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Radiological Survey of the Combustion Engineering Burial Site Hematite, Missouri

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Radiation Management Corporation

Prepared for
U.S. Nuclear Regulatory
Commission

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U.S. Nuclear Regulatory Commission
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ABSTRACT

This report presents the results of a radiological survey of the burial site adjacent to the Combustion Engineering (C-E) plant in Hematite, Missouri, performed by Radiation Management Corporation (RMC) in the spring and summer of 1982. Measurements were made to determine external radiation levels, surface and subsurface radionuclide concentrations and radioactivity in air and water. Results show uranium concentrations in burial pits as high as 38 and 21 pCi/g for U-238 and U-235 respectively. Results also show uranium concentrations in surface soils as high as 4.7 and 1.1 pCi/g for U-238 and U-235 respectively. Based on an estimated U-234/U-238 activity ratio of about 10 to 1, the highest U-234 activity in the burial pits is estimated to be approximately 400 pCi/g, and in surface soils approximately 47 pCi/g. Radium and thorium concentrations did not exceed background levels. Radioactivity in water which exceeded EPA drinking water standards was found in two onsite monitoring wells.

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I. INTRODUCTION

Radiation Management Corporation, under contract to the U. S. Nuclear Regulatory Commission (NRC), performed a radiological evaluation of the burial site adjacent to the Combustion Engineering plant in Hematite, Missouri. An initial site visit occurred in March 1982, and the detailed radiological evaluation was performed in the spring and summer of 1982.

The purpose of this survey was to clearly define the radiological conditions at the burial site and to determine if radioactive material is moving from the burial pits into the surrounding environment.

The methods used to evaluate this site included the following:

1) Measurement of external exposure rates at one meter above the ground surface and beta-gamma count rates at one cm. above the ground surface;

2) Measurement of radionuclide concentrations in surface soil and vegetation;

3) Measurement of radionuclide concentrations in

subsurface deposits;

4) Measurement of gross alpha and beta activity in surface and subsurface water samples;

5) Measurement of airborne radioactivity.

Measurements were performed onsite using an RMC designed mobile laboratory facility. Analyses which could not be performed onsite were sent to the RMC analytical laboratory in Philadelphia, Pennsylvania.

II. SITE CHARACTERISTICS

The project site (Fig. 1) is located adjacent to the Combustion Engineering plant in Hematite, Jefferson County, Missouri. The site is approximately 35 miles south of St. Louis in a rural area isolated from large residential and/or commercial developments. The plant proper is a restricted area, and completely fenced in. The burial site is located immediately to the east of the fence line and extends to a wooded area at the site boundary (Fig. 2). The active site is bounded by Route 21A on the north, railroad tracks to the south, and wooded areas on both sides. There is no method of controlling access to any areas other than the plant.

During its lifetime, the plant has had four different operators. The initial operations began in 1956, under Mallinckrodt Chemical. In 1961, United Nuclear took control; in 1970, United Nuclear and Gulf ran the facility in a joint venture; and in 1974, Combustion Engineering assumed responsibility. Burials were made in the late 50's and early 60's under the direction of both Mallinckrodt and United Nuclear, in accordance with all applicable NRC (AEC) regulations.

Plant operations involve processing and treating various uranium compounds. All manner of uranium materials, ranging from depleted to highly enriched uranium, have been used at this site. While any of these may have been buried, it is more likely that depleted uranium was disposed of rather than enriched, due to the commercial value of the enriched material. Records indicate that an estimated 27 kilograms of U-235 (60 mCi) have been disposed of. Because all materials were assayed for U-235 only (by scanning with a scintillator set to count the 186 keV gamma peak), no estimate of total U-238 and U-234 content has been made. Additionally, some work on thorium fuel was performed, so there exists the possibility that small quantities of thorium have been buried. No other radioisotopes have been used or disposed of at this site.

The nature of the buried material is described as being primarily contaminated combustibles and small pieces of equipment. Apparently, the bulk of buried material consisted of paper, plastic and wood items. Some metal items, such as pipes and buckets, have been buried, although no major metallic objects, except possibly a pickup truck, were disposed of.

These materials were buried in 40 pits, each approximately 20 feet by 40 feet by 12 feet deep. The individual pits were not marked or otherwise identified, although some can be located by ground settling. Each is covered by 2 to 5 feet of fill dirt. The pits were not lined or prepared in any way, nor were they capped with special materials. The soil is silty clay to a depth of approximately 30 feet, then gravel for about 10 feet to rock. Ground water ranges from depths of a few feet to 20 feet, depending on the season. Ground water flow is generally from the north to the south, possibly into Joachim Creek, which is about one-half mile from the site. The burial ground is an open grassy area with some apparent water runoff.

III. RADIOLOGICAL SURVEY METHODS

A) Measurement of External Radiation Levels

The burial site was gridded and surveyed for both gamma radiation levels at one meter above the ground surface and beta-gamma count rates at the ground surface.

Initially, precise exposure rate measurements at selected grid points were made with a high sensitivity Tissue Equivalent Ionization Chamber System, described in Appendix I. NaI(Tl) scintillation detector measurements were also made at these points, and a conversion factor for the NaI(Tl) count rate versus uR/hr was established. Once this factor was confirmed, the scintillation detector was used for all grid point measurements.

At each grid point, an end window G-M tube was used for surface measurements. Open and closed window readings were made at 1 cm and the ratio of the two used to indicate the presence or absence of surface contamination.

B) Measurement of Surface Radioactivity

Based on external measurements, surface soil samples were collected from locations where surface deposits were indicated, as well as locations where drainage characteristics indicated the possibility that radioactive materials may have been transported from their original burial locations. The samples were dried and sealed in 500 ml aluminum cans for counting on the intrinsic germanium (IG) gamma ray spectroscopy system described in Appendix I.

Sediment samples from Joachim Creek and the small creek east of the site were also collected and analyzed using the same method.

Onsite vegetation samples consisted of grasses which were located in areas where drainage and wind characteristics indicated the possibility that radioactive materials may have been transported from the original locations and deposited onto or taken up by vegetation.

C) Measurement of Subsurface Radioactivity

A series of holes through and bordering the burial site were drilled and lined with four-inch PVC casing. Each hole was logged at one-foot intervals using a one-inch by one-inch NaI(Tl) scintillation detector and scaler system. These preliminary measurements were used to indicate the locations and approximate magnitude of subsurface contamination. Selected holes were then logged using a specially designed IG detector coupled to a multi-channel analyzer system (see Appendix I). Soil layers with gamma count rates exceeding background rates, as measured with the NaI(Tl) detector, were logged at one-foot increments using the IG detector. Layers which did not exceed background were logged at two-foot increments.

D) Measurement of Radioactivity in Water

Whenever possible, water samples were taken from boreholes. Four permanent water monitoring wells were drilled to provide access to ground water flow through the burial site. These wells were located at points which intercept the ground water flow through the pit areas. Periodic samples were taken from these wells to measure any possible change in ground water radionuclide content. Samples were also taken from the two creeks near the burial area.

Water samples were filtered to remove suspended particulates, then 100 ml aliquots were evaporated in planchetts and counted for gross alpha and beta activity. All samples which showed gross activities greater then EPA drinking water standards were sealed in Marinelli beakers and counted using the gamma spectroscopic analysis system.

E) Measurement of Airborne Radioactivity

High volume air particulate samples were taken to measure long lived activities. These samples were counted for gross alpha and beta activity using a low background gas flow proportional counter with methods described in Appendix I.

F) Measurement of Radioactivity in Vegetation

Samples of vegetation were collected, dried, crushed and counted for gamma activity. These samples consisted only of grass, weeds and other common, non-edible vegetation.

Environmental sampling and measurements were performed to document the background radiological characteristics of offsite areas surrounding the CE plant. A summary of these measurements and analysis results is shown in Table 9.

IV. RADIOLOGICAL SURVEY RESULTS

A) External Radiation Levels

Results of the external radiation surveys are listed in Table 1 and shown in Fig. 3. As can be seen, the only detectable levels above normal background were found in the northwest corner of the burial site, adjacent to the facility security fence. It was readily determined that these elevated levels (>20 uR/hr) were due to sources onsite, rather than buried material, because containers of UF6 are routinely stored near the designated fence line in the security area. The survey results show that levels increase as one approaches these containers, confirming that the source is primarily the UF6 containers, rather than material in the burial site. The beta-gamma count rates verify the absence of measurable surface contamination.

The negative findings are not unexpected since it is known that only small quantities of U-235, U-234 and U-238 have been disposed of. The absence of detectable exposure levels indicates that little or no thorium wastes are present near the ground surface.

