DOE/OR/20722-76

DRAFT

Formerly Utilized Sites Remedial Action Program (FUSRAP)
Contract No. DE-AC05-81OR20722

POST-REMEDIAL ACTION REPORT FOR THE HAZELWOOD SITE - 1984

Hazelwood, Missouri

Bechtel National, Inc.
Advanced Technology Division

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July 1985

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POST-REMEDIDAL ACTION REPORT
FOR THE
HAZELWOOD SITE - 1984

JULY 1985

Prepared for

UNITED STATES DEPARTMENT OF ENERGY
OAK RIDGE OPERATIONS OFFICE
Under Contract No. DE-AC05-81OR20722

By

Bechtel National, Inc.
Advanced Technology Division
Oak Ridge, Tennessee

Bechtel Job No. 14501

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ABBREVIATIONS

cm	centimeter
ft	foot
ft^2	square foot
in.	inch
m	meter
m^2	square meter
mrem/yr	**millirem** per year
pCi/g	**picocuries** per **gram**

Words appearing in bold face print are explained in the glossary.

1.0 INTRODUCTION

The purpose of this report is to document the post-remedial action sampling conducted by Bechtel National, Inc. (BNI) at 9200 Latty Avenue and along the shoulders of the roadway from Coldwater Creek to Interstate Highway 170 in Hazelwood, Missouri. The location of Latty Avenue is shown in Figure 1. The report briefly describes the origin of the radioactive contamination in this area and the remedial action performed. It also provides the guidelines used in performing the remedial action and data on the current radiological status of the decontaminated areas.

Latty Avenue is located in the Cities of Berkeley and Hazelwood in suburban St. Louis. In 1966, low-level radioactive ore residues that had been stored at the St. Louis Airport Storage Site (SLAPSS), approximately 1 mile away, were brought to 9200 Latty Avenue. Some of the residues were dried in two buildings on-site before being shipped to a Colorado mill. The rest were removed from the property in 1973 to terminate a Nuclear Regulatory Commission license for storage, and the property was later sold to the current owner.

The residues stored at 9200 Latty Avenue were deposited directly on the ground. When the last of the residues were removed, a reported 12 to 18 in. (30 to 45 cm) of topsoil were also removed before the property was sold. However, due to leaching of the materials into the soil, parts of the property are radioactively contaminated in excess of the limits permitted by current Department of Energy (DOE) guidelines. The primary radioactive contaminant that leached from the residues was thorium-230: much of the uranium and radium in the ore had been removed during earlier processing and are present in the soil in only trace amounts. The soils along the shoulders of Latty Avenue were also contaminated as a result of spillage of the residues from trucks hauling them.

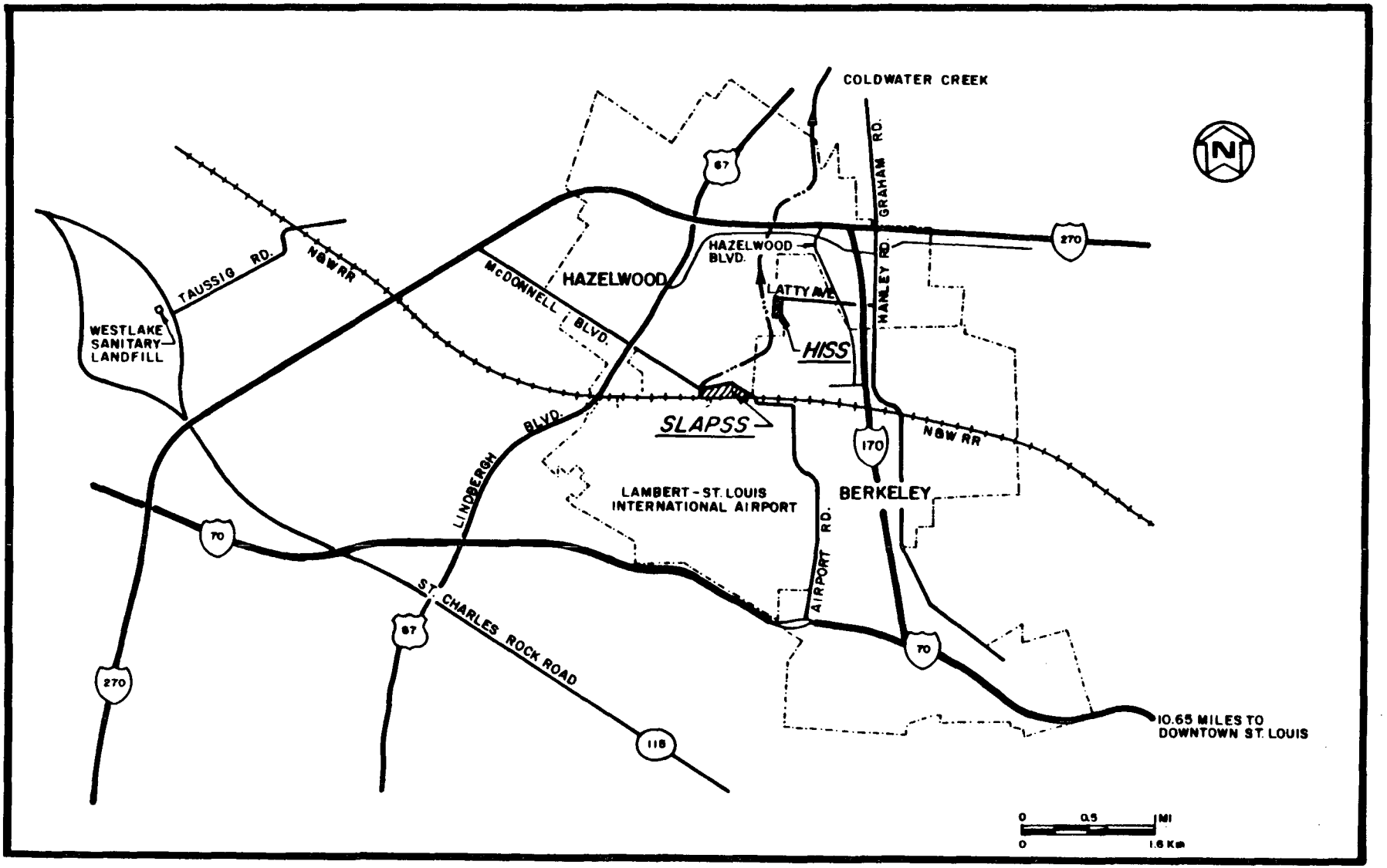

FIGURE 1 LOCATION OF LATTY AVENUE

Decontamination of the property at 9200 Latty Avenue and along the roadway was authorized by the 1984 Energy and Water Appropriations Act, which directed DOE to conduct the work as part of its Formerly Utilized Sites Remedial Action Program (FUSRAP). This program is a DOF effort to identify, decontaminate, or otherwise control sites where low-level radioactive contamination (exceeding current guidelines) remains from the early years of the nation's atomic energy program. FUSRAP is currently being managed by the DOE Oak Ridge Operations Office. BNI is the Project Management Contractor and acts as DOE's representative in the planning, management, and implementation of FUSRAP.

2.0 REMEDIAL ACTION GUIDELINES

The radioactive contamination at the property and along the roadway is primarily thorium-230. The DOE remedial action guideline for thorium-230 is 5 pCi/g of soil above **background** when averaged over a 33 x 33 ft (10 m x 10 m) area to a depth of 6 in. (15 cm) from the surface of the ground. For depths greater than 6 in. (15 cm), the guideline is 15 pCi/g above background using the same averaging method.

