N00236.001374
ALAMEDA POINT
SSIC NO. 5090.3

COMPREHENSIVE LONG-TERM ENVIRONMENTAL ACTION NAVY (CLEAN I)
Northern and Central California, Nevada, and Utah
Contract No. N62474-88-D-5086
Contract Task Order No. 0280

Prepared For:

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ADDENDUM TO THE REMEDIAL INVESTIGATION/FEASIBILITY STUDY DATA TRANSMITTAL MEMORANDUM SITE 1 AND SITE 2 RADIATION SURVEY REPORT NAVAL AIR STATION ALAMEDA, CALIFORNIA

FINAL

FEBRUARY 1997

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FINAL
REMEDIAL INVESTIGATION/FEASIBILITY STUDY
DATA TRANSMITTAL MEMORANDUM
SITES 1, 2, 3, RUNWAY AREA, 6, 7A, 7B, 7C, 9, 10B, 11, 13, 15, 16, AND 19

DATED 01 MAY 1996

VOLUME 1 OF 2 IS FILED AS ADMINISTRATIVE RECORD NO. **N00236.001214**

VOLUME 2 OF 2 IS FILED AS ADMINISTRATIVE RECORD NO. **N00236.001215**

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1.0 INTRODUCTION

PRC Environmental Management, Inc. (PRC) was requested by the Naval Facilities Engineering Command, Engineering Field Activity West (EFA WEST) under Comprehensive Long-Term Environmental Action Navy (CLEAN) Contract No. N62474-88-D-5086, Contract Task Order No. 0280, to perform a radiological survey of portions of the 1943-1956 Disposal Area (Site 1) and the West Beach Landfill (Site 2) at Naval Air Station (NAS) Alameda, California. This document provides the results of that radiological survey.

2.0 SUMMARY

PRC performed a near-surface radiological scoping survey of the accessible areas at Site 1 and Site 2, NAS Alameda, from September 18 through September 29, 1995. The purpose of the scoping survey was to (1) determine the presence and nature of near-surface radiological contamination and (2) recommend interim corrective actions to limit human exposure to Site contaminants and minimize the potential for contamination dispersion. [Definitions for the survey types as defined by the U.S. Nuclear Regulatory Commission's (NRC) NUREG/CR-5849 (NRC 1993) are provided in Attachment A.] In addition to the Site 1 and Site 2 scoping survey, limited surveying was performed in two manholes and the outfall of storm sewer line F originating from Building 5. The additional measurements were collected to so that a qualitative assessment could be made of the presence or absence of radioactive contamination in the storm sewer line.

For convenience in reporting results, Site 1 and Site 2 were divided into 20-meter grid blocks as shown in Figures 2-1 and 2-2, respectively. A 2-inch by 2-inch sodium-iodide (NaI) gamma scintillator and ratemeter/scaler was used to survey the area at each of the grid points. A 1-inch by 1-inch NaI microRoentgen (μR) survey meter was used to scan the transects between grid points. A total of 706 grid points were measured, 164 points in Site 1 and 542 points in Site 2. In addition, approximately 14,120 meters (nearly 8.5 miles) of transects were scanned. During the survey process, 23 individual radiological anomalies were noted and further analyzed. The details of the anomaly investigations, including gamma spectroscopic and radiochemical analyses, are provided in this document.

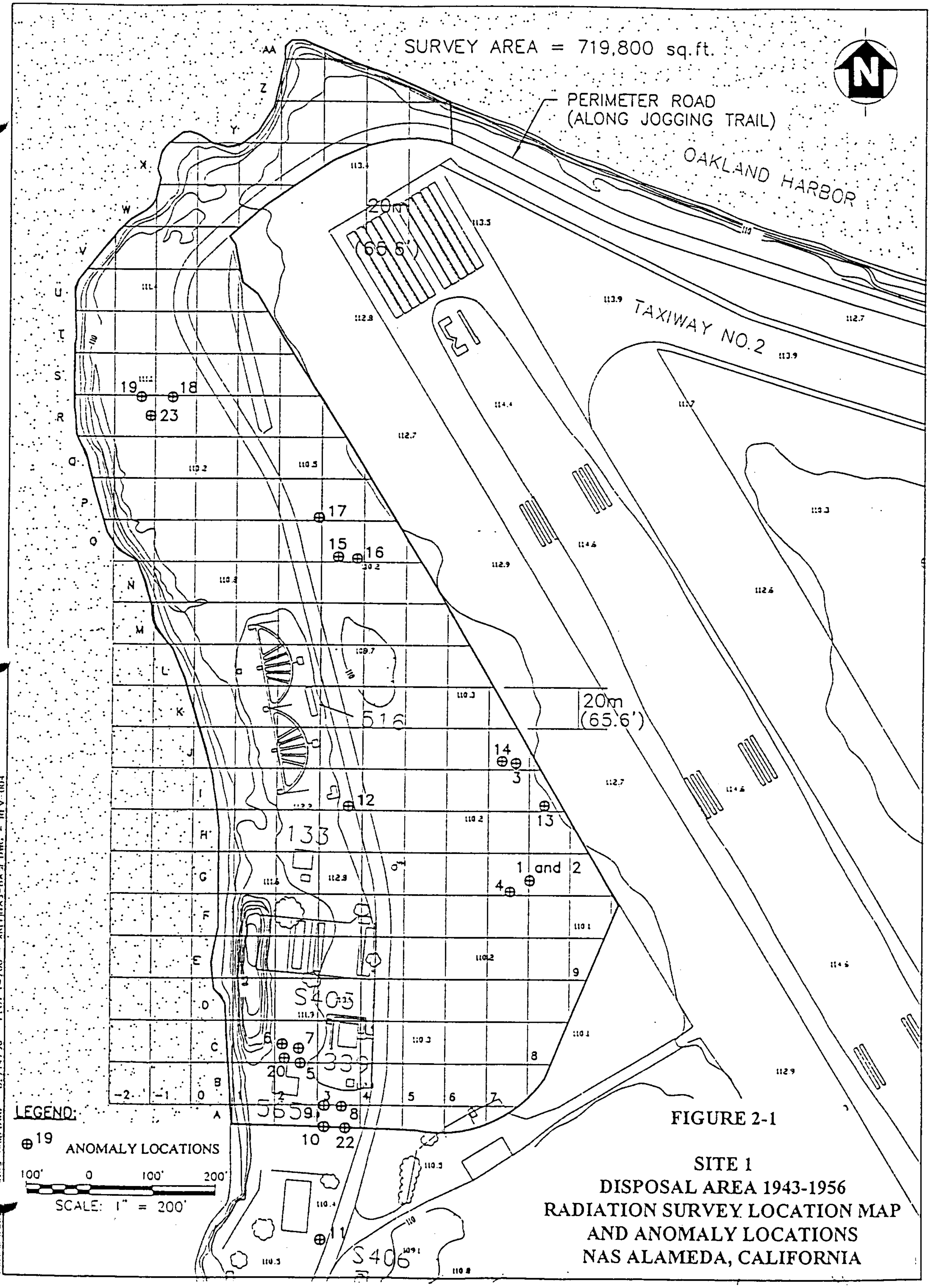

FIGURE 2-1

SITE 1
DISPOSAL AREA 1943-1956
RADIATION SURVEY LOCATION MAP
AND ANOMALY LOCATIONS
NAS ALAMEDA, CALIFORNIA

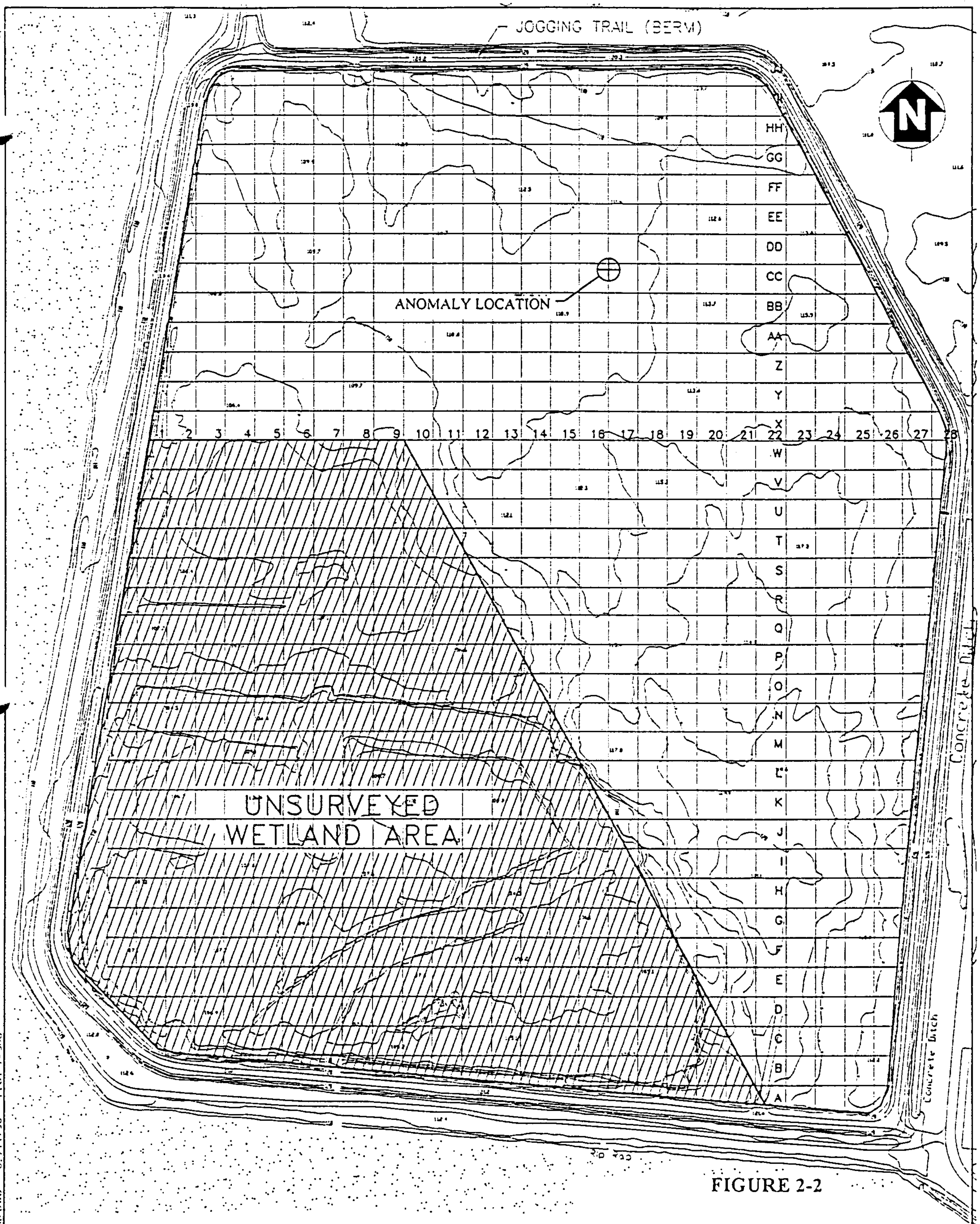

FIGURE 2-2

SITE 2
WEST BEACH LANDFILL
RADIATION SURVEY LOCATION MAP
AND ANOMALY LOCATIONS
NAS ALAMEDA, CALIFORNIA

20m (65.6')SQ. SURVEY GRID
SURVEY AREA = 2,342,077 sq.ft.

150' 0 150' 300'
SCALE: 1" = 300'

3.0 SITE BACKGROUND

Sites 1 and 2 have been used by the Navy for disposal of industrial and municipal wastes. Radioactive materials may have also been a minor component of the industrial waste that was disposed of in the landfills. Based on document reviews, interviews with installation personnel, experience at other Navy industrial landfill sites, and discussions with the Navy's Radiological Affairs Support Office (RASO), it is likely that sources of radioactivity include material such as instrument dials and gauge faces that were painted with radioluminescent paints that contained radium-226 or, less likely, strontium-90. A description of radioluminescent paints is found in Section 3.3.

Radioluminescent paints are phosphorescent substances mixed with radioactive materials into a paint base. This type of paint was used to enhance low-light visibility of indicator needles, knobs, gunsites, and numerals on gauges. It was also used in deck markers that lined the edge of ship decks.

Prior to the 1970s, the Navy disposed of radioactive material such as those described above with other nonradioactive wastes in landfills like Sites 1 and 2. The amount of radioactive material in the landfills is unknown. It is not uncommon, therefore, to find point sources of these radioactive materials buried in Navy industrial landfills. Currently, the Navy's surplus radioactive material program provides for the identification, removal, and proper disposal of such radioactive waste.

3.1 SITE 1: 1943 - 1956 DISPOSAL AREA

Site 1, the 1943 - 1956 Disposal Area, was used as a combination municipal and industrial landfill and operated from 1943 until 1956. During its years of operation, Site 1 was the NAS Alameda main site for waste disposal. Ecology and Environment, Inc. (E&E) reports that until 1952, the site received all waste generated at NAS Alameda except liquid waste, which was discharged directly into the Seaplane Lagoon (E&E 1983).

Site 1 has an area of approximately 120 acres (Canonie 1990). Interpretation of historical aerial photographs have shown that waste material may have been disposed of in the northwest corner of the site in a localized area as small as 12 acres. Additionally, the photographs suggest that another area to the east, also approximately 12 acres, was used to store construction and military material (PRC/Montgomery Watson 1993). Nonetheless, no conclusive data exclude the possibility that radioactive material was disposed of outside these small areas. Most of Site 1, however, has been paved and has become part of the still active Runways 13-31 and 7-25.

Details of the fill material and disposal histories, current operations, and hydrology of Site 1 are presented in the 1993 Solid Waste Water Quality Assessment Test (SWAT) report (PRC/Montgomery Watson 1993). The artificial fill material is reportedly 20 to 30 feet thick.

It is estimated that between 15,000 and 200,000 tons of solid waste were disposed of at Site 1 (E&E 1983). Wastes that are known to have been buried at the site include aircraft engines, cooked garbage from ships in port, cables, scrap metal, waste oil, waste paint, waste solvents, cleaning compounds, medical wastes, construction debris, dredge spoils, and low-level radioactive material (Canonie 1990). The amount of radioactive material that may be present in the landfill is not known and has not been estimated. The radiation survey grid covered approximately 16.5 acres in the northwestern corner of Site 1 (see Figure 2-1).

3.2 SITE 2: WEST BEACH LANDFILL

Site 2, the West Beach landfill, occupies approximately 110 acres in the southwestern corner of NAS Alameda and was used as a combination municipal and industrial landfill. It began receiving waste in 1952. Following the closure of Site 1 in 1956, Site 2 received all wastes generated at NAS Alameda except liquid waste. Site 2 reportedly received 1.6 million tons of waste (E&E 1983). It is estimated that 30,000 to 500,000 tons of that waste can be considered hazardous and that the disposal of hazardous materials was discontinued by the early 1970s (E&E 1983). The landfill is surrounded by an earthen berm that is approximately 55 feet wide and stands about 7 feet above the landfill surface. A number of piles of construction debris lie in the southeastern portion of the site. Site 2 is no longer used for any air station operations or activities.

Details of the fill material, disposal histories, and hydrology of this site are also presented in the 1993 SWAT report (PRC/Montgomery Watson 1993). The artificial fill material is reported to be approximately 30 feet thick. Material that was disposed of in Site 2 includes waste chemical drums, municipal garbage, solvents, oily wastes and sludges, paint waste, thinners, strippers, plating wastes, industrial strippers and cleaners, acids, mercury, polychlorinated biphenyl (PCB)-contaminated fluids and rags, batteries, low-level radioactive wastes, scrap metal, inert ordnance, asbestos, solid and liquid pesticides, tear gas agents, infectious waste, creosote, dredge spoils, and waste medicines and reagents (Canonie 1990).

The radiation survey grid covered approximately 54 acres of Site 2 (see Figure 2-2). A small wetland area within Site 2 provides a nesting area for birds and is well vegetated with grasses. This wetland area is composed of dredge spoils. Because this area did not receive any municipal or industrial wastes, it was not included in the radiation survey.

3.3 RADIOLUMINESCENT COMPONENTS

Sites 1 and 2 may contain radium-226 and its decay products (lead-214 and bismuth-214), strontium-90, or both in concentrations above naturally expected background levels. Based on the results of radiation investigations at other Navy landfills and from discussions with the RASO, radioluminescent equipment would probably be the primary constituent of any radiation inventory in the landfills at NAS Alameda.

It is suspected that radioactive luminescent dials, gauges, deckmarkers, and other components of electronic equipment may have been disposed of in the landfills. Before the 1970s, most radioluminescent components used by the military contained radium-226, and a few types contained strontium-90 mixed into a phosphorescent paint base. The interactions of the radioactive particles with the phosphor prompts the emission of a small but constant source of light. The paint was applied to the numerals and markers on some equipment so that they could be read in the dark.

Radium-226, with a half-life of approximately 1,600 years, decays by emission of an alpha particle, with associated gamma emissions (principally a 186 keV transition with a 4-percent probability). Radium-226 decay products, however, emit gamma radiations which are more abundant and of higher energy, permitting detection of radium sources.

Lead-214 and bismuth-214 are among the primary gamma-emitting radium-226 decay products. In radioluminescent devices, these decay products produce gamma radiation that can usually be detected if covered by less than 1 foot of soil. Figure 3-1 shows the decay of radium-226 and its decay products and lists the decay energies and branching ratios of the gamma emissions. Buried radium-containing material may have corroded dispersing radium-containing material into the surrounding soil. It is possible that such soils may contain elevated amounts of radium-226 and its decay products.

The dials and illuminators that may have been disposed of in Sites 1 and 2 can have activities that range from less than 1 microCurie (μCi) or 37,000 disintegrations per second (dps) to 25 μCi or about 925,000 dps. RASO suggests, however, that typically radium-226 sources in Navy landfills have an activity of about 1 μCi.

Strontium-90 was also used to a limited extent in radioluminescent instrumentation. It has a half-life of approximately 29 years and emits beta particles. Based upon Navy records, strontium-90 was predominantly used as a radioluminescent source in deckmarkers on ships. This is the primary concern regarding strontium-90 contamination in the Sites 1 and 2 landfills at NAS Alameda. Unrelated to the radioluminescence of the deckmarkers, the interaction of the beta particles with the dense (high atomic number) steel housing of these devices produces bremsstrahlung radiation, which is similar to X-ray and gamma radiations. Detection of the bremsstrahlung radiation during radiation survey activities is an indicator of the possible presence of a strontium-90-containing deck marker or other strontium-90-containing metallic device. It has been shown that bremsstrahlung radiation can be detected from a buried deck marker using a 2-inch by 2-inch NaI detector (Navy 1994). Gamma spectroscopic analysis is necessary, however, to distinguish bremsstrahlung radiation from other sources of radiation.

	Half Life	Gamma Decay Energy (keV)	Braching Ratio	40-Year Activity
Radium-226	1,600 years	186.2	0.033	0.98282 Ci
α ↓				
Radon-222	3.82 days	324.2	0.028	0.98282 Ci
α ↓				
Pollonium-218	3.05 minutes	no gammas		0.98282 Ci
α ↓				
Lead-214	26.8 minutes	351.92 295.21 241.98	0.372 0.192 0.075	0.98282 Ci
β^- ↓				
Bismuth-214	19.9 minutes	1,120.3 609.31	0.151 0.463	0.98282 Ci
β^- ↓				
Pollonium-214	164 micro-seconds	no gammas		0.98242 Ci
α ↓				
Lead-210	22.26 years	46.5	0.041	0.70442 Ci
β^- ↓				
Bismuth-210	5.01 days	no gammas		0.70425 Ci
β^- ↓				
Pollonium-210	138.4 days	no gammas		0.69943 Ci
α ↓				
Lead-206	stable			

FIGURE 3-1
DECAY CHAIN FOR 1 CURIE OF RADIUM-226

3.4 BACKGROUND RADIATION

Naturally occurring radiation sources in soils include, but are not limited to, uranium, thorium, and potassium isotopes. The soils that are found at NAS Alameda include arkosic sands, clays, and silts. The predominant source of naturally occurring radioactive isotopes in these soils is the arkosic sand fraction. These sands contain feldspars, a source of gamma-emitting potassium-40, and other components of granitic rock. Granitic rock contains a small amount of uranium isotopes that decay into other radioisotopes, including radium-226.

An important source of anthropogenic background radiation in soils is cesium-137. As the result of hundreds of atmospheric tests of nuclear weapons conducted primarily in the United States and the former Soviet Union, cesium-137 has become a widespread manmade radioisotope in the environment. The amount of cesium-137 in soils depends on the amount of surface erosion or soil tilling that has occurred since deposition. Therefore, the amount of cesium-137 present in surface soils can vary widely from site to site.

4.0 EMPIRICAL STUDIES OF SURVEY INSTRUMENTS

In addition to the walkover radiological surveys conducted for Sites 1 and 2 at NAS Alameda, empirical studies were performed on the survey instruments to assess their capabilities to detect radium-226 sources in the soils. The instruments assessed were the Ludlum Model 44-10 2-inch by 2-inch NaI detector coupled to the Ludlum Model 2221 ratemeter/scaler and the Ludlum Model 19 1-inch by 1-inch NaI μR exposure rate survey meter. The ratemeter/scaler was operated in scaler mode with the voltage set at 650 volts and the threshold set to 100 kilo-electron volts (keV). The Model 44-10 detector was operated with the window out. The range of the Model 19 detector was 0 to 5,000 μR per hour. The test source was an old instrument panel button containing 0.87 μCi of radium-226.

The 0.87 μCi radium-226 button was selected for this study because of its similarity to the expected sources of radiation at Sites 1 and 2. This source was recovered from a Navy landfill at Naval Station Treasure Island, Hunters Point Annex (HPA), near San Francisco, California. Because of the low level of the 0.87 μCi source, it did not produce an external radiation hazard. The button was safely handled in a plastic vial to ensure that no contamination was spread from the source. The purpose of the empirical studies was to demonstrate the detectors' capabilities to detect a near-surface radioactive source similar to the type of sources expected to be in the Site 1 and Site 2 landfills.

The empirical studies were performed to the east of Site 2 at the entrance to the restricted area. The soil was sandy and dry to about 12 inches deep. Beyond the 12-inch depth, the soil was damp compacted backfill.

4.1 LUDLUM MODEL 44-10 GAMMA SCINTILLATOR

The first step in the empirical study on the Ludlum Model 44-10 was to establish the background count rate of the test area. The background count rate of the study area was 1,746 counts per minute (cpm). For the purpose of the walkover survey, a measurement is considered significantly above background if the measurement is greater than the one-tailed 95 percent confidence level of the background count rate. Therefore, for the empirical study, the source is considered detected if the resulting count rate is significantly above the background count rate, that is, greater than or equal to 1,815 cpm. This value was calculated by the following equation:

$$SAB = B + 1.65\sqrt{B} \qquad \text{(Equation 4-1)}$$

where:

SAB	=	count rate significantly above background
B	=	background count rate

Following the determination of the background count rate, the detector's capabilities were examined. To test the detector, the 0.87 μCi radium-226 button was placed on the ground surface or buried at various depths, and the detector was placed at various distances from the source. The detector was suspended from a tripod and maintained at approximately 3 inches from the ground surface.

Figure 4-1 shows the profile of the region of soil in which the Ludlum Model 44-10 was able to successfully identify the presence of the 0.87 μCi radium-226 button. The maximum depth at which the source could be detected was about 18 inches with the detector directly above the source. The source could be detected on the ground surface up to 42 inches away from the detector. The volume of soil surveyed is approximately equal to 0.41 cubic meters (14.5 cubic feet). This is based on the assumption that the average radium-226 source in Sites 1 and 2 has an activity of approximately 0.87 μCi, or approximately 1 μCi.

The empirical study performed on the 2-inch by 2-inch NaI detector demonstrated the detector's ability to successfully survey a near-surface region of soil for a low-activity radium-226 source. It should be noted, however, that this study would have produced different results if a source with a significantly different activity was used. In addition, the ability to measure activity from radium-226 in near-surface soils would also be affected by soil density and soil moisture content. Soils having higher densities and moisture content, such as clay, would have a greater shielding effect displaying a decrease in count rate compared to the same amount of activity measured in a dry, sandy soil. The soils in the Sites 1 and 2 landfills were mostly dry, sandy soils containing small rocks.

4.2 LUDLUM MODEL 19 SURVEY METER

The empirical study performed on the Ludlum Model 19 1-inch by 1-inch NaI μR exposure rate survey meter was similar to the study performed on the Ludlum Model 44-10 2-inch by 2-inch NaI detector discussed in Section 4.1. The test was performed at the same location as the previous study using the same 0.87 μCi radium-226 button. For this study, however, instead of determining whether a count rate was greater than the background count rate, visual and audible variations in the detector's response above the background response indicated that the source was detected.

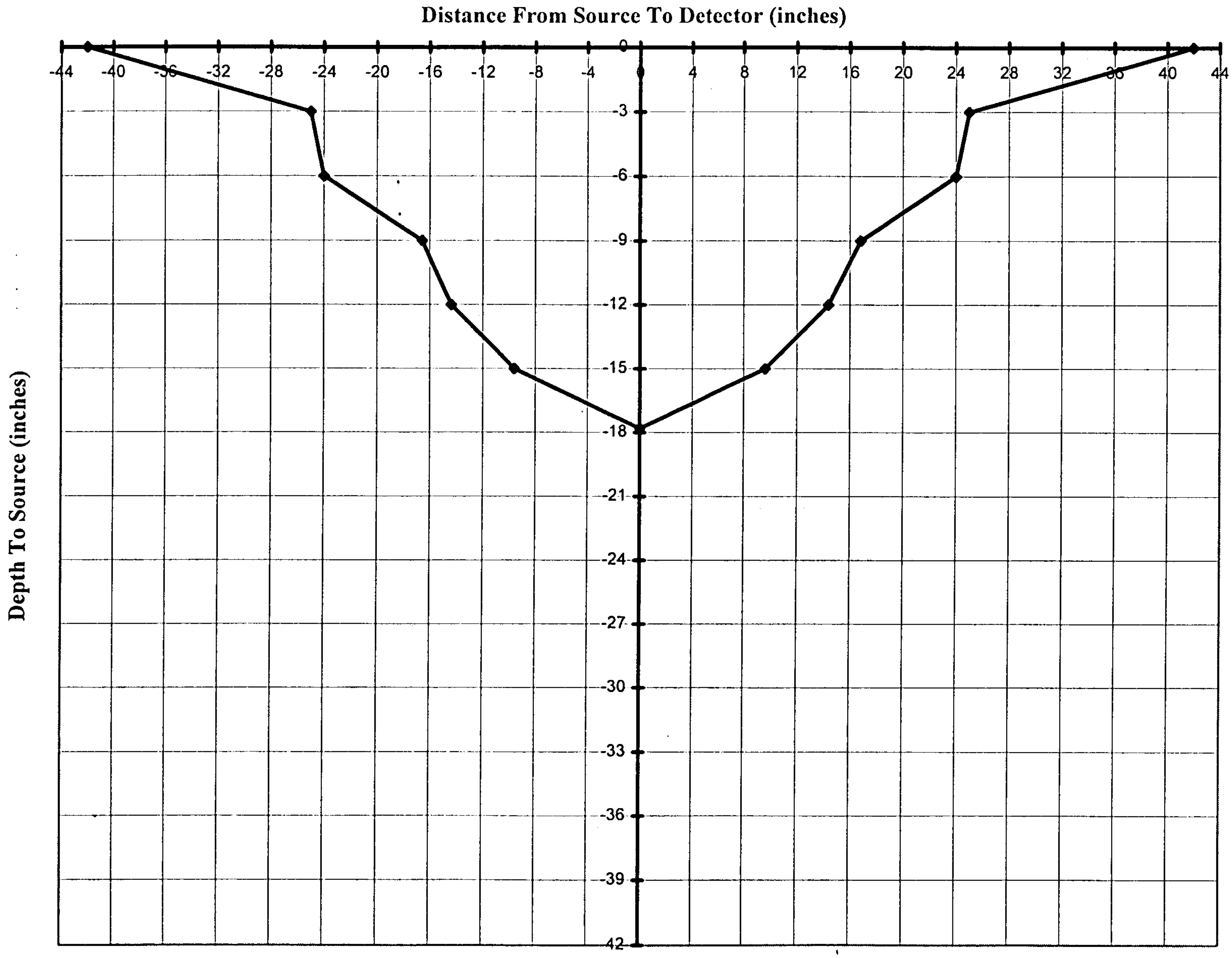

FIGURE 4-1
LUDLUM MODEL 44-10 SURVEY PROFILE (0.87 μCi RADIUM-226 SOURCE)
NAS ALAMEDA, CALIFORNIA

Figure 4-2 shows the profile of the region of soil in which the Ludlum Model 19 was able to successfully identify the presence of the 0.87 μCi radium-226 button. The maximum depth at which the source could be detected was about 7 inches with the detector directly above the source. The 1-meter- (40-inch-) wide area with a constant depth to source reflects the 1-meter-wide path of the transect survey caused by the side-to-side movement of the detector. The source could be detected on the ground surface up to about 15 inches away from the detector. Assuming that the surveyed transect is 18.3 meters long (1.7 meters of the 20 meter transect is surveyed by the two grid node surveys at the beginning and the end of the transect) and 1 meter wide, the volume of soil surveyed along the transect is approximately equal to 4.56 cubic meters (161.0 cubic feet). This is based on the assumption that the average radium-226 source in Sites 1 and 2 has an activity of approximately 0.87 μCi, or approximately 1 μCi.

In addition to burying the source at known depths in a known location and determining the range of the detector's response, a blind walkover survey test was performed. For this test, the 0.87 μCi radium-226 button was buried by one of the survey team members at a measured depth in a location unknown to a second team member. The second team member was then given a hypothetical transect to survey. The source was buried along or very near this transect. While using the Ludlum Model 19 survey meter, the second team member surveyed the transect to locate the source. The detector was kept as near to the ground surface as possible, and the walkover survey was performed at a regular survey pace of about 0.5 meter per second. Table 4-1 summarizes the results of the blind walkover survey test.

The empirical studies performed on the NaI μR survey meter demonstrated the detector's ability to successfully survey a near-surface region of soil for a low-activity radium-226 source. It should be noted, however, that this study would have produced different results if a source with a significantly different activity were used.