B) Surface Soil Analyses

A total of 11 surface soil samples were gathered from the burial site. In addition, five stream sediment samples were taken, two from the small creek bordering the burial site on the east, and three from Joachim Creek. All samples were dried, sealed and counted on the gamma spectroscopy system. Samples were analyzed for gamma spectra from U-238, U-235, K-40 and radium daughters.

The locations of the surface soil samples are shown in Fig. 4 and the analytical results in Table 2. Radionuclide concentrations in all creek sediment samples were indistinguishable from normal background concentrations, and were often within the lower limits of detection of the counting system used.

Several samples from the burial site surface showed measurable uranium activities, ranging from 1.7 to 4.9 pCi/g for U-238 and 0.6 to 1.1 pCi/g for U-235. U-234 activities were estimated to range from 2 to 47 pCi/g. In each case but one, a positive U-238 finding corresponded to a positive U-235 value (and an estimated positive U-234 value). For all samples, the radium daughter and K-40 activities were relatively constant. Although the uranium activities are slightly above background in some cases, they do not exceed NRC target criteria for contaminants in soil. (NRC target criteria for concentration limits and measurement lower limits of detection are summarized in Table 10.)

The source of this apparent low level surface contamination is not clear. While it is possible that the contamination is a result of burial activities, it is also possible that it resulted from past effluent (i.e. stack) releases. In either case, these surface activities seem to be a result of facility operations rather than unusually high naturally occurring radionuclides because no corresponding uranium daughter activities can be found.

C. Subsurface Soil Analysis

Subsurface contamination was assessed by extensive logging of holes drilled through and around the burial site, using both a one-inch by one-inch NaI(Tl) detector and an intrinsic germanium (IG) detector. A total of 14 holes were drilled on the site, 10 of which were lined with 4 inch PVC casing for logging. The other 4 were lined with 2 inch slotted casing, for use as water sampling wells. Fig. 5 shows the location of all holes drilled at the site. For three of these (holes 5, 7 and 11), cores were taken during drilling activities. Each core was dried and counted in a manner identical to the surface soil procedure. In addition, four core samples were sent to the RMC Analytical Laboratories for duplicate gamma spectral analysis and uranium determinations using alpha spectroscopy.

Each borehole was logged with the NaI(Tl) detector to identify areas of increased gross activity, then with the IG detector at selected locations, to quantify and qualify these increases. Each IG measurement was designed to determine the concentrations of U-238, U-235, Th-232 by its daughter Pb-212, and Ra-226 by its daughter Pb-214.

The results of the onsite core sample analyses are presented in Table 3. In general, concentrations are consistent with normal background levels, and are well within all target criteria. However, several samples from bore hole 7 showed slightly elevated U-235 and U-238 activities, without a corresponding increase in radium daughters, indicating the presence of facility waste material.

Table 4 contains the bore hole logging results. Elevated gross count rates, as detected by the NaI(Tl) detector, are present in boreholes 1 and 6, while increased U-235 and/or U-238 concentrations, as measured by the IG detector, are found in boreholes 6, 7 and 13 (boreholes 1 and 14 were not logged with the IG).

The isotopes shown in Table 4 were identified by measuring the following photopeaks: 93 keV for U-238, 186 keV for U-235 (corrected for estimated Ra-226 contribution), 239 keV for Pb-212 and 352 keV for Pb-214. Plots of spectral data for borehole 4, 2 foot depth, and borehole 6, 4 foot depth, are shown in Figs. 6 and 7 respectively, and demonstrate the ease with which these photopeaks can be identified, even at relatively low concentrations.

The highest concentrations were measured in borehole 6, where levels as high as 21 pCi/g U-235 and 38 pCi/g U-238 were recorded. U-234 concentrations were estimated to be as high as 400 pCi/g. Concentrations in boreholes 7 and 13 did not exceed 1 pCi/g U-235 and 14 pCi/g U-238. All levels, except the 38 pCi/g U-238 concentration, are within the NRC target criteria shown in Table 10. There were no elevated concentrations in the perimeter boreholes in the general direction of ground water flow (boreholes 8 and 11), nor were there elevated levels in other boreholes onsite which are believed to have been drilled directly through burial pits.

A set of core samples was sent to the RMC Analytical Laboratories for analysis and compared with onsite measurements. Results are presented in Table 5 and show general agreement except for the U-238 values. For this nuclide, the _in situ_ measurements gave consistently higher values than core sample analysis. The cause of this apparent systematic error has not been determined, and U-238 results for borehole measurements have not been reported, except in the case where gross NaI(Tl) counts are above background or where positive U-235 results are reported. All U-234 determinations were done at the RMC Analytical Laboratories using alpha spectroscopy since this nuclide could not be detected using field measurement techniques. Ratios of U-234/U-238 and U-235/U-238 by weight were found to have similar enrichment (or depletion) factors. These factors were used to estimate U-234 concentrations in surface and subsurface soils. Uranium isotopic determinations by alpha spectroscopy are shown in Table 5. Based on all the data, the average enrichment is estimated to be about 4%. Using this enrichment factor, an activity ratio for U-234 to U-238 of 10 is assumed.

D) Analyses of Radioactivity in Water

A total of 22 water samples were collected (Fig. 8), 11 from the water monitoring wells installed for this project (boreholes 2, 3, 9 and 12), 3 from other boreholes onsite, 2 from standing water and 6 from creek water.

A 100 ml aliquot from each sample was filtered, evaporated on a planchett and counted 100 minutes for gross alpha and beta activities. Results are listed in Table 6. Only one sample, taken from borehole 1, showed gross alpha activity exceeding the EPA interim primary drinking water limit for drinking water (15 pCi/l gross alpha). This sample was further analyzed for isotopic content, and found to contain elevated (i.e. above background level) U-238 and Th-232 concentrations as shown in Table 7.

Gross beta activity exceeding 50 pCi/l was found in five different samples, three of which came from borehole 9, which was located approximately 200 feet east of Combustion Engineering's settling ponds. The other two also came from onsite sampling locations. Further analysis of these samples indicates that the high gross beta levels are due in part to K-40. These samples also show elevated U-238, U-235 and Th-232 concentrations.

E) Airborne Radioactivity Measurements

A set of high volume air samples was collected in the vicinity of the burial site. The results are listed in Table 8, and show no unusual or elevated levels. These results are expected, because it is known that the buried material is not likely to be a source of airborne emissions, due to the absence of daughter activity which could produce gaseous emanations (radon).

F) Radioactivity in Vegetation

Several vegetation samples, from onsite and offsite locations, were analyzed on the gamma spectroscopy system. No unusual activity was found in any sample.

V. CONCLUSIONS

The results of this survey confirm that small quantities of uranium have been buried in the pits adjacent to the Combustion Engineering plant in Hematite, Missouri. Analysis of borehole activity and soil samples taken from the burial pits showed slightly elevated levels of U-235 and/or U-238 in some measurements, and only naturally occurring background activity in all others. The highest level measured during this survey was 38 pCi/g of U-238, which was the only measurement that exceeded the target criteria of 30 pCi/g U-238 or U-235. It can be assumed that elevated U-234 concentrations are also present, prehaps as high as 400 pCi/g. These measurements tend to confirm that generally only low level contaminated materials and equipment were disposed of in these pits.

These survey results also indicate the difficulty in trying to determine specific locations of buried contamination. This material cannot be located through past records because specific burial records were apparently not maintained, nor were individual burial pits marked or otherwise identified. In addition, the absence of uranium daughters (radium and daughters) makes it essentially impossible to locate low level contaminated buried material with surface measurement techniques.

The overall conclusions are that relatively small quantities of uranium have been buried and that the buried material is essentially stable at this time. The burial pits have little or no effect on the population or the surrounding environment.

REFERENCES

[1] U. S. Nuclear Regulatory Commission Letter Contract: NRC-02-80-034, 13 Aug 1980.

