ENGINEERING DESIGN FILE

Project File Number ______________________

Project/Task WAG 5 Comprehensive RI/FS

Subtask Inventory and Infiltration Rate Sensitivity Simulations

Title: Sensitivity Simulation Results for SL-1 Burial Grounds Groundwater Pathway Risk with Increased Inventory and Increased Infiltration

Summary: This summary briefly defines the problem or activity to be addressed in the EDF, gives a summary of the activities performed in addressing the problem and states the conclusions, recommendations, or results arrived at from this task.

The purpose of this Engineering Design File is to document results of GWSCREEN sensitivity simulations that were performed in March 1995 for the Remedial Investigation/Feasibility Report for Operable Units 5-05 and 6-01(SL-1 and BORAX-I Burial Grounds) The sensitivity simulations investigated the effect on simulated risk of increasing the inventory and infiltration rate. The simulations were only performed for the SL-1 burial ground and used the same parameterization as the OU 5-05 GWSCREEN simulations. The top three nuclides (Tc-99, H-3, and Pu-239) contributing to simulated groundwater pathway risks were evaluated.

While there was an increased groundwater pathway risk from either increasing the infiltration or from increasing the inventory, when the increases were simulated individually none of the sensitivity simulations resulted in risks that were greater than 1×10^{-6}. When increases were made simultaneously in both infiltration and inventory the groundwater pathway risks were marginally greater than 1×10^{-6}.

Distribution (complete package): Frank Webber MS3953, Jean Holdren MS2107, Chris Hiaring MS3953, Doug Burns MS 3960, Swen Magnuson MS2107, Jeff Sondrup MS2107.

Distribution (summary package only):

Authors:	Dept.	Reviewed	Date	Approved	Date
Swen Magnuson and Jeff Sondrup	IES (4160)	James McCarthy *(signature)*	2/16/1998	Frank Webber *(signature)*	2/23/98
(signature)	*(signature)*	LMITCO Review *(signature)*	Date 2/23/98	LMITCO Approval	Date

See Management Control Procedure (MCP) 6 for instructions on use of this form.

Sensitivity Simulation Results for SL-1 Burial Grounds Groundwater Pathway Risk with Increased Inventory and Increased Infiltration

Swen Magnuson and Jeff Sondrup
February 12, 1998

Introduction

The purpose of this Engineering Design File is to document results of GWSCREEN (Rood, 1994) sensitivity simulations that were performed in March 1995 for the Remedial Investigation/Feasibility Report for Operable Units 5-05 (SL-1) and 6-01 (BORAX-I) (Holdren et al. 1995). The sensitivity simulations investigated the effect on simulated risk of increasing the inventory and infiltration rate. The simulations were only performed for the SL-1 burial ground and used the same parameterization as the OU 5-05 GWSCREEN simulations. The top three nuclides contributing to simulated groundwater pathway risks were evaluated (Table 1). These nuclides had a range of radioactive half-lives and partition coefficients (Table 2).

Table 1. Top three nuclides in terms of groundwater pathway risk for SL-1 burial ground GWSCREEN simulations.

Rank	Nuclide	Risk	Comments
1	Tc-99	5.6×10^{-7}	Long half-life, low K_d
2	H-3	2.0×10^{-7}	Short half-life, K_d =0
3	Pu-239	8.7×10^{-8}	Long half-life, large K_d

Table 2. Partition coefficients (K_d) in ml/g.

Nuclide	Basalt (aquifer)	Sediment (source and unsaturated zone)
Tc-99	0.15	0.1
H-3	0	0
Pu-239	22	550

Tc-99 Sensitivity Simulations

Table 3 shows peak groundwater pathway risk results for the combination of inventory estimates and infiltration rates that were used in the simulations. The inventories used were the base inventory that was used in the RI/FS, and that same base inventory multiplied by a factor of either two or three. Two infiltration rates were used: 10 cm/y which was the base value used in the RI/FS, and 22 cm/y which is the average total annual precipitation on the Idaho National Engineering and Environmental Laboratory (Clawson et al, 1989). The higher infiltration rate was used to simulate the effect of a rip-rap barrier at the surface that would enhance net downward water infiltration by effectively precluding evapotranspiration. It is reasonable to use this higher infiltration rate because with a rip-rap surface barrier, essentially all the precipitation will infiltrate down to and through the waste zone. The risk results are presented for a receptor at the downgradient edge of the burial ground boundary. The risk scenario is the same as that presented in the RI/FS.

Table 3. Inventories and groundwater pathway risk results for Tc-99 sensitivity simulations.

Base Inventory = 0.0289 Ci			
2X Inventory = 0.057 Ci			
3X Inventory = 0.0867 Ci			
Risk Results			
	Base Inventory	2X Inventory	3X Inventory
I=10 cm/y	5.6×10^{-7}	1.1×10^{-6}	1.7×10^{-6}
I=22 cm/y	5.8×10^{-7}	1.2×10^{-6}	1.7×10^{-6}

H-3 Sensitivity Simulations

Table 4 shows peak groundwater pathway risk results for a combination of inventory estimates and infiltration rates for H-3.

