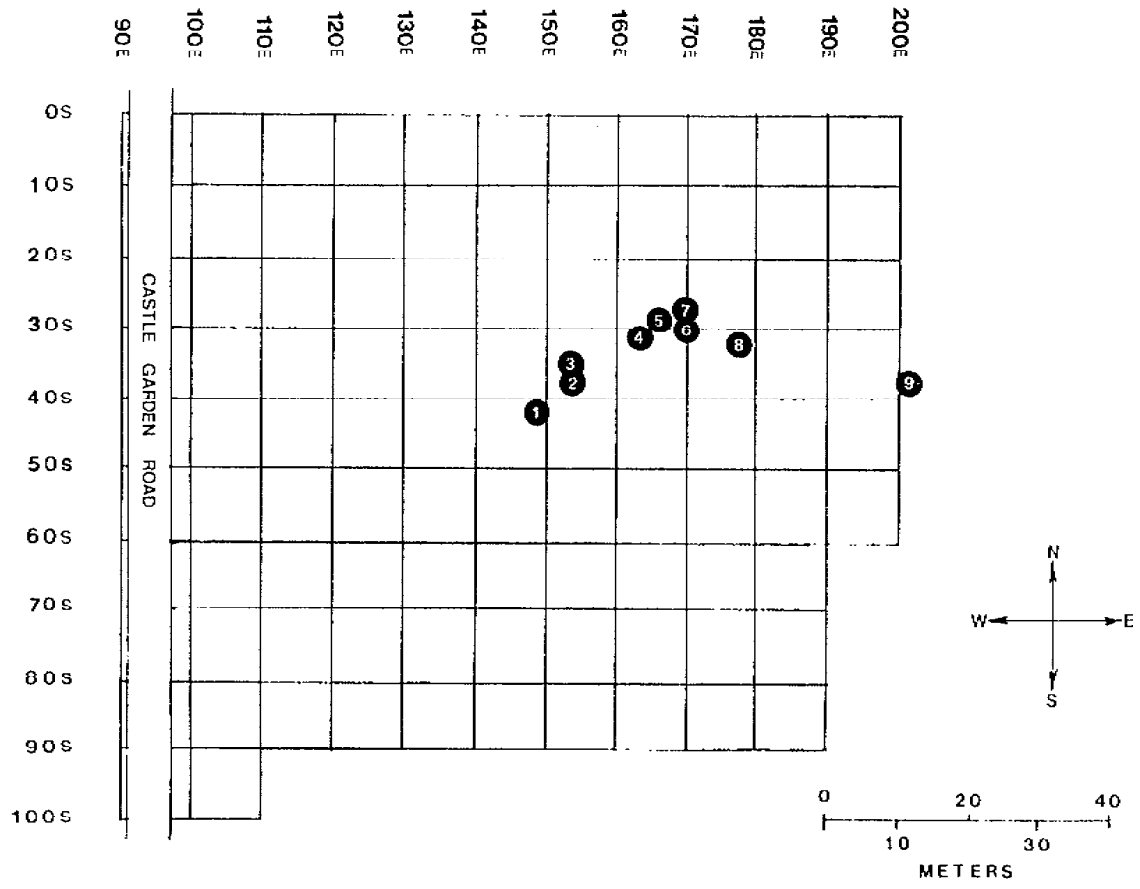


FIGURE 4. Locations of Elevated Direct Radiation Levels in the Old Incinerator Area.

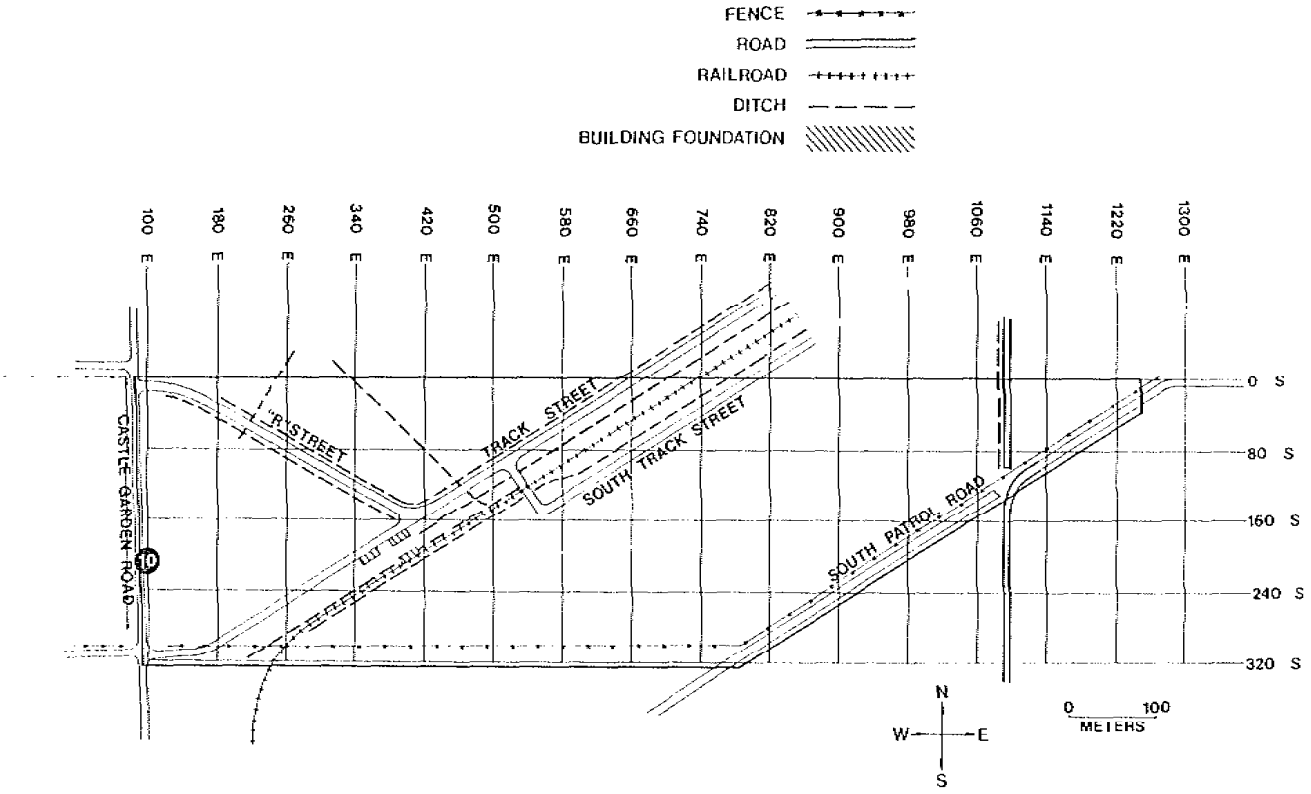


FIGURE 5. Location of an Elevated Direct Radiation Level Along Castle Garden Road.

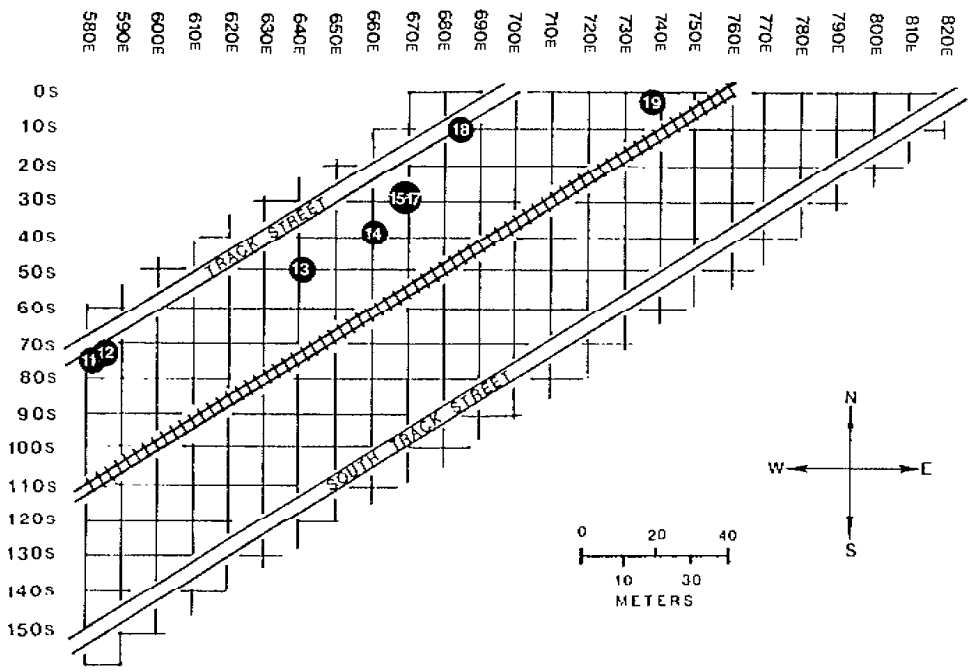


FIGURE 6. Locations of Elevated Direct Radiation Levels in the Track Street Area.

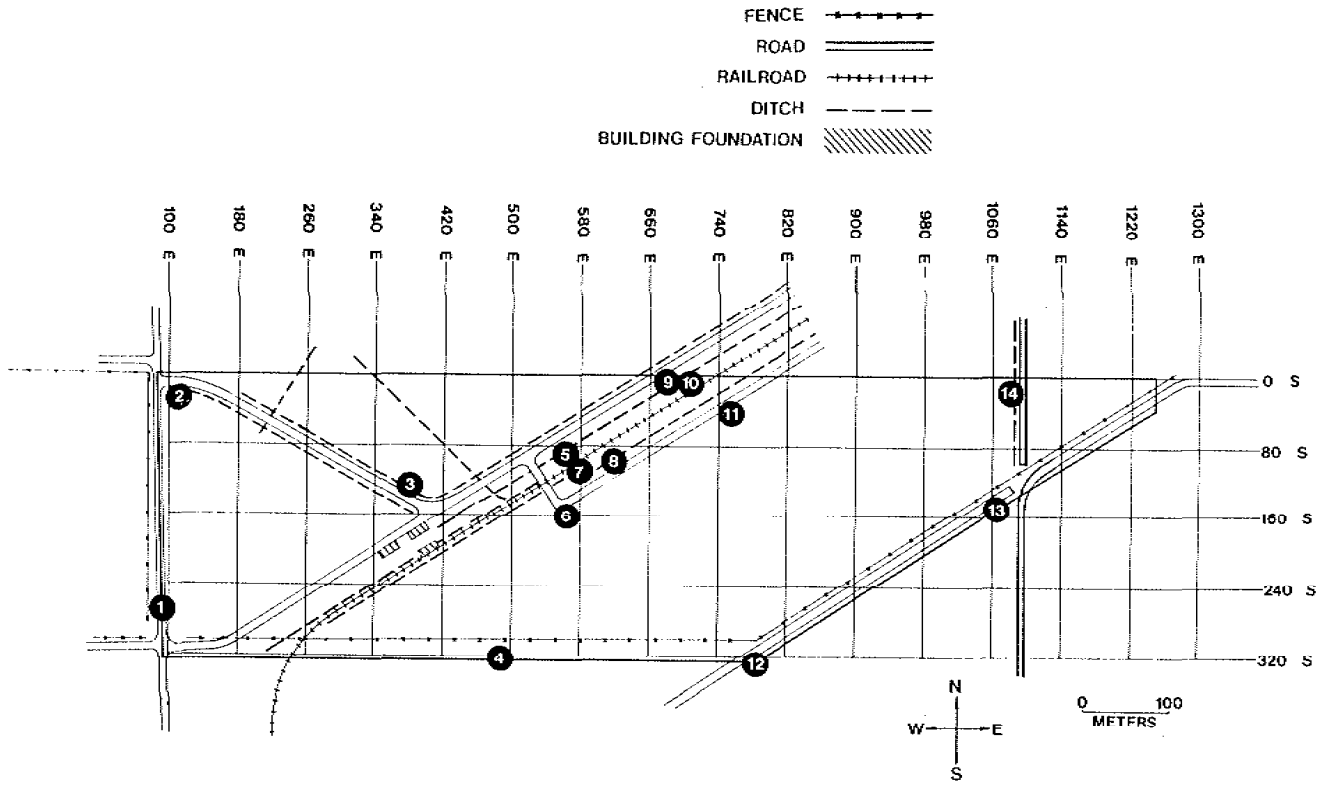


FIGURE 7. Locations of Deep Boreholes for Subsurface Investigations.

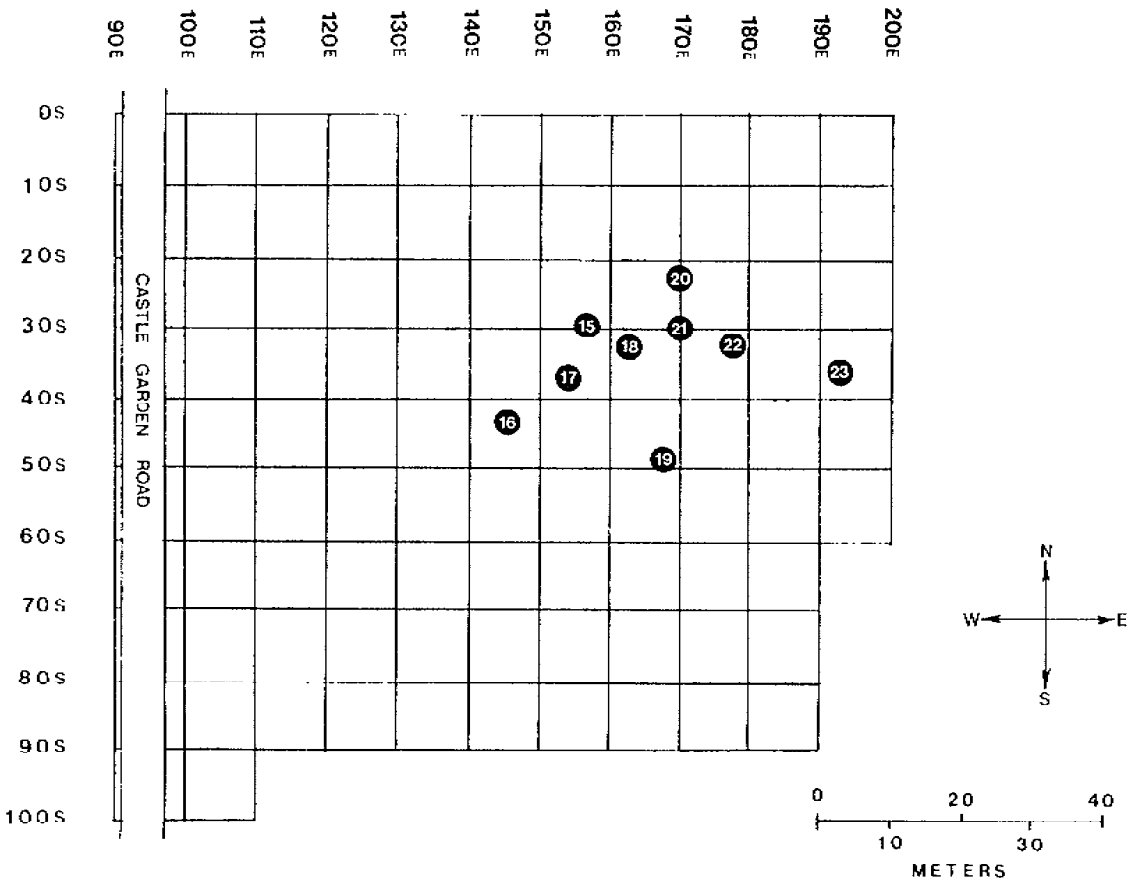


FIGURE 8. Locations of Shallow Boreholes in the Incinerator Areas.

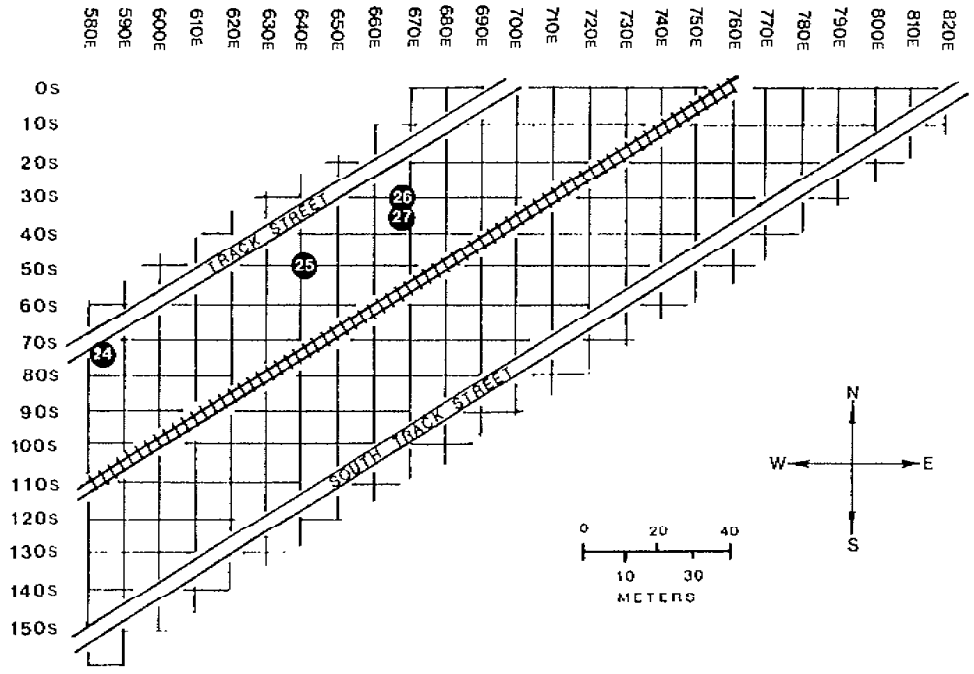


FIGURE 9. Locations of Shallow Boreholes in the Track Street Area.

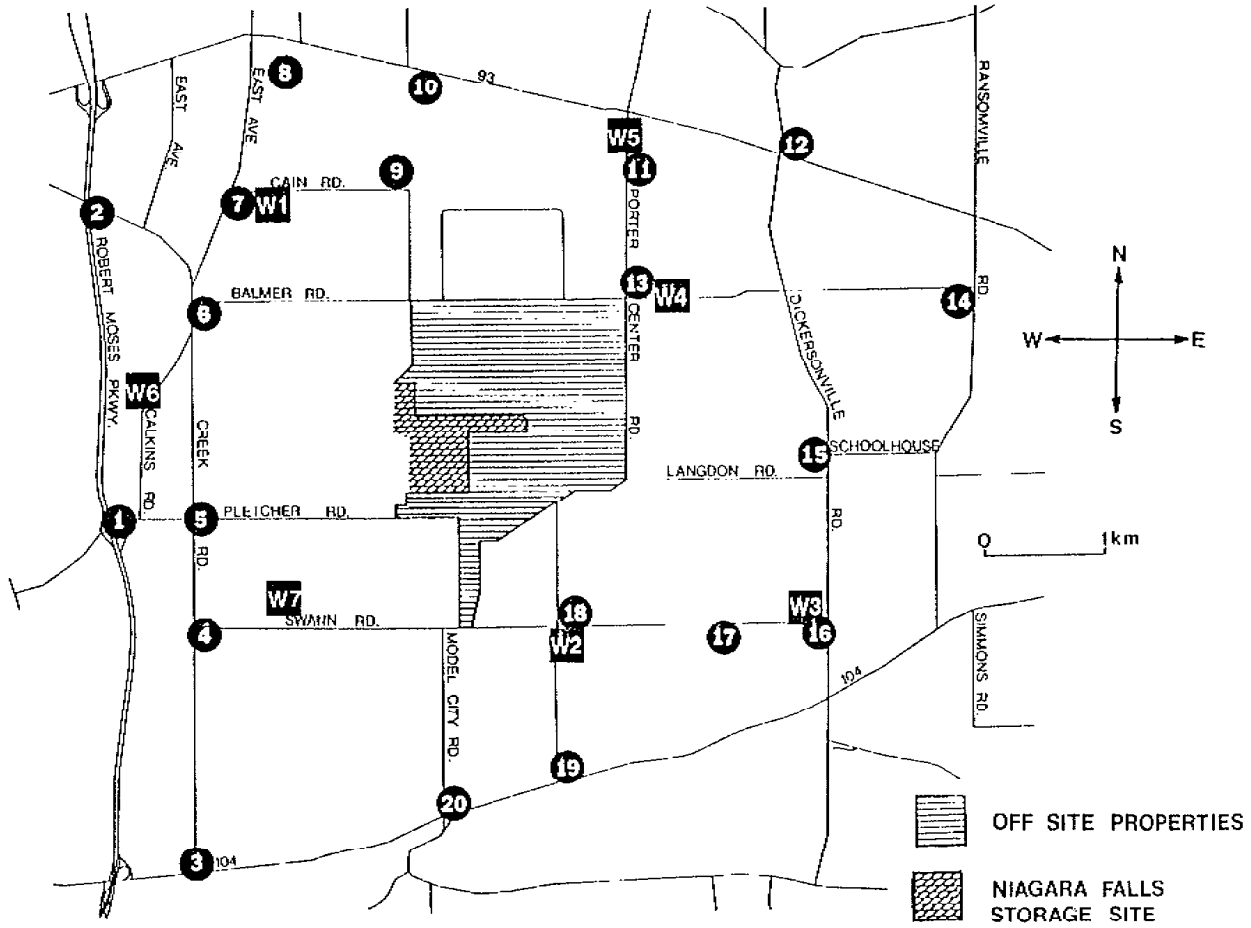


FIGURE 10. Map of Northern Niagara County, New York, Showing Locations of Background Measurements and Baseline Samples (#1-20: soil samples and direct measurements; W1-W7: water samples).

