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Projects

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of Energy

VERIFICATION OF REMEDIAL ACTIONS ALBANY RESEARCH CENTER ALBANY, OREGON

P. R. COTTEN

Environmental Survey and Site Assessment Program
Energy/Environment Systems Division

FINAL REPORT
OCTOBER 1989

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OF
REMEDIAL ACTIONS
ALBANY RESEARCH CENTER
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FINAL REPORT

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*Currently enrolled at the University of Tennessee.

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INTRODUCTION

The Albany Research Center (ARC) in Albany, Oregon, was established in 1943; it has been operated since that time by the U.S. Bureau of Mines, for a variety of activities related to strategic mineral resources and metallurgical processes. Between 1948 and 1978, the Center conducted work under contract with the Atomic Energy Commission (AEC) and the Energy Research and Development Agency (ERDA) - predecessor organizations of the U.S. Department of Energy. This work primarily involved the melting, machining, welding, and alloying of thorium; however, some of the operations also included separation, purification, and processing of limited quantities of uranium. Wastes from AEC and ERDA activities were treated at the Center, and portions of the facility were used for temporary storage and/or disposal of materials containing low levels of thorium, uranium, and their associated decay products. In addition to the work for Department of Energy (DOE) predecessors, ARC has performed work with radioactive materials, under the jurisdiction of the Nuclear Regulatory Commission.

During the period of AEC and ERDA contract work, process facilities and surrounding areas were periodically decontaminated in accordance with radiological guidelines prescribed at the time. A review of the documentation, relating to these efforts, was conducted by DOE, following termination of contract work in 1978. This review indicated that the existing documentation was not adequate to assure that buildings and land areas met current DOE guidelines for residual radioactive material. As a result, DOE initiated a characterization and assessment study to determine the radiological condition of the site. The survey was conducted by Argonne National Laboratory (ANL) in 1978. This survey concluded that, although the levels of residual contamination at the ARC did not pose an immediate health hazard, further decontamination of the property was advisable.[1,2] The Albany Research Center was therefore included in DOE's Formerly Utilized Sites Remedial Action Program (FUSRAP).

In 1984, Bechtel National, Inc. (BNI), the Project Management Contractor for FUSRAP, conducted additional radiological surveys of areas identified by ANL, to define the locations and levels of above-guideline contamination.[3] Remedial action to decontaminate identified areas was initiated by BNI in mid 1987 and completed in February 1988.[4] Eleven structures were addressed in the 1987/1988 remedial action activities; they are buildings 2, 4, 5, 17, 19, 23, 27, 28, 29, 30, and 31. During characterization and post-remedial action surveys, additional building surface areas, not previously considered under FUSRAP, were identified as having residual radioactive material contamination.[5] These areas will be addressed in future actions. Because of continuing activities involving radioactive materials in Building 23, that facility was not included in the BNI Post-Remedial Action Report and will be reevaluated during future actions. In addition to the buildings, remedial actions were conducted on outside land areas and surfaces; several drain systems were also remediated.

It is the policy of DOE to perform independent verifications of the effectiveness of remedial actions conducted within FUSRAP. The Environmental Survey and Site Assessment Program of Oak Ridge Associated Universities (ORAU) was designated by DOE as the organization responsible for this task at the Albany Research Center. Between August 1987 and April 1989, ORAU representatives performed verification activities, related to the ARC project. These activities included reviews of pertinent documents, confirmatory analyses of samples collected by the remedial action contractor, and independent radiological measurements and sampling of remediated areas. This report describes the procedures and findings of those activities.

SITE DESCRIPTION

The ARC facility is located approximately 110 kilometers (70 miles) south of Portland, Oregon (Figure 1) on a 17-ha (42-acre) site of the former Albany College in Albany, Oregon. The site is bounded on the north by Queen Avenue, on the east by Liberty Street, on the south by a tennis club facility, and on the west by Broadway Street (Figure 2). The site consists of three main areas: ARC proper, the main research facility; the former Biomass Research Facility which consists of approximately 0.8-ha (2-acre), located south of the main facility; and a 5.7-ha (14-acre) undeveloped area, known as the "Back Forty",

occupying the south end of the facility. There are 34 buildings and several smaller structures located at the ARC. Most of the buildings are currently being utilized. Several of these buildings are interconnected through adjoining hallways and rooms.

PROCEDURES

Objectives

The objectives of the verification were to confirm that the surveys, sampling, and analyses conducted prior to, during, and following remedial action and associated project documentation, provided an accurate and complete description of the condition of the property and, thereby, confirm that remedial actions have been effective in meeting established criteria.

General

1. Radiological survey reports and the post-remedial action report (references 1-4) were reviewed to assess the status of the facility. Data were evaluated to assure that areas exceeding established DOE guidelines were identified and had undergone remedial action. Post-remedial action radionuclide concentrations, surface contamination levels, and direct radiation levels were compared to guidelines, and the post-remedial action report and data were reviewed for general thoroughness and accuracy.

2. Comparison analyses were performed by ORAU on four post-remedial samples collected by BNI in Buildings 4 and 31 to determine radionuclide concentrations and to confirm the accuracy of BNI analytical data.

3. Survey teams from ORAU visited the site and performed visual inspections and independent measurements which include, independent alpha, beta-gamma, and gamma scans, exposure rate measurements, surface contamination measurements, and soil sampling at representative locations in remediated areas.

Independent Survey Procedures

Independent verification surveys were performed by ORAU in remediated areas (Figures 3-17). In addition, scans and/or measurements were conducted in the immediate vicinity of remediated areas and in non-remediated portions of the site, to assure that contaminated structures and land areas had been identified and had been or were being addressed.

Building Surveys

Gridding

A 2 m x 2 m (6.6 ft x 6.6 ft) reference grid system was established on the floor and lower walls in remediated areas of Buildings 5, 27, and 31, where remedial actions involved surface areas greater than 10 m^2 (108 ft^2). Grids were not established at remediated locations of smaller area; on upper walls, ceilings, and equipment; or in non-remediated areas. Measurements and samples from ungridded surfaces were referenced to pertinent building features or to floor grids, where available.

Surface Scans

Floor and lower wall surfaces were thoroughly scanned for alpha, beta-gamma, and gamma activity. Representative surfaces on upper walls, ceilings, ledges, beams, piping, fixtures, equipment, and ductwork were also scanned. Locations of elevated direct activity levels were brought to the attention of BNI and noted for further investigations.

Measurements of Surface Activity Levels

In gridded areas, measurements of activity levels were performed in randomly selected grid blocks. In each grid block surveyed, direct measurements of alpha and beta-gamma levels were systematically performed at the center and four points, midway between the center and the grid block corners. Smear samples for removable activity were performed at the location in each block, where the highest direct reading was obtained. A total of 43 grid block surveys were conducted in the buildings.

In ungridded areas, total and removable activity levels were measured at random locations and at selected location of elevated activity on floors, walls, ceilings, and miscellaneous overhead objects. A total of 122 locations were selected for single-point measurements.

Soil Sampling

Soil samples were collected from excavated floor areas inside Buildings 5, 27, 30, 31 and from underneath Building 27.

Miscellaneous Sampling

Several samples were collected from accessible drain lines. Residue samples were also collected from open trenches.

Exterior Surveys

Gridding

The 15 m (49.2 ft) grid systems (Figure 17) established by BNI, was used by ORAU to reference measurement and sampling locations. Large excavated areas [greater than 10 m^2 (108 ft^2)] were subdivided for survey.

Surface Scans

Surface scans were conducted throughout excavated areas, using a gamma scintillation detector. Locations of elevated gamma radiation levels were brought to the attention of BNI and marked for further investigation.

Soil Sampling

Surface soil samples were collected from 25 of the 31 excavated areas at the site. At remediated areas of greater than 10 m^2, five samples were collected from each 10 m^2 area and composited. Subsurface samples were collected from open pits and trenches.

Exposure Rate Measurements

Exposure rates were measured at locations where soil sampling was performed. Measurements were performed at the surface and at 1 m (3.3 ft) above the surface, using NaI gamma scintillation detectors, cross calibrated against a pressurized ionization chamber.

Background and Baseline Level Determinations

Soil samples were collected from 6 locations in the Albany area to provide baseline concentrations of radionuclides (Figure 18). Background exposure rates were measured at locations where baseline soil samples were collected. The background exposure rates and baseline radionuclide concentrations in soil are presented in Table 1. Exposure rates ranged from 7 to 11 μR/h at 1 m (3.3 ft) above the surface. Ra-226 concentrations in soil ranged from to 0.5 to 1.3 pCi/g; Th-232, 0.3 to 2.0 pCi/g; and U-238, 0.3 to 1.0 pCi/g. These levels are typical of those normally occurring in the environment.

Sample Analysis and Interpretation of Results

Samples and direct measurement data were returned to Oak Ridge, Tennessee, for analyses and interpretation. Smears for the determination of removable contamination were counted for gross alpha and beta activity. Soil and miscellaneous samples were analyzed by solid-state gamma spectrometry. Radionuclides of primary interest were Ra-226, Th-232, and U-238. Spectra were also reviewed for other identifiable photopeaks.

Findings of the inspections and radiological surveys were compared with the post-remedial action report prepared by BNI and the DOE guidelines established for this site (Appendix A). Major analytical equipment and procedures used for verification activities are described in Appendices B and C.

FINDINGS AND RESULTS

Document Review

A review of the characterization report and post-remedial action report, indicated that surveys and remedial actions were conducted in areas, where previous monitoring had indicated a probability of contamination, and at locations further defined by additional BNI surveys. Direct radiation levels and soil concentrations presented in the post-remedial action report were within the established guidelines for the ARC.

Confirmatory Sample Analyses

The results of confirmatory gamma spectrometry analyses on four BNI post-remedial action soil samples are summarized in Table 2. These samples were collected from Building 4, room 107 ("Owl Room"), and Building 31, room 14. Nine out of 12 data pairs were in agreement within their associated 99% confidence levels. A student T test, using Minitab statistical software, indicated that no difference exists between the means of paired data at the 95% confidence level; analysis of variance on paired Th-232 data yielded a correlation factor 0.7. Based on these comparison tests, it is ORAU's opinion that the BNI data are accurate, within the statistical limitations of the analytical procedures.

Building Surveys

Remedial actions were performed in 11 buildings at the ARC site. Verification surveys were performed by ORAU in all remediated areas, with exception of a small area behind the motor control center in Building 17, which was not accessible at the time of the survey visits. A verification survey performed in Building 23 indicated that residual contamination above guidelines remained in several remediated areas; there are continuing non-DOE related activities in this building, involving the use of low-level thorium containing sands, which hinder cleanup and survey. This building was therefore eliminated from consideration in this phase of the project. Remediations of Buildings 2, 19, and 27 are complete. In the other seven buildings remediations are only

partially complete and the remaining areas will be addressed during later project phases.

Results of the independent measurements and sampling, conducted by ORAU inside structures are presented below. Table 3 summarizes the results of surface activity measurements; concentrations of radionuclides in soil samples from beneath excavated floor areas are presented in Table 4. Gamma levels at 1 m above the floors, throughout surveyed building areas, were, with few exceptions, in the range of background (7 to 11 μR/h); levels were below 20 μR/h at all remediated locations.

Building 2

A contaminated sink drain was removed from room 105 (Figure 3). Gamma and beta-gamma scans were conducted in the vicinity of the remediated drain and throughout the remainder of room 105; no areas of elevated activity were noted. A direct measurement at the former drain area indicated total alpha and beta activity levels of 70 dpm/100 cm^2 and <390 dpm/100 cm^2, respectively. Removable activity for alpha and beta was 3 dpm/100 cm^2 and <6 dpm/100 cm^2, respectively.

Building 4

Remediated areas on the first floor were in rooms 104, 107, 108, and 109 (floor surfaces); rafters were cleaned in room 206 on the upper floor (Figures 4 and 5). Scans identified one small area of elevated beta-gamma levels on a door hinge in room 107; the total beta-gamma activity on this area was 5800 dpm/100 cm^2. On other building surfaces total alpha activity levels ranged from <34 to 180 dpm/100 cm^2, and total beta-gamma levels ranged from <370 to 910 dpm/100 cm^2. Removable alpha and beta activity levels were <3 to 5 dpm/100 cm^2 and <6 dpm/100 cm^2, respectively.

Independent analyses of two BNI-collected soil samples from the drainline excavation in rooms 107 and 108 were performed by ORAU (see Table 2). Radionuclide concentrations were in the ranges of baseline soils.

Building 5

Remediations in Building 5 were limited to several areas in the Machine Shop (Figure 6). A portion of the floor and lower wall area of the Machine Shop was gridded (Figure 7). Scans in this room did not identify any areas of residual activity. Direct measurements indicated total alpha activity, ranging from <50 to 390 dpm/100 cm^2, and beta-gamma activity ranging from <390 to 2700 dpm/100 cm^2. The location of highest beta-gamma measurement (2700 dpm/100 cm^2) was on a small (<100 cm^2) area near the east floor/wall interface; a beta-gamma measurement of 1800 dpm/100 cm^2 was recorded on a narrow window sill also on the east wall. Removable activity levels ranged from <3 to 5 dpm/100 cm^2, alpha, and <6 to 6 dpm/100 cm^2, beta.

Four soil samples from floor excavations contained radionuclide levels in the ranges of baseline soil (Table 4).

Building 19

The floor area where a contaminated hood was removed (Figure 8) was scanned and activity levels measured. Surface scans did not identify any residual activity; total alpha activity ranged from <34 to 40 dpm/100 cm^2 and beta-gamma activity was <370 dpm/100 cm^2. Removable alpha and beta activity levels were <3 dpm/100 cm^2 and <6 dpm/100 cm^2, respectively.

Building 27

Initial scans of room 102 (Figures 9 and 10) identified residual contamination on the floor in the southwest corner and on the lower west wall. Additional remediation, performed on these areas, reduced direct levels to within guidelines. Total activity measurements in rooms 102 and 102A after the further cleanup ranged from <40 dpm/100 cm^2 to 120 dpm/100 cm^2 for alpha and from <460 to 1000 dpm/100 cm^2 for beta-gamma. No removable activity was observed on smears.

Soil samples were collected from a drainline excavation in room 102 and from the crawl space beneath the southeast and southwest corners of the building. Radionuclide concentrations in the samples from the drainline

(Table 4) were in the ranges of baseline soil. Concentrations in samples collected from the crawl space in October 1987 (#3 and #5) were elevated (above baseline levels) for Ra-226, Th-232, and U-238. Resampling (#4 and #6) in April 1989 still indicated elevated levels; with the sample from the southeast corner containing the higher concentrations of 43.0 pCi/g, Ra-226; 13.0 pCi/g, Th-232; and 21.1 pCi/g, U-238. This sample was obtained from the location of maximum direct gamma measurement, identified during a scan of the crawlspace.

Building 28

Surface scans did not identify any areas of residual contamination in the remediated Building 28 corridor (Figure 11). Total alpha activity levels ranged from <40 to 160 dpm/100 cm^2, and total beta-gamma levels ranged from <460 to 1200 dpm/100 cm^2. The only location exceeding 1000 dpm/100 cm^2 was a small spot on the floor, in the southwest corner of the hallway to Room 15. There was no detectable removable activity in this area.

Building 29

Two contaminated sink drains were removed from Building 29 (Figure 12). The areas around these sinks, the rooms (109 and 111) and two adjacent rooms (108 and 110) were surveyed. Scans identified one area of elevated direct activity on the lower wall, above the drain in room 111. This area had a direct beta-gamma level of 5700 dpm/100 cm^2. Measurements at other locations ranged from <20 to 140 dpm/100 cm^2, alpha, and from <420 to 770 dpm/100 cm^2, beta-gamma.

Building 30

Ductwork and filters were removed in the Fabrication Room mezzanine; rafters and beams were vacuumed; and contaminated soil was removed from an area adjacent to a press in the Fabrication Room (Figure 13). Scans did not identify any areas of residual activity. Direct alpha measurements ranged from <20 to 60 dpm/100 cm^2; direct beta-gamma measurements ranged from <340 to 600 dpm/100 cm^2. Removable activity ranges were: alpha, <3 to 5 dpm/100 cm^2, and beta, <6 to 9 dpm/100 cm^2.

Two soil samples from beneath the press contained radionuclide concentrations in the ranges of baseline soils (Table 4).

Building 31

Rooms 1, 14, and 15 were remediated in Building 31 (Figures 14, 15, and 16). Verification surveys were performed in rooms 1 and 14. Scans did not identify any locations of residual activity. Direct alpha measurements ranged from <20 to 120 dpm/100 cm^2, and beta-gamma measurements ranged from <390 to 1200 dpm/100 cm^2. There were two locations on the lower north wall of Room 1 with total activity levels of 1200 dpm/100 cm^2 beta-gamma. No significant removable activity was present.

Three soil samples were collected from the excavated area in room 1. One of these samples contained 6.5 pCi/g of Th-232 and 6.1 pCi/g of U-238; other samples had concentrations in the ranges of baseline soil (Table 4). Two BNI samples from room 14 were obtained for confirmatory analyses. These samples also contained baseline levels of activity.

Outdoor Surveys

A total of 31 outdoor areas were remediated by BNI; ORAU conducted independent surveys on a majority of these areas. Results of these surveys are presented in Tables 5 and 6.

