U.S. Department of Energy

Oakland Operations Office, Oakland, California

FINAL OFF-SITE CESIUM-137 INVESTIGATION ADDENDUM TO WORK PLAN for WESTERN DOG PENS, BACKGROUND, AND OFF-SITE INVESTIGATIONS

at the

Laboratory for Energy-Related Health Research (LEHR)
University of California at Davis, California

Submitted to:

United States Department of Energy
Oakland Operations Office
1301 Clay Street
Oakland, California 95612-5208

Prepared by:

Weiss Associates
5500 Shellmound Street
Emeryville, California 94608

June 30, 1998
Rev. 0

DOE Oakland Operations Office Contract DE-AC03-96SF20686

Weiss Associates
Environmental and Geologic Services

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Approvals Page

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1301 Clay Street
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June 30, 1998
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ADDENDUM

This addendum to the *Final Work Plan for Western Dog Pens, Background, and Off-Site Investigations* (Weiss Associates, 1997) (the Work Plan) addresses additional shallow soil sampling and Cesium-137 (Cs-137) analysis along the Old Davis Road drainage ditch in the vicinity of the Radium Leach System (Figure 1). This additional sampling is being conducted because Cs-137 was detected at levels at or exceeding the lowest 10^{-6} Risk-based Action Standard (RBAS) (0.1pCi/g) in eight of the nine surface samples collected during the recent investigations in Areas 1 and 4 (see Figure 1) of this drainage ditch. The highest Cs-137 activity detected in these samples was 0.32 pCi/g in a sample collected in Area 1 near the pipe under Old Davis Road (Figure 1). Details of the previous investigations and results in this area are presented in the *Final Technical Report: Results of Western Dog Pens, Background and Off-Site Investigations* (Weiss Associates, 1998).

On June 1, 1998, a surface gamma radiation survey was conducted in the storm water drainage ditch along Old Davis Road using a hand-held scalar instrument (Ludlum 2221) with a 2 inch by 2 inch sodium-iodide gamma scintillation detector. Prior to conducting the survey, a background reading of 503 counts per minute (cpm) was established by taking measurements at four of the previous background boring locations. The drainage ditch gamma survey was conducted along the lowest point of the ditch in the four areas shown on Figure 1. These four areas were defined based on drainage patterns: Area 1 collects run-off from the southwestern part of the LEHR site, and the flow direction in the trench is to the north towards the pipe under Old Davis Road; Area 2 collects run-off from the northwest part of the LEHR site and from UC Davis facilities north of LEHR, and the flow direction in the trench is to the south; Area 3 collects run-off from UC Davis facilities west and northwest of that area, and the flow direction in the trench is to the south; and, Area 4 receives the run-off from Areas 1, 2, and 3, as well as from UC Davis facilities to the west, and the flow direction is south to Putah Creek.

Continuous readings were taken along the entire lengths of these areas, and one-minute integrated readings were taken at least every 10 lateral ft. In addition, one-minute integrated readings were taken at five of the previous surface soil sampling locations in Area 1, and at locations 5 ft north and south of each of these previous sampling locations. Gamma readings from this surface survey ranged from 370 cpm to 617 cpm, with no apparent pattern to the distribution of the readings. Readings at the previous sampling locations and at 5 ft from the previous sampling locations were within this same range. Readings for each of the four areas shown on Figure 1 were similar, with averages for the four areas ranging from 501 cpm for Area 1 to 552 cpm for Area 4. Based on the results of this survey, it appears likely that surface soil Cs-137 activities in the four areas surveyed are similar to each other and to the Cs-137 results already obtained for surface soils in Area 1. Given the relatively small range of readings throughout these areas, it also appears unlikely that any areas of significantly higher Cs-137 activities are present in these four areas.

Based on these survey results, surface soil sampling will focus on comparing Cs-137 levels in Areas 1, 2 and 3. Area 1 is the area most likely impacted by LEHR activities, Area 2 may be impacted by both LEHR and upstream activities, and Area 3 should not be impacted by LEHR activities and Cs-137 levels in this area may reflect only global fallout accumulation. Therefore, comparing the Cs-137 levels in these three areas should help determine whether the slightly elevated levels previously detected in Areas 1 and 4 are the result of impacts from the LEHR site, impacts from other local sources, or reflect global fall-out accumulation. Area 4 will not be included in this round of surface soil sampling because it receives run-off from Areas 1,2 and 3, so the significance of data from this area may be difficult to interpret.

The Wilcoxon Rank Sum (WRS) Test (EPA, 1992) was used to estimate the number of samples needed from each area so that statistically valid comparisons can be made. It was assumed that Cs-137 activities in Areas 2 and 3 would be more similar to those in Area 1 than to those at the previous background sampling locations; therefore, Area 1 was defined as the reference area for the WRS test, and previous data for this area were used in the calculations. The number of samples required was calculated so that the Type I and Type II errors are 0.2 or less and the delta between means is 30% or less.

Based on these assumptions and parameters, 8 additional samples will need to be collected in Area 1 and 12 samples each will need to be collected from Areas 2 and 3. Sample locations in each of these three areas will be determined by stretching a measuring tape along the deepest part of the trench and sampling at locations along the tape determined by a random number generator (see Table 1). In addition, 3 samples will be collected in Area 1 at previous sampling locations B-1, A-5 and A-11. Field duplicate samples from approximately 20% or 7 of these 35 sample locations will also be collected and analyzed.

In addition, 5 surface soil samples (4 primary and 1 field duplicate) will be collected from the storm water run-off ditch along Old Davis Road north of the railroad tracks and south of Interstate 80. Based on visual inspection and input from UC Davis, samples will be collected from locations within the storm water run-off ditch that appear to be in similar condition (i.e., similar surface soil types and vegetation with no evidence of recent reworking) and receive similar volumes of storm water run-off (i.e., similar run-off area with a similar proportion of pavement) as Area 1. These samples should provide additional data on Cs-137 levels in storm water ditch soils impacted only by global fall-out accumulation.

All 47 soil samples will be analyzed for Cs-137 at the LEHR site by Pacific Northwest National Laboratory (PNNL) using high-resolution gamma-ray spectrometry with a high-purity germanium (HPGe) diode and a multi-channel analyzer to obtain a nondestructive radiological analysis of a soil sample by passively measuring radioisotope emissions of associated gamma rays. The PNNL HPGe system requires approximately 1.5 liters (6 to 8 pounds) of sample per analysis. The surface soil samples will be collected in the same manner as those previously collected from the drainage trench; i.e., a hand auger with drive sampler will be used to collect the first six inches of soil beneath any loose vegetation/debris. The soil will be packed into a Marinelli beaker as described in the procedure in Attachment A prior to being transported to the on-site laboratory.

Sample collection is expected to begin on July 1, 1998. Once the sample has been received at the on-site laboratory, we anticipate that each sample will require approximately 1.5 hours to weigh, run, and document the results. This assumes a counting time of approximately 60 minutes. The three samples from previous locations represent the range of Cs-137 activities detected in Area 1, and will be used to compare the previous GEL results with the on-site HPGe system results and to determine the optimum count time to obtain the needed precision and minimum detectable activity (assumed to be approximately 0.03 pCi/g for both). If possible, the previously collected samples from these locations will be retrieved from GEL and analyzed instead of newly-collected samples from the same locations.