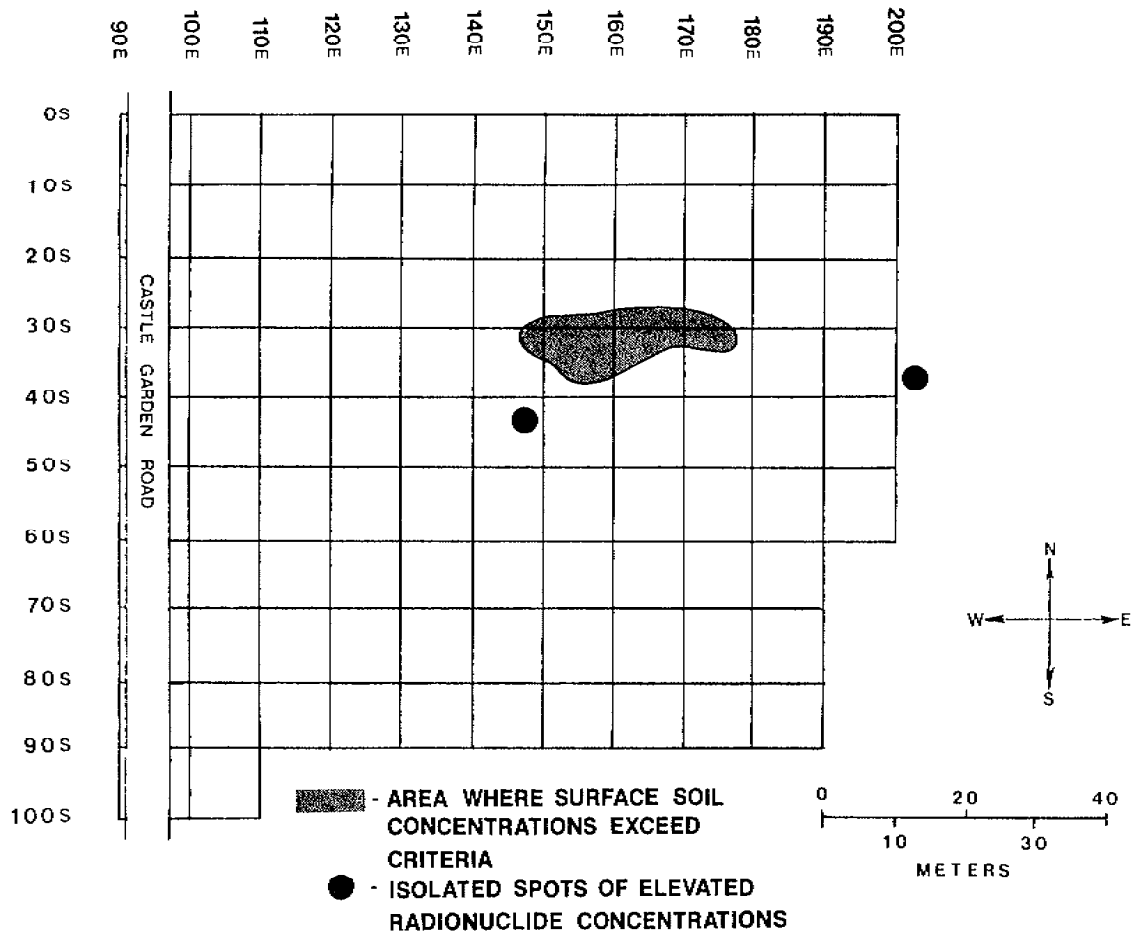


FIGURE 11. Map of the Incinerator Area, Indicating Locations Where Ra-226 Concentrations Exceed Criteria for Surface Soil.

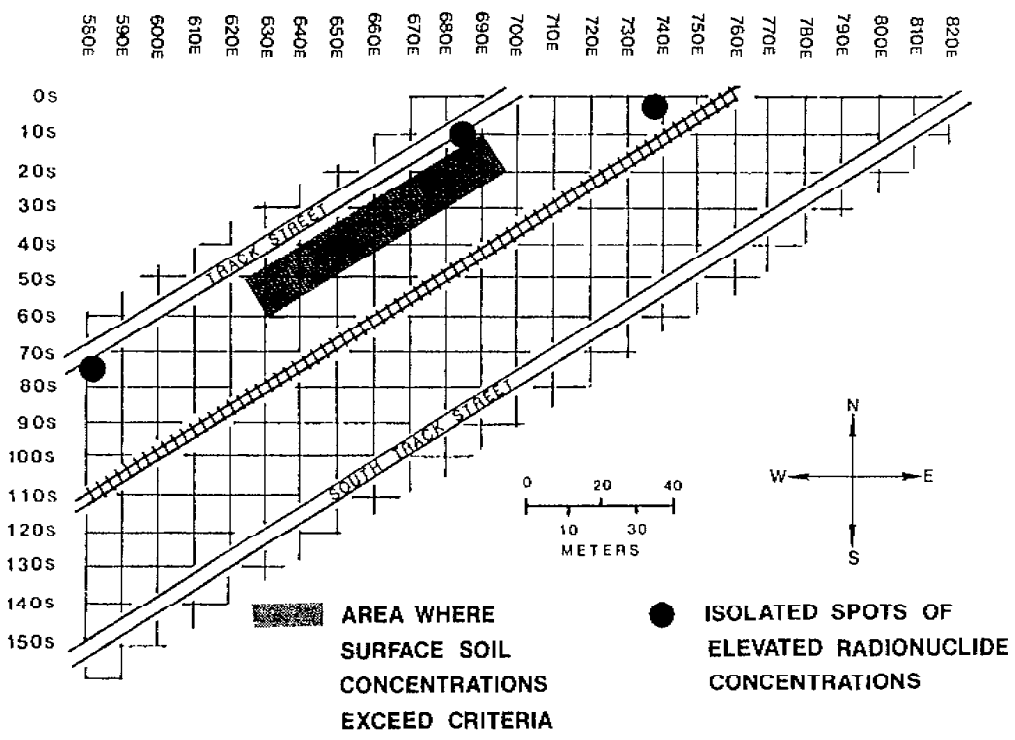


FIGURE 12. Map of the Track Street Area, Indicating Locations Where Ra-226 Concentrations Exceed Criteria for Surface Soil.

TABLE 1-A

BACKGROUND EXPOSURE RATES
AND
BASELINE RADIONUCLIDE CONCENTRATIONS IN SOIL

| 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 | <0.22 | 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 | <0.27 | <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 | <0.18 | 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 | 0.36 ± 0.08 |
| 18 | 7.7 | 0.73 ± 0.16 | <0.18 | 6.26 ± 9.23 | <0.23 | 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 | <0.18 to 1.18 | <0.02 to 1.05 |

[a] Refer to Figure 10.
[b] Measured at 1 m above the surface.
[c] Errors is 2σ based on counting statistics only.

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 10.
[b] Errors are 2σ based on counting statistics.

TABLE 2

DIRECT RADIATION LEVELS SYSTEMATICALLY
MEASURED AT 80 M GRID LINE INTERSECTIONS

| Grid Location | Gamma Exposure Rates at 1 m Above the Surface (μR/h) | Gamma Exposure Rates at the Surface (μR/h) | Beta-Gamma Dose Rates at the Surface (μrad/h) |
|---|---|---|---|
| 100E, 0S | 11 | 12 | 62 |
| 100E, 80S | 11 | 11 | 68 |
| 100E,160S | 11 | 11 | 69 |
| 100E,240S | 11 | 11 | 75 |
| 100E,320S | 9.8 | 8.7 | 48 |
| 180E, 0S | 11 | 11 | 62 |
| 180E, 80S | 11 | 11 | 83 |
| 180E,160S | 11 | 12 | 94 |
| 180E,240S | 11 | 12 | 68 |
| 180E,320S | 11 | 11 | 68 |
| 260E, 0S | 11 | 11 | 83 |
| 260E, 80S | 11 | 10 | 88 |
| 260E,160S | 12 | 12 | 78 |
| 260E,240S | 13 | 15 | 110 |
| 260E,320S | 12 | 12 | 86 |
| 340E, 0S | 11 | 12 | 110 |
| 340E, 80S | 12 | 12 | 81 |
| 340E,160S | 11 | 11 | 55 |
| 340E,240S | 11 | 11 | 62 |
| 340E,320S | 13 | 12 | 65 |
| 420E, 0S | 11 | 12 | 81 |
| 420E, 80S | 11 | 11 | 78 |
| 420E,160S | 11 | 12 | 55 |
| 420E,240S | 11 | 11 | 55 |
| 420E,320S | 11 | 12 | 68 |
| 500E, 0S | 12 | 11 | 81 |
| 500E, 80S | 12 | 12 | 91 |
| 500E,160S | 13 | 13 | 78 |
| 500E,240S | 12 | 11 | 73 |
| 500E,320S | 11 | 12 | 57 |
| 580E, 0S | 11 | 12 | 78 |
| 580E, 80S | 15 | 16 | 140 |
| 580E,160S | 11 | 12 | 44 |
| 580E,240S | 11 | 11 | 96 |
| 580E,320S | 11 | 11 | 73 |
| 660E, 0S | 12 | 11 | 88 |
| 660E, 80S | 14 | 13 | 68 |
| 660E,160S | 10 | 11 | 49 |
| 660E,240S | 11 | 11 | 68 |
| 660E,320S | 11 | 11 | 68 |
| 740E, 0S | 15 | 16 | 81 |
| 740E, 80S | 11 | 11 | 42 |

TABLE 2, cont.

DIRECT RADIATION LEVELS SYSTEMATICALLY
MEASURED AT 80 M GRID LINE INTERSECTIONS

| Grid Location | Gamma Exposure Rates at 1 m Above the Surface (μR/h) | Gamma Exposure Rates at the Surface (μR/h) | Beta-Gamma Dose Rates at the Surface (μrad/h) |
|---|---|---|---|
| 740E,160S | 11 | 11 | 83 |
| 740E,240S | 10 | 11 | 73 |
| 740E,320S | 10 | 11 | 91 |
| 820E, 0S | 11 | 10 | 47 |
| 820E, 80S | 11 | 11 | 81 |
| 820E,160S | 11 | 11 | 52 |
| 820E,240S | 11 | 11 | 78 |
| 820E,320S | 11 | 11 | 78 |
| 900E, 0S | 12 | 12 | 78 |
| 900E, 80S | 11 | 12 | 60 |
| 900E,160S | 9.5 | 9.5 | 65 |
| 900E,240S | 11 | 11 | 55 |
| 900E,320S | 10 | 11 | 55 |
| 980E, 0S | 11 | 11 | 73 |
| 980E, 80S | 11 | 11 | 85 |
| 980E,160S | 12 | 11 | 62 |
| 980E,240S | 11 | 11 | 79 |
| 1060E, 0S | 11 | 11 | 79 |
| 1060E, 80S | 11 | 11 | 83 |
| 1060E,160S | 11 | 11 | 59 |
| 1140E, 0S | 11 | 11 | 73 |
| 1140E, 80S | 11 | 11 | 70 |
| 1220E, 0S | 11 | 11 | 66 |

TABLE 3

DIRECT RADIATION LEVELS SYSTEMATICALLY MEASURED AT 10 M GRID LINE INTERSECTIONS IN THE AREA OF THE OLD INCINERATOR

| Grid Location | Gamma Exposure Rates at 1 m Above the Surface (uR/h) | Gamma Exposure Rates at the Surface (uR/h) | Beta-Gamma Dose Rates at the Surface (urad/h) |
|---|---|---|---|
| 100E, 0S | 11 | 12 | 62 |
| 100E, 10S | 11 | 11 | 52 |
| 100E, 20S | 13 | 15 | 86 |
| 100E, 30S | 11 | 12 | 86 |
| 100E, 40S | 11 | 11 | 61 |
| 100E, 50S | 11 | 11 | 98 |
| 100E, 60S | 11 | 10 | 68 |
| 100E, 70S | 11 | 11 | 61 |
| 100E, 80S | 11 | 11 | 68 |
| 100E, 90S | 11 | 11 | 55 |
| 100E,100S | 11 | 11 | 70 |
| 110E, 0S | 15 | 16 | 110 |
| 110E, 10S | 15 | 17 | 100 |
| 110E, 20S | 11 | 10 | 72 |
| 110E, 30S | 10 | 10 | 64 |
| 110E, 40S | 11 | 11 | 53 |
| 110E, 50S | 11 | 11 | 62 |
| 110E, 60S | 11 | 11 | 70 |
| 110E, 80S | 11 | 11 | 75 |
| 110E, 90S | 12 | 11 | 62 |
| 110E,100S | 11 | 12 | 69 |
| 120E, 0S | 12 | 13 | 82 |
| 120E, 10S | 12 | 12 | 68 |
| 120E, 20S | 11 | 10 | 53 |
| 120E, 30S | 11 | 11 | 62 |
| 120E, 40S | 11 | 11 | 65 |
| 120E, 50S | 11 | 12 | 81 |
| 120E, 60S | 11 | 12 | 64 |
| 120E, 70S | 12 | 12 | 91 |
| 120E, 80S | 12 | 12 | 81 |
| 120E, 90S | 12 | 12 | 87 |
| 130E, 0S | 11 | 11 | 78 |
| 130E, 10S | 10 | 11 | 72 |
| 130E, 20S | 10 | 11 | 59 |
| 130E, 30S | 10 | 11 | 78 |
| 130E, 40S | 11 | 11 | 62 |
| 130E, 50S | 12 | 12 | 64 |
| 130E, 60S | 11 | 11 | 75 |

TABLE 3, cont.

DIRECT RADIATION LEVELS SYSTEMATICALLY MEASURED
AT 10 M GRID LINE INTERSECTIONS IN THE AREA
OF THE OLD INCINERATOR

| Grid Location | Gamma Exposure Rates at 1 m Above the Surface (μR/h) | Gamma Exposure Rates at the Surface (μR/h) | Beta-Gamma Dose Rates at the Surface (μrad/h) |
|---|---|---|---|
| 130E, 70S | 12 | 12 | 86 |
| 130E, 80S | 12 | 12 | 66 |
| 130E, 90S | 12 | 12 | 81 |
| 140E, 0S | 12 | 12 | 75 |
| 140E, 10S | 11 | 11 | 65 |
| 140E, 20S | 10 | 11 | 72 |
| 140E, 30S | 11 | 11 | 61 |
| 140E, 40S | 12 | 12 | 83 |
| 140E, 50S | 12 | 12 | 62 |
| 140E, 60S | 12 | 11 | 68 |
| 140E, 70S | 12 | 12 | 78 |
| 140E, 80S | 11 | 11 | 66 |
| 140E, 90S | 12 | 12 | 79 |
| 150E, 0S | 12 | 11 | 60 |
| 150E, 10S | 11 | 11 | 90 |
| 150E, 20S | 11 | 11 | 66 |
| 150E, 30S | 12 | 12 | 83 |
| 150E, 40S | 15 | 15 | 120 |
| 150E, 50S | 11 | 11 | 62 |
| 150E, 60S | 11 | 11 | 72 |
| 150E, 70S | 11 | 12 | 95 |
| 150E, 80S | 11 | 12 | 53 |
| 150E, 90S | 11 | 12 | 66 |
| 160E, 0S | 11 | 11 | 73 |
| 160E, 10S | 11 | 11 | 42 |
| 160E, 20S | 11 | 12 | 74 |
| 160E, 30S | 13 | 13 | 120 |
| 160E, 40S | 12 | 12 | 74 |
| 160E, 50S | 11 | 12 | 73 |
| 160E, 60S | 12 | 11 | 65 |
| 160E, 70S | 11 | 12 | 62 |
| 160E, 80S | 11 | 11 | 85 |
| 160E, 90S | 11 | 11 | 53 |
| 170E, 0S | 11 | 11 | 62 |
| 170E, 10S | 11 | 11 | 48 |
| 170E, 20S | 12 | 11 | 53 |
| 170E, 30S | 39 | 93 | 320 |
| 170E, 40S | 12 | 12 | 74 |

TABLE 3, cont.

DIRECT RADIATION LEVELS SYSTEMATICALLY MEASURED
AT 10 M GRID LINE INTERSECTIONS IN THE AREA
OF THE OLD INCINERATOR

| Grid Location | Gamma Exposure Rates at 1 m Above the Surface (μR/h) | Gamma Exposure Rates at the Surface (μR/h) | Beta-Gamma Dose Rates at the Surface (μrad/h) |
|---|---|---|---|
| 170E, 50S | 12 | 11 | 88 |
| 170E, 60S | 11 | 11 | 75 |
| 170E, 70S | 11 | 11 | 88 |
| 170E, 80S | 11 | 11 | 90 |
| 170E, 90S | 11 | 11 | 73 |
| 180E, 0S | 11 | 11 | 62 |
| 180E, 10S | 11 | 11 | 62 |
| 180E, 20S | 12 | 12 | 42 |
| 180E, 30S | 13 | 12 | 64 |
| 180E, 40S | 12 | 12 | 83 |
| 180E, 50S | 11 | 11 | 82 |
| 180E, 60S | 11 | 11 | 69 |
| 180E, 70S | 12 | 11 | 77 |
| 180E, 80S | 11 | 11 | 83 |
| 180E, 90S | 11 | 11 | 83 |
| 190E, 0S | 11 | 12 | 70 |
| 190E, 10S | 11 | 12 | 72 |
| 190E, 20S | 11 | 11 | 81 |
| 190E, 30S | 11 | 11 | 62 |
| 190E, 40S | 12 | 12 | 99 |
| 190E, 50S | 12 | 12 | 85 |
| 190E, 60S | 12 | 11 | 87 |
| 190E, 70S | 11 | 12 | 77 |
| 190E, 80S | 11 | 12 | 75 |
| 200E, 0S | 11 | 12 | 62 |
| 200E, 10S | 11 | 12 | 73 |
| 200E, 20S | 11 | 11 | 72 |
| 200E, 30S | 11 | 11 | 68 |
| 200E, 40S | 11 | 12 | 79 |
| 200E, 50S | 11 | 11 | 64 |
| 200E, 60S | 11 | 12 | 73 |

TABLE 4

DIRECT RADIATION LEVELS SYSTEMATICALLY MEASURED
AT 10 M GRID LINE INTERSECTIONS IN THE TRACK STREET AREA

| Grid Location | Gamma Exposure Rates at 1 m Above the Surface (μR/h) | Gamma Exposure Rates at the Surface (μR/h) | Beta-Gamma Dose Rates at the Surface (μrad/h) |
|---|---|---|---|
| 680E, 0S | 12 | 12 | 81 |
| 690E, 0S | 11 | 10 | 57 |
| 700E, 0S | 12 | 13 | 78 |
| 710E, 0S | 13 | 12 | 60 |
| 720E, 0S | 14 | 15 | 78 |
| 730E, 0S | 15 | 13 | 68 |
| 740E, 0S | 15 | 16 | 81 |
| 750E, 0S | 17 | 18 | 65 |
| 760E, 0S | 15 | 16 | 86 |
| 770E, 0S | 15 | 16 | 100 |
| 780E, 0S | 13 | 14 | 88 |
| 790E, 0S | 15 | 15 | 110 |
| 800E, 0S | 13 | 15 | 99 |
| 810E, 0S | 11 | 11 | 47 |
| 820E, 0S | 11 | 11 | 47 |
| 660E, 10S | 12 | 12 | 78 |
| 670E, 10S | 12 | 12 | 73 |
| 680E, 10S | 14 | 15 | 120 |
| 690E, 10S | 13 | 13 | 42 |
| 700E, 10S | 13 | 12 | 47 |
| 710E, 10S | 14 | 15 | 65 |
| 720E, 10S | 15 | 15 | 78 |
| 730E, 10S | 17 | 15 | 81 |
| 740E, 10S | 15 | 15 | 160 |
| 750E, 10S | 15 | 15 | 100 |
| 760E, 10S | 15 | 15 | 99 |
| 770E, 10S | 13 | 15 | 91 |
| 780E, 10S | 13 | 14 | 110 |
| 790E, 10S | 13 | 13 | 78 |
| 800E, 10S | 11 | 11 | 57 |
| 810E, 10S | 10 | 10 | 49 |
| 820E, 10S | 12 | 12 | 60 |
| 650E, 20S | 13 | 13 | 60 |
| 660E, 20S | 13 | 13 | 81 |
| 670E, 20S | 13 | 12 | 65 |
| 680E, 20S | 13 | 15 | 83 |
| 690E, 20S | 15 | 15 | 78 |
| 700E, 20S | 14 | 15 | 88 |
| 710E, 20S | 14 | 15 | 65 |

TABLE 4, cont.

DIRECT RADIATION LEVELS SYSTEMATICALLY MEASURED
AT 10 M GRID LINE INTERSECTIONS IN THE TRACK STREET AREA

| Grid Location | Gamma Exposure Rates at 1 m Above the Surface (μR/h) | Gamma Exposure Rates at the Surface (μR/h) | Beta-Gamma Dose Rates at the Surface (μrad/h) |
|---|---|---|---|
| 720E, 20S | 15 | 15 | 78 |
| 730E, 20S | 16 | 18 | 94 |
| 740E, 20S | 16 | 18 | 110 |
| 750E, 20S | 15 | 15 | 91 |
| 760E, 20S | 16 | 18 | 120 |
| 770E, 20S | 13 | 12 | 49 |
| 780E, 20S | 11 | 12 | 73 |
| 790E, 20S | 10 | 10 | 62 |
| 800E, 20S | 11 | 12 | 47 |
| 640E, 30S | 11 | 10 | 55 |
| 650E, 30S | 12 | 12 | 60 |
| 660E, 30S | 13 | 13 | 100 |
| 670E, 30S | 18 | 20 | 86 |
| 680E, 30S | 14 | 15 | 81 |
| 690E, 30S | 14 | 14 | 70 |
| 700E, 30S | 14 | 15 | 56 |
| 710E, 30S | 15 | 16 | 91 |
| 720E, 30S | 15 | 15 | 78 |
| 730E, 30S | 15 | 15 | 110 |
| 740E, 30S | 15 | 15 | 88 |
| 750E, 30S | 15 | 15 | 140 |
| 760E, 30S | 13 | 15 | 86 |
| 770E, 30S | 11 | 12 | 62 |
| 780E, 30S | 11 | 11 | 65 |
| 790E, 30S | 12 | 12 | 83 |
| 620E, 40S | 12 | 12 | 83 |
| 630E, 40S | 11 | 12 | 44 |
| 640E, 40S | 12 | 12 | 65 |
| 650E, 40S | 11 | 11 | 81 |
| 660E, 40S | 15 | 16 | 94 |
| 670E, 40S | 12 | 13 | 52 |
| 680E, 40S | 14 | 14 | 100 |
| 690E, 40S | 13 | 13 | 83 |
| 700E, 40S | 15 | 15 | 81 |
| 710E, 40S | 15 | 15 | 83 |
| 720E, 40S | 15 | 15 | 60 |
| 730E, 40S | 15 | 15 | 94 |
| 740E, 40S | 12 | 12 | 73 |
| 750E, 40S | 12 | 12 | 73 |

TABLE 4, cont.