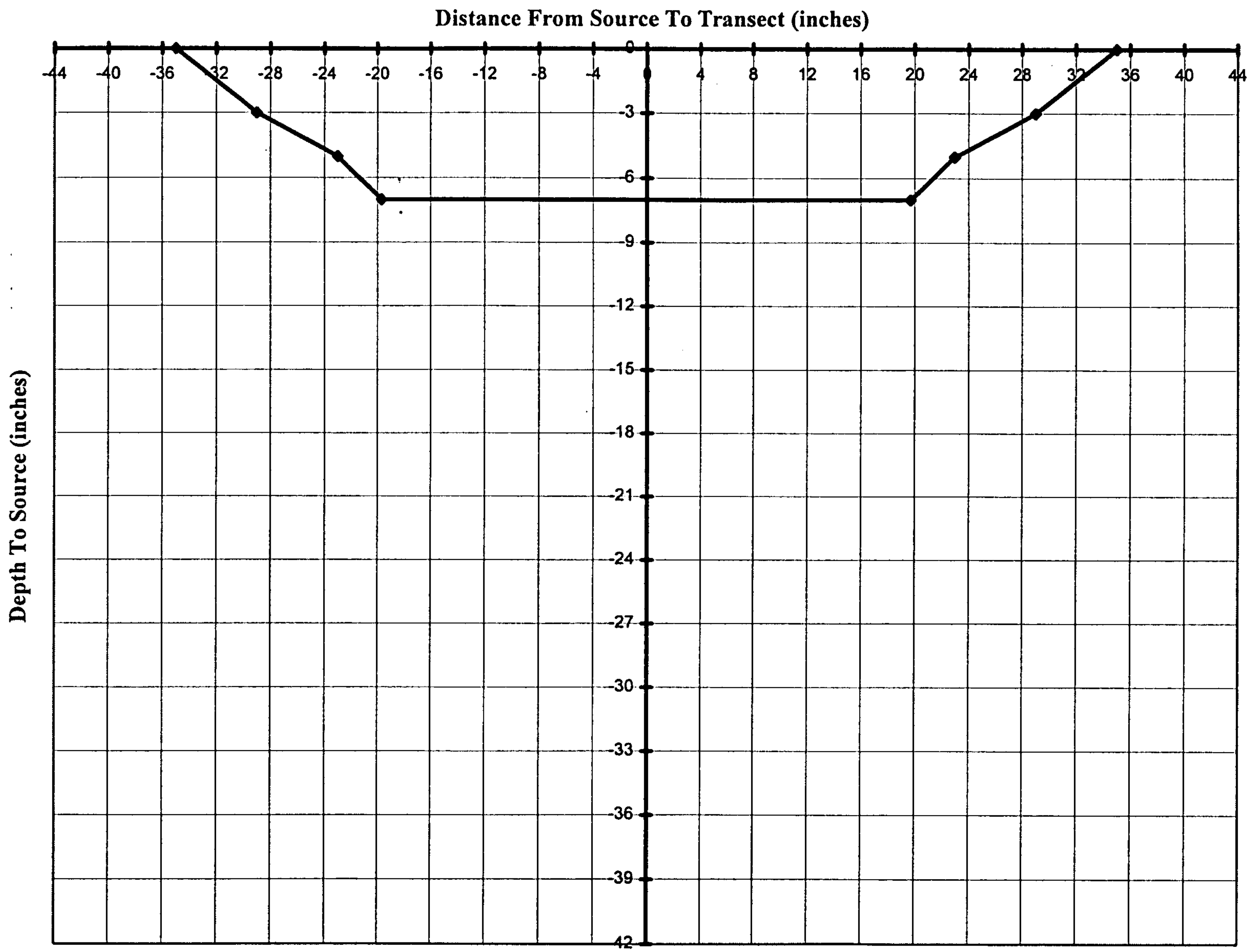

FIGURE 4-2
LUDLUM MODEL 19 SURVEY PROFILE (0.87 μCi RADIUM-226 SOURCE)
NAS ALAMEDA, CALIFORNIA

TABLE 4-1

BLIND WALKOVER SURVEY TEST RESULTS

Source Depth	Location Description	Distance Off Transect	Result
2 inches	sandy soil, short grasses	~ 6 inches	source located
4 inches	sandy soil, tall grasses	~ 12 inches	source located
6 inches	sandy soil with rocks	~ 12 inches	source not located [a]

Note: a The source was not located during the blind walkover survey; however, the source was detectable after identifying the location.

5.0 RADIOLOGICAL FIELD SURVEY METHODS AND RESULTS

The Site 1 and 2 radiological survey consisted of: (1) background radiation measurements, (2) grid node surveys, (3) transect walkover surveys, (4) in situ gamma spectroscopic analysis of field survey anomalies, and (5) soil sample analysis (background and anomaly samples) including gamma spectroscopic and radiochemical analysis.

5.1 BACKGROUND SURVEY

Background gamma radiation counts were measured at 30 locations within the perimeter of the base but not within Sites 1 or 2. Background measurements and soil samples were also collected at six different areas of NAS Alameda shown in Figure 5-1. The Ludlum Model 44-10 2-inch by 2-inch NaI detector was used coupled to the Ludlum Model 2221 rate scaler. The rate scaler was operated in scaler mode with the voltage set at 650 volts and the threshold set to 100 keV. The detector was operated with the window out. The goal of the background survey was to establish a site-wide background count rate with which to compare Site 1 and Site 2 survey results. For the purpose of the Site 1 and Site 2 surveys, a measurement is defined as "significantly above background" if that measurement is greater than the one-tailed 95 percent confidence level on the

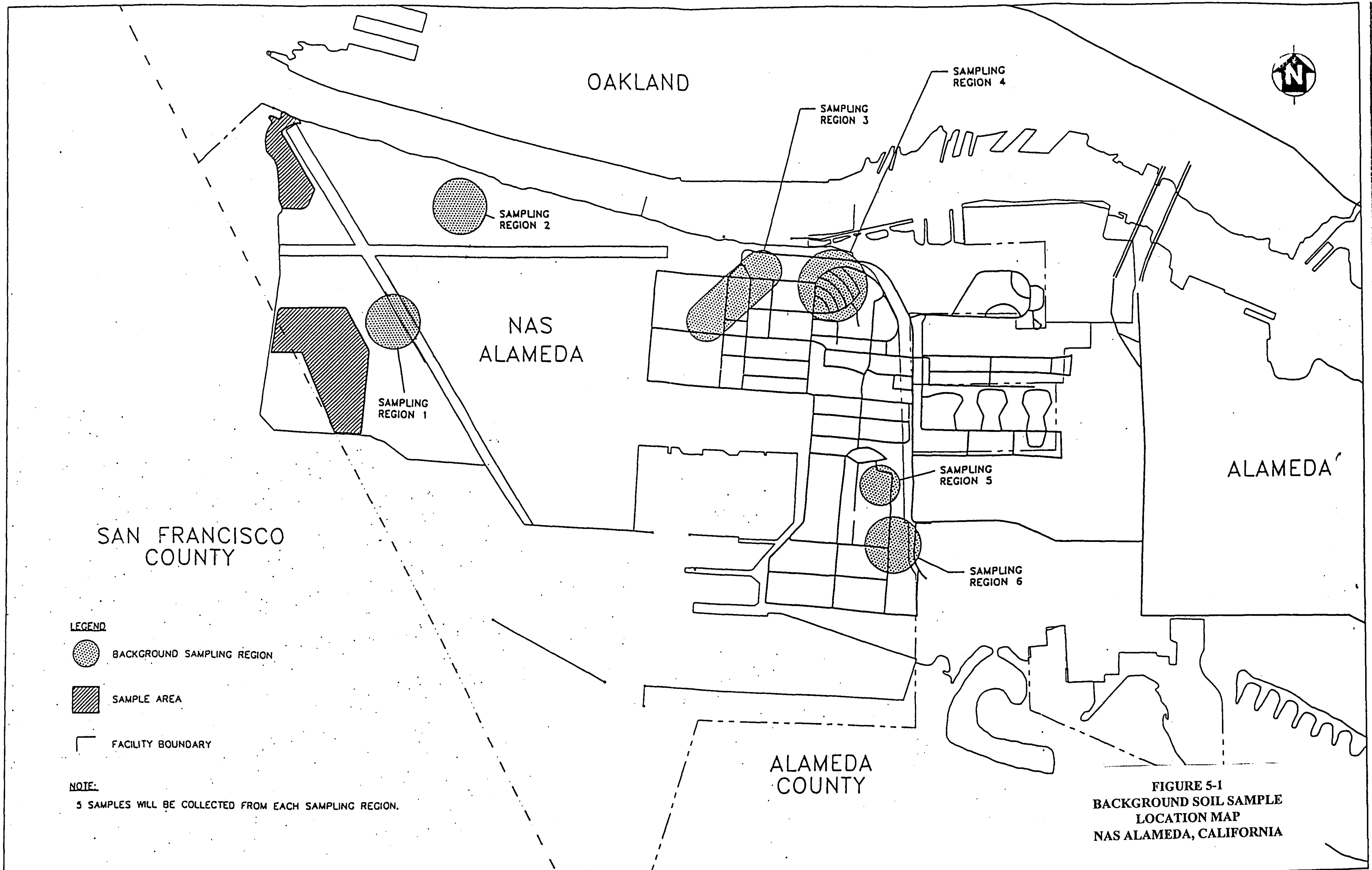

FIGURE 5-1
BACKGROUND SOIL SAMPLE LOCATION MAP
NAS ALAMEDA, CALIFORNIA

background count rates as given by Equation 4-1 while substituting the background standard deviation for the square root of the singe background count rate.

During the course of the background survey, radiation levels varied from 1,536 cpm to 2,267 cpm with a mean count rate of 1,840 cpm. Figure 5-2 displays the background count rates of the 30 background sampling locations. The solid line represents the 95 percent confidence level of the background count rate. Count rates detected in field surveys greater than this count rate (2,158 cpm) should be considered significantly above background. Complete results of the background survey are provided in Appendix A.

5.2 GRID NODE SURVEY

A 20-meter by 20-meter grid coordinate system was used to conduct the radiological survey for both Sites 1 and 2, as shown in Figures 2-1 and 2-2, respectively. Site 1 contained 164 grid nodes, and Site 2 contained 542 grid nodes. The work plan for the survey called for the use of a global positioning system (GPS) to establish locations within the grid system. As a result of unforeseen problems with the system, the GPS was not used. Instead, a compass, measuring tape, flags, and pylons were used to establish baseline transects off of which additional transects were established. The approximate accuracy of the grid system was approximately 5 to 10 meters within Site 1 and 10 to 20 meters within Site 2.

The grid node surveys were conducted using the Ludlum Model 44-10 detector coupled to the Ludlum Model 2221 rate scaler. The rate scaler was operated in scaler mode with the voltage set at 650 volts and the threshold set to 100 keV. The detector was operated with the window out.

During the course of the radiological survey within Sites 1 and 2, background radiation levels were found to vary by a large degree, from less than 900 cpm to more than 2,200 cpm. Areas that were low-lying, damp, or covered with vegetation generally demonstrated the lower count rates. Areas with at-surface gravel, roads and road beds, and areas with little vegetation generally demonstrated the higher count rates.

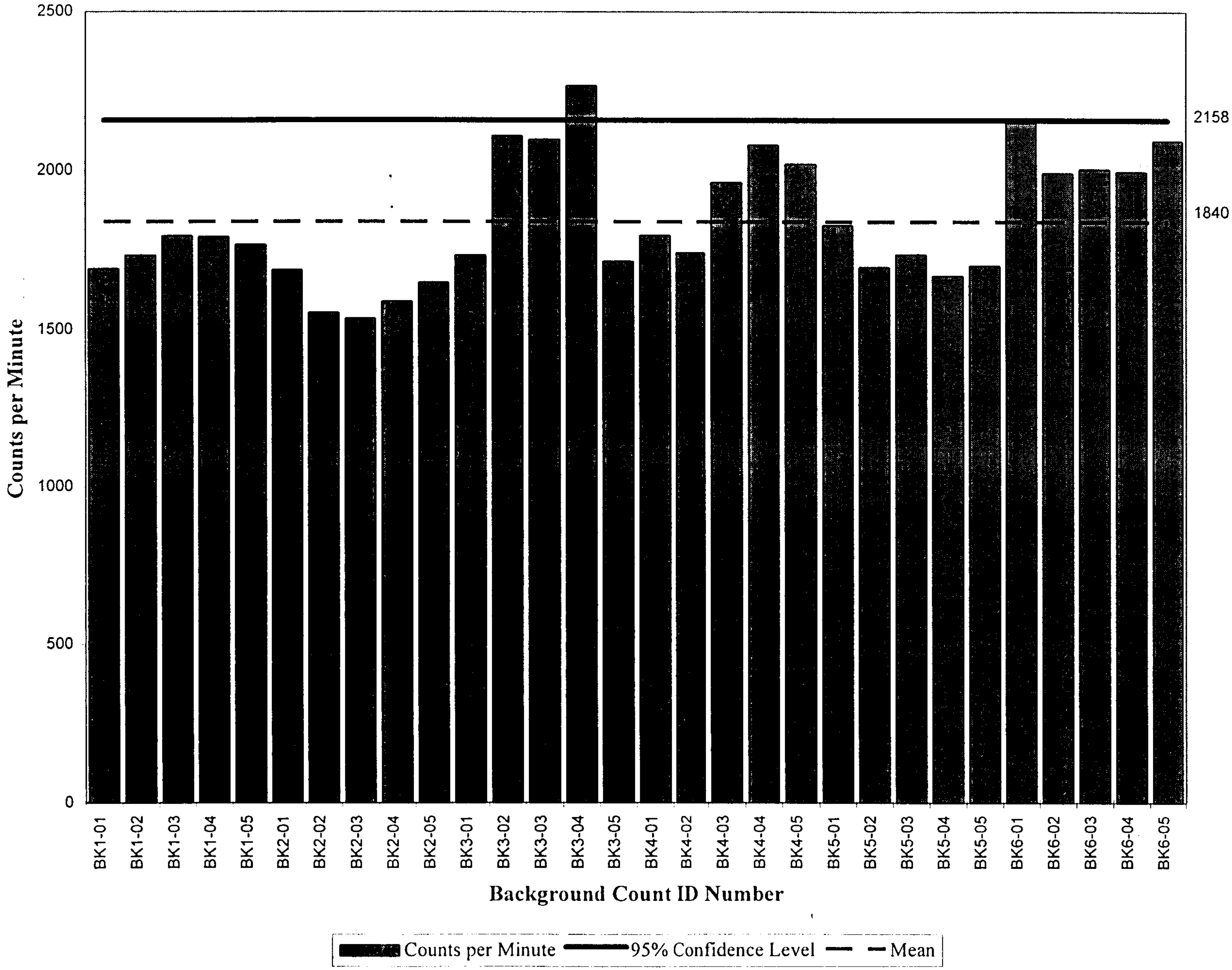

FIGURE 5-2
BACKGROUND SOIL ACTIVITY
NAS ALAMEDA, CALIFORNIA

The complete results of the grid node survey are provided in Appendix B. Figures 5-3 and 5-4 summarize the survey results. Figure 5-3 represents the raw data found in Appendix B. Figure 5-4 is a histogram plot showing the distribution of the data. The solid horizontal line on Figure 5-3 is the value (2,158 cpm) at which a measurement would have been considered above background as determined by the background survey discussed in Section 5.1. The figure shows that several of grid node survey points produced a result greater than the 95 percent confidence level of the background. The highest count rate occurred at survey point A-3. The survey at A-3 resulted in a 5,881 cpm count rate and an exposure rate of about 30 μR per hour as determined by the Ludlum Model 19 survey meter. This anomaly was labeled as Anomaly 22. Anomaly locations were marked with stakes or flags.

If the grid node measurement only slightly exceeded 2,158 cpm, however, the Ludlum Model 19 μR survey meter was used to survey the general area of that particular grid node. If the values at a specific point significantly exceeded the background for the area in which it was located, it was considered an anomaly. Although this method was more subjective than comparing measurements against a preestablished critical value, it was practical under the conditions present, that is, widely varying background. This method led to the labeling of one anomaly, Anomaly 17, at grid node P-3. The survey at P-3 resulted in a 2,245 cpm count rate and an exposure rate of 8 to 10 μR per hour using the Ludlum Model 19 survey meter. An exposure rate of 5 to 7 μR per hour was measured in the surrounding area. Table 5-1 summaries the two anomalies discovered by the grid node survey.

TABLE 5-1

GRID NODE SURVEY ANOMALIES

Anomaly Number	Grid Node	Count Rate (cpm)	Exposure Rate (μR/hr)
17	P-3	2,245	8 to 10
22	A-3	5,881	~ 30

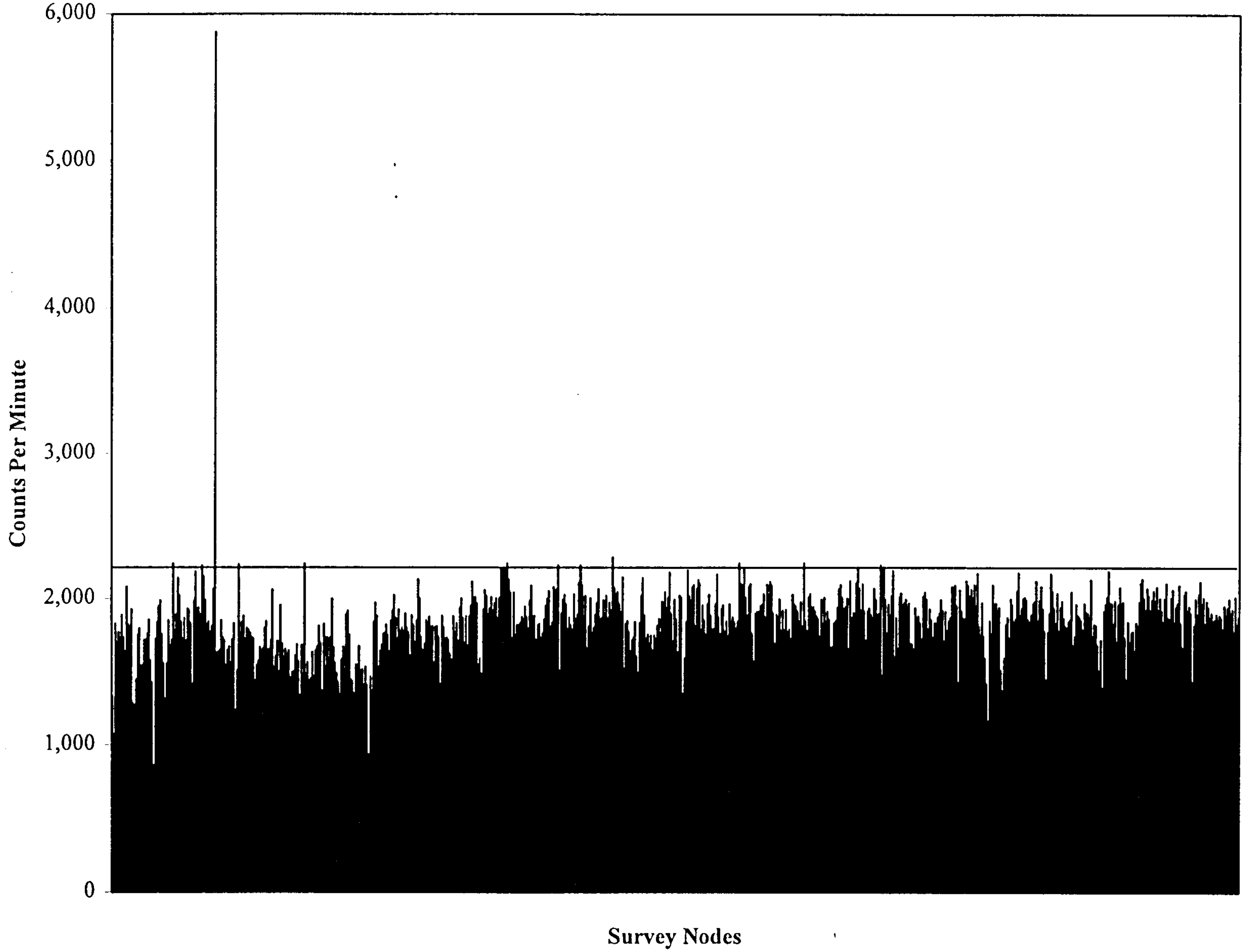

FIGURE 5-3
GRID NODE SURVEY RESULTS
SITES 1 AND 2, NAS ALAMEDA, CALIFORNIA

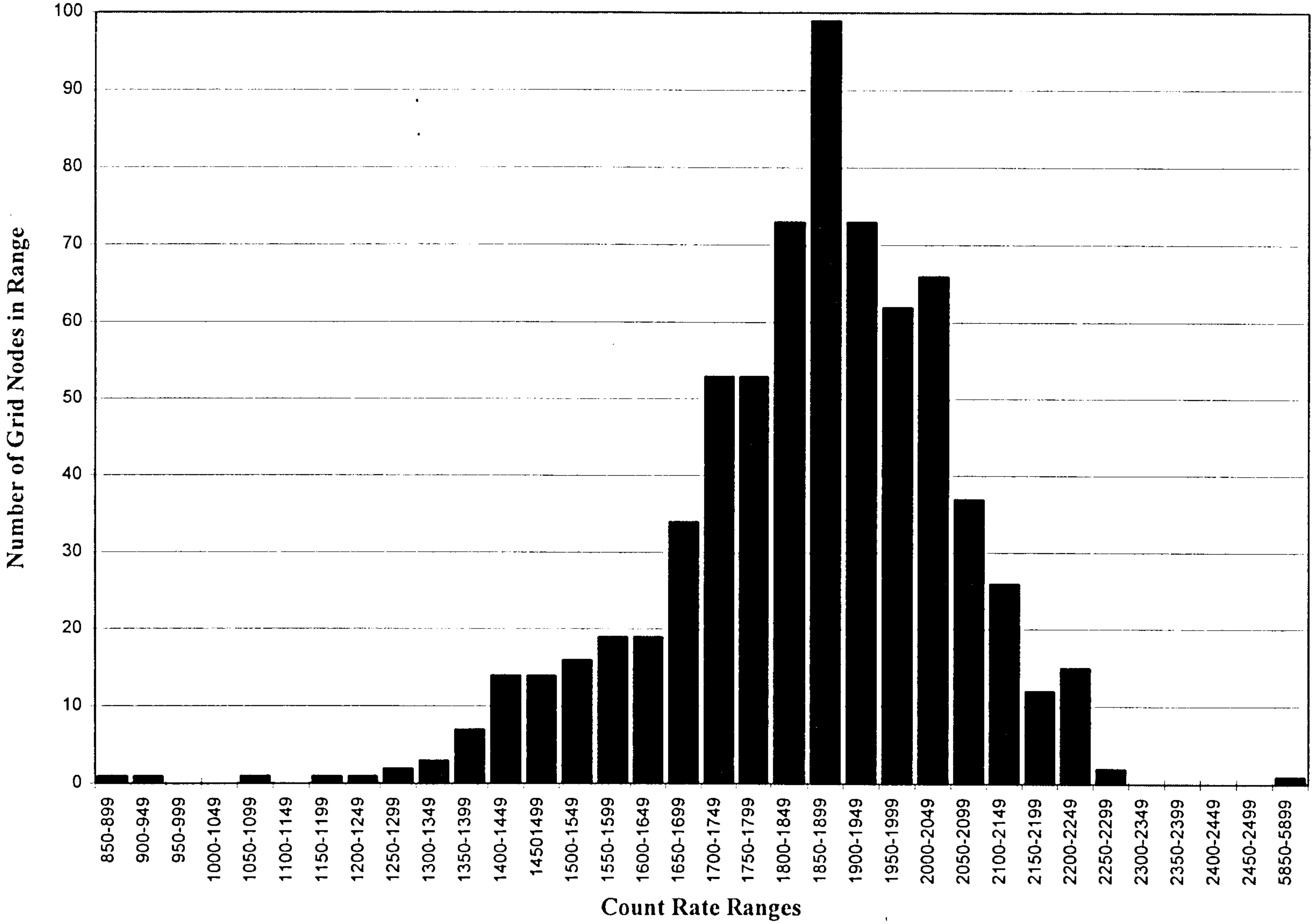

FIGURE 5-4
DISTRIBUTION OF GRID NODE SURVEY COUNT RATES
SITES 1 AND 2, NAS ALAMEDA, CALIFORNIA

5.3 TRANSECT WALKOVER SURVEY

The transects connecting the grid nodes are also shown in Figures 2-1 and 2-2 for Sites 1 and 2, respectively. Each of the 20-meter transects that connected the grid nodes were surveyed using the Ludlum Model 19 1-inch by 1-inch NaI μR exposure rate meter. The transect was surveyed at a pace of about 0.5 meter per second. During the survey, the detector was swept back and forth across the transect over an area about 1 meter wide while keeping the detector as near to the ground surface as possible. The detector's response was visually and audibly monitored. Approximately 14,120 meters of transects were scanned in Sites 1 and 2.

If elevated radiation levels were detected by the survey meter, the area of highest radiation was determined and the location was noted and marked as an anomaly. The Ludlum Model 44-10 2-inch by 2-inch NaI detector was then used to determine a count rate at the location. Table 5-2 summarizes all anomalies located during the transect walkover survey.

All anomalies found were located in Site 1 with the exception of Anomaly 21, which was found in Site 2, and Anomaly 11, which was found between the Site 1 and Site 2 survey areas west of the sand volleyball court in the recreation area south of the Site 1 survey area. Anomaly 11 was discovered in a random survey of the recreation area. The approximate locations of all anomalies are marked in Figures 2-1 and 2-2. Table 5-2 also identifies those anomalies at which a radioactive source was recovered from the near-surface. Each of these sources was recovered from a depth of no greater than 5 inches.

TABLE 5-2

TRANSECT WALKOVER SURVEY ANOMALIES

Anomaly Number	Location	Count Rate (cpm)	Exposure Rate (μR/hr)
1	8 m N of G-8	NC	17
2	8 m N of G-8	4,662	17
3	1.3 m W of J-8	4,523	12
4	13 m E of G-7	26,566	100
5	3 m N of trailer in C-D/2-3	10,462	30
6	just N and W of #5	5,238	20
7[a]	10 m W of D-3	NC	200 (8 to 10)
8	10 m E of B-3	5,189	20
9	5.3 m E of B-3	34,328	120
10	near A-3, in front of blue waste bin	22,988	100
11	2 m E of volley ball court, S of trailer	13,219	50
12[a]	between I-3/I-4, 7 m NE of northern corner yellow post/Bldg. 133	18,888	150 (5 to 7)
13[b]	between I-8/I-9	5,720	25
14	between J-8/J-7	13,431	50
15	between O-3/O-4	2,544	15
16	3.3 m E of O-4	23,379	100
18[a]	3.3 m E of S(-1)	27,129	190 (15)
19	2.6 m W of S(-1)	5,672	20
20	3.6 m W of C-3	32,826	120
21[a]	1.2 m S of DD-16	178,563	2,500 (10 to 12)
23[b]	5 m east of #18	NC	2,000

Notes:

cpm	counts per minute	μR/hr	microRoentgen per hour
N, S, E, W	north, south, east, and west	m	meters
NC	no count rate determined	( )	post recovery rate

a Source recovered.

b Exposure rate did not drop off dramatically with distance suggesting a deep, strong source.

Based on the historical information on the types of waste that went into both the Site 1 and the Site 2 landfills (see Sections 3.1 and 3.2), one would expect the radioactive waste content in the respective landfills to be more evenly distributed than is seen by the number of anomalies detected in each site. The fact that only one anomaly was located in Site 2 may be primarily due to the thickness of the cover material in Site 2. The thickness of the cover material was noticeable because there was less surface debris found in Site 2 than in Site 1. Also, rodent burrows in Site 2 were relatively free of debris, suggesting that the animals encountered very little debris while digging the borrows. Borrows observed in Site 1, however, typically contained some debris or trash. It was also more difficult to survey Site 2 because of the tall grasses and brush that densely covered most of the area. The amount of vegetation often made it difficult to get the μR survey meter close to the ground surface. With the meter more than a few inches off the ground surface, the area that it can effectively survey is greatly reduced.

6.0 IN SITU GAMMA SPECTROSCOPY

At each of the anomaly locations, an in situ gamma energy spectrum was collected to identify the radioisotopes present above background levels in the soil. The instruments used to collect the spectrum were the EG&G ORTEC MicroNOMAD™ Portable Spectroscopy System for NaI Detectors, the EG&G ORTEC ScintiPack™ and high voltage supply, and the Teledyne 2-inch by 2-inch NaI photomultiplier tube. The MicroNOMAD™ system allowed for the collection of the spectra in the field for later analysis using a personal computer and the EG&G MicroMCB™ for Windows NaI Emulator and Analysis Software, Version 1.2.

The sources of radiation present in the soil were identified by analyzing the photopeaks in the gamma energy spectrum. The MicroMCB™ software has the capabilities of comparing the photopeak energies to radioisotopes in its library and selecting the best match. This computer analysis was then verified by PRC analysts using radiological information and decay tables. The accuracy of the computer analysis is based on the efficiencies of the energy and efficiency calibrations performed with a known radioactive standard. The following sections detail the procedures involved in the gamma spectroscopy calibrations, data collection, and analysis.

6.1 CALIBRATION

Before analyzing the gamma energy spectra collected in the field at the anomaly locations, PRC collected an energy spectrum for a known radiation standard. The standard selected for the purpose of analyzing the NAS Alameda anomalies was a 560 milliliter multinuclide standard source dispersed in an epoxy fill obtained by PRC from Isotope Products Laboratories in Burbank, California. The source is identified by catalog number EG-MLAM-062 and source number 470-61. As required by the work plan, this source is traceable to the National Institute of Standards and Technology (NIST). The certificate of calibration is included in Appendix C. The calibration spectrum was collected prior to spectrum analysis at the PRC field laboratory at HPA.

The multinuclide NIST traceable source was selected primarily based on its cesium-137 content. Cesium-137 decays by beta emission to barium-137-metastable which releases a 662 keV photon in its conversion to barium-137. The conversion ratio is 85.1 percent. The photopeak produced by the 662 keV gamma ray is well defined and easily identifiable in the spectrum of the standard. Using this peak as a mid-range point in a multi-point calibration ensures an accurate analysis of peaks near the 662 keV energy level. This is important to the in situ analysis of the NAS Alameda anomalies because the primary suspect radioactive contaminant, radium-226, has an easily identifiable daughter, bismuth-214, that gamma decays with an energy of 609 keV.

6.2 DATA COLLECTION AND ANALYSIS

All in situ energy spectra were collected at each anomaly in the same manner. The detector setup involved suspending the photomultiplier tube, coupled to the preamplifier, from a tripod so that the detector would remain 3 inches above the ground surface. Figure 6-1 is a schematic of the detector setup. The duration of the counting time was either 15 or 30 minutes, and the spectrum was collected on the buffer of the MicroNOMAD™ system.