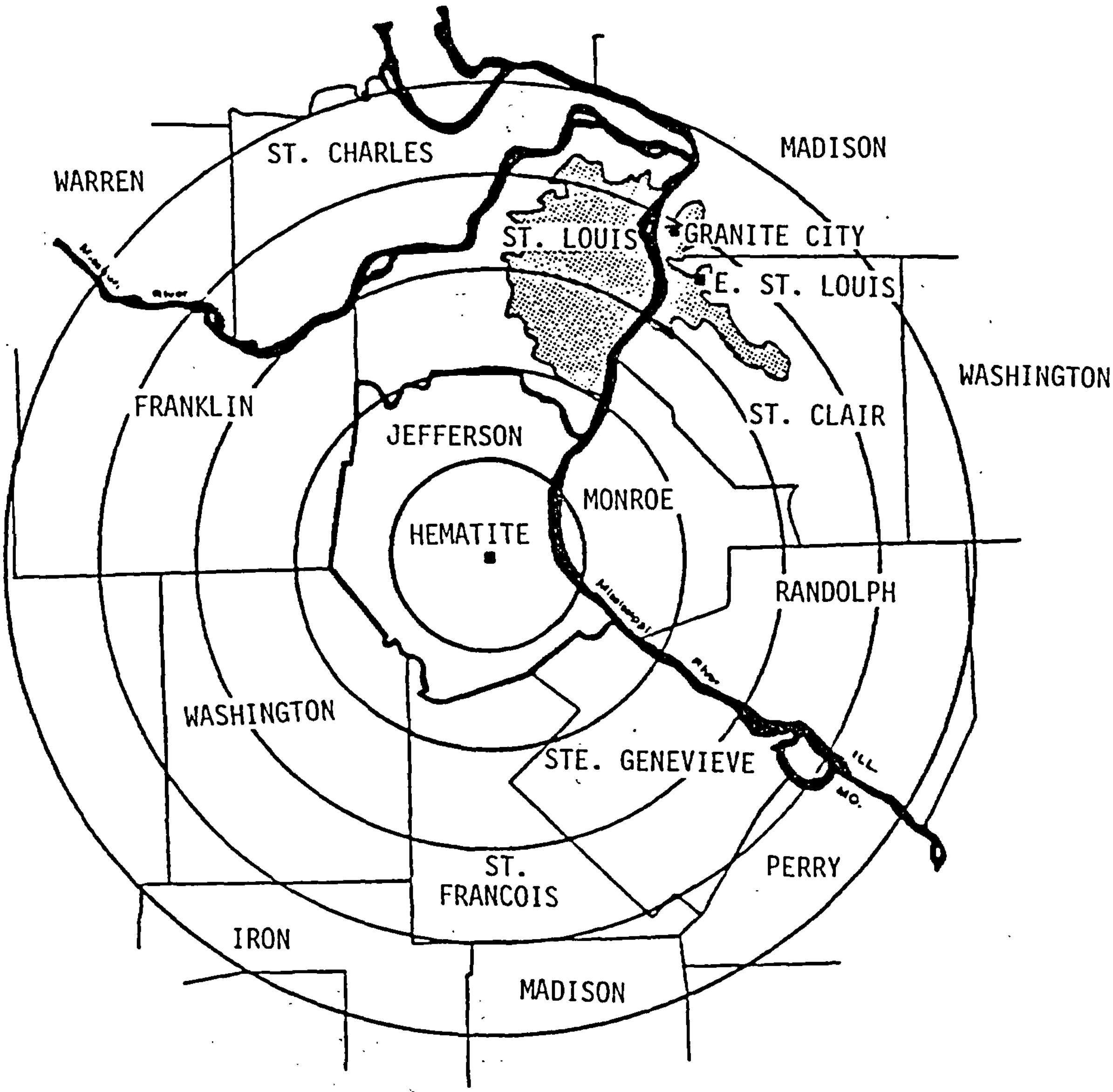


Fig. 1. Location of Combustion Engineering Facility, Hematite, Missouri

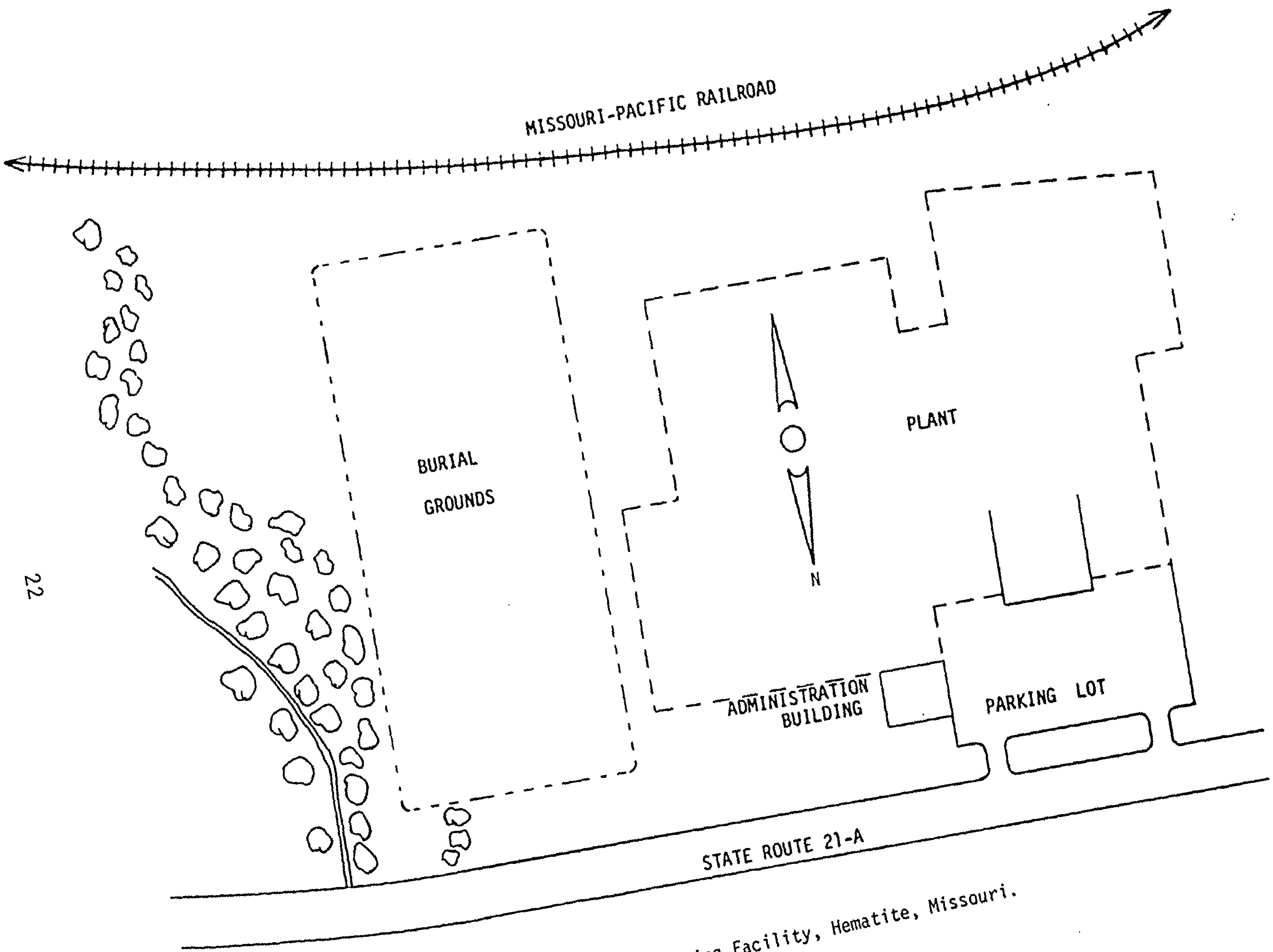


Fig. 2. Burial site at Combustion Engineering Facility, Hematite, Missouri.