DIRECT RADIATION LEVELS SYSTEMATICALLY MEASURED
AT 10 M GRID LINE INTERSECTIONS IN THE TRACK STREET AREA

| Grid Location | Gamma Exposure Rates at 1 m Above the Surface (μR/h) | Gamma Exposure Rates at the Surface (μR/h) | Beta-Gamma Dose Rates at the Surface (μrad/h) |
|---|---|---|---|
| 760E, 40S | 10 | 9.8 | 60 |
| 770E, 40S | 11 | 12 | 68 |
| 600E, 50S | 12 | 12 | 62 |
| 610E, 50S | 11 | 11 | 57 |
| 620E, 50S | 12 | 12 | 73 |
| 630E, 50S | 13 | 13 | 78 |
| 640E, 50S | 16 | 16 | 120 |
| 650E, 50S | 13 | 15 | 130 |
| 660E, 50S | 14 | 14 | 96 |
| 670E, 50S | 15 | 16 | 83 |
| 680E, 50S | 15 | 18 | 150 |
| 690E, 50S | 15 | 17 | 130 |
| 700E, 50S | 15 | 17 | 83 |
| 710E, 50S | 15 | 16 | 100 |
| 720E, 50S | 12 | 12 | 70 |
| 730E, 50S | 12 | 12 | 91 |
| 740E, 50S | 10 | 9.8 | 68 |
| 750E, 50S | 12 | 11 | 62 |
| 580E, 60S | 12 | 12 | 75 |
| 590E, 60S | 11 | 11 | 68 |
| 600E, 60S | 13 | 13 | 78 |
| 610E, 60S | 12 | 12 | 110 |
| 620E, 60S | 15 | 15 | 83 |
| 630E, 60S | 14 | 15 | 110 |
| 640E, 60S | 14 | 15 | 100 |
| 650E, 60S | 14 | 14 | 100 |
| 660E, 60S | 15 | 16 | 120 |
| 670E, 60S | 15 | 15 | 88 |
| 680E, 60S | 17 | 18 | 150 |
| 690E, 60S | 15 | 15 | 94 |
| 700E, 60S | 15 | 17 | 110 |
| 710E, 60S | 12 | 12 | 62 |
| 720E, 60S | 11 | 12 | 55 |
| 730E, 60S | 11 | 11 | 83 |
| 740E, 60S | 12 | 12 | 52 |
| 580E, 70S | 12 | 12 | 68 |
| 590E, 70S | 13 | 12 | 83 |
| 600E, 70S | 12 | 12 | 62 |
| 610E, 70S | 13 | 14 | 94 |

TABLE 4, cont.

DIRECT RADIATION LEVELS SYSTEMATICALLY MEASURED
AT 10 M GRID LINE INTERSECTIONS IN THE TRACK STREET AREA

| Grid Location | Gamma Exposure Rates at 1 m Above the Surface (μR/h) | Gamma Exposure Rates at the Surface (μR/h) | Beta-Gamma dose Rates at the Surface (μrad/h) |
|---|---|---|---|
| 620E, 70S | 13 | 13 | 88 |
| 630E, 70S | 14 | 13 | 110 |
| 640E, 70S | 15 | 16 | 99 |
| 650E, 70S | 15 | 16 | 110 |
| 660E, 70S | 16 | 19 | 110 |
| 670E, 70S | 17 | 18 | 100 |
| 680E, 70S | 15 | 16 | 65 |
| 690E, 70S | 12 | 13 | 65 |
| 700E, 70S | 12 | 12 | 55 |
| 710E, 70S | 10 | 9.8 | 52 |
| 580E, 80S | 15 | 15 | 110 |
| 590E, 80S | 14 | 15 | 73 |
| 600E, 80S | 12 | 13 | 94 |
| 610E, 80S | 13 | 13 | 65 |
| 620E, 80S | 14 | 14 | 110 |
| 630E, 80S | 15 | 15 | 160 |
| 640E, 80S | 15 | 16 | 100 |
| 650E, 80S | 15 | 15 | 110 |
| 660E, 80S | 14 | 13 | 68 |
| 670E, 80S | 13 | 12 | 49 |
| 680E, 80S | 12 | 11 | 81 |
| 690E, 80S | 10 | 8.7 | 52 |
| 580E, 90S | 12 | 12 | 52 |
| 590E, 90S | 12 | 12 | 110 |
| 600E, 90S | 13 | 15 | 75 |
| 610E, 90S | 15 | 15 | 100 |
| 620E, 90S | 15 | 15 | 130 |
| 630E, 90S | 15 | 16 | 96 |
| 640E, 90S | 15 | 16 | 110 |
| 650E, 90S | 13 | 13 | 83 |
| 660E, 90S | 12 | 11 | 52 |
| 670E, 90S | 12 | 12 | 86 |
| 680E, 90S | 10 | 10 | 55 |
| 580E,100S | 12 | 13 | 100 |
| 590E,100S | 15 | 16 | 94 |
| 600E,100S | 14 | 15 | 99 |
| 610E,100S | 15 | 15 | 99 |
| 620E,100S | 14 | 15 | 94 |
| 630E,100S | 16 | 19 | 140 |

TABLE 4, cont.

DIRECT RADIATION LEVELS SYSTEMATICALLY MEASURED
AT 10 M GRID LINE INTERSECTIONS IN THE TRACK STREET AREA

| Grid Location | Gamma Exposure Rates at 1 m Above the Surface (μR/h) | Gamma Exposure Rates at the Surface (μR/h) | Beta-Gamma Dose Rates at the Surface (μrad/h) |
|---|---|---|---|
| 640E,100S | 12 | 12 | 81 |
| 650E,100S | 12 | 12 | 78 |
| 660E,100S | 10 | 9.8 | 55 |
| 670E,100S | 12 | 12 | 78 |
| 580E,110S | 15 | 17 | 140 |
| 590E,110S | 15 | 18 | 110 |
| 600E,110S | 13 | 15 | 96 |
| 610E,110S | 12 | 12 | 75 |
| 620E,110S | 12 | 12 | 78 |
| 630E,110S | 11 | 11 | 55 |
| 640E,110S | 9.8 | 10 | 34 |
| 650E,110S | 11 | 11 | 52 |
| 660E,110S | 11 | 12 | 47 |
| 580E,120S | 12 | 12 | 91 |
| 590E,120S | 12 | 12 | 81 |
| 600E,120S | 11 | 11 | 62 |
| 610E,120S | 12 | 12 | 91 |
| 620E,120S | 13 | 13 | 55 |
| 630E,120S | 9.8 | 9.8 | 44 |
| 580E,130S | 12 | 12 | 65 |
| 590E,130S | 11 | 11 | 73 |
| 600E,130S | 12 | 12 | 60 |
| 610E,130S | 9.8 | 8.4 | 78 |
| 620E,130S | 11 | 11 | 88 |
| 580E,140S | 12 | 11 | 70 |
| 590E,140S | 11 | 11 | 52 |
| 600E,140S | 11 | 11 | 68 |
| 580E,150S | 9.8 | 8.7 | 52 |
| 590E,150S | 12 | 11 | 62 |

TABLE 5

DIRECT RADIATION LEVELS AT LOCATIONS
IDENTIFIED BY THE WALKOVER SURFACE SCAN

| Location[a] | Grid Location | Exposure Rate (μR/h) | | Surface Dose Rate (μrad/h) | Soil Sample[b] | Contact Exposure Rate After Sample Removal (μR/h) |
|---|---|---|---|---|---|---|
| | | Contact | 1 m Above Surface | | | |
| 1 | 148E, 43S | 26 | 19 | 150 | B1 | 28 |
| 2 | 154E, 38S | 35 | 22 | 200 | B2 | 32 |
| 3 | 153E, 36S | 51 | 24 | 250 | B3 | 71 |
| 4 | 163E, 31S | 75 | 24 | 160 | B4 | 98 |
| 5 | 166E, 29S | 59 | 32 | 220 | B5 | 43 |
| 6 | 170E, 30S | 93 | 39 | 320 | B6 | 130 |
| 7 | 169E, 32S | 26 | 21 | 140 | B7 | 26 |
| 8 | 178E, 32S | 71 | 32 | 350 | B8 | 91 |
| 9 | 202E, 37S | 24 | 16 | 240 | B9 | 32 |
| 10 | 109E,210S | 220 | 15 | 1230 | B10 | 13 |
| 11 | 552E, 76S | 28 | 16 | 180 | B11 | 32 |
| 12 | 584E, 74S | 59 | 18 | 140 | B12 | 63 |
| 13 | 641E, 50S | 200 | 24 | 1470 | B13 | 200 |
| 14 | 660E, 39S | 22 | 16 | 160 | B14 | 28 |
| 15 | 668E, 33S | 97 | 26 | 530 | B15 | 160 |
| 16 | 669E, 31S | 51 | 20 | 530 | B16 | 49 |
| 17 | 668E, 30S | 410 | 38 | 3770 | B17 | 550 |
| 18 | 684E, 10S | 21 | 18 | 160 | B18 | 21 |
| 19 | 738E, 4S | 20 | 18 | 160 | B19 | 20 |

[a] Refer to Figures 4, 5, and 6.
[b] Soil concentrations presented in Table 9.

TABLE 6

RADIONUCLIDE CONCENTRATIONS IN SURFACE SOIL SAMPLES
FROM 80 M GRID LINE INTERSECTIONS

| Location | Radionuclide Concentrations (pCi/g) | | | |
|---|---|---|---|---|
| | Ra-226 | U-235 | U-238 | Cs-137 |
| 100E, 0S | 0.57 ± 0.19[a] | <0.24 | <2.94 | 0.18 ± 0.09 |
| 100E, 80S | 0.71 ± 0.18 | <0.24 | <4.09 | 0.08 ± 0.09 |
| 100E,160S | 1.36 ± 0.29 | <0.24 | <3.94 | 0.66 ± 0.15 |
| 100E,240S | 0.48 ± 0.21 | <0.25 | <4.33 | 0.42 ± 0.14 |
| 100E,320S | 0.72 ± 0.28 | <0.29 | <5.15 | 0.29 ± 0.16 |
| 180E, 0S | 0.60 ± 0.23 | <0.24 | <3.77 | 0.47 ± 0.15 |
| 180E, 80S | 0.42 ± 0.23 | <0.24 | <5.67 | 0.59 ± 0.13 |
| 180E,160S | 0.56 ± 0.22 | <0.24 | <4.08 | 0.70 ± 0.13 |
| 180E,240S | 0.53 ± 0.24 | <0.24 | <3.99 | 0.34 ± 0.12 |
| 180E,320S | 1.43 ± 0.26 | <0.24 | <4.39 | 0.32 ± 0.11 |
| 260E, 0S | 0.66 ± 0.21 | 1.23 ± 0.56 | <4.06 | 0.40 ± 0.14 |
| 260E, 80S | 0.60 ± 0.20 | <0.24 | <3.21 | 0.53 ± 0.14 |
| 260E,160S | 0.67 ± 0.25 | <0.24 | <2.30 | 0.41 ± 0.13 |
| 260E,240S | 0.48 ± 0.23 | <0.24 | <3.32 | 0.43 ± 0.13 |
| 260E,320S | 0.55 ± 0.25 | <0.23 | <4.53 | 0.49 ± 0.14 |
| 340E, 0S | 0.78 ± 0.21 | <0.24 | <4.68 | <0.04 |
| 340E, 80S | 0.52 ± 0.23 | <0.24 | <4.16 | <0.04 |
| 340E,160S | 0.53 ± 0.20 | 0.52 ± 0.46 | <4.92 | 0.32 ± 0.13 |
| 340E,240S | 0.53 ± 0.19 | <0.24 | <3.76 | 0.26 ± 0.10 |
| 340E,320S | 0.58 ± 0.30 | <0.23 | <3.79 | 0.26 ± 0.14 |
| 420E, 0S | 0.63 ± 0.27 | <0.23 | <4.15 | 0.45 ± 0.13 |
| 420E, 80S | 0.65 ± 0.23 | <0.24 | <4.41 | 0.61 ± 0.08 |
| 420E,160S | 1.11 ± 0.29 | <0.24 | <4.47 | 0.54 ± 0.18 |
| 420E,240S | 0.56 ± 0.20 | <0.24 | <4.63 | 0.49 ± 0.15 |
| 420E,320S | 0.49 ± 0.20 | <0.24 | <4.81 | 0.79 ± 0.15 |
| 500E, 0S | 0.55 ± 0.26 | <0.24 | <3.81 | <0.04 |
| 500E, 80S | 0.43 ± 0.23 | <0.24 | <3.95 | 0.55 ± 0.14 |
| 500E,160S | 0.61 ± 0.26 | <0.24 | <4.68 | 0.30 ± 0.12 |
| 500E,240S | 0.56 ± 0.23 | <0.25 | <3.88 | 0.23 ± 0.12 |
| 500E,320S | 0.47 ± 0.24 | <0.24 | 8.54 ± 11.07 | 0.51 ± 0.16 |
| 580E, 0S | 0.30 ± 0.20 | <0.24 | <3.99 | <0.05 |
| 580E, 80S | 0.56 ± 0.20 | <0.24 | 4.88 ± 10.75 | 0.16 ± 0.09 |
| 580E,160S | 0.64 ± 0.20 | <0.24 | <5.60 | 0.16 ± 0.12 |
| 580E,240S | 0.70 ± 0.20 | <0.25 | <3.23 | 0.34 ± 0.12 |
| 580E,320S | 1.28 ± 0.31 | <0.25 | <3.69 | 0.49 ± 0.15 |
| 660E, 0S | 0.43 ± 0.19 | <0.24 | <3.52 | 0.26 ± 0.10 |
| 660E, 80S | <0.16 | <0.24 | <3.76 | 0.55 ± 0.14 |
| 660E,160S | 0.47 ± 0.22 | <0.21 | <3.63 | 0.07 ± 0.06 |
| 660E,240S | 0.63 ± 0.40 | <0.24 | <2.04 | 0.32 ± 0.11 |
| 660E,320S | 0.57 ± 0.21 | <0.22 | <3.41 | 0.51 ± 0.13 |
| 740E, 0S | 2.60 ± 0.22 | <0.24 | <5.60 | 0.82 ± 0.18 |
| 740E, 80S | 0.51 ± 0.20 | <0.24 | <4.13 | 0.25 ± 0.11 |
| 740E,160S | <0.13 | 0.26 ± 0.54 | <3.45 | 0.63 ± 0.16 |
| 740E,240S | 0.56 ± 0.20 | <0.24 | <1.94 | 0.38 ± 0.12 |
| 740E,320S | 0.49 ± 0.21 | 0.65 ± 0.56 | <4.38 | 0.41 ± 0.13 |
| 820E, 0S | 0.77 ± 0.21 | <0.24 | 7.73 ± 7.40 | 0.71 ± 0.20 |

TABLE 6, cont.

RADIONUCLIDE CONCENTRATIONS IN SURFACE SOIL SAMPLES
FROM 80 M GRID LINE INTERSECTIONS

| Location | Radionuclide Concentrations (pCi/g) | | | |
|---|---|---|---|---|
| | Ra-226 | U-235 | U-238 | Cs-137 |
| 820E, 80S | 0.64 ± 0.28 | <0.24 | <3.70 | 0.33 ± 0.11 |
| 820E,160S | 0.49 ± 0.21 | <0.24 | <3.80 | 0.42 ± 0.15 |
| 820E,240S | 0.45 ± 0.19 | <0.24 | <5.14 | 0.37 ± 0.14 |
| 820E,320S | 0.52 ± 0.21 | <0.24 | <1.41 | 0.54 ± 0.12 |
| 900E, 0S | 0.47 ± 0.17 | <0.24 | <4.24 | 0.80 ± 0.08 |
| 900E, 80S | 0.56 ± 0.33 | <0.26 | <5.31 | 0.59 + 0.18 |
| 900E,160S | 0.55 ± 0.22 | <0.24 | <4.75 | 0.69 ± 0.14 |
| 900E,240S | 0.56 ± 0.21 | <0.24 | <4.20 | 0.52 ± 0.12 |
| 900E,320S | 0.74 ± 0.20 | <0.24 | <4.91 | 0.67 ± 0.12 |
| 980E, 0S | 0.53 ± 0.19 | <0.24 | <4.85 | 0.50 ± 0.13 |
| 980E, 80S | 0.42 ± 0.19 | <0.24 | <4.51 | 0.25 ± 0.11 |
| 980E,160S | 0.50 ± 0.27 | <0.24 | <3.95 | 0.76 ± 0.16 |
| 980E,240S | 0.50 ± 0.23 | <0.24 | <5.29 | 0.59 ± 0.15 |
| 1060E, 0S | 0.69 ± 0.20 | <0.24 | <4.18 | 0.34 ± 0.14 |
| 1060E, 80S | 0.61 ± 0.23 | <0.24 | <6.21 | 0.31 ± 0.17 |
| 1060E,160S | 0.76 ± 0.20 | <0.24 | <3.49 | 0.58 ± 0.13 |
| 1140E, 0S | 0.61 ± 0.21 | <0.24 | <4.52 | 0.43 ± 0.11 |
| 1140E, 80S | 0.68 ± 0.25 | <0.24 | <3.22 | 0.25 ± 0.12 |
| 1220E, 0S | 0.45 ± 0.19 | <0.24 | <4.72 | 0.78 ± 0.16 |

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

TABLE 7

RADIONUCLIDE CONCENTRATIONS IN SURFACE SOIL SAMPLES
FROM 10 M GRID INTERVALS IN THE INCINERATOR AREA

| Location | Radionuclide Concentrations (pCi/g) | | | |
|---|---|---|---|---|
| | Ra-226 | U-235 | U-238 | Cs-137 |
| 100E, 0S | 0.57 ± 0.19[a] | <0.24 | <2.94 | 0.18 ± 0.09 |
| 100E, 10S | 0.54 ± 0.22 | <0.24 | <2.50 | <0.05 |
| 100E, 20S | 2.20 ± 0.28 | <0.24 | <4.87 | 0.09 ± 0.04 |
| 100E, 30S | 0.52 ± 0.28 | <0.25 | <4.07 | 0.46 ± 0.16 |
| 100E, 40S | 0.52 ± 0.20 | <0.24 | <1.89 | 0.30 ± 0.10 |
| 100E, 50S | <0.13 | <0.24 | 5.69 ± 8.91 | 0.71 ± 0.07 |
| 100E, 60S | 0.54 ± 0.02 | <0.24 | <3.80 | 0.12 ± 0.10 |
| 100E, 70S | 0.72 ± 0.30 | <0.26 | <4.15 | 0.17 ± 0.14 |
| 100E, 80S | 0.71 ± 0.18 | <0.24 | <4.09 | 0.08 ± 0.09 |
| 100E, 90S | 0.84 ± 0.22 | <0.24 | <4.05 | 0.09 ± 0.09 |
| 100E,100S | 0.57 ± 0.25 | <0.24 | 5.32 ± 8.36 | 0.17 ± 0.10 |
| 110E, 0S | 0.67 ± 0.30 | <0.24 | <4.19 | <0.04 |
| 110E, 10S | 0.61 ± 0.18 | <0.24 | <2.49 | 0.15 ± 0.10 |
| 110E, 20S | 0.61 ± 0.18 | <0.24 | <2.49 | 0.10 ± 0.11 |
| 110E, 30S | 0.62 ± 0.11 | <0.24 | <3.83 | <0.03 |
| 110E, 40S | 0.60 ± 0.19 | <0.24 | 5.46 ± 7.96 | 0.17 ± 0.12 |
| 110E, 50S | 0.47 ± 0.18 | <0.24 | <3.28 | <0.04 |
| 110E, 60S | 0.71 ± 0.18 | <0.24 | <2.73 | 0.10 ± 0.12 |
| 110E, 70S | 0.66 ± 0.21 | <0.24 | <3.84 | 0.17 ± 0.08 |
| 110E, 80S | 0.58 ± 0.19 | <0.24 | <4.45 | 0.07 ± 0.08 |
| 110E, 90S | 0.82 ± 0.24 | <0.24 | <4.71 | 0.29 ± 0.07 |
| 110E,100S | 0.75 ± 0.11 | <0.24 | <3.49 | 0.27 + 0.08 |
| 120E, 0S | 0.61 ± 0.11 | <0.24 | <3.83 | <0.04 |
| 120E, 10S | 0.85 ± 0.42 | <0.24 | <3.34 | 0.19 ± 0.13 |
| 120E, 20S | 0.55 ± 0.20 | <0.24 | <3.76 | 0.06 ± 0.07 |
| 120E, 30S | <0.14 | <0.24 | <1.89 | <0.03 |
| 120E, 40S | 0.51 ± 0.07 | <0.24 | <4.06 | <0.03 |
| 120E, 50S | 0.59 ± 0.30 | <0.24 | <4.64 | <0.04 |
| 120E, 60S | 0.42 ± 0.21 | <0.24 | <4.11 | 0.50 ± 0.13 |
| 120E, 70S | 0.74 ± 0.24 | <0.28 | <5.35 | 0.40 ± 0.17 |
| 120E, 80S | 0.42 ± 0.20 | <0.24 | <5.19 | 0.08 ± 0.08 |
| 120E, 90S | 0.47 ± 0.18 | <0.25 | <3.17 | 0.06 ± 0.10 |
| 130E, 0S | 0.54 ± 0.30 | <0.24 | <4.75 | 0.05 ± 0.09 |
| 130E, 10S | 0.33 ± 0.21 | <0.24 | <3.95 | 0.51 ± 0.11 |
| 130E, 20S | 0.53 ± 0.15 | <0.24 | <2.88 | 0.11 ± 0.07 |
| 130E, 30S | 0.74 ± 0.18 | <0.24 | <3.06 | 0.12 ± 0.09 |
| 130E, 40S | 0.41 + 0.15 | <0.24 | <3.02 | <0.03 |
| 130E, 50S | 0.63 ± 0.28 | <0.24 | <4.29 | 0.27 ± 0.11 |
| 130E, 60S | 0.62 ± 0.20 | 0.18 ± 0.42 | <4.64 | 0.23 ± 0.11 |
| 130E, 70S | 0.64 ± 0.26 | <0.24 | <3.62 | 0.40 ± 0.12 |

TABLE 7, cont.