Surface Scans

Gamma scans were performed in 25 remediated areas and over property immediately adjacent to remediations to verify the adequacy of removal. Several small areas of residual contamination were identified and brought to the attention of BNI. Additional cleanup was conducted and followup scans confirmed the effectiveness of this further action.

Exposure Rates

Table 5 summarizes results of exposure rate measurements in remediated areas. Levels ranged from 7 to 22 μR/h at 1 m (3.3 ft) and from 8 to 19 μR/h

at contact with the surface. General gamma levels, recorded in non-remediated areas during the scanning, ranged from 7 to 13 μR/h at surface contact.

Radionuclide Concentrations in Soil

Levels of radionuclides, measured in soil samples from remediated areas, are summarized in Table 6. Radium 226 concentrations ranged from <0.1 to 13 pCi/g; Th-232, <0.2 to 11 pCi/g; and U-238, <0.5 to 42 pCi/g. With few exceptions the concentrations were in the ranges of baseline soil. No gamma emitting nuclides, other than those that are naturally occurring, were noted in any of the samples.

COMPARISON OF RESULTS WITH GUIDELINES

Building Surveys

Based on samples from the various facilities, it was determined by BNI and ANL that natural thorium is the limiting radionuclide contaminant, present on surfaces of buildings, remediated during this phase of the project.[1,3,4,5] The applicable guidelines for thorium contamination are: 1000 dpm/100 cm^2, average over 1 m^2; 3000 dpm/100 cm^2, maximum in any 100 cm^2 area; and 200 dpm/100 cm^2, removable. It was noted during initial surveys that alpha radiation levels were not representative of the true surface activity, because the alpha particles were being attenuated due to porous and dusty conditions of the surfaces; some surfaces had also been painted, thus preventing detection of the alpha emissions. As a result, beta-gamma activity levels were used as the measure of compliance with guidelines.

Building surveys identified seven locations, where surface activity exceeded 1000 dpm/100 cm^2. These locations are listed in Table 7. Five of these areas were small enough that averaging across the adjacent 1 m^2 of surface resulted in an average value of less than the 1000 dpm/100 cm^2 guideline. The hinge in Building 4 was removed and cleaned; followup scans indicated levels were indistinguishable from background. The wall/floor

interface in Building 29 was identified as an area of residual contamination in the Characterization Report and will be addressed during future remediation.[5]

Two buildings also had associated soil contamination above the 5 pCi/g levels for Ra-226 and Th-232 in surface soil. The samples from the crawlspace under Building 27 represented the maximum levels in small areas (<1 m^2), based on gamma surface scans; these concentrations therefore satisfy the "hot spot" criteria of 50 pCi/g average over 1 m^2, and averaging with the adjacent soil beneath the crawlspace would result in satisfying the guidelines, relative to 100 m^2. One sample from the floor excavation in room 1 of Building 31 contained slightly more than 5 pCi/g of Th-232; however, this area was backfilled making the location subsurface and thereby satisfying the 15 pCi/g guideline level.

Exposure rates inside buildings were all well below 29 μR/h (20 μR/h above average background of 9 μR/h) and therefore this guideline is met.

Outdoor Surveys

Exposure rates throughout the property were near the range of normal background levels, with a maximum of 22 μR/h (13 μR/h above background). Based on a reasonable occupancy scenario it would not be possible for an individual on this property to exceed the basic dose limit of 100 mrem/year.

Six soil samples contained Ra-226 and/or Th-232 concentrations in excess of 5 pCi/g but less than 15 pCi/g. Because these sample areas were from excavations that have been backfilled, the 15 pCi/g level is applicable. In addition, the concentrations, when averaged over the adjacent 100 m^2 area, would be less than these maximum values. The soil concentration guidelines are therefore satisfied.

CONCLUSION

During the period of August 1987 to April 1989, Oak Ridge Associated Universities' Environmental Survey and Site Assessment Program conducted activities to independently verify the adequacy of FUSRAP remedial actions at the Albany Research Center. The verification activities included document

review, confirmatory laboratory analyses, visual inspections, and independent direct measurements and sample analysis.

Independent surveys identified several locations of residual contamination in both indoor and outdoor locations. These areas were brought to the attention of BNI; either further cleanup was performed, where activity exceeded guidelines, or the locations were noted for future attention. It should be noted that additional areas of residual contamination still exist in most of the buildings and that these areas will be addressed during later phases of the project. Based on the results and findings of the verification, it is ORAU's opinion that remedial actions have been effective in satisfying the established DOE guidelines and the documentation supporting the remedial action process is adequate and accurate. A verification letter to that effect has been provided to the Department of Energy's Division of Facility and Site Decommissioning.[6]