Approximately 30% of the 47 samples will be sent to General Engineering Laboratories (GEL) in Charleston, South Carolina, for confirmation analysis. These samples will be analyzed for Cs-137 by Gamma Spectrometry, EPA Method 901.1. The detection limit required for the Gamma Spectrometry analysis is 0.01 pCi/g. One equipment rinseate sample will also be sent to the off-site laboratory for analysis.

Sample collection, handling, labeling, and data documentation will comply with Standard Operating Procedure (SOP) 10.3, *Sample Collection, Handling and Data Documentation for Field Analysis using Gamma Spectrometer and Beta Scintillation Detector* (Attachment A) and with SOPs 1.1, 3.1, and 15.1 contained in the Work Plan (Weiss Associates, 1997). The on-site HPGe analysis will be conducted by PNNL in accordance with their established procedures (Attachment A). Quality assurance/quality control and health and safety procedures will be in accordance with those presented in Sections 7 and 8 of the Work Plan (Weiss Associates, 1997). Additional health and safety procedures will be implemented because of hazards associated with Old Davis Road vehicular traffic. These include wearing orange safety vests at all times while working in and around the run-off trenches, and using caution when crossing the street.

The results of all sampling described above will be presented and evaluated in a technical memorandum. Based on this evaluation, a course of action will be recommended. If additional sampling is recommended, a brief work plan will be prepared and reviewed by the U.S. Department of Energy (DOE) and the remedial project managers (RPMs) prior to conducting the work.

REFERENCES

U.S. Environmental Protection Agency (EPA), 1992, Statistical Methods for Evaluating the Attainment of Cleanup Standards, Volume 3: Reference-Based Standards for Soil and Solid Media, EPA 230-R-94-004, December.

Weiss Associates, 1997, Final Work Plan for Western Dog Pens, Background and Off-Site Investigations at the Laboratory for Energy Related Health Research (LEHR), University of California, Davis, California, October 3.

Weiss Associates, 1998, Final Technical Report: Results of Western Dog Pens, Background and Off-Site Investigations at the Laboratory for Energy Related Health Research (LEHR), University of California, Davis, California, June.

FIGURE

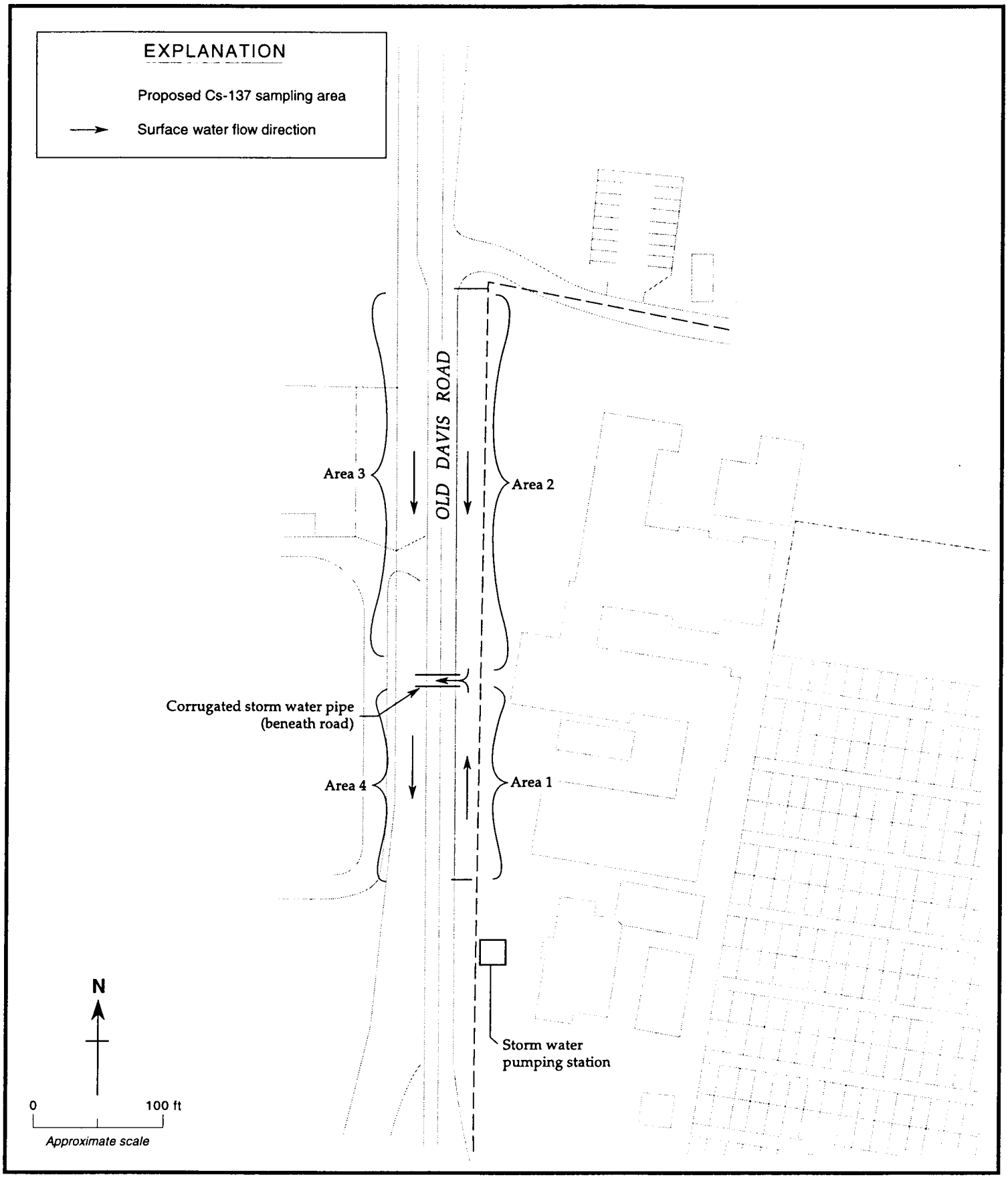

Figure 1. Proposed Off-Site Cs-137 Sampling Areas, LEHR Site, UC Davis, California

Weiss Associates

TABLE

Table 1 Randomly Selected Cs-137 Sampling Locations for Three Areas of Investigation, LEHR Site, UC Davis, California

Investigation Area	Distance From Pipe Under Old Davis Road	Investigation Area	Distance From Pipe Under Old Davis Road
Area 1	0 ft S	Area 2	217 ft N
	14 ft S		258 ft N
	45 ft S		268 ft N
	77 ft S		288 ft N
	94 ft S	Area 3	5 ft N
	100 ft S		17 ft N
	116 ft S		22 ft N
	121 ft S		23 ft N
Area 2	8 ft N		27 ft N
	17 ft N		67 ft N
	19 ft N		72 ft N
	128 ft N		136 ft N
	130 ft N		149 ft N
	159 ft N		162 ft N
	190 ft N		178 ft N
	195 ft N		220 ft N

ATTACHMENT A

STANDARD OPERATING PROCEDURES

SAMPLE COLLECTION, HANDLING AND DATA DOCUMENTATION FOR FIELD ANALYSIS USING GAMMA SPECTROMETER AND BETA SCINTILLATION DETECTOR

STANDARD OPERATING PROCEDURE

1.0 PURPOSE

This Standard Operating Procedure has been developed for sample preparation, handling, transport, and data documentation when using a field gamma spectrometer and/or beta scintillation detector.