Table 4. Inventories and groundwater pathway risk results for H-3 sensitivity simulations.

Base Inventory = 0.906 Ci			
2X Inventory = 1.81 Ci			
3X Inventory = 2.72 Ci			
Risk Results			
	Base Inventory	2X Inventory	3X Inventory
I=10 cm/y	2.0×10^{-7}	4.0×10^{-7}	6.0×10^{-7}
I=22 cm/y	4.0×10^{-7}	7.9×10^{-7}	1.2×10^{-6}

Pu-239 Sensitivity Simulations

Table 5 shows peak groundwater pathway risk results for a combination of inventory estimates and infiltration rates for Pu-239.

Table 5. Inventories and groundwater pathway risk results for Pu-239 sensitivity simulations.

Base Inventory = 0.0438 Ci			
2X Inventory = 0.0876 Ci			
3X Inventory = 0.131 Ci			
Risk Results			
	Base Inventory	2X Inventory	3X Inventory
I=10 cm/y	8.7×10^{-8}	1.7×10^{-7}	2.6×10^{-7}
I=22 cm/y	3.8×10^{-7}	7.5×10^{-7}	1.1×10^{-6}

Discussion

While there was an increased groundwater pathway risk from either increasing the infiltration or from increasing the inventory, when the increases were simulated individually none of the sensitivity simulations resulted in risks that were greater than 1×10^{-6}. When increases were made simulaneously in both infiltration and inventory the groundwater pathway risks were marginally greater than 1×10^{-6}.

It can be seen in these results, however, that for H-3 and Pu-239, increasing infiltration from 10 to 22 cm/y increased risk by approximately factors of 2 and 4, respectively. This should serve as a caution that increased groundwater pathway risk caused by an infiltration-enhancing barrier may be important at other locations with different inventories and less confidence in the conservativeness of the applied model.

References

Clawson, K. L, G. E. Start, and N. R. Ricks, 1989, *Climatography of the Idaho National Engineering Laboratory 2nd Edition*, DOE/ID-12118, National Oceanic and Atmospheric Administration, Idaho Falls, Idaho.

Holdren, K. J., R. G. Filemyr, and D. W. Vetter, 1995, *Remedial Investigation/Feasibility Report for Operable Units 5-05 and 6-01 (SL-1 and BORAX Burial Grounds)*, INEL-95/0027, Revision 0, March 1995, Lockheed Martin Idaho Technologies Company, Idaho Falls, Idaho.

Rood, A. S., 1994, *GWSCREEN: A Semi-Analytical Model for Assessment of the Groundwater Pathway from Surface for Buried Contamination: Version 2.0 Theory and User's Manual*, EGG-GEO-10797, EG&G Idaho, Inc., January.

ENGINEERING DESIGN FILE

Function File Number – INEEL/INT-98-00498
EDF Serial Number – EDF-ER-034

Project File Number WAG 5

Project/Task WAG 5 Comprehensive RI/FS Operable Unit 5-12

Subtask ARA-23

Title: Results of the Radiological Survey and Sampling of the ARA-II SL-1 Reactor Foundation

Summary:

The Operable Unit 5-12, ARA-23 site is the subsurface structures (e.g., SL-1 Reactor Foundation and underground utilities) and contamination within the ARA-I and ARA-II facility fences and all surface soils within the boundary of the aerial isopleth radiologically contaminated soil encompassing the ARA-I and ARA-II facilities.

This EDF documents the soil and concrete sampling program that was conducted at the SL-1 Reactor Foundation to establish contamination levels in the overlying soils, around the outside of the concrete foundation and from the top of the foundation to the basalt/concrete interface.

The levels of contamination in the soils over and around the SL-1 foundation are not very different from those levels in the areas adjacent to this site and there does not appear to be any unusual isotopes present. It appears that the contamination in the soils is slightly higher along the perimeter of the foundation. This could be due to leaching, wind dispersion, or activity in the soils during the initial SL-1 cleanup. The concrete foundation appears to contain minimal Cs-137 or any other man-made isotope.

Distribution (complete package):

Distribution (summary package only):

Author	Dept.	Reviewed	Date	Approved	Date
C. P. Oertel	41E4			F. L. Webber	5/15/98
		LMITCO Review	Date	LMITCO Approval	Date
CP Oertel		Chris Haring	5/15/98	Frank Webber	5/15/98