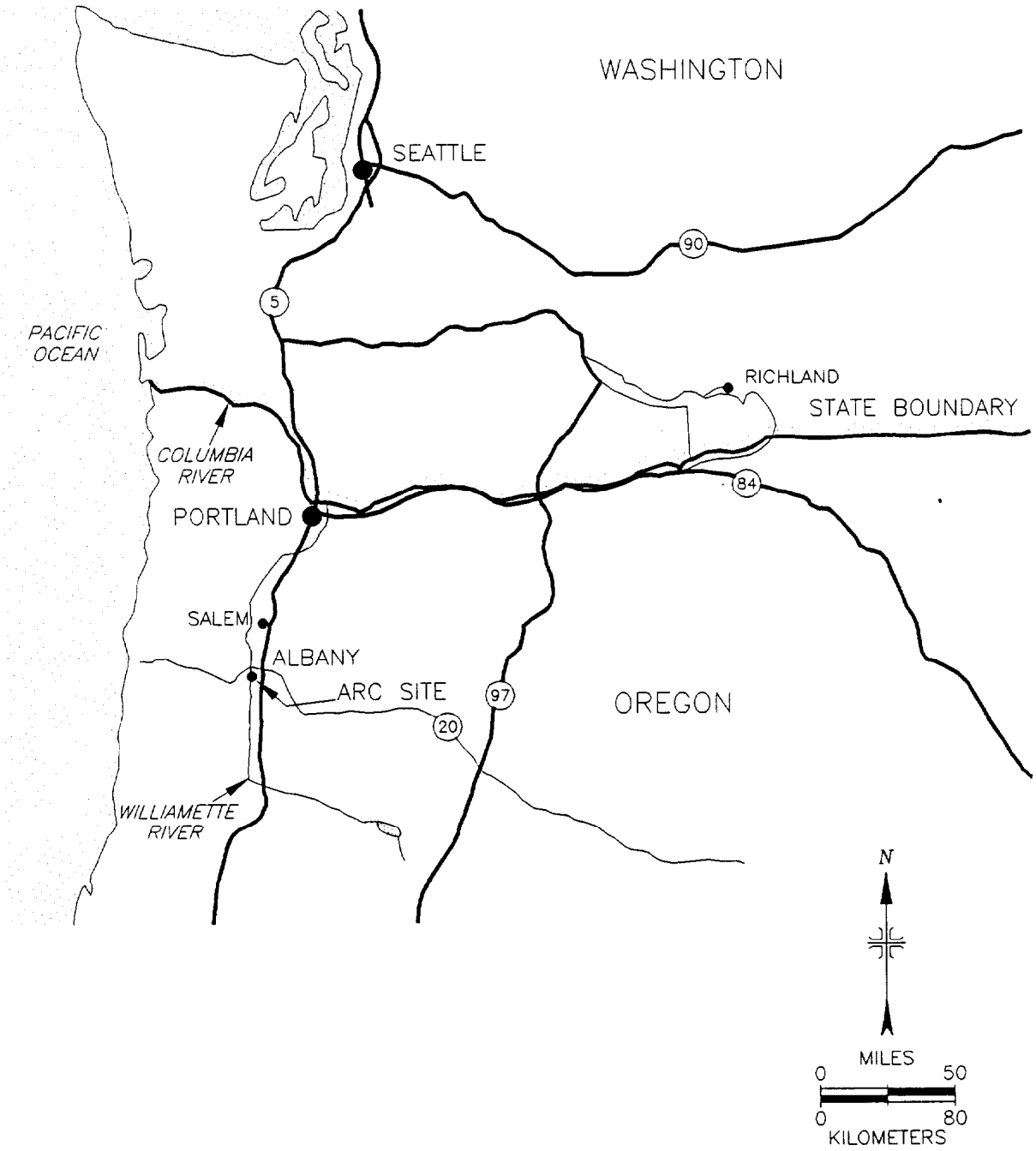

FIGURE 1: Location of the Albany Research Center

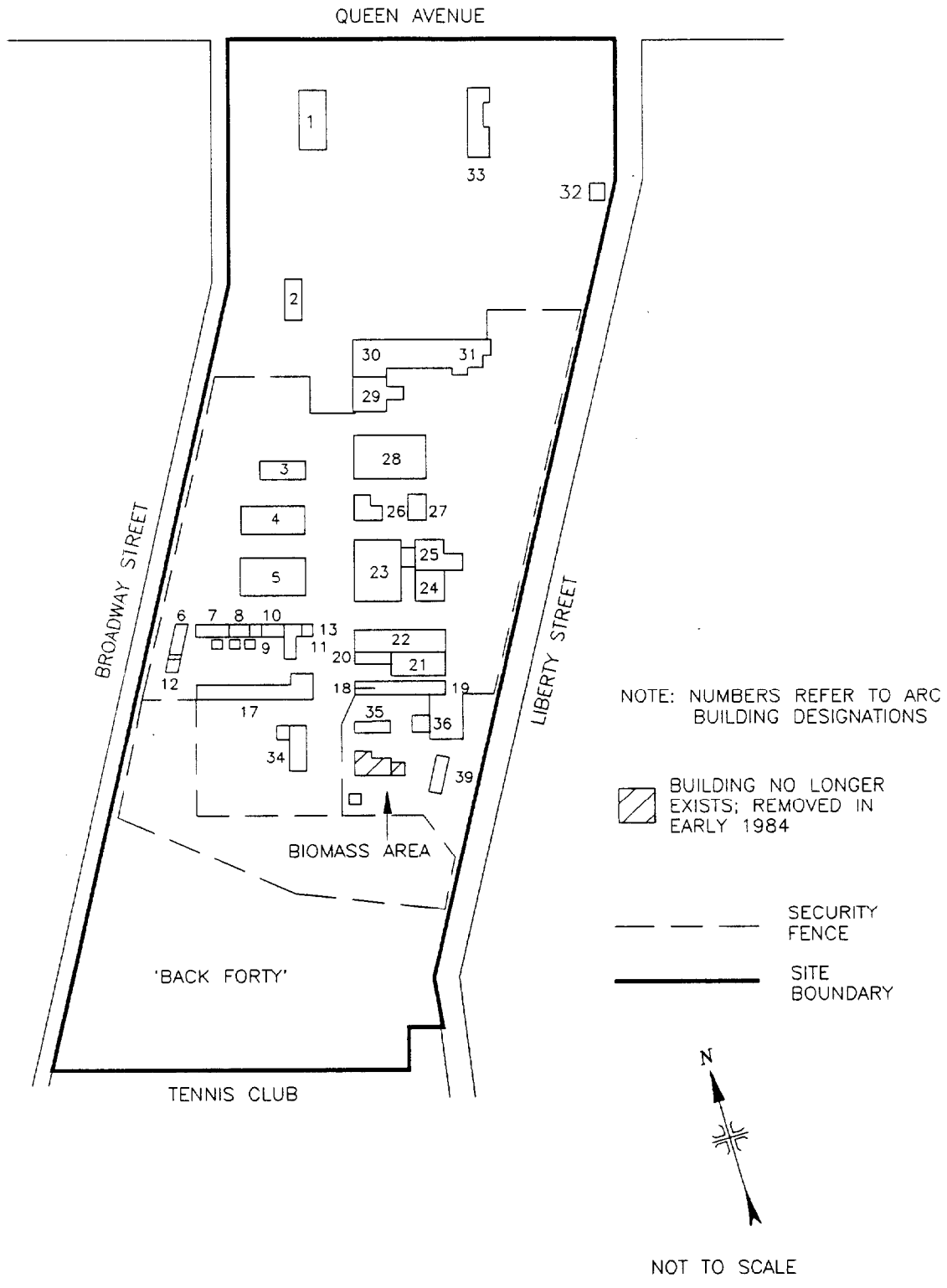

FIGURE 2: Plot Plan of the Albany Research Center

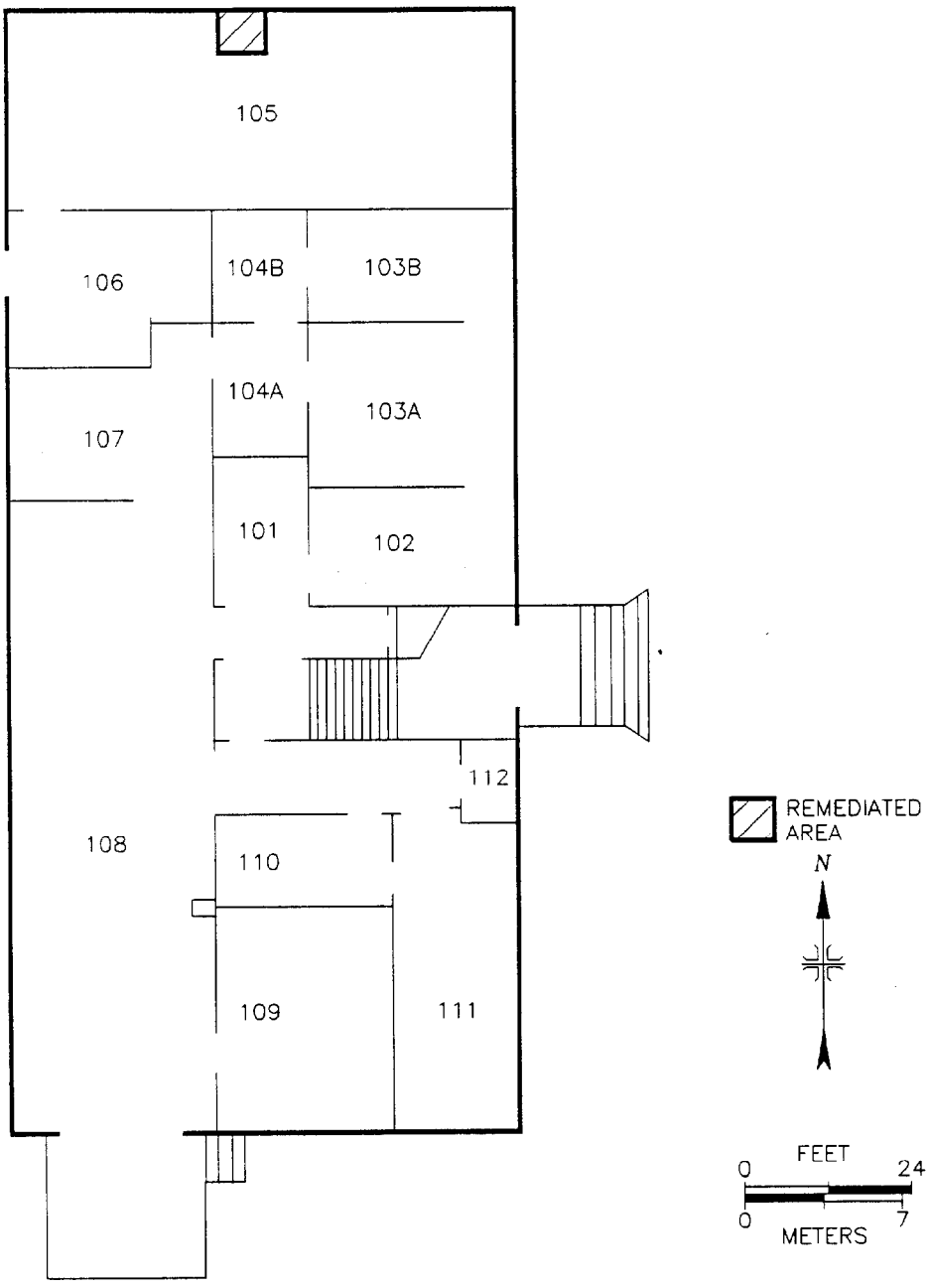

FIGURE 3: Layout of Building 2, Indicating Location of Remedial Action

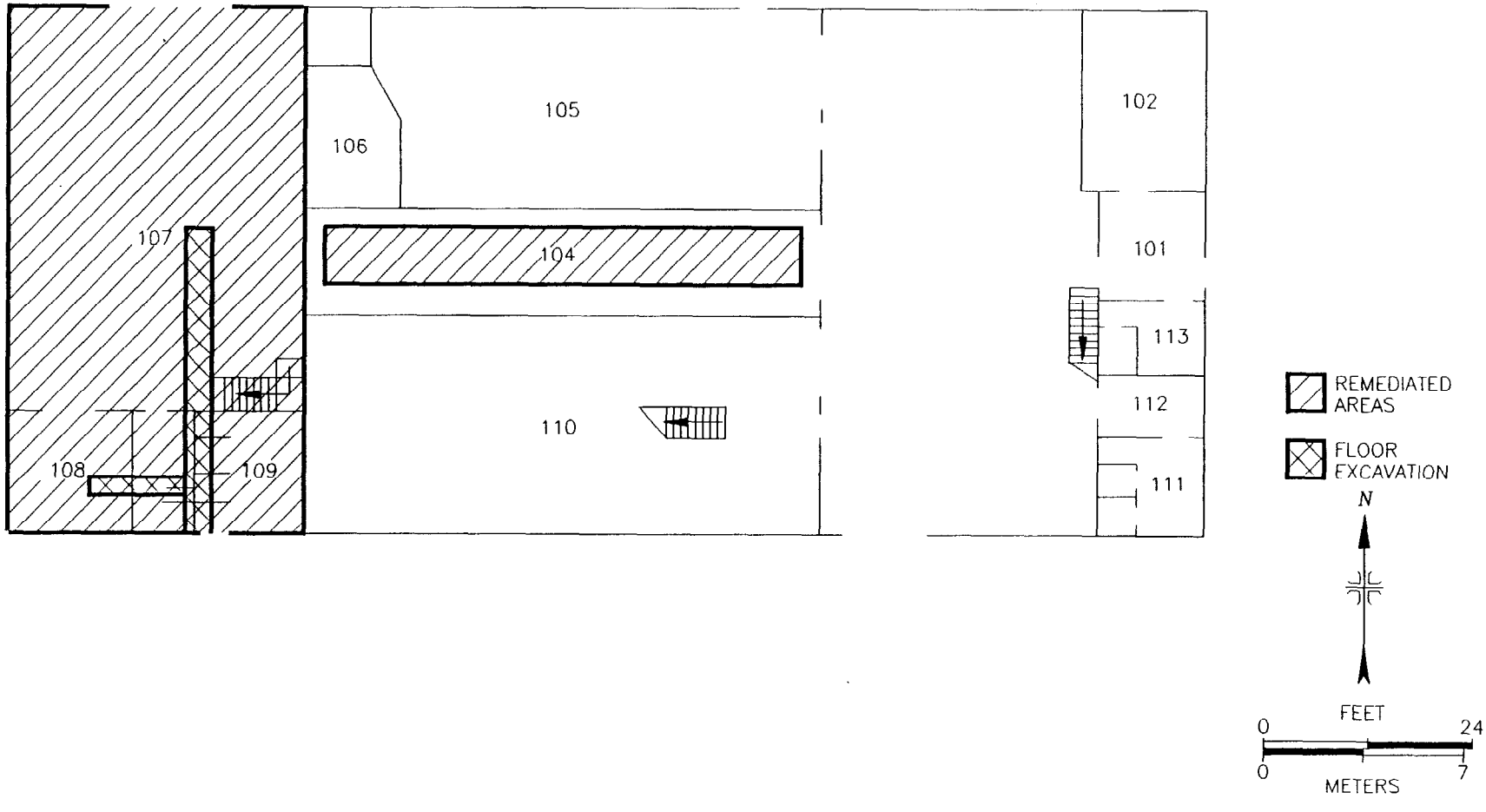

FIGURE 4: Layout of First Floor, Building 4, Indicating Locations of Remedial Action

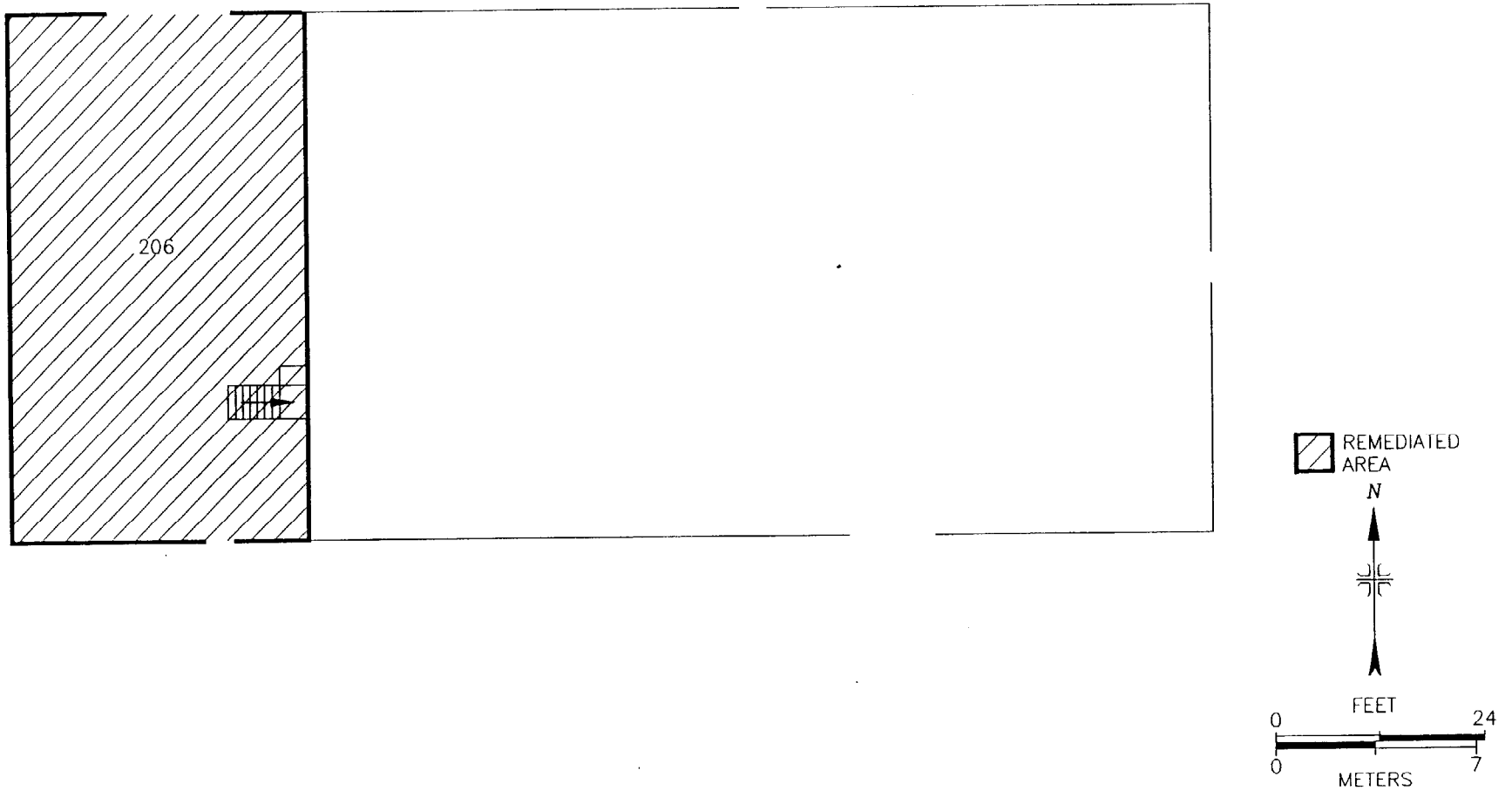

FIGURE 5: Layout of Second Floor, Building 4, Indicating Location of Remedial Action