This guideline was derived to protect members of the general public from any foreseeable radiation **exposure**. This means that if the concentration of thorium-230 in all the soil on a property were equal to the DOE guidelines, the resident would not receive a **dose** to the whole body that was larger than the DOE radiation protection standard of 500 **mrem**/yr. This would be true even if the resident grew all his own food in the contaminated soil, drank water from a well in the contaminated soil, lived in a house built in the middle of the contamination, drank milk only from cows grazing strictly on grass grown in the contaminated soil, and ate meat only from animals that had grazed on the contaminated soil. Since this scenario is highly improbable, these assumptions provide a large margin of safety for members of the general public who may have contact with the site.

3.0 REMEDIAL ACTION

The first priority for the cleanup was to remove radioactive soil from along the roadway itself. This was necessary so that the road shoulders could be released for unrestricted use, allowing the Cities of Berkeley and Hazelwood to proceed with plans for road and drainage improvement projects. Blueprints were supplied by city authorities so that the cleanup effort would include all areas that might be affected by the improvement program.

Based on the blueprints of the improvement program, Oak Ridge National Laboratory (ORNL) surveyed all areas within the Cities' temporary slope and construction line (TSCL) for radioactive contamination. The TSCL includes all areas that could potentially be disturbed during the drainage improvement project. The radiological survey determined the depth and extent of the contamination. Areas beyond the TSCL will be radiologically surveyed at a future date to determine whether more extensive excavations will be required.

Based on the data from the ORNL survey (Ref. 1), BNI determined what areas would require remedial action to bring them into compliance with the DOE guideline. The limits of excavation are illustrated in Figures 2A through 2G (pages 8 to 14). The depth of excavation ranged from 6 in. (15 cm) to over 3 ft (1 m).

During remedial action, the contaminated soil was excavated and hauled to a storage pile at 9200 Latty Avenue (Ref. 2). This pile was stabilized so that material from the pile cannot recontaminate the cleaned areas. The material will be stored at this location until a permanent disposal site is developed by the State of Missouri. At that time, the material will be moved to the disposal site.

4.0 POST-REMEDIAL ACTION SAMPLING

To ensure that the cleaned areas indeed met the DOE guideline, several methods were used to measure residual radioactivity. These consisted of walkover gamma surveys, field analysis of soil samples, and laboratory analysis of soil samples. Because the primary **radionuclide** is thorium-230, laboratory analysis of soil samples was the principal method for verifying compliance. This is because thorium-230 is an **alpha emitter** and, with portable instruments, cannot be directly detected in soil at the low levels specified by the DOE guidelines.

Although thorium-230 cannot be detected in soil with portable radiation detectors, walkover gamma scans were still conducted to locate any isolated areas where gamma-emitting radionuclides such as radium-226 might exceed the guidelines. From historical data collected from the Latty Avenue site, it was known that the thorium-230 to radium-226 ratio could be as high as 200 to 1. This meant that if radium-226 concentrations exceeded the guidelines, thorium-230 was bound to exceed them as well. For this reason, additional soil was removed if the surface gamma scan showed an exposure rate more than twice the normal background level. Because surface gamma scans can be conducted more quickly than soil sampling and analysis, these scans saved time in identifying areas where residual radioactivity had to be removed.

Two types of walkover scans were conducted. To monitor soil in the immediate vicinity of the storage pile, the gamma detector was shielded with lead so that the only radiation detected was that coming from the ground. This was necessary because gamma radiation coming from the materials stored in the pile increased the local background radiation level and gave false readings from the soil being monitored. Measurements were made at individual points on a 12.5-ft (3.8-m) grid.

Areas not directly adjacent to 9200 Latty Avenue were surveyed for residual gamma activity using an unshielded gamma detector. For this type of survey, the detector is held within a few inches of the

soil and slowly moved over the surface in a scanning motion. This method was used whenever possible (as opposed to using a shielded probe) because more of the soil surface is surveyed by the detector.

Once gamma radiation in excess of twice background was no longer detected in the excavated areas, soil samples were taken at 25-ft (7.6-m) intervals along the bottom and from the walls of the excavations. These samples were taken to ensure that sufficient material had been excavated to meet the thorium-230 guideline. If, after analysis of the soil, any sample showed a residual concentration of thorium-230 still in excess of the DOE guideline, additional soil was removed in the appropriate direction (i.e., from the sidewalls or floor of the excavation), and another set of soil samples was taken for analysis. This procedure was repeated until the analysis indicated that the thorium-230 concentration was below the guideline.

The soil samples were analyzed by two methods: one performed in a field laboratory for quick turnaround and the other in an independent laboratory on a slower, confirmatory basis. The field laboratory analysis used **gross alpha counting** of the soil to quickly scan the samples for radioactivity in excess of the guideline. This procedure was developed by BNI especially for use on the Latty Avenue site. It consists of drying and grinding the sample and then uniformly spreading 0.02 ounces (0.5 gram) of the soil on a planchet that is counted for 10 minutes in a low-background alpha counter. The gross alpha counts are then compared with the calibration line to determine whether or not the remedial action guideline was met. The technique was **calibrated** using the soil samples collected by ORNL during their initial survey. The calibration line and **coefficient of correlation** are shown in Figure 3. Also shown are the 95 percent confidence interval estimates of the thorium-230 concentration when three 10-minute gross alpha counts are averaged and compared with the calibration line.

Figures 2A through 2G show the locations at which soil samples analyzed by gross alpha counting were taken. At the completion of the project, over 1,400 samples had been collected and tested using this technique. The final gross alpha results indicate that thorium-230 concentrations in the excavated areas are below the guideline when averaged over the 1,080 ft^2 area (100 m^2) specified by DOE guidelines.

To confirm the findings of the gross alpha counting, approximately 300 samples were selected from the 1,400 taken along the roadway and were sent to the Eberline Analytical Corporation laboratory in Alburquerque, New Mexico for analysis by standard radiochemical methods. Table 1 lists the results of the laboratory analysis of these samples; the locations from which the samples were taken are shown in Figures 2A through 2G. The results listed in Table 1 also demonstrate that the cleanup guideline was met.

5.0 POST-REMEDIAL ACTION STATUS

As shown in the figures and data table, the sampling performed after removal of the radioactive materials shows that no radioactive contamination in excess of the DOE remedial action guideline is present in the areas excavated. Several individual results exceed 15 pCi/g; however, when averaged over the 1,080-ft^2 (100-m^2) area specified in the DOE guidelines, all results meet the guideline. The averages are calculated by plotting all the results and averaging those falling within a given 33-ft x 33-ft (10-m x 10-m) area.

An independent review of the remedial action is being conducted by ORNL to verify the adequacy of actions taken by BNI. Upon completion of this review, the land within the TSCL will be officially released for unrestricted use.