2.0 REFERENCES

2.1 SOP 2.1 – Sample Handling, Packaging and Shipping

2.2 SOP 17.1 – Sample Labeling

2.3 SQP 4.2 – Records Management

3.0 PROCEDURE

3.1 Responsibilities

The Project Task Leader is responsible for ensuring that samples for field analysis using the High Priority Germanium Detector (HPGe) and Beta Scint Detector (BSD) are properly collected and the sampling event is properly documented in accordance with this procedure. This will be accomplished through staff training and by maintaining quality assurance/quality control (QA/QC).

The Project QA Specialist (PQAS) is responsible for periodic review of field generated documentation associated with this sampling. If perceived variances occur, the PQAS is also responsible for issuing notices of nonconformances and requests for corrective action.

Field personal assigned to these sampling activities are responsible for completing their tasks according to the specifications outlined in this SOP and other appropriate procedures. All staff are responsible for reporting deviations from procedures to the Field Coordinator or the PQAS.

The Laboratory Technician is responsible for analyzing the samples in accordance with the established procedures.

3.2 Sample Preparation and Handling

Table 1 describes the sample specifications, including required weight, volume, quality and container types, needed for each Gamma Spectrometry (GS) using a High Purity Germanium Detector (HPGe) and Beta Scint Detector (BSD) analysis.

Table 1. Sample Specifications for HPGe and BSD Analysis

Parameter	Gamma Spectromety Using HPGe Detector (Radium-226/Cesium-137)	Beta Scint Detector (Strontium-90)
Sample Container	Marinelli Beaker	1 gallon Ziploc Bag
Sample Volume/weight	1 liter beaker/6 pounds	1 gallon bag/6 pounds
Other Requirements	No voids in container	No objects > ¼" mesh or organic matter

3.3 Gamma Spectrometer Sample Preparation

Procedures that will be followed during sample preparation for the gamma spectrometer analysis are presented below.

- Place soil directly in the Marinelli beaker with minimal disturbance to soil;
- Ensure that no voids are present in the beaker;
- Seal the top of the beaker using electrical tape;
- Place sample label on the top cover of the beaker;
- Sample labels shall be in accordance with SOP 17.1 and shall include the Weiss Associates (WA) sample ID, sampling time and date, requested analyses, and the sampler's initials;
- If appropriate, ensure that the sample container is frisked by the Radiological Control Technician (RCT) in accordance with SOP 2.1 if samples are collected from within a Controlled Area (CA); and,
- If appropriate, deliver the sample to the "courier" outside of the CA within five minutes of collection or hand carry sample within 5 minutes of sample collection to gamma spectrometer operator.

3.4 Beta Scintillation Detector Sample Preparation

Procedures that will be followed during sample preparation for the BSD are presented below.

- Place soil to be analyzed in the sifting device with a minimum of ¼" Mesh screen;
- Sift the sample and remove any other visible debris and organic matter;
- Collect the sifted soil sample and place it in a 1 gallon ziploc bag;
- Seal and label the bag;
- Sample labels shall include the WA sample ID, sampling time and date, requested analyses, and the sampler's initials;
- If appropriate, ensure that the sample container is frisked by the rad tech if the sample was collected from within a controlled area; and
- If appropriate, deliver the sample to the "courier" outside of the CA or hand carry the sample to the BSD operator.

3.5 Sample Transport

Once the samples have been cleared out of the CA, either the field sampler or a designated courier will transport the samples to the Animal Hospital No. 1 (AH-1) where the field analytical instruments have been setup. Sample transport from a CA shall follow the procedures described below.

- Place soil samples received from the CA inside a transport container;
- Transport container shall consist of a cooler or other rigid box;
- Each sample received from the CA shall be logged in the Sample Transport Log by the courier (sample of the log is attached);
- The sample ID, sample time, delivery time at the laboratory, and the transporter's initials shall be included on each Sample Transport Log;
- Upon arrival at the laboratory, samples shall be placed in the pre-designated "SAMPLE DROP-OFF" area; and,
- The Laboratory Technician shall be notified by radio 5-10 minutes prior to each sample drop-off.

3.6 Sample Documentation

Sample documentation will consist of recording the sample ID, sampler ID, field sample location, depth, soil type, time and date of sample collection, and resultant concentration as determined from the HPGe and/or BSD and are shown on the Gamma Spectrometry and Beta Scintillation Detector Sampling and Analysis Log (Attachment 5.1).

3.7 Sample Storage/Disposal

Once the samples have been analyzed, the Laboratory Technician will place the soil samples in their original container, seal each container, and place the container in a predetermined "ANALYSIS COMPLETE" area.

Depending on the analytical results of each sample, it will either be temporarily stored or disposed. Samples selected for storage will be placed in the "STORAGE AREA." The Construction Engineer will determine whether samples need to be stored.

At the completion of analytic testing, the sample will be returned to its point of origin by a field technician, sampler, and/or pre-designated courier. Each sample will be disposed of at its original location. The courier will note the fate of each sample on the Sample Transport Log.

3.8 Analytical Result Documentation

The Laboratory Technician will submit to the Weiss Associate (WA) Project Task Leader (PTL) or field geologist the analytical results at the completion of each day. The Laboratory Technician will tabulate analytical results in the Field Screening Analytical Results Form (attached).

4.0 RECORDS

Records generated as a result of implementation of this SOP will be controlled and maintained in the project record files in accordance with SQP 4.2.

5.0 ATTACHMENTS

5.1 Field Screening Sampling and Analysis Log

A form referenced or attached to this SOP may be replaced with a substitute form, with the approval of the PQAM, if the substitute form contains equivalent information as the referenced form.

Attachment 5.1

Field Screening Sampling and Analysis Form

Field Screening Sampling and Analysis Form

Sample ID	Sample Location	Sample Depth	Soil Type	Time / Date	Sampler	Ra-226 Conc.	Cs-137 Conc.	Sr-90 Conc.

Post-it® Fax Note 7671	Date	# of pages ▶ 21
To Salem Attiga	From S. Kowall	
Co./Dept.	Co.	
Phone #		
Fax # 925-938-0105		

Operational Procedures for Beta Sensor

Sensor Startup

1. Remove all necessary components from padded storage container: beta sensor, HP 6024A DC power supply (plus power cord), power supply-to-sensor cable, HP 100LX palmtop computer, and computer-to-sensor serial cable.

2. Connect power cord to back of DC power supply and plug into AC outlet (ensure that unit is turned OFF prior to plugging into AC power source).

3. Connect power cable to sensor and DC power supply. Screw-type bayonet connector is attached to sensor (connector orientation is restricted by positioning tabs) and power leads are connected to two RED plugs on DC power supply (BLACK plug is not used). Ensure that positive (+) and negative (-) leads are not reversed (if this occurs inadvertently, the in-line fuse will blow when DC power supply is turned on and must be replaced).

4. Connect palmtop computer to sensor using serial cable (9-pin D-type connector at sensor, smaller tabbed connector at computer; note proper orientation of the latter connector).