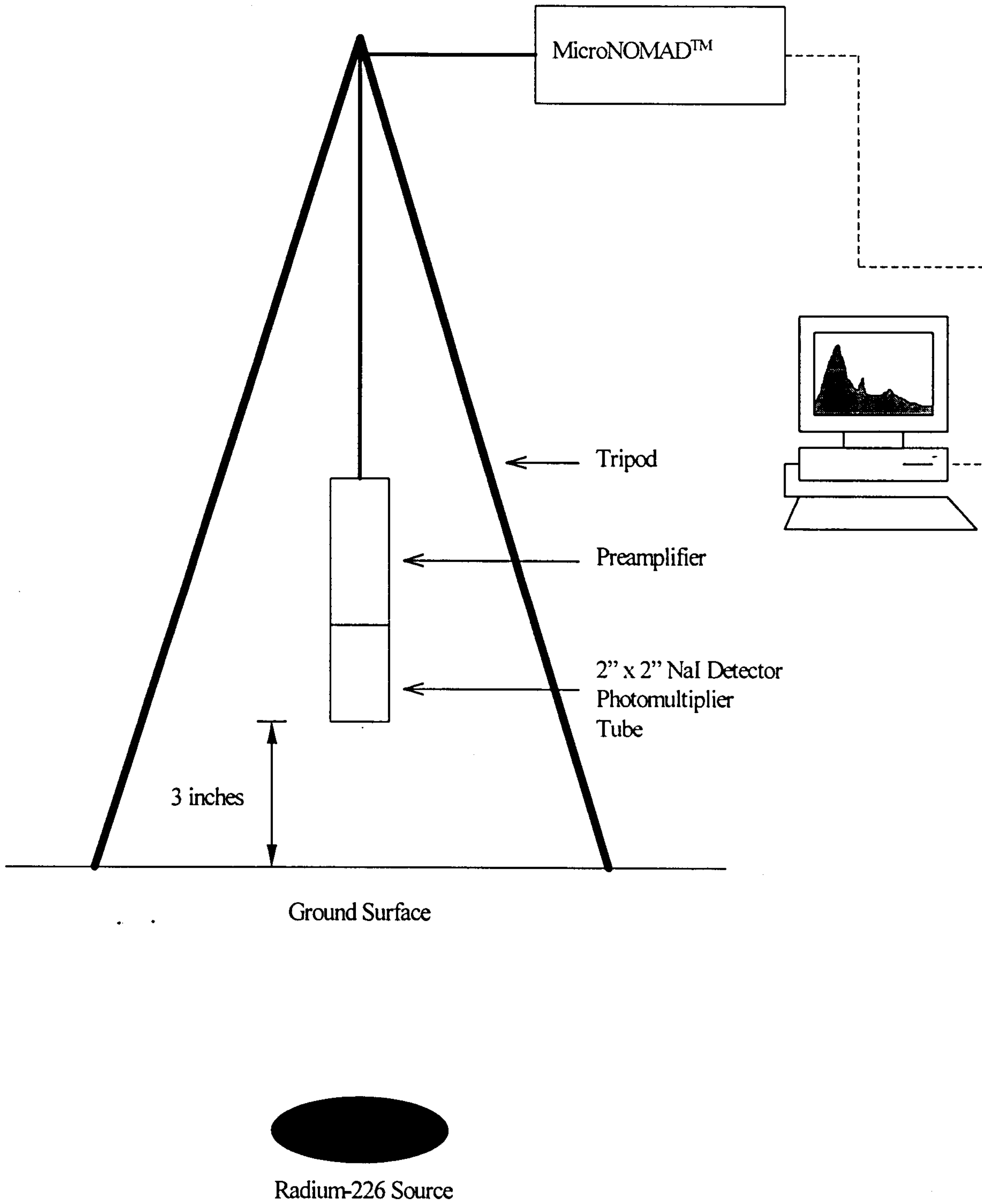

FIGURE 6-1
IN SITU GAMMA SPECTROSCOPY SYSTEM SETUP

The buffer was periodically downloaded onto a personal computer and stored on the computer hard disk and a floppy disk. Analysis was performed on the personal computer using the MicroMCB™ software.

The principal radioactive contaminant expected, radium-226, results in the scenario depicted in Figure 3-1 in some degree of secular equilibrium depending on the physical condition of the source. From an initially pure radium-226 source, 99 percent of equilibrium is reached is reached in 23.5 days. Detection of radium-226 is based on identification of the bismuth-214609 keV photopeak which cannot exist unsupported by radium-226. The half-life of bismuth-214 is 19.7 minutes. Analysis is based on the assumption that bismuth-214 is in secular equilibrium with radium-226. Direct measurements of the photon resulting form the radium-226 alpha decay is not practicable due to the lower intensity (4 percent) and high background due to the Compton continuum and backscatter peaks due to high energy photons.

6.3 ANALYTICAL RESULTS

Table 6-1 summarizes the results and conclusions of the in situ gamma spectroscopic analysis of the Site 1 and Site 2 anomalies found during the radiological investigation. The intent of this analysis was to identify the isotopic source of the anomaly and to semi-quantify its activity. Identification of the bismuth-214 609 keV photopeak indicates the presence of radium-226 in the soil at levels above background. The activity of the bismuth-214 was determined by the MicroMCB™ program and, for the purpose of this study, the activity of the radium-226 is inferred for the bismuth activity. The results of the in situ analysis do not, however, allow the analyst to determine whether the radium-226 activity is caused by a discrete point source, such as a dial face painted with luminescent paint, or a dispersed source distributed in the soil. Because of the unknown factors involved, such as depth of the source, soil densities, and the physical nature of the source, it is not possible to fully quantify radium-226 activities using the in situ spectrum analyses.

The relationship between the strength of the bismuth-214 609 keV peak and the total spectrum count rate should be noted. If a high count rate is associated with a weak peak, it may be an indication of diffuse activity or a strong source that is buried deep in the soil. This is particularly evident in spectrum of anomaly number 23. The relationship could also indicate that the measurements were not taken directly above the source, but rather a short distance away. In these instances, the amount of soil between the source and the detector creates muffled peaks that are difficult to distinguish. The converse of this relationship should also be true; that is, a low count rate associated with a well defined peak, as in the spectrum for anomaly number 17, may be an indication that the source is weak but near the surface.

A typical in situ spectrum for an anomaly (anomaly No. 10) is shown in Figure 6-2. The highlighted peak area is the bismuth-214 609 keV gamma photopeak, which demonstrates the presence of radium-226. Figure 6-3 is a background in situ spectrum. The vertical scale is displayed as "FS" in the figures in the box labeled "Vert" and should be noted. The elevated regions on the low-energy (left side) of both spectra are a result of the Compton edge effects typical of NaI detectors (Knoll 1989). Appendix D contains the spectra from the in situ gamma spectroscopic analysis of all anomalies.

TABLE 6-1

IN SITU GAMMA SPECTROSCOPY RESULTS

Anomaly No.	Collection Time (minutes)	Ra-226 Activity[a] (µCi)	Total Spectrum cpm	Comments
1	15	0.003	12,546	small peak
2	15	0.005	24,881	small peak
3	15	0.004	22,596	very small peak
4	14	0.026	179,235	small peak
5	30	0.005	19,203	small peak
6	30	0.003	14,358	small peak
7[b]	30	0.001	7,674	source removed / small peak
8	15	0.006	27,666	very small peak
9	15	0.022	116,061	small peak
10	15	0.042	95,967	well defined peak
11	30	0.014	35,529	well defined peak
12[b]	NA	NA	NA	source removed / no spectrum taken
13	15	0.004	34,474	small peak
14	15	0.039	73,232	well defined peak
15	30	0.002	9,780	very small peak
16	30	0.019	106,572	very small peak
17	30	0.009	6,982	well defined peak
18[b]	30	0.146	143,196	source removed / well defined peak
19	30	no peak identified	16,421	no peaks identified
20	15	0.023	150,708	small peak
21[b]	NA	NA	NA	source removed / no spectrum taken
22	15	0.013	29,986	well defined peak
23	15	0.724	209,402	very small peak
Background	15	no peak identified	6,492	no peaks identified

Notes:
- NA — No spectrum was collected as a result of the response of the Ludlum Model 44-10 2-inch by 2-inch detector, indicating that the location did not exhibit counts above background once the source was removed.
- cpm — counts per minute
- a — Ra-226 (radium-226) activity equal to the bismuth-214 activity as determined by the MicroMCB™ program (the background activity has been subtracted).
- b — A discrete source was located and removed before the spectrum was collected.

FIGURE 6-2

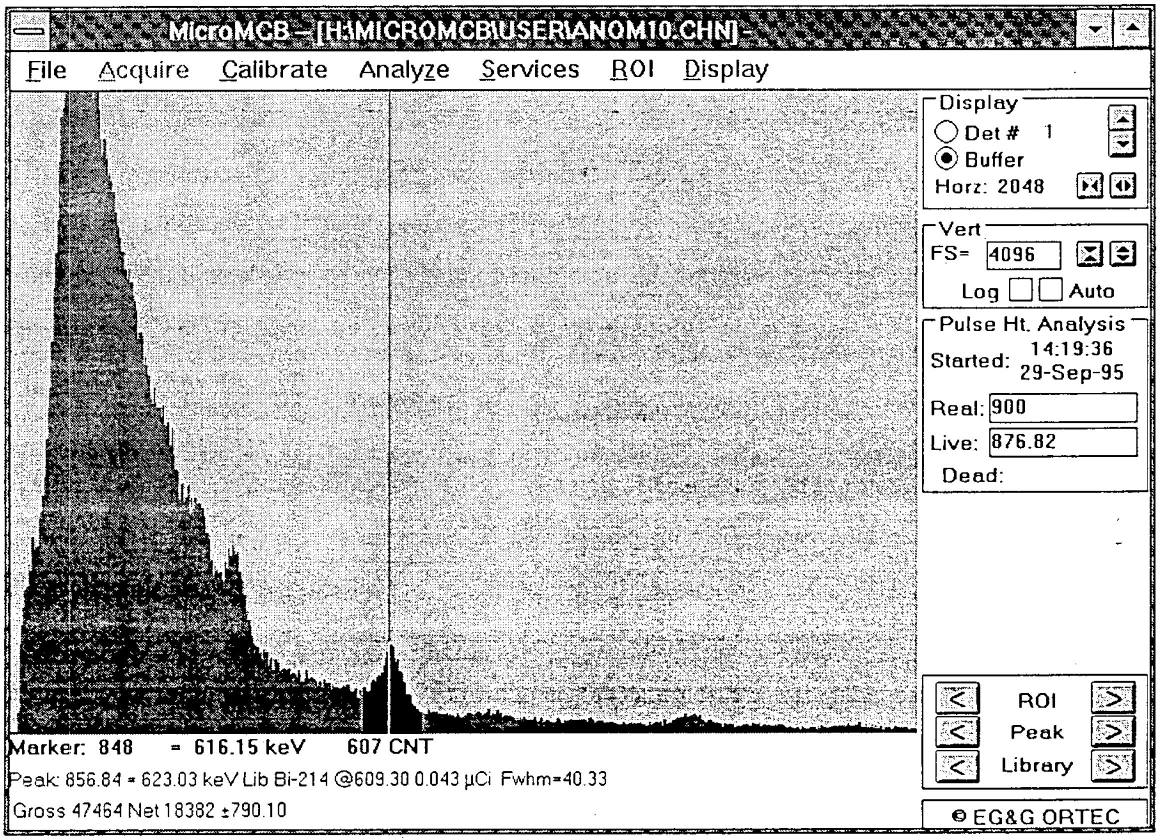

FIGURE 6-2
IN SITU SPECTRUM OF ANOMALY 10

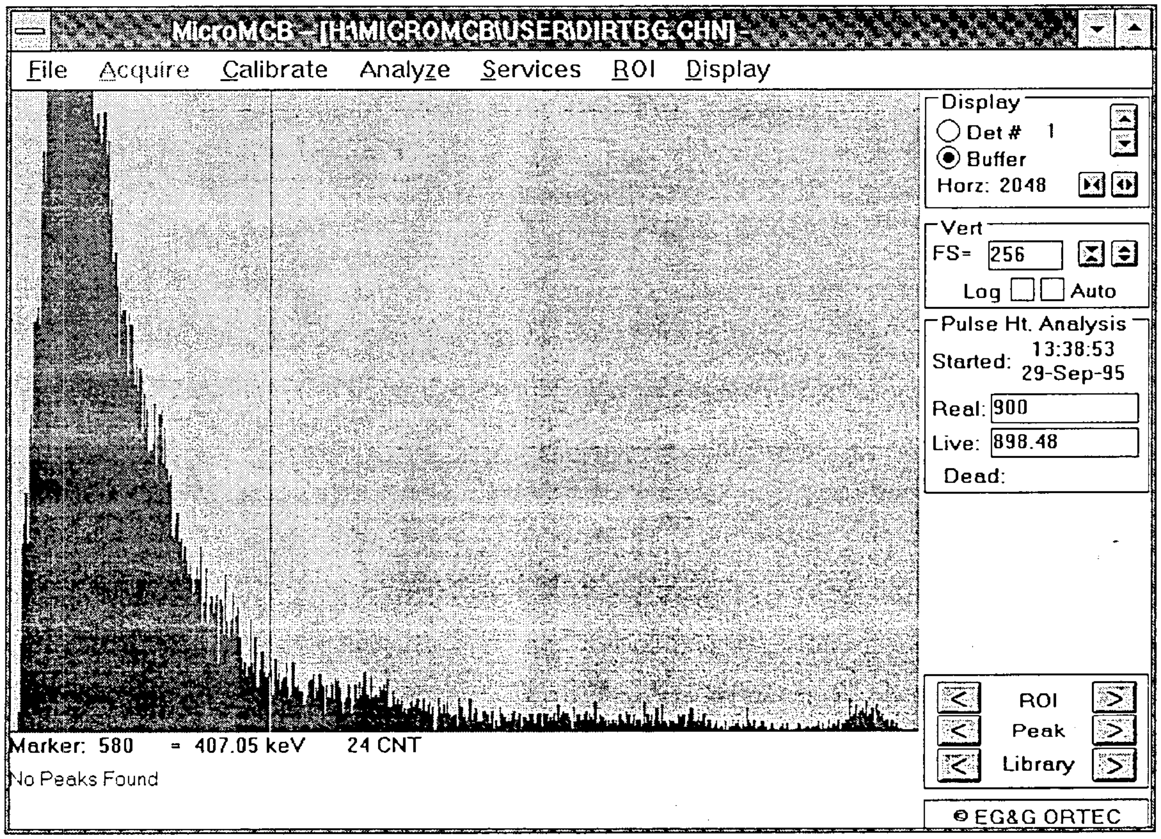

FIGURE 6-3
IN SITU BACKGROUND SPECTRUM

7.0 SOIL SAMPLE ANALYSIS

At each anomaly location, a surface soil sample was collected. The soil samples were placed in 500 milliliter (ml) plastic wide-mouth containers with screw-on lids. In four instances, extremely low-level radioactive sources were recovered from the soil sample. These sources were placed in glass sample jars. After a gamma spectroscopic analysis, these pieces of material were shown to be contaminated with radium-226. Table 7-1 summarizes the descriptions of these radioactive sources.

These sources are controlled by PRC and they are stored NAS Alameda. The anomaly soil samples, along with the 30 soil samples collected from each of the background sampling locations at NAS Alameda, are also stored in PRC's radiation laboratory at HPA.

Before leaving the field, PRC surveyed each sample container using the Ludlum Model 19 μR exposure rate meter. None of the soil samples produced exposure rates greater than 12 μR per hour. All soil samples were then taken to HPA for gamma spectroscopic analysis. At HPA, the soil samples were allowed to air dry for 11 days. Then the sample containers were tightly sealed with electrical tape and stored for 1 month to allow the radium-226 decay products to reach secular equilibrium.

Drying the samples results in a concentrated, or dry weight, soil activity. To correlate the concentrated sample activities back to natural site activities, it will be necessary to obtain a dry-to-wet soil weight ratio averaged over a full year. Multiplying the dry soil activities by this ratio will give a more realistic activity for anomalous soils in the field.

TABLE 7-1

RADIOACTIVE SOURCES RECOVERED FROM SITES 1 AND 2

Anomaly No.	Depth to Source (inches)	Physical Description	Approximate Activity[a] (μCi)	Exposure Rate[b] (μR/hr)
7	surface	~ 2 inch long cylinder, threaded and open at one end	0.61	300
12	3	small cylinder ~ 0.25 inches in diameter by ~ 1 inch long	0.23	180
18	3	~ 1.3 inch diameter disk (may have been a deck marker)	0.70	200
21	5	metal plate with curved sides approximately 3 inches by 1.5 inches	9.46	3,500

Notes: μCi microCurie

μR/hr microRoentgen per hour

a The activity was approximated using the Ludlum Model 44-10 2-inch by 2-inch NaI detector and the known activity of the 0.87 μCi radium-226 button using the following equation:

$$A\ (\mu Ci) = \frac{C_2 - B}{C_1 - B} \cdot 0.87\ \mu Ci \qquad \text{(Equation 7-1)}$$

where:

A = the activity of the unknown source in μCi

C_2 = number of counts due to the unknown source at a distance x from the detector

C_1 = number of counts due to the known 0.87 μCi button at a distance x from the detector

B = number of background counts

b Exposure rates taken at one inch from the sample jar containing the source.

7.1 GAMMA SPECTROSCOPY

The gamma spectroscopic analysis of the soil samples collected at NAS Alameda was performed at PRC's radiation laboratory at HPA. The MicroNOMAD™ system and the MicroMCB™ software were used to obtain gamma decay energy spectra for the soil samples. The detector and samples were placed in a cylindrical copper-lined lead container to shield against background radiation as well as other radioactive sources in the laboratory. Figure 7-1 is a schematic of the analytical equipment setup.

Calibration of the MicroNOMAD™ system was performed using the same NIST traceable multinuclide standard discussed in Section 6.1, while the counting geometry was the same as for the soil samples (see Figure 7-1).

Before counting the soil samples, PRC weighed the samples using a mechanical 5-pound scale marked in 0.5-ounce increments. The weight of the soil samples ranged form 440 grams to 860 grams. The sample weights were input into the MicroMCB™ program before the spectrum collection began.

Each soil sample was counted for 20 minutes. The detector response was displayed directly to a lap-top personal computer without the use of the MicroNOMAD™ buffer. All spectra were saved onto the computer's hard disk and then backed-up onto a floppy disk.

The purpose of the gamma spectroscopic analysis was to identify and semi-quantify the presence of radium-226 and any other gamma-emitting radionuclides present in the soil samples. Radium-226 and its decay products were the only radionuclides identified in the soil samples using this method. To quantify the radium-226 present in the samples, it was determined that a region of interest (ROI) should be defined that would contain the bismuth-214 609 keV photopeak in each soil sample spectrum. The bismuth-214 609 keV photopeak was used to identify the presence of radium-226 in the same manner discussed in Section 6.2. The spectrum of a background soil sample is given in Figure 7-2, and a spectrum for a soil sample containing

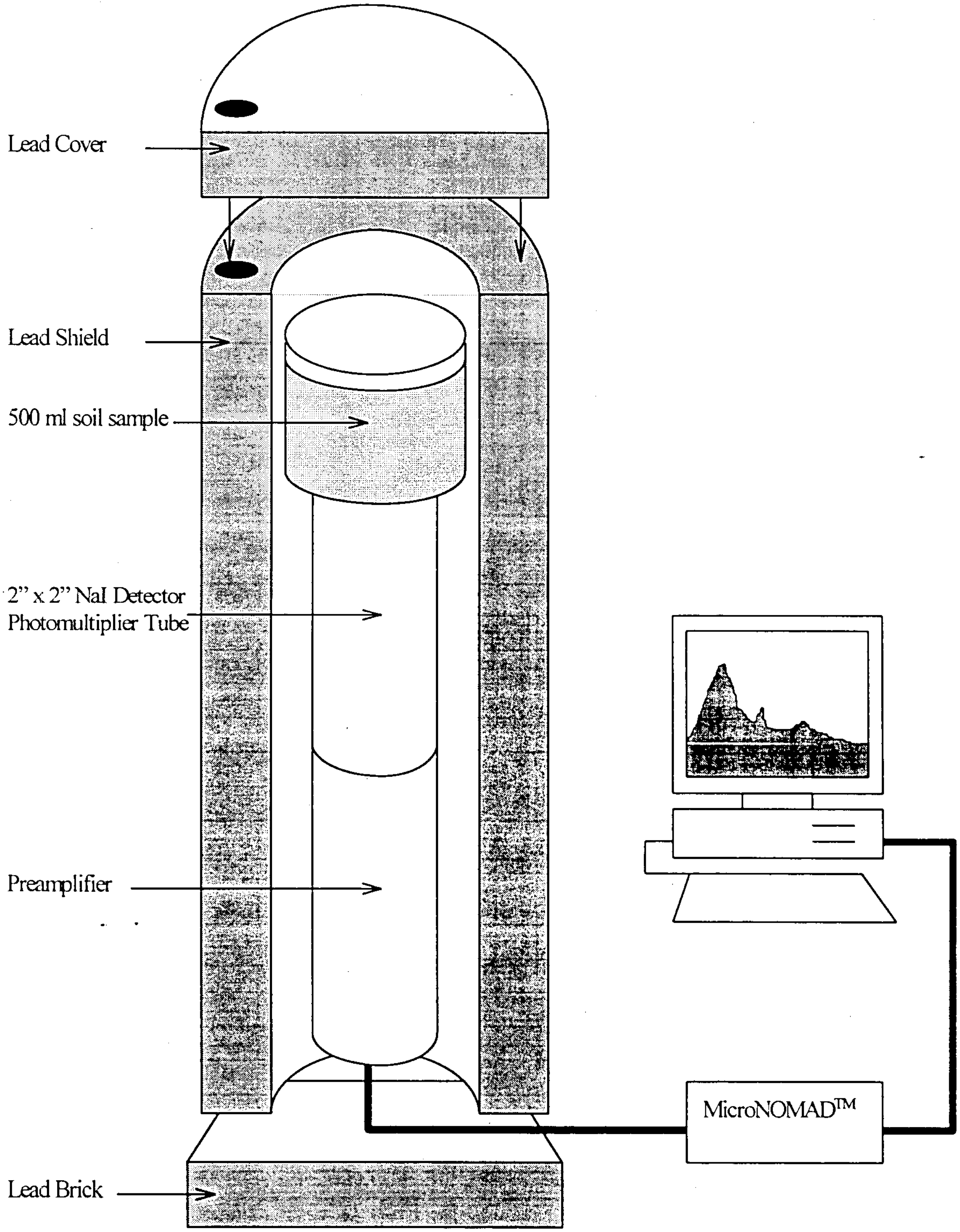

FIGURE 7-1
GAMMA SPECTROSCOPY LABORATORY SYSTEM SETUP

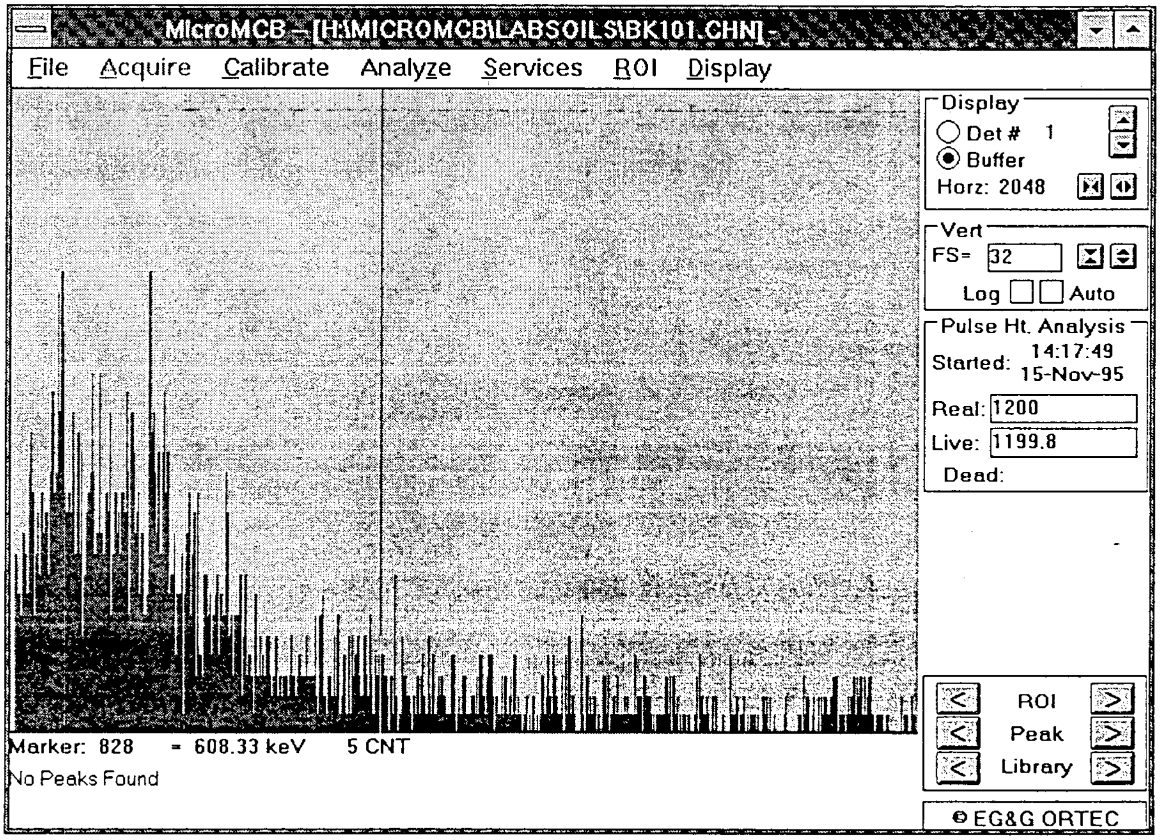

FIGURE 7-2
BACKGROUND SOIL SAMPLE SPECTRUM

radium-226 is given in Figure 7-3 with the photopeaks and their gamma decay energies labeled for radium-226 and its decay products.

Identifying a constant ROI was necessary because of minor shifts in the bismuth-214 609 keV peaks from spectrum to spectrum. If the MicroMCB™ program was allowed to pick the ROI for the bismuth-214 609 keV peaks, each peak may have had a different ROI energy range. A ROI range from 559.47 keV to 680.22 keV was selected based on the range of ROIs identified by the program. Choosing a constant ROI also allowed for consistent measurements of the background samples. Therefore, the gamma spectroscopic analysis was performed only within the ROI.

Table 7-2 summarizes the ROI analysis of the background soil samples. The ROI gross counts, ROI net counts, and the error associated with the net counts were determined by the MicroMCB™ program analysis. The ROI activity, assumed to be the result of bismuth-214, was calculated by the following equation:

$$Activity\ (pCi/g) = \frac{ROI\ Net\ Counts}{t \cdot E \cdot 2.22 \cdot M \cdot BR} \qquad \text{(Equation 7-2)}$$

where:

t	=	counting time = 20 minutes
E	=	counting efficiency = 0.011 counts per disintegration (this is the approximate efficiency at 609 keV determined by the calibration of the mixed standard source and the MicroMCB™ program)
2.22	=	conversion factor (disintegrations per minute to pCi)
M	=	weight of sample in grams
BR	=	branching ratio of the bismuth-214 609 keV gamma = 0.463

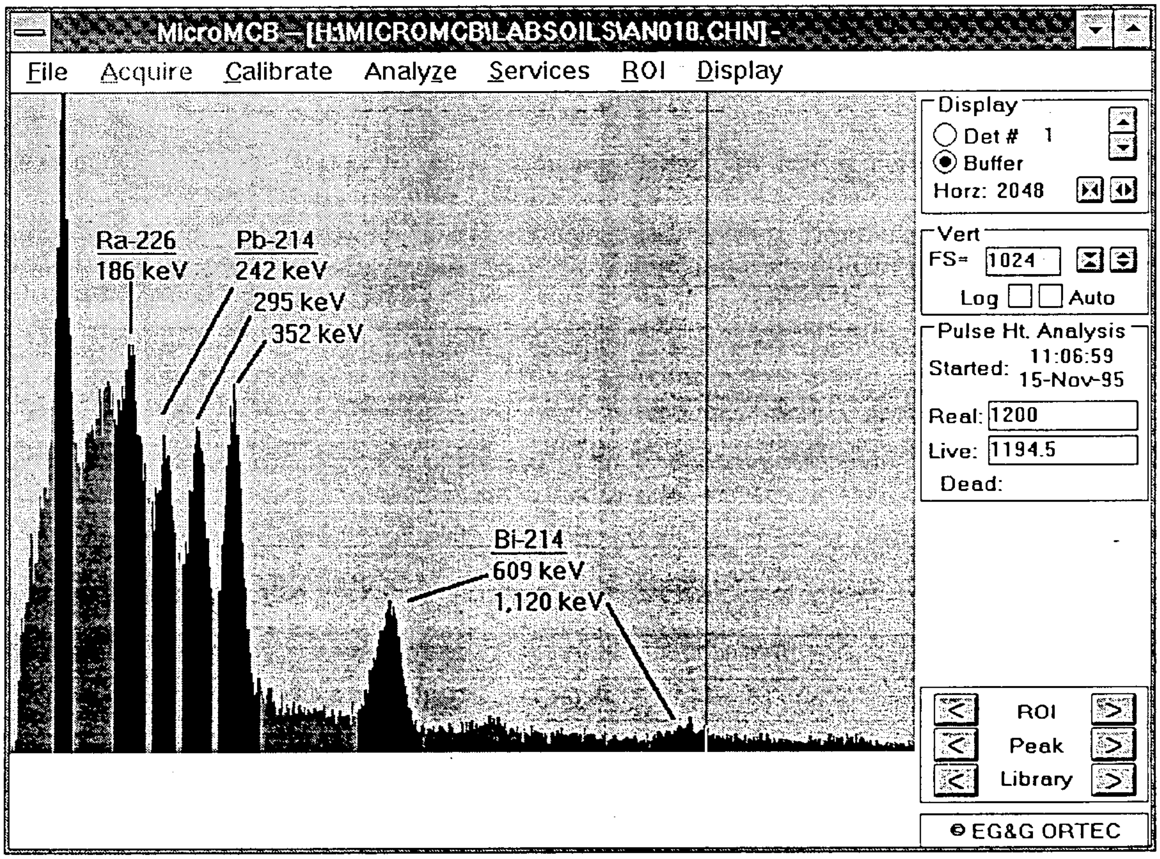

FIGURE 7-3
ANOMALY SOIL SAMPLE SPECTRUM

TABLE 7-2

BACKGROUND SOIL SAMPLE DATA

Background Sample No.	ROI Gross Counts	ROI Net Counts	± Net Counts	Sample Size (grams)	Background ROI Activity[a] (pCi/g)	MDA (pCi/g)
1-01	348	108	94.1	695	0.69	0.10
1-02	480	-15	114.5	695	< 0.14	0.14
1-03	397	-43	107.8	782	< 0.12	0.12
1-04	419	-182	126.7	695	< 0.13	0.13
1-05	485	128	98.1	723	0.78	0.12
2-01	456	-67	117.3	652	< 0.14	0.14
2-02	400	-70	111.6	765	< 0.13	0.13
2-03	444	142	90.3	795	0.79	0.11
2-04	407	-33	107.8	680	< 0.13	0.13
2-05	432	-8	107.9	666	< 0.14	0.14
3-01	497	57	108.3	439	0.57	0.17
3-02	537	70	111.7	624	0.50	0.15
3-03	505	-45	120.5	567	< 0.16	0.16
3-04	533	176	98.3	510	1.53	0.14
3-05	440	193	82.2	524	1.63	0.12
4-01	462	22	108.1	638	0.15	0.14
4-02	420	90	94.0	454	0.88	0.15
4-03	463	188	86.5	595	1.40	0.12
4-04	494	109	101.6	588	0.82	0.14
4-05	498	-107	126.2	482	< 0.18	0.18
5-01	524	56	112.2	687	0.36	0.14
5-02	481	179	90.5	617	1.28	0.12
5-03	428	263	68.1	730	1.59	0.08
5-04	512	47	110.9	709	0.29	0.14
5-05	566	-11	123.7	773	< 0.15	0.15
6-01	509	97	105.0	680	0.63	0.13
6-02	503	-130	128.9	815	< 0.14	0.14
6-03	494	82	104.9	758	0.48	0.13
6-04	545	-114	132.6	780	< 0.14	0.14
6-05	600	23	123.9	865	< 0.14	0.14

Notes:
- pCi/g — picoCuries per gram
- a — Using Equation 7-2, negative net count activities have been replaced by the MDA.
- ROI — Region of interest
- MDA — Minimum detectable activity

The minimum detectable activity (MDA) for a laboratory gamma spectroscopic measurement given in Table 7-2 is calculated using the following equation taken from NRC guidance NUREG/CR-5849 (NRC 1993). The equation for the MDA of a typical laboratory procedure for soil analysis is:

$$MDA = \frac{2.71 + 4.65\sqrt{(B_R \cdot t)}}{t \cdot E \cdot S \cdot Y \cdot 2.22} \quad \text{(Equation 7-3)}$$

where:

MDA	=	activity in picoCuries per gram
B_R	=	background count rate in counts per minute
t	=	counting time in minutes
E	=	detector efficiency in counts per disintegration
S	=	sample size in grams
Y	=	branching ratio of radionuclide decay energy
2.22	=	conversion from disintegrations per minute to picoCuries

Table 7-3 summarizes the statistics of the background soil sample set.