RADIONUCLIDE CONCENTRATIONS IN SURFACE SOIL SAMPLES
FROM 10 M GRID INTERVALS IN THE INCINERATOR AREA

| Location | Radionuclide Concentrations (pCi/g) Ra-226 | U-235 | U-238 | Cs-137 |
|---|---|---|---|---|
| 130E, 80S | 0.69 ± 0.22 | <0.24 | <5.05 | 0.39 ± 0.15 |
| 130E, 90S | 0.84 ± 0.24 | <0.24 | <4.25 | 0.42 ± 0.13 |
| 140E, 0S | 0.57 ± 0.19 | <0.24 | <3.78 | <0.03 |
| 140E, 10S | 0.46 ± 0.22 | <0.25 | <7.91 | 0.29 ± 0.15 |
| 140E, 20S | 0.52 ± 0.24 | <0.24 | 7.86 ± 8.36 | 0.05 ± 0.08 |
| 140E, 30S | 0.65 ± 0.24 | <0.24 | 6.04 ± 12.29 | <0.02 |
| 140E, 40S | 0.55 ± 0.11 | <0.24 | <3.60 | <0.04 |
| 140E, 50S | 0.96 ± 0.37 | <0.24 | <5.41 | 0.51 ± 0.14 |
| 140E, 60S | 0.59 ± 0.20 | <0.24 | <4.20 | 0.25 ± 0.10 |
| 140E, 70S | 0.48 ± 0.21 | <0.24 | <4.26 | 0.27 ± 0.13 |
| 140E, 80S | 0.59 ± 0.17 | <0.24 | <4.64 | 0.29 ± 0.12 |
| 140E, 90S | 0.83 ± 0.27 | <0.24 | <4.23 | <0.03 |
| 150E, 0S | 0.49 ± 0.16 | <0.24 | <3.57 | 0.41 ± 0.11 |
| 150E, 10S | 0.64 ± 0.23 | <0.24 | <3.92 | 0.61 ± 0.13 |
| 150E, 20S | 0.56 ± 0.20 | <0.24 | <2.34 | <0.03 |
| 150E, 30S | 0.53 ± 0.15 | <0.24 | <3.58 | <0.03 |
| 150E, 40S | 5.19 ± 0.50 | <0.24 | <5.47 | 0.67 ± 0.15 |
| 150E, 50S | 0.59 ± 0.19 | <0.24 | <3.63 | 0.25 ± 0.11 |
| 150E, 60S | 0.54 ± 0.23 | <0.24 | <2.19 | 0.11 ± 0.11 |
| 150E, 70S | 0.51 ± 0.18 | <0.24 | <3.92 | 0.09 ± 0.10 |
| 150E, 80S | 0.63 ± 0.24 | <0.24 | <4.20 | <0.03 |
| 150E, 90S | 0.61 ± 0.21 | <0.24 | <3.80 | 0.28 ± 0.13 |
| 160E, 0S | 0.63 ± 0.24 | <0.24 | <3.86 | <0.04 |
| 160E, 10S | 0.46 ± 0.27 | <0.24 | <3.23 | 0.53 ± 0.11 |
| 160E, 20S | 1.04 ± 0.29 | 0.20 ± 0.89 | <5.17 | 0.51 ± 0.12 |
| 160E, 30S | 6.61 ± 0.60 | 1.67 ± 1.06 | 19.9 ± 0.5 | 1.11 ± 0.10 |
| 160E, 40S | 2.24 ± 0.34 | <0.24 | <5.82 | 0.89 ± 0.19 |
| 160E, 50S | 1.29 ± 0.29 | <0.24 | <4.79 | 0.78 ± 0.16 |
| 160E, 60S | 0.68 ± 0.21 | <0.24 | <2.45 | 0.11 ± 0.08 |
| 160E, 70S | 0.56 ± 0.21 | <0.24 | <4.04 | 0.20 ± 0.11 |
| 160E, 80S | <0.16 | <0.24 | <3.21 | 0.13 ± 0.10 |
| 160E, 90S | 0.50 ± 0.16 | <0.22 | <3.15 | 0.33 ± 0.11 |
| 170E, 0S | 0.82 ± 0.21 | <0.24 | <3.14 | 0.45 ± 0.13 |
| 170E, 10S | 0.51 ± 0.18 | <0.24 | <3.39 | 0.57 ± 0.14 |
| 170E, 20S | 0.60 ± 0.39 | <0.24 | 5.41 ± 9.02 | 0.95 ± 0.17 |
| 170E, 30S | 12.8 ± 0.8 | 1.47 ± 1.47 | 20.2 ± 0.5 | 1.48 ± 0.26 |
| 170E, 40S | 0.69 ± 0.24 | <0.24 | 8.08 ± 11.25 | 0.35 ± 0.14 |
| 170E, 50S | 0.84 ± 0.22 | <0.24 | <3.82 | 0.32 ± 0.10 |
| 170E, 60S | 0.53 ± 0.20 | <0.24 | <4.02 | 0.23 ± 0.10 |
| 170E, 70S | 0.67 ± 0.22 | <0.24 | <4.51 | 0.06 ± 0.09 |

TABLE 7, cont.

RADIONUCLIDE CONCENTRATIONS IN SURFACE SOIL SAMPLES
FROM 10 M GRID INTERVALS IN THE INCINERATOR AREA

| Location | Radionuclide Concentrations (pCi/g) | | | |
|---|---|---|---|---|
| | Ra-226 | U-235 | U-238 | Cs-137 |
| 170E, 80S | 0.49 ± 0.18[a] | <0.24 | <3.57 | 0.31 ± 0.13 |
| 170E, 90S | 0.64 ± 0.16 | <0.24 | <3.44 | 0.16 ± 0.09 |
| 180E, 0S | 0.60 ± 0.23 | <0.24 | <3.27 | 0.47 ± 0.15 |
| 180E, 10S | 1.30 ± 0.24 | <0.24 | <4.48 | 0.70 ± 0.12 |
| 180E, 20S | 0.66 ± 0.21 | <0.24 | <4.21 | 0.34 ± 0.17 |
| 180E, 30S | 1.10 ± 0.26 | <0.24 | <4.67 | 0.40 ± 0.14 |
| 180E, 40S | 0.54 ± 0.27 | <0.24 | <5.05 | 0.40 ± 0.16 |
| 180E, 50S | 0.65 ± 0.19 | <0.24 | <4.46 | 0.19 ± 0.11 |
| 180E, 60S | 0.66 ± 0.23 | <0.24 | <3.58 | 0.19 ± 0.16 |
| 180E, 70S | 0.58 ± 0.20 | <0.24 | <3.58 | 0.45 ± 0.12 |
| 180E, 80S | 0.42 ± 0.23 | <0.24 | <5.67 | 0.59 ± 0.13 |
| 180E, 90S | 0.52 ± 0.19 | <0.24 | <4.37 | 0.21 ± 0.08 |
| 190E, 0S | 0.45 ± 0.23 | <0.24 | <2.89 | <0.03 |
| 190E, 10S | 0.72 ± 0.20 | <0.24 | <4.65 | 0.14 ± 0.08 |
| 190E, 20S | 0.87 ± 0.26 | <0.24 | <4.01 | 0.55 ± 0.15 |
| 190E, 30S | 0.49 ± 0.17 | <0.24 | <2.54 | 0.28 ± 0.09 |
| 190E, 40S | 0.55 ± 0.28 | <0.25 | <4.26 | 0.36 ± 0.10 |
| 190E, 50S | 0.62 ± 0.20 | <0.24 | <3.36 | 0.37 ± 0.12 |
| 190E, 60S | 0.60 ± 0.22 | <0.24 | <2.99 | <0.04 |
| 190E, 70S | 0.47 ± 0.21 | <0.24 | <2.98 | 0.21 ± 0.10 |
| 190E, 80S | 0.50 ± 0.24 | <0.24 | <2.35 | 0.17 ± 0.09 |
| 200E, 0S | 0.55 ± 0.20 | <0.24 | <3.96 | 0.06 ± 0.07 |
| 200E, 10S | 0.46 ± 0.22 | <0.24 | <4.30 | 0.20 ± 0.11 |
| 200E, 20S | 6.61 ± 0.50 | <0.24 | <6.04 | 0.46 ± 0.14 |
| 200E, 30S | 0.48 ± 0.19 | <0.24 | <2.46 | 0.52 ± 0.11 |
| 200E, 40S | 0.85 ± 0.20 | <0.24 | <5.02 | 0.40 ± 0.13 |
| 200E, 50S | <0.16 | <0.24 | <3.23 | 0.41 ± 0.12 |
| 200E, 60S | 0.53 ± 0.22 | <0.24 | <0.64 | 0.21 ± 0.08 |

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

TABLE 8

RADIONUCLIDE CONCENTRATIONS IN SURFACE SOIL SAMPLES
FROM 10 M GRID INTERVALS IN THE TRACK STREET AREA

| Location | Radionuclide Concentrations (pCi/g) | | | |
|---|---|---|---|---|
| | Ra-226 | U-235 | U-238 | Cs-137 |
| 670E, 0S | 0.38 ± 0.13[a] | <0.24 | <5.64 | 0.22 ± 0.17 |
| 680E, 0S | 0.56 ± 0.18 | <0.24 | <3.57 | 0.53 ± 0.13 |
| 690E, 0S | [b] | [b] | [b] | [b] |
| 700E, 0S | 1.23 ± 0.25 | <0.24 | <4.02 | 0.08 ± 0.11 |
| 710E, 0S | 1.17 ± 0.31 | <0.24 | <2.97 | 0.34 ± 0.11 |
| 720E, 0S | 1.59 ± 0.41 | 0.94 ± 0.86 | 5.53 ± 0.47 | 2.32 ± 0.30 |
| 730E, 0S | 1.56 ± 0.36 | <0.24 | <5.60 | 0.84 ± 0.20 |
| 740E, 0S | 2.60 ± 0.22 | <0.24 | <4.57 | 0.82 ± 0.16 |
| 750E, 0S | 4.41 ± 0.47 | <0.24 | 3.44 ± 0.54 | 0.50 ± 0.19 |
| 760E, 0S | 5.16 ± 0.02 | <0.21 | 6.63 ± 4.92 | 0.36 ± 0.06 |
| 770E, 0S | 4.06 ± 0.51 | <0.24 | <7.71 | 1.10 ± 0.25 |
| 780E, 0S | 0.91 ± 0.28 | <0.24 | <5.13 | 0.17 ± 0.13 |
| 790E, 0S | 2.44 ± 0.33 | <0.24 | 2.01 ± 0.46 | 0.59 ± 0.18 |
| 800E, 0S | 1.51 ± 0.33 | <0.24 | <6.39 | 1.21 ± 0.31 |
| 810E, 0S | 0.59 ± 0.26 | <0.24 | <4.29 | 0.49 ± 0.15 |
| 660E, 10S | 0.70 ± 0.22 | <0.24 | 0.97 ± 0.39 | 0.32 ± 0.11 |
| 670E, 10S | 2.13 ± 0.33 | <0.24 | <4.63 | 0.55 ± 0.14 |
| 680E, 10S | 1.50 ± 0.31 | <0.24 | <5.69 | 0.66 ± 0.15 |
| 690E, 10S | 1.10 ± 0.28 | <0.24 | <4.96 | 0.07 ± 0.15 |
| 700E, 10S | 0.91 ± 0.19 | 0.59 ± 0.45 | <2.60 | 0.25 ± 0.06 |
| 710E, 10S | 2.45 ± 0.38 | <0.24 | 3.00 ± 0.52 | 0.71 ± 0.17 |
| 720E, 10S | 4.17 ± 0.46 | <0.50 | <7.82 | 0.51 ± 0.23 |
| 730E, 10S | 2.25 ± 0.36 | <0.24 | 9.23 ± 0.14 | 1.01 ± 0.11 |
| 740E, 10S | 6.03 ± 0.17 | 0.67 ± 0.32 | 7.93 ± 5.59 | 0.31 ± 0.03 |
| 750E, 10S | 3.37 ± 0.38 | <0.24 | <6.06 | 0.57 ± 0.14 |
| 760E, 10S | 2.41 ± 0.38 | <0.24 | <4.61 | 0.54 ± 0.14 |
| 770E, 10S | 2.58 ± 0.42 | <0.24 | <6.78 | 0.74 ± 0.24 |
| 780E, 10S | 1.64 ± 0.40 | <0.24 | <4.83 | 0.58 ± 0.19 |
| 790E, 10S | 0.68 ± 0.21 | <0.24 | 0.69 ± 0.35 | 0.69 ± 0.17 |
| 800E, 10S | 0.55 ± 0.20 | <0.24 | <4.04 | 0.77 ± 0.15 |
| 810E, 10S | 0.35 ± 0.22 | <0.24 | <2.04 | 0.80 ± 0.14 |
| 820E, 10S | 0.52 ± 0.24 | <0.24 | <5.15 | 0.33 ± 0.12 |
| 650E, 20S | 1.50 ± 0.26 | <0.24 | <2.92 | 0.70 ± 0.15 |
| 660E, 20S | 9.74 ± 0.70 | <0.60 | <7.22 | 1.45 ± 0.27 |
| 670E, 20S | 0.86 ± 0.27 | <0.24 | <4.83 | <0.05 |
| 680E, 20S | 1.40 ± 0.27 | <0.24 | <3.98 | 0.14 ± 0.12 |
| 690E, 20S | 6.49 ± 1.81 | <2.27 | 2.68 ± 0.59 | <0.29 |
| 700E, 20S | 1.45 ± 0.14 | <0.24 | <4.63 | 0.70 ± 0.16 |
| 710E, 20S | 1.80 ± 0.31 | <0.24 | <3.77 | 0.60 ± 0.18 |
| 720E, 20S | 4.87 ± 1.40 | <1.68 | 1.49 ± 0.38 | 0.50 ± 0.90 |
| 730E, 20S | 3.37 ± 0.43 | <0.24 | <5.77 | 0.66 ± 0.16 |

TABLE 8, cont.

RADIONUCLIDE CONCENTRATIONS IN SURFACE SOIL SAMPLES
FROM 10 M GRID INTERVALS IN THE TRACK STREET AREA

| Location | Radionuclide Concentrations (pCi/g) | | | |
|---|---|---|---|---|
| | Ra-226 | U-235 | U-238 | Cs-137 |
| 740E, 20S | 3.36 ± 0.44 | <0.24 | <5.65 | 0.73 ± 0.21 |
| 750E, 20S | 2.23 ± 0.38 | <0.24 | <5.71 | 0.68 ± 0.14 |
| 760E, 20S | 3.60 ± 0.41 | <0.24 | <5.61 | 0.47 ± 0.18 |
| 770E, 20S | 0.56 ± 0.11 | 0.33 ± 0.59 | <4.12 | 0.99 ± 0.16 |
| 780E, 20S | 0.51 ± 0.21 | <0.24 | <3.55 | 0.68 ± 0.17 |
| 790E, 20S | 0.59 ± 0.21 | <0.24 | <4.48 | 0.22 ± 0.15 |
| 800E, 20S | 0.45 ± 0.21 | <0.24 | <4.72 | 0.44 ± 0.13 |
| 640E, 30S | 3.71 ± 0.37 | <0.24 | <4.34 | 0.67 ± 0.13 |
| 650E, 30S | 0.43 ± 0.29 | <0.24 | <4.52 | 0.42 ± 0.12 |
| 660E, 30S | 1.66 ± 0.33 | 0.45 ± 0.78 | <5.72 | 0.21 ± 0.10 |
| 670E, 30S | 4.20 ± 0.46 | <0.24 | <5.03 | 0.82 ± 0.21 |
| 680E, 30S | 3.19 ± 0.35 | <0.24 | <6.03 | 0.25 ± 0.14 |
| 690E, 30S | 2.15 ± 0.44 | <0.24 | <6.20 | 0.78 ± 0.20 |
| 700E, 30S | 1.13 ± 0.33 | 0.55 ± 0.62 | <5.76 | 0.66 ± 0.21 |
| 710E, 30S | 8.06 ± 0.20 | <2.13 | <2.48 | <0.25 |
| 720E, 30S | 1.35 ± 0.29 | <0.24 | 1.38 ± 0.38 | 0.67 ± 0.16 |
| 730E, 30S | 2.77 ± 0.26 | <0.24 | <5.81 | 0.79 ± 0.20 |
| 740E, 30S | 1.34 ± 0.22 | <0.24 | <4.11 | 0.73 ± 0.16 |
| 750E, 30S | 1.95 ± 0.33 | <0.24 | <3.99 | 0.94 ± 0.17 |
| 760E, 30S | 1.30 ± 0.31 | <0.24 | <3.98 | 0.71 ± 0.15 |
| 770E, 30S | 0.46 ± 0.11 | <0.24 | <5.00 | 0.71 ± 0.11 |
| 780E, 30S | 0.57 ± 0.11 | <0.23 | <2.53 | 0.72 ± 0.15 |
| 790E, 30S | 0.52 ± 0.19 | <0.24 | <3.74 | 0.55 ± 0.13 |
| 620E, 40S | 2.70 ± 0.35 | <0.24 | <4.55 | 0.55 ± 0.13 |
| 630E, 40S | 1.82 ± 0.29 | <0.24 | <3.42 | 0.53 ± 0.17 |
| 640E, 40S | 0.56 ± 0.21 | <0.24 | <2.55 | 0.83 ± 0.17 |
| 650E, 40S | b | b | b | b |
| 660E, 40S | 4.96 ± 0.46 | <0.24 | <6.19 | 0.45 ± 0.16 |
| 670E, 40S | 0.88 ± 0.30 | <0.24 | <3.51 | 0.88 ± 0.17 |
| 680E, 40S | 1.54 ± 0.30 | <0.24 | <4.64 | 0.92 ± 0.17 |
| 690E, 40S | 3.64 ± 1.83 | <1.40 | <11.18 | <0.29 |
| 700E, 40S | 2.97 ± 0.22 | <0.24 | <5.68 | 0.76 ± 0.19 |
| 710E, 40S | 3.36 ± 0.37 | <0.24 | <5.06 | 0.38 ± 0.13 |
| 720E, 40S | 2.22 ± 0.34 | 0.65 ± 0.84 | <5.04 | 0.66 ± 0.17 |
| 730E, 40S | 3.14 ± 0.42 | <0.24 | <4.74 | 1.35 ± 0.21 |
| 740E, 40S | 0.54 ± 0.26 | <0.24 | <4.11 | 0.99 ± 0.16 |
| 750E, 40S | 0.70 ± 0.56 | <0.24 | <4.50 | 0.72 ± 0.16 |
| 760E, 40S | 0.22 ± 0.17 | <0.17 | <3.76 | 0.78 ± 0.16 |
| 770E, 40S | 0.58 ± 0.22 | <0.24 | <3.75 | 0.83 ± 0.17 |
| 610E, 50S | 3.60 ± 0.47 | <0.24 | 1.03 ± 0.30 | 0.82 ± 0.22 |

TABLE 8, cont.

RADIONUCLIDE CONCENTRATIONS IN SURFACE SOIL SAMPLES
FROM 10 M GRID INTERVALS IN THE TRACK STREET AREA

| Location | Radionuclide Concentrations (pCi/g) | | | |
|---|---|---|---|---|
| | Ra-226 | U-235 | U-238 | Cs-137 |
| 620E, 50S | 0.60 ± 0.29 | <0.24 | 0.92 ± 0.36 | 0.74 ± 0.15 |
| 630E, 50S | 0.72 ± 0.29 | <0.24 | <3.63 | 1.28 ± 0.21 |
| 640E, 50S | b | b | b | b |
| 650E, 50S | 1.78 ± 0.33 | 0.41 ± 0.63 | <6.59 | 0.56 ± 0.18 |
| 660E, 50S | 1.84 ± 0.29 | <0.24 | 6.51 ± 6.59 | 0.45 ± 0.14 |
| 670E, 50S | 4.20 ± 0.15 | <0.16 | 2.90 ± 0.66 | <0.25 |
| 680E, 50S | 0.64 ± 0.19 | <0.24 | <3.49 | <0.02 |
| 690E, 50S | 4.56 ± 0.46 | <0.24 | 3.15 ± 0.50 | 0.77 ± 0.16 |
| 700E, 50S | 2.95 ± 0.56 | <0.24 | <5.01 | 0.67 ± 0.17 |
| 710E, 50S | 1.81 ± 0.41 | <0.24 | <7.38 | 0.51 ± 0.13 |
| 720E, 50S | 0.61 ± 0.24 | <0.24 | <4.93 | 0.72 ± 0.16 |
| 730E, 50S | 0.49 ± 0.16 | <0.24 | <3.05 | 0.55 ± 0.13 |
| 740E, 50S | 0.36 ± 0.19 | <0.24 | <2.85 | 1.11 ± 0.16 |
| 750E, 50S | 0.47 ± 0.18 | <0.19 | <3.59 | 0.31 ± 0.10 |
| 580E, 60S | 0.63 ± 0.24 | <0.26 | <3.25 | 0.85 ± 0.16 |
| 590E, 60S | 4.46 ± 0.38 | <0.24 | <4.87 | 0.70 ± 0.14 |
| 600E, 60S | 0.99 ± 0.26 | <0.24 | <3.76 | 0.69 ± 0.15 |
| 610E, 60S | 0.66 ± 0.22 | <0.24 | 8.20 ± 8.73 | 0.79 ± 0.16 |
| 620E, 60S | 5.56 ± 1.32 | <1.69 | 1.94 ± 0.59 | <0.17 |
| 630E, 60S | 1.77 ± 0.31 | 0.42 ± 0.74 | <5.14 | 0.78 ± 0.17 |
| 640E, 60S | 0.77 ± 0.26 | 0.85 ± 0.67 | <3.68 | 1.25 ± 0.20 |
| 650E, 60S | 1.37 ± 0.38 | <0.24 | <4.46 | 0.77 ± KO.19 |
| 660E, 60S | 5.59 ± 1.87 | 4.56 ± 6.10 | 4.96 ± 0.59 | <0.26 |
| 670E, 60S | 2.90 ± 0.45 | <0.24 | <5.72 | 0.55 ± 0.16 |
| 680E, 60S | 5.01 ± 0.56 | <0.24 | <6.72 | 0.72 ± 0.17 |
| 690E, 60S | 2.04 ± 0.36 | <0.24 | <5.16 | 0.93 ± 0.17 |
| 700E, 60S | 1.67 ± 0.45 | <0.24 | <7.09 | 1.31 ± 0.27 |
| 710E, 60S | 0.75 ± 0.23 | <0.24 | <3.92 | 0.86 ± 0.17 |
| 720E, 60S | 0.60 ± 0.22 | <0.23 | <4.51 | 0.34 ± 0.12 |
| 730E, 60S | 0.57 ± 0.20 | <0.24 | <2.05 | 0.57 ± 0.12 |
| 740E, 60S | 0.50 ± 0.19 | <0.24 | <3.19 | 0.71 ± 0.08 |
| 580E, 70S | 2.17 ± 0.37 | <0.24 | 2.78 ± 0.37 | 0.66 ± 0.19 |
| 590E, 70S | 0.75 ± 0.28 | <0.24 | <4.30 | 0.84 ± 0.16 |
| 600E, 70S | 0.53 ± 0.28 | 0.51 ± 0.68 | 3.95 ± 0.36 | 0.86 ± 0.20 |
| 610E, 70S | <0.19 | <0.24 | <4.00 | 0.71 ± 0.18 |
| 620E, 70S | 1.22 ± 0.27 | 0.49 ± 0.79 | <4.26 | 0.78 ± 0.16 |
| 630E, 70S | 2.09 ± 0.36 | <0.24 | 1.12 ± 0.51 | 0.74 ± 0.17 |
| 640E, 70S | 5.31 ± 1.67 | <1.61 | <22.85 | <0.26 |
| 650E, 70S | 2.66 ± 0.37 | <0.24 | <7.53 | 0.68 ± 0.16 |
| 660E, 70S | 1.21 ± 0.27 | <0.24 | <4.48 | 0.36 ± 0.15 |

TABLE 8, cont.