5. Ensure that VOLTAGE knob on DC power supply is at minimum setting (full counter-clockwise position) and CURRENT knob is at maximum setting (full clockwise position) before turning on power. Turn unit on via push button and increase voltage slowly by turning VOLTAGE knob clockwise until 18 volts are indicated on the left (voltage) meter. Current should automatically stabilize at 4 amps on right (current) meter. Allow electronics to warm up and stabilize for 15-30 minutes.

6. Ensure palmtop computer has adequate battery supply or connect to AC power via the unit's AC-DC converter. If necessary, refer to HP100LX user's guide for details regarding this unit. Turn on computer. Following warm-up period (see #5 above), the system will be ready to initiate measurements.

Sensor Operation

1. Following warm up, initiate individual measurements by typing *go* and pressing the ENTER key at the C:\BETA> prompt. This command calls up a batch file (go.bat) that includes the user-specified measurement parameters* and an executable file (betacon.exe). It is assumed at this point that the sensor is calibrated for the soils being analyzed (if not, refer to Sensor Calibration section below).

2. Set up sensor at the location where analyses are to be performed. Initiate a location-specific background measurement by typing *go* and pressing the ENTER key at the C:\BETA> prompt. Record results (note: results will be indicated in units of pCi/g, which is the default setting, although true units are "counts per second"). Repeat

twice, for a total of three background measurements, and calculate the average of these values. Record the average value.

3. Place an "uncontaminated" soil sample (i.e., one that contains 0 pCi/g, above background, of the contaminant in question) in a tray directly below the sensor, initiate a measurement, and record the results. Initiate measurements on a series of spiked soils (i.e., samples with known quantities of the contaminant in question) and record results. At least four spiked soils, whose concentrations span the anticipated range of contamination levels, are recommended for a viable calibration. Using a linear least-squares method, calculate the slope and intercept values of the resulting linear calibration curve.

4. Modify the batch file (go.bat) by substituting the new values for slope, intercept, and background as described in above note (Sensor Operation section). The sensor is now calibrated and ready for making measurements on samples with unknown contaminant concentrations.

Sensor Shutdown

1. When counting is complete, turn VOLTAGE knob on DC power supply down (full counter clockwise) and turn unit off via push button.

2. Disconnect all cables and place individual components in padded storage container to preclude damage.

Sample Preparation and Handling

1. Samples of possibly contaminated soil should be handled as if contaminated until proven otherwise. While handling the samples, the operator must wear protective gloves and a respiratory filter to prevent inhalation of sample dust. Do not handle contaminated samples if skin lesions, cuts or open sores could be exposed to the soil. Use a plastic liner bag in the sample tray to completely collect and enclose the sample after measurements are complete. After completing the measurements, invert the plastic bag and seal the liner opening with tape.

2. An adequate sample for the BetaScint sensor requires sufficient soil to fill the sample tray with an even layer not less than one centimeter in thickness and not more than the depth of the tray. This may require between one and three kilograms of sample depending on soil type and moisture content. Clumps of soil larger than one centimeter in diameter should be broken up. Stones or other non-soil particles larger than one centimeter in diameter must be removed. Be particularly careful to remove any sharp particles that might puncture the sensor's plastic window covering if it comes in contact with the soil.

3. Excess moisture content in the sample can interfere with accuracy of the measurements. The soil must be dry enough so that larger particles can be easily broken up with the fingers. A commercial household-type soil-moisture tester may be used to determine relative moisture content (On a scale of 1 to 4, with 1 representing the dry end of the scale, a measurement of 1 or 2 is normally sufficiently dry for good results). If the moisture content is too high, spread the sample in the tray and allow to dry as long as necessary before taking readings.

4. Sample identification must include sufficient information to uniquely identify the sample such as place, date, time and name of person responsible for the sampling and/or a unique sample number that refers to a log of such information. Record the sample identification information, the date and time of testing and the measurement results in pCi/g. Also record any unusual laboratory conditions or other facts related to the measurement.

PNNL TECHNICAL PROCEDURE

GEA-001 -- ASSAY OF RADIUM-226 IN SOIL USING HIGH-RESOLUTION GAMMA-RAY SPECTROMETRY

APPLICABILITY

This procedure applies to the operation of a Radium-226 Assay System designed and constructed by PNNL. The PNNL Assay System incorporates high resolution gamma-ray spectrometry using a germanium diode (HPGe), together with integrated computer software, to determine the Radium-226 content of unprocessed soils. An analysis using the PNNL Assay System is performed by collecting soil in a 1-L Marinelli-type beaker (designed to fit snugly around the end of the diode), counting the soil to determine the levels of radioactive species, and comparing the results to a count of the radionuclide background as measured on uncontaminated soil from the site. The soil is not treated or dried before counting to preserve the secular equilibrium established in the raw soil between Radium-226 and its daughter products, Lead-214 and Bismuth-214. Menu-driven software requires Operator responses to questions regarding soil weight, sample identification, Operator identification, location, and other appropriate information. An example of software prompts and Operator input are provided. The software adjusts previously determined efficiency calibrations to correct for any attenuating effects of moisture in the soil. A library of gamma-ray energies is used by the gamma-ray analysis software to generate a report of observed levels of activity, or upper limits of activity when the radionuclide is not observed.

DEFINITIONS

- efficiency calibration: the measured relationship of counts recorded by the detection equipment and radiation emitted by the source.

- calibration standard: a radiation emitter whose absolute rate of emission is known.

- check source: a radiation emitter used to establish equipment operability. The check source is generally run before and after each series of assays. However, in routine counting situations, the check source results of the next day can be used to bracket the validity of counts taken the previous day after the check source had been run. The results of the control-source check are maintained in a log book.

- verification: used in this procedure to indicate a demonstration of equipment operability.

RESPONSIBLE STAFF

- The Technical Lead
- The Operator
- The Analyst

Author/Proj. Mgr.	Date	Technical	Date
Line Mgr.	Date	QP Representative	Date

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PROCEDURE

4.1 OBJECTIVE

The objective of the work conducted using this procedure is to obtain a nondestructive radiological analysis of the contents of suspect soil by passively measuring radicisotope emissions of associated gamma rays, as specified by the client.

Exhibit 1 provides information regarding calibration and operation of the gamma-ray spectrometer. Other exhibits calibration and operation or provide a check-list for use in training a new operator.

4.2 SCOPE

The client is responsible to:

- provide a suitable sample of unprocessed soil in a timely manner
- provide a source of reliable electrical power (110-V AC, 15 Amp circuit)
- specify applicable QA and training requirements

An analysis may be limited to an estimate of Radium-226 levels based upon the observed activity of its daughter products, Lead-214 and Bismuth-214. A comparison to the 186-keV gamma ray may be used to support claims of secular equilibrium or to warn of a break in secular equilibrium and the need for a recount later on.

4.3 PREREQUISITES

4.3.1 Personnel Qualifications

The Operator shall:

- have documented training and experience with the operation of gamma-ray spectrometers
- have demonstrated the ability to operate IBM/PC-type computers
- be qualified by documented training to handle sealed radioactive sources
- be qualified by documented training to handle liquid nitrogen

A new Operator shall spend at minimum of one day of instrument operation with an experienced Operator to ensure a basic understanding of the operation of the PNNL Radium-225 Assay System.