TABLE 7-3

BACKGROUND SOIL SAMPLE STATISTICS

Statistic	Activity (pCi/g)	Activity (µCi)
Mean ROI activity	0.54	0.0004
Maximum ROI activity	1.63	0.0011
Minimum ROI activity	0.13	0.0001
Standard deviation	0.50	0.0003
95 percent confidence level	1.36	0.0091
Mean sample size	666.1 grams	666.1 grams

Notes: pCi/g - picoCuries per gram
µCi - microCurie

Table 7-4 summarizes the ROI analysis of the anomaly soil samples. ROI reports generated by the program are included in Appendix E. The ROI gross counts, ROI net counts, and the error associated with the net counts was determined by the MicroMCB™ program analysis. The "Calculated Ra-226 Activity" is calculated using equation 7-2, and the MDA is calculated using equation 7-3. The calculated activity values are considered to be the best estimate for the true sample activity.

Figure 7-4 shows the relationship of the radium-226 activity of the anomaly samples to the mean background and the 95 percent confidence level of the mean background. If a samples MDA was greater than its calculated activity, it was replaced by the MDA in the figure. An anomaly sample may be considered above background if its activity is greater than the 95 percent confidence level of the mean background. Figure 7-5 shows the calculated net activities or MDAs with error bars. The error bars represent the error associated with the net counts of each anomaly sample.

To maintain a readable scale in Figures 7-4 and 7-5, the anomaly soil samples with the highest radium-226 activity, AN011, AN014, AN018, and AN021, are not shown. Table 7-4 lists the activities of these samples and their associated errors.

The gamma spectroscopic analysis of the anomaly soil samples revealed that several of the samples contained elevated levels of radium-226, including three of the four samples collected from locations where radium-226 sources were recovered. The following soil samples are considered to contain radium-226 at levels above background, that is, both the calculated and computed activities are greater than 1.36 pCi per gram:

AN004	AN005	AN007	AN011	AN014
AN016	AN018	AN020	AN021	AN022

TABLE 7-4

ANOMALY SOIL SAMPLE DATA

Anomaly Soil Sample Number	ROI Gross Counts	ROI Net Counts	± Net Counts	Sample Size (grams)	Calculated Ra-226 Net Activity (pCi/g)	± Calculated Ra-226 Activity (pCi/g)	Calculated Ra-226 MDA (pCi/g)
AN001	537	70	111.7	496	0.62	1.00	0.17
AN002	786	154	130	510	1.34	1.13	0.19
AN003	567	72	114.9	602	0.53	0.84	0.16
AN004	1026	229	146.2	496	2.04	1.30	0.22
AN005	696	339	99.1	595	2.52	0.74	0.13
AN006	646	41	126.8	695	0.26	0.81	0.16
AN007	1140	370	114.1	517	3.16	0.98	0.21
AN008	550	60	114.8	638	0.42	0.80	0.15
AN009	555	33	117.8	680	0.21	0.77	0.15
AN010	631	191	108.9	695	1.22	0.69	0.14
AN011	6381	3521	281.6	404	38.54	3.08	0.46
AN012	515	103	105	716	0.64	0.65	0.13
AN013	586	119	111.9	510	1.03	0.97	0.17
AN014	8211	4824	307.3	638	33.44	2.13	0.40
AN015	571	104	111.8	425	1.08	1.16	0.18
AN016	797	357	109.6	454	3.48	1.07	0.17
AN017	492	104	90.5	468	0.98	0.86	0.16
AN018	20569	12842	466.5	546	104.01	3.78	0.65
AN019	457	127	94.2	510	1.10	0.82	0.14
AN020	1676	938	142.7	411	10.09	1.54	0.23
AN021	10029	6509	315.9	432	66.63	3.23	0.49
AN022	3782	1995	222.2	609	14.49	1.61	0.30
AN023	584	34	120.9	638	0.24	0.84	0.16

Notes: Ra-226 radium-226
pCi/g picoCuries per gram
NPI no peak was identified by the MicroMCB™ ROI report
ROI Region of interest
MDA Minimum detectable activity

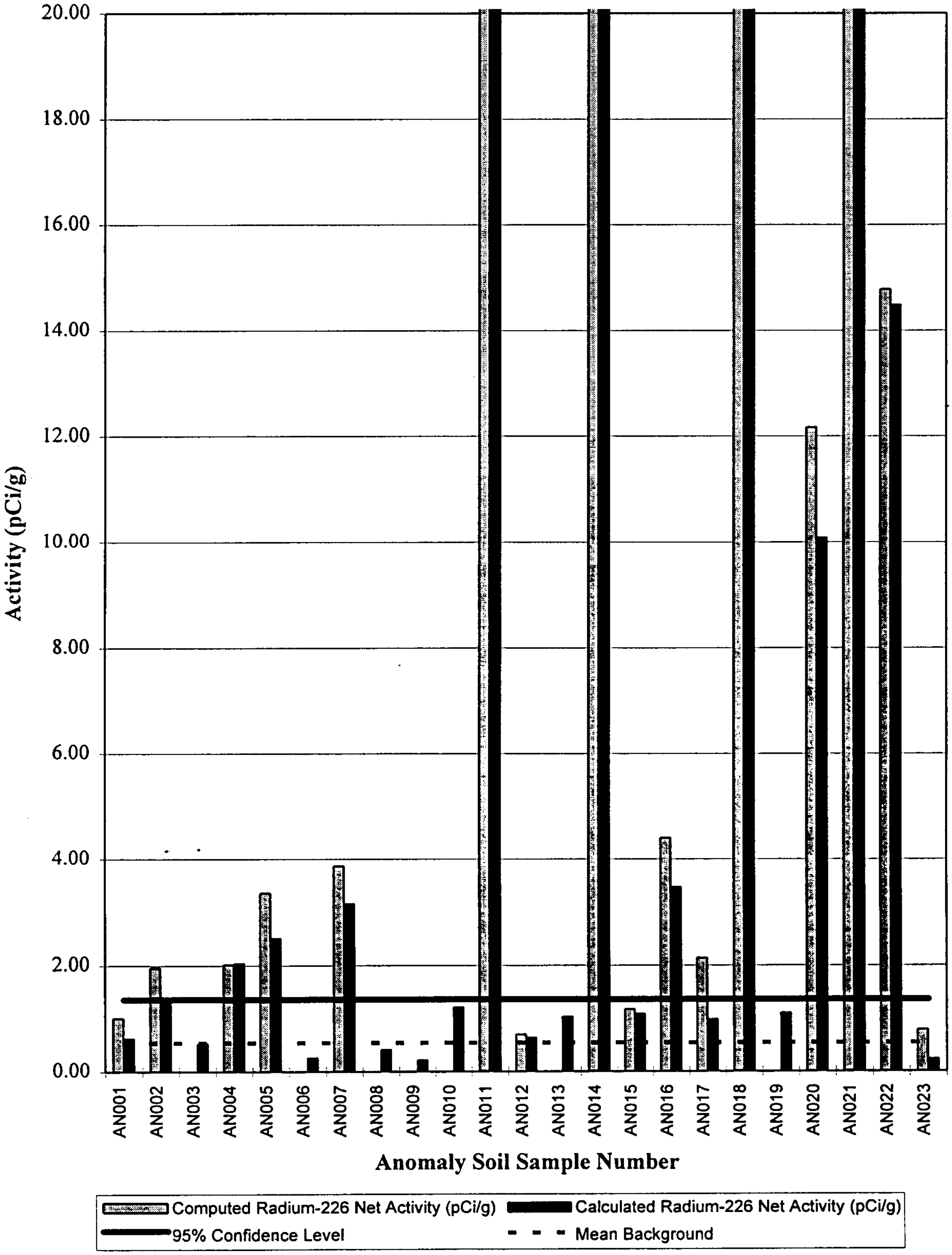

FIGURE 7-4
RADIUM-226 ACTIVITY OF ANOMOLY SOIL SAMPLES

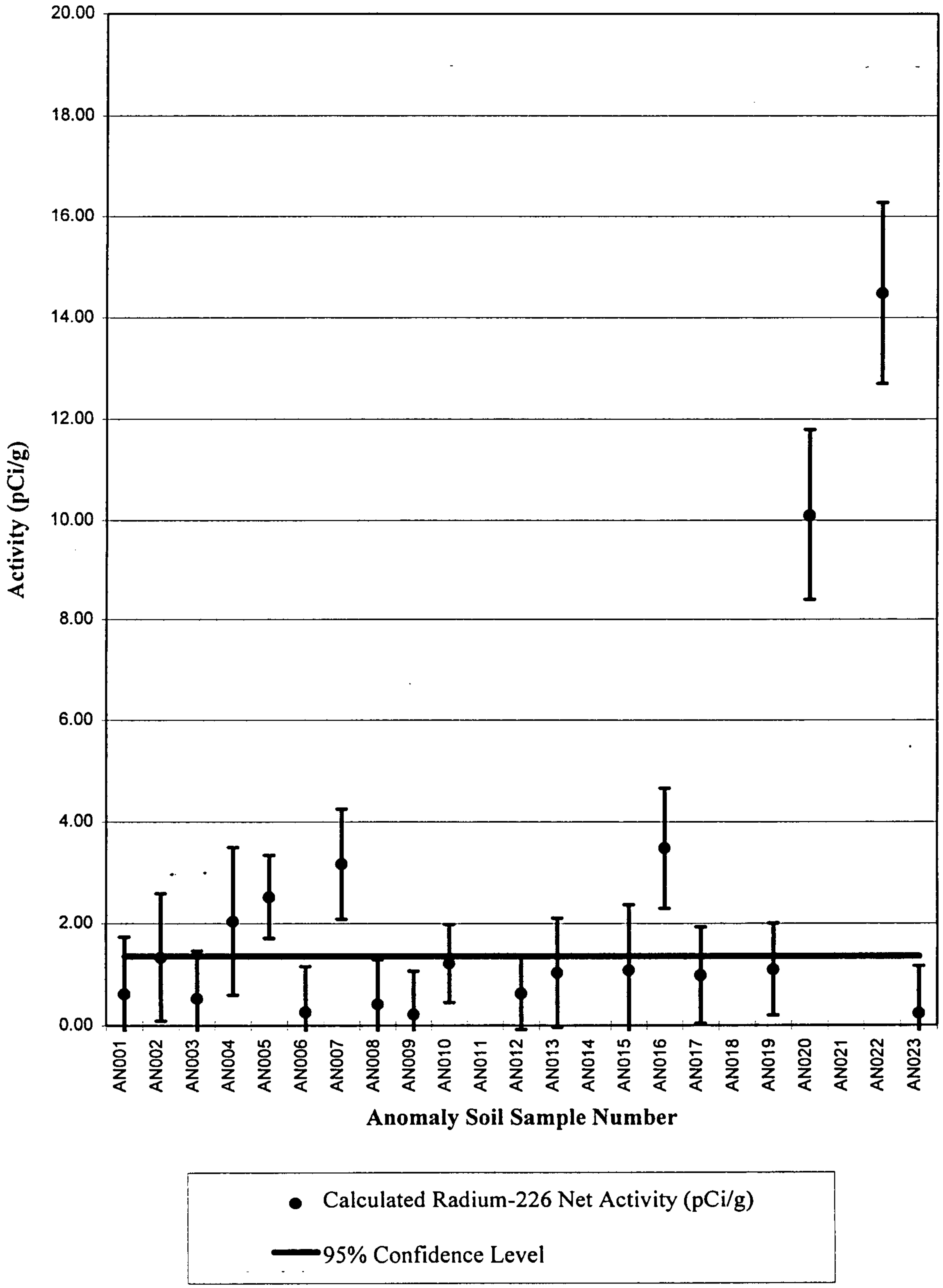

FIGURE 7-5
SOIL SAMPLE ACTIVITIES WITH ERROR BARS

7.2 OFF-SITE LABORATORY ANALYSIS

Six soil samples were sent to Berringer Laboratories, Inc., Golden, Colorado, for radiochemical and gamma spectroscopic analysis. These samples included background samples BK01-01, BK03-03, and BK05-05 and anomaly soil samples AN003, AN018, and AN021. The anomaly samples were chosen so that a sample containing low levels of radium-226 (AN003), a sample containing moderate levels of radium-226 (AN021), and a sample containing high levels of radium-226 (AN018) would be analyzed. These analyses were performed as a quality control measure for the results obtained from PRC's on-site field laboratory gamma spectroscopic analysis.

The soil samples were analyzed for thorium-230 (the parent of radium-226), uranium-234 (the parent of thorium-230), and uranium-238 (a parent of uranium-234). These three radioisotopes are naturally occurring and may exist in a state of secular equilibrium with naturally occurring radium-226. Thorium-232 was also analyzed for because it is a naturally occurring parent of radium-228, an unlikely but possible isotope of radium also used in radioluminescent paints. Table 7-5 summarizes the radiochemical analysis results and demonstrates that, for these analytes, the anomaly soil sample concentrations are not distinguishable from the background soil sample concentrations.

A gamma spectroscopic analysis was also performed on the soil samples. The analysis attempted to quantify several isotopes including potassium-40, cobalt-60, cesium-137, radium-226 and its decay products lead-214 and bismuth-214, and radium-228. The results of the laboratory's analysis are given in Table 7-6.

A comparison of the off-site laboratory gamma spectroscopy results to the gamma spectroscopy results obtained in PRC's field laboratory at HPA is given in Table 7-7. As seen in the table, the data are not equivalent, but they are similar.

TABLE 7-5

RADIOCHEMICAL ANALYSIS RESULTS

SAMPLE ID NUMBER	URANIUM-238 CONCENTRATION (pCi/g)	URANIUM-234 CONCENTRATION (pCi/g)	THORIUM-230 CONCENTRATION (pCi/g)	THORIUM-232 CONCENTRATION (pCi/g)
BK03-03	0.2 ± 0.4	0.3 ± 0.4	0.6 ± 0.5	0.6 ± 0.5
BK05-05	0.2 ± 0.4	0.3 ± 0.4	0.8 ± 0.6	0.1 ± 0.3
BK01-01	0.5 ± 0.5	0.1 ± 0.3	0.8 ± 0.6	0.7 ± 0.6
AN018	0.2 ± 0.4	0.4 ± 0.4	0.7 ± 0.5	0.2 ± 0.3
AN003	0.3 ± 0.4	0.1 ± 0.3	0.3 ± 0.4	0.4 ± 0.4
AN021	0.2 ± 0.4	0.2 ± 0.4	0.5 ± 0.5	0.6 ± 0.5
LLD	0.4	0.4	0.4	0.4
Analytical Method	EPA 908.0	EPA 908.0	USAEC HASC-300	USAEC HASC-300

Notes:
- pCi/g — picoCuries per gram
- LLD — lower limit of detection
- EPA — U.S. Environmental Protection Agency
- USAEC — U.S. Atomic Energy Commission

TABLE 7-6
LABORATORY GAMMA SPECTROSCOPY RESULTS

ANALYTE	SAMPLE ID NUMBER	CONCENTRATION (pCi/g)	LLD
potassium-40	BK03-03	7.5 ± 2.0	----
	BK05-05	9.9 ± 2.0	----
	BK01-01	9.1 ± 1.9	----
	AN018	5.0 ± 2.8	----
	AN003	8.8 ± 1.9	----
	AN021	9.9 ± 3.3	----
cobalt-60	all samples	U	0.1/0.2
cesium-137	BK03-03	0.18 ± 0.08	----
	BK05-05	0.21 ± 0.09	----
	BK01-01	U	0.2
	AN018	U	0.2
	AN003	U	0.1
	AN021	U	0.2
lead-214	BK03-03	0.5 ± 0.2	----
	BK05-05	0.5 ± 0.2	----
	BK01-01	0.6 ± 0.2	----
	AN018	75 ± 3	----
	AN003	1.1 ± 0.3	----
	AN021	74 ± 3	----
bismuth-214	BK03-03	0.6 ± 0.2	----
	BK05-05	0.5 ± 0.2	----
	BK01-01	0.5 ± 0.2	----
	AN018	75 ± 3	----
	AN003	1.3 ± 0.3	----
	AN021	71 ± 3	----
radium-226	BK03-03	0.6 ± 0.2	----
	BK05-05	0.5 ± 0.2	----
	BK01-01	0.5 ± 0.2	----
	AN018	75 ± 3	----
	AN003	1.3 ± 0.3	----
	AN021	71 ± 3	----
radium-228	BK03-03	0.5 ± 0.3	----
	BK05-05	0.5 ± 0.3	----
	BK01-01	U	0.5
	AN018	U	0.9
	AN003	0.4 ± 0.3	----
	AN021	U	0.8

Notes: pCi/g picoCuries per gram LLD lower limit of detection U undetected

TABLE 7-7

COMPARISON OF GAMMA SPECTROSCOPY RADIUM-226 CONCENTRATIONS

SAMPLE ID NUMBER	ON-SITE ANALYSIS CONCENTRATION (pCi/g)	OFF-SITE ANALYSIS CONCENTRATION (pCi/g)
Mean Background	0.54	0.5 ± 0.2
AN003	0.53 ± 0.8	1.3 ± 0.3
AN021	67 ± 3	71 ± 3
AN018	104 ± 4	75 ± 3

Note: pCi/g picoCuries per gram

One noticeable difference is that the off-site laboratory results found the activity of sample AN018 to be considerably lower than the result obtained by the on-site analysis. It should also be noted that, when comparing the activities of AN018 to AN021, the results of the off-site laboratory analysis found that the activities of the two samples are nearly equal. The on-site analysis of the samples resulted in a greater difference in the activities. The differing results may result from any combination of the following actions taken by the off-site laboratory:

- A high-purity germanium detector was used (more sensitive than a 2-inch by 2-inch NaI detector)
- Samples were oven dried and transformed into a fine powder (previously samples were air dried for 11 days and left in their natural form)
- The samples were sealed for 9 days to allow them to equilibrate (previously samples were sealed for 1 month prior to analysis)
- All samples analyzed were ground into a fine powder and homogenized and a 200 gram representative sample was taken (previous samples were not truly homogenized and were counted in their natural state)
- A different analytical software package was used

Although the results from the off-site laboratory do differ from the results obtained on site, the results do show that the on-site analytical method is an effective method of qualifying radioisotopes in soil samples and semiquantifying their activity. Thus, the on-site methods should be viewed as an effective tool in determining the presence and extent of radium-226 contamination in soil samples.

8.0 LIMITED DRAIN LINE SURVEY

On September 29, 1995, PRC personnel conducted limited surveying of the interior of several storm sewer manholes and the outfall for storm sewer line F. This storm sewer line originates from the building drain lines within Building 5 at NAS Alameda. The purpose of taking these radioactivity measurements was to make a qualitative assessment of the presence or absence of radioactive contamination in the storm sewer line. Historical information on the operations conducted in Building 5, the Small Parts Paint Shop, indicates that radioluminescent paint containing radium-226 and/or strontium-90 may have been disposed of through the building drain lines, which at one time connected directly to the storm sewer system.

Measurements at three locations were taken using the Ludlum Model 44-10 2-inch by 2-inch NaI detector. The location of the first storm sewer manhole where radioactivity measurements were taken was approximately 150 feet from the west side of Building 5. The detector was lowered down the manhole which supplies access to the storm sewer drain line. A 5-minute measurement resulted in 243,009 counts (48,602 cpm).

The second measurement was taken in a manhole located about 200 feet further down the storm sewer line from the first survey point. At this point, the storm sewer line flow changes directions from west to south towards the Seaplane Lagoon. A 5-minute measurement yielded 11,908 counts (2,382 cpm).

The third measurement was taken at the outfall of storm sewer line F, about 1,800 feet down the line from the second survey point. At this point, the storm sewer line ends and deposits its contents into the Seaplane Lagoon. A 5-minute measurement taken near the rocks and sediment onto which the drain line spills yielded 4,308 counts (862 cpm).

For these radioactivity measurements, no background comparison measurements were performed; therefore, it is not possible to determine how much of the elevated activity found at the first manhole is due to radioactive contamination, or from differences in construction materials. Table 8-1 summarizes the results of the Building 5 drain line measurements.

TABLE 8-1

BUILDING 5 STORM SEWER LINE RADIOACIVITY RESULTS

Survey Point	Location	Counts per Minute
1	150 feet from building 5, flowing west	48,602
2	200 feet from point 1, at the bend in the line (from west to south)	2,382
3	1,800 feet from point 2, above rocks and sediment	862

A gamma energy spectrum was collected at the first storm sewer manhole location in an attempt to identify the isotopic identity of the elevated activity. A 15-minute survey using the MicroNOMAD™ system was performed. The spectrum obtained indicates that radium-226 may be a contributor to the elevated activity; however, because no calibration was performed on the MicroNOMAD™ system for the geometry of the storm sewer manhole, the efficiency of the detector in this geometry could not be determined. Thus, the radium-226 activity could not be quantified.

9.0 QUALITY CONTROL

During the radiological investigation, PRC implemented control measures to ensure the quality of the survey results, the soil sample collection, and the soil sample analysis. Work on this project was conducted in accordance with PRC's CLEAN Quality Assurance Management Plan (PRC 1990).

9.1 GAMMA COUNT RATE AND EXPOSURE MEASUREMENTS

The quality control (QC) method for field survey activities involving exposure rate and count rate measurements were maintained by daily source checking the field instruments using a 1 μCi cesium-137 standard sealed source. The instrument responses were noted and compared to the previous source check to recognize any large variations in the responses. The acceptable tolerance on consecutive source checks was plus or minus 10 percent. The calibration of each instrument was also checked daily. For the gamma count ratemeter/scaler, a certificate of calibration and a bench test data sheet were supplied by Ludlum Measurements, Inc. documenting the initial calibration of the detector system. Initial calibration information for this instrument is included in Appendix C.

9.2 GAMMA SPECTROSCOPY

QC methods were also implemented for gamma spectroscopic analyses. The gamma spectroscopy system was calibrated each day the equipment was used. The calibration process involved an energy and efficiency calibration. The energy calibration ensured that detected energies were displayed in the correct position on the gamma spectrum. This was crucial for the library-directed peak search routine used to identify gamma-emitting radioisotopes. Efficiency calibration established the relationship between energy and activity making quantification of the radioisotopes possible. The calibration source was a multi-nuclide NIST-traceable standard containing radioisotopes with a broad range of gamma decay energies.

All soils samples were stored in PRC's radiation laboratory at HPA. This laboratory has very limited access. All samples remained locked in the laboratory until six of the samples were shipped to the off-site laboratory for analysis.

9.3 OFF-SITE ANALYTICAL LABORATORY

For the soil samples analyzed at the off-site laboratory, Berringer Laboratories, Inc., appropriate PRC chain-of-custody procedures were followed. The laboratory was certified and used approved U.S. Environmental Protection Agency methods. Analyses included both gamma spectroscopy and radiochemical analysis. The off-site laboratory results were used to determine the limitations of and to verify the data obtained in the on-site gamma spectroscopic analyses performed at HPA.

10.0 CONCLUSIONS

The radiation survey and the near-surface soil samples collected at Sites 1 and 2 at NAS Alameda have shown that radioactive materials are present in the landfills at levels greater than background. The scoping survey, using the μR survey meter and the 2-inch by 2-inch NaI count rate meter, identified 23 anomaly locations. Four discrete sources containing radium-226 were located and recovered from four of the anomaly locations. Upon removal of the sources, radiation levels dropped to background at two of the four locations. Therefore, at 21 of the 23 anomaly locations, an in situ gamma decay energy spectrum was collected using the MicroNOMAD™ system.

The peak search routine of the spectrum analysis software was able to identify the bismuth-214 609 keV photopeak in 20 of the 21 spectra, thus indicating the presence of radium-226 below the ground surface. The fact that the bismuth peak was not identified by the analysis software for the one anomaly (Anomaly 19), does not eliminate the possibility that the source of the anomaly was radium-226. A visual analysis of the spectra (for Anomaly 19) does show a slight peak in the energy range of bismuth-214 that was not recognized by the analysis software. In this case, the source could be buried deep in the soil resulting in muffled peaks. Strontium-90 was eliminated as a potential source in this and all other spectra collected (in-situ and soil samples) because no peaks were observed that could be attributed to bremsstrahlung radiation.

The activity of the sources below the ground surface and the exposure rates are listed in Table 5-2. The highest exposure rate recorded at a location where a source was not recovered was 2.0 milliRoentgen (mR) per hour at the ground surface (Anomaly 23). This could conservatively correlate to a whole body dose rate of 1.0 millirem (mrem) per hour, caused only by external radiation assuming a person is standing over the source. The Navy's administrative control level on ionizing radiation is 500 mrem per year or 0.5 mrem per hour for radiation workers.

However, because the entire surface area of the sites was not surveyed, it should not be assumed that Anomaly 23 has the highest exposure rate of any location in Sites 1 and 2. By using the results of the empirical studies performed on the Ludlum Models 19 and 44-10 radiation survey instruments and the spacing of the transects, an approximation of the surface area surveyed suggests that less than 6.3 acres, or less than 10 percent, of the combined areas of Sites 1 and 2 were actually scanned or surveyed. This approximation is uncertain, however, because it assumes that all of the radium-226 sources in Site 1 and 2 are equal to the 0.87 μCi test source. Also, as discussed in Section 5.3, all areas of the sites were not easily surveyed.

Several of the near-surface soil samples collected at the anomaly locations also exhibited radiation levels above background. Gamma spectroscopic analysis identified radium-226 as the isotopic contributor to the soil's elevated activity. Ten of the twenty-three samples had an activity greater than the critical value (95% confidence level) of 1.36 pCi per gram. The sample with the highest activity, from Anomaly 18, was in excess of 100 pCi per gram. No photopeaks characteristic of bremsstrahlung radiation, which would suggest the presence of strontium-90, were identified in any of the soil sample spectra; therefore, strontium-90 was not analyzed for by the laboratory. Elevated levels of radium-226 were confirmed in some of the soil samples by an off-site laboratory.

The results of the soil sample analyses suggest that the radiation sources in Sites 1 and 2 are not all discrete point sources. The soil samples that exhibited elevated activities contain radium-226 dispersed in the soil. The dispersed radium may, however, result from the degradation of once discrete radium-226-contaminated sources. The exposure rates of the soil samples are all less than 12 μR per hour at the sample container surface.

The results of the limited survey of the storm sewer manholes and outfall for storm sewer line F indicate that the line may be contaminated with radium-226. Although the activity noticeably decreased with distance away from the building, no background activity was established for these measurements; therefore, it is impossible to determine how much of the increased activity is due to radioactive contamination, or from differences in construction materials at the different locations. Because of the lack of background measurements and the lack of calibration data for the gamma spectroscopic analysis, the amount of contamination could not be quantified.

For all soil surveys and gamma spectroscopic analyses that resulted in elevated count rates, radium-226 was determined to be the isotopic source of the elevated activity. Nothing in any of the spectra suggests the presence of bremsstrahlung radiation resulting from strontium-90 in contact with a metallic surface.

The empirical studies on the survey instruments discussed in Sections 4.1 and 4.2 were used to determine the volume of soil surveyed. A major assumption in the calculation is that the 0.87 μCi radium-226 source is similar in activity to the types of sources expected to be contained in Sites 1 and 2. The total volume of the soil surveyed is the sum of the soil volume surveyed in the grid node survey by the Ludlum Model 44-10 and the soil volume surveyed by the Ludlum Model 19 during the transect walkover survey. The grid node survey volume is estimated at 0.41 cubic meters; 706 grid nodes were surveyed in Sites 1and 2 for a total of 280.6 cubic meters. Because of overlap in the surveys with the two instruments, the Sites 1 and 2 transects between grid nodes were assumed to be 18.3 meters long. It is estimated that a distance of approximately 14,120 meters was surveyed in Sites 1 and 2 using the Ludlum Model 19 survey meter. Thus, the transect survey volume is estimated at 3,514 cubic meters, assuming that the cross-sectional area of the survey volume is 0.249 square meter (see Figure 4-2). The total volume of the surveyed soil at Sites 1 and 2 is, therefore, approximately 3,797 cubic meters.

The total activity of the sources and hot spots discovered during the radiological survey is the sum of the in situ anomaly activities and the activities of the recovered sources. The in situ anomaly activities are listed in Table 6-1. The sum of these activities is 1.11 μCi. The sum of the activity of the sources recovered is 11.0 μCi (see Table 7-1). The total approximate activity of the sources located in Site 1 is therefore 11.1 μCi.

11.0 RECOMMENDATIONS

As a result of the initial analysis of the field survey data, it was determined that none of the 23 anomalies located in Sites 1 and 2 present an immediate health hazard to individuals (PRC 1995); however, to minimize the potential for unmonitored, non-occupational exposure, and to prevent the spread of radioactive contaminants, the recommendation that area controls be implemented was developed based on the following concerns: The primary concern is the unauthorized removal of discrete radium-226 sources from the landfills. As witnessed by this survey, sources can be located within inches of the ground surface and in some cases, directly on the ground surface. As demonstrated by the four sources recovered, the activity of unrecovered sources can be in excess of 9 μCi, and with an exposure rate greater than 3,500 μR per hour at 1 inch from the source. The second concern is exposure to soils containing elevated levels of dispersed radium-226. Exposure to these soils could pose a human health hazard through inadvertent ingestion. The maximum activity encountered in the 23 anomaly soils samples was greater than 100 pCi per gram of dry soil. The third concern is direct exposure to radium-226 sources in the near-surface soils. Although the highest exposure encountered during the survey (2,500 μR per hour at anomaly 21 with the source in place) does not pose a great external radiation hazard, locations with greater exposure rates may exist. These sources may also pose a radon gas hazard if tents or structures are placed over the areas of concern.