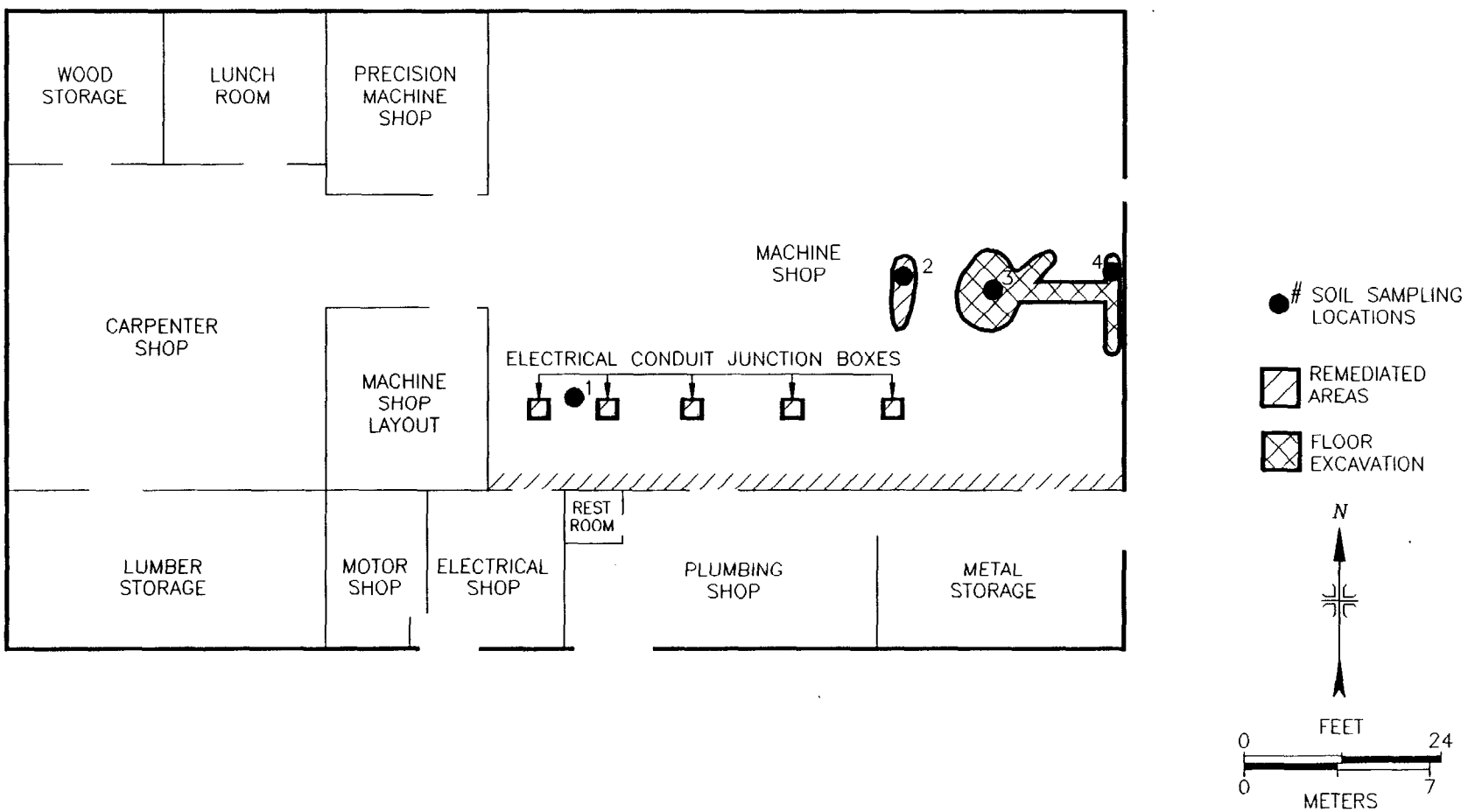

FIGURE 6: Layout of Building 5, Indicating Locations of Remedial Action

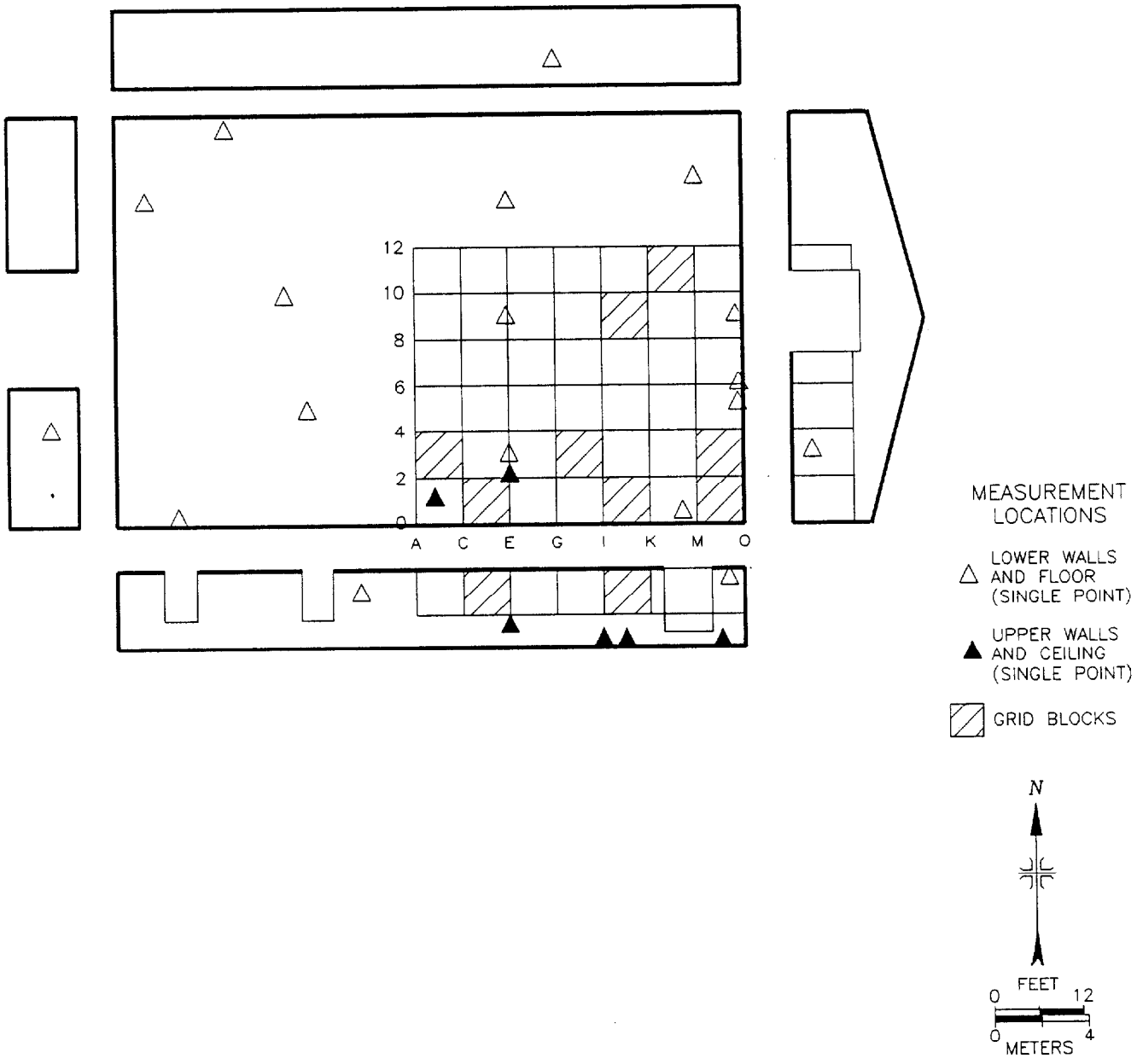

FIGURE 7: Layout of Machine Shop, Building 5, Indicating Measurement Locations

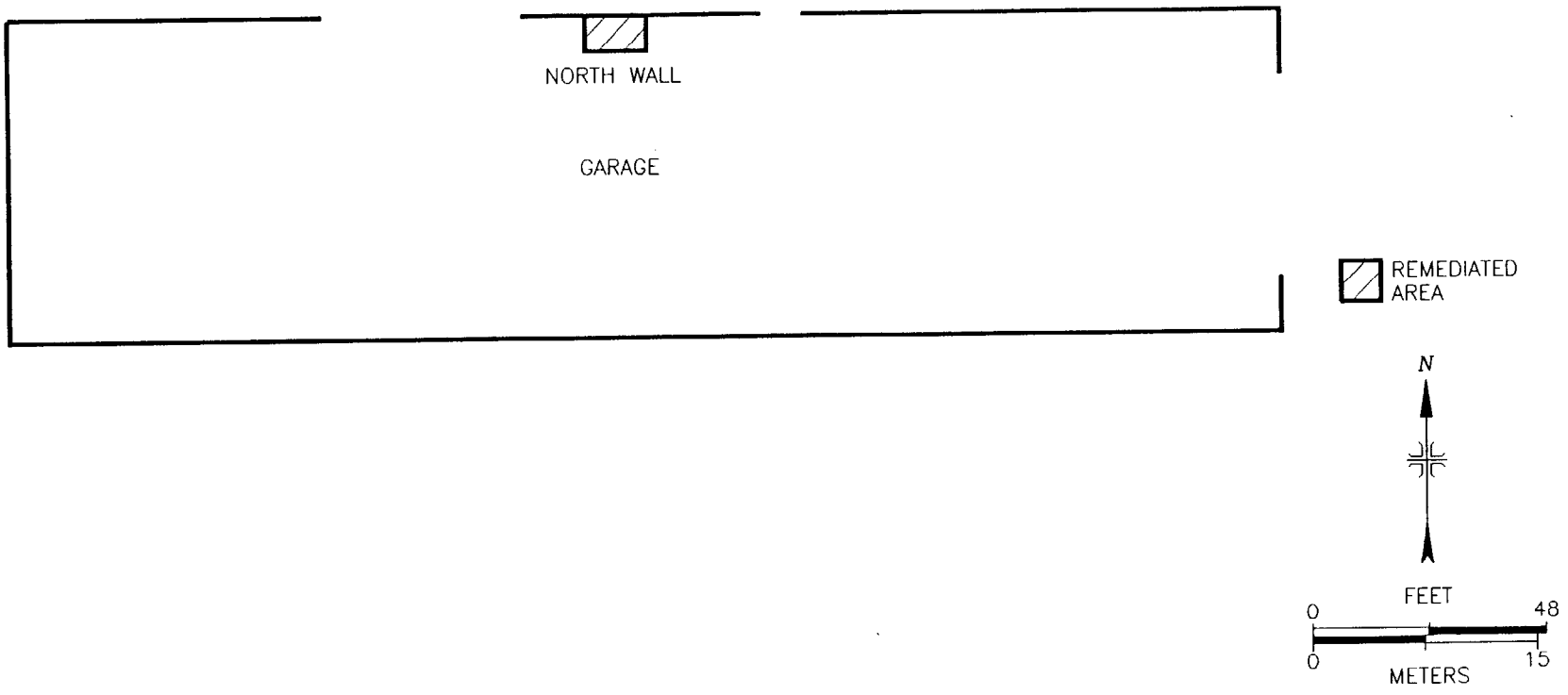

FIGURE 8: Layout of Building 19, Indicating Location of Remedial Action

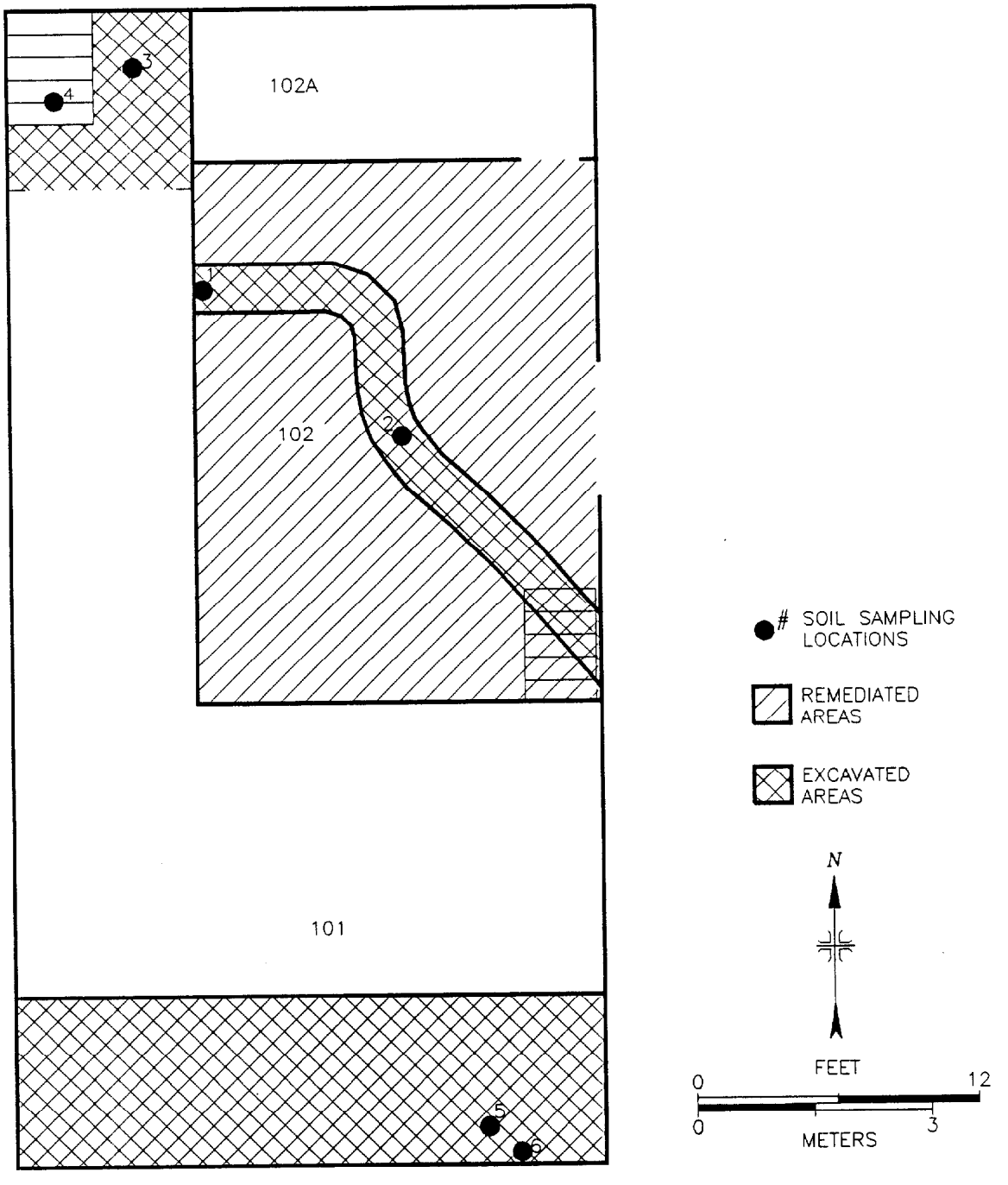

FIGURE 9: Layout of Building 27, Indicating Locations of Remedial Action

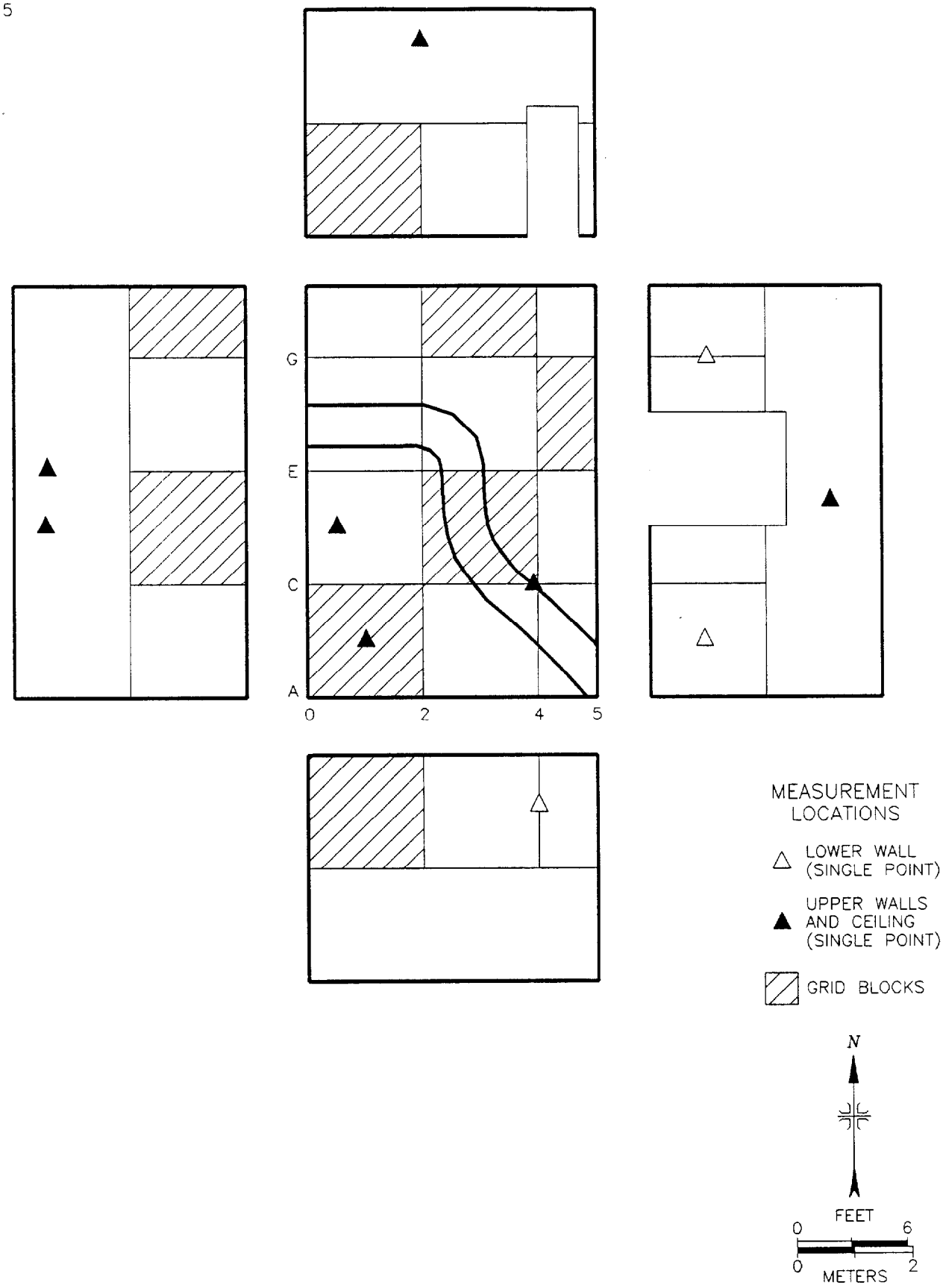

FIGURE 10: Room 102, Building 2, Indicating Reference Grid and Measurement Locations