The Analyst, who interprets the results, shall have a functional knowledge of gamma-ray spectrometry either:

- through formal college course work in Nuclear Physics or Nuclear Chemistry or
- through a minimum of 2 years of related work experience.

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4.3.2 Safety

The location for conducting the radiological assay is selected by the OPERATOR. A dry location is required because some high-voltage electrical instrumentation is used.

Principles of ALARA are followed when dealing with any potential or known radiological hazard.

4.3.3 Special Equipment

The portion of the soil assay system used for GAMMA-RAY DETECTION consists of:

- Refer to Exhibit 1 for a schematic of the gamma-ray interconnections and a list of electronic modules, cables, and devices with acceptable alternatives.
- The PNNL-built lead cave is illustrated in Exhibit 2

Replacement or redesign of the following system components shall be under the supervision or direction of the TECHNICAL LEAD and shall involve, at a minimum, a cross calibration, as described in Section 4.4.2 below, to assure that operation of the system is equivalent to operation before the replacement or redesign:

- high-purity germanium (HPGe) spectrometer and associated preamplifier
- lead sample-counting cave
- gamma-ray check source used for daily equipment verification
- gamma-ray calibration standards used to establish efficiency calibration
- electronic components such as timer and counter NIM modules

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4.3.4 Measuring and Test Equipment

Many components of the PNNL Radium-226 Assay System are not critical to the integrity of the resulting data, i.e., replacing the component does not necessitate recalibration of the system. Such components include (but are not limited to):

· mechanical components such as trolleys, carts, and/or dollies for maneuvering detectors

· electrical components such as electrical wiring (i.e., wiring to distribute house power as opposed to electronic wiring), portable NIM bins (such as Berkeley Nucleonics Corp. PORTANIM, Model AP-1 and/or Model AP-3), etc.

· computer-related components such as serial/parallel interfaces, memory chips, disk drives, print buffers, etc.

4.3.4.1 Calibration

The PNNL Radium-226 Assay System is calibrated using radioactive standards traceable to NIST. The calibration is performed on samples of uncontaminated (blank) soil that are spiked with Radium-226.

Details on the NIST-traceable calibration standards are contained in documents contained in the associated Project files maintained by the TECHNICAL LEAD.

4.3.4.2 Instrument Performance Verification (Operability Check)

An operability check to verify the correct operation of the equipment is performed twice each day as part of a series of assays: once before any container is counted and once after all containers in a series have been counted.

GAMMA-RAY SPECTROMETER: The HPGe gamma-ray spectrometer is verified as operable by counting a thorium check source, as described in Sections 4.4.2.1-4.4.2.6. If the control standard is a thorium salt of sufficient age to demonstrate secular equilibrium in ratios of photopeak areas associated with the decay of daughter products then no decay correction is applied to the net photopeak areas. If the thorium salt is not in secular equilibrium, then the appropriate decay corrections are to be applied to the resulting net photopeak areas. The results of the operability check shall be maintained in a log book.

4.3.4.3 Tolerances

A scale or balance capable of measuring weights up to 7 kg with 0.5% uncertainty is acceptable to meet specifications of this procedure.

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4.4 INSTRUCTIONS

The OPERATOR is responsible for all steps leading to data acquisition, initial data reduction, data storage on transportable magnetic media when appropriate, and the initial review for data validity before final review by the ANALYST and/or PROGRAM MANAGER. Exhibit 15 provides an example check-list for training a new operator in system set-up and operation. An alternative method may be used provided key information [sample ID, operator ID, sample weight, date, time, location] specified in Exhibit 15 is contained within the alternate method, and that the information is initialed/signed and dated by the OPERATOR. This form, or its equivalent shall be completed during each day's data collection.

4.4.1 *PREPARATORY*: Assure that liquid nitrogen has been kept in the dewar for at least a day prior to the assay. After the system is moved to the work area, select a site which is reasonably isolated from other sources of radiation and is accessible to a 15-Amp source of 110-V A.C. electrical power.

POWER-UP: Apply power to the computer, printer, and HPGe diode [slowly at approximately 100 V per second].

4.4.2 *INSTRUMENT OPERABILITY CHECK*

COMPONENT REPLACEMENT (AS NEEDED): If changes are made to any of the components listed in Section 4.3.3, Special Equipment, (e.g., the detector, preamp, amplifier, power supply, etc.) or if the geometry of the source relative to the detector is changed, then it shall be necessary to cross-calibrate the old control value to a new control value by counting the check source successively for 10 counts. The new control value is the arithmetic average of the 10 counts.

GAMMA-RAY SPECTROMETER OPERABILITY CHECK: Verify that the equipment is operational by performing the following operability check:

4.4.2.1 *CHECK SOURCE PLACEMENT*: With the snout of the HPGe diode positioned in the lead sample cave, place the Marinelli beaker containing the thoria standard over the diode snout and shut the door of the sample cave.

4.4.2.2 *GAIN SET*: Enter 'GAIN' on the computer keyboard to activate the ADCAM 'MCA' commercial software. Set the gain and zero (energy calibration) of the system to 1 keV/channel by adjusting the centroids of the 238.7- and 911.7-keV peaks to within ±2 channels of 238.7 and 911.7, respectively.

4.4.2.3 *ZERO ADJUST (OPTIONAL)*: If necessary, adjust the energy-spectrum zero using the turn-screw potentiometer, marked 'ZERO', on the face of the 918A ADCAM MULTICHANNEL BUFFER module. If necessary, adjust the energy-spectrum gain using the coarse and/or fine gain controls on the ORTEC 570 or 571 Amplifier module. The 'LLD' dial on the ADCAM module is generally preset to limit gamma-ray counts to channel 40 or above in the spectrum and may be adjusted accordingly by the OPERATOR.

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4.4.2.4 *EFFICIENCY CHECK*: With the gain of the system set, count the check source with a preset live time of 600 s using the following string of keystrokes:

<ALT-4> <ALT-2> 600 <CR> <ALT-0> <ALT-2> <ALT-3> <ALT-1>

When the count has ended, enter the following string of keystrokes to save the spectrum and to set the regions of interest prior to entry in the log:

<ALT-5> <ALT-7> <ALT-1> \cal\thorium.r <CR>
<ALT-4> a <CR>
<ALT-0> <ALT-6> <ALT-6> PRN <CR>

4.4.2.5 *LOG ENTRY*: Enter into the log book the net areas for the 3 reported photopeaks, 238-, 911-, and 2614-keV, as determined by the commercial ADCAM 'MCA' commercial software using the steps described in Section 4.4.2.4 above. The net areas are used to determine the operability of the HPGe gamma-ray spectrometer. The log book is maintained as a record of the equipment operability

4.4.2.6 *DEVIATIONS*: Two (2) of the 3 net photopeak areas must be within 3% of the control values for the instrument to be considered operable. The OPERATOR is allowed to perform 1 recount of the thoria check source if the 2-of-3 net-area criteria is not met on the first count. If the recount indicates that the instrument is not operating correctly, then the OPERATOR shall attempt to ascertain the cause and to remedy the situation. The instrumentation shall be returned to proper operating specifications before any waste container is assayed. Subsequent recounts of the check source should be performed twice to verify instrument performance. The client shall be notified of any instrument deviation if the count performed subsequent to assaying work indicates that the instrument is not operating properly. The cause of any equipment-related problems shall be recorded in the log book.