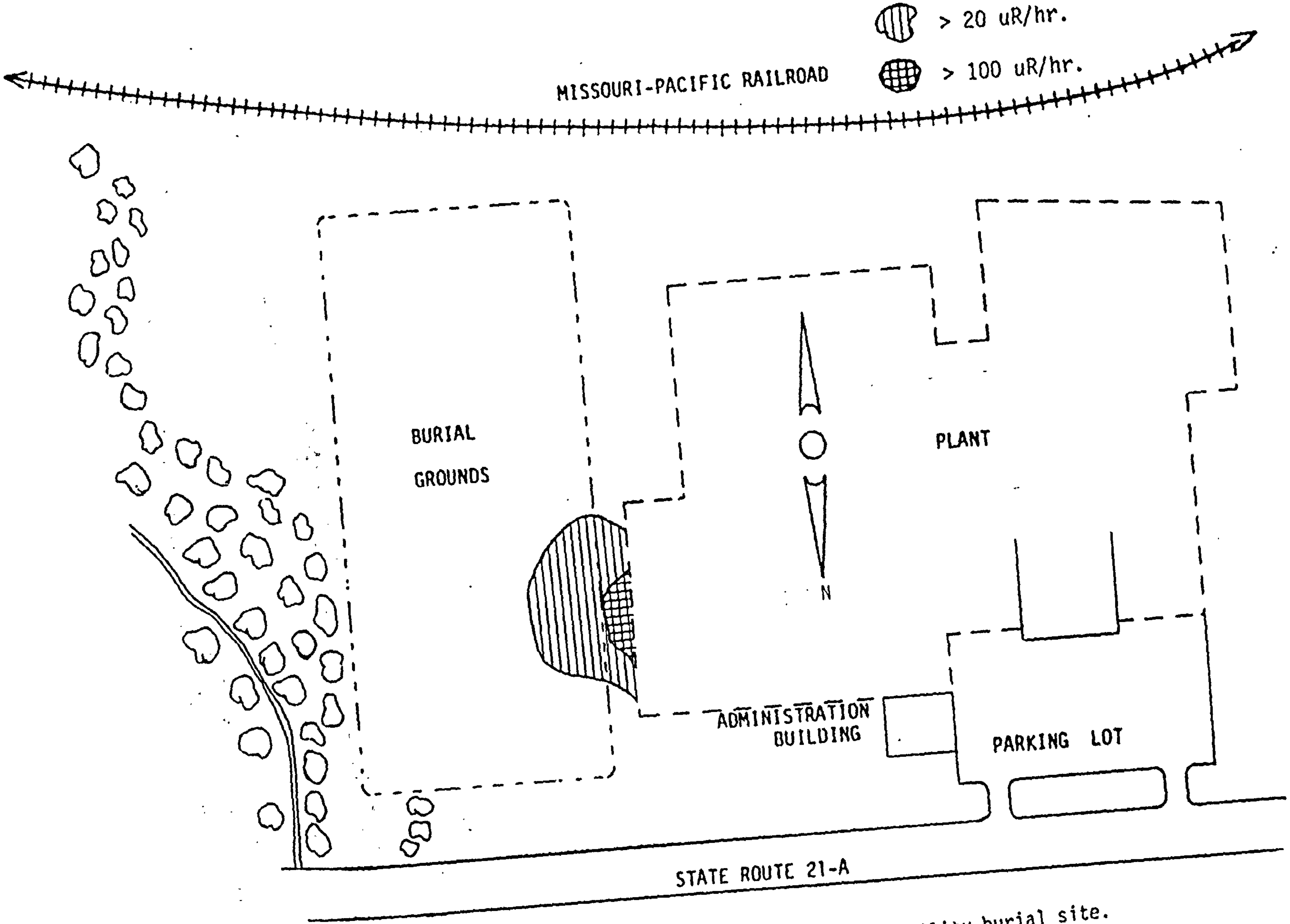


Fig. 3. External exposure rates in μR/hr, Combustion Engineering Facility burial site.

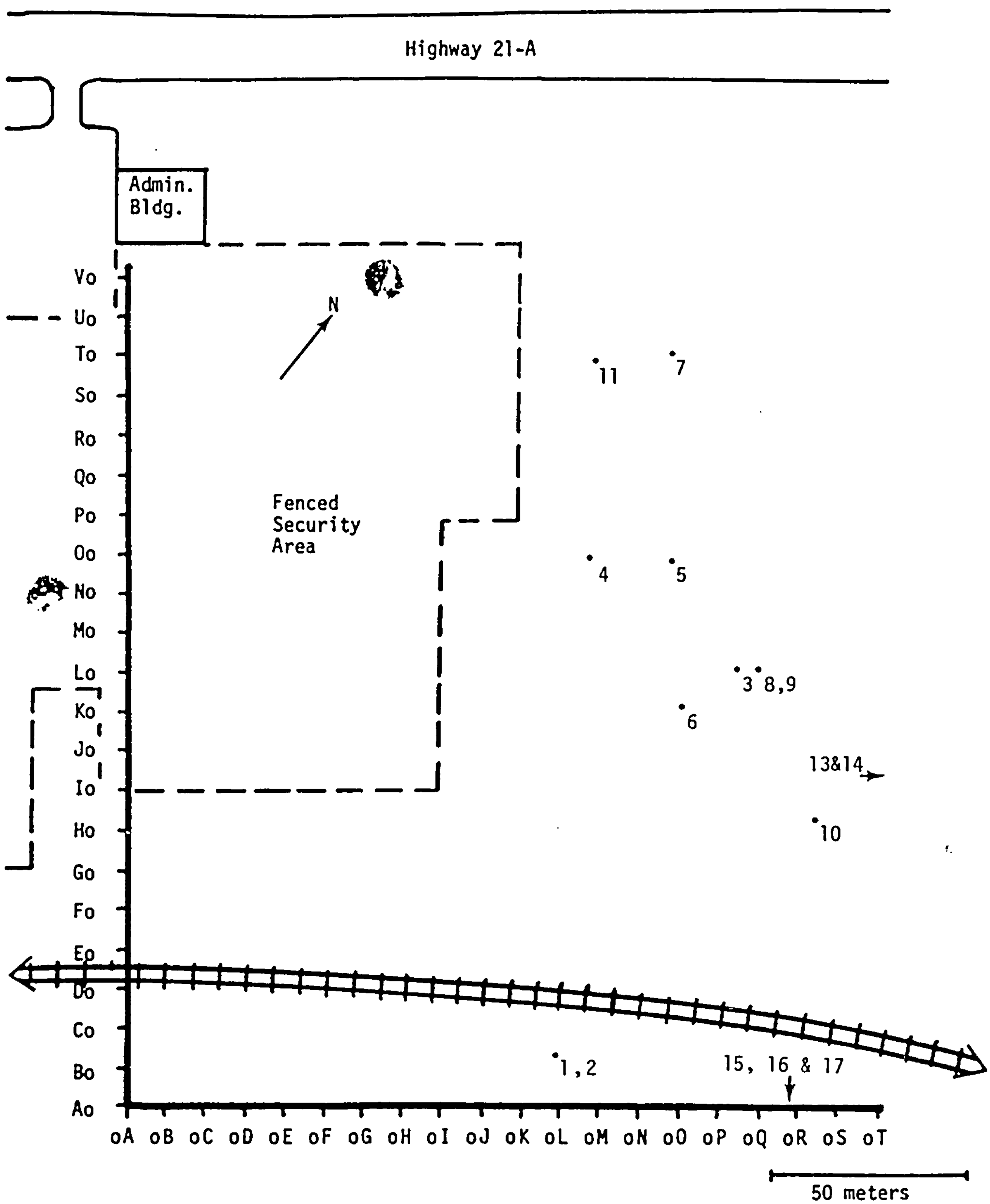


Fig. 4. Locations of surface soil samples. Samples 13 and 14 are sediments from the creek on the east border of the burial site. Samples 15, 16 and 17 are sediments from Joachim Creek.