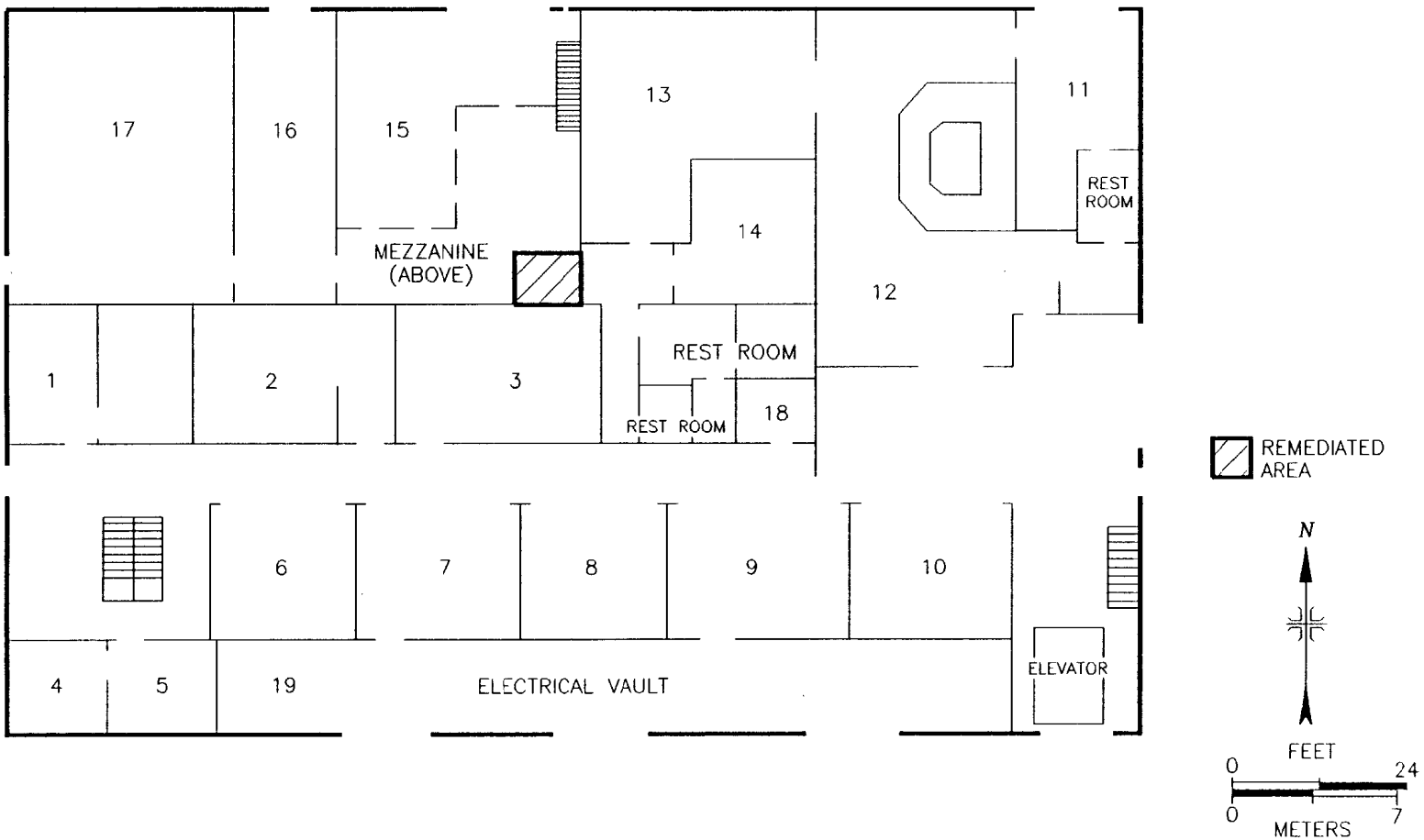

FIGURE 11: Layout of Building 28, Indicating Location of Remediated Area

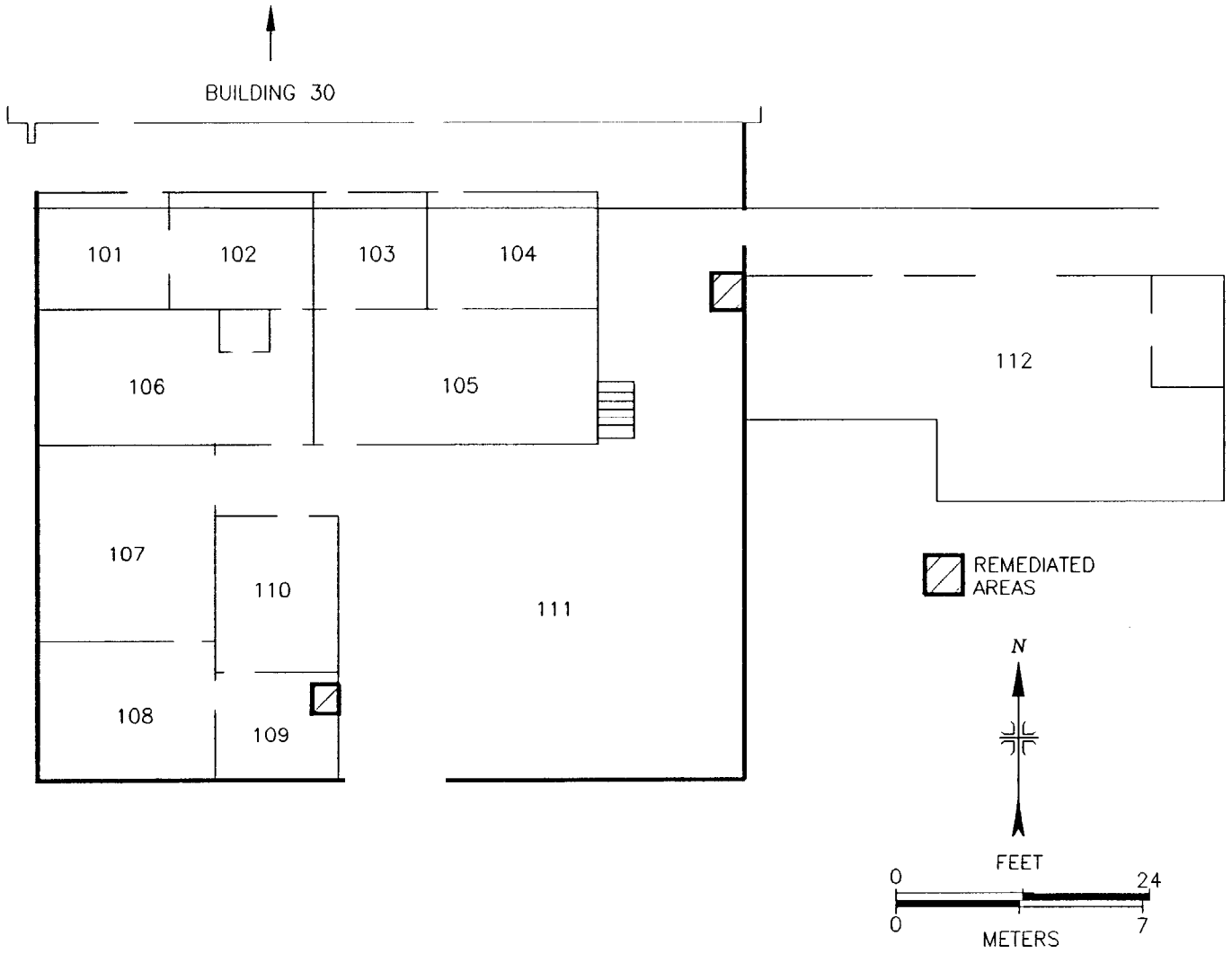

FIGURE 12: Layout of Building 29, Indicating Locations of Remediated Areas

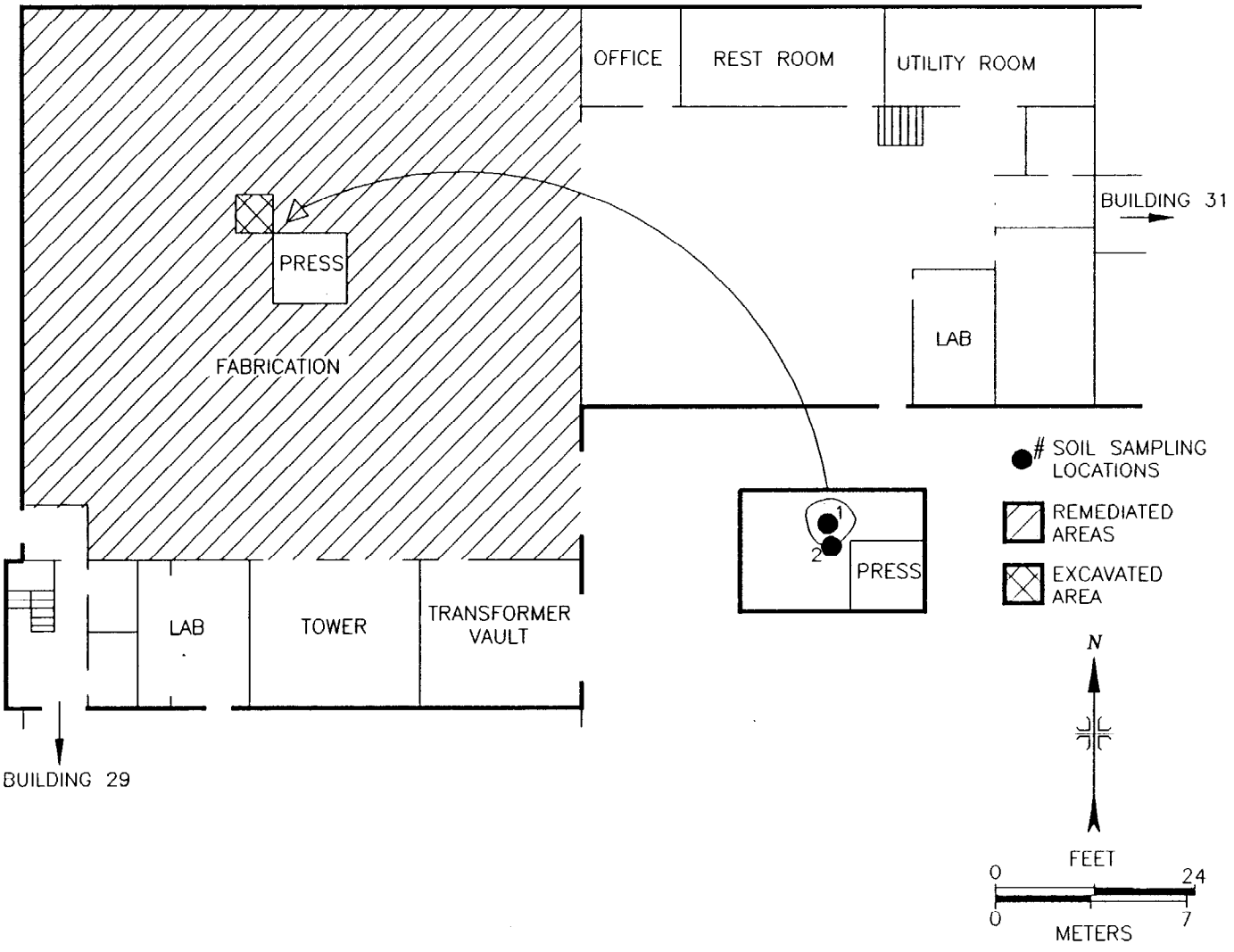

FIGURE 13: Layout of Building 30, Indicating Remediated Areas

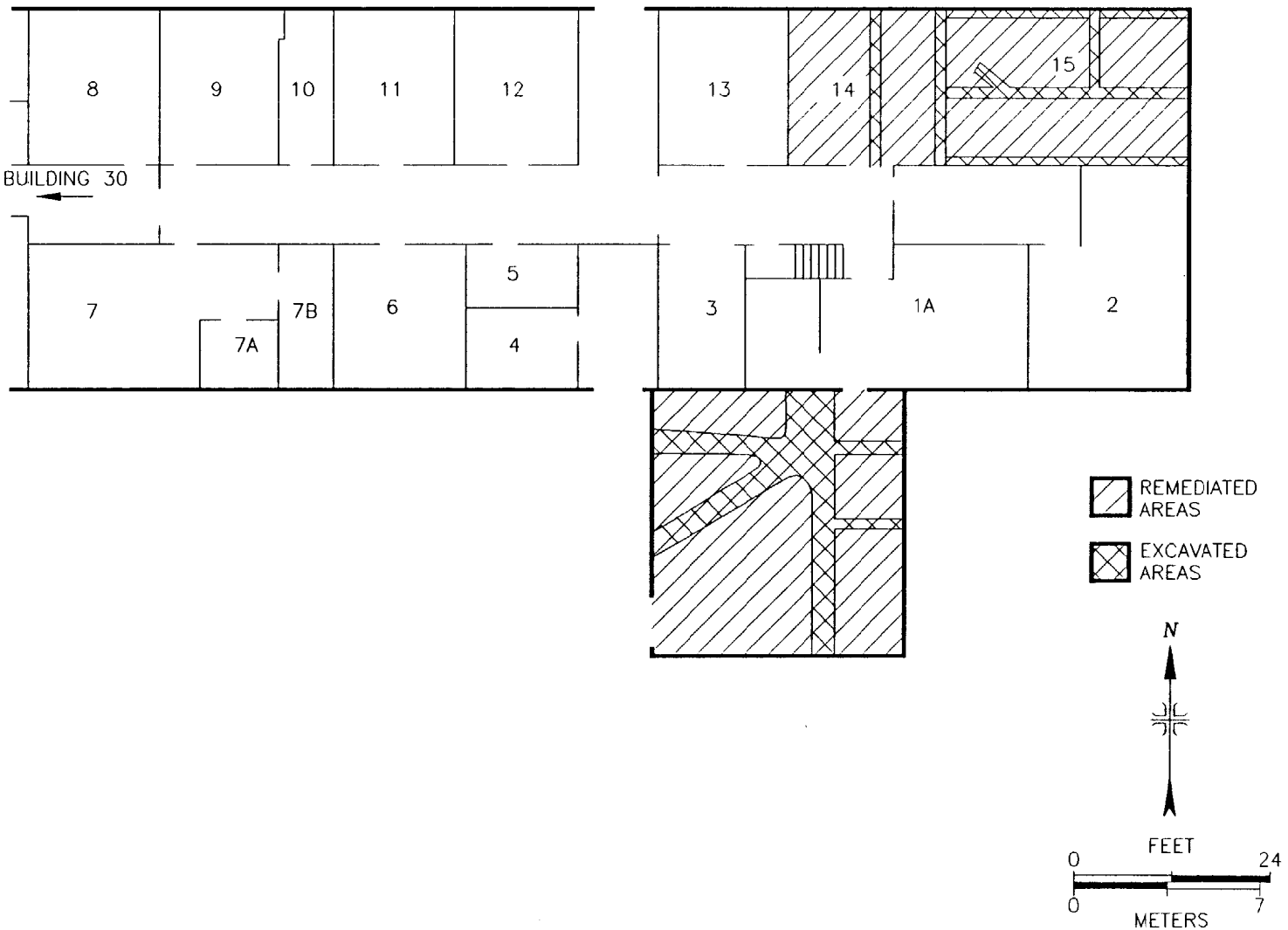

FIGURE 14: Layout of Building 31, Indicating Remediated Areas

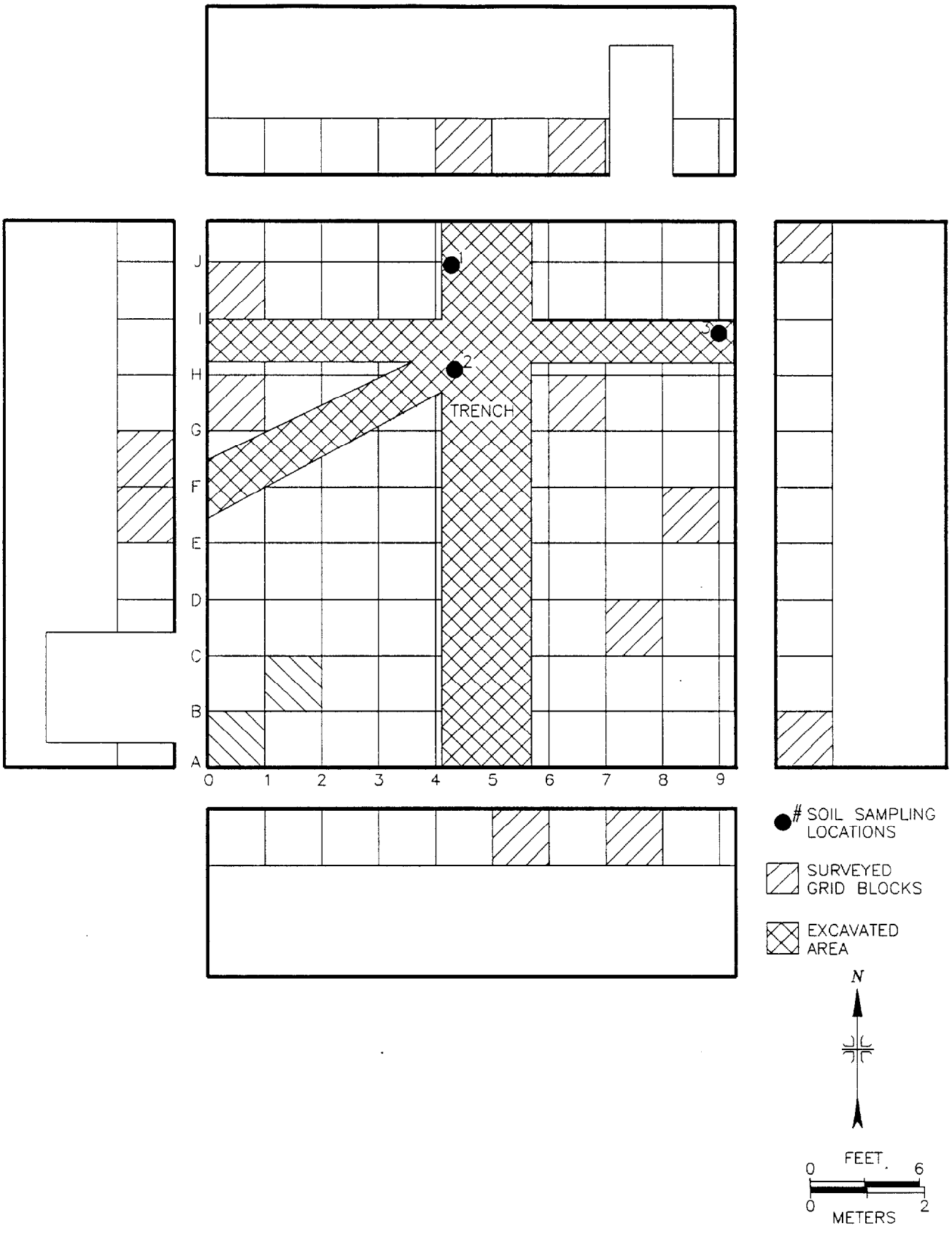

FIGURE 15: Layout of Room 1, Building 31, Indicating Soil Sampling and Measurement Locations

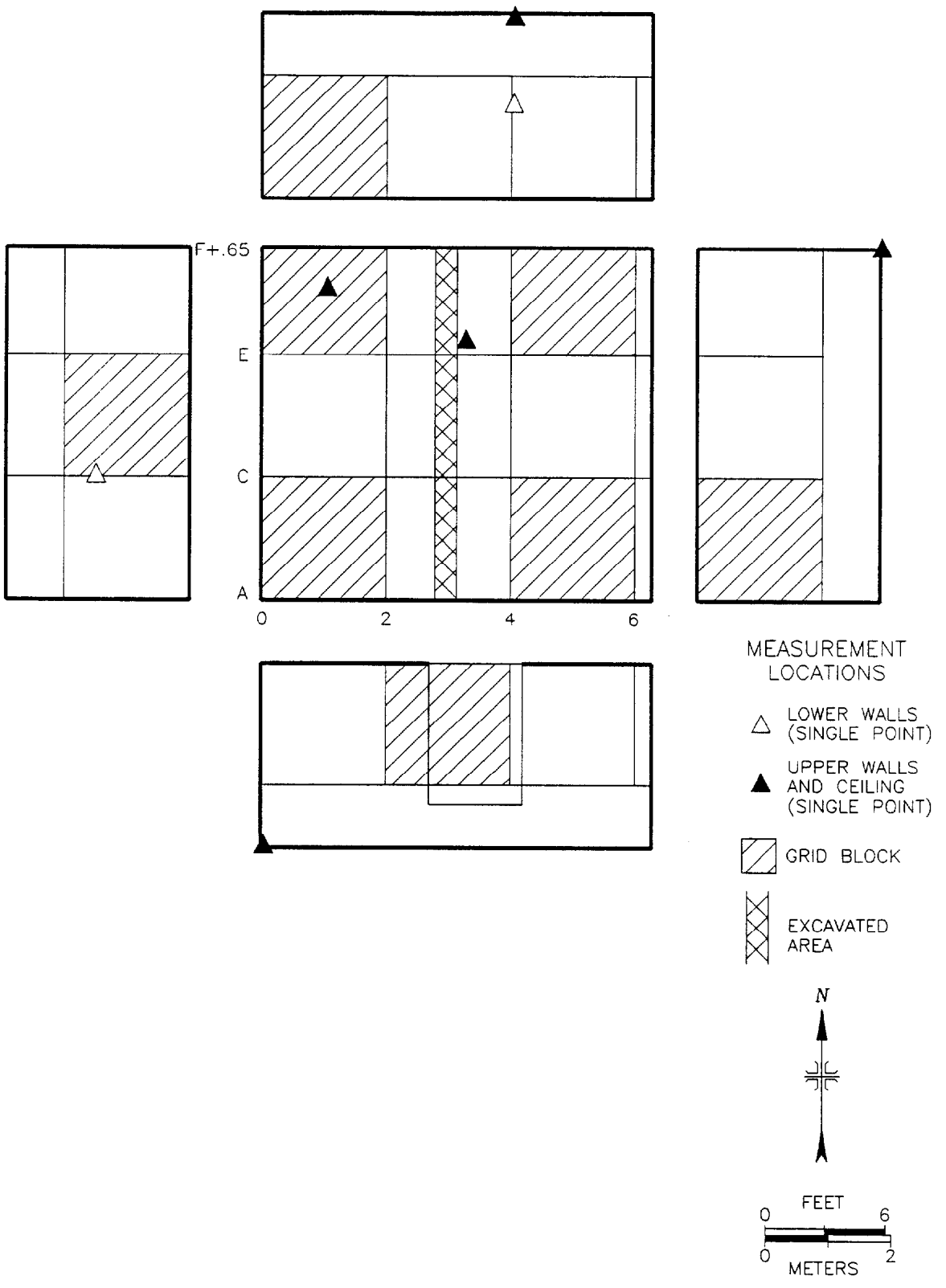

FIGURE 16: Layout of Room 14, Building 31, Indicating Measurement Locations

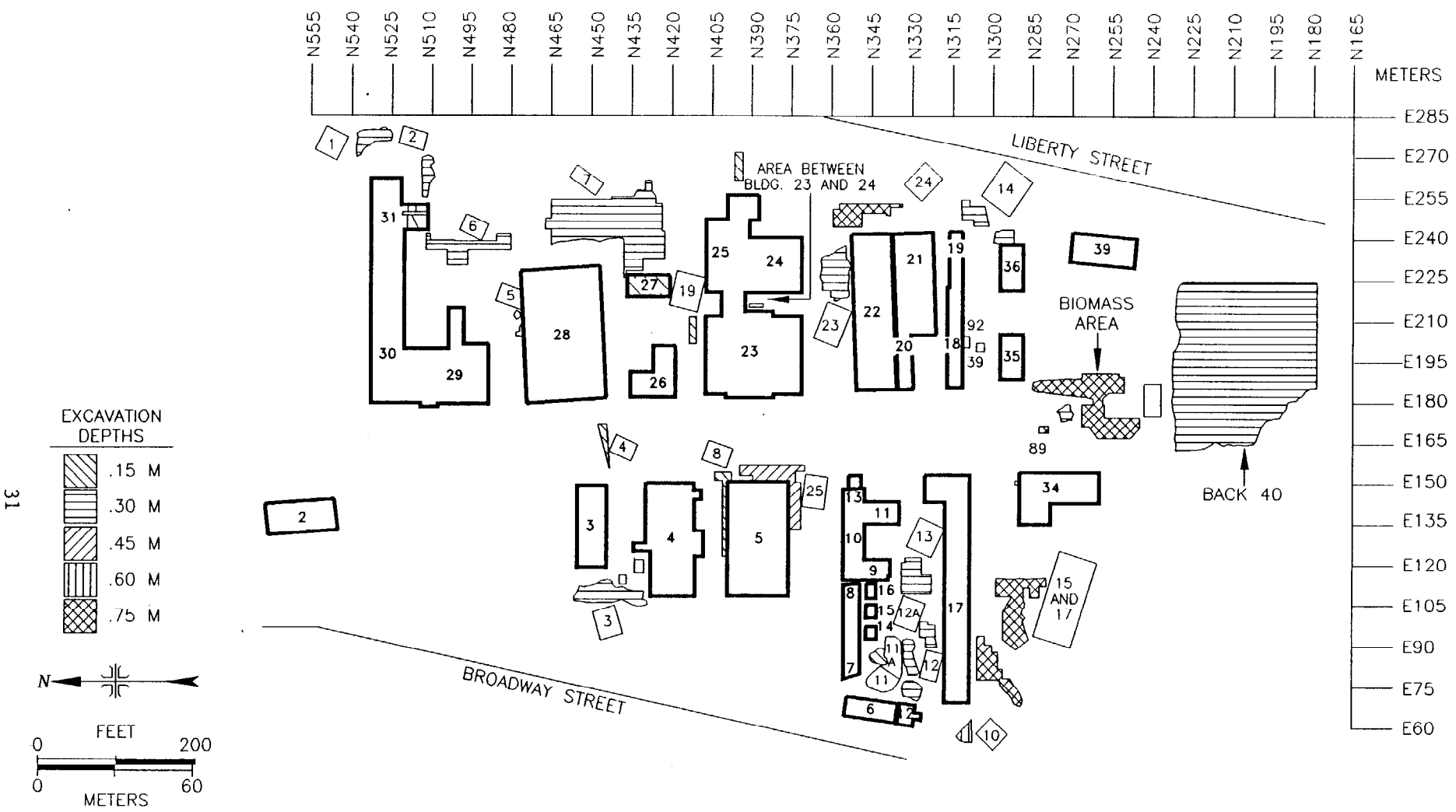

FIGURE 17: Site Layout, Indicating Locations of Remediated Soil Areas, Survey Reference Grid, and Surveyed Locations