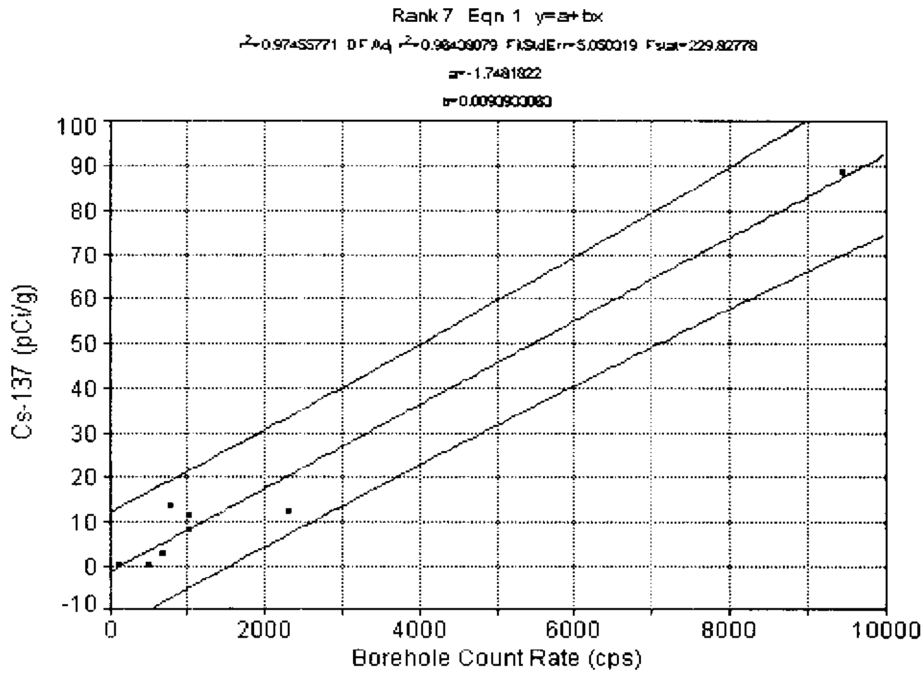

Figure 9. Cesium-137 versus borehole count rate//ARAII/SL-1.

background corrected. The intent of these measurements was to establish qualitative estimates of the isotopic composition of the pad contamination. These measurements were not calibrated against any type of known standard as in conventional gamma spectrometry. The gamma ray spectrum shown in Figure 10 was taken for 1 hour at the SL-1 pad.

The characteristic Cs-137 and K-40 peaks are shown along with the natural emitters Bi214 and Ac-228. As with the NaI measurements, the consistent presence of the Cs-137 and K-40 peaks provides a real time energy calibration for this detection system. Analysis of this spectrum using the program GammaVision (EG&G Ortec) indicates nothing unusual in the isotopic composition of the concrete.

As stated earlier, the calculation of the amount of any radioisotope using this method is difficult because no exact geometrical calibration standard exists for this measurement; however, an estimate of the Cs-137 content can be made by assuming a point source geometry for which a calibration curve was developed in the ICPP gamma spectrometry laboratory prior to this fieldwork. Using this calibration curve and knowing the surface area and density of the measured concrete pad, a concentration per unit mass was calculated. These calculations were performed assuming four depths of Cs-137 penetration into the pad. This data is shown on Table 4.

The data in Table 4 show that the most conservative value of the background corrected Cs-137 value is about 50 pCi/g for 1-cm penetration into the pad. The data in Table 4 are shown with a one sigma random error. Also, the above numbers were matched very closely with a separate 30-minute count taken at the same location.

The above data do not show quantitative agreement with the two samples taken from the concrete pad (see Table 3, Hole 3-1). The two samples taken from the coredrill show barely detectable levels of Cs-137. This disagreement is due to the fact that the HpGe measurements performed above the pad were uncollimated and the contribution from the surrounding berm was unknown. The intent of the