4.4.5 *GAMMA-RAY COUNT OF SOIL SAMPLE*: This section provides the specifics for equipment set-up, and actions required, to perform *GAMMA-RAY ANALYSIS*.

4.4.5.1 *POSITION SAMPLE INSIDE GAMMA-RAY DETECTOR SAMPLE CHAMBER* : Open the door of the sample chamber and position the Marinelli-type beaker containing the soil sample over the snout of the gamma-ray spectrometer. Close the door of the lead sample chamber.

4.4.5.2 *BEGIN GAMMA-RAY DATA ACQUISITION*: Invoke the acquisition code by typing 'BARREL' (which is the name of the batch file that starts the controlling software) at the computer prompt. Answer the software menu questions as required. A sample software session is illustrated in Exhibit 7. Assure that 'BKG' appears in the 'SAMPLE Identification Text' when prompted by 'ID:' to establish the count as system background. Count the empty Marinelli-type beaker for 1000 seconds.

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4.4.5.3 *CALIBRATION COUNT*: If the system has been previously calibrated using the Radium-226-spiked soil standards, then proceed with the instructions of section 4.4.5.4.

Assure that the standard used for the efficiency calibration is positioned properly over the diode snout within the lead cave. Perform an efficiency calibration using the step below that corresponds to the appropriate situation:

4.4.5.3.1 *GAMMA-RAY CALIBRATION OF BLANK SOIL REFERENCE*: Position the blank calibration standard over the snout of the HPGe gamma-ray detector. Count the standard with the gamma-ray detector for a minimum of 1000 s or longer, as determined by the TECHNICAL LEAD, sufficient to establish good counting statistics, typically to provide an uncertainty on the overall activity level at <10% for activity levels under 10 pCi/g when in equilibrium with the daughter products.

4.4.5.3.2 *GAMMA-RAY CALIBRATION OF CALIBRATION SOURCES*: Position the calibration standard over the snout of the HPGe gamma-ray detector. Count the standard with the gamma-ray detector for a minimum of 1000 s or longer, as determined by the TECHNICAL LEAD, sufficient to establish good counting statistics, typically to provide an uncertainty on the overall activity level at <5% for the 20 pCi/g source and <10% for the other sources.

4.4.5.3.3 *GAMMA-RAY CALIBRATION CONFIRMATION*: Plot or graph the observed activity levels the for two daughters, Pb-214 and Bi-214, versus the known calibration standard activity levels to confirm that the efficiency curves used by the software are valid . Contact the TECHNICAL LEAD in the event that the calibration results do not appear linear with a 1-to-1 ratio of reported activity vs. known activity.

4.4.5.4 *ROUTINE SOIL COUNTING USING GAMMA-RAY SPECTROMETRY*: Assure that a beaker of soil has been collected, lightly tamped down to remove air pockets, sealed with a lid, weighed, and inserted over the snout of the HPGe gamma-ray counting diode.

4.4.5.4.1 *GAMMA-RAY DATA ACQUISITION*: Answer the software menu questions as required providing such information as sample weight, sample identification number, OPERATOR identification, location, etc. A sample software session is illustrated in Exhibit 7. Assure that 'BKG' does not appear in the 'SAMPLE Identification Text' when prompted by 'ID:'. Acquire gamma-ray data for a minimum of 300 s or longer, based on the OPERATOR's estimation and any other available information.

4.4.5.4.2 Summarize the results of the gamma-ray analysis of data by reporting the activity found for the Ra-226, Pb-214, and Bi-214. Include the reported uncertainties.

Assay subsequent soil samples as specified in 4.4.5.4.

4.4.6 Review the hardcopy record of the data at the completion of each assay for any obvious errors or problems. If corrections or modifications are required, the OPERATOR shall effect the appropriate changes and/or recount the sample, as deemed necessary by the OPERATOR or TECHNICAL LEAD. The OPERATOR shall initial any corrections made to the hardcopy record. The OPERATOR shall initial the hardcopy record and forward all data to the TECHNICAL LEAD or ANALYST for final review.

4.4.7 The hardcopy record of the data that is automatically printed out at the end of each soil assay and a floppy-disc copy of all data shall be delivered to the TECHNICAL LEAD or designated ANALYST for review.

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4.5 DOCUMENTATION

Software control is provided for in the most recent revision of the applicable Quality Assurance Project Plan.[1] All data collected and processed are recorded on hard disc and copied to floppy disc for archiving. Traceability information and preliminary results shall be printed on the hardcopy record discussed in 4.4.6. The signed version of the hardcopy printout of the computer entry and analysis serves as the primary field documentation. Secondary or support documentation include the log book and data recorded on magnetic media. Secondary documentation is not provided to the client unless requested or specified. Sufficient raw data are on the floppy disc for subsequent reanalysis of all data. For record keeping purposes, the hardcopy output is considered the record copy and is delivered to the customer for storage and control.

4.6 ANALYSIS

All data shall be acquired and all calculations shall be performed by software[2] that is under configuration management, with the exception of hand corrections which shall be initialed and dated by the OPERATOR, ANALYST, or TECHNICAL LEAD. The gamma-ray spectra shall be deconvoluted using the 'RAYGUN'[2] code and levels of radioisotopes shall be computed by the 'RAYGUN' code. Efficiency curves shall be based on measurements obtained using the calibration source placed in the position(s) specified in Sections 4.4.5.3 and 4.4.6.3.

4.7 ACCEPTANCE CRITERIA

The TECHNICAL LEAD or ANALYST determines the acceptability of the resulting data based on the system operability and the appropriateness of the data for achieving written client specifications. The client specification is typically for radiological data in support of meeting applicable solid-waste disposal requirements.[3]

4.8 DATA REVIEW

All data shall be reviewed by the TECHNICAL LEAD or designated ANALYST prior to release to the client; as indicated by the TECHNICAL LEAD's or ANALYST's signature and date attached to the summary of data which shall accompany the hardcopy record sent to the client.

REFERENCES

1) "PNL (329) Gamma-Scanner/Neutron Analysis Activities Quality Assurance Project Plan MCS-032, Revision 2", Pacific Northwest Laboratory, Richland, Washington.

2) W. K. Hensley, E. A. Lepel, M. E. Yuly, and K. H. Abel, "Adaptation and Implementation of RAYGUN Gamma-Ray Analysis Code on the IBM PC", J. Radioanal. Nucl. Chem., Art. 124, 481 (1988).

3) For example, N. P. Willis, October 1993, "Hanford Site Solid Waste Acceptance Criteria", WHC-EP-0063-4, Westinghouse Hanford Company, Richland, Washington.