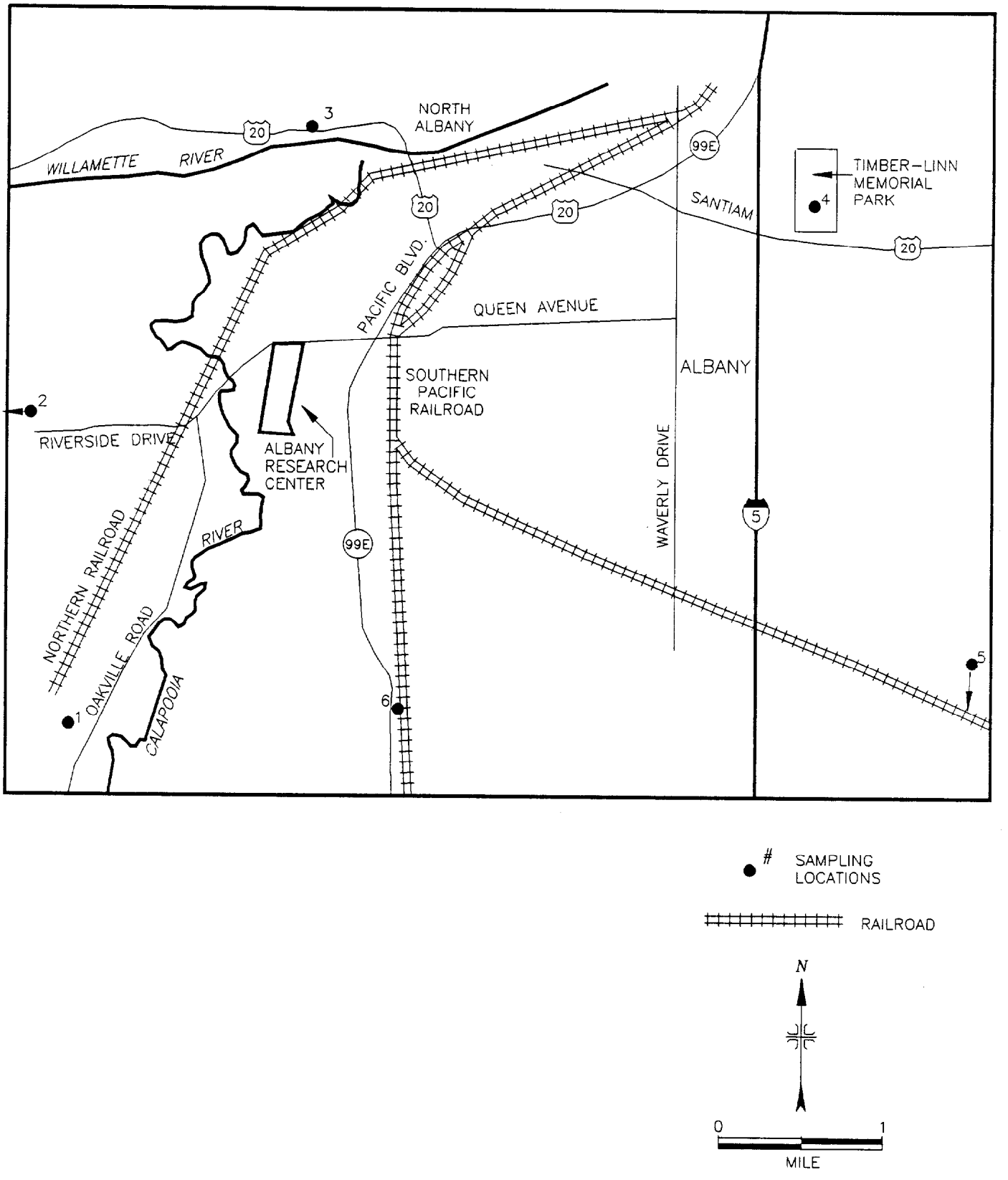

FIGURE 18: Map of the Albany Area, Indicating Background Sampling and Measurement Locations

TABLE 1

BASELINE RADIATION LEVELS AND
BASELINE RADIONUCLIDE CONCENTRATIONS IN SOIL
ALBANY RESEARCH CENTER
ALBANY, OREGON

Location[a]	Exposure Rate (μR/h) at 1 m above ground surface	Radionuclide Concentrations (pCi/g)		
		Ra-226	Th-232	U-238
1	9	0.6 ± 0.1[b]	0.6 ± 0.2	0.4 ± 0.7
2	10	1.1 ± 0.1	1.1 ± 0.2	<0.6
3	7	0.5 ± 0.5	0.4 ± 0.4	1.0 ± 1.0
4	8	0.5 ± 0.1	0.3 ± 0.2	0.3 ± 0.5
5	10	1.3 ± 0.1	1.3 ± 0.2	<0.7
6	11	1.0 ± 0.1	2.0 ± 0.7	0.9 ± 0.2
Range	7 to 11	0.5 to 1.3	0.3 to 2.0	0.3 to 1.0
Average	9.2	0.83	0.95	0.65

[a]Refer to Figure 18.
[b]Uncertainties represent the 95% confidence levels, based only on counting statistics; additional laboratory uncertainties of ± 6 to 10% have not been propagated into these data.

TABLE 2

RESULTS OF CONFIRMATORY ANALYSES ON SOIL SAMPLES
ALBANY RESEARCH CENTER
ALBANY, OREGON

Location	Sample Identification[a]		Radionuclide Concentrations (pCi/g) Ra-226	Th-232	U-238
Building 4	North/South Trench	BNI	1.5 ± 0.6[b]	1.4 ± 0.9	<0.4
		ORAU	0.5 ± 0.2	0.7 ± 0.2	1.0 ± 0.3
	East/West Trench	BNI	1.4 ± 0.9	1.0 ± 1.2	<0.5
		ORAU	0.8 ± 0.2	1.1 ± 0.2	<0.6
Building 31	Room 14	BNI	1.0 ± 0.3	1.7 ± 0.6	<0.6
		ORAU	0.5 ± 0.2	1.0 ± 0.3	0.7 ± 0.5
	Room 14	BNI	0.7 ± 0.3	3.0 ± 1.5	<0.6
		ORAU	0.6 ± 0.2	1.4 ± 0.3	2.1 ± 0.6

[a]Sample identification as presented in the BNI post-remedial action report.
[b]Uncertainties represent the 99% confidence levels, based only on counting statistics; additional laboratory uncertainties of ± 6 to 10% have not been propagated into these data.

TABLE 3

SUMMARY OF SURFACE ACTIVITY MEASUREMENTS
ALBANY RESEARCH CENTER
ALBANY, OREGON

Building Number[a]	Room	Sample Location	Number of Measurements		Total Activity Range (dpm/100 cm^2)		Removable Activity Range (dpm/100 cm^2)	
			Grid Blocks	Single Pts	Alpha	Beta-Gamma	Alpha	Beta
2	105	Drain- N. Wall		1	70	<390	3	<6
4	104	Floor		10	<34 - 70	<370 - 720	<3 - 5	<6
		Lower Wall		3	<34	<370	<3	<6
		Upper Wall		1	<34	460	<3	<6
4	107	Upper Wall		5	<34 - 110	<370 - 910	<3 - 3	<6
		Door Hinge		1	-	5800[b]	<3	<6
4	108	Upper Wall		1	<34	<370	<3	<6
4	109	Shower Drain		1	<34	<370	<3	<6
4	206	Upper Wall		2	79 - 180	<370	<3 - 3	<6
		Floor		1	80	<370	5	<6
5	Machine Shop	Floor	8	13	<50 - 60	<390 - 2700[b]	<3 - 5	<6 - 6
		Lower Wall	2	5	<50 - 390	<390 - 1800[b]	<3 - 3	<6
		Upper Wall/Ceiling		6	<50 - 180	<390 - 720	<3	<6
19	-	Floor		2	<34 - 40	<370	<3	<6
27	102	Floor	5		<40	<460	<3	<6
		Lower Wall	4	3	<40 - 80	<460	<3	<6
		Upper Wall		7	<40 - 100	<460 - 1000	<3 - 3	<6 - 6
	102A	Floor		4	<40 - 120	<460	<3	<6 - 6
		Lower Wall		4	<40 - 70	<460	<3	<6 - 7

TABLE 3 (Continued)

SUMMARY OF SURFACE ACTIVITY MEASUREMENTS
ALBANY RESEARCH CENTER
ALBANY, OREGON

Building Number[a]	Room Number	Sample Location	Number of Measurements		Total Activity Range (dpm/100 cm^2)		Removable Activity Range (dpm/100 cm^2)	
			Grid Blocks	Single Pts	Alpha	Beta-Gamma	Alpha	Beta
28	15	Floor		5	<40 - 160	<460	<3	<6
		Lower Wall		4	<40 - 40	<460 - 1200[b]	<3	<6
29	108	Floor		2	<20 - 20	<420	<3	<6 - 6
		Lower Wall		2	<20	<400	<3	<6 - 6
	109	Floor			<40 - 140	<460	<3	<6 - 14
	110	Floor		2	<20 - 30	<420	<3	<6
		Lower Wall		1	30	<420	<3	<6
	111	Floor		6	<20 - 40	<420 - 770	<3	<6
		Lower Wall		4	30 - 40	<420 - 5700[c]	<3 - 3	<6 - 12
30	Press Room Fuel Fab	Under Press Floor		5	<50	<400	<3	<6
	Press Room	Floor		7	<20 - 60	<400 - 530	<3 - 5	<6
		Lower Walls		7	<20 - 50	<340 - 600	<3 - 3	<6 - 9
31	1	Floor	7		<20	<390 - 500	<3	<6
		Lower Walls	8		<20	<390 - 1200[b]	<3	<6
	14	Floor	5		35 - 70	<480	<3 - 3	<6 - 6
		Lower Wall	4	2	44 - 120	<480 - 720	<3	<6 - 6
		Upper Wall		5	<25 - 60	<480	<3	<6 - 8

[a]Refer to Figures 3 to 16.
[b]Refer to Table 7 for resolution.
[c]Further remediation performed.

TABLE 4

RADIONUCLIDE CONCENTRATIONS IN SUBFLOOR SOIL
ALBANY RESEARCH CENTER
ALBANY, OREGON

Building	Location[a]		Radionuclide Concentrations (pCi/g) Ra-226	Th-232	U-238
5	1		<0.2	1.4 ± 0.4[b]	<0.8
	2		0.3 ± 0.3	1.4 ± 0.5	0.9 ± 1.1
	3		<0.2	1.3 ± 0.4	<0.8
	4		<0.2	1.3 ± 0.4	<0.8
27	1		0.4 ± 0.1	0.5 ± 0.2	<0.4
	2		0.6 ± 0.2	0.8 ± 0.3	<0.7
	3	October 1987	2.5 ± 0.2	8.2 ± 0.4	6.4 ± 1.4
	4	April 1989	1.8 ± 0.1	4.3 ± 0.3	2.9 ± 0.8
	5	October 1987	16.0 ± 0.4	6.1 ± 0.4	5.6 ± 3.3
	6	April 1989	43.0 ± 0.6	13.0 ± 0.5	21.0 ± 1.1
30	1		<0.2	0.7 ± 0.6	0.9 ± 1.1
	2		0.6 ± 0.3	0.9 ± 0.4	<0.6
31	1		0.9 ± 0.3	6.5 ± 0.9	6.1 ± 2.2
	2		0.7 ± 0.2	2.1 ± 0.5	2.0 ± 1.2
	3		<0.2	0.7 ± 0.4	<0.8

[a]Refer to Figures 6,9,13 and 15.
[b]Uncertainties represent the 95% confidence levels, based only on counting statistics; additional laboratory uncertainties of ± 6 to 10% have not been propagated into these data.

TABLE 5

GAMMA EXPOSURE RATE MEASUREMENTS
ALBANY RESEARCH CENTER
ALBANY, OREGON

Area/Location[a]	Grid Location		Exposure Rate (μR/h)	
	N	E	Contact	1 m above surface
1	539	275	13	11
	541	275	13	11
	537	277	10	11
	539	277	11	11
	533	279	10	10
	535	279	10	11
	537	279	10	10
	539	279	10	10
	529	281	10	12
	533	281	10	12
	535	281	10	10
	537	281	10	10
	539	281	10	10
	527	283	10	12
	529	283	10	12
	533	283	10	10
	535	283	10	10
	537	283	10	10
	527	285	10	10
	529	285	10	10
	531	287	10	12
	531	289	10	10
2	512	261	13	12
	512	263	12	12
	512	265	13	12
	511	267	16	15
	512	267	18	13
	511	269	13	13
	512	269	16	13
	511	271	13	12
	512	271	13	12
	512	273	13	11
	511	275	12	12
	512	275	13	11
	511	278	11	10
3	450	114	12	12
	451	114	12	10
	437	115	13	13
	450	116	15	13

TABLE 5 (Continued)

GAMMA EXPOSURE RATE MEASUREMENTS
ALBANY RESEARCH CENTER
ALBANY, OREGON

Area/Location[a]	Grid Location		Exposure Rate (μR/h)	
	N	E	Contact	1 m above surface
3 (Cont'd)	452	116	13	13
	444	117	10	12
	446	117	13	12
	450	118	13	12
	450	119	10	10
	490	120	13	13
	453	126	11	10
	431	115	10	11
	440	115	10	10
	445.5	115	19	10
	426	116	11	10
	437	116	10	10
	427	117	11	10
	429	117	11	11
	434	117	10	10
	436	117	9	10
	438	117	12	10
	440	117	12	10
	441	117	12	10
	445	117	12	10
	447	117	12	12
	451	117	13	10
	439	118	13	10
	428	119	11	10
	439.5	119	13	12
	435	120	12	10
	442	120	13	10
	449	120	10	10
	438	122	12	10
4	442	166	10	10
	442	168	11	11
	442	170	11	10
	443	175	11	10
	442	177	11	10
	443	177	10	10
5	475	195	11	9
	475	210	9	9
	475	215	10	9

TABLE 5 (Continued)

GAMMA EXPOSURE RATE MEASUREMENTS
ALBANY RESEARCH CENTER
ALBANY, OREGON

Area/Location[a]	Grid Location		Exposure Rate (μR/h)	
	N	E	Contact	1 m above surface
6	497	239	9	10
	499	239	9	10
	501	239	10	9
	503	239	10	10
	497	241	9	9
	499	241	9	10
	501	241	10	9
	503	241	10	9
	481	243	13	11
	483	243	13	11
	485	243	10	10
	487	243	10	10
	489	243	10	11
	493	243	10	10
	495	243	10	10
	497	243	11	10
	499	243	10	10
	501	243	11	10
	503	243	11	10
	505	243	11	10
	507	243	10	10
	509	243	11	11
	511	243	10	11
	491	244	11	11
	481	245	11	10
	483	245	11	10
	485	245	11	11
	491	245	11	11
	501	245	11	10
	505	245	11	11
	511	245	10	11
	481	247	10	10
	483	247	10	10
	485	247	10	9
7	435	235	9	9
	425	240	10	9
	430	240	9	9
	435	240	9	9
	425	245	9	9

TABLE 5 (Continued)

GAMMA EXPOSURE RATE MEASUREMENTS
ALBANY RESEARCH CENTER
ALBANY, OREGON

Area/Location[a]	Grid Location		Exposure Rate (μR/h)	
	N	E	Contact	1 m above surface
7 (Cont'd)	430	245	9	8
	435	245	9	8
	465	245	11	10
	425	250	9	9
	430	250	9	9
	435	250	9	8
	440	250	9	8
	445	250	9	9
	450	250	9	8
	455	250	9	9
	460	250	9	9
	465	250	9	9
	425	255	9	9
	430	255	9	9
	435	255	9	9
	440	255	9	9
	445	255	9	9
	450	255	9	9
	455	255	11	9
	460	255	14	9
	465	255	10	10
	425	261	9	9
	430	261	9	9
	435	261	9	10
	440	261	9	9
	445	261	9	9
	450	261	9	9
	455	261	9	9
	460	261	9	9
	465	261	11	9
	430	265	9	9
	430	269	11	11
9	410	211	11	11
	411	219	11	10
11	324	92	10	9
	325	103	11	8
11A	325	82	10	9
	324	86	9	9

TABLE 5 (Continued)

GAMMA EXPOSURE RATE MEASUREMENTS
ALBANY RESEARCH CENTER
ALBANY, OREGON

Area/Location[a]	Grid Location		Exposure Rate (μR/h)	
	N	E	Contact	1 m above surface
12	316	103	11	8
	316	108	11	8
12A	336	97	11	9
13	320	125	11	9
	328	129	10	9
14	291	249	11	11
	295	252	11	10
	298	254	11	10
	305	256	11	10
	305	260	11	10
	310	266	10	10
15	284	99	11	11
	285	106	11	11
	285	109	12	10
	290	110	13	13
	284	113	11	11
	290	115	12	10
16	282	81	11	11
	285	86	11	10
	289	89	11	11
	295	89	11	10
	299	92	11	9
	295	92	11	10
	293	97	12	10
	299	97	10	10
	295	100	11	11
	297	105	13	11
17	286	120	11	10
	280	122	13	13
	290	122	13	12
	277	124	12	13
	274	125	10	10
	275	125	13	12