RADIONUCLIDE CONCENTRATIONS IN SURFACE SOIL SAMPLES
FROM 10 M GRID INTERVALS IN THE TRACK STREET AREA

| Loration | Radionuclide Concentrations (pCi/g) | | | |
|---|---|---|---|---|
| | Ra-226 | U-235 | U-238 | Cs-137 |
| 670E, 70S | 0.72 ± 0.33 | <0.24 | <4.47 | 0.82 ± 0.15 |
| 680E, 70S | 0.75 ± 0.25 | <0.26 | <4.14 | 0.33 ± 0.16 |
| 690E, 70S | 0.83 ± 0.26 | <0.29 | <5.47 | 0.73 ± 0.15 |
| 700E, 70S | 0.69 ± 0.32 | <0.24 | <3.31 | 0.53 ± 0.13 |
| 710E, 70S | 0.35 ± 0.17 | <0.24 | <2.55 | 0.69 ± 0.13 |
| 590E, 80S | 1.07 ± 0.36 | <0.24 | <5.23 | 1.20 ± 0.21 |
| 600E, 80S | 0.56 ± 0.25 | <0.24 | <6.43 | 0.82 ± 0.16 |
| 610E, 80S | 0.64 ± 0.25 | <0.24 | <4.92 | <0.05 |
| 620E, 80S | 1.89 ± 0.33 | <0.24 | <5.32 | 1.06 ± 0.20 |
| 630E, 80S | 6.89 ± 1.82 | <2.38 | 2.05 ± 0.56 | 0.60 ± 0.67 |
| 640E, 80S | 3.84 + 0.43 | <0.24 | <4.59 | 0.76 ± 0.18 |
| 650E, 80S | 5.11 ± 0.48 | <0.24 | <5.90 | 0.58 ± 0.16 |
| 660E, 80S | <0.16 | <0.24 | <3.76 | 0.55 ± 0.14 |
| 670E, 80S | 0.64 ± 0.30 | 0.37 ± 0.56 | <4.36 | 0.96 ± 0.19 |
| 680E, 80S | 1.44 ± 0.19 | <0.24 | <3.48 | 0.47 ± 0.09 |
| 690E, 80S | <0.44 | <1.06 | 0.36 ± 0.27 | 1.37 ± 0.72 |
| 700E, 80S | 0.98 ± 0.35 | <0.25 | 9.29 ± 7.93 | 0.63 ± 0.17 |
| 580E, 90S | 0.63 ± 0.29 | <0.24 | <4.71 | 0.19 ± 0.11 |
| 590E, 90S | 0.96 ± 0.28 | <0.24 | <5.70 | 0.63 ± 0.18 |
| 600E, 90S | 0.80 ± 0.30 | <0.24 | <6.14 | 1.07 ± 0.19 |
| 610E, 90S | <0.46 | <0.22 | 4.70 ± 0.51 | <0.24 |
| 620E, 90S | 1.44 ± 0.36 | <0.24 | 1.20 ± 0.37 | 0.85 ± 0.16 |
| 630E, 90S | 3.71 ± 0.45 | 1.01 ± 0.75 | <5.58 | 1.04 ± 0.19 |
| 640E, 90S | 2.83 ± 0.42 | 1.29 ± 0.78 | <6.30 | 0.70 ± 0.18 |
| 650E, 90S | 0.55 ± 0.18 | <0.24 | <2.81 | 0.08 ± 0.07 |
| 660E, 90S | 0.69 ± 0.25 | <0.22 | <2.52 | 0.75 ± 0.18 |
| 670E, 90S | 0.67 ± 0.27 | <0.24 | <4.42 | 0.34 ± 0.13 |
| 680E, 90S | 0.61 + 0.12 | <0.24 | <4.61 | 0.16 ± 0.10 |
| 580E,100S | 0.73 ± 0.29 | <0.24 | <4.10 | 0.69 ± 0.16 |
| 590E,100S | 4.94 ± 2.23 | <2.22 | 3.78 ± 0.66 | <0.30 |
| 600E,100S | 1.35 ± 0.29 | <0.24 | <3.64 | 0.84 ± 0.19 |
| 610E,100S | 2.88 ± 0.46 | <0.24 | <4.01 | 1.12 ± 0.21 |
| 620E,100S | 2.38 ± 0.32 | <0.24 | <4.72 | 0.80 ± 0.18 |
| 630E,100S | 1.88 ± 0.34 | <0.24 | <4.20 | 1.02 ± 0.18 |
| 640E,100S | 0.90 ± 0.23 | 0.34 ± 0.48 | <4.36 | 0.54 ± 0.10 |
| 650E,100S | 0.70 ± 0.21 | <0.26 | <4.80 | 0.55 ± 0.16 |
| 660E,100S | 0.50 ± 0.19 | <0.24 | <3.42 | 0.83 ± 0.17 |
| 670E,100S | 0.31 ± 0.24 | <0.24 | <.78 | 0.52 ± 0.15 |

TABLE 8, cont.

RADIONUCLIDE CONCENTRATIONS IN SURFACE SOIL SAMPLES
FROM 10 M GRID INTERVALS IN THE TRACK STREET AREA

| Location | Radionuclide Concentrations (pCi/g) | | | |
|---|---|---|---|---|
| | Ra-226 | U-235 | U-238 | Cs-137 |
| 580E,110S | 6.24 ± 2.67 | <1.79 | 4.62 ± 0.54 | 0.68 ± 0.69 |
| 590E,110S | 5.46 ± 0.50 | 0.83 ± 0.69 | <6.76 | 0.74 ± 0.20 |
| 600E,110S | 1.92 ± 0.41 | <0.24 | <5.17 | 1.21 ± 0.27 |
| 610E,110S | 0.68 ± 0.19 | <0.24 | <3.43 | 1.02 ± 0.15 |
| 620E,110S | 0.36 ± 0.21 | <0.22 | <3.00 | 0.48 ± 0.16 |
| 630E,110S | 0.64 ± 0.22 | <0.24 | <3.96 | 0.67 ± 0.13 |
| 640E,110S | 0.31 ± 0.29 | <0.23 | <2.20 | 0.86 ± 0.12 |
| 650E,110S | 0.52 ± 0.25 | <0.24 | <4.15 | 0.39 ± 0.13 |
| 660E,110S | 0.60 ± 0.21 | 0.22 ± 0.70 | <3.57 | <0.04 |
| 580E,120S | 0.40 ± 0.20 | <0.24 | <3.23 | 0.31 ± 0.12 |
| 590E,120S | 0.85 ± 0.25 | <0.24 | <4.26 | 0.71 ± 0.17 |
| 600E,120S | 0.56 ± 0.23 | <0.24 | <5.62 | 0.66 ± 0.16 |
| 610E,120S | 0.63 ± 0.21 | <0.24 | <5.02 | 0.16 ± 0.08 |
| 620E,120S | 0.87 ± 0.27 | <0.24 | <4.89 | 0.22 ± 0.14 |
| 630E,120S | 0.39 ± 0.20 | <0.24 | <2.99 | 1.35 ± 0.19 |
| 580E,130S | 0.72 ± 0.22 | <0.24 | <4.23 | 0.56 ± 0.13 |
| 590E,130S | 0.74 ± 0.22 | <0.24 | 4.16 ± 8.78 | 0.49 ± 0.14 |
| 600E,130S | 0.74 ± 0.28 | <0.24 | <3.92 | 0.97 ± 0.22 |
| 610E,130S | 0.28 ± 0.15 | <0.24 | <2.31 | 0.87 ± 0.14 |
| 620E,130S | 0.74 ± 0.23 | <0.24 | <3.58 | 0.75 ± 0.15 |
| 580E,140S | 1.00 ± 0.24 | <0.24 | <3.13 | 0.62 ± 0.16 |
| 590E,140S | 0.68 ± 0.21 | <0.24 | <3.30 | 0.69 ± 0.14 |
| 600E,140S | 0.45 ± 0.21 | <0.26 | <4.50 | 0.45 ± 0.13 |
| 580E,150S | 0.32 ± 0.22 | <0.24 | <3.14 | 0.59 ± 0.13 |

[a] Errors are 2σ based on counting statistics.
[b] Sample not obtained - grid point on paved surface.

TABLE 9

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

| Sample No.[a] | Location | Radionuclide Concentrations (pCi/g)[b] | | | |
|---|---|---|---|---|---|
| | | Ra-226 | U-235 | U-238 | Cs-137 |
| B1 | 148E, 43S | 3.99 ± 1.43[c] | 4.49 ± 2.33 | 51.6 ± 0.7 | 0.51 ± 0.17 |
| B2 | 154E, 38S | 15.1 ± 0.9 | 1.73 ± 1.78 | 17.8 ± 0.5 | 0.57 ± 0.23 |
| B3 | 153E, 36S | 45.1 ± 1.8 | 4.57 ± 2.48 | 68.5 ± 0.8 | 1.33 ± 0.39 |
| B4 | 163E, 31S | 141 ± 3 | <0.25 | 23.3 ± 0.5 | 3.15 ± 0.59 |
| B5 | 166E, 29S | 26.5 ± 1.2 | 0.93 ± 1.68 | 6.13 ± 0.39 | 6.52 ± 0.40 |
| B6 | 170E, 30S | 88.3 ± 1.9 | 3.33 ± 2.88 | 39.3 ± 0.6 | 1.18 ± 0.22 |
| B7 | 169E, 32S | 9.32 ± 0.72 | 1.18 ± 1.46 | 22.2 ± 0.5 | 5.93 ± 0.43 |
| B8 | 178E, 32S | 63.7 ± 1.9 | <0.24 | 22.3 ± 0.5 | 1.09 ± 1.15 |
| B9 | 202E, 37S | 23.3 ± 1.2 | 3.99 ± 1.99 | 34.7 ± 0.6 | 2.77 ± 0.43 |
| B10 | 109E,210S | ---[d] | --- | --- | --- |
| B11[e] | 582E, 76S | 0.44 ± 0.56 | 9.08 ± 2.19 | 125 ± 1 | 0.82 ± 0.27 |
| B12[f] | 584E, 74S | 0.98 ± 0.32 | 6.57 ± 2.11 | 119 ± 1 | 0.68 ± 0.28 |
| B13 | 641E, 50S | 246 ± 3 | 6.64 ± 4.75 | 10.4 ± 0.5 | <0.49 |
| B14 | 660E, 39S | 1.39 ± 0.44 | 2.57 ± 1.42 | 32.2 ± 0.5 | 3.40 ± 0.74 |
| B15 | 668E, 33S | 222 ± 3 | 6.87 ± 5.17 | 24.4 ± 0.6 | 0.54 ± 0.09 |
| B16 | 669E, 31S | 55.3 ± 1.7 | 3.79 ± 2.71 | 10.7 ± 0.5 | 2.16 ± 0.46 |
| B17 | 668E, 30S | 431 ± 4 | <0.24 | 6.49 ± 0.39 | <0.59 |
| B18 | 684E, 10S | 6.05 ± 0.54 | <0.24 | <6.31 | 2.94 ± 0.28 |
| B19 | 738E, 4S | 6.95 ± 0.65 | 3.01 ± 1.46 | 41.8 ± 0.7 | 0.55 ± 0.22 |

[a] Refer to Figures 4, 5, and 6.
[b] Refer to Table 5 for direct radiation levels.
[c] Errors are 2σ based on counting statistics.
[d] Ra-226 level 3.73 pCi.
[e] Sample B11 contains 13.9 ± 1.2 Th-232.
[f] Sample B12 contains 12.5 ± 1.2 Th-232.

TABLE 10

RADIONUCLIDE CONCENTRATIONS IN BOREHOLE SOIL SAMPLES

| Borehole No.[a] | Grid Location | Depth (m) | Radionuclide Concentrations (pCi/g) Ra-226 | U 235 | U-238 | Cs-137 |
|---|---|---|---|---|---|---|
| H1 | 92E, 269S | 0.3 | 0.33 ± 0.24[b] | <0.24 | <4.59 | <0.03 |
| | | 2.5 | 0.67 ± 0.23 | <0.24 | <2.64 | 0.57 ± 0.49 |
| H2 | 121E, 23S | Surface | 0.51 ± 0.16 | <0.24 | <3.16 | 0.45 ± 0.07 |
| | | 0.5 | 0.75 ± 0.18 | <0.24 | <3.12 | <0.02 |
| | | 1.0 | 0.50 ± 0.14 | <0.24 | <3.44 | <0.03 |
| | | 2.0 | 0.52 ± 0.15 | 0.27 ± 0.59 | <2.79 | <0.03 |
| | | 3.0 | 0.45 ± 0.16 | <0.24 | 3.80 ± 13.81 | <0.02 |
| H3 | 380E,140S | Surface | 0.93 ± 0.29 | <0.24 | <5.20 | 0.39 ± 0.13 |
| | | 0.5 | 0.64 ± 0.24 | <0.24 | <4.86 | <0.03 |
| | | 1.0 | 0.54 ± 0.22 | <0.24 | <5.17 | <0.04 |
| | | 2.0 | 0.75 ± 0.20 | <0.24 | <4.86 | 0.05 ± 0.05 |
| | | 3.0 | 0.38 ± 0.19 | <0.22 | <4.01 | <0.03 |
| H4 | 490E,321S | 0.3 | 0.50 ± 0.14 | <0.24 | <2.82 | <0.02 |
| | | 3.0 | 0.56 ± 0.28 | <0.24 | <4.09 | <0.02 |
| H5 | 560E, 85S | Surface | 2.52 ± 0.32 | <0.24 | <2.83 | 0.90 ± 0.14 |
| | | 0.5 | 0.49 ± 0.16 | <0.24 | <3.41 | <0.03 |
| | | 1.0 | 0.61 ± 0.17 | <0.18 | <3.44 | <0.03 |
| | | 2.0 | 0.41 ± 0.16 | <0.24 | <4.34 | 0.47 ± 0.12 |
| H6 | 560E,160S | Surface | 0.29 ± 0.16 | <0.24 | <1.98 | 0.15 ± 0.08 |
| | | 0.5 | 0.53 ± 0.21 | <0.24 | <2.95 | <0.03 |
| | | 1.0 | 0.55 ± 0.23 | <0.24 | <2.84 | <0.04 |
| | | 2.0 | 0.42 ± 0.22 | <0.19 | <2.39 | <0.03 |
| | | 3.0 | 1.39 ± 0.18 | <0.24 | <2.66 | <0.03 |
| H7 | 580E,100S | Surface | 0.37 ± 0.16 | <0.24 | <2.65 | 0.27 ± 0.10 |
| | | 0.5 | 0.44 ± 0.21 | <0.24 | <3.70 | <0.03 |
| | | 1.0 | 0.51 ± 0.18 | 0.41 ± 0.50 | <4.65 | <0.03 |
| | | 2.0 | 0.75 ± 0.22 | <0.24 | <4.01 | 0.54 ± 0.09 |
| | | 3.0 | 0.61 ± 0.14 | <0.24 | <4.34 | <0.03 |
| H8 | 625E,115S | Surface | 3.14 ± 0.45 | <0.24 | <5.63 | 0.19 ± 0.20 |
| | | 0.5 | 0.43 ± 0.20 | <0.24 | <4.33 | <0.03 |
| | | 1.0 | 0.62 ± 0.25 | <0.24 | <5.35 | <0.03 |
| | | 2.0 | 0.63 ± 0.19 | <0.24 | <4.23 | 0.06 ± 0.08 |
| H9 | 680E, 5S | Surface | 0.77 ± 0.25 | <0.24 | <2.97 | 0.47 ± 0.12 |
| | | 0.5 | 0.52 ± 0.21 | <0.24 | <4.97 | <0.03 |

TABLE 10, cont.

RADIONUCLIDE CONCENTRATIONS IN BOREHOLE SOIL SAMPLES

| Borehole No. | Grid Location | Depth (m) | Radionuclide Concentrations (pCi/g) Ra-226 | U-235 | U-238 | Cs-137 |
|---|---|---|---|---|---|---|
| | | 1.0 | 0.60 ± 0.20 | <0.24 | <4.63 | <0.03 |
| | | 2.0 | 0.66 ± 0.17 | <0.24 | <3.97 | <0.03 |
| | | 3.0 | 0.59 ± 0.22 | <0.24 | <4.32 | <0.03 |
| H10 | 702E, 20S | Surface | 1.41 ± 0.28 | <0.24 | <5.18 | 0.62 ± 0.14 |
| | | 0.5 | 0.68 ± 0.24 | <0.24 | <3.14 | <0.03 |
| | | 1.0 | 0.51 ± 0.22 | <0.24 | <3.54 | <0.04 |
| | | 2.0 | 1.16 ± 0.30 | <0.24 | <3.55 | <0.03 |
| | | 3.0 | 0.50 ± 0.20 | <0.24 | <3.63 | <0.04 |
| H11 | 745E, 37S | Surface | 0.44 ± 0.19 | <0.24 | <4.14 | 0.64 ± 0.17 |
| | | 0.5 | 0.12 ± 0.25 | <0.24 | <4.99 | <0.04 |
| | | 1.0 | 0.58 ± 0.18 | <0.24 | <2.73 | <0.04 |
| | | 2.0 | 0.59 ± 0.16 | <0.24 | <3.51 | <0.03 |
| H12 | 778E,319S | 0.3 | 0.50 ± 0.14 | <0.24 | <2.62 | <0.02 |
| | | 3.0 | 0.56 ± 0.28 | <0.24 | <4.09 | <0.02 |
| H13 | 1063E,155S | 0.3 | 0.48 ± 0.17 | <0.23 | <3.77 | <0.04 |
| | | 2.0 | 0.34 ± 0.17 | <0.24 | <3.50 | <0.03 |
| | | 3.0 | 0.61 ± 0.18 | <0.19 | <3.47 | <0.02 |
| H14 | 1080E, 20S | Surface | 0.53 ± 0.20 | <0.24 | <3.10 | 0.65 ± 0.12 |
| | | 0.5 | 0.88 ± 0.22 | <0.24 | <4.94 | <0.04 |
| | | 1.0 | 1.17 ± 0.30 | <0.24 | <4.82 | <0.04 |
| | | 2.0 | 1.16 ± 0.28 | <0.24 | <4.37 | <0.03 |
| | | 3.0 | 0.95 ± 0.26 | <0.24 | <4.43 | <0.04 |
| H15 | 156E, 30S | Surface | 3.46 ± 0.43 | <0.41 | <8.03 | 0.16 ± 1.10 |
| | | 1.0 | 1.80 ± 0.29 | <0.36 | 2.73 ± 0.38 | <0.06 |
| H16 | 144E, 43S | Surface[c] | 1.66 ± 0.32 | 0.68 ± 0.61 | 10.6 ± 0.4 | 0.85 ± 0.37 |
| H17 | 154E, 38S | Surface[c] | 15.1 ± 0.9 | 1.73 ± 1.78 | 17.8 ± 0.5 | 0.57 ± 0.23 |
| H18 | 162E, 32S | 0.3 | 0.68 ± 1.16 | <0.04 | <5.87 | <0.04 |
| H19 | 168E, 49S | 0.3 | 11.6 ± 0.7 | 1.38 ± 1.18 | 1.22 ± 0.32 | 1.21 ± 0.23 |
| H20 | 170E, 22S | Surface | 0.63 ± 0.22 | <0.30 | <5.73 | 0.14 ± 0.18 |
| | | 0.5 | 0.63 ± 0.23 | <0.27 | <6.00 | <0.05 |

TABLE 10, cont.

RADIONUCLIDE CONCENTRATIONS IN BOREHOLE SOIL SAMPLES

| Borehole No. | Grid Location | Depth (m) | Radionuclide Concentrations (pCi/g) Ra-226 | U-235 | U-238 | Cs-137 |
|---|---|---|---|---|---|---|
| H21 | 170E, 30S | Surface | 88.3 ± 1.9 | 3.33 ± 2.88 | 39.3 ± 0.6 | 1.16 ± 0.22 |
| | | 0.1 | 3.36 ± 1.33 | 2.36 ± 2.02 | 28.6 ± 0.5 | <0.23 |
| H22 | 178E, 32S | Surface[c] | 63.7 ± 1.9 | <0.24 | 22.3 ± 0.5 | 1.09 ± 1.15 |
| H23 | 193E, 36S | 1.0 | 0.89 ± 0.24 | <0.29 | <6.05 | <0.05 |
| H24 | 584E, 74S | Surface | 0.98 ± 0.32 | 6.57 ± 2.11 | 119 ± 1 | 0.68 ± 0.28 |
| | | 0.5 | <0.16 | <0.24 | <4.63 | <0.04 |
| | | 1.0 | 0.43 ± 0.19 | <0.24 | <4.41 | <0.03 |
| H25 | 641E, 50S | Surface[c] | 246 ± 3 | 6.64 ± 4.75 | 10.4 ± 0.5 | <0.49 |
| H26 | 668E, 30S | Surface[c] | 431 ± 4 | <0.24 | 6.49 ± 0.38 | <0.59 |
| H27 | 668E, 33S | Surface[c] | 222 ± 3 | 6.67 ± 5.17 | 24.4 ± 0.6 | 0.54 ± 0.09 |

[a] Refer to Figures 7, 8, and 9.
[b] Errors are 2σ based on counting statistics.
[c] Subsurface sample not collected due to negative findings of borehole logging measurements.