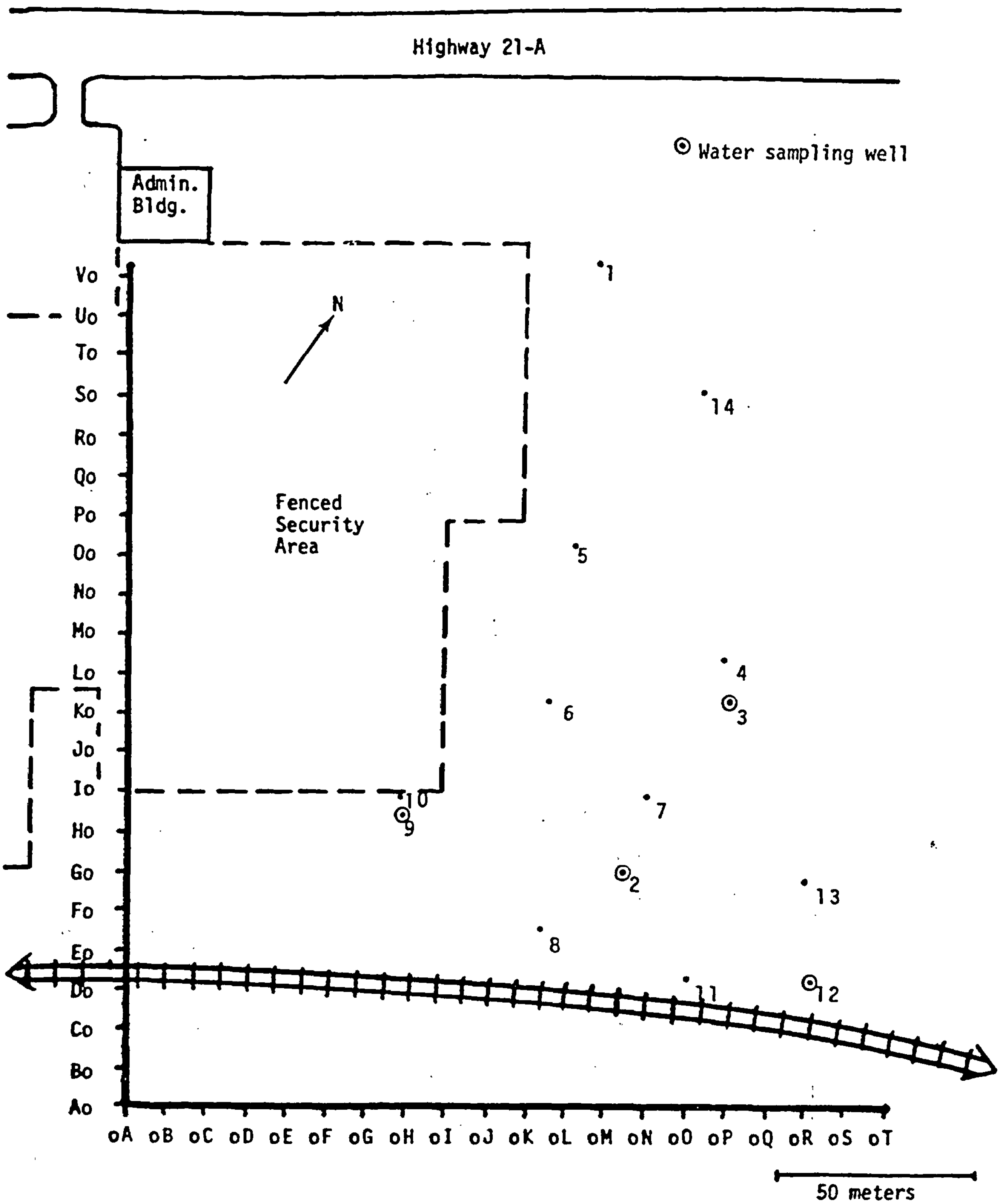


Fig. 5. Location of boreholes used for subsurface logging and water sampling.

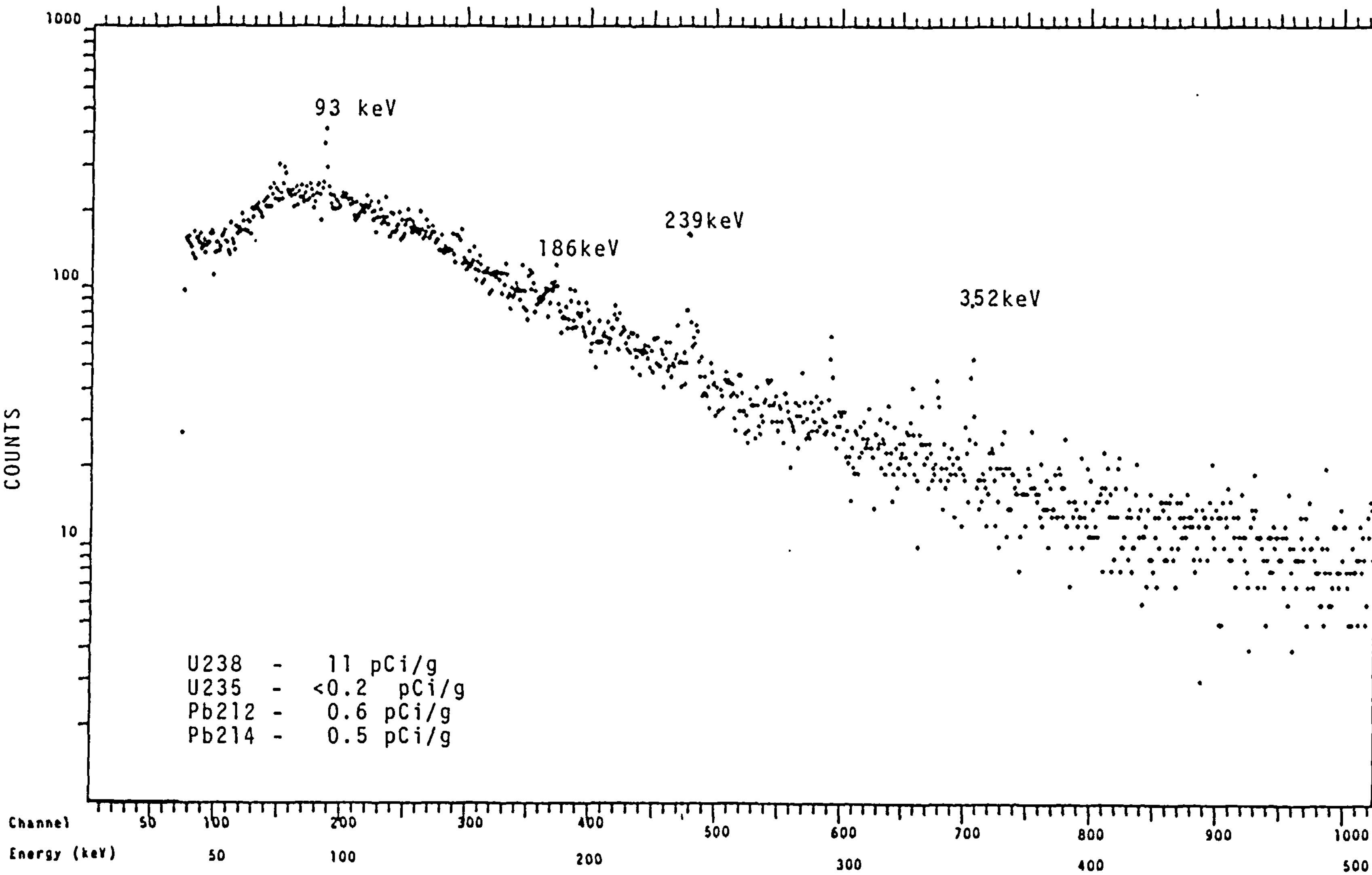


Fig. 6. *In situ* gamma spectrum at the 2 foot depth at borehole 4, using the IG detector and a 10 minute count.