TABLE 5 (Continued)

GAMMA EXPOSURE RATE MEASUREMENTS
ALBANY RESEARCH CENTER
ALBANY, OREGON

Area/Location[a]	Grid Location		Exposure Rate (μR/h)	
	N	E	Contact	1 m above surface
17 (Cont'd)	280	125	11	12
	294	125	12	12
	287	126	13	13
	288	126	12	12
23	356	227	11	11
	364	232	10	10
	354	238	11	10
	358	238	11	10
	354	242	13	10
24	350	256	10	9
	360	257	10	9
	335	263	10	10
	350	264	10	10
25	371	143	10	10
	368	146	10	10
	370	148	10	10
	371	150	11	10
	368	152	11	11
	370	155	11	11
	371	157	12	12
	369	159	11	11
	370	160	11	11
	377	160	13	11
	385	160	13	9
	369	164	10	10
	392	164	13	8
	372	165	10	9
	380	165	10	10
	388	165	10	7
	366	166	11	10
	375	166	11	9
	382	166	9	10
	391	166	10	10

TABLE 5 (Continued)

GAMMA EXPOSURE RATE MEASUREMENTS
ALBANY RESEARCH CENTER
ALBANY, OREGON

Area/Location[a]	Grid Location		Exposure Rate (μR/h)	
	N	E	Contact	1 m above surface
Sewer Line Excavation North of Bldg. 5	410	110	11	10
	406	115	9	10
	405	125	11	11
	405	130	11	11
	405	135	11	11
	405	140	11	11
	405	145	11	11
	405	150	11	10
	405	155	11	10
	398	160	11	10
	405	160	11	10
Near Bldgs. 23, 24, & 25	389.5	223	9	9
	385.5	224	9	10
	387.5	224.5	9	9
	394.5	271	8	8
	394.5	273.5	8	8
	395	276.5	8	8
	395	279.5	9	8
Biomass Area	276	181	12	13
	250	182	10	10
	276	184	16	22
	261	186	10	10
	241	187	12	10
	271	189	10	10
	269	191	10	10
	255	192	12	11
	248	198	12	11
	265	198	12	10
	281	198	11	11
	271	200	15	13
	256	202	11	10
Back 40	215	185	10	10
	195	205	12	11
	180	210	10	10
	190	210	12	12
	195	210	10	10
	200	210	12	12
	205	210	12	12

TABLE 5 (Continued)

GAMMA EXPOSURE RATE MEASUREMENTS
ALBANY RESEARCH CENTER
ALBANY, OREGON

Area/Location[a]	Grid Location		Exposure Rate (μR/h)	
	N	E	Contact	1 m above surface
Back 40 (Cont'd)	210	210	13	12
	215	210	12	12
	220	210	13	13
	225	210	12	12
	230	210	12	12
	190	215	10	11
	195	215	12	12
	200	215	13	13
	205	215	13	13
	210	215	14	13
	215	215	13	14
	220	215	16	13
	225	215	13	13
	230	215	13	13
	190	220	11	11
	195	220	12	12
	200	220	12	12
	205	220	13	13
	210	220	15	15
	215	220	13	15
	220	220	15	15
	225	220	14	15
	230	220	13	13
	190	225	11	11
	195	225	13	12
	200	225	12	12
	205	225	12	12
	210	225	13	13
	215	225	15	15
	220	225	15	15
	225	225	13	14
	230	225	11	12
	190	230	12	13
	195	230	12	12
	200	230	13	13
	205	230	15	14
	210	230	13	13
	215	230	12	13
	220	230	16	15

TABLE 5 (Continued)

GAMMA EXPOSURE RATE MEASUREMENTS
ALBANY RESEARCH CENTER
ALBANY, OREGON

Area/Location[a]	Grid Location		Exposure Rate (μR/h)	
	N	E	Contact	1 m above surface
Back 40 (Cont'd)	225	230	15	13
	230	230	12	12
	190	235	11	11
	195	235	12	11
	200	235	13	12
	205	235	12	12
	210	235	13	12
	215	235	13	13
	220	235	15	15
	225	235	14	15
	230	235	13	13
	180	240	11	10
	190	240	11	10
	195	240	12	12
	200	240	12	12
	205	240	12	12
	210	240	12	13
	215	240	13	13
	220	240	13	13
	225	240	13	13
	230	240	14	13

[a]Refer to Figure 17.

TABLE 6

RADIONUCLIDE CONCENTRATIONS IN OUTDOOR SOIL
ALBANY RESEARCH CENTER
ALBANY, OREGON

Area[a]	Location	Depth[b] (cm)	Radionuclide Concentrations (pCi/g) Ra-226	Th-232	U-238
1	Composite		0.9 ± 0.2[c]	1.7 ± 0.3	<1.0
2	Composite		0.8 ± 0.3	1.8 ± 0.6	<0.8
	513N, 270E		13.0 ± 0.4	7.9 ± 0.6	42 ± 2
	310N, 70E		12.0 ± 0.8	0.8 ± 0.9	13 ± 2
3	Composite Sec A		1.2 ± 0.2	3.6 ± 0.4	<1.4
	Composite Sec B		0.9 ± 0.4	4.1 ± 0.7	<0.9
	Composite Sec C		0.9 ± 0.2	11 ± 0.7	<2.1
	Composite Sec A		0.8 ± 0.3	1.4 ± 0.4	1.7 ± 0.7
	Composite Sec B		1.0 ± 0.3	2.2 ± 0.5	<0.9
	Composite Sec C		0.9 ± 0.2	1.7 ± 0.6	<0.6
	Composite Sec D		<0.6	5.5 ± 1.4	<3.1
	Composite Sec E		0.9 ± 0.3	4.3 ± 0.6	<0.8
	Composite Sec F		0.9 ± 0.3	3.6 ± 0.6	<1.1
4	Composite		0.9 ± 0.2	2.3 ± 0.7	<0.7
5	475N, 205E		0.8 ± 0.1	2.9 ± 0.3	<0.7
	Composite		0.5 ± 0.1	2.2 ± 0.4	<0.9
6	Composite Sec A		0.9 ± 0.3	2.9 ± 0.7	4.0 ± 1.9
	Composite Sec B		0.6 ± 0.2	6.3 ± 0.5	3.0 ± 1.5
	Composite Sec C		0.7 ± 0.3	2.7 ± 0.6	1.8 ± 1.3
	Composite Sec D		0.6 ± 0.1	3.0 ± 0.3	<1.2
	490N, 237E		1.0 ± 0.2	10.0 ± 0.5	20 ± 2
7	465N, 261E		0.6 ± 0.1	3.8 ± 0.3	<1.3
	455N, 261E		0.6 ± 0.1	0.8 ± 0.2	<0.5
	445N, 261E		0.5 ± 0.1	0.8 ± 0.2	<0.7
	435N, 261E		0.6 ± 0.1	1.8 ± 0.2	<0.6
	425N, 261E		1.6 ± 0.2	2.3 ± 0.4	6.4 ± 1.2
	460N, 250E		0.8 ± 0.1	3.4 ± 0.3	<0.8
	450N, 250E		0.4 ± 0.1	1.1 ± 0.2	<0.7
	440N, 250E		0.7 ± 0.1	3.2 ± 0.4	5.4 ± 1.2
	430N, 250E		0.8 ± 0.2	<0.3	<0.8
	435N, 455E		1.6 ± 0.1	1.6 ± 0.2	4.6 ± 0.7
	430N, 240E		0.8 ± 0.1	<0.3	<0.9
	435N, 235E		3.9 ± 0.3	1.2 ± 0.2	<0.8
	430N, 265E		1.1 ± 0.3	4.1 ± 0.4	4.0 ± 1.2

TABLE 6 (Continued)

RADIONUCLIDE CONCENTRATIONS IN OUTDOOR SOIL
ALBANY RESEARCH CENTER
ALBANY, OREGON

Area[a]	Location	Depth (cm)	Radionuclide Concentrations (pCi/g) Ra-226	Th-232	U-238
9	Location #1		1.2 ± 0.2	1.0 ± 0.3	4.9 ± 1.5
	Location #2		1.3 ± 0.3	1.1 ± 0.7	1.2 ± 0.7
11A	324N, 86E		<0.5	<0.7	<1.9
	325N, 82E		0.8 ± 0.2	1.1 ± 0.5	2.8 ± 1.6
11	325N, 103E		0.9 ± 0.3	1.0 ± 0.4	<0.8
	324N, 92E		<0.2	<0.3	<0.8
12	316N, 108E		1.5 ± 0.3	1.3 ± 0.7	1.2 ± 1.8
	316N, 103E		1.1 ± 0.3	1.3 ± 0.4	2.0 ± 1.5
12A	336N, 97E		1.0 ± 0.2	1.0 ± 0.4	<0.8
13	320N, 125E		1.0 ± 0.3	1.1 ± 0.4	9.3 ± 1.1
	328N, 129E		1.3 ± 0.2	0.8 ± 0.8	0.4 ± 0.6
14	Composite		0.7 ± 0.2	1.2 ± 0.4	<0.8
16	Composite Sec A		0.9 ± 0.2	1.1 ± 0.5	<0.6
	Composite Sec B		0.7 ± 0.2	0.8 ± 0.4	<0.7
	Composite Sec C		1.3 ± 0.3	1.2 ± 0.4	1.9 ± 0.6
15 & 17	Composite Sec A		1.1 ± 0.2	2.1 ± 0.5	0.7 ± 1.5
	Composite Sec B		1.1 ± 0.2	1.7 ± 0.4	<0.5
	Composite Sec C		0.9 ± 0.2	0.5 ± 0.6	<0.8
	Composite Sec D		1.1 ± 0.2	1.2 ± 0.4	1.1 ± 1.0
	Composite Sec E		0.9 ± 0.3	1.2 ± 0.4	<0.5
23	Composite		0.6 ± 0.2	0.6 ± 0.3	<0.4
24	Composite		1.3 ± 0.3	1.1 ± 0.4	<0.9
25	Composite Sec A		1.0 ± 0.2	0.7 ± 0.4	1.6 ± 0.7
	Composite Sec B		0.8 ± 0.2	1.9 ± 0.6	0.7 ± 1.4
	Composite Sec C		0.7 ± 0.2	0.7 ± 0.4	1.0 ± 0.5
	Composite Sec D		0.8 ± 0.2	0.8 ± 0.5	<0.6
	Composite Sec E		0.6 ± 0.2	1.2 ± 0.4	<0.6
	Composite Sec F		0.6 ± 0.2	1.0 ± 0.4	<0.7

TABLE 6 (Continued)

RADIONUCLIDE CONCENTRATIONS IN OUTDOOR SOIL
ALBANY RESEARCH CENTER
ALBANY, OREGON

Area[a]	Location	Depth (cm)	Radionuclide Concentrations (pCi/g) Ra-226	Th-232	U-238
Sewer Excavation Between Bldgs. 4 & 5					
	405N, 160E		1.0 ± 0.2	1.3 ± 0.5	0.4 ± 0.8
	405N, 55E		0.9 ± 0.2	1.2 ± 0.5	1.3 ± 1.1
	405N, 150E		0.8 ± 0.3	<0.3	0.5 ± 1.7
	405N, 45E		0.8 ± 0.3	1.2 ± 0.5	1.3 ± 0.9
	405N, 140E		1.1 ± 0.2	1.3 ± 0.4	0.7 ± 1.3
	405N, 135E		0.8 ± 0.3	1.0 ± 0.4	<0.7
	405N, 130E		0.8 ± 0.2	1.2 ± 0.5	0.6 ± 0.5
	405N, 125E		1.1 ± 0.2	1.0 ± 0.5	<0.8
	405N, 115E		0.7 ± 0.2	0.7 ± 0.4	<0.6
	405N, 110E		0.7 ± 0.2	1.0 ± 0.3	<0.5
	398N, 160E		0.8 ± 0.2	<0.3	1.5 ± 1.1
Near Bldgs. 23, 24 & 25					
	385.5N, 224E		0.4 ± 0.1	0.3 ± 0.2	<0.4
	385.5N, 224E	(15-30)	0.4 ± 0.2	0.5 ± 0.3	<0.5
	387.5N, 224.5E		0.7 ± 0.2	<0.3	1.5 ± 1.1
	387.5N, 224.5E	(15-30)	<0.2	<0.2	<0.6
	389.5N, 223E		<0.1	0.6 ± 0.3	<3.0
	389.5N, 223E	(15-30)	<0.3	<0.2	<0.5
	395N, 279.5E		<0.1	0.7 ± 0.3	<0.5
	395N, 279.5E	(15-30)	0.8 ± 0.2	0.8 ± 0.3	0.6 ± 1.4
	395N, 276.5E		<0.1	0.3 ± 0.2	0.5 ± 0.8
	395N, 276.5E	(15-30)	<0.1	<0.2	0.5 ± 0.9
	394.5N, 273.5E		0.4 ± 0.1	0.7 ± 0.3	0.5 ± 0.4
	394.5N, 273.5E	(15-30)	<0.1	0.4 ± 0.3	<0.5
	394.5N, 271E		1.1 ± 0.2	1.1 ± 0.3	<0.6
	394.5N 271E	(15-30)	0.9 ± 0.2	0.8 ± 0.2	1.3 ± 0.6
Biomass	255N, 192E		1.0 ± 0.2	<0.4	<0.9
	248N, 198E		1.2 ± 0.2	1.3 ± 0.4	2.8 ± 0.9
	256N, 202E		0.8 ± 0.3	1.1 ± 0.4	<0.8
	265N, 198E		0.9 ± 0.8	1.2 ± 0.8	<1.2
	271N, 00E		<0.3	1.4 ± 0.9	2.3 ± 3.1
	281N, 198E		<0.4	1.6 ± 0.8	<1.4
	269N, 189E		0.7 ± 0.3	1.3 ± 0.4	<0.8
	271N, 189E		0.9 ± 0.2	0.8 ± 0.5	<0.6

TABLE 6 (Continued)

RADIONUCLIDE CONCENTRATIONS IN OUTDOOR SOIL
ALBANY RESEARCH CENTER
ALBANY, OREGON

Area[a]	Location	Depth (cm)	Radionuclide Concentrations (pCi/g) Ra-226	Th-232	U-238
	276N, 184E		0.8 ± 0.4	0.7 ± 0.8	6.1 ± 1.5
	276N, 184E		0.9 ± 0.2	1.1 ± 0.3	<0.5
	250N, 182E		1.1 ± 0.3	1.1 ± 0.5	1.7 ± 2.0
	241N, 187E		0.6 ± 0.2	<0.2	<0.6
	261N, 187E		1.1 ± 0.3	1.3 ± 0.8	<0.7
Back 40	215N, 185E		1.0 ± 0.1	1.0 ± 0.1	1.9 ± 0.2
	195N, 205E		11 ± 0.4	1.8 ± 0.4	9.1 ± 0.7
	180N, 210E		1.5 ± 0.2	1.6 ± 0.3	2.3 ± 0.9
	180N, 240E		1.1 ± 0.1	1.2 ± 0.2	<0.7
	230N, 220E		1.4 ± 0.4	2.8 ± 0.8	6.1 ± 1.1
	225N, 220E		1.3 ± 0.3	2.2 ± 0.6	3.8 ± 1.9
	220N, 220E		1.9 ± 0.3	2.0 ± 0.6	4.4 ± 0.9
	215N, 220E		1.5 ± 0.3	2.2 ± 0.5	<0.1
	210N, 220E		1.5 ± 0.3	2.9 ± 0.5	1.2 ± 0.8
	205N, 220E		1.1 ± 0.2	2.0 ± 0.6	<1.0
	200N, 220E		<0.2	2.3 ± 0.5	1.3 ± 0.7
	195N, 220E		2.3 ± 0.4	2.9 ± 0.6	7.0 ± 0.3
	190N, 220E		0.3 ± 0.2	1.4 ± 0.3	3.9 ± 0.9
	190N, 225E		0.9 ± 0.2	1.3 ± 0.4	<0.8
	195N, 225E		1.8 ± 0.3	1.8 ± 0.4	5.3 ± 0.8
	200N, 225E		0.7 ± 0.2	0.5 ± 0.3	1.2 ± 0.9
	205N, 225E		1.1 ± 0.3	1.9 ± 0.5	<0.7
	210N, 225E		1.8 ± 0.3	3.2 ± 0.5	6.9 ± 1.7
	215N, 225E		1.9 ± 0.3	3.5 ± 0.6	<1.0
	220N, 225E		1.4 ± 0.3	4.2 ± 0.5	0.6 ± 0.8
	225N, 225E		2.1 ± 0.3	2.8 ± 0.5	4.2 ± 1.2
	230N, 225E		<0.1	0.5 ± 0.2	<3.0
	230N, 230E		2.1 ± 0.3	3.8 ± 0.9	1.0 ± 2.4
	225N, 230E		1.6 ± 0.3	2.9 ± 0.7	7.8 ± 1.8
	220N, 230E		2.9 ± 0.4	9.9 ± 0.9	<1.4
	215N, 230E		<0.2	1.1 ± 0.4	1.5 ± 0.8
	210N, 230E		1.6 ± 0.3	1.9 ± 0.6	<1.0
	205N, 230E		1.1 ± 0.3	3.3 ± 0.5	<1.0
	200N, 230E		1.1 ± 0.3	2.3 ± 0.5	2.4 ± 0.8
	195N, 230E		1.3 ± 0.2	2.3 ± 0.4	2.8 ± 1.9
	190N, 230E		1.0 ± 0.2	1.0 ± 0.5	<0.7
	190N, 235E		0.7 ± 0.2	1.0 ± 0.4	0.9 ± 0.6
	195N, 235E		1.3 ± 0.3	1.1 ± 0.5	1.2 ± 1.2
	200N, 235E		1.3 ± 0.3	1.6 ± 0.8	<0.8