TABLE 11

RADIONUCLIDE CONCENTRATIONS IN SUBSURFACE WATER SAMPLES

| Sample No. | Borehole No.[a] | Grid Location | Radionuclide Concentrations (pCi/l) Gross Alpha | Gross Beta |
|---|---|---|---|---|
| W1 | H1 | 92E,269 | <5.21 | 8.53 ± 7.75 |
| W2 | H2 | 121E, 23S | 9.06 ± 2.42[b] | 5.55 ± 2.13 |
| W3 | H3 | 380E,140S | 8.86 ± 9.21 | 2.34 ± 12.32 |
| W4 | H4 | 490E,321S | <3.67 | 13.5 ± 5.9 |
| W5 | H5 | 560E, 85S | 3.23 ± 1.96 | 21.9 ± 2.7 |
| W6 | H6 | 560E,160S | 1.47 ± 1.98 | 6.30 ± 2.23 |
| W7 | H7 | 580E,100S | 11.7 ± 7.7 | 28.5 ± 8.7 |
| W8 | H8 | 625E,115S | 1.85 ± 7.04 | 12.6 ± 8.3 |
| W9 | H9 | 680E, 5S | 4.47 ± 4.25 | 24.5 ± 5.9 |
| W10 | H10 | 702E, 20S | <1.17 | <1.36 |
| W11 | H11 | 745E, 37S | 4.52 ± 5.03 | 7.99 ± 5.61 |
| W12 | H12 | 778E,319S | 8.53 ± 4.79 | <5.42 |
| W13 | H13 | 1063E,155S | 13.9 ± 6.8 | 3.60 ± 8.27 |
| W14 | H14 | 1080E, 20S | 4.61 ± 2.74 | 44.0 ± 4.1 |

[a] Refer to Figure 7.
[b] Errors are 2σ based on counting statistics.

## REFERENCES


1. E.A. Vierzba and A. Wallo, A Background Report and Evaluation of Resurvey Requirements for the Former 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 Scanning 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 levels (μR/h) using factors determined by comparing the response of the scintillation detector with that of a Reuter Stokes model RSS-111 pressurized ionization chamber at several locations on property N/N' South.

## 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 for soil samples having elevated Ra-226 content.

## 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. The length of the hole was scanned and measurements were performed at 30-50 cm intervals in all holes. The logging data were used to identify regions of possible residues and guide the selection of subsurface soil sampling locations. Due to the varying ratios of Ra-226, U-238, and Cs-137 there was no attempt to estimate soil radionuclide concentrations directly from the logging results.

Soil Sample Analysis

Soil 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 400 to 600 g of soil. Net soil weights were determined and samples counted using a 23% Ge(Li) detector (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 (secular equilibrium assumed)
U-235 - 0.143 MeV
U-238 - 1.001 MeV from Pa-234 (secular equilibrium assumed)
Th-232 - 0.911 MeV from Ac-228 (secular equilibrium assumed)
Cs-137 - 0.662 MeV

Several samples were also analyzed for U-238 by neutron activation. Approximately 12-20 g of soil was irradiated for 30 minutes in a neutron flux of $10^8$ n/cm$^2$/sec from a 25 mg Cf-252 spontaneous fission source. After a two minute wait time, the U-239 peak (74.6 kev) was counted for 1000 seconds and the U-238 calculated.

Strontium-90 analysis was performed following standard procedures specified in "Radiochemical Analytical Procedures for Analysis of Environmental Samples," EMSL-LV-0539-17, March 1979.

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 20 ml of concentrated nitric acid. Fifty milliliters of each sample was evaporated to dryness and counted for gross alpha and gross beta using a Tennelec Model LB5100 low-background proportional counter.

Calibration and Quality Assurance

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

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

# APPENDIX B

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

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

| Mode of Exposure | Exposure conditions | Guideline value | Guideline source |
|---|---|---|---|
| 1. External gamma radiation | Continuous exposure to individual in general population (whole body) | 60 μR/hr | Nuclear Regulatory Commission (NRC) Standards for Protection Against Radiation (10 CFR 20.105) |
| | Indoor gamma radiation (above background) | 20 μR/h | EPA Standards for Uranium Mill Tailings (40 CFR 192) |
| 2. Surface alpha contamination[a] | Ra-226 contamination fixed on surfaces | 100 dpm/100 $cm^2$ | *NRC Guidelines for Facilities* and Equipment Prior to Release for Unrestricted Use or Termination of Licenses for By-product, Source, or Special Nuclear Material (Adapted from NRC Reg. Guide 1.86) |
| | Removable Ra-226 | 20 dpm/100 $cm^2$ | |
| 3. Surface beta contamination[a] | Removable beta-gamma | 1000 dpm/100 $cm^2$ | Same as number 2 |
| 4. Beta-gamma dose rate | Average dose rate on an area no greater than 1 $m^2$ | 0.2 mrad/h | Same as number 2 |
| | Maximum dose rate in any 100 $cm^2$ area | 1.0 mrad/h | Same as number 2 |
| 5. Exposure to radon | Maximum permissible concentration of Rn-220 in air in unrestricted areas | 3.0 pCi/l | NRC 10 CFR 20.103, Appendix B, Table II |
| | Average annual radon daughter concentration (including background) | 0.030 WL maximum<br>0.020 WL preferrable | EPA Standards for Mill Tailings |

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

| Mode of Exposure | Exposure conditions | Guideline value | Guideline source |
|---|---|---|---|
| 6. Radionuclides in water | Gross Alpha | 15 pCi/l | EPA Interim Drinking |
| | Gross Beta | 50 pCi/l | Water Standards (40 CFR 141) |
| | Maximum contaminant level for combined Ra-226 and Ra-228 in drinking water | 5 pCi/l | |
| | Maximum permissible concentration of the following radionuclides in water for unrestricted area: | | NRC (10 CFR 20.103 Appendix B, Table II) |
| | Ra-226 | 30 pCi/l | |
| | U-238 | 40,000 pCi/l | |
| | Th-230 | 2,000 pCi/l | |
| | Pb-210 | 100 pCi/l | |
| 7. Radionuclides in soil | Concentration above background-averaged over an area of 100 $m^2$ | | |
| | Ra-226 | 5 pCi/g (surface)<br>15 pCi/g (subsurface) | EPA Standards for Uranium Mill Tailings |
| | U-238 | 40 pCi/g | Interim Soil Limits |
| | Th-232 | 20 pCi/g | for D&D Projects, |
| | Sr 90 | 100 pCi/g | LA-UR-79-1665-Rev. |
| | Cs-137 | 80 pCi/g | J.W. Healy et al. |
| | U-enriched in U-235 | 30 pCi/g | NRC Branch Technical Position Paper (Federal Register, October 23, 1981) |

[a] Applicable to building and equipment surfaces only.

# APPENDIX C

## REPORT OF GROUND-PENETRATING RADAR SURVEY OF OFF-SITE PROPERTY N/N' SOUTH AT THE NIAGARA FALLS STORAGE SITE

DETECTION SCIENCES GROUP

# FINAL REPORT
# GROUND-PENETRATING RADAR SURVEY
# OF AREAS Q AND N/N' AT THE
# FORMER LAKE ONTARIO ORDNANCE WORKS
# LEWISTON, NEW YORK

RADARVISION

DETECTION SCIENCES GROUP
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FINAL REPORT

# GROUND-PENETRATING RADAR SURVEY OF AREAS Q AND N/N' AT THE FORMER LAKE ONTARIO ORDNANCE WORKS LEWISTON, NEW YORK

Prepared for

OAK RIDGE ASSOCIATED UNIVERSITIES, INC
Oak Ridge, Tennessee 37830

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Purchase Order No. C-25303
Letter Release No. 3
Dated October 15, 1982

Report No. J147-82

December, 1982

RADARVISION

## TABLE OF CONTENTS



## Illustrations

## INTRODUCTION AND SUMMARY

Starting on October 25, and continuing through November 7, 1982, Detection Sciences Group conducted a ground-penetrating radar survey of designated locations in Area Q and Areas N/N' at the former Lake Ontario Ordnance Works, Lewiston, New York. The radar survey was performed in accordance with Oak Ridge Associated Universities, Inc. Purchase Order No. C-25303, Letter Release No. 3, dated October 15, 1982, and per field instructions received from O.R.A.U. personnel.

The first area to be surveyed was a site in Area N at the southeast corner of "R" Street and Castle Garden Road. The radar survey zone was from 20S to 50S, extending from 140E to 185E. The radar anomalies and the radar survey lines are shown in **Figure** 1. The next task to be performed was the inspection of 24 boring sites located in Area Q. The boring locations and the co-ordinates of the borings that were relocated are given in **Table** 1. The third task was to run a series of survey lines between 760S and 840S, extending from 160E to 180E in Area Q. The results of the survey in this location are shown in Figure 2. The next task was to run six survey lines parallel to Track Street and South Track Street in Area N'. The radar survey lines and the radar anomalies are shown in Figure 3. The last task was to inspect the locations of 3 borings to be placed in the corners of the southwest triangle of Area N, bounded by Castle Garden Road, "R" Street, and Track Street. These locations are tabulated in **Table 2.**

Out of the 24 boring locations surveyed in Area Q, 3 locations - Q1, Q4, and Q9 - were found to have underground pipes. These locations were moved 2 to 3 meters away from the pipes to avoid potential drilling problems. As a precautionary measure, 8 other boring locations in Area Q were moved 1 to 3 meters away from their original locations. In all cases, the relocated sites were chosen to be as near as possible to the original site chosen for the boring. Of the 3 boring sites in the southwest triangle of Area N, none had to be relocated.

Prior to the radar work, O.R.A.U. had placed pin flags at locations where monitoring instruments indicated activity. It was noted that the radar signatures obtained where there were clusters of pin flags were significantly different than the radar signatures observed over most of the surrounding area. Specifically, the radar signatures at the pin flag clusters tended to be much darker and more pronounced than the prevailing radar signatures of the overall site. The apparent correlation between the radar signatures and the pin flag clusters has been subdivided into two categories: those areas having very dark, strong signal returns, and those areas having moderately dark, strong returns. The difference between the two subdivisions is only a difference of degree. In general, this kind of radar signature is indicative of non-ionic liquids being present in the ground. Although water is itself a non-ionic liquid, the radar signatures are not typical for wet, saturated ground. More likely, the radar signatures are due to the presence of petroleum solvents or oils that do not readily disperse in the ground. Determination of the composition of the non-ionic liquids (including the possibility that it is perched water) would require physical samples to be taken from these locations, a task that is not part of the radar survey program.

## DESCRIPTION OF THE SURVEY

The entire survey was conducted with the 120 MHz radar antenna. With the exception of the survey lines along Track Street and South Track Street, the survey was run with our antenna shield on the antenna to prevent any stray, above-ground reflections or electrical interference from obscuring the data.

The survey vehicle was used to tow the antenna on the long survey lines along Track Street and South Track Street. For the north-south survey lines between 76ØS and 84ØS in Area Q, we also utilized the vehicle to tow the antenna over the ground. All of the other survey work was performed by hand-pulling the 120 MHz antenna over the ground.

A significant gain was made in survey efficiency by using a labor-saving device consisting of a knotted rope 12 meters long. At the center of the rope was a loop through which a chaining pin or other pointed device could be inserted into the ground at the proposed location for a boring. The knots in the rope were spaced at 2 meter intervals, and were painted with high-visibility paint. Using this rope made it unnecessary to lay out a steel tape to measure and mark the 2 meter intervals used for ground locations in the vicinity of the proposed boring. Also, by leaving the center pin in place, the 12-meter rope was quickly rotated 90 degrees on the ground to mark off the orthogonal survey line crossing the proposed location of the boring. Using this technique, we were able to inspect more than twice as many boreholes in a single day as had previously been the case with manually laying out the 2-meter ground locations with a steel tape.

With the exception of using the antenna shield and the knotted marker rope, the survey methods were the same as have been described in previous reports.

Area N'.

The area scanned by the radar between Track Street and South Track Street is shown in Figure 3. This area is surprisingly free of any radar evidence of past usage, and shows mostly undisturbed ground free from any type of contaminants. A few, highly localized concentrations of dark and medium dark radar reflectors are observed, but do not appear to have any significance (in contrast to the dark reflectors extending over significant portions of the site surveyed in Area N).

Borings - Area N.

The locations of the three boring locations in Area N that were inspected by radar are listed in Table II. The three sites were all satisfactory, and none of the borings were relocated.

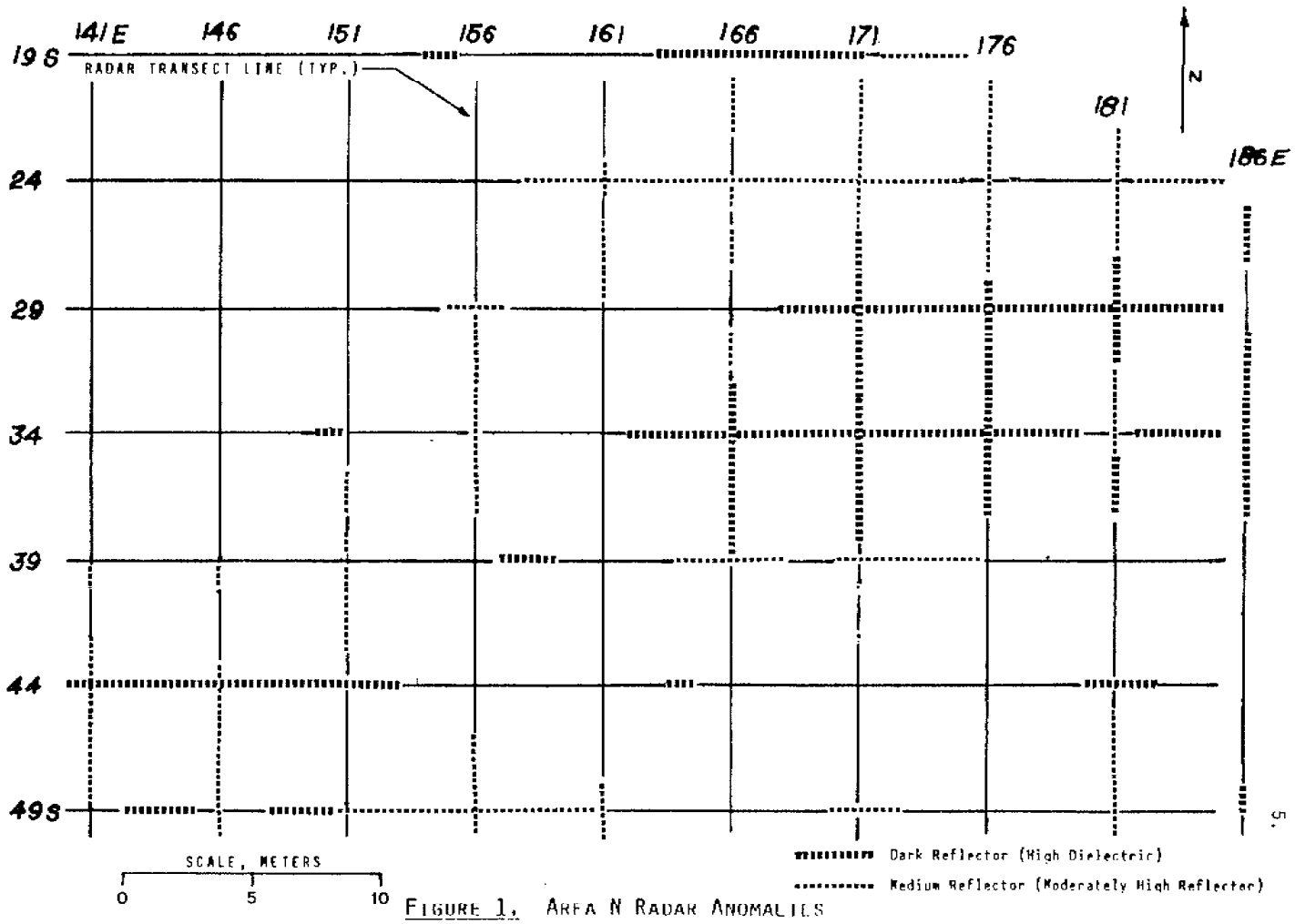


FIGURE 1. AREA N RADAR ANOMALIES

TABLE I

BORING LOCATIONS DETERMINED BY RADAR

AREA Q

| Boring Number | Direction of Relocation | Proposed Location | Final Location | Notes |
|---|---|---|---|---|
| Q1 | Move 2m North | 1502S, 103E | 1500S, 103E | N-S Pipe @ 107.5E |
| Q2 | - | 1504S, 112E | 1504S, 112E | |
| Q3 | Move 2m West | 1503S, 133E | 1503S, 131E | |
| Q4 | Move 2m North | 1501S, 22E | 1499S, 22E | E-W Pipe @ 1502E |
| Q5 | Move 3m North | 1507S, 25E | 1504S, 25E | |
| Q6 | - | 1503S, 31E | 1503S, 31E | |
| Q7 | - | Storage Yard† | Storage Yard† | Gravel area |
| Q8 | - | 1340S, 48E | 1340S, 48E | |
| Q9 | Move 3m East | 1266S, 176E | 1266S, 179E | N-S Pipe @ 175E |
| Q10 | - | 1222S, 155E | 1222S, 155E | |
| Q11 | Move 2m South | 1167S, 159E | 1169S, 159E | |
| Q12 | Move 1m West | 1080S, 28E | 1080S, 27E | |
| Q13 | - | 744S, 30E | 744S, 30E | |
| Q14 | Move 1m East | 334S, 20E | 334S, 21E | |
| Q15 | - | 569S, 200E | 569S, 200E | |
| Q16 | - | 544S, 440E | 44S, 440E | |
| Q17 | - | 320S, 526E | 320S, 526E | |
| Q18 | - | 330S, 760E | 330S, 760E | |
| Q19 | - | 805S, 175E | 805S, 175E | Dark anomaly zone |
| Q20 | Move 1m North | 805S, 170E | 804S, 170E | |
| Q21 | - | 805S, 165E | 805S, 165E | |
| Q22 | - | 820S, 175E | 820S, 175E | |
| Q23 | Move 2m South | 820S, 170E | 822S, 170E | |
| Q24 | Move 2m North | 820S, 165E | 818S, 165E | |

† Town of Lewiston Public Works storage yard; 26.2m south, 8.8m west of wooden light pole.