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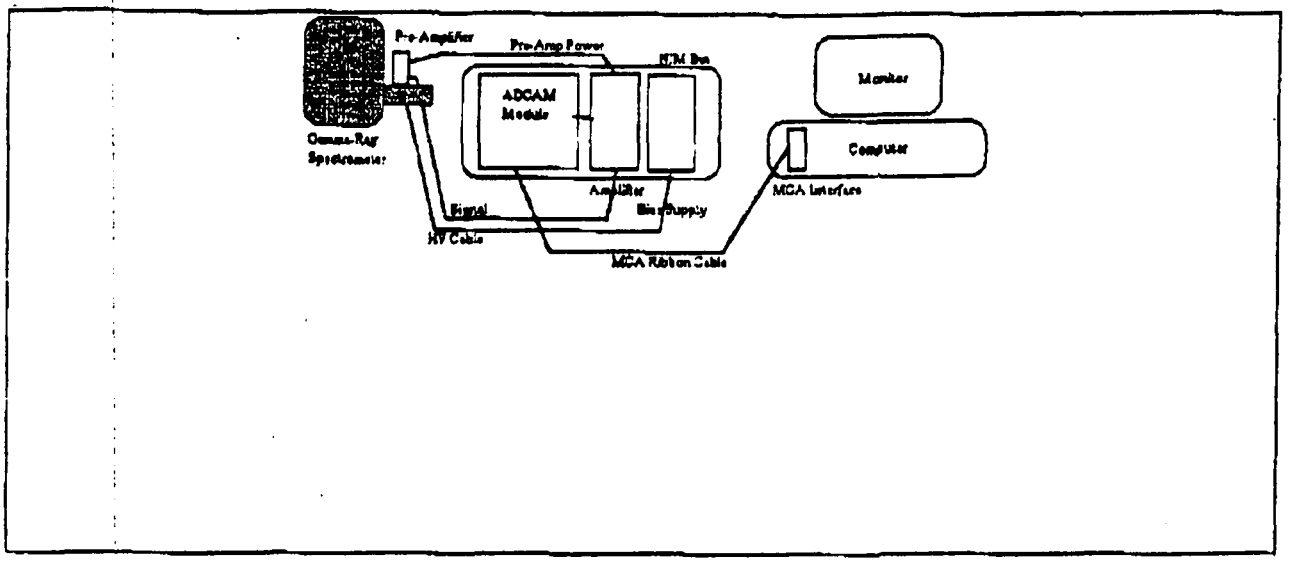

Generic Function	Specific Device	Operating Setting(s)	Acceptable Alternate Devices
Gamma-Ray Spectrometer		000 V D.C.	75% HPGe
Preamplifier			
Co-axial Cabling	1) Detector Bias 2) Signal 3) Pre-Amp Power		
Amplifier	ORTEC 571	Gain[1]: 11.14 Coarse Gain: 50 Shaping Time: 3μs BLR Auto: UP Input: 100Ω BNC Terminator Delay/Out: DOWN POS/NEG: UP	ORTEC 570
High-Voltage Power	ORTEC 459		ORTEC 659
IBM/PC-compatible computer w/ 8-bit slot for ADCAM interface card	Toshiba 5100 Portable with WonUnder One for ADCAM Interface		
ADCAM Multichannel Buffer	ORTEC 918A	COINC/ANTI:NEUTRAL S1: 01111111 S2: 01111101 S3: 11000101	
Lead Sample Cave	Custom Built	Refer to Exhibit 2	
Operability Check Source		Thoria	
Calibration Standards	56238-30-1 56238-30-2 56238-30-3 56238-30-4 56238-30-5	Blank Soil Standard Soil with 1.156 pCi/gm Ra-226 Soil with 1.957 pCi/gm Ra-226 Soil with 4.744 pCi/gm Ra-226 Soil with 19.439 pCi/gm Ra-226	
NIM Bin Power Supply		DRAFT	Berkeley PORTANIM Model AP-1 or AP-3

[1] Reference settings only. The actual settings may vary on a daily basis as part of the operability check determinations.

The following represents a typical interactive session with the GEA software used to control the Radium-226 assay system. User responses are entered as ***bold face italic***. The response represented by *<CR>* indicates that the 'RETURN', 'Enter', or 'Carriage Return' key on the computer keyboard is pressed. Note that the first response after typing ***barrel*** is ***s*** to place the GEA code into **SINGLE measurement mode**. The following listing is for illustration only and does not represent required responses to GEA input requests.

```
E:\>
E:\>barrel

E:\>CHDIR \GEA

E:\GEA>GEA



                    SEGMENTED  BARREL  SCANNER  PROGRAM
                      by Bruce Geelhood & Walt Hensley
                 BATTELLE -- PACIFIC NORTHWEST LABORATORIES


-----------------------------------------------
                        Current Program mode:
BARREL SCANNING MODE --  COLLECT both Gamma & Neutron Data
   ROYGUN NOT run for each segment
   GROSS weight using GRAM units in ROYGUN

Change program MODE desired
  N ==> No MODE Change
Mode selection COMMANDS    Current --> changes to
  B ==>  BARREL scanning mode
  W ==>  BARREL scanning mode --> WELL logging mode
  S ==>  BARREL scanning mode --> SINGLE measurement mode

Enter desired MODE [N]:  s

-----------------------------------------------
                        Current Program mode:
 SINGLE MEASUREMENT MODE

Change program MODE desired
  N ==> No MODE Change
Mode selection COMMANDS    Current --> changes to
  B ==>  SINGLE measurement mode --> BARREL scanning mode
  W ==>  SINGLE measurement mode --> WELL logging mode
  S ==>  SINGLE measurement mode

Enter desired MODE [N]:  <CR>
The efficiency file is \EFF\SURFACE.EFF
Do you want to change it ? [n] <CR>


Change program control FLAGS if needed
  N ==> No Change
  * --> Return to MODE menu
TOGGLE COMMANDS    Current --> changes to
  H ==>  HARDCOPY of QUAL & /PLOTs --> No HARDCOPY
  W ==>  use gross WEIGHT --> use net WEIGHT
  U ==>  use gram --> use kilogram UNITS
  C ==>  use NEW 386 computer --> use OLD computer
  D ==>  DEBUG information
Enter desired action [N]:  <CR>
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```
-----------------------------------------------
                        Current Program mode:
The system time is 12: 0:58   10/22/91
Change program control PARAMETERS if needed
  N ==> No Change
  * --> Return to MODE menu
VALUE ENTRY COMMANDS
  C ==> change COMPUTER CLOCK/CALENDER
  W ==> change slit WIDTH from:    1.00 inches
  R ==> change hard disk ROLLOUT directory from:  \$AVDAT\
  H ==> change HARD disk file saving -- MINIMUM BACKUP
Enter desired action [N]:  <CR>


-----------------------------------------------

   Entering "ABORT" causes program to abort
   Entering a RETURN uses previous text

Enter 4 character site token (A4)
Site:""
Site: site

Enter site description text (A50)
Site:""
Site: ------ site description text entered here ------

Enter operator information text (A50)
Operator:""
Operator: --- operator information text is entered here ---


-----------------------------------------------

Item  Channel#  True Energy                Error
   1     238.8     238.578 keV     238.633 keV        -.055 keV
   2     338.6     338.420 keV     338.281 keV         .139 keV
   3     583.7     583.022 keV     583.148 keV        -.126 keV
   4     728.0     727.250 keV     727.277 keV        -.027 keV
   5     911.9     911.160 keV     911.124 keV         .036 keV
   6     969.8     968.970 keV     968.937 keV         .033 keV
   7    2615.2    2614.350 keV    2614.357 keV        -.007 keV
Calibration constants:  Zero=    .0907 keV  &  Gain=    .99866 keV/chan

Are you satisfied? [Y]: <CR>


-----------------------------------------------

The acceptable counting times for each segment are 1 --> 10,000 seconds
Enter desired count time for each segment (sec.)[ 100.0]:<time entered here>
Is a  100.0 second count time acceptable? [Y]:  <CR>

*************************************************
** Position the sample in the counting geometry **
*************************************************

   Entering -1 causes program to ABORT
Enter the next sequential SAMPLE number for today? [01]:appropriate entry here

SAMPLE Number:   1
```