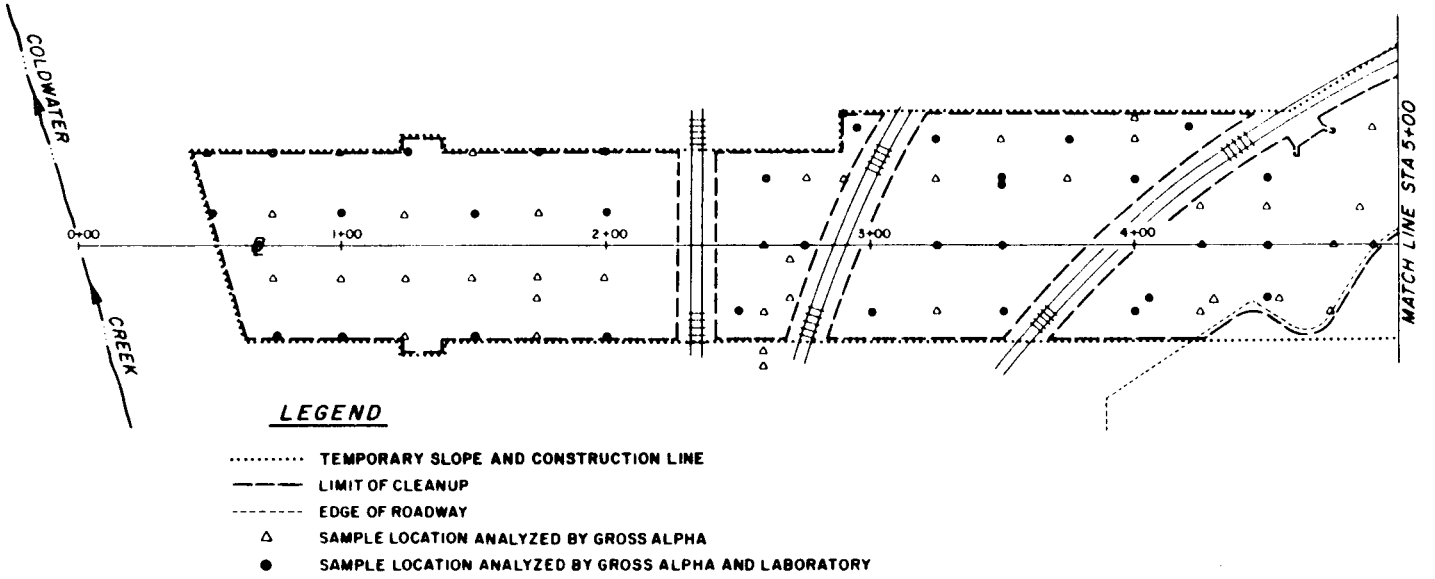

FIGURE 2A LIMITS OF REMEDIAL ACTION EXCAVATION AND LOCATIONS OF POST-REMEDIAL ACTION SAMPLES ALONG LATTY AVENUE

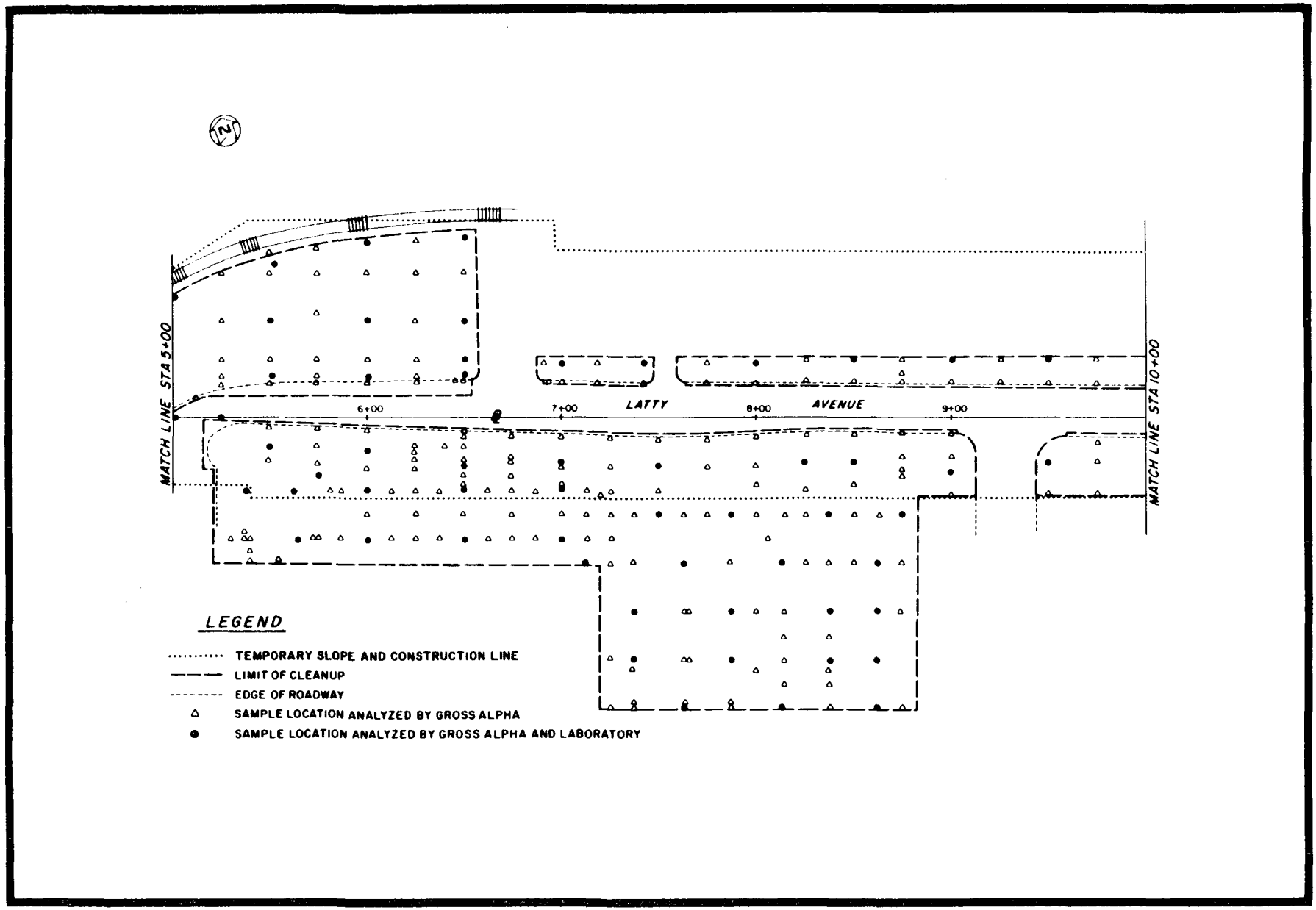

FIGURE 2B LIMITS OF REMEDIAL ACTION EXCAVATION AND LOCATIONS OF POST-REMEDIAL ACTION SAMPLES ALONG LATTY AVENUE

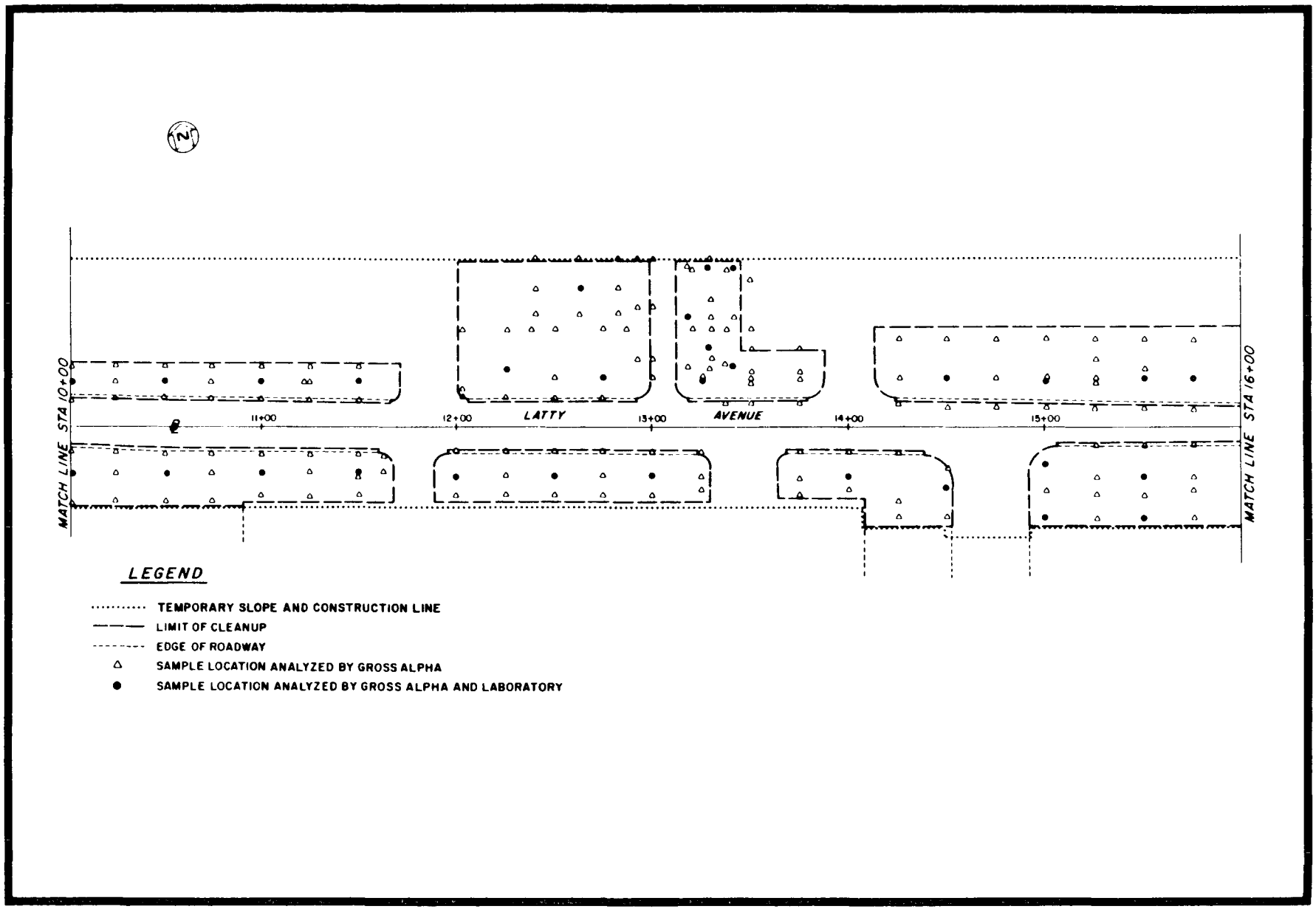

FIGURE 2C LIMITS OF REMEDIAL ACTION EXCAVATION AND LOCATIONS OF POST-REMEDIAL ACTION SAMPLES ALONG LATTY AVENUE

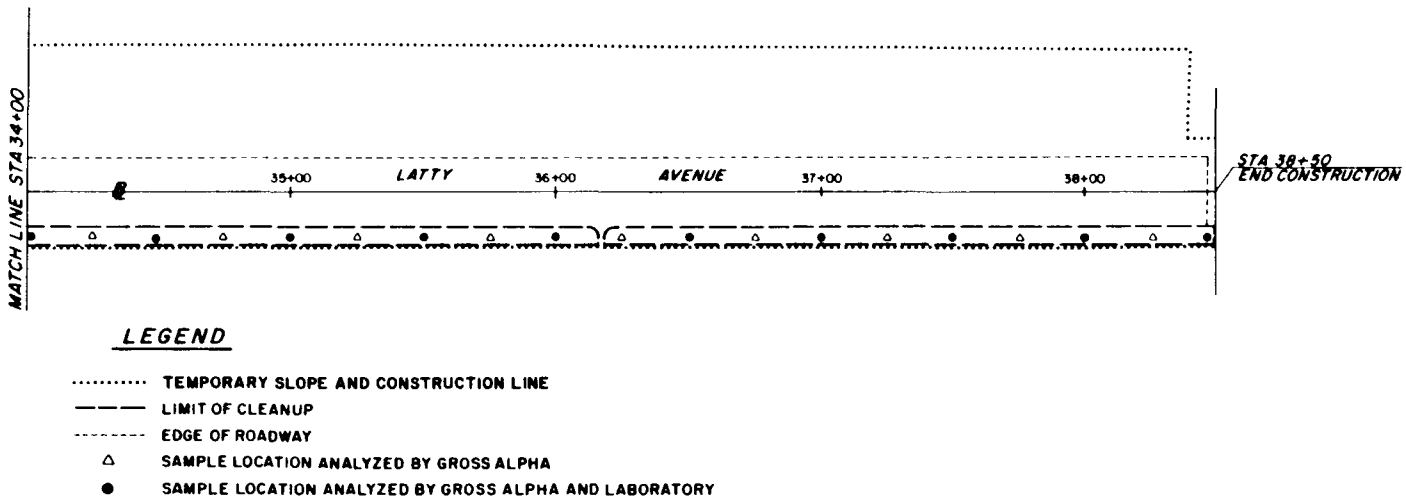

FIGURE 2D LIMITS OF REMEDIAL ACTION EXCAVATION AND LOCATIONS OF POST-REMEDIAL ACTION SAMPLES ALONG LATTY AVENUE