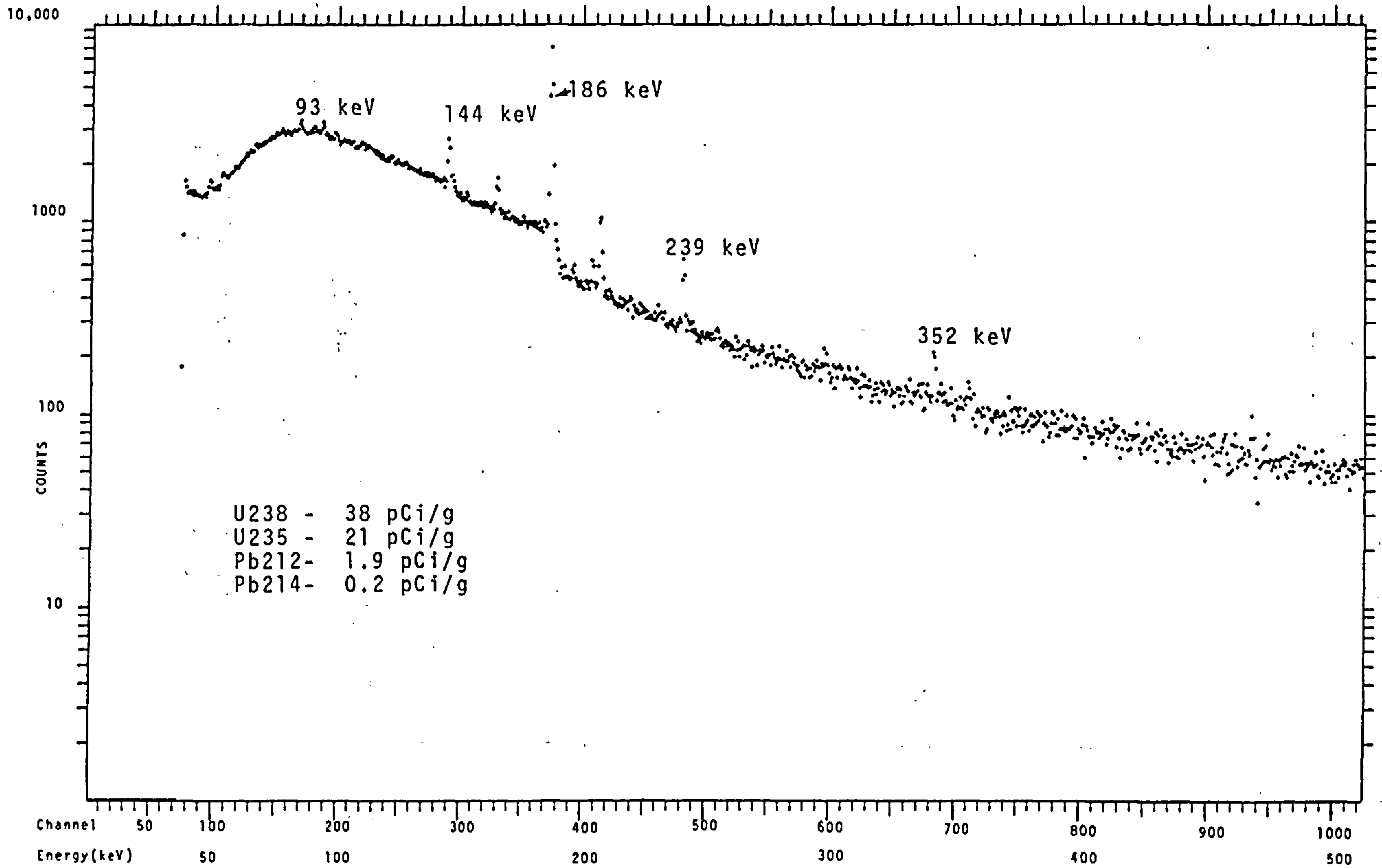


Fig. 7. _In situ_ gamma spectrum at the 4 foot depth in borehole 6, using the IG detector and a 10 minute count.

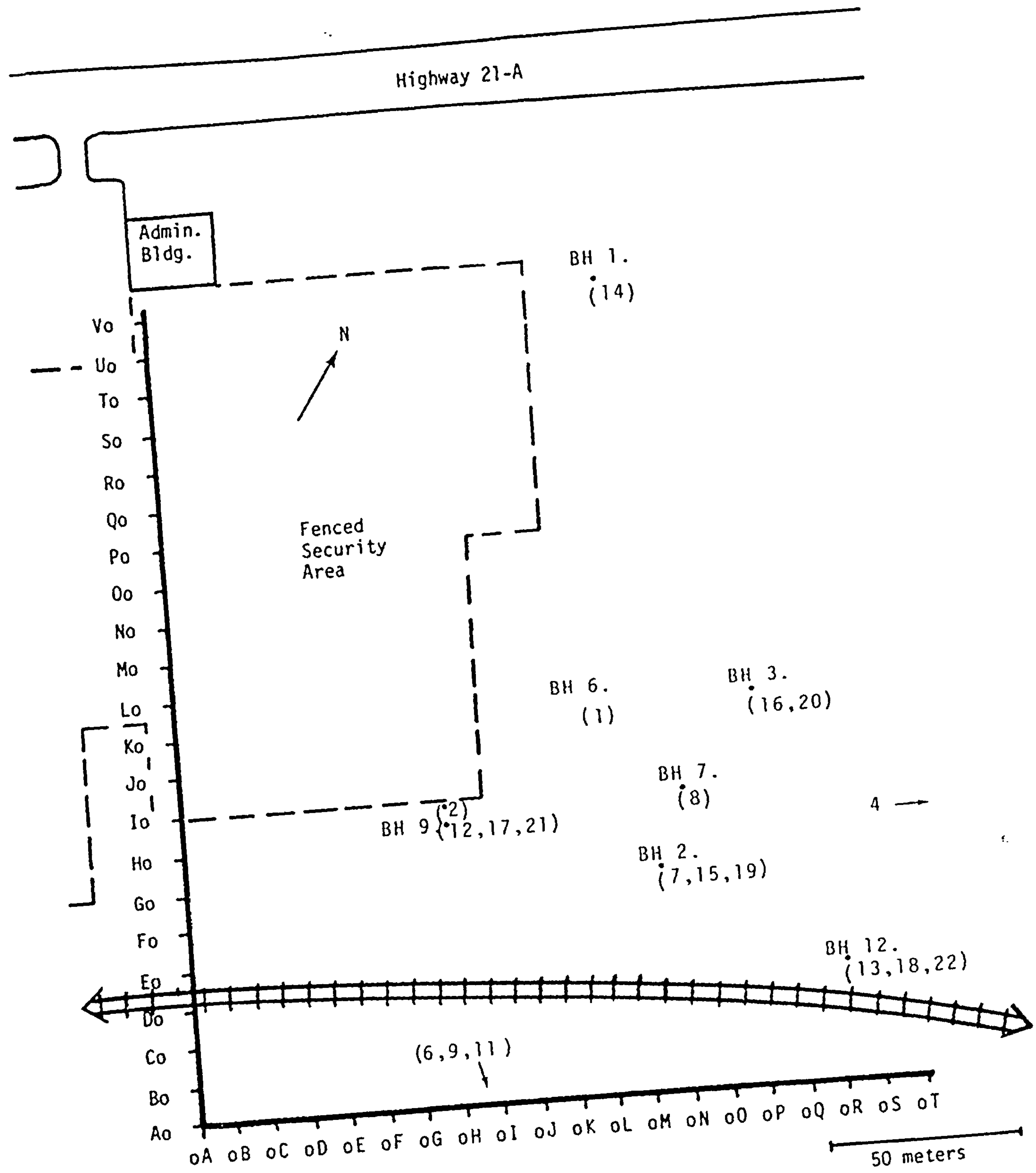


Fig. 8. Location of water samples. Sample numbers listed in Table 6 are shown in parentheses.

Table 1

Gamma radiation levels and beta-gamma count rates at grid locations

Grid Location	NaI Count Rate (c/min)	Exposure Rate (uR/hr)	Beta-Gamma Count Rate, closed window (c/min)	Beta-Gamma Count Rate, open window (c/min)
G00K	1700	9	40	70
G00L	1700	9	50	50
G00M	1800	10	50	40
G00N	1600	9	50	40
G000	1700	9	30	40
G00P	1900	10	50	40
G00Q	1700	9	30	50
H00K	1700	9	30	40
H00L	1700	9	40	50
H00M	1700	9	40	20
H00N	1700	9	30	40
H000	1800	10	30	30
H00P	1700	9	60	40
H00Q	1500	8	30	40
I00K	1700	9	50	50
I00L	1700	9	40	60
I00M	1800	10	30	50
I00N	1700	9	70	50
I000	1600	9	50	40
I00P	1800	10	40	50
I00Q	1600	9	40	40
J00K	1500	8	50	50
J00L	1800	10	40	50
J00M	1700	9	70	60
J00N	1800	10	60	60
J000	1700	9	70	60
J00P	1800	10	60	40
J00Q	1600	9	60	40
K00K	1700	9	40	40
K00L	1600	9	30	60
K00M	1700	9	50	60
K00N	1900	10	70	60
K000	1800	10	40	50
K00P	1800	10	50	50
K00Q	1900	10	50	70
L00K	1700	9	70	50
L00L	1900	10	40	60
L00M	1800	10	60	60
L00N	1900	10	50	50
L000	1800	10	60	50
L00P	1900	10	40	60
M00K	1700	9	50	70
M00L	2000	11	60	80
M00M	2100	12	30	60
M00N	2000	11	50	60

Table 1, cont.