In addition, the following actions may be considered: (1) The northwest point can be completely surveyed. If additional surveys are performed within this area and no sources are found, access can still be allowed. (2) Postings can be used to disallow unauthorized access to other areas of Site 1. (3) The frequently used jogging trails within Sites 1 and 2 can be surveyed and signs posted to prevent unauthorized access into other areas. If near-surface sources are found near the jogging trail, they would need to be removed or access to the trail restricted. (4) As another option, using existing barriers, Site 2 can be completely closed-off.

There remains a concern regarding the possible radium-226 contamination in the interior drain lines of Building 5 and the related storm sewer line F. Although access to the drain system is not routine, personnel could be exposed to unknown levels of radiation if they enter the lines. It is recommended that personnel access into the storm sewer system for Building 5 be controlled. For remediation purposes, further investigation of the extent of contamination within the Building 5 drain lines and also storm sewer line F is necessary.

12.0 REFERENCES

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APPENDICES

FINAL
ADDENDUM TO THE
REMEDIAL INVESTIGATION/FEASIBILITY STUDY
DATA TRANSMITTAL MEMORANDUM
SITE 1 AND SITE 2 RADIATION SURVEY REPORT

DATED 01 FEBRUARY 1997

APPENDIX A
BACKGROUND SURVEY RESULTS

APPENDIX A
BACKGROUND SURVEY RESULTS

Date	Time	Site No.	Location No.	Counts per Minute
9/21/95	1645	1	1	1692
	1650	1	2	1734
	1655	1	3	1795
	1700	1	4	1792
	1705	1	5	1768
	1712	2	1	1688
	1715	2	2	1554
	1720	2	3	1536
	1725	2	4	1589
	1730	2	5	1649
	1410	3	1	1735
	1415	3	2	2109
	1420	3	3	2098
	1425	3	4	2267
	1430	3	5	1716
	1315	4	1	1797
	1320	4	2	1743
	1325	4	3	1964
	1330	4	4	2081
	1335	4	5	2021
	1615	5	1	1829
	1620	5	2	1697
	1625	5	3	1737
	1630	5	4	1670
	1635	5	5	1702
	1520	6	1	2150
	1525	6	2	1993
	1530	6	3	2005
	1535	6	4	1997
	1540	6	5	2094

Mean =	1840
Standard Deviation =	193
1.65 x Standard Deviation =	318
95 Percent Upper Confedence Limit =	2158

APPENDIX B

GRID NODE SURVEY RESULTS

APPENDIX B
GRID NODE SURVEY RESULTS
NAS ALAMEDA, CALIFORNIA

Date	Sample Grid Location	Counts Per Minute (cpm)	Reading µR/H	Remarks
9/23/95	B-7	1341	5	19' North, 42 degrees East of high voltage box
9/23/95	B-8	1074	6	due East of B-7
9/23/95	C-8	1835	6	North of B-8
9/23/95	D-8	1705	7	
9/23/95	E-8	1778	7	
9/23/95	F-8	1734	6	
9/23/95	G-8	1894	6	
9/24/95	H-8	1744	7	
9/24/95	I-8	1644	7	
9/24/95	J-8	2087	7	
9/24/95	J-8 +15M	1830	7	to asphalt edge
9/24/95	H-9	1790	5-9	between H-8/H-9
9/24/95	H-9 + ~13m	1931	5-7	to asphalt edge
9/24/95	H-7	1290	5-7	
9/24/95	H-6	1276	4-6	
9/24/95	H-5	1452	4-7	
9/24/95	H-4	1757	5-6	
9/24/95	H-3	1800	5-6	
9/24/95	H-2	1542	5-7	
9/24/95	H-2 + 13M	1551	5-7	up to waterline
9/24/95	G-2	1724	5-7	
9/24/95	G-2 + 10M	1725	5-7	up to waterline
9/24/95	G-3	1765	5-7	
9/24/95	G-4	1861	5-7	
9/24/95	G-5	1585	5-7	
9/24/95	G-6	1434	5-7	
9/24/95	G-7	864	4-6	survey in heavy vegetation
9/24/95	G-9	1729	6-8	
9/24/95	G-10	1846	5-7	
9/24/95	F-10	1953	6-8	
9/24/95	F-11	1993	6-8	to edge of asphalt
9/24/95	F-9	1766	7-10	
9/24/95	F-7	1566	6-8	
9/24/95	F-6	1321	4-6	
9/24/95	F-5	1565	4-6	
9/24/95	F-4	1858	5-7	in red building
9/24/95	F-3	1683	5-7	in red building
9/24/95	F-2	1724	5-7	in red building
9/24/95	E-2	2247	8-10	South of red building wall
9/24/95	E-3	1785	8-10	
9/24/95	E-4	1899	8-10	

APPENDIX B
GRID NODE SURVEY RESULTS
NAS ALAMEDA, CALIFORNIA

Date	Sample Grid Location	Counts Per Minute (cpm)	Reading μR/H	Remarks
9/24/95	E-5	2147	5-7	on jogging trail
9/24/95	E-6	2028	6-10	
9/24/95	E-7	1849	6-8	
9/24/95	E-9	1732	5-7	
9/24/95	E-10	1875	6-8	further West was ~7 μr/h along A transect towards asphalt
9/24/95	D-9	1718	6-8	
9/24/95	D-7	1937	6-8	
9/24/95	D-6	1926	6-8	
9/24/95	D-5	1842	6-8	
9/24/95	D-4	1419	8-10	
9/24/95	D-3	1988	~10	source of 200 μr/h 10M West of D-3 (bet D-3 and D-4)
9/24/95	D-2	2193	10-20	at berm near red building
9/24/95	C-7	1936	5-7	
9/24/95	C-6	1948	5-7	
9/24/95	C-5	1898	5-7	
9/24/95	C-4	2235	6-8	
9/24/95	C-3	2162	8-10	
9/24/95	C-2	1997	6-8	
9/24/95	B-6	1829	6-8	
9/24/95	B-5	1851	5-7	
9/24/95	B-4	1776	5-7	in fenced area of field trailer
9/24/95	B-3	1818	**5-7**	in fenced area of field trailer
9/24/95	B-2	2073	**5-7**	almost to berm
9/24/95	A-3	5881	**30**	
9/24/95	A-2	1636	6-8	
9/25/95	I-2	1642	5-7	
9/25/95	J-2	1655	5-9	
9/25/95	K-2	1857	5-9	
9/25/95	L-2	1741	5-9	(North-South) 5-7 (East-West)
9/25/95	M-2	1722	5-8	
9/25/95	N-2	1548	5-7	(North-South) 5-9 (East-West) across road
9/25/95	O-2	1656	5-7	(East-West) same
9/25/95	P-2	1680	5-7	(On Perimeter Road) took reading on gram
9/25/95	Q-2	1564	5-7	
9/25/95	R-2	1727	5-7	
9/25/95	S-2	1837	5-7	
9/25/95	I-1	1242	5-7	on beach/sand
9/25/95	I-3	1518	5-7	
9/25/95	I-4	2242	6-10	on perimeter road

APPENDIX B
GRID NODE SURVEY RESULTS
NAS ALAMEDA, CALIFORNIA

Date	Sample Grid Location	Counts Per Minute (cpm)	Reading µR/H	Remarks
9/25/95	I-5	1770	6-10	
9/25/95	I-6	1845	5-7	
9/25/95	I-7	1889	5-8	
9/25/95	I-9	1731	6-8	
9/25/95	J-7	1805	4-12	
9/25/95	J-6	1793	5-7	
9/25/95	J-5	1773	5-7	
9/25/95	J-4	1744	5-7	next to well 2' from Perlimeter Road
9/25/95	J-3	1734	5-7	
9/25/95	J-1	1445	5-7	on debris near water
9/25/95	K-1	1551	4-7	
9/25/95	K-3	1580	5-8	
9/25/95	K-4	1673	5-9	near Perimeter Road
9/25/95	K-5	1644	5-7	
9/25/95	K-6	1666	5-7	
9/25/95	K-7	1805	6-8	
9/25/95	L-7	1851	6-8	next to runaway asphalt
9/25/95	L-6	1656	5-7	
9/25/95	L-5	1661	5-7	
9/25/95	L-4	1721	5-8	
9/25/95	L-3	2066	5-9	on Perimeter Road
9/25/95	L-1	1536	6-8	
9/25/95	L-0	1610	5-7	at water line
9/25/95	M-1	1715	4-6	
9/25/95	M-0	1504	5-7	
9/25/95	M-3	1961	5-8	on Perimeter Road
9/25/95	M-4	1698	5-7	
9/25/95	M-5	1600	5-9	
9/25/95	M-6	1662	5-7	
9/25/95	N-5	1622	5-7	North-5 to North-6 (Pavement) 5-7
9/25/95	N-4	1652	5-9	
9/25/95	N-3	1463	5-7	
9/25/95	N-1	1503	5-7	
9/25/95	N-0	1508	5-7	
9/25/95	O-0	1616	4-6	
9/25/95	O(-1)	1691	5-7	
9/25/95	O-1	1576	5-7	
9/25/95	O-3	1343	5-9	next to road
9/25/95	O-4	1689	5-7	
9/25/95	O-5	1484	5-7	
9/25/95	P-3	2245	8-10	

APPENDIX B
GRID NODE SURVEY RESULTS
NAS ALAMEDA, CALIFORNIA

Date	Sample Grid Location	Counts Per Minute (cpm)	Reading µR/H	Remarks
9/25/95	P-4	1485	5-7	
9/25/95	P-1	1571	5-7	
9/25/95	P-0	1445	5-7	
9/25/95	P(-1)	1459	6-8	next to well
9/25/95	P(-2)	1642	5-9	on berm near waterline, short of 20 meters
9/25/95	Q-1	1470	5-9	
9/25/95	Q-0	1652	6-8	
9/25/95	Q(-1)	1679	6-8	
9/25/95	Q(-2)	1817	6-8	next to berm
9/25/95	Q-3	1702	5-7	
9/25/95	R-3	1373	5-7	
9/25/95	R-1	1834	5-7	on Perimeter Road
9/25/95	R-0	1535	5-7	
9/25/95	R(-1)	1742	6-8	
9/25/95	R(-2)	1593	5-7	
9/25/95	S-1	1741	5-7	
9/25/95	S-0	2006	6-9	on Perimeter Road
9/25/95	S(-1)	1675	5-7	
9/25/95	S(-2)	1569	5-7	
9/25/95	T-1	1497	6-8	
9/25/95	T-0	1433	6-8	
9/25/95	T(-1)	1352	6-8	
9/25/95	T(-2)	1589	5-7	
9/25/95	T(-3)	1678	5-7	
9/25/95	U(-3)	1516	5-7	North 20m from T(-3)
9/25/95	U(-2)	1899	5-7	
9/25/95	U(-1)	1923	5-9	on Perimeter Road 10' East of U(-2), went up to 9 µR/h
9/25/95	U-0	1761	5-7	
9/25/95	U-1	1455	5-7	
9/25/95	V-1	1442	5-7	OK Pavement/runway intersection
9/25/95	V-0	1356	5-7	West edge of Perimeter Road
9/25/95	V(-1)	1556	5-7	
9/25/95	V(-2)	1484	5-7	
9/25/95	W(-1)	1680	5-7	
9/25/95	W-0	1469	5-7	
9/25/95	X-1	1522	5-7	
9/25/95	X-0	1414	5-7	
9/25/95	Y-2	1540	5-7	
9/25/95	Y-3	1417	5-7	
9/25/95	Z-2	939	5-7	

APPENDIX B
GRID NODE SURVEY RESULTS
NAS ALAMEDA, CALIFORNIA

Date	Sample Grid Location	Counts Per Minute (cpm)	Reading µR/H	Remarks
9/25/95	Z-3	1473	5-7	
9/25/95	Z-4	1370	5-7	
9/25/95	Z-5	1849	5-7	1705 hours. Site 1 survey completed.
9/26/95	KK9	1978	6-8	Begin Site 2 survey. At berm
9/26/95	JJ9	1888	6-8	
9/26/95	II9	1536	6-8	
9/26/95	HH9	1650	6-8	
9/26/95	GG9	1692	6-8	
9/26/95	FF9	1768	6-8	
9/26/95	EE9	1772	6-8	
9/26/95	DD9	1828	6-8	
9/26/95	CC9	1758	6-8	
9/26/95	BB9	1643	6-8	
9/26/95	AA9	1858	6-8	
9/26/95	Z9	1927	6-8	
9/26/95	Y9	2032	6-8	
9/26/95	X9	1874	6-8	
9/26/95	X8	1732	6-8	
9/26/95	Y8	1931	6-8	
9/26/95	Z8	1785	6-8	
9/26/95	AA8	1810	6-8	
9/26/95	BB8	1783	6-8	
9/26/95	CC8	1904	6-8	
9/26/95	DD8	1809	6-8	
9/26/95	EE8	1776	6-8	
9/26/95	FF8	1613	6-8	
9/26/95	GG8	1892	6-8	
9/26/95	HH8	1825	6-8	
9/26/95	II8	1706	6-8	
9/26/95	JJ8	1858	6-8	
9/26/95	KK8	2139	6-8	
9/26/95	KK7	2010	6-8	
9/26/95	JJ7	1745	6-8	
9/26/95	II7	1653	6-8	
9/26/95	HH7	1700	6-8	
9/26/95	GG7	1857	6-8	
9/26/95	FF7	1828	6-8	
9/26/95	EE7	1880	6-8	
9/26/95	DD7	1815	6-8	
9/26/95	CC7	1817	6-8	
9/26/95	BB7	1566	6-8	

APPENDIX B
GRID NODE SURVEY RESULTS
NAS ALAMEDA, CALIFORNIA

Date	Sample Grid Location	Counts Per Minute (cpm)	Reading µR/H	Remarks
9/26/95	AA7	1814	6-8	
9/26/95	Z7	1818	6-8	
9/26/95	Y7	1745	6-8	near water's edge, can't do -X7 and -X6
9/26/95	Y6	1420	6-8	
9/26/95	Z6	1889	6-8	
9/26/95	AA6	1812	6-8	
9/26/95	BB6	1729	6-8	
9/26/95	CC6	1742	6-8	
9/26/95	DD6	1725	6-8	
9/26/95	EE6	1630	6-8	
9/26/95	FF6	1586	6-8	
9/26/95	GG6	1885	6-8	
9/26/95	HH6	1770	6-8	
9/26/95	II6	1839	6-8	
9/26/95	JJ6	1717	6-8	
9/26/95	KK6	1944	6-8	
9/27/95	KK5	2008	5-7	
9/27/95	JJ5	1877	6-8	
9/27/95	II5	1702	6-8	
9/27/95	HH5	1888	6-8	
9/27/95	GG5	1685	6-8	
9/27/95	FF5	1886	6-8	
9/27/95	EE5	1957	6-8	
9/27/95	DD5	2123	6-8	
9/27/95	CC5	1944	6-8	
9/27/95	BB5	2020	6-8	
9/27/95	AA5	1977	6-8	
9/27/95	Z5	1554	6-8	
9/27/95	Y5	1600	6-8	
9/27/95	Y4	1489	6-8	
9/27/95	Z4	1931	6-8	
9/27/95	AA4	2065	6-8	
9/27/95	BB4	2028	6-8	
9/27/95	CC4	1897	6-8	
9/27/95	DD4	1940	6-8	
9/27/95	EE4	2017	6-8	
9/27/95	FF4	1921	6-8	
9/27/95	GG4	1975	6-8	
9/27/95	HH4	2010	6-8	
9/27/95	II4	1872	6-8	
9/27/95	JJ4	2013	6-8	

APPENDIX B
GRID NODE SURVEY RESULTS
NAS ALAMEDA, CALIFORNIA

Date	Sample Grid Location	Counts Per Minute (cpm)	Reading µR/H	Remarks
9/27/95	KK4	2217	6-8	at edge of berm
9/27/95	DD3	2187	6-8	
9/27/95	CC3	2221	6-8	
9/27/95	BB3	2206	6-8	
9/27/95	AA3	2249	6-8	
9/27/95	Z3	2141	6-8	
9/27/95	Y3	2050	6-8	0940/Reset for transects 10 to 15 hours
9/27/95	AA10	1735	6-8	
9/27/95	Z10	2049	6-8	
9/27/95	Y10	1756	6-8	
9/27/95	BB10	1828	6-8	
9/27/95	CC10	1823	6-8	
9/27/95	DD10	1840	6-8	
9/27/95	EE10	1879	6-8	
9/27/95	FF10	1854	6-8	
9/27/95	GG10	1950	6-8	
9/27/95	HH10	1880	6-8	
9/27/95	II10	1801	6-8	
9/27/95	JJ10	1992	6-8	
9/27/95	KK10	2095	6-8	
9/27/95	KK11	1887	6-8	
9/27/95	JJ11	1890	6-8	
9/27/95	II11	1725	6-8	
9/27/95	HH11	1825	6-8	
9/27/95	GG11	1834	6-8	
9/27/95	FF11	1736	6-8	
9/27/95	EE11	1770	6-8	
9/27/95	DD11	1865	6-8	
9/27/95	CC11	1957	6-8	
9/27/95	BB11	2008	6-8	
9/27/95	AA11	2057	6-8	
9/27/95	Z11	1810	6-8	
9/27/95	Y11	1841	6-8	
9/27/95	W11	2085	6-8	
9/27/95	U12	2010	6-8	
9/27/95	V12	2070	6-8	
9/27/95	W12	2235	6-9	on gravel road
9/27/95	X12	1507	6-8	
9/27/95	Y12	1908	6-8	
9/27/95	AA12	2001	6-8	
9/27/95	BB12	2032	6-8	

APPENDIX B
GRID NODE SURVEY RESULTS
NAS ALAMEDA, CALIFORNIA

Date	Sample Grid Location	Counts Per Minute (cpm)	Reading µR/H	Remarks
9/27/95	CC12	1969	6-8	
9/27/95	DD12	1799	6-8	
9/27/95	EE12	1882	6-8	
9/27/95	FF12	1825	6-8	
9/27/95	GG12	1792	6-8	
9/27/95	HH12	2037	6-8	
9/27/95	II12	1864	6-8	
9/27/95	JJ12	1895	6-8	
9/27/95	KK12	2117	6-8	at berm
9/27/95	KK13	2235	6-8	
9/27/95	JJ13	2101	6-8	
9/27/95	II13	1884	6-8	
9/27/95	HH13	2025	6-8	
9/27/95	GG13	1664	6-8	
9/27/95	FF13	1816	6-8	
9/27/95	EE13	2009	6-8	
9/27/95	DD13	1770	6-8	
9/27/95	CC13	1805	6-8	
9/27/95	BB13	1899	6-8	
9/27/95	AA13	1978	6-8	
9/27/95	Z13	2071	6-8	
9/27/95	Y13	1871	6-8	
9/27/95	X13	1872	6-8	
9/27/95	W13	1995	6-8	
9/27/95	V13	1900	6-8	
9/27/95	U13	2025	6-8	
9/27/95	T13	1870	6-8	
9/27/95	Q14	1981	6-8	
9/27/95	R14	1920	6-8	
9/27/95	S14	2291	6-8	
9/27/95	T14	2080	6-8	
9/27/95	U14	2035	6-8	
9/27/95	V14	2053	6-8	
9/27/95	W14	1970	6-8	
9/27/95	X14	1911	6-8	
9/27/95	Y14	2155	6-8	
9/27/95	Z14	1524	6-8	
9/27/95	AA14	1834	6-8	
9/27/95	BB14	1854	6-8	
9/27/95	CC14	1780	6-8	
9/27/95	Dd14	1645	6-8	

APPENDIX B
GRID NODE SURVEY RESULTS
NAS ALAMEDA, CALIFORNIA

Date	Sample Grid Location	Counts Per Minute (cpm)	Reading µR/H	Remarks
9/27/95	EE14	1725	6-8	
9/27/95	FF14	1742	6-8	
9/27/95	GG14	1845	6-8	
9/27/95	HH14	1612	6-8	
9/27/95	II14	1495	6-8	
9/27/95	JJ14	1840	6-8	
9/27/95	KK14	2024	6-8	
9/27/95	KK15	2148	6-8	
9/27/95	JJ15	1892	6-8	
9/27/95	II15	1729	6-8	
9/27/95	HH15	1760	6-8	
9/27/95	GG15	1695	6-8	
9/27/95	FF15	1755	6-8	
9/27/95	EE15	1650	6-8	
9/27/95	DD15	1756	6-8	
9/27/95	CC15	1727	6-8	
9/27/95	BB15	1821	6-8	
9/27/95	AA15	1868	6-8	
9/27/95	Z15	1771	6-8	
9/27/95	Y15	1984	6-8	
9/27/95	X15	1951	6-8	
9/27/95	W15	2051	6-8	
9/27/95	V15	1942	6-8	
9/27/95	U15	2015	6-8	
9/27/95	T15	2187	6-8	
9/27/95	S15	1908	6-8	
9/27/95	R15	1711	6-8	
9/27/95	Q15	1999	6-8	
9/27/95	P15	1870	6-8	
9/27/95	M16	1634	6-8	
9/27/95	N16	2027	6-8	
9/27/95	O16	2015	6-8	
9/27/95	P16	1352	6-8	Off gravel
9/27/95	Q16	1599	6-8	
9/27/95	R16	1850	6-8	
9/27/95	S16	2199	6-8	on gravel road
9/27/95	T16	2024	6-8	
9/27/95	U16	1990	6-8	
9/27/95	V16	2087	6-8	
9/27/95	W16	2101	6-8	
9/27/95	X16	1820	6-8	

APPENDIX B
GRID NODE SURVEY RESULTS
NAS ALAMEDA, CALIFORNIA

Date	Sample Grid Location	Counts Per Minute (cpm)	Reading µR/H	Remarks
9/27/95	Y16	2077	6-8	
9/27/95	Z16	2136	6-8	
9/27/95	AA16	2111	6-8	
9/27/95	BB16	1794	6-8	
9/27/95	CC16	1961	6-8	
9/27/95	DD16	1860	6-8	
9/27/95	EE16	1761	6-8	
9/27/95	FF16	1970	6-8	
9/27/95	GG16	2031	6-8	
9/27/95	HH16	1893	6-8	
9/27/95	II16	1801	6-8	
9/27/95	JJ16	1800	6-8	
9/27/95	KK16	1968	6-8	
9/27/95	KK17	2173	6-8	
9/27/95	JJ17	1882	6-8	
9/27/95	II17	1764	6-8	
9/27/95	HH17	1938	6-8	
9/27/95	GG17	1961	6-8	
9/27/95	FF17	1781	6-8	
9/27/95	EE17	1854	6-8	
9/27/95	DD17	1749	6-8	
9/27/95	CC17	1968	6-8	
9/27/95	BB17	1845	6-8	
9/27/95	AA17	1880	6-8	
9/27/95	Z17	1848	6-8	
9/27/95	Y17	1800	6-8	
9/27/95	X17	1851	6-8	
9/27/95	W17	2249	6-8	
9/27/95	V17	2109	6-8	
9/27/95	U17	2099	6-8	
9/27/95	T17	2213	6-8	
9/27/95	S17	2017	6-8	
9/27/95	R17	1890	6-8	
9/27/95	Q17	2091	6-8	next to M038-A
9/27/95	P17	2107	6-8	
9/27/95	O17	1770	6-8	
9/27/95	N17	1574	6-8	
9/27/95	M17	1905	6-8	
9/27/95	L18	1918	6-8	
9/27/95	M18	1915	6-8	
9/27/95	N18	1955	6-8	

APPENDIX B
GRID NODE SURVEY RESULTS
NAS ALAMEDA, CALIFORNIA

Date	Sample Grid Location	Counts Per Minute (cpm)	Reading µR/H	Remarks
9/27/95	O18	1968	6-8	
9/27/95	P18	2039	6-8	
9/27/95	Q18	1880	6-8	
9/27/95	R18	2105	6-8	
9/27/95	S18	2030	6-8	
9/27/95	T18	2121	6-8	
9/27/95	U18	2099	6-8	
9/27/95	V18	1911	6-8	
9/27/95	W18	1700	6-8	
9/27/95	X18	1901	6-8	
9/27/95	Y18	1880	6-8	
9/27/95	Z18	2003	6-8	
9/27/95	AA18	1788	6-8	
9/27/95	BB18	1927	6-8	
9/27/95	CC18	1790	6-8	
9/27/95	DD18	1929	6-8	
9/27/95	EE18	1780	6-8	
9/27/95	FF18	1799	6-8	
9/27/95	GG18	1731	6-8	
9/27/95	HH18	2033	6-8	
9/27/95	II18	1967	6-8	
9/27/95	JJ18	1955	6-8	
9/27/95	KK18	1921	6-8	
9/27/95	K19	1853	6-8	
9/27/95	L19	1983	6-8	
9/27/95	M19	1818	6-8	
9/27/95	N19	2251	6-8	at edge of gravel road
9/27/95	O19	1855	6-8	
9/27/95	P19	1784	6-8	
9/27/95	Q19	2020	6-8	
9/27/95	R19	2041	6-8	
9/27/95	S19	1949	6-8	
9/27/95	T19	1951	6-8	
9/27/95	U19	1923	6-8	
9/27/95	V19	1886	6-8	
9/27/95	W19	1872	6-8	
9/27/95	X19	1749	6-8	
9/27/95	Y19	2002	6-8	
9/27/95	Z19	1831	6-8	
9/27/95	AA19	2012	6-8	
9/27/95	BB19	1848	6-8	

APPENDIX B
GRID NODE SURVEY RESULTS
NAS ALAMEDA, CALIFORNIA

Date	Sample Grid Location	Counts Per Minute (cpm)	Reading µR/H	Remarks
9/27/95	CC19	1918	6-8	
9/27/95	DD19	1865	6-8	
9/27/95	EE19	1672	6-8	
9/27/95	FF19	1682	6-8	
9/27/95	GG19	1841	6-8	
9/27/95	HH19	1856	6-8	
9/27/95	II19	1946	6-8	
9/27/95	JJ19	2073	6-8	
9/27/95	KK19	2103	6-8	at berm
9/27/95	KK20	2015	6-8	
9/27/95	JJ20	1935	6-8	
9/27/95	II20	1951	6-8	
9/27/95	HH20	2008	6-8	
9/27/95	GG20	1662	6-8	
9/27/95	FF20	2129	6-8	
9/27/95	EE20	1875	6-8	
9/27/95	DD20	1912	6-8	
9/27/95	CC20	1907	6-8	
9/27/95	BB20	2116	6-8	
9/27/95	AA20	2224	6-8	
9/27/95	Z20	2080	6-8	
9/27/95	Y20	1927	6-8	
9/27/95	X20	2107	6-8	
9/27/95	W20	1924	6-8	
9/27/95	V20	1720	6-8	
9/27/95	U20	1921	6-8	
9/27/95	T20	1940	6-8	
9/27/95	S20	1899	6-8	
9/27/95	R20	1874	6-8	
9/27/95	Q20	2075	6-8	
9/27/95	P20	2002	6-8	
9/27/95	O20	1897	6-8	
9/27/95	N20	1906	6-8	
9/27/95	M20	2237	6-8	
9/27/95	L20	1478	6-8	
9/27/95	K20	2225	6-8	
9/27/95	J20	2003	6-8	
9/27/95	I20	1767	6-8	
9/27/95	H-21	1967	6-8	
9/27/95	G-21	1892	6-8	
9/27/95	F-21	2026	6-8	

APPENDIX B
GRID NODE SURVEY RESULTS
NAS ALAMEDA, CALIFORNIA

Date	Sample Grid Location	Counts Per Minute (cpm)	Reading µR/H	Remarks
9/27/95	E-21	2197	6-8	
9/27/95	I-21	1606	6-8	
9/27/95	J-21	1878	6-8	
9/27/95	K-21	1664	6-8	
9/27/95	L-21	2016	6-8	
9/27/95	M-21	2043	6-8	
9/27/95	N-21	1963	6-8	
9/27/95	O-21	1978	6-8	
9/27/95	P-21	2001	6-8	
9/27/95	Q-21	1946	6-8	
9/27/95	R-21	1977	6-8	
9/27/95	S-21	1701	6-8	
9/27/95	T-21	1698	6-8	
9/27/95	U-21	1660	6-8	
9/27/95	V-21	1942	6-8	
9/27/95	W-21	1851	6-8	
9/27/95	X-21	1888	6-8	
9/27/95	Y-21	1840	6-8	
9/27/95	Z-21	1727	6-8	
9/27/95	AA-21	2022	6-8	
9/27/95	BB-21	2049	6-8	
9/27/95	CC-21	2006	6-8	
9/27/95	DD-21	1797	6-8	
9/27/95	EE-21	1935	6-8	
9/27/95	FF-21	1860	6-8	
9/27/95	GG-21	1742	6-8	
9/27/95	HH-21	1841	6-8	
9/27/95	II-21	1840	6-8	
9/27/95	JJ-21	1879	6-8	
9/27/95	KK-21	1907	6-8	
9/27/95	KK-22	1999	6-8	
9/27/95	JJ-22	1925	6-8	
9/27/95	II-22	1714	6-8	
9/27/95	HH-22	1917	6-8	
9/27/95	GG-22	1787	6-8	
9/27/95	FF-22	1856	6-8	
9/27/95	EE-22	1877	6-8	
9/27/95	DD-22	2088	6-8	
9/27/95	CC-22	2010	6-8	
9/27/95	BB-22	2098	6-8	
9/27/95	AA-22	1957	6-8	

APPENDIX B
GRID NODE SURVEY RESULTS
NAS ALAMEDA, CALIFORNIA

Date	Sample Grid Location	Counts Per Minute (cpm)	Reading µR/H	Remarks
9/27/95	Z-22	1429	6-8	
9/27/95	Y-22	2065	6-8	
9/27/95	X-22	1922	6-8	
9/27/95	W-22	1873	6-8	
9/27/95	V-22	1870	6-8	
9/27/95	U-22	2128	6-8	
9/27/95	T-22	2099	6-8	
9/27/95	S-22	2025	6-8	
9/27/95	R-22	2072	6-8	
9/27/95	Q-22	2012	6-8	
9/27/95	P-22	2101	6-8	
9/27/95	O-22	1957	6-8	
9/27/95	N-22	2180	6-8	
9/27/95	M-22	1816	6-8	
9/27/95	L-22	1753	6-8	
9/27/95	K-22	1977	6-8	
9/27/95	J-22	1752	6-8	
9/27/95	I-22	1600	6-8	
9/27/95	H-22	1424	6-8	
9/27/95	G-22	1167	6-8	thick vegetation
9/27/95	F-22	1853	6-8	
9/27/95	E-22	1762	6-8	
9/27/95	D-22	2099	6-8	
9/27/95	C-22	1941	6-8	
9/27/95	A-23	1973	6-8	
9/27/95	B-23	1922	6-8	
9/27/95	C-23	1945	6-8	
9/27/95	D-23	1516	6-8	thick vegetation
9/27/95	E-23	1370	6-8	thick vegetation
9/27/95	F-23	1599	6-8	thick vegetation
9/27/95	G-23	1831	6-8	
9/27/95	H-23	1876	6-8	
9/27/95	I-23	1735	6-8	
9/27/95	J-23	2002	6-8	
9/27/95	K-23	1964	6-8	
9/27/95	L-23	1847	6-8	
9/27/95	M-23	1866	6-8	
9/27/95	N-23	2058	6-8	
9/27/95	O-23	2183	6-8	
9/27/95	P-23	1890	6-8	
9/27/95	Q-23	1941	6-8	