TABLE 6 (Continued)

RADIONUCLIDE CONCENTRATIONS IN OUTDOOR SOIL
ALBANY RESEARCH CENTER
ALBANY, OREGON

Area[a]	Location	Depth (cm)	Radionuclide Concentrations (pCi/g) Ra-226	Th-232	U-238
Back 40	205N, 235E		1.1 ± 0.2	0.8 ± 0.4	<0.6
	210N, 235E		1.0 ± 0.3	0.9 ± 0.5	2.9 ± 1.0
	230N, 10E		0.9 ± 0.2	1.3 ± 0.4	0.7 ± 0.5
	225N, 210E		1.0 ± 0.3	2.0 ± 0.5	6.4 ± 2.2
	220N, 210E		2.1 ± 0.3	2.6 ± 0.5	2.4 ± 0.7
	215N, 210E		1.0 ± 0.2	1.3 ± 0.4	<1.0
	210N, 210E		1.5 ± 0.2	3.0 ± 0.5	3.7 ± 1.2
	205N, 210E		0.9 ± 0.2	1.0 ± 0.3	<0.8
	200N, 210E		0.9 ± 0.2	0.9 ± 0.4	0.5 ± 0.5
	195N, 210E		1.6 ± 0.3	0.9 ± 0.4	<1.0
	190N, 210E		1.6 ± 0.3	1.0 ± 0.4	1.6 ± 1.0
	190N, 215E		1.0 ± 0.2	1.0 ± 0.3	<0.7
	195N, 15E		4.1 ± 0.5	2.5 ± 0.6	1.3 ± 1.0
	200N, 215E		1.4 ± 0.3	2.3 ± 0.5	4.0 ± 1.3
	205N, 215E		1.9 ± 0.3	3.2 ± 0.5	<0.9
	210N, 215E		2.1 ± 0.3	2.6 ± 0.5	2.8 ± 1.6
	215N, 15E		1.7 ± 0.3	2.9 ± 0.5	1.1 ± 1.1
	220N, 215E		1.3 ± 0.2	4.0 ± 0.6	12.0 ± 1.9
	225N, 215E		1.3 ± 0.3	3.5 ± 0.6	9.2 ± 1.1
	230N, 215E		1.6 ± 0.3	3.3 ± 0.6	3.3 ± 2.0
	215N, 235E		1.7 ± 0.4	2.5 ± 0.5	2.0 ± 2.3
	220N, 235E		3.3 ± 0.4	2.7 ± 0.6	1.4 ± 0.9
	225N, 35E		1.3 ± 0.2	1.4 ± 0.4	0.8 ± 2.8
	230N, 235E		1.8 ± 0.4	<0.5	5.9 ± 1.5
	230N, 40E		3.7 ± 0.4	3.1 ± 0.7	1.6 ± 1.0
	225N, 240E		1.4 ± 0.3	1.8 ± 0.4	<1.0
	220N, 240E		1.6 ± 0.3	2.1 ± 0.4	0.9 ± 2.2
	215N, 240E		0.9 ± 0.2	1.5 ± 0.3	1.0 ± 0.6
	210N, 240E		0.9 ± 0.3	1.8 ± 0.4	<0.9
	205N, 240E		<0.2	1.2 ± 0.3	<0.7
	200N, 240E		0.8 ± 0.2	1.3 ± 0.3	0.9 ± 0.5
	195N, 240E		0.8 ± 0.3	0.9 ± 0.5	<0.7
	190N, 240E		0.8 ± 0.2	0.6 ± 0.3	<0.6

[a]Refer to Figure 17.
[b]Samples collected from soil surface (0-15 cm) unless noted otherwise.
[c]Uncertainties represent the 95% confidence levels, based only on counting statistics; additional laboratory uncertainties of ± 6 to 10% have not been propagated into these data.

TABLE 7

BUILDING SURFACES WITH BETA-GAMMA ACTIVITY
EXCEEDING 1000 dpm/100 cm^2
ALBANY RESEARCH CENTER
ALBANY, OREGON

Building	Location	Beta-Gamma Activity Level (dpm/100 cm^2)	Resolution
4	Room 107, Door Hinge	5800	Removed and Cleaned; followup scan negative.
5	Machine Shop, Wall/Floor Interface	2700	Average with adjacent surface yields <1000 dpm/100 cm^2.
	Machine Shop, Window Sill	1800	Average with adjacent surface yields <1000 dpm/100 cm^2.
28	Corridor to Room 15, floor	1200	Average with adjacent surface yields <1000 dpm/100 cm^2.
29	Room 111, Wall/Floor Interface	5700	Identified for attention in later remediations.
31	Room 1, lower wall	1200	Average with adjacent surface yields <1000 dpm/100 cm^2.
	Room 1, lower wall	1200	Average with adjacent surface yields <1000 dpm/100 cm^2.

REFERENCES

1. Argonne National Laboratory, Formerly Utilized MED/AEC Sites Remedial Action Program Radiological Survey of the Albany Metallurgical Research Center, United States Bureau of Mines, Albany, Oregon, DOE/EV-0005/40, ANL-OHS/HP-83-102, Argonne, IL, August 1983.

2. Argonne National Laboratory, Radiological Survey of the Albany Metallurgical Research Center, United States Bureau of Mines Biomass Facility and the "Back Forty" Area, Albany, Oregon, DOE/EV-0005/39, ANL-OHS/HP-83-101, Argonne, IL, April 1983.

3. Bechtel National, Inc., Radiological Survey of the Albany Research Center, Oak Ridge, TN, January 1985.

4. Bechtel National, Inc., Post - Remedial Action Report for the Albany Research Center, Oak Ridge, TN, April 1989.

5. Bechtel National, Inc., Radiological Characterization Report for the Albany Research Center, Oak Ridge, TN, April 1989.

6. Letter from J.D. Berger (ORAU) to J.J. Fiore (DOE/NE), "Verifications of 1987/1988 Remedial Actions at the Albany Research Center," Oak Ridge, TN, August 31, 1989.

APPENDIX A

SUMMARY OF RADIATION GUIDELINES APPLICABLE TO THE ALBANY RESEARCH CENTER

APPENDIX A

SUMMARY OF RADIATION GUIDELINES
APPLICABLE TO THE ALBANY RESEARCH CENTER

BASIC DOSE LIMITS

The basic limit for the annual radiation dose received by an individual member of the general public is 100 mrem/yr.

SOIL (LAND) CONCENTRATIONS

Radionuclide	Soil Concentration (pCi/g above background)[a,b,c]
Radium-226 Radium-228 Thorium-232 Thorium-232	5 pCi/g, averaged over the first 15 cm of soil below the surface; 15 pCi/g when averaged over any 15-cm-thick soil layer below the surface layer.
Other radionuclides	Soil guidelines will be calculated on a site-specific basis using the DOE manual developed for this use.

No specific uranium criteria were derived for this site, because characterization data indicated that uranium soil contamination is in equilibrium with its decay series and compliance with the remedial action guidelines for the daughter product Ra-226 ensures an acceptable level of uranium.

External Gamma Radiation

The average level of gamma radiation inside a building or habitable structure on a site to be released for unrestricted use shall not exceed the background level by more than 20 μR/h.

INDOOR/OUTDOOR STRUCTURE SURFACE ACTIVITY

	Allowable Residual Surface Activity (dpm/100 cm^2)[d]		
Radionuclide[e]	Average[f,g]	Maximum[g,h]	Removable[g,i]
Transurancis, Ra-226, Ra-228, Th-230, Th-228, Pa-231, Ac-227, I-125, I-129	100	300	20
Th-Natural, Th-232, Sr-90, Ra-223, Ra-224, U-232, I-126, I-131, I-133	1,000	3,000	200
U-Natural, U-235, U-238, and associated decay products	5,000 α	15,000 α	1,000 α
Beta-gamma emitters (radionuclides with decay modes other than alpha emission or spontaneous fission) except Sr-90 and others noted above	5,000 β - γ	15,000 β - γ	1,000 β - γ

Applicable guidelines within various ARC buildings will vary, depending upon the primary contaminant. For the majority of building surfaces, the major contaminant is Th-232. Guidelines associated with radionuclide decay series are 1000 dpm/100 cm^2, average; 3000 dpm/100 cm^2, maximum; and 200 dpm/100 cm^2, removable. For areas where uranium is the primary contaminant, the guidelines are 5000 dpm/100 cm^2, average; 15000 dpm/100 cm^2, maximum; and 1000 dpm/100 cm^2, removable.

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[a]These guidelines take into account ingrowth of radium-226 from thorium-230 and of radium-228 from thorium-232, and assume secular equilibrium. If either thorum-230 and radium-226 or thorium-232 and radium-228 are both present, not in secular equilibrium, the guidelines apply to the higher concentrations. If other mixtures of radionuclides occur, the concentrations of individual radionuclides shall be reduced so that the dose of the mixtures will not exceed the basic dose limit.

[b]These guidelines represent unrestricted-use residual concentrations above background averaged across any 15-cm-thick layer at any depth and over any contiguous 100-m^2 surface area.

[c]Localized concentrations in excess of these limits are allowable provided that the average concentration over a 100-m^2 area does not exceed these limits.

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

[e]Where surface contamination by both alpha-and beta-gamma-emitting radionuclides exists, the limits established for alpha-and-beta-gamma-emitting radionuclides should apply independently.

[f]Measurements of average contamination should not be averaged over more than 1 m^2. Of objects of less surface area. The average shall be derived for each such object.

[g]The average and maximum radiation levels associated with surface contamination resulting from beta-gamma emitters should not exceed 0.2 mrad/h and 1.0 mrad/h, respectively, at 1 cm.

[h]The maximum contamination level applies to an area of not more than 100 cm^2.

[i]The amount of removable radioactive material per 100 cm^2 of surface area should be determined by wiping that area with dry filter or soft absorbent paper, applying moderate pressure, and measuring the amount of radioactive material on the wipe with an appropriate instrument of know efficiency. When removable contamination on objects of surface area less than 100 cm^2 is determined, the activity per unit area should be based on the actual area and the neither surface should be wiped. The numbers in this column are maximum amounts.

Reference

U.S. Department of Energy, U.S. Department of Energy Guidelines for Residual Radioactivity at Formerly Utilized Sites Remedial Action Program and Remote Surplus Facilities Management Program Sites, Revision 2, March 1987.

APPENDIX B

MAJOR SAMPLING AND ANALYTICAL EQUIPMENT

APPENDIX B

MAJOR SAMPLING AND ANALYTICAL EQUIPMENT

The display or description of a specific product is not to be construed as an endorsement of that product or its manufacturer by the authors or their employer.

A. Direct Radiation Measurements

Eberline "RASCAL"
Portable Ratemeter-Scaler
Model PRS-1
(Eberline, Santa Fe, NM)

Eberline PRM-6
Portable Ratemeter
(Eberline, Santa Fe, NM)

Eberline Alpha Scintillation Detector
Model AC-3-7
(Eberline, Santa Fe, NM)

Eberline GM Pancake Probe
Model HP-260
(Eberline, Santa Fe, NM)

Victoreen GM "Pancake" Detector
Model 489-110
(Victoreen, Cleveland, OH)

Victoreen NaI Scintillation Detector
Model 489-55
(Victoreen, Cleveland, OH)

Ludlum Scaler/Ratemeter
Model 2220
(Ludlum, Sweetwater, TX)

Ludlum Floor Monitor
Model 289
(Ludlum, Sweetwater, TX)

B. Laboratory Analyses

Automatic low-background Alpha-Beta Counter
Model LB5110-2080
(Tennelec, Oak Ridge, TN)

High-Purity Germanium Detector
Model GMX-23195-S, 23% efficiency
(EG&G ORTEC, Oak Ridge, TN)

Used in conjunction with:
Lead Shield, G-16
(Gamma Products, Inc., Palos Hills, IL)

High Purity Germanium Detector
Model IGC25, 25% efficiency
(Princeton Gamma-Tech, Princeton, NJ)

Used in conjunction with:
Lead Shield
(Nuclear Data, Schaumburg, IL)

Multichannel Analyzer
ND-66/ND-680 System
(Nuclear Data Inc., Schaumburg, IL)

APPENDIX C

MEASUREMENT AND ANALYTICAL PROCEDURES

APPENDIX C

MEASUREMENT AND ANALYTICAL PROCEDURES

Surface Scans

Surface scans were performed by passing the probes slowly over the surface. The distance between the probe and the surface was maintained at a minimum - nominally about 1 cm (0.4 in). Identification of elevated levels was based on increases in the audible signal from the recording or indicating instrument. Combinations of detectors and instruments used for the scans were:

Alpha
- ZnS probe with PRS-1 scaler/ratemeter
- Large-area gas proportional probe with Model 2220 scaler/ratemeter

Beta-gamma
- Pancake G-M probe with PRM-6 ratemeter or PRS-1 scaler/ratemeter
- Large area gas proportional probe with Model 2220 scaler/ratemeter

Gamma
- NaI scintillation detector with PRM-6 ratemeter

Alpha and Beta-Gamma Surface Measurements

Measurements of total alpha radiation activity levels were performed using Eberline Model PRS-1 portable scaler/ratemeters with Model AC-3-7 alpha scintillation probes. Measurements of total beta-gamma radiation levels were performed using Eberline Model PRS-1 portable scaler/ratemeters with Model HP-260 thin-window "pancake" GM probes. Count rates (cpm) were converted to disintegration rates (dpm/100 cm^2) by dividing the net rate by the 4π efficiency and correcting for the active area of the detector. Effective window areas were 59 cm^2 for the ZnS detectors and 15 cm^2 for the GM detectors. The background count rate for ZnS alpha probes averaged approximately 2 cpm; the average background count rate was approximately 40 cpm for the GM detectors.

Removable Activity Measurements

Smear measurements were performed using numbered filter paper disks, 47 mm in diameter. Smears were placed in labeled envelopes with the locations and other pertinent information recorded. Smears were counted on a low-background alpha/beta gas-proportional counter at the Oak Ridge laboratory.

Exposure Rate Measurements

Measurements of gamma exposure rates were performed using Eberline PRM-6 portable ratemeters with Victoreen Model 489-55 gamma scintillation probes containing 3.2 cm (1.25 in) x 3.8 cm (1.50 in) NaI(Tl) scintillation crystals. Count rates were converted to exposure rates (μR/h) by cross-calibrating with a Reuter Stokes Model RSS-111 pressurized ionization chamber.

Soil Sample Analysis

Soil samples were dried, mixed, and a portion sealed in 0.5 liter (0.53 qt) Marinelli beaker. The quantity placed in each beaker was chosen to reproduce the calibrated counting geometry and ranged from 600 to 900 g (1.3 to 2.0 lb) of soil. Net soil weights were determined and the samples counted using high-purity intrinsic germanium detectors coupled to a Nuclear Data Model ND-680 pulse height analyzer system. Background and Compton stripping, peak search, peak identification, and concentration calculations were performed using the computer capabilities inherent in the analyzer system. Energy peaks used for determination of radionuclides of concern were:

Ra-226 - 0.609 MeV from Bi-214 (secular equilibrium assumed)
Th-232 - 0.911 MeV from Ac-228 (secular equilibrium assumed)
U-238 - 0.094 MeV from Th-234 or 1.001 MeV from Pu-234m (secular equilibrium assumed)

Uncertainties and Detection Limits

The uncertainties associated with the analytical data presented in the tables of this report, represent the 95% confidence levels for that data. These uncertainties were calculated based on both the gross sample count levels and the associated background count levels. When the net sample count was less than the 95% statistical deviation of the background count, the sample concentration was reported as less than the detection limits of the procedure. Because of variations in background levels, sample weights or volumes, and Compton contributions from other radionuclides in samples, the detection limits differ from sample to sample and instrument to instrument. Additional uncertainties of $\pm$ 6 to 10%, associated with sampling and laboratory procedures, have not been propagated into the data presented in this report.

Calibration and Quality Assurance

Laboratory and field survey procedures are documented in manuals developed specifically for the Oak Ridge Associated Universities' Environmental Survey and Site Assessment Program.

With the exception of the measurements conducted with portable gamma scintillation survey meters, instruments were calibrated with NBS-traceable standards. The calibration procedures for the portable gamma instruments are performed by comparison with an NBS calibrated pressurized ionization chamber.

Quality control procedures on all instruments included daily background and check-source measurements to confirm equipment operation within acceptable statistical fluctuations. The ORAU laboratory participates in the EPA and DOE/EML Quality Assurance Programs.