Grid Location	NaI Count Rate (c/min)	Exposure Rate (uR/hr)	Beta-Gamma Count Rate, closed window (c/min)	Beta-Gamma Count Rate, open window (c/min)
M00O	2000	11	40	60
M00P	1800	10	40	80
N00K	1800	10	80	100
N00L	2300	13	70	90
N00M	2100	12	60	110
N00N	2100	12	40	60
N00O	1800	10	70	60
N00P	1500	8	50	70
O00K	2100	12	90	70
O00L	2400	14	70	80
O00M	2300	13	60	70
O00N	2500	14	70	110
O00O	1800	10	70	70
P00K	2000	11	40	60
P00L	3200	17	80	100
P00M	2700	14	90	100
P00N	2800	15	80	100
P00O	2200	12	70	70
Q00K	4100	22	50	60
Q00L	5000	26	60	90
Q00M	3800	20	60	100
Q00N	3000	15	50	80
Q00O	2600	13	80	50
R00K	4500	23	100	140
R00L	11000	56	140	130
R00M	5000	26	110	80
R00N	3500	18	60	50
R00O	2600	13	40	70
S00K	50000	256	360	320
S00L	13000	67	110	90
S00M	6000	31	100	140
S00N	3800	20	90	110
S00O	2800	14	80	80
T00K	45000	231	530	490
T00L	12000	62	120	150
T00M	5000	26	100	110
T00N	3700	19	80	90
T00O	2700	14	90	100
U00K	17000	87	80	100
U00L	8000	41	90	90
U00M	4000	21	80	60
U00N	3500	18	70	60
U00O	2500	13	90	110
U00K	5000	26	130	110
U00L	3500	18	70	80
U00M	3500	18	60	80
U00N	3000	15	80	100
U00O	2300	12	90	70

Table 2

Surface soil sample radionuclide concentrations (pCi/g +/- % counting error) by gamma analysis

Sample #	Sample Location	Mass (g)	U-238	U-235	Ac-228	Pb-212	Pb-214	Bi-214	K-40
1	B50L	210	1.4E0+/-110	7.5E-2+/-200	7.7E-1+/-67	3.4E-1+/-49	8.2E-1+/-44	2.2E-1+/-110	6.3E0+/-42
2	B50L	299	1.2E0+/-110	2.7E-2+/-380	7.5E-1+/-63	5.9E-1+/-30	9.7E-1+/-35	5.9E-1+/-46	8.5E0+/-34
3	L55P	315	3.1E-1+/-330	8.6E-2+/-130	4.9E-1+/-90	6.0E-1+/-29	8.9E-1+/-36	5.9E-1+/-44	1.2E1+/-28
4	000M	224	3.1E0+/-60	6.8E-1+/-89	6.4E-1+/-80	6.6E-1+/-30	8.1E-1+/-44	4.5E-1+/-74	1.2E1+/-27
5	0000	267	1.7E0+/-85	5.6E-1+/-71	3.0E-1+/-110	6.3E-1+/-26	8.EE-1+/-39	4.4E-1+/-53	6.5E0+/-35
6	K310	224	4.9E0+/-39	1.1E0+/-71	5.7E-1+/-81	3.7E-1+/-47	8.5E-1+/-41	4.4E-1+/-59	9.0E0+/-32
7	T000	176	3.0E0+/-72	9.4E-1+/-110	7.9E-1+/-75	7.8E-1+/-29	1.1E0+/-44	3.1E-1+/-99	6.5E0+/-45
8	L50Q	266	3.8E-1+/-330	1.0E-1+/-110	5.7E-1+/-73	4.9E-1+/-33	9.4E-1+/-35	6.2E-1+/-42	5.5E0+/-42
9	L50Q	228	7.1E-1+/-210	8.5E-2+/-150	5.2E-1+/-90	4.8E-1+/-37	1.2E0+/-32	6.0E-1+/-47	1.0E1+/-30
10	H55R	319	7.8E-1+/-170	6.72-2+/-170	3.5E-1+/-120	6.7E-1+/-27	1.2E0+/-29	4.4E-1+/-57	1.1E1+/-28
11	T00M	148	3.3E0+/-78	6.7E-1+/-97	6.2E-1+/-100	4.7E-1+/-51	5.7E-1+/-79	9.3E-1+/-45	9.9E0+/-38
12	Offsite Bkg	174	3.6E-1+/-460	1.5E-1+/-130	1.1E-1+/-330	2.4E-1+/-70	8.5E-1+/-48	4.9E-1+/-65	8.7E0+/-37
13	Small creek upstream	303	3.2E-1+/-370	7.7E-3+/-1200	8.0E-1+/-61	4.3E-1+/-37	5.6E-1+/-51	4.7E-1+/-55	4.1E0+/-58
14	Small creek downstream	320	4.0E-1+/-280	4.3E-3+/-2000	6.1E-1+/-71	1.9E-1+/-66	4.7E-1+/-57	2.9E-1+/-73	1.4E0+/-130
15	Joachim Creek upstream	256	2.4E-1+/-480	3.9E-2+/-250	2.3E-1+/-150	9.9E-2+/-130	2.9E-1+/-90	7.6E-2+/-250	2.6E0+/-72
16	Joachim Creek downstream	234	3.0E-2+/-3800	3.1E-2+/-320	1.2E-1+/-280	2.4E-1+/-66	4.2E-1+/-66	1.9E-1+/-110	5.3E0+/-41
17	Joachim Creek midstream	272	4.2E-1+/-290	6.2E-3+/-1400	1.5E-1+/-220	2.7E-1+/-49	5.9E-1+/-84	2.3E-1+/-84	1.6E0+/-90

Table 3

Soil core sample radionuclide concentrations
(pCi/g +/- % counting error), by gamma analysis

Borehole #5

Depth (ft)	Mass (g)	U-238	U-235	Ac-228	Pb-212	Pb-214	Bi-214	K-40
0	217	7.7E-1+/-200%	1.2E-1+/-120%	1.9E-1+/-220%	5.6E-1+/-36%	1.0E0+/-39%	7.0E-1+/-42%	9.9E0+/-31%
1	277	9.9E-1+/-130%	4.1E-2+/-220%	6.1E-1+/-75%	5.0E-1+/-32%	9.7E-1+/-33%	6.3E-1+/-46%	1.1E1+/-26%
2	326	1.1E0+/-110%	4.6E-2+/-210%	8.4E-1+/-56%	7.0E-1+/-25%	7.1E-1+/-42%	6.3E-1+/-40%	1.1E1+/-28%
3	229	4.1E-1+/-360%	2.4E-2+/-430%	8.2E-1+/-62%	4.8E-1+/-38%	1.1E0+/-35%	6.7E-1+/-45%	8.6E0+/-34%
4	232	6.3E-1+/-200%	-2.2E-2+/-500%	4.2E-1+/-110%	5.0E-1+/-37%	1.4E0+/-29%	7.4E-1+/-41%	8.5E0+/-34%
5	248	5.6E-1+/-260%	-2.6E-3+/-3800%	5.7E-1+/-79%	6.4E-1+/-28%	1.1E6+/-33%	8.5E-1+/-34%	1.2E1+/-26%
6	284	9.7E-1+/-150%	5.2E-2+/-220%	1.5E0+/-42%	8.0E-1+/-27%	9.8E-1+/-37%	8.0E-1+/-39%	1.3E1+/-27%
7	247	9.2E-1+/-160%	1.2E-2+/-680%	1.1E0+/-46%	5.8E-1+/-31%	9.5E-1+/-37%	5.3E-1+/-47%	1.1E1+/-27%
8	262	4.8E-1+/-260%	3.9E-2+/-260%	5.9E-1+/-74%	6.2E-1+/-28%	1.1E0+/-32%	8.3E-1+/-34%	8.5E0+/-31%
9	256	8.8E-1+/-150%	3.1E-2+/-320%	6.0E-1+/-74%	5.9E1+/-30%	1.3E0+/-29%	8.4E-1+/-35%	1.0E1+/-28%
10	218	1.8E0+/-98%	3.5E-2+/-280%	6.5E-1+/-79%	8.6E-1+/-26%	9.2E-1+/-43%	8.1E-1+/-40%	1.2E1+/-29%
11	232	1.3E0+/-130%	6.0E-2+/-180%	7.2E-1+/-72%	8.8E-1+/-24%	1.1E0+/-35%	5.9E-1+/-47%	8.5E0+/-33%
12	251	3.3E-1+/-430%	1.2E-1+/-100%	7.0E-1+/-65%	4.4E-1+/-36%	9.9E-1+/-35%	5.5E-1+/-50%	1.0E1+/-28%
13	209	1.6E0+/-110%	6.0E-2+/-210%	9.6E-1+/-37%	5.3E-1+/-24%	2.1E0+/-24%	1.2E0+/-31%	1.1E1+/-29%

Borehole #7

Depth (ft)	Mass (g)	U-238	U-235	Ac-228	Pb-212	Pb-214	Bi-214	K-40
0	216	1.1E0+/-160%	2.6E-1+/-74%	1.4E-1+/-290%	5.3E-1+/-36%	-5.3E-1+/-33%	6.3E-1+/-49%	9.7E0+/-33%
1	252	1.3E0+/-110%	9.4E-1+/-130%	6.6E-1+/-71%	8.3E-1+/-23%	1.2E0+/-30%	5.2E-1+/-50%	6.9E0+/-36%
2	199	2.4E0+/-78%	8.4E-2+/-170%	8.9E-1+/-67%	9.1E-1+/-25%	1.2E0+/-37%	5.9E-1+/-53%	9.2E0+/-35%
3	236	2.1E0+/-77%	2.6E-1+/-74%	6.6E-1+/-77%	4.4E-1+/-41%	9.2E-1+/-38%	7.8E-1+/-38%	1.2E1+/-27%
4	222	1.4E0+/-120%	3.1E-1+/-76%	3.4E-1+/-140%	5.8E-1+/-33%	1.0E0+/-37%	5.3E-1+/-50%	1.1E1+/-30%
8	219	3.0E0+/-61%	1.4E0+/-64%	7.0E-1+/-76%	8.1E-1+/-43%	8.7E-1+/-43%	6.7E-1+/-45%	1.3E1+/-26%
9	249	1.1E0+/-120%	4.0E-1+/-66%	9.0E-1+/-56%	6.0E-1+/-29%	9.2E-1+/-37%	6.2E-1+/-43%	9.3E0+/-30%
10	225	1.5E0+/-120%	7.5E-1+/-67%	6.3E-1+/-79%	5.9E-1+/-31%	9.9E-1+/-38%	5.5E-1+/-50%	1.2E1+/-28%
11	211	1.4E0+/-120%	9.8E-2+/-130%	5.6E-1+/-91%	6.4E-1+/-32%	1.2E0+/-44%	7.1E-1+/-44%	9.5E0+/-32%

Table 3, cont.