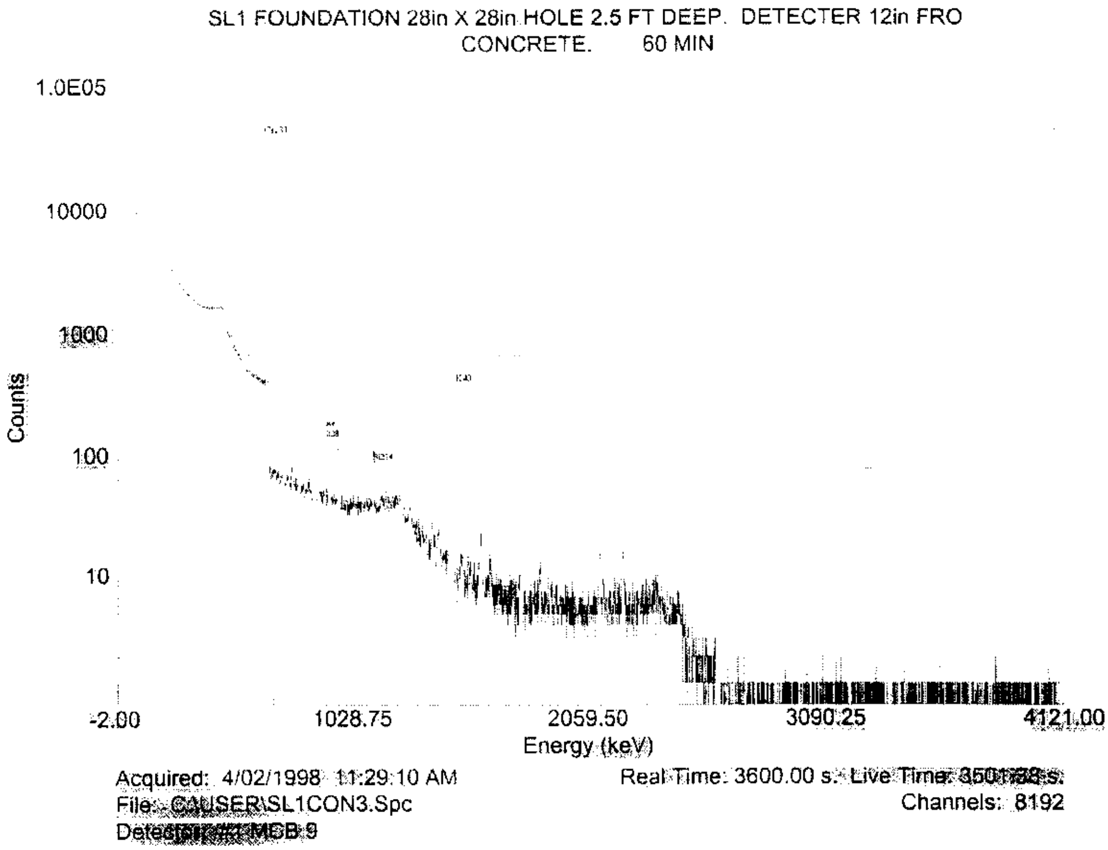

Figure 10. SL1CON3.

Table 4. Assumed radionuclide depth distributions and values of positive detected isotopes.

Isotope	Assumed Depth (cm)	Activity (pCi/g)	Uncertainty (%)
Cs-137	1	52.4	3.8
	2.54	20.6	3.8
	5.08	10.3	3.8
	10.16	5.2	3.8

measurements was really to see if any unexpected isotopes were present in the concrete. Qualitative comparison of the spectra taken with the field system and the core samples analyzed at the RML confirms the lack of any unexpected or unusual isotopes in the concrete. The RML data showed no positive detects (other than Cs-137) in either of the two concrete samples taken for gamma spectrometry while the field spectra also showed no positive detects for any isotopes other than the Cs-137.

5. SUMMARY AND CONCLUSIONS

The main intent of these radiation measurements was to establish a qualitative profile of the possible distribution of contamination at the SL-1 site. This was accomplished by measuring radiation levels in boreholes over the foundation structure and by performing high-resolution qualitative spectral measurements over an exposed portion of the foundation.

The highest values for the borehole readings were generally noted at distances furthest from the pad center. These higher readings track closely with higher Cs-137 and gross beta activities at those distances. Though a direct correlation or mechanism is speculative, apparently the contamination in the soils at this site is higher along the periphery of the foundation, possibly because of several factors such as leaching, wind dispersion, and replacement of the soils above the foundation during the original cleanup. In any case, the levels of contamination in the soils over and around the SL-1 pad are not grossly different from those levels in the areas adjacent to this site and unusual isotopes are not apparently present in the soils.

No pattern of radioactive contamination is evident as a function of depth of soil at this location based on these samples and borehole measurements.

The concrete foundation appears (based on two samples) to contain minimal Cs-137 or any other anthropogenic isotopes at the top or bottom of the structure near the basalt interface.

1. INTRODUCTION

The Stationary Low Power Reactor No. 1 (SL-1) site is located at the Idaho National Engineering and Environmental Laboratory (INEEL) in Waste Area Group (WAG) 5 within the Auxiliary Reactor Area (ARA) ARA-II facility. ARA-II was constructed in 1957 and housed the SL-1 reactor. The reactor was operated from August 1958 until December 1960, and was destroyed by an accidental nuclear excursion in January 1961. Subsequent to decontamination, the three main buildings were converted to offices and welding shops. The facility also housed numerous minor structures such as a guardhouse, well house, chlorination building, decontamination and laydown building, electrical substation, and several storage tanks. The facility was shutdown in 1986. Many of the building structures and ARA-II are gone due to concurrent decontamination and decommissioning activities.

This site has been the subject of studies involving the location and amount of radioactive contamination. A soil sampling program was conducted within the SL-1 perimeter fences during the forty five day period following the SL-1 incident (January 1961) (IDO 19302) and a series of nondestructive radiation level measurements on surface soils was performed in the areas adjacent to the SL-1 site (ARA-23) in 1997 (ER-WAG5-104).

The effort described in this report involved characterizing the makeup and extent of contamination over and around the covered (with about 3.5 ft of overburden soil) SL-1 foundation. Nine sampling locations were selected (see DOE/ID-10556) to perform this characterization and were divided into three groups. The first group was designed to establish the contamination levels around the outside of the foundation. The second group was designed to establish the contamination levels from the top of the soil to and including the top of the concrete foundation. The third group was designed to establish the contamination levels from the top of the foundation to basalt through the concrete foundation, including the interface between the concrete and the basalt. Table 1 shows the sample locations and depths from ground surface to concrete or basalt.

This work included the following:

- Drilling boreholes at nine locations over and near the foundation location.
- Performing downhole measurements with a scintillation detector at incremental depths. This detector measured the gamma field at each depth for five minutes. The depth profile spectra were then compared to surface background spectra.
- Collecting samples from each borehole for submission to the Radiation Measurements Laboratory (RML) for analysis of gamma emitters and gross alpha/beta levels.
- Removing overburden to expose a section of the concrete foundation.

Table 1. Sample locations and depth of cover over concrete.