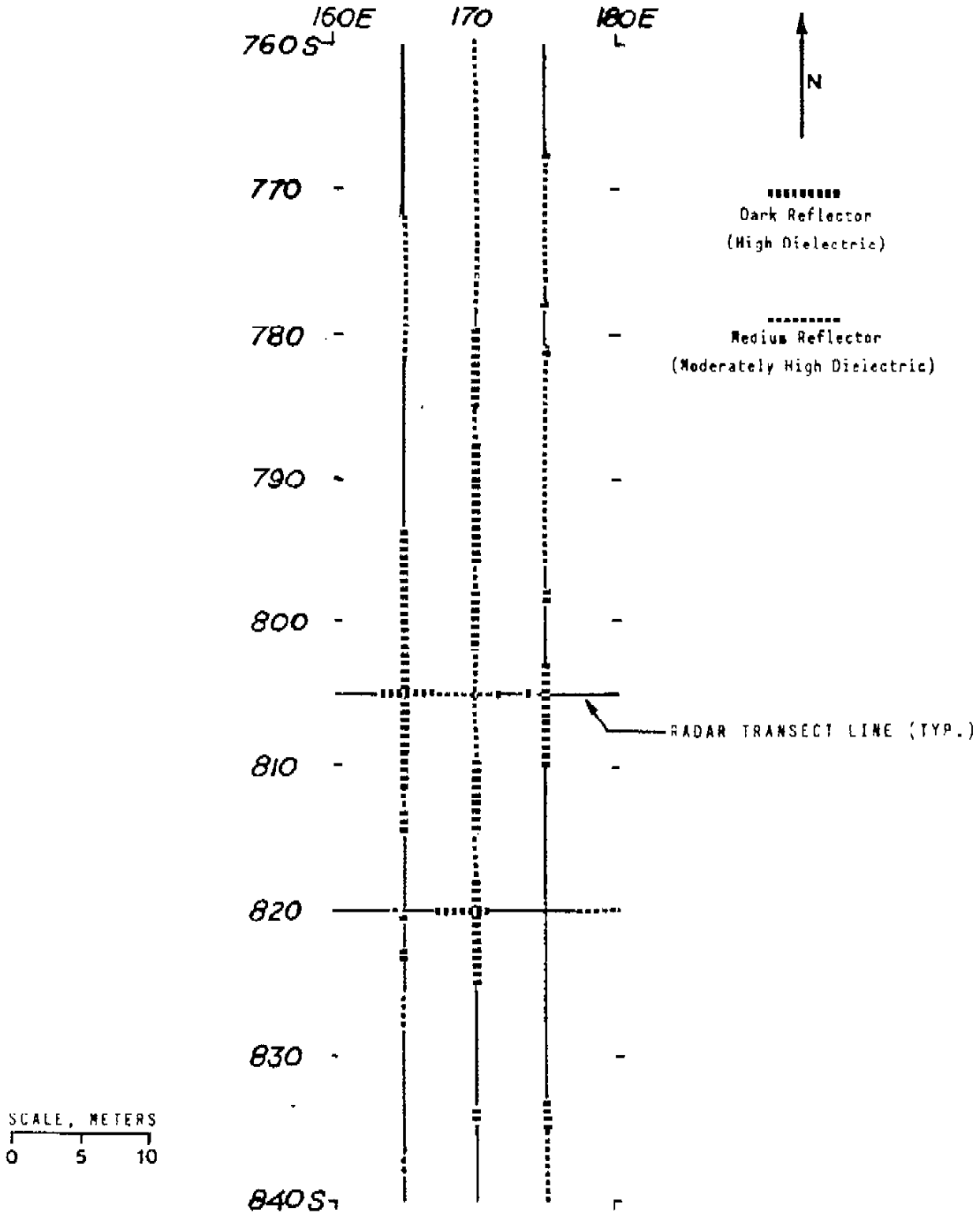


FIGURE 2. AREA Q RADAR ANOMALIES

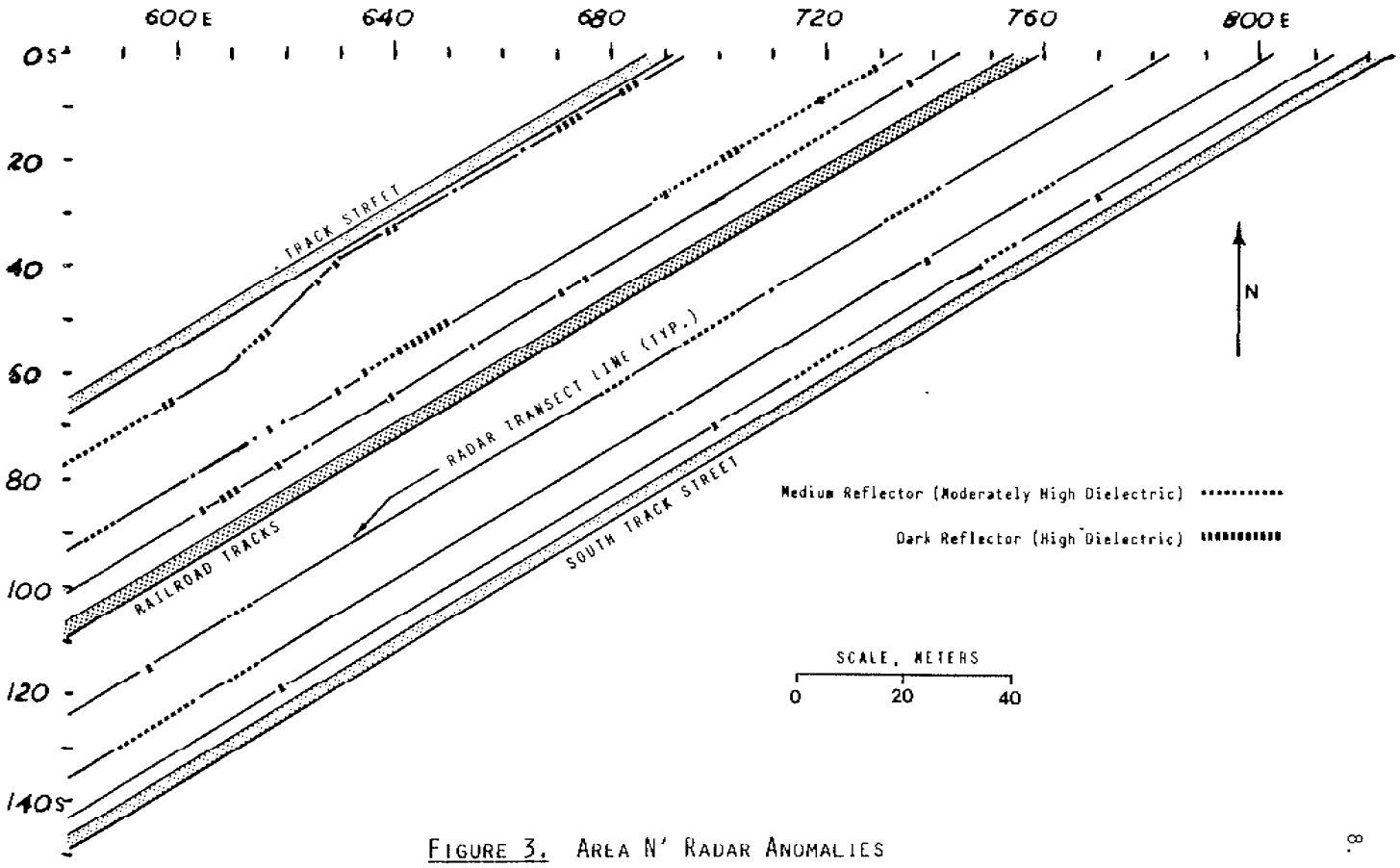


FIGURE 3. AREA N' RADAR ANOMALIES

TABLE II

BORING LOCATIONS DETERMINED BY RADAR

AREA N

| Boring Number | Direction of Relocation | Proposed Location | Final Location | Notes |
|---|---|---|---|---|
| N1 | - | 270S, 590E | 270S, 590E | |
| N2 | - | 40S, 102E | 40S, 102E | |
| N3 | - | 150S, 404E | 150S, 404E | |

# APPENDIX

Liquid Contaminants

Field Charts

## LIQUID CONTAMINANTS

The presence of liquid contaminants in the ground creates distinct radar signatures according to the electrical properties of the liquid. Ionic liquids are electrically active due to the ions having electrical charge. Examples of ionic liquids are acids and salts. The presence of an ionic liquid in the ground lowers the electrical resistance of the ground, an effect that is observed by the radar system as a lighter-than-normal contrast.

Non-ionic liquids in the ground also modify the electrical characteristics of the ground, but in a different way: non-ionic liquids increase the dielectric constant of the ground, an effect that is observable by the radar system as a darker-than-normal contrast.

Fresh water is a special case of a non-ionic liquid. For reasons explained in the following paragraphs, water is usually distinguishable from other non-ionic liquids in the ground.

### Ionic Liquids

As the radar signal travels into the ground, the energy is attenuated in proportion to the electrical conductivity of the ground. Normally, the ground has relatively high resistivity (the inverse of conductivity). The presence of electrically-active liquids will lower the electrical resistivity of the ground, resulting in more rapid loss of the radar signal. This shows in the radar record as an area of lighter-than-normal contrast. Experience with the radar system allows us to make close estimates of the resistivity values. In effect, the radar can be used as an imaging resistivity meter because of its extreme sensitivity to this parameter. Vertical and horizontal boundaries which only show as broad trend lines with conventional resistivity probes become sharply delineated on the radar record, thus allowing the boundaries of a contamination zone to be established with high accuracy.

### Non-ionic Liquids

Non-ionic liquids such as petroleum-based solvents, oils, or other non-electrically active substances do not alter the electrical conductivity. Instead, non-ionic liquids tend to increase the dielectric constant of the ground. Higher dielectric values affect the coefficient of reflection according to the following equation:

$$\rho = \frac{\sqrt{\epsilon_1} - \sqrt{\epsilon_2}}{\sqrt{\epsilon_1} + \sqrt{\epsilon_2}}$$

where $\rho$ - coefficient of reflection

$\epsilon_1$ = dielectric constant, layer 1

$\epsilon_2$ = dielectric constant, layer 2

Layer 1 is taken as the first layer through which the radar energy is passing, and layer 2 is the second layer. The reflection at the interface is dependent on the contrast, or relative difference, between the dielectric constants of the two layers.

When using this equation, it is convenient to use the relative dielectric constant normalized to air, which has a relative dielectric constant of unity. On this scale, various types of soils all have relative dielectric constants that are clustered in a narrow range between 3 and 5. (The numbers are dimensionless, being relative values.) These values are for dry conditions. The addition of moisture or other liquids greatly alters these values. For example, average moisture conditions in the ground result in a relative dielectric constant around 12. Wet, saturated ground can have relative dielectric values of 30 to 35. Peat, an extreme example of water-laden material, exhibits relative dielectric constants of 58 to 65. The addition of water can change the dielectric constant by more than an order of magnitude. The variability among soil types is less than a factor of two. Thus, the radar reflections, which depend on the contrast, or difference, between reflecting layers, is very sensitive to the presence of water.

A similar situation holds true for other liquids whose presence in the ground modify the dielectric constants. The difference between water and other liquids is the ease with which water disperses in the ground compared to oily or more viscous liquids. Also, the moisture content of the ground tends to reach steady-state, equilibrium conditions a foot or two below the surface. What this does is to create a general moisture "background" that tends to be constant over extended areas as well a exhibiting a constant vertical profile beginning near the surface.

Localized wet spots produce a greater contrast in the radar record, and are often observable at the surface as a low spot in the ground. What is important is that the wet spot retains its structural integrity on the radar record. Wet glacial till still looks like ordinary glacial till, soil horizons observed outside a wet area are still preserved in the wet area, etc. In the case of oil, sludge, and liquid industrial waste, the structural appearance of the ground is typically altered, because these materials do not disperse like water, and therefore tend to show localized alterations in the overall radar appearance of the ground. Another phenomenon is observed when liquids other than water are in the ground: the radar signal often resonates, or "rings", producing a series of identical waves on the radar record. This is most likely due to layering effects, where the depth of a liquid-laden layer produces a resonant cavity effect, resulting in multiple echoes from the same reflecting layer. Again, because of the dispersive nature of water, such resonant cavities are almost never observed in wet, saturated ground.

These observations may be summed as follows: wet areas increase the radar contrast, but do not alter the structural appearance of the ground. Other liquids which do not have the dispersive properties of water also increase the contrast, but tend to alter the structural appearance of the ground. Finally, the observation of resonant signatures is most often associated with liquids other than water, and is seldom observed when water alone is present.

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

# RADARVISION

TAPE NO.: 8245 LOCATION: LEWISTON NY AREA N' CLIENT: ORAU
DATE: 10/25/82

| RANGE ADJ | RANGE MULTIPLY X1 | X2 | X4 | RANGE GAIN | FILTER H | M | L | SENSITIVITY | SCAN SETTING 51.2 | 25.6 | 12.8 | 6.4 | 3.2 | SLOW | TAPE SPEED 15 | 3 3/4 | 15/16 | TAPE CHANNEL 1 | 2 | 4 | COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 350 | ▨ | | | 9 12.5 0 | | ▨ | | 250 | | | ▨ | | | | | ▨ | | ▨ | | | J147-82 |

| GRID NO. | GRID LINE | MARKER CODE | TAPE COUNT START | TAPE COUNT FINISH | FIRST MARK | LAST MARK | COMMENTS |
|---|---|---|---|---|---|---|---|
| | | | | | | | DEATH 12 FT. |
| 1 | 141E | —— | 000 | 0057 | 20S | 50S | TEST RUN DIRT PILES 40S TO 50S |
| 2 | 141E | 2#0 | 057 | 128 | 20S | 50S | NOTE DIRT PILES |
| 3 | 146E | 3#0 | 128 | 196 | 20S | 50S | DIRT PILES 40S TO 50S DITCH AT 36S |
| 4 | 151E | 4#0 | 196 | 285 | 20S | 50S | DITCH AT 29S DIRT PILE AT 43-50S |
| 5 | 156E | 5#0 | 285 | 352 | 20S | 50S | DIRT AT END DITCH AT 25S DARK AREA AT 35S COINCIDES WITH THE CLUSTER OF PIN FLAGS |
| 6 | 161E | 6#0 | 352 | 413 | 20S | 50S | NO SURFACE EVIDENCE OF ANOMALIES |
| 6 | 166E | 6#0 | 413 | 469 | 20S | 50S | NO SURFACE EVIDENCE OF ANOMALIES |
| 8 | 171E | 8#0 | 469 | 530 | 20S | 50S | SURFACE TRASH EVIDENT IN DARK AREA TO 36S |
| 9 | 176E | 2#0 | 530 | 584 | 20S | 50S | " " " |
| 10 | 181E | 3#0 | 584 | 638 | 20S | 50S | START 22S |
| 11 | 186E | 4#0 | 638 | 689 | 25S | 50S | SURFACE TRASH IN DARK AREA |
| 12 | 195 | 5#0 | 689 | 746 | 175E | 190E | START 175E DITCH 156E |
| 13 | 245 | 6#0 | 746 | 807 | 185E | 190E | DITCH 154E |
| 14 | 295 | 7#0 | 807 | 869 | 185E | 140E | HEAVY RADAR REFLECTOR AT PIN FLAGS |

FIELD LOGS

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

# RADARVISION

TAPE NO.: 8245 LOCATION: LEWISTON, NY CLIENT: ORAU
DATE: 10/25/82 AREA N'

| RANGE ADJ | RANGE MULTIPLY X1 | X2 | X4 | RANGE GAIN | FILTER H | M | L | SENSITIVITY | SCAN SETTING 51.2 | 25.6 | 12.8 | 6.4 | 3.2 | SLOW | TAPE SPEED 15 | 3 3/4 | 15/16 | TAPE CHANNEL 1 | 2 | 4 | COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 350 | | | | 9.0 | | | | 250 | | | | | | | | | | | | | J147-82 |

| GRID NO. | GRID LINE | MARKER CODE | TAPE COUNT START | TAPE COUNT FINISH | FIRST MARK | LAST MARK | COMMENTS |
|---|---|---|---|---|---|---|---|
| 15 | 345 | 8#0 | 869 | 924 | 185E | 140E | SURFACE TRASH EVIDENT AT BEGINNING CLUSTER OF PIN FLAGS IN DARK AREA 154E |
| 16 | 395 | 2#0 | 924 | 976 | 185E | 140E | |
| 17 | 445 | 3#0 | 976 | 1033 | 185E | 140E | DIRT PILE AT 145E - 140E |
| 18 | 495 | 4#0 | 1033 | 1089 | 185E | 140E | DIRT PILE AT END |
| | | | | | | | 1340S, 48E |

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# RADARVISION

TAPE NO.: 8245 LOCATION: LEWISTON, NY CLIENT: ORAU
DATE: 10/26/82 AREA Q

| RANGE ADJ | RANGE MULTIPLY X1 | X2 | X4 | RANGE GAIN | FILTER H | M | L | SENSITIVITY | SCAN SETTING 51.2 | 25.6 | 12.8 | 6.4 | 3.2 | SLOW | TAPE SPEED 15 | 3 3/4 | 15/16 | TAPE CHANNEL 1 | 2 | 4 | COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 350 | | | | 9.5 12 | | | | 250 | | | | | | | | | | | | | J147-82 |

| GRID NO. | GRID LINE | MARKER CODE | TAPE COUNT START | TAPE COUNT FINISH | FIRST MARK | LAST MARK | COMMENTS |
|---|---|---|---|---|---|---|---|
| | | | | | | | SYSTEMATIC BOREHOLES |
| 19 | As | 3#0 | 1089 | 1130 | -6m | +6m | N→S 1502S, 103E / every 2m |
| 20 | As | 2#0 | 1130 | 1163 | -6m | +6m | W→E " " 2 @ BOREHOLE |
| 21 | Bs | 3#0 | 1163 | 1197 | -6m | +6m | N→S 1504S, 112E |
| 22 | Bs | 4#0 | 1197 | 1229 | -6m | +6m | W→E " " |
| 23 | Cs | 5#0 | 1229 | 1261 | -6M | +6M | N→S 1503S, 133E |
| 24 | Cs | 6#0 | 1261 | 1291 | -6M | +6M | W→E " " |
| 25 | As | 7#0 | 1291 | 1329 | -6M | +6M | N→S 1501S, 22E |
| 26 | As | 8#0 | 1329 | 1359 | -6M | +6M | W→E " " |
| 27 | Bs | 4#0 | 1359 | 1389 | -6M | +6M | N→S 1507S, 25E |
| 28 | Bs | 2#0 | 1389 | 1420 | -6M | +6M | W→E " " |
| 29 | Cs | 3#0 | 1420 | 1455 | -6M | +6M | N→S 1503S, 31E |
| 30 | Cs | 4#0 | 1455 | 1493 | -6M | +6M | W→E " " |
| 31 | Q7 | 5#0 | 1493 | 1526 | -6m | +6m | N→S 26.2 METERS S OF WILDDOG LIGHT POLE |
| 32 | Q7 | 6#0 | 1526 | | -6m | +6m | W→E 8.8 " W " " |

FIELD LOGS

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# RADARVISION

TAPE NO.: 8245 LOCATION: LEWISTON, NY CLIENT: ORAU
DATE: 10/26/82 AREA Q

| RANGE ADJ | RANGE MULTIPLY X1 | X2 | X4 | RANGE GAIN | FILTER H | M | L | SENSITIVITY | SCAN SETTING 51.2 | 25.6 | 12.8 | 6.4 | 3.2 | SLOW | TAPE SPEED 15 | 3 3/4 | 15/16 | TAPE CHANNEL 1 | 2 | 4 | COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 350 | | | | 9 : 12 0 | | | | 250 | | | | | | | | | | | | | J147-82 |

| GRID NO. | GRID LINE | MARKER CODE | TAPE COUNT START | TAPE COUNT FINISH | FIRST MARK | LAST MARK | COMMENTS |
|---|---|---|---|---|---|---|---|
| | | | | | | | SYSTEMATIC BOREHOLES |
| 33 | Q8 | 7#0 | 1556 | 1585 | -6M | +6M | N→S Q8 @ 13405, 48E (UNDISTURBED EARTH) |
| 34 | Q8 | 8#0 | 1585 | 1612 | -6M | +6M | W→E Q8 " " (BELOW FLOW BOND) |
| | | | | | | | CHANNEL 2 |
| 35 | Q9 | — | 000 | 071 | -6M | +6M | N→S Q9 12665, 176E (PIPE RUNS N-S @ 12675) |
| 36 | Q9 | 2#0 | 071 | 135 | -6M | +6M | W→E Q9 " " |
| 37 | Q10 | 3#0 | 135 | 250 | -6M | +6M | N→S Q10 12225, 155E |
| 38 | Q10 | 4#0 | 250 | 309 | -6M | +6M | W→E Q10 " " |
| 39 | Q11 | 5#0 | 309 | 368 | -6M | +6M | N→S Q11 11675, 159E |
| 40 | Q11 | 6#0 | 368 | 424 | -6M | +6M | W→E Q11 " " |
| 41 | Q12 | 7#0 | 424 | 475 | -6M | +6M | N→S Q12 10805, 28E |
| 42 | Q12 | 8#0 | 475 | 525 | -6M | +6M | W→E Q12 " " |
| 43 | Q13 | 2#0 | 525 | 573 | -6M | +6M | N→S Q13 7445, 30E |
| 44 | Q13 | 3#0 | 573 | 619 | -6M | +6M | W→E Q13 " " |

FIELD LOGS

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(617) 369-7999

# RADARVISION

TAPE NO.: 8245 LOCATION: LEWISTON, NY CLIENT: ORAU
DATE: 10/26/82 AREA Q

| RANGE ADJ | RANGE MULTIPLY X1 | X2 | X4 | RANGE GAIN | FILTER H | M | L | SENSITIVITY | SCAN SETTING 51.2 | 25.6 | 12.8 | 6.4 | 3.2 | SLOW | TAPE SPEED 15 | 3 3/4 | 15/16 | TAPE CHANNEL 1 | 2 | 4 | COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 350 | | | | 9 12 | | | | 250 | | | | | | | | | | | | | J147-82 |

| GRID NO. | GRID LINE | MARKER CODE | TAPE COUNT START | TAPE COUNT FINISH | FIRST MARK | LAST MARK | COMMENTS |
|---|---|---|---|---|---|---|---|
| 45 | Q14 | 1#0 | 619 | 676 | -6M | +6M | N→S Q14 3345, 20E |
| 46 | Q14 | 5#0 | 676 | 724 | -6M | +6M | W→E Q14 " " |
| 47 | Q15 | 6#0 | 724 | 781 | -6M | +6M | N→S Q15 5695, 200E |
| 48 | Q15 | 7#0 | 781 | 827 | -6M | +6M | W→E Q15 " " |
| 49 | Q16 | 8#0 | 827 | 870 | -6M | +6M | N→S Q16 5445 440E |
| 50 | Q16 | 3#0 | 870 | 908 | -6M | +6M | W→E Q16 " " |
| 51 | Q17 | 2#0 | 908 | 939 | -4M | +6M | N→S Q17 3205, 526E |
| 52 | Q17 | 3#0 | 939 | 969 | -4M | +6M | W→E Q17 " " BRUSH PILE AT BEGINNING |
| 53 | Q18 | 4#0 | 969 | 1005 | -6M | +6M | N→S Q18 3305 760E |
| 54 | Q18 | 5#0 | 1005 | 1041 | -6M | +6M | W→E Q18 " " |
| | | | | | | | |
| | | | | | | | |
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| | | | | | | | |

FIELD LOGS

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# RADARVISION

TAPE NO.: 8245 LOCATION: LEWISTON, NY CLIENT: ORAU
DATE: 10/27/82 AREA Q

| RANGE ADJ | RANGE MULTIPLY X1 | X2 | X4 | RANGE GAIN | FILTER H | M | L | SENSITIVITY | SCAN SETTING 51.2 | 25.6 | 12.8 | 6.4 | 3.2 | SLOW | TAPE SPEED 15 | 3¾ | 15/16 | TAPE CHANNEL 1 | 2 | 4 | COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 356 | | | | ? 12 0 | | | | 250 | | | | | | | | | | | | | J147-82 |

| GRID NO. | GRID LINE | MARKER CODE | TAPE COUNT START | TAPE COUNT FINISH | FIRST MARK | LAST MARK | COMMENTS |
|---|---|---|---|---|---|---|---|
| 55 | 805S | 6 #0 | 1041 | 1090 | 160E | 180E | W→E 12.8 IPS |
| 56 | 820S | 7#0 | 1090 | 1135 | 160E | 180E | W→E 12.8 IPS |
| 57 | 165E | 8#0 | 1135 | 1283 | 760S | 840S | N→S 1 EVERY 5M; 2 AT BORINGS 15 IPS |
| 58 | 175E | 4#0 | 1283 | 1401 | 760S | 840S | N→S " " " |
| 59 | 170E | 2#0 | 1401 | 1529 | 760S | 840S | " " " " |
| | | | | | | | HOT SPOT CLUSTER @ 770S, 170E |
| | | | | | | | " " " 780S→810S LINE 1700 |
| | | | | | | | CHANNEL 4 |
| | | | | | | | AREA N' TRACK ST. |
| 60 | | — | 000 | 600 | 580E | 820E | SW→NE 3M NW OF RD ℄ 1 MARK EVERY 10M |
| 61 | | 2 #1 | 600 | 985 | " | " | " 14M NW OF RD ℄ (AT ANGLE) |
| 62 | | 3#1 | 985 | 1279 | " | " | 10M SE OF RR ℄ |