APPENDIX B
GRID NODE SURVEY RESULTS
NAS ALAMEDA, CALIFORNIA

Date	Sample Grid Location	Counts Per Minute (cpm)	Reading µR/H	Remarks
9/27/95	R-23	2006	6-8	
9/27/95	S-23	2015	6-8	
9/27/95	T-23	1998	6-8	
9/27/95	U-23	1864	6-8	
9/27/95	V-23	1847	6-8	
9/27/95	W-23	1896	6-8	
9/27/95	X-23	1973	6-8	
9/27/95	Y-23	1986	6-8	
9/27/95	Z-23	2124	6-8	
9/27/95	AA-23	1853	6-8	
9/27/95	BB-23	1994	6-8	
9/27/95	CC-23	2088	6-8	
9/27/95	DD-23	1936	6-8	
9/27/95	EE-23	1789	6-8	
9/27/95	FF-23	1448	6-8	
9/27/95	GG-23	1777	6-8	
9/27/95	HH-23	1906	6-8	
9/27/95	II-23	2177	6-8	
9/27/95	GG-24	2057	6-8	
9/27/95	FF-24	1940	6-8	
9/27/95	EE-24	1836	6-8	
9/27/95	DD-24	2042	6-8	
9/27/95	CC-24	1783	6-8	
9/27/95	BB-24	1944	6-8	
9/27/95	AA-24	1987	6-8	
9/27/95	Z-24	1872	6-8	
9/27/95	Y-24	1818	6-8	
9/27/95	X-24	1805	6-8	
9/27/95	W-24	1848	6-8	
9/27/95	V-24	1862	6-8	
9/27/95	U-24	2050	6-8	
9/27/95	T-24	1684	6-8	
9/27/95	S-24	1751	6-8	
9/27/95	R-24	1966	6-8	
9/27/95	Q-24	1890	6-8	
9/27/95	P-24	1877	6-8	
9/27/95	0-24	1858	6-8	
9/27/95	N-24	1791	6-8	
9/27/95	M-24	1972	6-8	
9/27/95	L-24	1913	6-8	
9/27/95	K-24	1906	6-8	

APPENDIX B
GRID NODE SURVEY RESULTS
NAS ALAMEDA, CALIFORNIA

Date	Sample Grid Location	Counts Per Minute (cpm)	Reading µR/H	Remarks
9/27/95	J-24	1872	6-8	
9/27/95	I-24	2136	6-8	
9/27/95	H-24	1749	6-8	
9/27/95	G-24	1829	6-8	
9/27/95	F-24	1822	6-8	
9/27/95	E-24	1688	6-8	
9/27/95	D-24	1511	6-8	
9/27/95	C-24	1722	6-8	
9/27/95	B-24	1393	6-8	
9/27/95	A-24	1922	6-8	
9/27/95	A-25	1968	6-8	
9/27/95	B-25	2018	6-8	
9/27/95	C-25	2195	6-8	
9/27/95	D-25	1976	6-8	
9/27/95	E-25	1974	6-8	
9/27/95	F-25	1829	6-8	
9/27/95	G-25	1988	6-8	
9/27/95	H-25	1707	6-8	
9/27/95	I-25	1964	6-8	
9/27/95	J-25	2084	6-8	
9/27/95	K-25	1972	6-8	
9/27/95	L-25	1982	6-8	
9/27/95	M-25	1742	6-8	
9/27/95	N-25	1449	6-8	
9/27/95	O-25	1843	6-8	
9/27/95	P-25	1706	6-8	
9/27/95	Q-25	1773	6-8	
9/27/95	R-25	1782	6-8	
9/27/95	S-25	1648	6-8	
9/27/95	T-25	1840	6-8	
9/27/95	U-25	1816	6-8	
9/27/95	V-25	1983	6-8	
9/27/95	W-25	2112	6-8	
9/27/95	X-25	2142	6-8	
9/27/95	Y-25	2011	6-8	
9/27/95	Z-25	1927	6-8	
9/27/95	AA-25	2078	6-8	
9/27/95	BB-25	2029	6-8	
9/27/95	CC-25	1924	6-8	
9/27/95	DD-25	2001	6-8	
9/27/95	EE-25	2060	6-8	

APPENDIX B
GRID NODE SURVEY RESULTS
NAS ALAMEDA, CALIFORNIA

Date	Sample Grid Location	Counts Per Minute (cpm)	Reading µR/H	Remarks
9/27/95	CC-26	1989	6-8	
9/27/95	BB-26	2085	6-8	
9/27/95	AA-26	1928	6-8	
9/27/95	Z-26	2009	6-8	
9/27/95	Y-26	1924	6-8	
9/27/95	X-26	1843	6-8	
9/27/95	W-26	2006	6-8	
9/27/95	V-26	2111	6-8	
9/27/95	U-26	1877	6-8	
9/27/95	T-26	1866	6-8	
9/27/95	S-26	2012	6-8	
9/27/95	R-26	2067	6-8	
9/27/95	Q-26	1841	6-8	
9/27/95	P-26	1948	6-8	
9/27/95	O-26	1973	6-8	
9/27/95	N-26	2097	6-8	
9/27/95	M-26	1838	6-8	
9/27/95	L-26	1670	6-8	
9/27/95	K-26	2033	6-8	
9/27/95	J-26	2055	6-8	
9/27/95	I-26	1922	6-8	
9/27/95	H-26	1952	6-8	
9/27/95	G-26	1911	6-8	
9/27/95	R-26	1432	6-8	
9/27/95	E-26	1825	6-8	
9/27/95	D-26	2004	6-8	
9/27/95	C-26	1897	6-8	
9/27/95	B-26	2036	6-8	
9/27/95	A-26	2121	6-8	
9/27/95	I-27	1966	6-8	
9/27/95	J-27	2013	6-8	
9/27/95	K-27	1833	6-8	
9/27/95	L-27	1987	6-8	
9/27/95	M-27	1946	6-8	
9/27/95	N-27	1874	6-8	
9/27/95	O-27	1905	6-8	
9/27/95	P-27	1853	6-8	
9/27/95	Q-27	1860	6-8	
9/27/95	R-27	1897	6-8	
9/27/95	S-27	1857	6-8	
9/27/95	T-27	1890	6-8	

APPENDIX B
GRID NODE SURVEY RESULTS
NAS ALAMEDA, CALIFORNIA

Date	Sample Grid Location	Counts Per Minute (cpm)	Reading µR/H	Remarks
9/27/95	U-27	1873	6-8	
9/27/95	V-27	1796	6-8	
9/27/95	W-27	1954	6-8	
9/27/95	X-27	1888	6-8	
9/27/95	Y-27	1942	6-8	
9/27/95	Z-27	2003	6-8	
9/27/95	AA27	1905	6-8	
9/27/95	Y-28	1932	6-8	
9/27/95	X-28	1776	6-8	
9/27/95	W-28	2016	6-8	
9/27/95	V-28	1827	6-8	
9/27/95	U-28	1878	6-8	Site 2 survey complete

APPENDIX C

CERTIFICATES OF CALIBRATION

CERTIFICATE OF CALIBRATION
MULTINUCLIDE STANDARD SOURCE

Customer: PRC ENVIRONMENTAL MANAGEMENT, INC.
P.O.No.: 15930
Catalog No.: EG-MLAM-062
Reference Date: November 1 1994
Source No.: 470-61
Total Radioactivity: 1.039 μCi.
Total Radioactivity: 38.4 kBq.

Description of Source

a. Capsule type: Customer supplied jar
b. Nature of active deposit: Multinuclide and Am-241 dispersed in an epoxy fill
c. Active diameter/volume: Approximately 560 ml (Mass of epoxy = 851.36 g)
d. Backing: Plastic
e. Cover: Plastic

Nuclide	Activity. ~~(μCi)~~ PCi	Gamma-Ray Energy(MeV)	Branching Ratio %	Systematic Uncert.	Random Uncert.	Overall Uncert.
Am-241	0.031100	0.0595	36.0	3.0%	1.2%	3.2%
Cd-109	0.308089	0.088	3.63	3.0%	2.0%	3.6%
Co-57	0.011170	0.122, 0.136	85.6, 10.68	3.0%	2.1%	3.7%
Te-123m	0.01240	0.159	84.0	3.0%	1.6%	3.4%
Cr-51	0.364	0.320	9.86	3.0%	0.7%	3.1%
Sn-113	0.0497	0.392	64.89	3.0%	1.5%	3.4%
Sr-85	0.0653	0.514	98.4	3.0%	1.1%	3.2%
Cs-137	0.0404	0.662	85.1	3.0%	1.7%	3.4%
Co-60	0.0537	1.173, 1.333	99.86, 99.98	3.0%	1.8%	3.5%
Y-88	0.1029	0.898, 1.836	94.0, 99.36	3.0%	1.1%	3.2%

Method of Calibration

This source was made from a weighed aliquot of solution whose concentration, in μCi/g, was determined by gamma spectrometry.

NIST Traceability

This calibration is implicitly traceable to the National Institute of Standards and Technology.

Leak Test(s)

See reverse side for Leak Test(s) applied to this source.

Notes

1. Nuclear data was taken from "Table of Radioactive Isotopes", edited by Virginia S. Shirley, 1986.
2. IPL participates in an NIST measurement assurance program to establish and maintain implicit traceability for a number of nuclides, based on the blind assay (and later NIST certification) of Standard Reference Materials (As in NRC Regulatory Guide 4.15).
3. Overall uncertainty is calculated at the 99% confidence level.
4. Reference Half lives:

Am-241	432.2 ± 0.65 years	Te-123m	119.7 ± 0.1 days	Sr-85	64.84 ± 0.004 days
Cd-109	1.2665 ± 0.0019 years	Cr-51	27.706 ± 0.007 days	Cs-137	30.1 ± 0.2 years
Co-57	271.79 ± 0.09 days	Sn-113	115.09 ± 0.04 days	Co-60	5.271 ± 0.001 years
Y-88	99.9% , 99.9824%				

QUALITY CONTROL

14 OCTOBER 1994
Date Signed

ISOTOPE PRODUCTS LABORATORIES
1800 No. Keystone Street
Burbank, California 91504
(818) 843 - 7000

IPL Ref No. 470-61

Scientific and Industrial Instruments

POST OFFICE BOX 810 PH. 915-235-5494
501 OAK STREET FAX NO. 915-235-4672
SWEETWATER, TEXAS 79556, U.S.A.

CERTIFICATE OF CALIBRATION

CUSTOMER HAZCO SERVICES INC ORDER NO. 947436

Mfg. Ludlum Measurements, Inc. Model 2221 Serial No. 117331

Ludlum Measurements, Inc. Model 44-10 Serial No. PR120483

Date 01/30/95 Cal Due Date 01/30/96 Cal. Interval 1 Year Meterface 202-159

Check mark ☑ applies to applicable instr. and/or detector IAW mfg. spec. T. 71 °F RH 25 % Alt 713.8 mm Hg

☑ New Instrument Instrument Received ☐ Within Toler. +-10% ☐ 10-20% ☐ Out of Tol. ☐ Requiring Repair

☑ Mechanical ck. ☑ Meter Zeroed ☐ Background Subtract ☑ Input Sens. Linearity

☑ F/S Resp. ck ☑ Reset ck. ☑ Window Operation ☑ Geotropism

☑ Audio ck. ☐ Alarm Setting ck. ☑ Batt. ck. (Min. Volt) 4.4 VDC

Instrument Volt Set Comments V Input Sens. Comments mV Det. Oper. Comments V at Comments mV Threshold Dial Ratio 100 = 10 mV

☑ HV Readout (2 points) Ref./Inst. 499 / 500 V Ref./Inst. 2003 / 2000 V

COMMENTS:

Detector		44-10	44-9	43-65
High voltage	:	757v.	900v.	650v.
Threshold dial	:	642	500	350
Millivoltage	:	n/a	50mv.	35mv.
Window dial	:	40	n/a	n/a
Window position	:	"ON"	"OFF"	"OFF"

Window position "OFF" for gross counts only.

Firmware #261010
High voltage for 44-10 is peak voltage only.
10mv. setting for gross counts only.
≈8.9% Resolution for Cs137.
High voltage for all detectors set with detector connected.

Gamma Calibration: GM detectors positioned perpendicular to source except for M 44-9 in which the front of probe faces source.

RANGE/MULTIPLIER	REFERENCE CAL. POINT	INSTRUMENT REC'D "AS FOUND READING"	INSTRUMENT METER READING*
X 1K	400kcpm		400
X 1K	100kcpm		100
X 100	40kcpm		400
X 100	10kcpm		100
X 10	4kcpm		400
X 10	1kcpm		100
X 1	400cpm		400
X 1	100cpm		100

*Uncertainty within ± 10% C.F. within ± 20% ALL Range(s) Calibrated Electronically

Digital Readout REFERENCE CAL. POINT	INSTRUMENT RECEIVED	INSTRUMENT METER READING*	Log Scale REFERENCE CAL. POINT	INSTRUMENT RECEIVED	INSTRUMENT METER READING*
400kcpm		40009 (0)	500kcpm		485K
40kcpm		3999 (0)	50kcpm		52K
4kcpm		400 (0)	5kcpm		5.2K
400cpm		40 (0)	500cpm		500
40cpm		4 (0)	50cpm		55

Ludlum Measurements, Inc. certifies that the above instrument has been calibrated by standards traceable to the National Institute of Standards and Technology, or to the calibration facilities of other International Standards Organization members, or have been derived from accepted values of natural physical constants or have been derived by the ratio type of calibration techniques. The calibration system conforms to the requirements of MIL-STD-45662A and ANSI N323-1978.

State of Texas Calibration License No. LO-1963

Reference Instruments and/or Sources:

Cs-137 Gamma S/N ☑ 1162 ☐ G112 ☐ M565 ☐ 5105 ☐ T1008 ☐ T879 ☐ Neutron Am-241 Be S/N T-304

☑ Alpha S/N 1619 Th230 3442cpm ☐ Beta S/N ☑ Other Am241 5.5uCi

☑ m 500 S/N 79956 ☐ Oscilloscope S/N ☑ Multimeter S/N 53801574

Calibrated By: Elias Chavez Date 1-30-95

Reviewed By: Rhonda Harris Date 1-31-95

FORM C22A 09/28/94

LMI
Designer and Manufacturer of Scientific and Industrial Instruments

POST OFFICE BOX 810 PH. 915-235-5494
501 OAK STREET FAX NO. 915-235-4672
SWEETWATER, TEXAS 79556, U.S.A.

Bench Test Data For Detector

Detector 44-10 Serial No. PR120483

Customer HAZCO SERVICES INC Order #. 947436

Counter 2221 Serial No. 117331 Counter Input Sensitivity 10 mV

Count Time 0.1min. Distance Source to Detector 7.5cm

Other

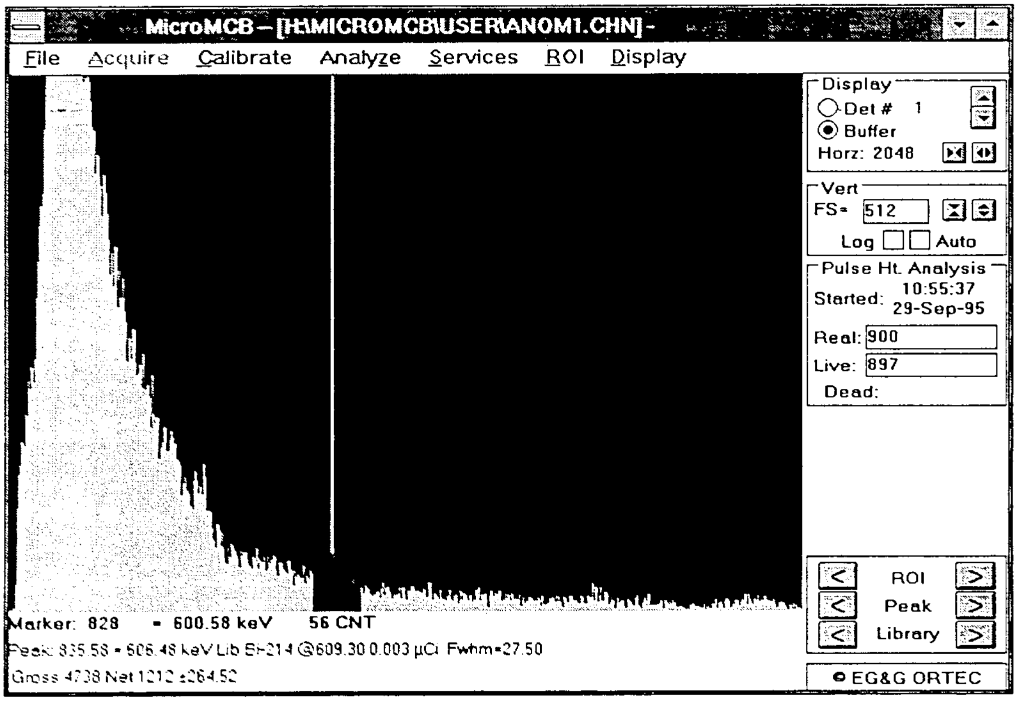
High Voltage	Background	Isotope Am 241 Size 5.5 µCi	Isotope Size	Isotope Size	Isotope Size
900	824	6383			
950	804	6898			
1000	830	7238			
1050	821	7273			
1100	823	7268			
1150	883	7234			
1200	825	7325			
1250	820	7315			