Sample Location	Depth Ground Surface to Concrete/Basalt (ft)	Northing	Easting	Elevation	Notes
3-1	2.92	675402.69	325992.20	5058.02	
2-1	2.5	675409.76	325985.13	5057.55	
1-1	5.2 (basalt)	675416.80	325978.00	5057.02	
2-2	2.16	675389.28	325981.65	5057.47	
1-2	4.5 (basalt)	675385.73	325978.06	5057.30	
2-3	2.83	675392.80	326002.11	5058.13	
1-3	6.5 (basalt)	675385.75	326009.23	5057.98	
2-4	2.67	675410.45	326005.58	5057.99	
2-5	2.75	675413.33	326002.88	5057.98	
Concrete Core		675402.69	325992.20	5058.02	Same as sample 3-1.
Concrete was 3.5 ft thick					

Survey Datum NAD27 State Plane and NGVD 1929 Vertical

- Performing high-resolution gamma spectrometry measurements using a high purity germanium detector (HpGe) suspended one foot above an exposed foundation section. This was done to perform a qualitative isotopic composition determination of the concrete foundation. The measurements were performed for both 30 and 60 minutes and background spectra were also taken to correct the data for area background.

2. BOREHOLE SITING WORK

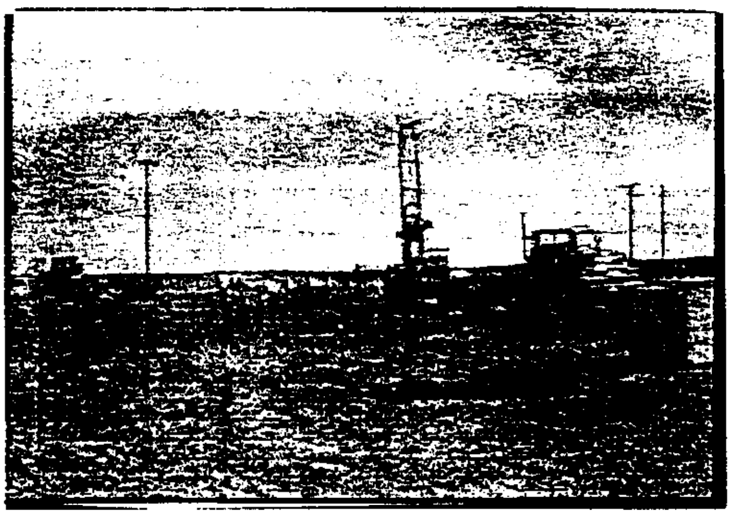

Figure 1. A drill rig setup at the SL-1 site.

LMITCO employees previously positioned hole markers over the concrete foundation and at locations around the periphery. Holes were drilled in a steady manner to avoid bit entanglement with buried rebar.

Holes were cased with polyvinylchloride casing to prevent material sloughing onto radiation detectors inserted for measurements. Soil samples were taken at incremental depth locations in the boreholes and submitted to the RML for radiological analyses (discussed later).

Holes were backfilled with original material after completing work at each hole location. Appendix A shows the chain of custody forms that match hole locations to analytical sample identification.

Following partial characterization of the low levels of contamination using gamma ray measurements, it was decided to excavate a section of the concrete foundation in order to perform high-resolution gamma spectrometry measurements on the foundation. A 28-in.^{2} section of the foundation was exposed for these measurements, as shown in Figure 2. A 2.5 ft coredrill sample was taken of the concrete foundation and two samples were taken from this core (one representing the top of the pad, the other from the pad-basalt interface) for gamma, gross alpha, and gross beta analyses at the RML.

3. BOREHOLE RADIATION MEASUREMENTS

To estimate the radiation fields in the bottom of the boreholes, a 2 in. × 2 in. sodium iodide (NaI) scintillation detector was sheathed in protective plastic and lowered to various depths in each hole. This detector was coupled to a Quantrad Sensor Scout II handheld multichannel analyzer system with a 512 k spectral display. Figure 3 shows a LMITCO employee preparing the detector for hole measurements.

Five-minute counts were taken at depths from 2.5 ft belowgrade to 6.25 ft belowgrade. Several boreholes were not over three feet deep, thus only a single NaI measurement was made. The Quantrad Sensor unit contains an onboard algorithm for estimating the dose in mR or mR/hour units based on the assumption that all gamma ray radiation will generate an equal dose regardless of the energy of the radiation. Technically this is not absolute and many different algorithms have been developed by numerous researchers to calculate dose equivalent numbers for spectral data. Additional corrections must be applied to this assumption because all NaI detectors do not have a uniform response to varying energies (that is, differing crystal efficiencies) and also have different geometries and interaction

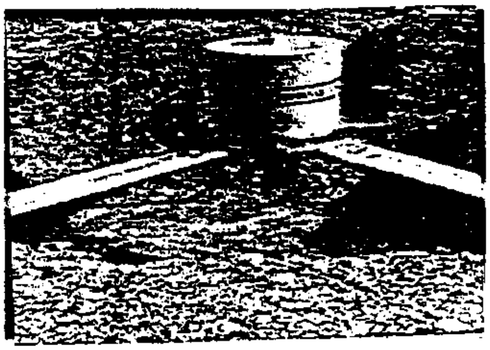

Figure 2.