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```
The system time is 12: 1:52   10/22/91
    If ID starts with "BKG" it will become the new background
Enter SAMPLE Identification Text (A40):
ID: --- User enters BKG or appropriate sample ID ----
Enter Cup seal number -- TID# (A16):  TID or none

Gross Weight of the SAMPLE (+#==>Lbs.)(-#==>kg) [  51.0]? enter gross weight
Empty Weight of the SAMPLE (+#==>Lbs.)(-#==>kg) [  50.0]? enter tare weight
Gross SAMPLE Weight =      23.13 kilograms =      51.00 pounds
  Net SAMPLE Weight =        .45 kilograms =       1.00 pounds

Making calibration file:  \DATA\91102302.CAL


Do you wish to change anything?

  N ==> No Change
ENTRY ERROR CORRECTIONS
  G ==> GENERAL information change SITE/OPR
  E ==> ENERGY calibration change
  C ==> COUNTING time change from      300. seconds
  B ==> BASIC sample information change ID/WT
DEFAULT changes
  L ==> LIBRARY change from: \ROY\DRUM1.DAT

Enter desired action [N]:  <CR>


*********************************
** You must now be ready to count **
*********************************

Please hit return <CR> when ready to continue

You have 5 Sec. to abort by Mashing ESC

...
```

The GEA program continues at this point to collect data and create the hardcopy record.

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OPERABILITY, CALIBRATION, AND MEASUREMENT CHECKLIST

I. Instrumentation Checks

Gamma-Ray Spectrometry System

_____G1. Check HPGe operability with thoria standard (4.4.2)
_____G2. Set gain and zero controls for HPGe system (4.4.2)
G3. Check efficiency of HPGe at beginning and end of day and record log entry (4.4.2)

_____ start
_____ end

_____G4. Assure check source counts indicate equipment is in control (4.4.2)
_____G5. Determine detector background at field location

II. Calibrations

Gamma-Ray Spectrometry System

_____G3. Position HPGe gamma-ray spectrometer (4.4.5.3)
G4. Perform efficiency calibration blank sample (4.4.5.3)

III. Soil Sample Assay

Record gross weight of soil sample _____ gross pounds

Gamma-Ray Spectrometry System

_____G1. Position sample on of HPGe detector as done for calibration steps (4.4.5.4)
_____G2. Perform gamma ray data acquisition (4.4.5.4)

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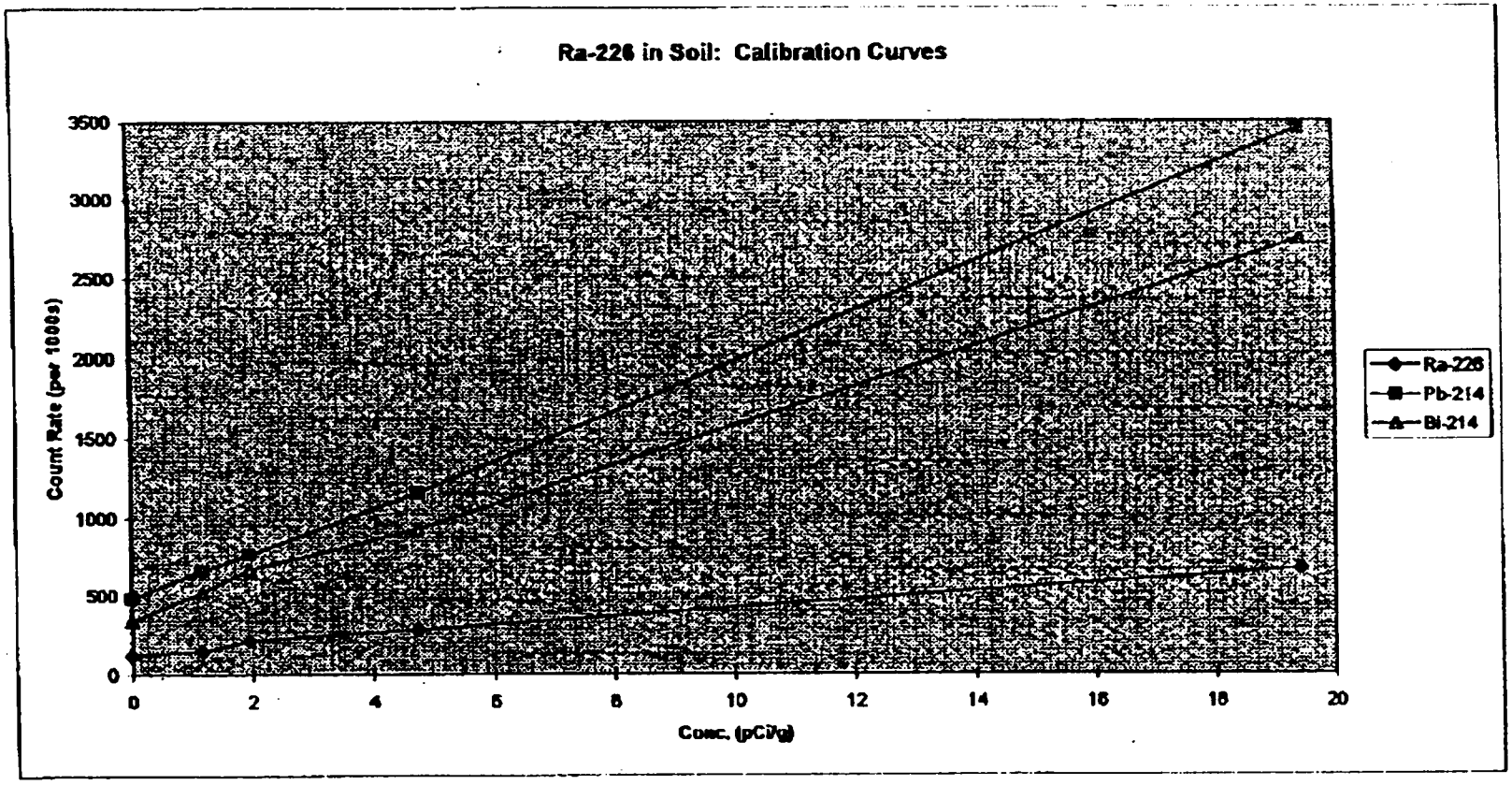
Ra-226 Calibration Curves

Run No.	Standard ID	Added Activity (pCi/g)	Net Counts Observed in 1000-s Count: Ra-226 186 keV	Pb-214 351 keV	Bi-214 609 keV
98043001	Empty Cave		0	0	64
98043002	56238-30-1	0	119	483	339
98043003	56238-30-2	1.156	146	664	521
98043004	56238-30-3	1.957	212	769	671
98043005	56238-30-4	4.744	282	1157	929
98043006	56238-30-5	19.439	674	3453	2743