Signature Elias Chavez Date 1-30-95

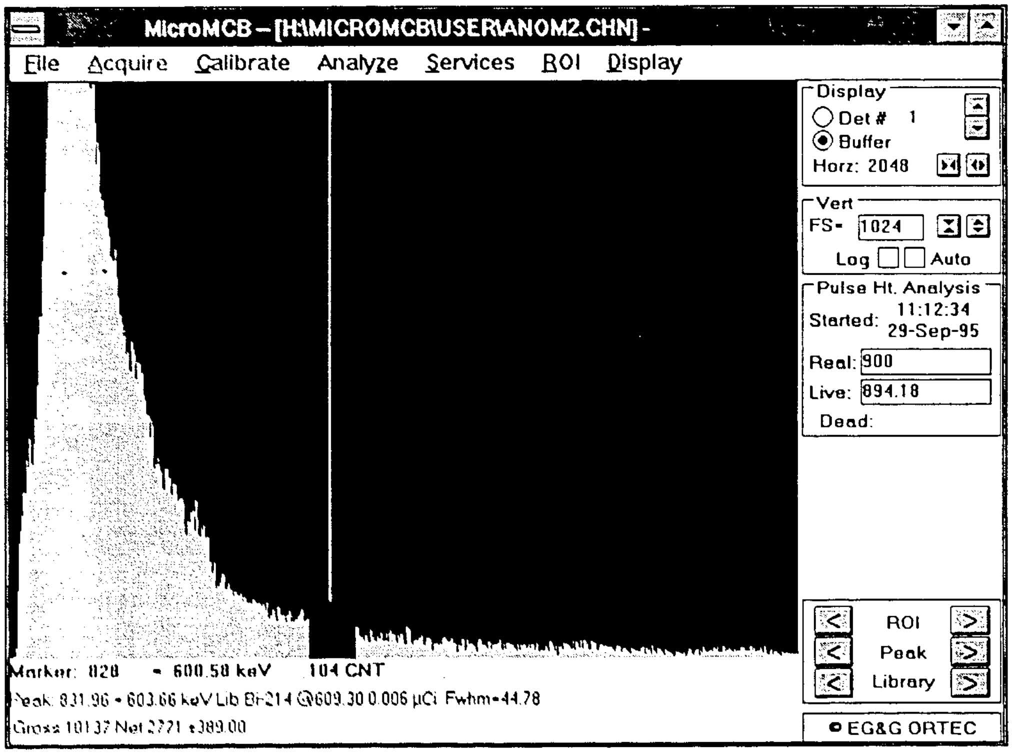
FORM C4A 02/23/94

APPENDIX D

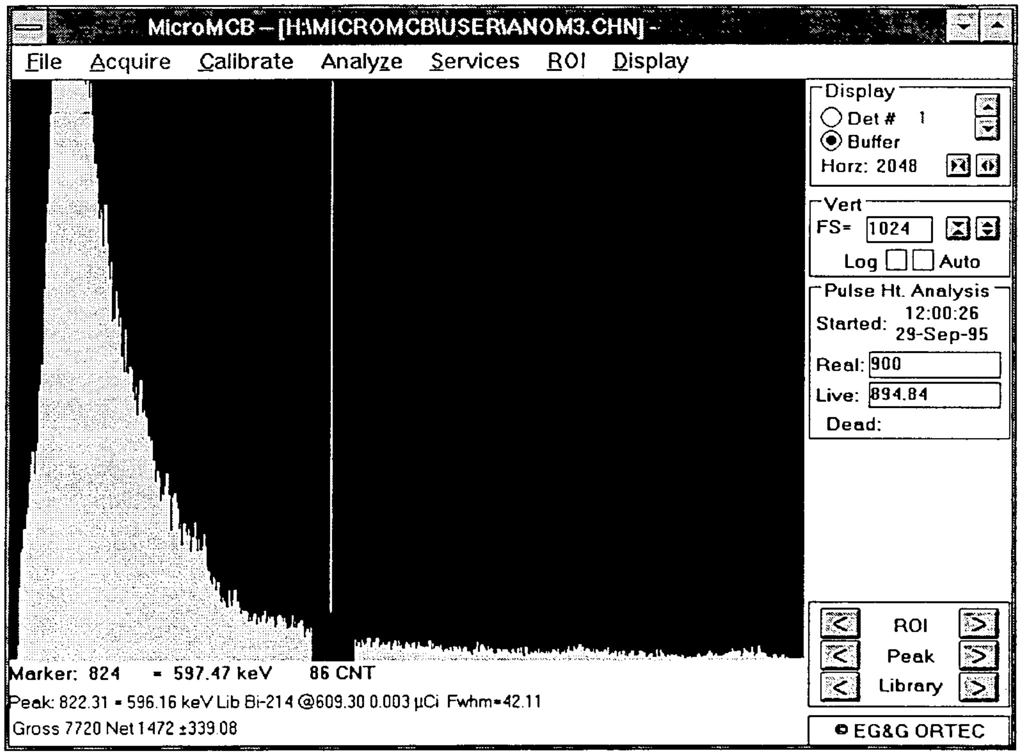
IN SITU SPECTRA FROM SITE 1 AND SITE 2 ANOMALY LOCATIONS



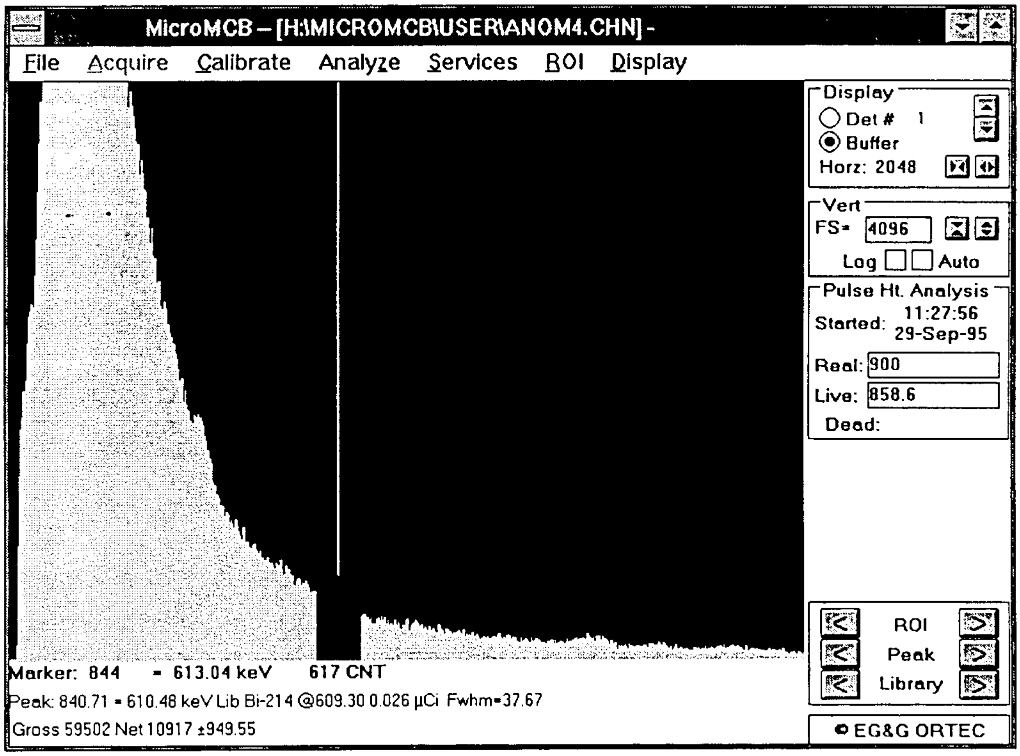
In Situ Spectrum of Anomaly 1



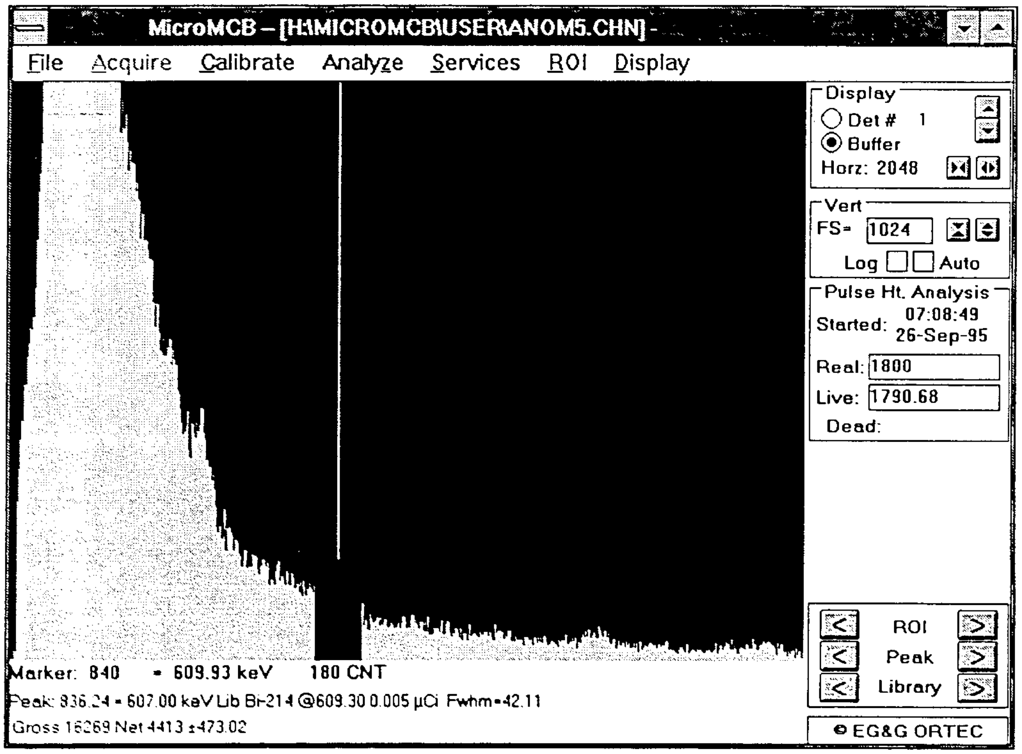
In Situ Spectrum of Anomaly 2



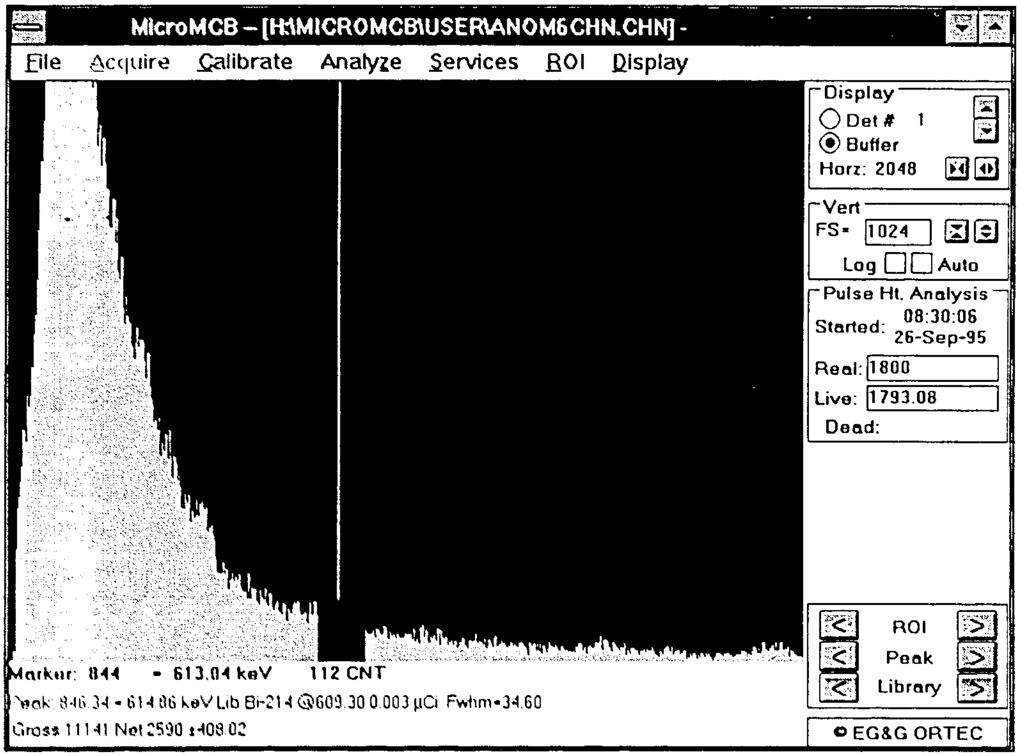
In Situ Spectrum of Anomaly 3



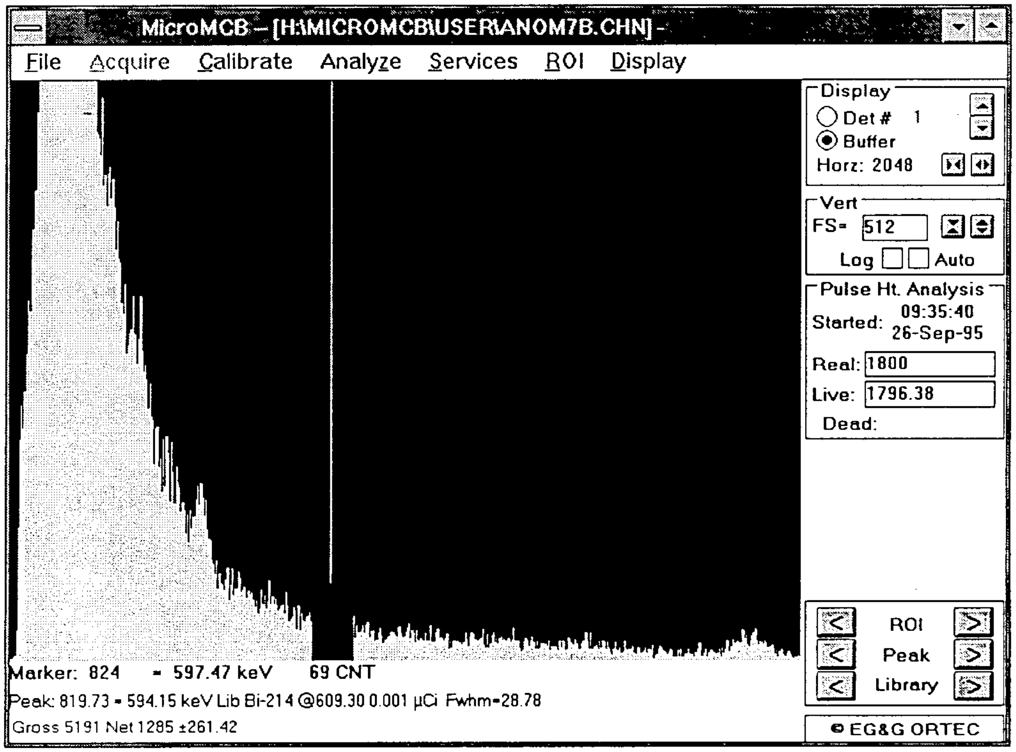
In Situ Spectrum of Anomaly 4



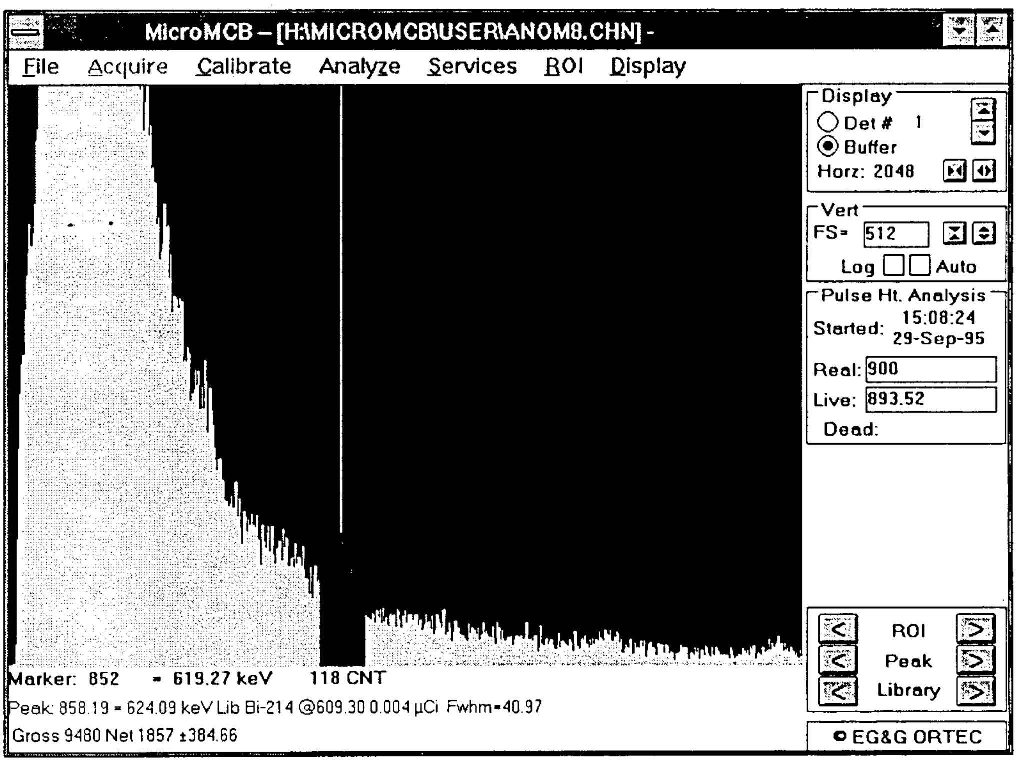
In Situ Spectrum of Anomaly 5



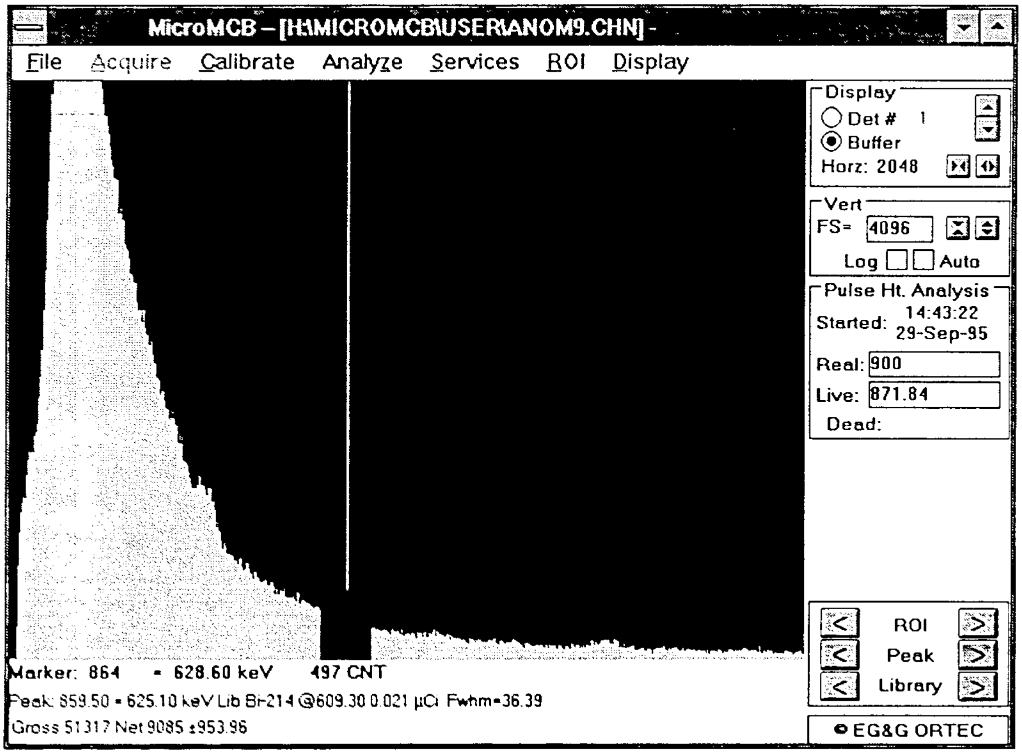
In Situ Spectrum of Anomaly 6



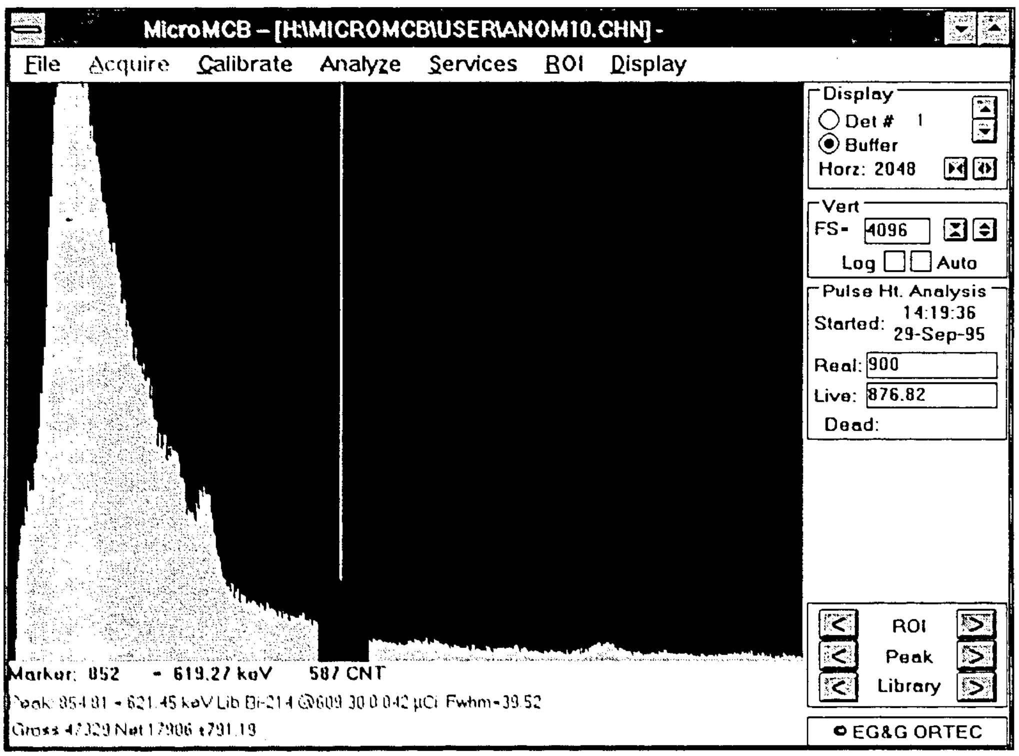
In Situ Spectrum of Anomaly 7



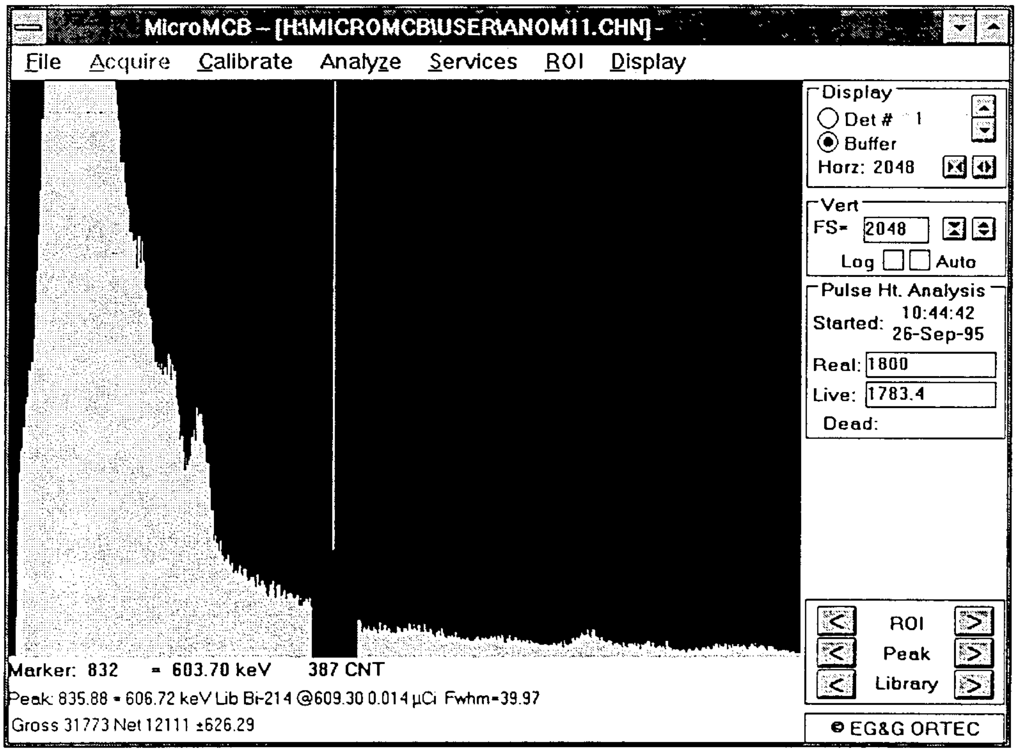
In Situ Spectrum of Anomaly 8



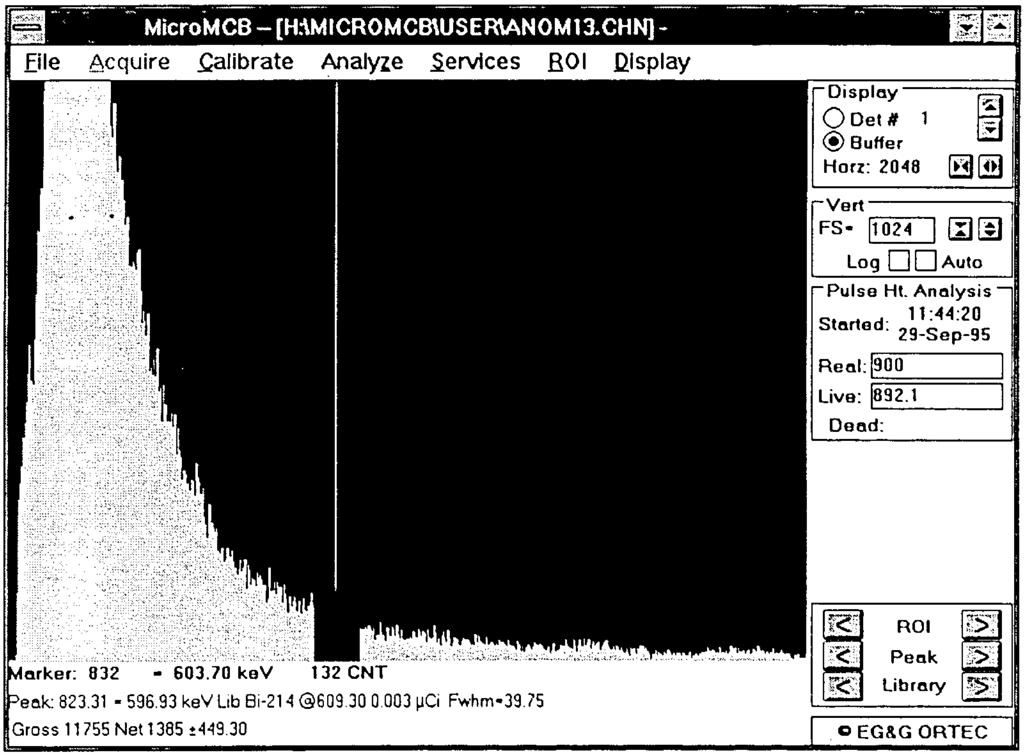
In Situ Spectrum of Anomaly 9



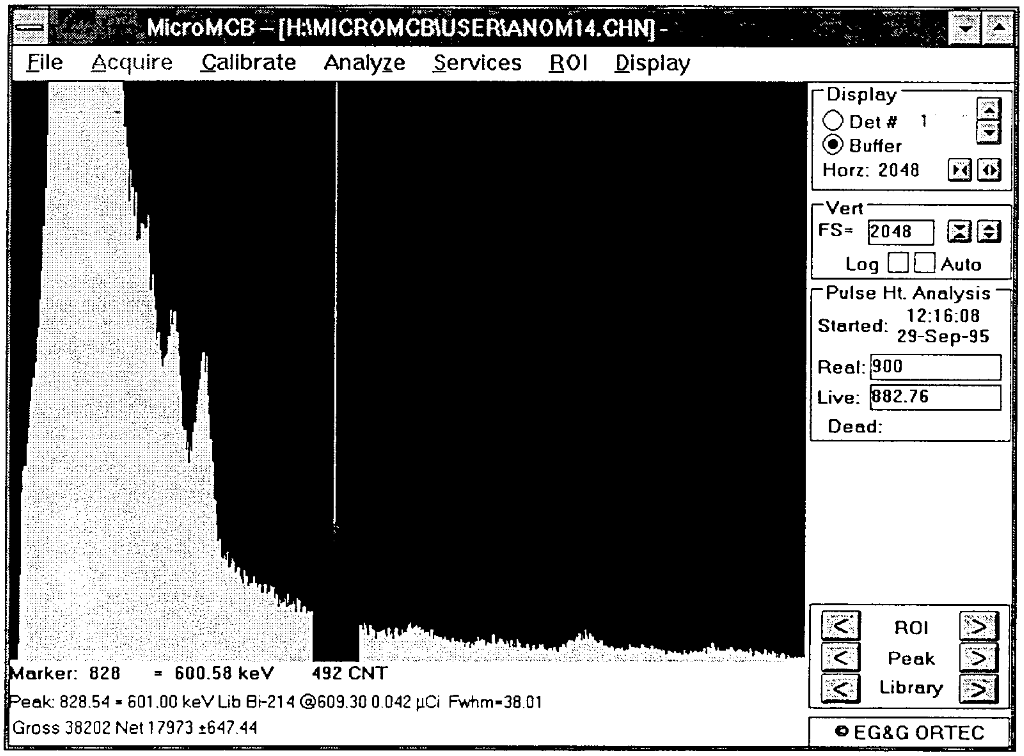
In Situ Spectrum of Anomaly 10



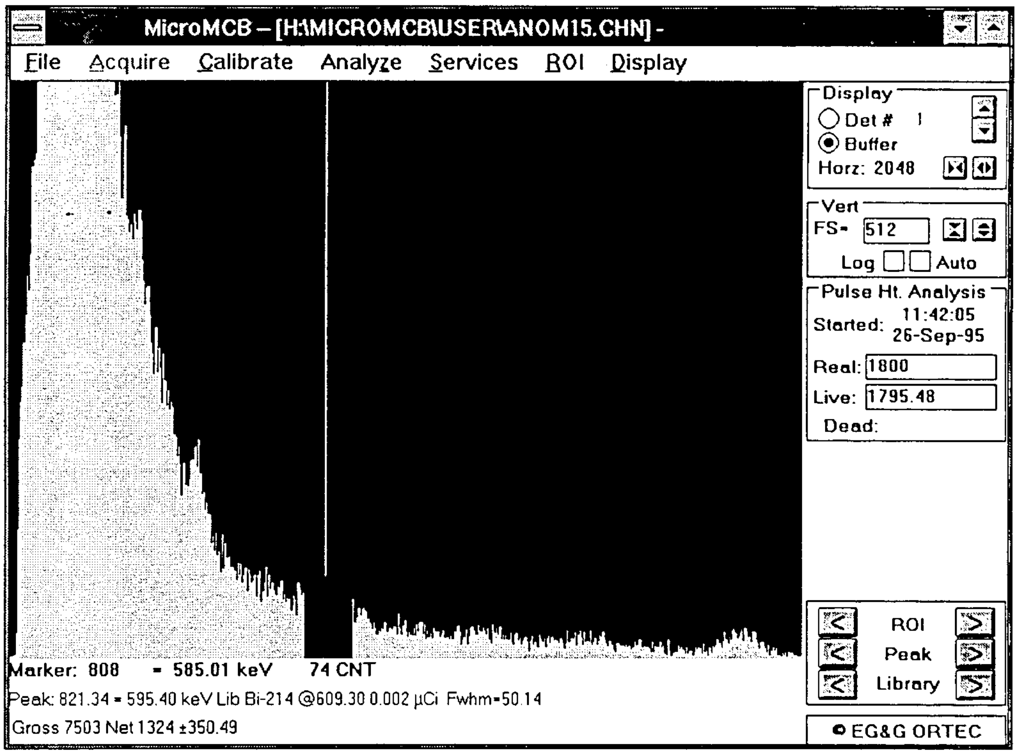
In Situ Spectrum of Anomaly 11



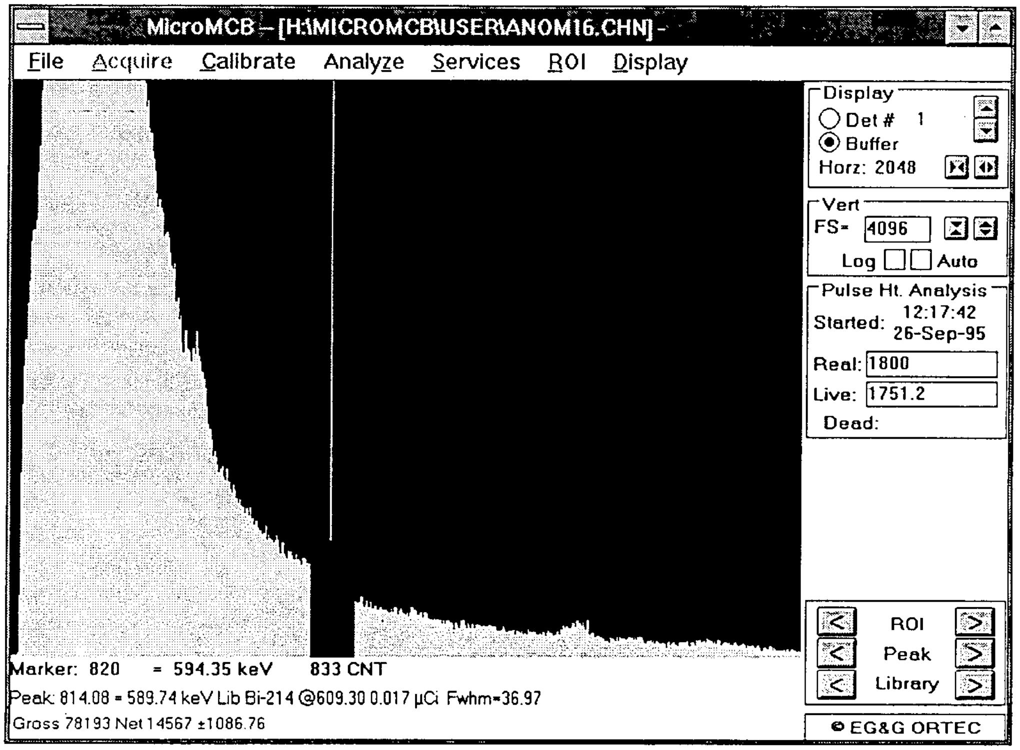
In Situ Spectrum of Anomaly 13



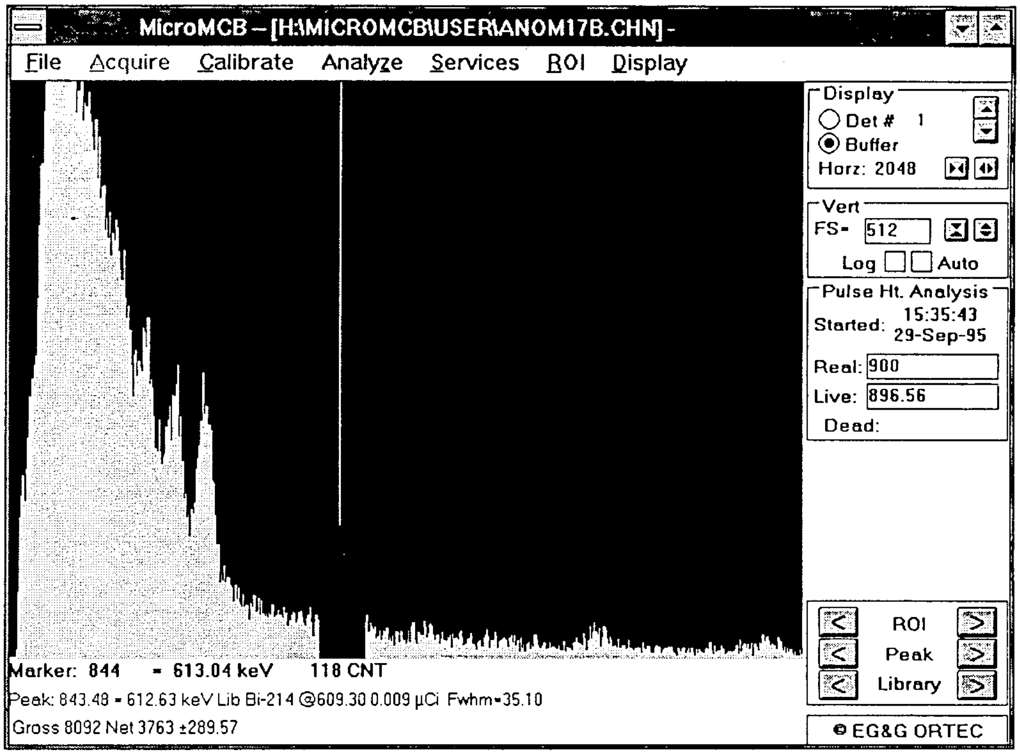
In Situ Spectrum of Anomaly 14



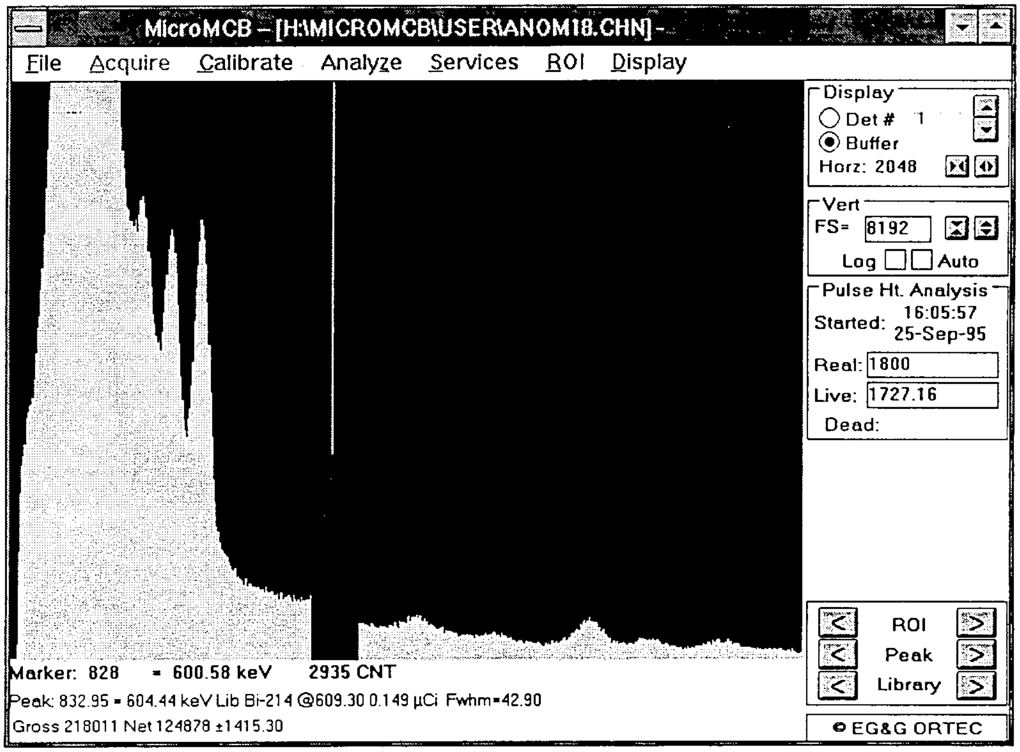
In Situ Spectrum of Anomaly 15



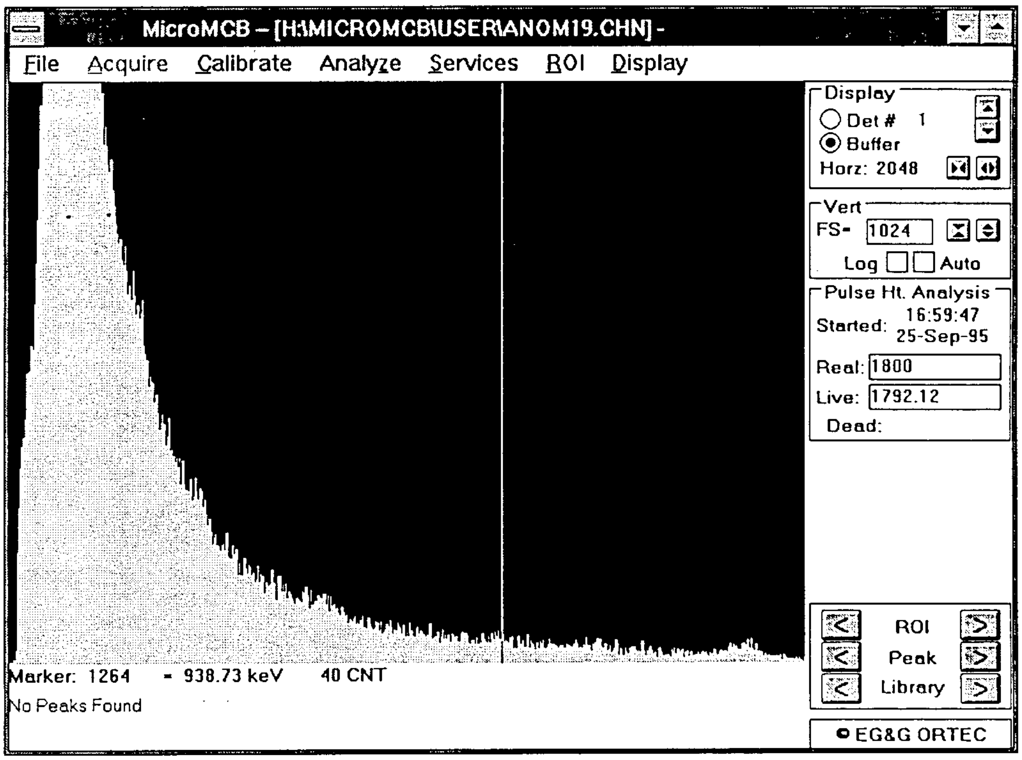
In Situ Spectrum of Anomaly 16



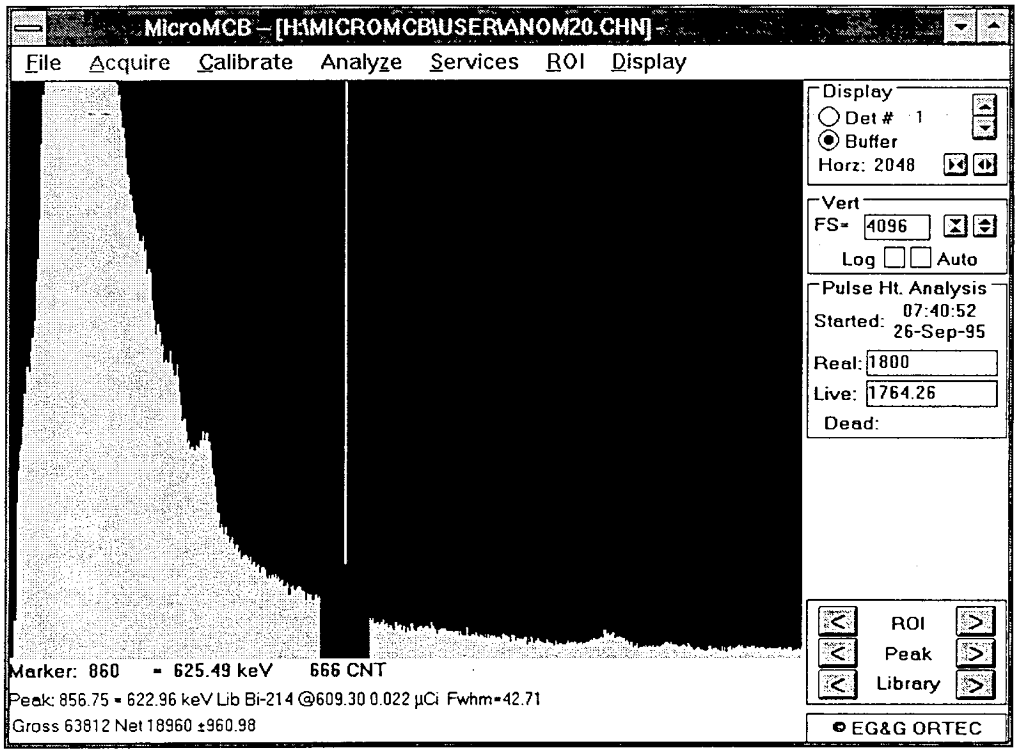
In Situ Spectrum of Anomaly 17



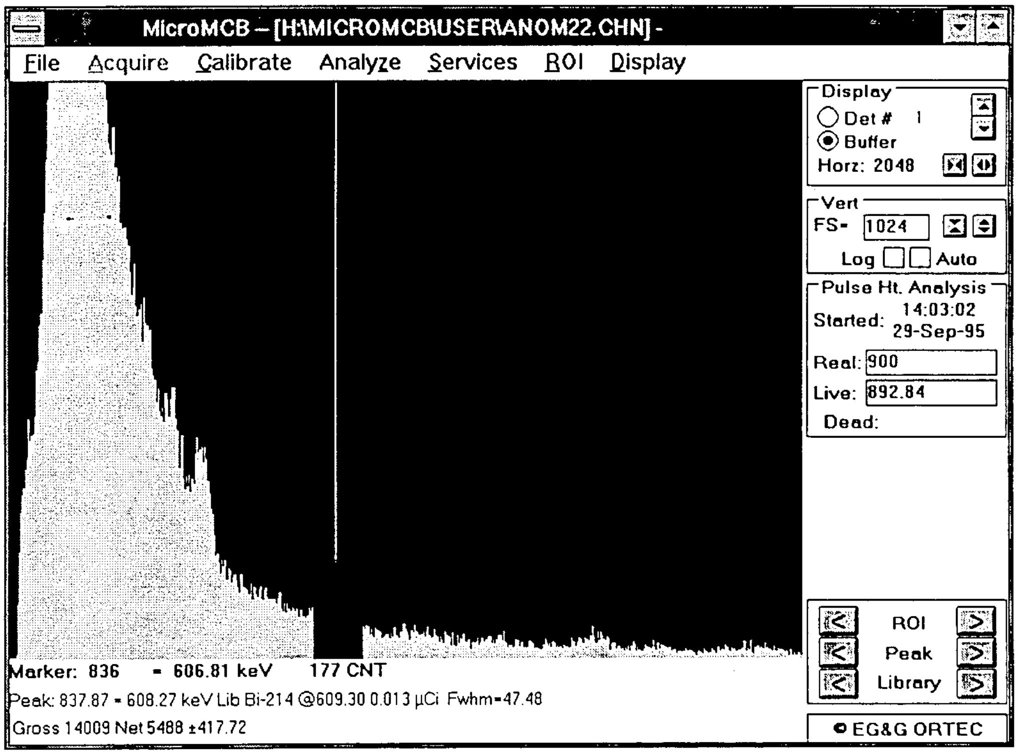
In Situ Spectrum of Anomaly 18



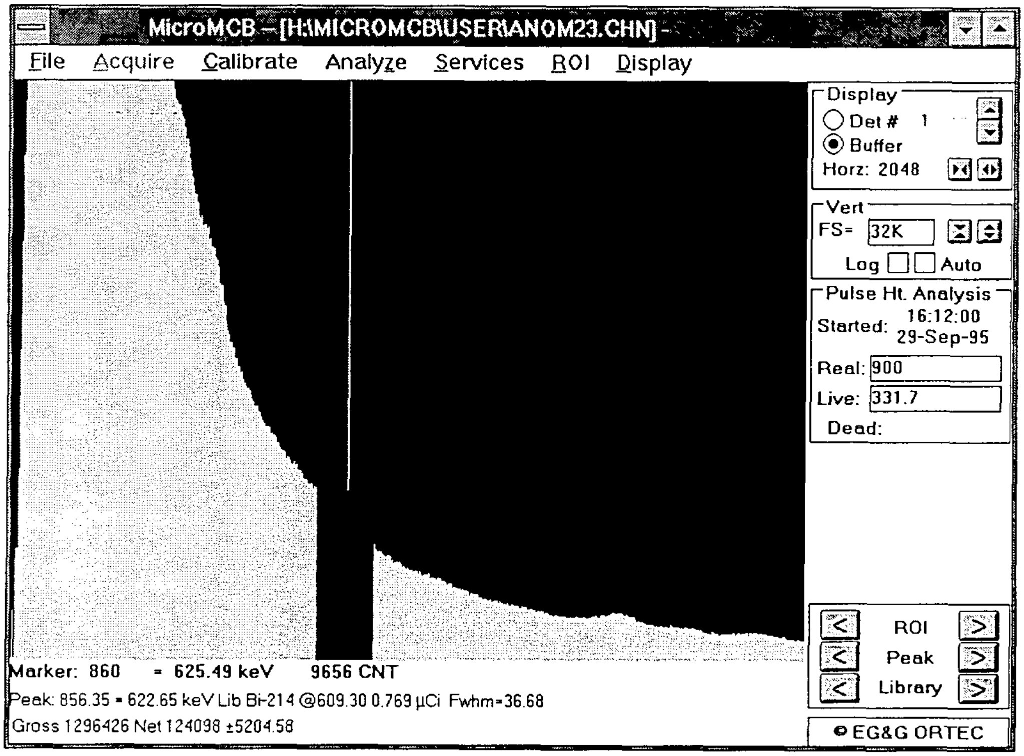
In Situ Spectrum of Anomaly 19



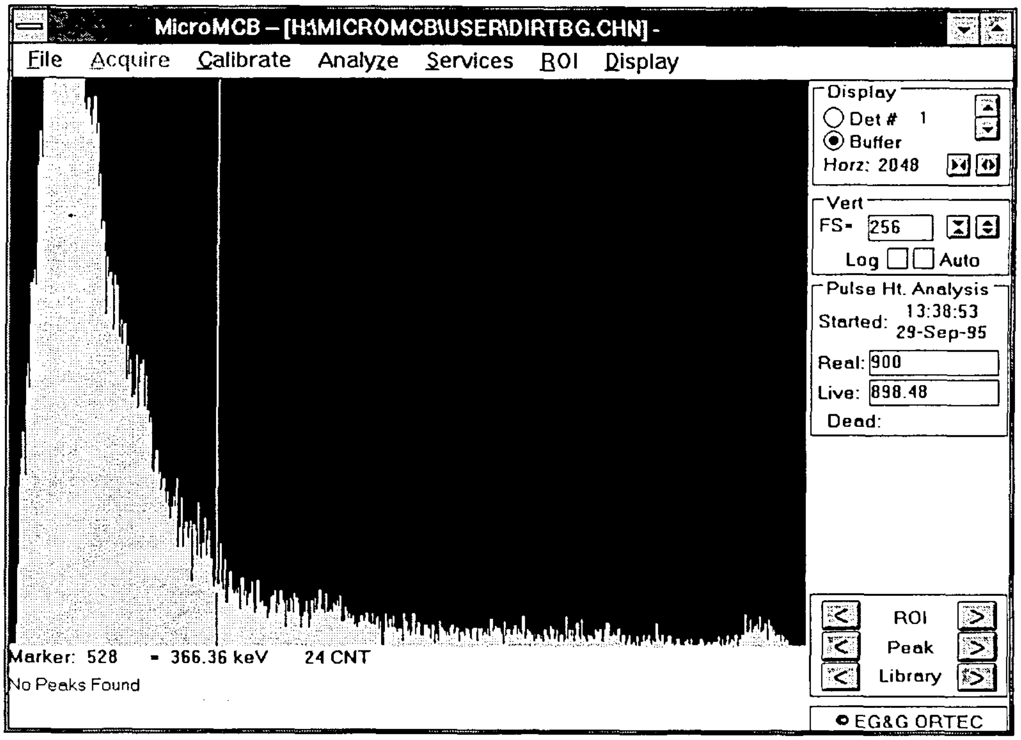
In Situ Spectrum of Anomaly 20



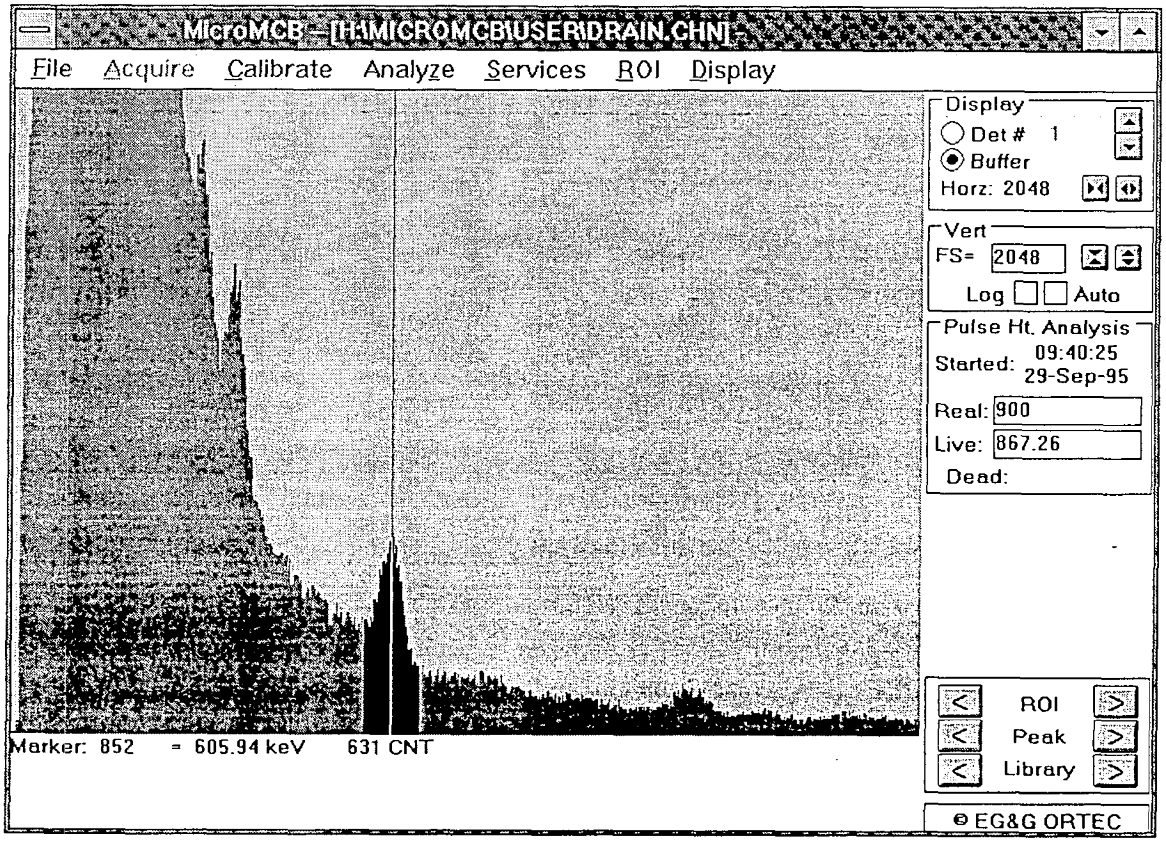
In Situ Spectrum of Anomaly 22



In Situ Spectrum of Anomaly 23



In Situ Background Spectrum



In Situ Spectrum of Storm Sewer Manhole 6F-2 of Storm Sewer Line F

APPENDIX E

REGION OF INTEREST REPORTS FOR THE ANOMALOUS SOIL SAMPLES

**NAS Alameda Near-Surface Soil Survey Anomaly Soil Sample Analysis:
Region of Interest Reports for Channels 760 through 924**

Sample AN001

Detector #1 ACQ 14-Nov-95 at 12:11:40 RT 1200 LT 1199.78
MicroNOMAD 12380

ROI # 1 RANGE: 760 = 559.47 keV to 924 = 680.22 keV
AREA: Gross = 537 Net = 70 ±111.67
CENTROID: 812.23 = 597.64 keV
SHAPE: FWHM = 5.26
ID: Bi-214 at 609.30
ACTIVITY: < 0.001 μCi

Sample AN002

Detector #1 ACQ 14-Nov-95 at 12:41:03 RT 1200 LT 1199.72
MicroNOMAD 12380

ROI # 1 RANGE: 760 = 559.47 keV to 924 = 680.22 keV
AREA: Gross = 786 Net = 154 ±130.01
CENTROID: 819.82 = 603.21 keV
SHAPE: FWHM = 25.47
ID: Bi-214 at 609.30
ACTIVITY: 0.001 μCi

Sample AN003

Detector #1 ACQ 14-Nov-95 at 13:06:47 RT 1200 LT 1199.78
MicroNOMAD 12380

ROI # 1 RANGE: 760 = 559.47 keV to 924 = 680.22 keV
AREA: Gross = 567 Net = 72 ±114.85
CENTROID: 782.86 = 576.14 keV
SHAPE: FWHM = 12.04
No Close Library Match

Sample AN004

Detector #1 ACQ 14-Nov-95 at 13:30:54 RT 1200 LT 1199.66
MicroNOMAD 12380

ROI # 1 RANGE: 760 = 559.47 keV to 924 = 680.22 keV
AREA: Gross = 1026 Net = 229 ±146.20
CENTROID: 807.07 = 593.86 keV
SHAPE: FWHM = 14.45
ID: Bi-214 at 609.30
ACTIVITY: 0.001 μCi

NAS Alameda Near-Surface Soil Survey Anomaly Soil Sample Analysis:
Region of Interest Reports for Channels 760 through 924

Sample AN005

Detector #1 ACQ 14-Nov-95 at 13:55:30 RT 1200 LT 1199.72
MicroNOMAD 12380

ROI # 1 RANGE: 760 = 559.47 keV to 924 = 680.22 keV
AREA: Gross = 696 Net = 339 ±99.12
CENTROID: 835.20 = 614.51 keV
SHAPE: FWHM = 28.65
ID: Bi-214 at 609.30
ACTIVITY: 0.002 μCi

Sample AN006

Detector #1 ACQ 14-Nov-95 at 14:17:47 RT 1200 LT 1199.74
MicroNOMAD 12380

ROI # 1 RANGE: 760 = 559.47 keV to 924 = 680.22 keV
AREA: Gross = 646 Net = 41 ±126.78
CENTROID: 857.16 = 630.69 keV
SHAPE: FWHM = 19.14
No Close Library Match

Sample AN007

Detector #1 ACQ 14-Nov-95 at 14:41:16 RT 1200 LT 1199.64
MicroNOMAD 12380

ROI # 1 RANGE: 760 = 559.47 keV to 924 = 680.22 keV
AREA: Gross = 1140 Net = 370 ±144.14
CENTROID: 821.23 = 604.24 keV
SHAPE: FWHM = 15.39
ID: Bi-214 at 609.30
ACTIVITY: 0.002 μCi

Sample AN 008

Detector #1 ACQ 14-Nov-95 at 15:05:01 RT 1200 LT 1199.78
MicroNOMAD 12380

ROI # 1 RANGE: 760 = 559.47 keV to 924 = 680.22 keV
AREA: Gross = 555 Net = 60 ±114.79
CENTROID: 713.92 = 526.01 keV
SHAPE: FWHM = 6.07
No Close Library Match

Sample AN009

Detector #1 ACQ 14-Nov-95 at 15:51:23 RT 1200 LT 1199.78
MicroNOMAD 12380

ROI # 1 RANGE: 760 = 559.47 keV to 924 = 680.22 keV
AREA: Gross = 555 Net = 33 ±117.75
CENTROID: 679.73 = 501.33 keV
SHAPE: FWHM = 11.81
No Close Library Match

Sample AN010

Detector #1 ACQ 14-Nov-95 at 16:14:21 RT 1200 LT 1199.76
MicroNOMAD 12380

ROI # 1 RANGE: 760 = 559.47 keV to 924 = 680.22 keV
AREA: Gross = 631 Net = 191 ±108.86
CENTROID: 797.64 = 586.95 keV
SHAPE: FWHM = 1.01
No Close Library Match

Sample AN011

Detector #1 ACQ 14-Nov-95 at 16:36:34 RT 1200 LT 1198.26
MicroNOMAD 12380

ROI # 1 RANGE: 760 = 559.47 keV to 924 = 680.22 keV
AREA: Gross = 6381 Net = 3521 ±281.62
CENTROID: 844.03 = 621.01 keV
SHAPE: FWHM = 37.13
ID: Bi-214 at 609.30
ACTIVITY: 0.016 μCi

Sample AN012

Detector #1 ACQ 14-Nov-95 at 17:02:10 RT 1200 LT 1199.78
MicroNOMAD 12380

ROI # 1 RANGE: 760 = 559.47 keV to 924 = 680.22 keV
AREA: Gross = 515 Net = 103 ±104.98
CENTROID: 820.13 = 603.43 keV
SHAPE: FWHM = 33.04
ID: Bi-214 at 609.30
ACTIVITY: < 0.001 μCi

NAS Alameda Near-Surface Soil Survey Anomaly Soil Sample Analysis:
Region of Interest Reports for Channels 760 through 924

Sample AN013

Detector #1 ACQ 14-Nov-95 at 17:24:44 RT 1200 LT 1199.76
MicroNOMAD 12380

ROI # 1 RANGE: 760 = 559.47 keV to 924 = 680.22 keV
AREA: Gross = 586 Net = 119 ±111.89
CENTROID: 787.18 = 579.30 keV
SHAPE: FWHM = 46.71
No Close Library Match

Sample AN014

Detector #1 ACQ 14-Nov-95 at 17:47:14 RT 1200 LT 1197.72
MicroNOMAD 12380

ROI # 1 RANGE: 760 = 559.47 keV to 924 = 680.22 keV
AREA: Gross = 8211 Net = 4829 ±307.33
CENTROID: 846.20 = 622.61 keV
SHAPE: FWHM = 43.28
ID: Bi-214 at 609.30
ACTIVITY: 0.022 μCi

Sample AN015

Detector #1 ACQ 14-Nov-95 at 18:09:59 RT 1200 LT 1199.78
MicroNOMAD 12380

ROI # 1 RANGE: 760 = 559.47 keV to 924 = 680.22 keV
AREA: Gross = 571 Net = 104 ±111.83
CENTROID: 808.20 = 594.68 keV
SHAPE: FWHM = 17.48
ID: Bi-214 at 609.30
ACTIVITY: < 0.001 μCi

Sample AN016

Detector #1 ACQ 14-Nov-95 at 18:32:32 RT 1200 LT 1199.72
MicroNOMAD 12380

ROI # 1 RANGE: 760 = 559.47 keV to 924 = 680.22 keV
AREA: Gross = 797 Net = 357 ±109.62
CENTROID: 838.42 = 616.88 keV
SHAPE: FWHM = 6.69
ID: Bi-214 at 609.30
ACTIVITY: 0.002 μCi

Sample AN017

Detector #1 ACQ 15-Nov-95 at 10:45:03 RT 1200 LT 1199.8
MicroNOMAD 12380

ROI # 1 RANGE: 760 = 559.47 keV to 924 = 680.22 keV
AREA: Gross = 492 Net = 190 ±90.52
CENTROID: 850.40 = 625.71 keV
SHAPE: FWHM = 111.82
ID: Bi-214 at 609.30
ACTIVITY: 0.001 μCi

Sample AN018

Detector #1 ACQ 15-Nov-95 at 11:06:59 RT 1200 LT 1194.5
MicroNOMAD 12380

ROI # 1 RANGE: 760 = 559.47 keV to 924 = 680.22 keV
AREA: Gross = 20569 Net = 12842 ±466.51
CENTROID: 847.91 = 623.87 keV
SHAPE: FWHM = 42.33
ID: Bi-214 at 609.30
ACTIVITY: 0.058 μCi

Sample AN019

Detector #1 ACQ 15-Nov-95 at 11:44:49 RT 1200 LT 1199.8
MicroNOMAD 12380

ROI # 1 RANGE: 760 = 559.47 keV to 924 = 680.22 keV
AREA: Gross = 457 Net = 127 ±94.19
CENTROID: 791.68 = 582.59 keV
SHAPE: FWHM = 43.55
No Close Library Match

Sample AN020

Detector #1 ACQ 15-Nov-95 at 12:08:38 RT 1200 LT 1199.5
MicroNOMAD 12380

ROI # 1 RANGE: 760 = 559.47 keV to 924 = 680.22 keV
AREA: Gross = 1676 Net = 938 ±142.73
CENTROID: 823.49 = 608.55 keV
SHAPE: FWHM = 37.20
ID: Bi-214 at 609.30
ACTIVITY: 0.005 μCi

Sample AN021

Detector #1 ACQ 15-Nov-95 at 12:33:11 RT 1200 LT 1197.36
MicroNOMAD 12380

ROI # 1 RANGE: 760 = 559.47 keV to 924 = 680.22 keV
AREA: Gross = 10029 Net = 6509 ±315.89
CENTROID: 846.30 = 622.68 keV
SHAPE: FWHM = 44.52
ID: Bi-214 at 609.30
ACTIVITY: 0.029 μCi

Sample AN022

Detector #1 ACQ 15-Nov-95 at 12:57:29 RT 1200 LT 1198.9
MicroNOMAD 12380

ROI # 1 RANGE: 760 = 559.47 keV to 924 = 680.22 keV
AREA: Gross = 3782 Net = 1995 ±222.21
CENTROID: 838.69 = 617.07 keV
SHAPE: FWHM = 31.74
ID: Bi-214 at 609.30
ACTIVITY: 0.009 μCi

Sample AN023

Detector #1 ACQ 15-Nov-95 at 13:22:50 RT 1200 LT 1199.76
MicroNOMAD 12380

ROI # 1 RANGE: 760 = 559.47 keV to 924 = 680.22 keV
AREA: Gross = 584 Net = 34 ±120.87
CENTROID: 800.83 = 589.29 keV
SHAPE: FWHM = 0.87
ID: Bi-214 at 609.30
ACTIVITY: < 0.001 μCi

N00236.001374
ALAMEDA POINT
SSIC NO. 5090.3

ATTACHMENTS

FINAL
ADDENDUM TO THE
REMEDIAL INVESTIGATION/FEASIBILITY STUDY
DATA TRANSMITTAL MEMORANDUM
SITE 1 AND SITE 2 RADIATION SURVEY REPORT

DATED 01 FEBRUARY 1997

ATTACHMENT A

DEFINITIONS OF RADIOLOGICAL SURVEY TYPES

2.3 Radiological Surveys Supporting Decommissioning

Several different surveys may be required as part of the decommissioning process. Since each is intended to provide radiological data for different primary applications or objectives, the survey techniques, thoroughness, data accuracy, and documentation requirements may vary. This section identifies and briefly describes the types of radiological surveys. Additional details on conducting surveys are provided in Section 6.0.

The major steps in the decommissioning process are sequential and each step builds on information gathered from earlier activities. Although the various surveys may appear to be independent, survey results may, in practice, serve multiple purposes. For example, survey measurements obtained during the scoping phase or the characterization phase, may be useable in describing the final site conditions, if the location where those measurements were performed has not experienced subsequent activities which may have altered the radiological status. Conversely, data obtained following remedial action may, if they indicate residual contamination, serve as characterization information to guide further cleanup. Survey activities should be planned to enable optimum use of the data, thereby reducing the level of survey effort associated with a decommissioning project. Such planning should consider the accuracy and specificity of measurements, relative to time constraints and cost, at each stage of the survey.

2.3.1 Background Survey

Because guidelines for residual radioactivity at decommissioned sites are presented in terms of radiation levels or activity levels above normal background for the area or facility, it will also be necessary to perform a background survey. This survey will require measuring both direct radiation levels (usually gamma exposure rates) and concentrations of the potential radionuclide contaminants in construction materials and in soil (and sometimes in groundwater) in the vicinity of the site. Where only gamma emitting contaminants are present and soils are not affected, it may be adequate to perform only background exposure rate determinations. It is useful to perform such a survey prior to commencing licensed operations; such surveys may be part of the environmental baseline surveys required at some of the more complex types of facilities. If such information is already available, it may be used. Otherwise, a survey to establish background will have to be conducted.