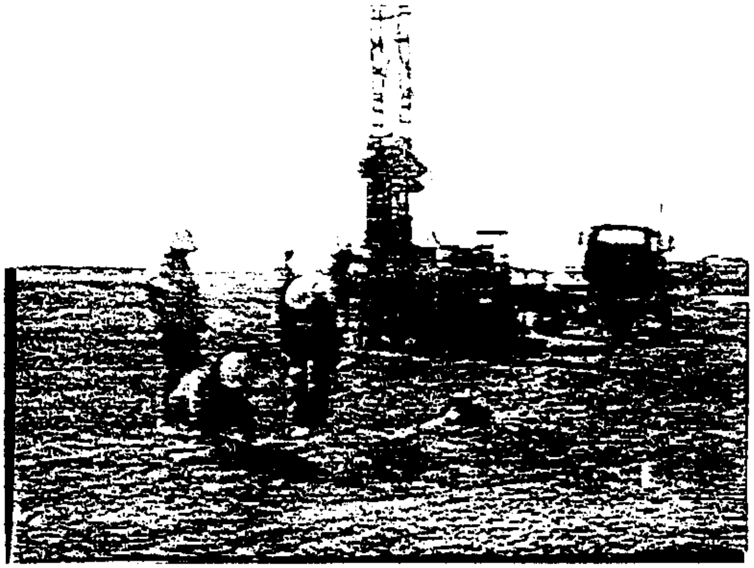

Figure 3.

volumes. Fortunately, some of this data for NaI scintillators can be found in the literature ("Calculated Efficiencies of NaI Crystals," NRL Report 4833). The dose calculation algorithm in the Scout II uses the efficiency to determine the response curve for the detector at a particular energy. From this response curve, an estimated dose is calculated. Figure J-4 shows a typical NaI spectrum of a borehole.

The two major peaks in these spectra are the Cs-137 at 661 kev and K-40 at 1460 kev. These peaks are present in all spectra of this type and provide a real time energy calibration for this instrument. The Scout detector was precalibrated in the ICPP gamma spectrometry laboratory using NIST traceable point sources and then calibrated at each borehole using these two well-known gamma rays. Table 2 shows the results of the mR/hour values at each depth for each borehole. The counts per second and background counts per second also are shown.

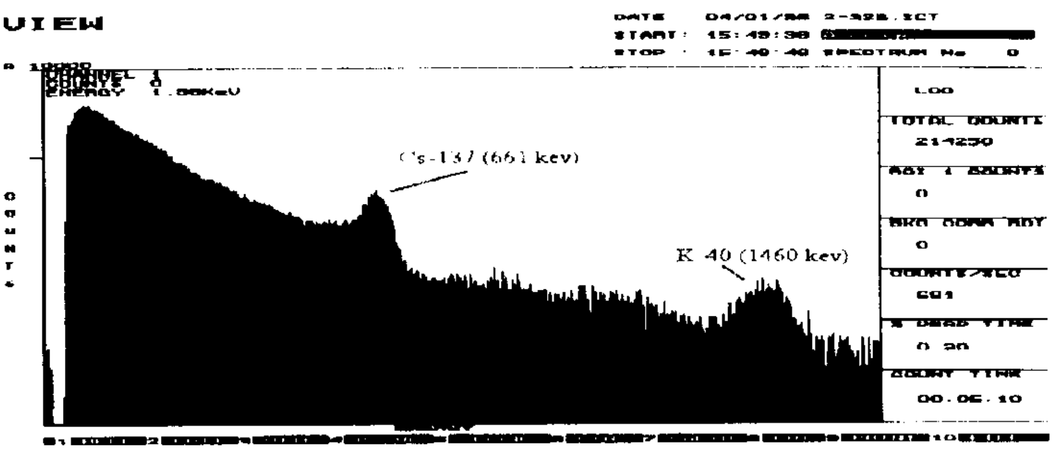

Figure 4. ScoutMaster V2.1a

Table 2. Scout NaI measurements in well casings.

(uncorrected for casing thickness)

Hole ID	Depth (ft)	Count Rate (cps)	Dead Time (%)	MR	mR/hour	Distance from Center pad (ft)
3_1	6.25	124	0.06	3.16E-04	4.31E-03	3.0
3_1	2.5	515	0.22	8.70E-03	6.60E-02	3.0
2_4	2.5	497	0.22	6.00E-03	6.70E-02	19.5
2_3	2.5	691	0.3	7.80E-03	9.10E-02	13.5
2_5	2.75	787	0.34	8.80E-03	1.00E-01	18.0
2_1	1.5	1013	0.44	1.20E-02	1.30E-01	15.0
2_2	1.5	1011	0.44	1.00E-02	1.30E-01	21.0
1_2	5	1000	0.45	1.30E-02	1.40E-01	27.0
2_1	2.5	2297	0.9	2.20E-02	2.50E-01	15.0
1_3	6.5	2119	0.91	4.20E-02	2.70E-01	30.0
1_1	5	2533	1.03	2.50E-02	2.90E-01	27.0
1_3	2	3524	1.4	3.50E-02	4.00E-01	30.0
1_1	2	4790	1.9	4.60E-02	5.20E-01	27.0
1_2	2.5	9449	3.8	9.10E-02	1.07E+00	27.0
Bkd	0	275	0.11			
Bkd	0	400	0.15			

The values in Table 2 are arranged by increasing counts per second and estimated dose rate. When the mR/hour values are examined against depth there is no clear pattern. Figure 5 shows the mR/hour values are about the same low levels at all the depths shown here.