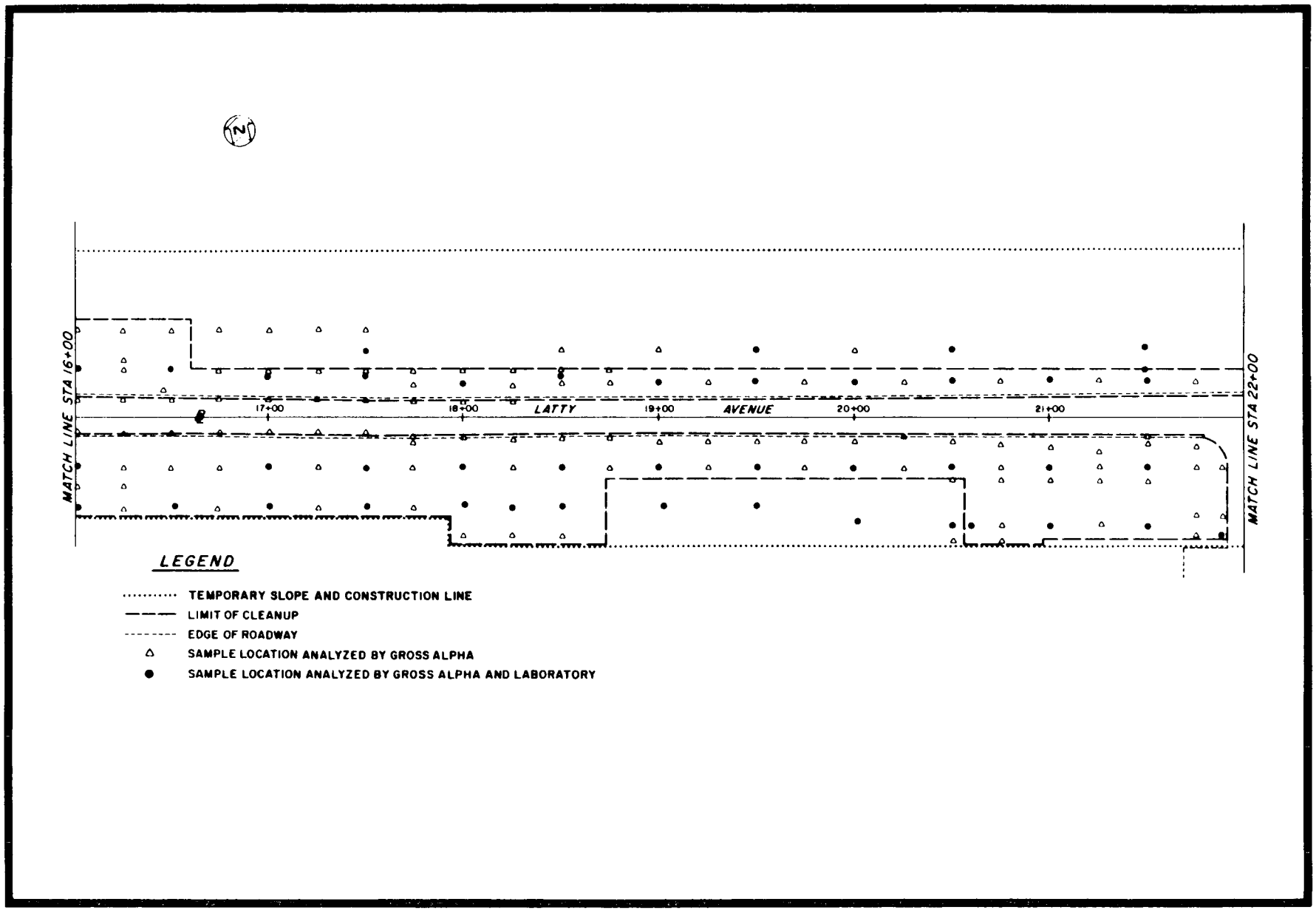

FIGURE 2E LIMITS OF REMEDIAL ACTION EXCAVATION AND LOCATIONS OF POST-REMEDIAL ACTION SAMPLES ALONG LATTY AVENUE

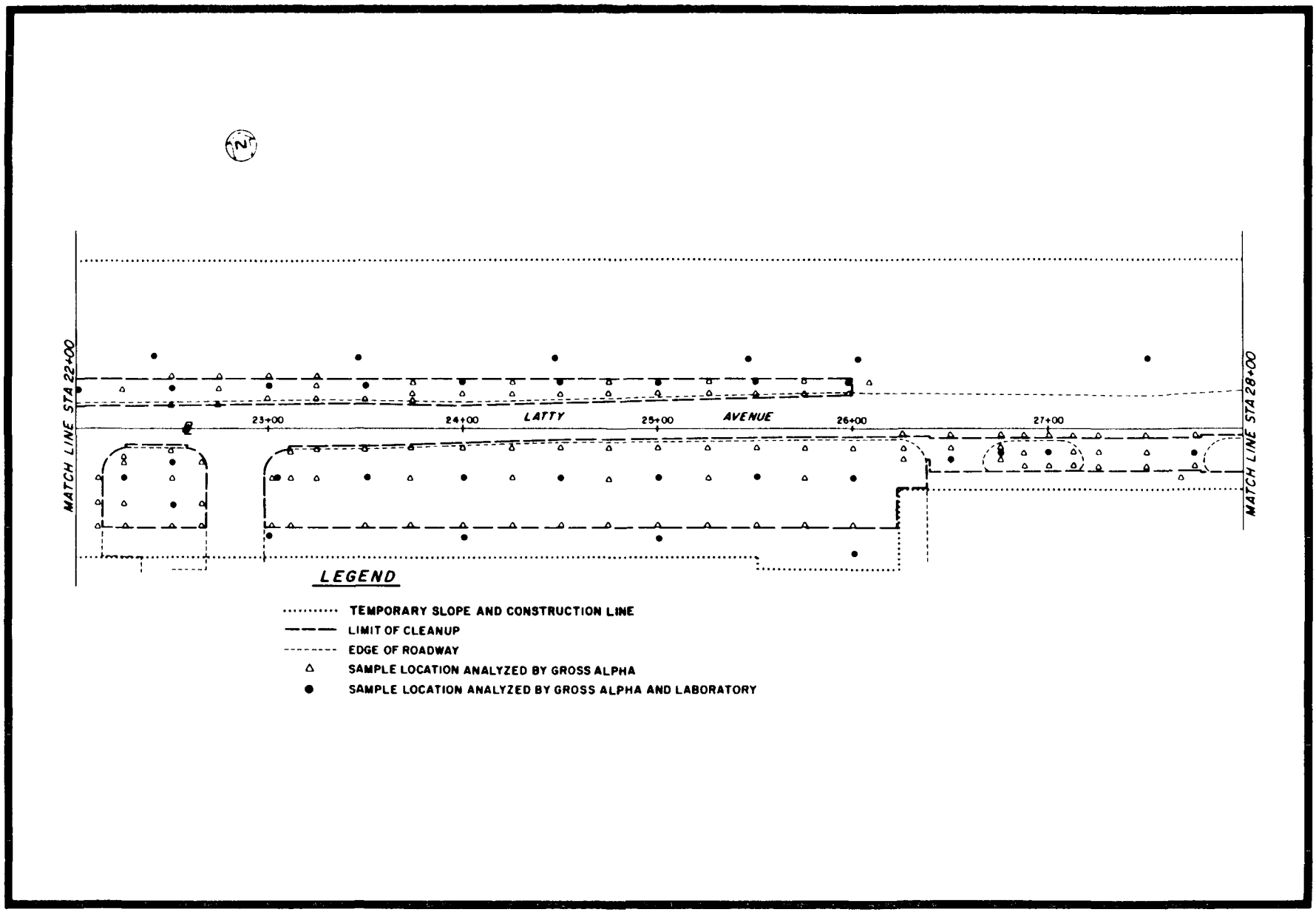

FIGURE 2F LIMITS OF REMEDIAL ACTION EXCAVATION AND LOCATIONS OF POST-REMEDIAL ACTION SAMPLES ALONG LATTY AVENUE

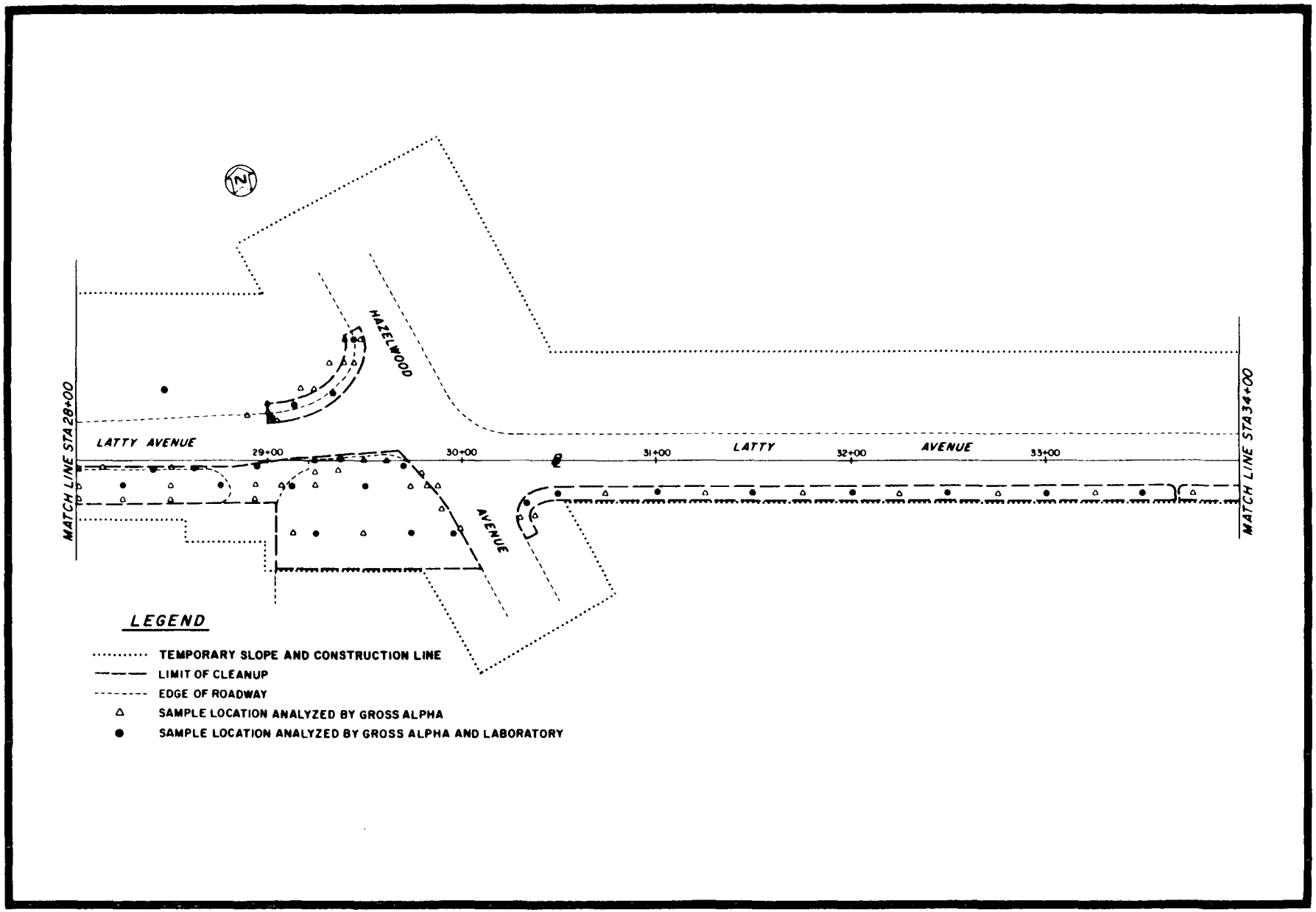

FIGURE 2G LIMITS OF REMEDIAL ACTION EXCAVATION AND LOCATIONS OF POST-REMEDIAL ACTION SAMPLES ALONG LATTY AVENUE

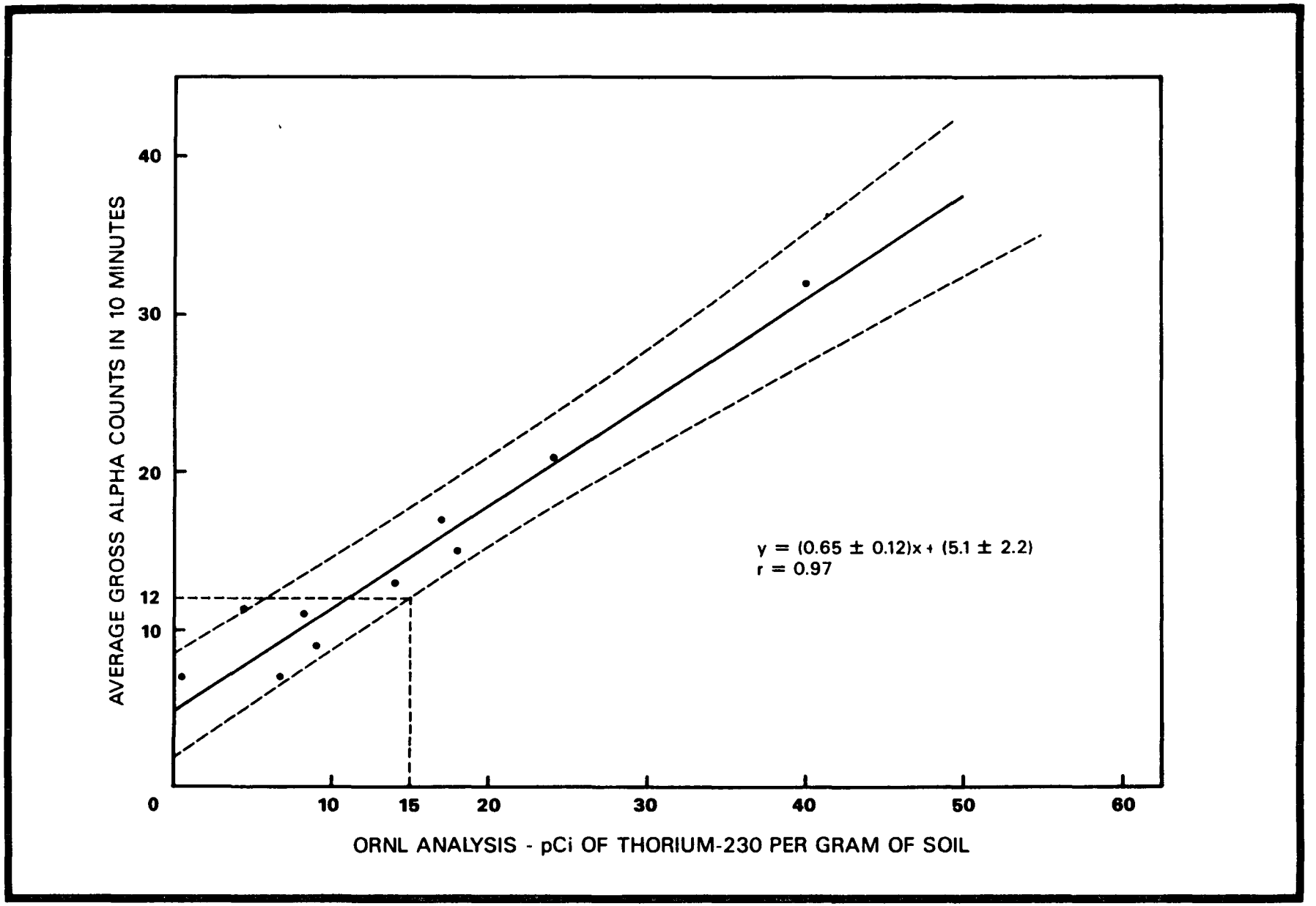