Background is determined by measurements and/or sampling at locations on site or in the immediate vicinity of the site (out to several kilometers from the site boundary), which are unaffected by site operations. Preferable locations for interior background determinations are within on-site buildings of similar construction, but having no history of licensed operations. Background direct radiation levels within buildings may differ from those in open land areas, because of the presence of naturally occurring radioactive materials in construction materials and the shielding effect that construction materials may also provide. Background samples and measurements for land areas should be collected at locations which are unaffected by effluent releases (upwind and upstream) and other site operations (upgradient from disposal areas). Locations of potential runoff from areas of surface contamination should also be avoided. Other locations which may have been affected or disturbed by non-site activities and should be avoided include waste management areas and their drainage pathways; roads, parking lots, and other large paved surfaces; storm drains and ditches, receiving industrial or agricultural runoff; railroad tracks; material handling areas such as truck and rail loading facilities; and fill areas.

Because the background levels will be subtracted from total radiation or radioactivity levels to determine the net residual activity from licensed operations, it is necessary that backgrounds be determined with a detection sensitivity and accuracy at least equivalent to data from which it will be subtracted. This can be achieved by using the same instruments and techniques for background surveys as are used in assessing final site conditions.

The degree to which the average background of a particular radiological parameter, determined for a specific site, is representative of the true background level is a factor in determining the number of background measurements required for that determination. Many radionuclides are not present in the environment at levels which are sufficient to be either quantifiable using reasonable, standard measurement techniques or which are significant, relative to the guideline values for unrestricted release. On the other hand, levels of direct radiation (exposure rates) and some naturally occurring (uranium and thorium decay series) or man-made (Cs-137) radionuclides are typically present in the environment at levels which are easily quantifiable and may have background levels which are significant, relative to guideline values. Experience has indicated the variance in the average background value from a set of 6 to 10 measurements will usually not exceed ± 40% to 60% of the average at the 95% confidence level. However, localized geologic formations, different types of soil, and construction materials at the background measurement locations may result in individual background values which have greater variability. Consequently, additional measurements and samples may be required to assure a representative average value.

For practical purposes, it is recommended that 6 to 10 measurements for each parameter of concern be initially performed and the average and 95% confidence level be determined. If the upper 95% level bound on the background average is less than 10% of the guideline value for that parameter, variations in background may be considered insignificant and no further determination are necessary. However, if the upper 95% level bound on the background average is greater than 10% of the guideline value, the background data should be tested to assure that the average represents the true mean to within ± 20% at the 95% confidence level. If necessary, additional background determinations should be performed to satisfy this level of representativeness. The procedure for testing the data and determining the number of additional samples needed is described in Section 8.7.

2.3.2 Scoping Survey

Early in the decommissioning process, it will be necessary to identify the potential radionuclide contaminants at the site; the relative ratios of these nuclides; and the general extent of contamination (if any) — both in activity levels and affected area or volume. Although the license and operational history documentation will assist to varying degrees in providing this information, it will usually be necessary to supplement that information with actual survey data. A scoping survey is therefore performed. The scoping survey typically consists of limited direct measurements (exposure rates and surface activity levels) and samples (smears, soil, water, and material with induced activity), obtained from site locations considered to be the most likely to contain residual activity, and from other site locations both immediately adjacent to the radioactive materials use areas and in areas not expected to have been affected by the site operations. This survey provides a preliminary assessment of site conditions, relative to guideline values, and enables initial guidance in classification of the site into "affected" and "unaffected" areas (see Section 4.2.1 for further information on classification of areas by contamination potential). The scoping survey provides the basis for initial estimates of the level of effort required for decommissioning and for planning the characterization survey.

Measurements and sampling in known areas of residual contamination need not be as comprehensive or be performed to the same sensitivity level as will be required for the characterization or final status surveys. However, when planning and conducting this scoping survey, the licensee should remember that some of the data, particularly that from locations not affected by site operations, may be used as final status results or to supplement the characterization and/or final survey results. Similar measuring and sampling techniques as used for those categories of surveys may, therefore, be warranted.

2.3.3 Characterization Survey

After locations which may require decontamination have been identified, a **characterization survey** is performed to more precisely define the extent and magnitude of contamination. The characterization survey should be in sufficient detail to provide data for planning the decontamination effort, including the decontamination techniques, schedules, costs, and waste volumes and necessary health and safety considerations during decontamination. Characterization is typically concentrated on those portions of the site which are known to have been or are suspected of having been affected by site operations involving radioactive materials. The type of information obtained from a characterization survey is often limited to that necessary to differentiate a surface or area as contaminated or non-contaminated. A high degree of accuracy may not be required for such a decision, when the data indicate levels well above the guidelines. On the other hand, when data are near the guideline values, a higher degree of accuracy is usually necessary to assure the appropriate decision regarding the true radiological conditions. Also, one category of radiological data, such as soil radionuclide concentration or total surface activity, may be sufficient to determine the status as contaminated, and other measurements, e.g. exposure rates or removable contamination levels, may therefore not be performed during characterization.

As was the situation with the scoping survey, the choice of survey technique should be commensurate with the intended use of the data, including considerations for possible future use of the results to supplement the final status survey data.

2.3.4 Remediation Control Survey

The effectiveness of decontamination efforts in reducing residual radioactivity to acceptable levels is monitored as the decontamination is in progress by a **remediation control survey**. This type of survey activity guides the cleanup in a real-time mode; it also assures that remediation workers, the public, and the environment are adequately protected against exposures to radiation and radioactive materials arising from the decontamination activities. The remediation control survey typically provides a simple radiological parameter, such as direct radiation near the surface being decontaminated. The level of radiation, below which there is reasonable assurance that the guideline values have been attained, is determined and used for immediate, in-field decisions. Such a survey is intended for expediency and does not provide thorough or accurate data describing the final radiological status of the site. The remediation control survey is applicable to monitoring of surfaces and soils or other bulk materials only if the radionuclides of concern are detectable by field survey techniques. For radionuclides and media which cannot be evaluated at guideline values by field procedures, samples are be collected and analyzed to evaluate effectiveness of decontamination efforts. For large projects, use of mobile field laboratories can provide more timely decisions regarding the effectiveness of remedial actions. Examples of situations for which remediations control surveys would not be practicable are soil contaminated with pure alpha or beta emitting radionuclides and surfaces with very low energy beta contamination such as H-3.

2.3.5 Final Status Survey

A survey to determine the final condition of the site is performed after decontamination activities (if any were required), are complete. This survey is known by several titles, including **termination survey**, **post remedial-action survey**, **final status survey** and **final survey**. The term final status survey is used in this Manual. It is this survey which provides data to demonstrate that all radiological parameters (total surface activity, removable surface activity, exposure rate, and radionuclide concentrations in soil and other bulk materials) satisfy the established guideline values and conditions. Results of the survey are documented in a detailed report, which becomes part of the licensee's application to terminate a license and thereby release the facility for unrestricted use. This type of survey is the principal focus of this Manual.

Although the final status survey is discussed here as if it were an activity performed at a single specified stage of the documenting process, this may not be the case. Data from surveys conducted at other stages of the decommissioning, such as the scoping survey and characterization survey, can, under proper conditions, be incorporated into the final status survey.

2.3.6 Confirmatory Survey

After acceptance of the licensee's termination survey report, the NRC may perform (or arrange for its agent to perform) a confirmatory survey. As the name implies, a **confirmatory survey** is performed to confirm the adequacy and accuracy of the licensee's final status survey. The confirmatory survey develops radiological data of the same type as that presented by the licensee, but is usually limited in scope to spot-checking conditions at selected site locations, comparing findings with those of the licensee, and performing independent statistical evaluations of the data developed by the confirmatory survey and the licensee's final status survey. Although the scope may vary, a confirmatory survey typically addresses from 1 to 10% of the site, but may be extended, if questions or anomalies develop or are identified. The NRC uses the report of this survey in supporting a decision on the licensee's application to terminate a license and release the facility for unrestricted use.