However, when the estimated mR/hour values are plotted against radial distance from the center of the foundation, a pattern of increasing estimated dose with increasing distance from the center of the pad emerges, as shown in Figure 6.

Samples taken at the SL-1 site were analyzed at the Radiation Measurements Laboratory at TRA for Cs-137 using conventional gamma spectrometry and for gross alpha and gross beta activity values. No sample was taken from Hole 2-4 owing to a plugged drill sampler. Because of budget constraints only the highest level sample of the group No. 1 perimeter holes was submitted to the RML for gamma, gross alpha, and gross beta analyses. This data is shown in Table 3.

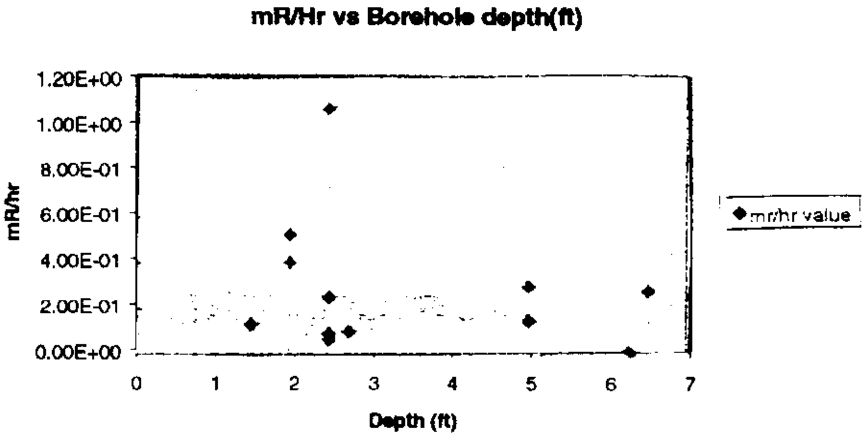

Figure 5. mR/hour versus borehole depth (ft).

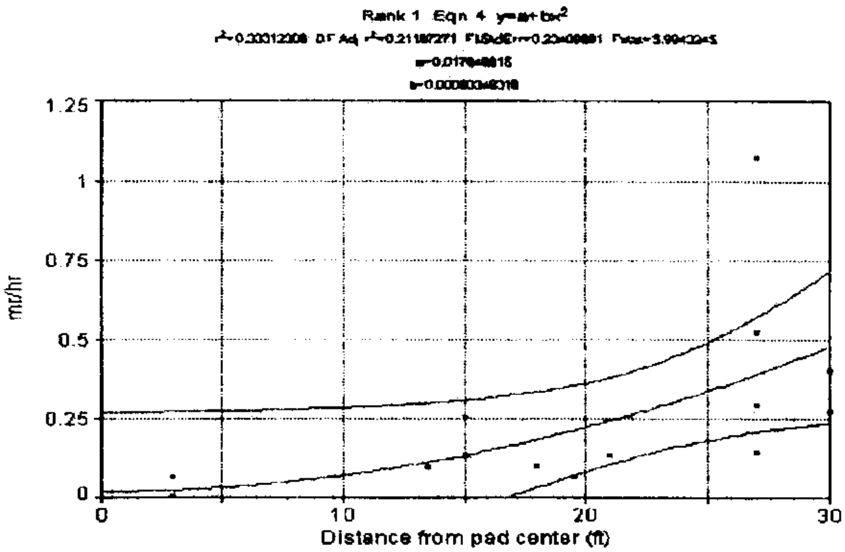

Figure 6. Radial distribution of estimated exposure.

Table 3.

Hole ID	Cs-137 (pCi/g)	Gross Alpha (pCi/g)	Gross Beta (pCi/g)	Distance from Center Pad (ft)
3_1	-0.005	0.1	2.7	3.0
3_1	0.021	0.5	0.8	3.0
2_4				19.5
2_3	2.36	16	150	13.5
2_5	13.5	10	17	18.0
2_1	11.4	6	51	15.0
2_2	7.77	4	71	21.0
1_2				27.0
2_1	12	6	75	15.0
1_3				30.0
1_1				27.0
1_3				30.0
1_1				27.0
1_2	88.2	5	284	27.0

This pattern of increasing estimated activity with distance from the pad center also is seen if the Cs-137 values are plotted against distance from the center of the pad as shown in Figure 7.