FIGURE 3 CALIBRATION OF GROSS ALPHA COUNT AND THORIUM-230 CONCENTRATION IN SOIL

TABLE 1

LABORATORY ANALYSIS OF SOIL SAMPLES

FROM REMEDIAL ACTION EXCAVATION ALONG LATTY AVENUE

(Concentration pCi/g ± 2 Sigma)

Coordinates		
E	N-S*	Thorium-230
50.0	12.5	8.00 ± 2.00
75.0	35.0	22.00 ± 3.00
75.0	-35.0	31.00 ± 2.00
100.0	12.5	6.00 ± 1.00
100.0	-35.0	5.00 ± 1.00
125.0	35.0	4.00 ± 1.00
150.0	12.5	7.00 ± 1.00
150.0	-35.0	9.00 ± 1.00
175.0	33.0	1.00 ± 0.30
175.0	35.0	33.00 ± 2.00
200.0	12.5	6.00 ± 1.00
200.0	-35.0	4.00 ± 1.00
250.0	-25.0	4.00 ± 1.00
260.0	25.0	1.30 ± 0.40
275.0	0.0	2.70 ± 0.20
292.5	61.0	4.60 ± 0.60
300.0	-25.0	11.00 ± 1.00
325.0	0.0	8.00 ± 1.00
325.0	40.0	20.00 ± 2.00
350.0	0.0	2.10 ± 0.60
350.0	23.0	2.60 ± 0.30
350.0	25.0	8.00 ± 1.00
350.0	-25.0	5.00 ± 1.00
375.0	40.0	3.00 ± 1.00
375.0	-50.0	6.00 ± 1.00
400.0	25.0	9.00 ± 1.00
400.0	-25.0	2.10 ± 0.30
405.0	-20.0	10.00 ± 1.00
420.0	45.0	4.00 ± 1.00
450.0	0.0	3.20 ± 0.30
450.0	25.0	11.00 ± 2.00
450.0	-20.0	0.70 ± 0.20
500.0	0.0	2.50 ± 0.30
500.0	62.5	10.00 ± 1.00
522.0	0.0	3.80 ± 0.40
537.5	-37.5	9.00 ± 1.00
550.0	21.0	4.00 ± 1.00
550.0	-15.0	16.00 ± 4.00
550.0	50.0	3.10 ± 0.70

TABLE 1

(continued)