FIELD LOGS

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# RADARVISION

TAPE NO.: 8246 LOCATION: LEWISTON, NY CLIENT: ORAU
DATE: 10/29/82 AREA N'

| RANGE ADJ | RANGE MULTIPLY X1 | X2 | X4 | RANGE GAIN | FILTER H | M | L | SENSITIVITY | SCAN SETTING 51.2 | 25.6 | 12.8 | 6.4 | 3.2 | SLOW | TAPE SPEED 15 | 3 3/4 | 15/16 | TAPE CHANNEL 1 | 2 | 4 | COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 350 | | | | 9 12 | | | | 250 | | | | | | | | | | | | | J147-82 |

| GRID NO. | GRID LINE | MARKER CODE | TAPE COUNT START | TAPE COUNT FINISH | FIRST MARK | LAST MARK | COMMENTS |
|---|---|---|---|---|---|---|---|
| 63 | | 2#0 | 1140 | 1340 | 580E | ON | SW→NE 6M NW OF R.R. ℄ 1 MARK EVERY 10m (ON ANGLE) |
| 64 | | 3#0 | 1340 | 1490 | 580E | ON | REPEAT #63 (WHEEL JAMMED) |
| | | | | | | | |
| | | | | | | | CHANNEL 4 |
| | | - | 000 | 090 | 580E | | SW→NE 12M NW OF R.R. ℄ [ABORT] |
| 65 | | 2#0 | 090 | 436 | 580E | TYOME ON SLOW | " " " " " " " |
| 66 | | 3#0 | 436 | 699 | 580E | | SW→NE 9M SE OF ROAD ℄, THEN DIAGONAL |
| | | | | | | | @605, 610E (ON SE SIDE) TO 503, 620E TO 403, 630E, |
| | | | | | | | THEN PARALLEL TO ROAD, 2M SE OF ROAD ℄ |
| | | | | | | | |
| | | | | | | | |
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| | | | | | | | |
| | | | | | | | |

FIELD LOGS

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# RADARVISION

TAPE NO.: 8246 LOCATION: LEWISTON NY CLIENT: USAU
DATE: 11/1/82 AREA N & N'

| RANGE ADJ | RANGE MULTIPLY X1 | X2 | X4 | RANGE GAIN | FILTER H | M | L | SENSITIVITY | SCAN SETTING 51.2 | 25.6 | 12.8 | 6.4 | 3.2 | SLOW | TAPE SPEED 15 | 3 3/4 | 15/16 | TAPE CHANNEL 1 | 2 | 4 | COMMENTS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 350 | | | | ? 1/0 | | | | 250 | | | | | | | | | | | | | J147-82 |

| GRID NO. | GRID LINE | MARKER CODE | TAPE COUNT START | TAPE COUNT FINISH | FIRST MARK | LAST MARK | COMMENTS |
|---|---|---|---|---|---|---|---|
| 67 | N1 | 4 #0 | 650 | 688 | -6 | +6 | N→S 1 @ 2M, 2 @ 600MHz 590E, 270S |
| 68 | N1 | 5 #0 | 688 | 726 | -4 | +6 | W→E " " " |
| 69 | N2 | 6 #0 | 726 | 765 | -6 | +6 | N→S " " 40S, 10ZE |
| 70 | N2 | 7#0 | 765 | 808 | -6 | +6 | W→E " " " |
| 71 | N3 | 8#0 | 808 | 844 | -6 | +6 | N→S " " 150S, 40ZE |
| 72 | N3 | 2#0 | 844 | 881 | -6 | +6 | W→E " " " |
| 73 | | 3#0 | 881 | 930 | | | SE→NW HOT SPOTS 1@2M, 2@HOT SPOT |
| | | | 600 MHZ ANTENNA | | | | TRAVELED FROM 40S, 60E TO 30S, 67OE |
| 74 | | 4#0 | 930 | 956 | 580E 77S | 590E 66S | SE→NW HOT SPOT 2@ HOT SPOT |
| | | | INDICATES | | SIGHT LINE | | TRAVELED 8M TOTAL 1@2M HOT SPOTS AT 2&4M |

FIELD LOGS

# APPENDIX D

## EVALUATION OF RADIATION EXPOSURES ON OFF-SITE PROPERTY N/N' SOUTH NIAGARA FALLS STORAGE SITE LEWISTON, NEW YORK

APPENDIX D

Evaluation of Radiation Exposures
on Off-Site Property N/N' South
Niagara Falls Storage Site
Lewiston, New York

## INTRODUCTION

The U.S. Department of Energy has completed a radiological survey and determined that portions of the Department of Labor property, Lewiston, New York, are contaminated with low-level radioactive residues resulting from previous uses of this property. This property was part of the former Lake Ontario Ordnance Works, now known as the Niagara Falls Storage Site (NFSS) and associated off-site properties, where radioactive wastes from Manhattan Engineer District and Atomic Energy Commission operations were handled and stored. These wastes were primarily residues from uranium processing operations. However, they also included contaminated rubble and scrap from decommissioned facilities, 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) in Schenectady, New York. Receipt of additional wastes was discontinued at the site in 1954. Although some storage of radioactive materials on the Niagara Falls Storage Site continues under the control of the Department of Energy, work involving handling of radioactive waste has not been performed on the off-site properties for approximately 25 years.

In 1954 a preliminary cleanup of the site was performed by Hooker Chemical Company. Approximately 1298 acres of the original 1511 acre site were then declared excess and eventually sold by the General Services Administration to various private, commercial, and governmental agencies. The Department of Labor is the current owner of a 76.6 acre tract, identified as off-site property N/N' South. This property is not occupied or in use.

The property was surveyed by Oak Ridge Associated Universities, Oak Ridge, Tennessee, during October and November 1982, and March 1983, and found to contain radioactive contamination. The survey indicated radionuclides from the naturally occurring uranium and actinium decay series and small quantities of Cs-137.

Cesium-137 is a man-made radionuclide created through the fission process such as in a nuclear reactor. Cesium-137 has a half-life* of approximately 30 years and emits beta and gamma radiation. The naturally occurring decay series, known as the uranium and actinium series, are believed to have been created when the earth was formed, and they are still present today because of their very long half-lives. These series are presented in Tables D-1 and D-2.

As a radionuclide decays it changes into another substance. In the case of U-238, for example, the decay produces Th-234. Thorium-234 is called the "daughter" of U-238, U-238 is the "parent" of Th-234. In turn, Th-234 is the "parent" of Pa-234. Radioactive decay started by U-238, U-235, or Th-232 continues as shown in the tables until a stable nuclide is formed.

The radionuclides in these decay series are present in small quantities throughout the environment. Concentrations of them normally occur in soil, air, water, food, etc., and are referred to as background concentrations. Radiation exposures resulting from this environmental radioactivity are referred to as background exposures. These background exposures are not caused by any human activity, and to a large extent, can be controlled only through man's moving to areas with lower background exposures. Each and every human receives some background exposure daily.

The use of radioactive materials for scientific, industrial, or medical purposes may cause radiation exposures above the background level to be received by workers in the industry, and to a lesser extent, by members of the general public. Scientifically based guidelines have been developed to place an upper limit on these additional exposures. Limits established for exposures to the general public are much lower than the limits established for workers in the nuclear industry.

## RADIATION LEVELS ON PROPERTY N/N' SOUTH

The survey identified elevated levels of direct radiation and contamination of the soil above the normal background levels. The major radionuclides noted in these soils are Ra-226, U-238, and Cs-137. Increased levels of radioactivity

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* *The half-life is the time required for half of the atoms of a radioactive substance to disintegrate ("decay" or transform).*

resulting from contaminated residues on this property can cause an increased radiation exposure to persons. The exposure potentially comes from one primary source or pathway: direct radiation emitted by the radionuclides in the residue or soil. Additional exposures may also be received through inhalation of suspended airborne particulates and radon gas and its daughter products* and ingestion of contaminated food or water. In Table D-3 the exposure levels associated with this property are summarized and compared with the guidelines and background levels.

External Radiation Exposure Levels

As Tables D-1 and D-2 indicate, several members of the naturally occurring decay series emit gamma radiation as does Cs-137. (Gamma rays are penetrating radiation like x-rays.) Contaminated areas can, therefore, be sources of external gamma radiation exposure.

The National Council on Radiation Protection and Measurements has recommended maximum annual whole-body exposure of 500,000 microroentgens** per year to an individual exposed in the general population. This is equivalent to a continuous level of approximately 57 microroentgens per hour. The maximum exposure level noted on this property was 550 microroentgens per hour. This level was present only at contact with one small isolated area of contaminated surface soil. The average exposure rate of 12 microroentgens per hour at about 3 feet above the surface is a better estimate of the average exposure an individual might receive. For comparison, the average background level in the Lewiston area is about 8 microroentgens per hour, and continuous exposure at this level would produce an annual exposure of about 69,800 microroentgens. Also, a typical chest x-ray (according to data from the Department of Health and Human Services) might yield an exposure of about 27,000 microroentgens.

The soil is contaminated with radium and lesser levels of uranium and cesium which emit beta and gamma radiations. Nuclear Regulatory Commission (NRC) guidelines for decommissioning former nuclear facilities require that the dose

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* *Radon-222 is a gas that results from the decay of radium-226, a member of the naturally occurring uranium series (see Table D-1).*

** *The Roentgen is the unit of exposure to X- or gamma radiation. A microroentgen is one-millionth of a Roentgen.*

rate (from beta and gamma radiation) measured at a distance of one centimeter above the surface does not exceed 1.0 millirad* per hour and 0.2 millirad per hour average. The maximum dose rate measured at this site was 3.8 millirad per hour and the average was 0.08 millirad per hour. Although the maximum level exceeds NRC guidelines, the primary concern of this guideline is exposure of skin surface. The thickness of ordinary shoe soles is adequate to protect the skin of feet from beta radiation. In most cases, exposures are negligible at a distance of 1 ft away from the surface and areas of body skin are adequately protected from these exposures if they remain away from these surfaces. Beta radiation from surface residues are therefore not a significant factor in evaluating the potential health effects at this site.

Exposure from Inhalation of Airborne Radioactive Particulates

A very small amount of the radioactive contamination on this property may become airborne by resuspension of particulates from the surface layer of soil. The actual fraction of material that becomes resuspended is dependent on a number of factors including surface conditions (e.g. damp, dry, covered by ground vegetation, etc.), particle size, activities on the site which disturb the surface soil, and micrometeorological conditions (e.g. surface wind speed and direction). Determining average levels of airborne radionuclides requires air sampling over an extended time period and was beyond the scope of the ORAU survey. However, an estimate of the potential airborne concentrations can be made based on the average concentration of radioactive material in the surface soil and using standard computation procedures of the Nuclear Regulatory Commission.

Areas of significantly higher surface contamination levels are isolated and small (usually less than 6 inches in diameter). The average surface soil concentration for property N/N' South is therefore best approximated by the samples collected at the grid line interactions. Radium-226 is the major radionuclide of concern on this site and the average concentration in surface soil is 1.34 picocuries** per gram or about 0.64 picocuries per gram above the level normally present in surface soils in the Lewiston area. The resulting

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* *The rad is the unit of beta-gamma dose. A millirad is one-thousandth of a rad.*

** *The curie is the unit indicating the quantity of a radioactive substance. A picocurie is one-millionth-millionth of a curie.*

concentration of resuspended Ra-226, based on a resuspension factor of $5 \times 10^{-9}$ per meter, would be about $1 \times 10^{-16}$ microcuries per cubic centimeters of air. For comparison, the Nuclear Regulatory Commission's guideline level for continuous exposure of the general public is $2 \times 10^{-12}$ microcuries per cubic centimeter. The estimated concentration of airborne Ra-226 is almost a factor of 20,000 less than the guidance level and would therefore not result in a significant increase in radiation exposure to individuals on this property.

Exposure From Inhalation of Radon in Air

The deposits of radium bearing residues in soil may be indirect sources of radiation exposure on site. As shown in Table D-1, Ra-226 changes to Rn-222 as a result of radioactive decay. Radon-222 is an inert gas which can emanate from the ground and, with its daughter products, result in lung exposures. Radon levels in the vicinity of the NFSS are continuously monitored by Department of Energy contractors. Sampling near property N/N' South indicted an average radon concentration of approximately 0.4 picocuries per liter of air from January 1981 through June 1981*. The guideline for continuous exposure of the general public is 3 picocuries per liter. For comparison the average area background level in the Lewiston area during 1979 and 1980 was 0.23 picocuries per liter. This source is not considered significant.

Other Exposure Considerations

Loose radioactive contamination can result in exposure through ingestion (eating or drinking) of contaminated foodstuffs. This site is not used for raising crops and average radionuclide concentrations in the ground water at this site are within the EPA drinking water limits. These pathways would not, therefore, result in significant exposures.

## ESTIMATES OF HEALTH EFFECTS

The primary health effect associated with radiation exposure is an increased risk of cancer. In general, the risk is assumed to increase as the total dose of radiation increases. Total dose is dependent not only on exposure rate and

* *Data from National Lead Co. of Ohio, Review of Radon Monitoring at the Niagara Falls Storage Site, Cincinnati, OH, March 31, 1980.*

concentration levels on the property, but also on the nature and duration of the exposure. In addition, a given individual's increased risk is dependent upon many factors including the individual's age at onset of exposure, variability in latency period (time between exposure and physical evidence of disease), the individual's personal habits and state of health, previous or concurrent exposure to other hazardous agents, and the individual's family medical history. Because of these variables, large uncertainties would exist in any estimates of the number of increased cancers in a relatively small exposed population such as might be the situation on this site. Estimates of the increased risks have been calculated and are given in Table D-4. Assumptions made in performing these calculations are:

1. The levels reported in Table D-3 are representative of the conditions and will not change during the year or from year to year.

2. Averge exposure levels in Table D-3 are representative of the averages to which an individual working on the property might be exposed.

3. An individual would spend a working lifetime, i.e. 40 hours per week, 50 weeks per year, for 45 years (age 20 to 65) on the site.

4. Background exposure rates to individuals while not on the property will be 8 microroentgens per hour from external gamma radiation.

The risk estimates are based on the 1980 National Academy of Sciences report, "The Effects on Populations of Exposure to Low Levels of Ionizing Radiation," and the 1977 report by the United States Scientific Committee on Effects of Atomic Radiation. The lifetime risk estimate used to calculate the values in Table D-4 is 100 cancer deaths per million persons exposed per rem of radiation exposure. It is believed by many radiation biologists that with low dose rates such as those encountered at this property, the actual risks of cancer are much less than 100 per million persons per rem, zero not being excluded.

The Ra-226 and radon air concentrations estimated or measured for this property are a small fraction of the guidance level and exposures and risk from these pathways would be negligible. In addition, exposures and risk from the pathways of ingestion of crops grown on contaminated soils and water containing

radionuclides from the soil are also considered negligible, based on the low-levels and use of this property. Exposures and risk are therefore limited to one pathway — direct exposure to gamma radiation.

The estimated increased risk due to cancer from exposure to the average radiation levels on property N/N' South, for a working lifetime is 0.036 per 1000 deaths. This can be compared with the average lifetime risks of cancer in Niagara County of 218 per 1000 deaths based on 1977 crude death rate statistics for this same year. The average lifetime risks of cancer in the State of New York and the United States are 216 per 1000 deaths and 203 per 1000 deaths, respectively. An individual working under the assumed conditions will therefore be subject to an increased risk of dying from cancer of 0.0036 percent or an increase in total risk from 21.8 to 21.8036 percent when compared to the average risk in Niagara County. This may also be expressed as a percent increase in overall risk of getting a fatal cancer of 0.0165 percent - a negligible increase.

## SUMMARY

In summary, portions of Niagara Falls Storage Site off-site property N/N' South are contaminated with low-level residues containing Cs-137 and naturally occurring radionuclides. The level of Ra-226 contamination in the surface soil in some areas of the property exceeds the present criterion for release of this property for unrestricted use. Although under current conditions of property use this contamination is capable of producing slight radiation exposures to persons on the property, these exposures are well within the scientifically based guidelines and risks to such persons are negligible.

TABLE D-1

URANIUM DECAY SERIES

| Parent | Half-Life | Major Decay Products | Daughter |
|---|---|---|---|
| Uranium-238 | 4.5 billion years | alpha | Thorium-234 |
| Thorium-234 | 24 days | beta, gamma | Protactinium-234 |
| Protactinium-234 | 1.2 minutes | beta, gamma | Uranium-234 |
| Uranium-234 | 250,000 years | alpha | Thorium-230 |
| Thorium-230 | 80,000 years | alpha | Radium-226 |
| Radium-226 | 1,600 years | alpha | Radon-222 |
| Radon-222 | 3.8 days | alpha | Polonium-218 |
| Polonium-218 | 3 minutes | alpha | Lead-214 |
| Lead-214 | 27 minutes | beta, gamma | Bismuth-214 |
| Bismuth-214 | 20 minutes | beta, gamma | Polonium-214 |
| Polonium-214 | .0002 seconds | alpha | Lead-210 |
| Lead-210 | 22 years | beta | Bismuth-210 |
| Bismuth-210 | 5 days | beta | Polonium-210 |
| Polonium-210 | 140 days | alpha | Lead-206 |
| Lead-206 | stable | none | none |

TABLE D-2

ACTINIUM DECAY SERIES

| Parent | Half-Life | Decay Products | Daughter |
|---|---|---|---|
| Uranium-235 | 710 million years | alpha | Thorium-231 |
| Thorium-231 | 25.5 hours | beta | Protactinium-231 |
| Protactinium-231 | 32,000 years | alpha | Actinium-227 |
| Actinium-227 | 21.6 years | beta, gamma | Thorium-227 |
| Thorium-227 | 18.2 days | alpha | Radium-223 |
| Radium-223 | 11.4 days | alpha | Radon-219 |
| Radon-219 | 4.0 seconds | alpha | Polonium-215 |
| Polonium-215 | .0018 seconds | alpha | Lead-211 |
| Lead-211 | 36.1 minutes | beta, gamma | Bismuth-211 |
| Bismuth-211 | 2.15 minutes | alpha | Thallium-207 |
| Thallium-207 | 4.79 minutes | beta | Lead-207 |

TABLE D-3

SUMMARY OF EXPOSURE LEVELS ON PROPERTY N/N' SOUTH
LEWISTON, NEW YORK

| Exposure Source | Levels on Site | | Background Levels | Guidelines for General Public | Guidelines for Radiation Workers |
|---|---|---|---|---|---|
| | Average | Maximum | | | |
| Gamma Radiation from Cesium-137 and uranium and actinium decay | 12 μR/h[a] | 550μR/h | 8 μR/h | 0.5 rem[b] per year for individual, equivalent to 250 μR/h above natural background for 40 h/wk and continuous exposure. | 5 rems per year |
| Radionuclides (Radium-226) in air | $1 \times 10^{-16}$ μCi/cc[c] | --- | unknown | $2 \times 10^{-12}$ μCi/cc for continuous (168 h/wk) exposure | $5 \times 10^{-11}$ μCi/cc for 40 h/wk exposure |
| Radon in air | 0.4 pCi/l | --- | 0.23 pCi/l (1979 & 1980 avg.) | 3 pCi/l | 30 pCi/l for 40 h/wk exposure |
| Radionuclides (gross alpha concentration) in Ground Water | 5.9 pCi/l | 13.9 pCi/l | Appr. 0.8 pCi/l | 15 pCi/l, EPA Standard for Public Drinking Water Systems | 400 pCi/l |
| Radionuclides in Soil:[d] | | | | | |
| Radium-126 | 1.3 pCi/g | 431 pCi/g | Appr. 0.7 pCi/g | EPA Mill Tailings (Criteria is 5 pCi/g above background averaged over 100 m2 of surface soil.) | none |
| Cesium-137 | 0.5 pCi/g | 6.5 pCi/g | Appr. 0.5 pCi/g | 80 pCi/g above background (Criteria developed by Los Alamos sci. Lab. for cleanup at sites contaminated by fission product residues. | none |

TABLE D-3, cont.

SUMMARY OF EXPOSURE LEVELS ON PROPERTY N/N' SOUTH
LEWISTON, NEW YORK

| Exposure Source | Levels on Site | | Background Levels | Guidelines for General Public | Guidelines for Radiation Workers |
|---|---|---|---|---|---|
| | Average | Maximum | | | |
| Uranium-238 | 4.4 pCi/g | 125 pCi/g | Appr. 3.3 pCi/g | 40 pCi/g Interim Soil Limits for D & D Projects, LA-UR-79-1865-Rev, J.W. Healy, et al. | none |
| Uranium-235 | 0.3 pCi/g | 9.1 pCi/g | Appr. 0.2 pCi/g | 30 pCi/g (U enriched in U-235) NRC Branch Technical Paper (Federal Register, October 23, 1981) | none |

[a] The Roentgen (R) is a unit which was defined for radiation protection purposes for people exposed to penetrating gamma radiation. A microroentgen (μR) is one millionth of a Roentgen.

[b] The rem is the unit of ionizing radiation that produces the same biological damage in man as an absorbed dose of 1 roentgen of high voltage x-ray. A roentgen of gamma exposure to a man is equivalent to one rem.

[c] The microcurie (μCi) and picocurie (pCi) are units which are defined for expressing the amount of radioactivity present in a substance. 1 μCi = $10^{-6}$ Ci, 1 pCi = $10^{-12}$ Ci.

[d] For soil concentrations, only the systematically collected soils were used in determining the average level.

TABLE D-4

SUMMARY OF WORKING LIFETIME RADIATION
EXPOSURES AND ESTIMATES OF ASSOCIATED CANCER RISK
FOR PROPERTY N/N' SOUTH, LEWISTON, NEW YORK

| Source of Exposure | Working Lifetime Dose Equivalent Corrected for Background | Increased Risk Due to All Cancers |
|---|---|---|
| External gamma radiation | 0.36 rems | 0.036 per 1000[a] |
| Inhalation of resuspended particulates | negligible | 0 |
| Inhalation of radon | negligible | 0 |
| Ingestion of food and water contaminated by radioactive materials on-site | negligible | 0 |
| TOTAL | 0.36 rems | 0.036 per 1000[b] |

[a] Using the risk coefficient of 100 cancer deaths/$10^6$ person rem. This is approximately a mean value from BEIR-III (1980) and UNSCEAR (1977).

[b] The average lifetime risk of death due to cancer in the United States is 203 per 1000 (20.3 percent); in Niagara County the average lifetime risk is 218 per 1000 (21.8 percent).