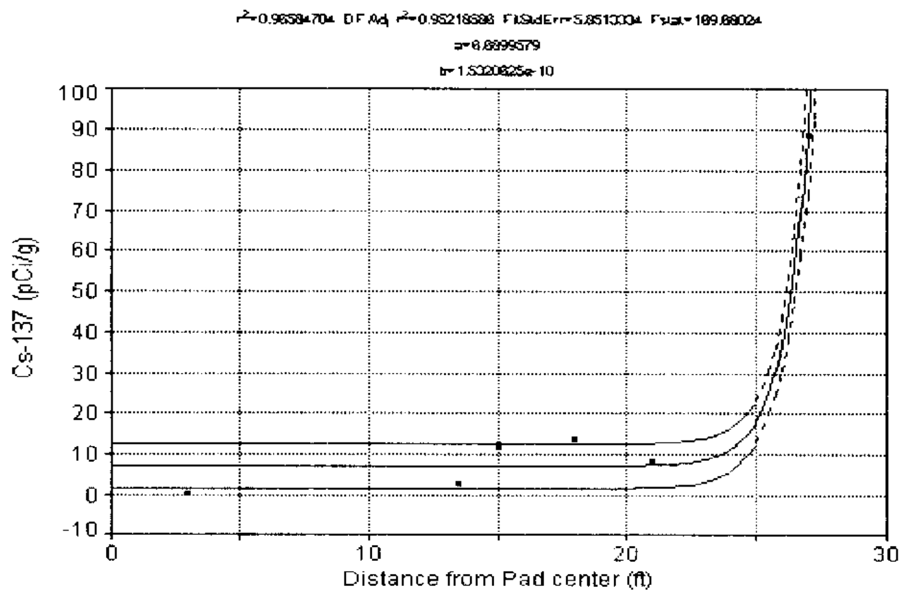

Figure 7. Cesium-137 conccentration versus distance from pad center.

The pattern of increasing estimated dose with distance from the center of the pad appears to be true for the gross beta activity, primarily from Cs-137 contribution, but no such pattern appears for the gross alpha data, as shown in Figure 8.

Finally, a graph of the RML determined Cs-137 values versus the borehole count rates is shown in Figure 9.

The slope of the fitted line in Figure 9 is 0.0093 pCi/g/cps. This value is interesting because it closely matches the theoretical value of 0.0091 pCi/g/cps calculated for a uniform 4-in. depth distribution of Cs-137 in the previously studied ARA-23 area.[a] This correlation may indicate that the depth profile of Cs-137 at this site is uniform rather than exponential.

4. HIGH RESOLUTION GERMANIUM DETECTOR MEASUREMENTS

To estimate the isotopic composition of the exposed concrete foundation, a high resolution germanium detector used for field studies (EG&G Ortec Model No. GEM-30185-P) was coupled to an EG&G Ortec DART multichannel analyzer. The detector was pointed directly at the exposed foundation from a distance of about 1 ft. The detector was not collimated for these measurements. However, background measurements were taken at the radiation area boundary and the foundation spectra were

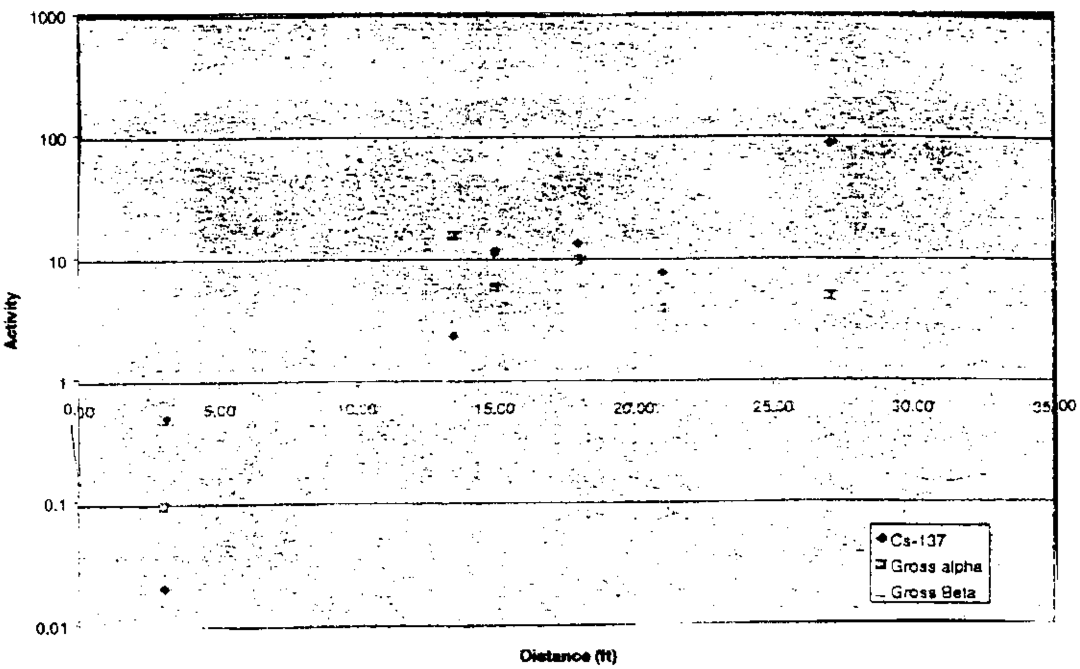

Figure 8. Activity versus distance form pad center.

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a. ER-WAG5-104, 1997, page 7