Coordinates		
E	N-S*	Thorium-230
550.0	85.0	3.30 ± 0.30
562.4	-37.5	4.00 ± 1.00
562.5	-62.5	0.50 ± 0.10
575.0	-30.0	4.00 ± 1.00
600.0	21.0	1.60 ± 0.30
600.0	-17.0	1.70 ± 0.70
600.0	50.0	2.00 ± 0.60
600.0	90.0	2.90 ± 0.30
600.0	-37.5	1.60 ± 0.10
600.0	-62.5	3.00 ± 1.00
650.0	22.0	2.60 ± 0.70
650.0	30.0	4.00 ± 1.00
650.0	-25.0	15.00 ± 2.00
650.0	50.0	3.70 ± 0.40
650.0	92.5	3.70 ± 0.40
650.0	-37.5	10.00 ± 1.00
650.0	-62.5	1.90 ± 0.20
700.0	28.0	23.00 ± 1.00
700.0	-23.0	0.80 ± 0.40
700.0	-37.5	1.00 ± 0.10
700.0	-62.5	1.30 ± 0.30
712.5	-75.0	1.50 ± 0.20
737.5	-100.0	1.10 ± 0.20
737.5	-125.0	1.00 ± 0.20
742.0	28.0	9.00 ± 4.00
750.0	-25.0	8.00 ± 1.00
750.0	-50.0	1.10 ± 0.20
762.5	-75.0	12.00 ± 1.00
762.5	-150.0	6.00 ± 1.00
787.5	-50.0	1.90 ± 0.50
787.5	-100.0	14.00 ± 1.00
787.5	-125.0	1.20 ± 0.10
800.0	28.0	3.00 ± 0.40
812.5	-75.0	1.70 ± 0.10
812.5	-150.0	1.20 ± 0.10
825.0	-23.0	10.00 ± 1.00
837.5	-50.0	2.10 ± 0.50
837.5	-100.0	1.90 ± 0.50
837.5	-125.0	19.00 ± 2.00
850.0	30.0	3.80 ± 0.50
850.0	-23.0	14.00 ± 1.00
862.5	-75.0	1.10 ± 0.10

TABLE 1

(continued)

Coordinates		
E	N-S*	Thorium-230
862.5	-100.0	1.20 ± 0.40
862.5	-125.0	0.70 ± 0.10
862.5	-150.0	1.90 ± 0.50
874.0	-150.0	2.70 ± 0.60
874.0	-425.0	0.80 ± 0.20
875.0	-50.0	1.30 ± 0.10
900.0	30.0	3.90 ± 0.30
900.0	-28.0	27.00 ± 3.00
950.0	30.0	3.10 ± 0.60
950.0	-23.0	4.30 ± 0.40
1000.0	23.0	3.80 ± 0.30
1000.0	-23.0	7.00 ± 1.00
1050.0	23.0	2.70 ± 0.20
1050.0	-23.0	2.70 ± 0.30
1100.0	23.0	3.30 ± 0.30
1100.0	-23.0	7.00 ± 1.00
1150.0	23.0	1.70 ± 0.30
1150.0	-23.0	7.00 ± 1.00
1200.0	-25.0	10.00 ± 1.00
1225.0	29.0	2.90 ± 0.40
1250.0	-25.0	8.60 ± 1.50
1262.5	70.5	1.30 ± 0.40
1275.0	25.0	2.90 ± 0.30
1300.0	25.0	1.30 ± 1.40
1300.0	-25.0	41.00 ± 4.00
1318.0	56.0	22.00 ± 2.00
1325.0	23.0	2.00 ± 0.20
1329.0	40.0	2.00 ± 1.00
1329.0	81.0	0.50 ± 0.40
1341.0	31.0	6.00 ± 1.00
1341.0	81.0	3.00 ± 1.00
1400.0	-25.0	16.00 ± 2.00
1450.0	25.0	9.00 ± 1.00
1450.0	-20.0	1.00 ± 0.40
1450.0	-31.0	31.30 ± 2.20
1500.0	23.0	7.00 ± 1.00
1500.0	-19.0	1.70 ± 0.40
1500.0	-46.0	4.40 ± 0.40
1550.0	25.0	10.00 ± 1.00
1550.0	-25.0	2.60 ± 0.30
1550.0	-46.0	8.00 ± 1.00
1575.0	25.0	14.90 ± 1.00

TABLE 1

(continued)

Coordinates		
E	N-S*	Thorium-230
1600.0	25.0	5.90 ± 0.80
1600.0	-25.0	3.00 ± 1.00
1600.0	-46.0	2.10 ± 0.40
1650.0	25.0	8.00 ± 1.00
1650.0	-45.0	22.00 ± 4.00
1700.0	25.0	5.00 ± 0.40
1700.0	-25.0	2.40 ± 0.80
1700.0	-45.0	20.00 ± 2.00
1750.0	25.0	17.00 ± 1.00
1750.0	-25.0	1.20 ± 0.80
1750.0	-45.0	23.00 ± 4.00
1800.0	17.0	2.30 ± 0.30
1800.0	-25.0	23.00 ± 6.00
1800.0	-45.0	9.00 ± 3.00
1825.0	-46.0	23.00 ± 2.00
1850.0	25.0	4.90 ± 0.20
1850.0	-25.0	15.00 ± 1.00
1850.0	-45.0	7.00 ± 1.00
1900.0	18.0	2.30 ± 0.40
1900.0	-25.0	11.00 ± 1.00
1950.0	18.0	8.00 ± 0.30
1950.0	-25.0	1.60 ± 0.30
2000.0	18.0	5.80 ± 0.40
2000.0	-25.0	5.00 ± 1.00
2050.0	0.0	4.40 ± 0.40
2050.0	-25.0	5.00 ± 1.00
2050.0	-55.0	4.00 ± 1.00
2100.0	19.0	16.00 ± 1.00
2100.0	-25.0	6.00 ± 1.00
2100.0	-55.0	8.00 ± 1.00
2150.0	18.0	0.60 ± 0.10
2150.0	-25.0	7.00 ± 2.00
2150.0	-55.0	8.00 ± 1.00
2188.0	-60.0	62.00 ± 6.00
2200.0	20.0	2.40 ± 0.60
2225.0	-25.0	2.70 ± 0.40
2250.0	20.5	2.30 ± 0.20
2250.0	-17.0	1.90 ± 0.20
2250.0	-37.5	14.00 ± 1.00
2300.0	22.0	1.70 ± 0.20
2303.0	-25.0	7.00 ± 1.00
2331.0	-200.0	14.00 ± 3.00

TABLE 1

(continued)

Coordinates		
E	N-S*	Thorium-230
2350.0	22.0	3.60 ± 0.50
2350.0	-25.0	2.70 ± 0.50
2400.0	24.0	3.00 ± 1.00
2400.0	-25.0	3.00 ± 0.70
2450.0	24.0	5.00 ± 1.00
2450.0	-25.0	2.90 ± 0.70
2500.0	24.0	10.00 ± 1.00
2500.0	-25.0	11.00 ± 1.00
2550.0	24.0	16.00 ± 1.00
2550.0	-25.0	2.30 ± 0.50
2600.0	24.0	2.10 ± 0.20
2600.0	-25.0	1.40 ± 0.20
2650.0	-16.0	9.00 ± 1.00
2650.0	-25.0	24.30 ± 0.70
2675.0	-12.0	6.30 ± 0.30
2700.0	-12.0	3.50 ± 0.20
2725.0	-12.0	2.10 ± 0.30
2775.0	-12.0	6.70 ± 0.60
2825.0	-12.5	4.30 ± 0.20
2840.0	-3.0	0.20 ± 0.10
2862.5	-3.0	2.20 ± 0.30
2875.0	-12.5	7.80 ± 0.80
2890.0	23.0	2.20 ± 0.40
2894.0	-2.0	2.40 ± 0.50
2912.5	-12.5	2.60 ± 0.30
2925.0	37.5	2.30 ± 0.30
2925.0	-37.5	2.50 ± 0.30
2937.5	0.0	2.00 ± 0.30
2945.0	62.5	3.40 ± 0.30
2950.0	-12.5	9.00 ± 1.00
2975.0	-2.0	5.70 ± 0.50
2975.0	-37.5	1.40 ± 0.30
3000.0	-35.0	7.00 ± 1.00
3034.0	-22.0	7.80 ± 0.60
3050.0	-16.5	4.10 ± 0.20
3100.0	-16.5	1.50 ± 0.50
3150.0	-16.8	7.00 ± 1.00
3200.0	-16.3	5.40 ± 0.60
3250.0	-16.8	14.00 ± 1.00
3300.0	-16.3	5.40 ± 0.40
3350.0	-16.5	4.50 ± 0.40
3400.0	-16.5	10.00 ± 2.00

TABLE 1

(continued)

Coordinates		
E	N-S*	Thorium-230
3450.0	-17.0	2.30 ± 0.30
3500.0	-17.0	0.60 ± 0.10
3550.0	-17.0	9.00 ± 1.00
3600.0	-17.0	1.50 ± 0.20
3650.0	-17.0	6.00 ± 0.40
3700.0	-17.0	3.30 ± 0.30
3750.0	-17.0	3.20 ± 0.30
3800.0	-17.0	6.50 ± 0.40
3846.0	-17.0	2.00 ± 0.20

*Negative numbers indicate a location south of the baseline of the survey grid.

REFERENCES

1. Cottrell, Woodrow, Oak Ridge National Laboratory, personal transmittal of preliminary data listing to R.C. Robertson, Bechtel National, Inc., Oak Ridge Office, March 1984.

2. U.S. Department of Energy. Remedial Action Work Plan for the Hazelwood Site, ORO-848, Oak Ridge, TN, June 1984.

GLOSSARY

Alpha emitter - See radiation.

Background (Radiation) - Background radiation refers to naturally occurring radiation emitted from either cosmic (e.g., from the sun) or terrestrial (e.g., from the earth) sources. Exposure to this type of radiation is unavoidable and its level varies greatly depending on geographic location; e.g., New York state receives approximately 100 mrem/yr, Colorado receives about 300 mrem/yr, and some areas in South America receive up to 7000 mrem/yr. Naturally occurring terrestrial radionuclides include uranium, radium, potassium, thorium, etc.

Calibrated - Radiation detectors typically measure the number of radioactive particles that enter the detector. These are called "counts" because the detector counted a radioactive particle (which could be alpha, beta, or gamma). When measuring radioactivity in soil, the measurement is used to determine the concentration of the radionuclide in the soil in picocuries of radiation per gram of soil. Calibration of the detector is done so that the "counts" can be converted to picocuries per gram of soil. This is usually done by seeing how many "counts" the detector registers when measuring a known amount of radiation as determined under laboratory conditions.

Coefficient of Correlation - This number gives an indication of how well data values, when graphed, can be represented by a straight line. The closer the coefficient of correlation is to 1, the better the line "fits" the data. The coefficient of correlation was calculated during statistical analysis of the calibration data for the gross alpha counting technique. In this case, a good "fit" meant that the method used to measure the concentration of thorium-230 in the soil in fact yielded satisfactorily accurate results.

Contamination - Contamination is used here to mean a concentration of radioactive material (in this case, thorium-230) in the soil that exceeds the DOE guideline.

Dose - Dose is used to relate radiation exposure to an effect on the body. Dose is measured in mrem. Examples of dose are: a dose of 500,000 mrem to the whole body in a short time causes death in 50 percent of the people who receive it; a dose of 5,000,000 mrem may be delivered to a cancerous tumor during radiation treatment; normal background radiation results in an annual dose of about 100 mrem; DOE radiation protection standards limit the dose to members of the general public to 500 mrem/yr; a typical chest x-ray gives a dose of about 20 mrem; living in a brick house results in a dose of about 75 mrem/yr.

Exposure - Radiation emitted from radioactive materials outside the body 'expose' the whole body when radiation interacts with it. The rate at which this exposure occurs is referred to as the exposure rate. Exposure is typically measured in mrad and the exposure rate is typically given as mrad/h. The dose to the whole body can be calculated by multiplying the exposure rate by the number of hours that the exposure occurred. For example, if an individual was exposed to 0.2 mrad/h for 40 hours per week for 52 weeks per year, the whole body dose would be 416 mrem.

Gamma Radiation - See radiation.

Gram - A gram is a metric unit for weight. It takes 454 grams to make 1 pound; 1 ounce equals 28 grams.

Gross Alpha Counting - One mode of radioactive decay is the emission of alpha particles. By counting these particles as they are released, the concentration of radioactive material in the soil can be calculated. This method is typically used as a screening procedure because it is not possible to tell what type of radionuclide (i.e., uranium, radium, or thorium) is responsible for

the alpha particle. A very conservative assumption is that all the alphas originate from thorium-230; using this assumption when removing radioactive material from an area usually results in removing sufficient material to lower the concentration of radionuclides to levels less than the guideline. Gross alpha counting of soil can give only very rough approximations of the thorium-230 content because the soil shields the alpha particles from the detector. Since the alphas cannot even penetrate a piece of paper, the soil effectively stops all alphas except those emitted from the surface of the soil. Use of this technique was necessary to obtain information on soil samples as rapidly as possible so that backfilling of open excavations could proceed. More precise determinations of thorium-230 content are possible with laboratory analyses, but these usually take 2 weeks to complete.

Leaching - Leaching is a chemical process whereby the radionuclides from the ore residues were dissolved in water (runoff following precipitation) and seeped into the surrounding soil. Storage piles of radioactive materials are usually covered with waterproof materials to prevent leaching from occurring.

mrem - mrem is the unit used to measure radiation doses. The DOE limit is 500 mrem in any one year for members of the general public. For comparison, a typical medical x-ray is about 20 mrem. Naturally occurring radioactive substances in the ground result in a yearly exposure to everyone of about 100 mrem. To date, no difference can be detected in the health of population groups exposed to 500 mrem/yr and in the health of groups who are not exposed.

Picocurie - A picocurie is the unit of measure for radioactivity just as an ounce is a unit to measure weight. One picocurie means that one radioactive particle is released on an average of every 27 seconds.

Radiation - There are three primary types of radiation: alpha, beta, and gamma. Alpha radiation travels less than an inch in air before it stops. Alpha radiation cannot penetrate the outer layer of skin on the body. Beta radiation can penetrate the outer layers of skin, but cannot reach the internal organs of the body. Gamma radiation is the most penetrating type and can usually reach the internal organs.

Radionuclide - A radionuclide is another word meaning a particular radioactive element. For example, uranium-235 is a radionuclide, uranium-238 is another, thorium-232 another, and so on.

Remedial Action - Remedial action is a general term used to mean "cleanup of contamination." It refers to any action required so that a property can be released for unrestricted use. In practice, this may mean removing grass and soil, cutting trees, removing asphalt, etc.

Residues - These are the by-product of processing operations designed to remove uranium from its ores.

Thorium-230 - Thorium-230 is a special type of thorium that results from the **radioactive decay** of uranium. It is typically found in concentrations of less than 1 pCi/g in soil. However, when ores are processed to remove uranium, the thorium-230 becomes concentrated. It has a half-life of 77,000 years; in other words it takes 77,000 years for half of a given quantity of thorium-230 to decay into a different element. **Radioactive decay** refers to the change in chemical composition of a radioactive material that accompanies the emission of alpha or beta particles from that material. The radioactive element becomes a different element, which may or may not be radioactive. For example, the following chain describes the radioactive decay of uranium-238: uranium-238 -- thorium-234 -- protactinium-234 -- uranium-234 -- thorium-230 -- radium-226 -- radon-222 -- polonium-218 -- lead-214 -- bismuth-214 -- polonium-214 -- lead-210 -- bismuth-210 -- polonium-210 -- lead-206. Lead-206 is stable; therefore the original atom of uranium-238 has become one of lead-206 and is no longer radioactive.

Unrestricted use - This means that a given property can be used for absolutely any purpose (i.e., residence, business, playground, farming) without regard for the radioactive contamination that was present prior to remedial action on that property.