Borehole #11

Depth (ft)	Mass (g)	U-238	U-235	Ac-228	Pb-212	Pb-214	Bi-214	K-40
0	175	4.6E-1+/-360%	6.8E-2+/-220%	6.5E-1+/-33%	6.9E-1+/-33%	1.3E0+/-39%	5.3E-1+/-63%	1.1E1+/-35%
1	254	9.6E-1+/-140%	1.4E-2+/-700%	6.9E-1+/-27%	6.5E-1+/-27%	7.5E-1+/-41%	6.6E-1+/-41%	9.0E0+/-31%
2	240	1.0E0+/-140%	1.7E-1+/-120%	5.0E-1+/-91%	4.2E-1+/-41%	5.3E-1+/-62%	3.3E-1+/-75%	6.1E0+/-42%
3	245	1.1E0+/-140%	1.1E-2+/-800%	4.9E-1+/-91%	6.6E-1+/-28%	1.1E0+/-34%	8.3E-1+/-37%	1.3E1+/-25%
4	235	1.2E0+/-130%	9.2E-2+/-120%	2.5E-1+/-150%	2.0E-1+/-83%	8.4E-1+/-42%	2.5E-1+/-100%	5.1E0+/-50%
5	212	2.3E-1+/-580%	1.9E-1+/-110%	3.2E-1+/-120%	3.8E-1+/-49%	5.8E-1+/-60%	3.8E-1+/-75%	6.3E0+/-44%
6	232	1.2E0+/-140%	1.4E-2+/-750%	6.0E-1+/-76%	6.2E-1+/-28%	8.3E-1+/-44%	4.5E-1+/-58%	1.0E1+/-31%
7	246	8.9E-1+/-160%	1.1E-2+/-770%	7.2E-1+/-68%	6.2E-1+/-29%	7.9E-1+/-42%	5.5E-1+/-49%	1.3E1+/-25%
8	263	3.0E0+/-47%	1.0E-2+/-630%	9.4E-1+/-52%	8.6E-1+/-22%	8.2E-1+/-41%	5.8E-1+/-44%	9.7E0+/-30%
9	249	3.2E-2+/-4000%	2.0E-2+/-440%	2.5E-1+/-150%	2.4E-1+/-66%	2.0E-1+/-120%	2.9E-1+/-77%	3.5E0+/-57%
10	279	7.6E-1+/-170%	6.4E-2+/-130%	1.5E-1+/-220%	3.0E-1+/-44%	4.8E-1+/-58%	5.4E-1+/-47%	5.3E0+/-44%
11	272	1.6E0+/-84%	1.2E-2+/-570%	1.1E0+/-47%	4.9E-1+/-32%	1.3E0+/-27%	4.1E-1+/-57%	7.4E0+/-33%
12	283	7.3E-2+/-1900%	6.8E-2+/-160%	1.6E0+/-39%	7.2E-1+/-29%	8.4E-1+/-42%	7.2E-1+/-42%	1.3E1+/-27%
13	278	1.7E0+/-78%	1.1E-2+/-760%	1.0E0+/-48%	5.3E-1+/-30%	9.3E-1+/-35%	6.0E-1+/-41%	1.2E1+/-25%
14	296	8.2E-1+/-170%	2.4E-2+/-410%	1.0E0+/-52%	6.6E-1+/-30%	1.0E0+/-34%	6.9E-1+/-42%	1.2E1+/-28%

Table 4

Borehole NaI counts and IG analysis (pCi/g +/- counting error)

Borehole #1

Depth	Gross NaI Counts/Min	U-235	U-238	Pb-212	Pb-214
0	3.47E3+/-2%				
2	3.24E3+/-2%				
4	3.24E3+/-2%				
6	4.92E3+/-2%				
7	1.15E4+/-2%				
8	3.61E3+/-2%				
10	3.03E3+/-2%				
12	3.25E3+/-2%				
14	3.34E3+/-2%				
16	3.08E3+/-2%				
18	3.29E3+/-2%				

Borehole #4

Depth	Gross NaI Counts/Min	U-235	U-238	Pb-212	Pb-214
0	2.5E3+/-2%	1.0E-1+/-45%	-----------	3.5E-1+/-17%	5.3E-1+/-21%
2	3.1E3+/-2%	1.8E-2+/-29%	-----------	5.6E-1+/-12%	4.8E-1+/-17%
4	3.3E3+/-2%	4.5E-3+/-440%	-----------	6.1E-1+/-11%	6.0E-1+/-12%
6	3.5E3+/-2%	9.8E-3+/-497%	-----------	6.1E-1+/-11%	6.9E-1+/-10%
8	3.3E3+/-2%	1.1E-1+/-42%	-----------	3.1E-1+/-18%	8.6E-1+/-8%
10	3.3E3+/-2%	1.0E-1+/-43%	-----------	6.1E-1+/-12%	1.1E0+/-7%
12	3.2E3+/-2%	5.9E-2+/-373%	-----------	6.5E-1+/-10%	8.6E-1+/-11%
14	3.1E3+/-2%	3.0E-2+/-600%	-----------	7.7E-1+/-8%	7.4E-1+/-16%
16	3.2E3+/-2%	7.8E-2+/-112%	-----------	6.8E-1+/-10%	1.1E0+/-8%
18	3.1E3+/-2%	5.8E-2+/-81%	-----------	8.1E-1+/-8%	7.4E-1+/-10%

Table 4, cont.

Borehole #5

Depth	Gross NaI Counts/Min	U-235	U-238	Pb-212	Pb-214
0	3.83E+/-2%	1.5E-1+/-25%	-----------	6.8E-1+/-9%	6.7E-1+/-10%
2	3.0E3+/-2%	9.3E-2+/-49%	-----------	7.2E-1+/-9%	6.5E-1+/-11%
4	3.3E3+/-2%	1.2E-1+/-43%	-----------	5.8E-1+/-13%	7.8E-1+/-10%
6	3.3E3+/-2%	7.3E-2+/-177%	-----------	7.3E-1+/-9%	8.9E-1+/-8%
8	3.4E3+/-2%	5.5E-2+/-83%	-----------	5.2E-1+/-15%	6.3E-1+/-12%
10	3.4E3+/-2%	2.9E-2+/-161%	-----------	8.1E-1+/-9%	1.2E0+/-7%
12	3.5E3+/-2%	7.4E-3+/-63%	-----------	4.7E-1+/-14%	9.8E-1+/-8%
14	3.2E3+/-2%	3.6E-3+/-1250%	-----------	5.5E-1+/-12%	9.0E-1+/-8%
16	3.1E3+/-2%	7.5E-2+/-59%	-----------	5.5E-1+/-12%	1.0E0+/-6%

Borehole #6

Depth	Gross NaI Counts/Min	U-235	U-238	Pb-212	Pb-214
0	3.1E3+/-2%	1.4E0+/-4%	1.0E1+/-12%	6.7E-1+/-12%	3.9E-1+/-10%
1	3.3E3+/-2%	5.6E-1+/-9%	1.0E1+/-12%	5.6E-1+/-10%	8.1E-1+/-10%
2	3.6E3+/-2%	9.1E-1+/-6%	1.3E1+/-10%	6.1E-1+/-10%	5.3E-1+/-11%
3	3.8E3+/-2%	1.1E1+/-5%	8.3E0+/-18%	4.9E-1+/-16%	2.1E-1+/-17%
4	1.6E4+/-1%	2.1E1+/-1%	3.8E1+/-9%	1.9E0+/-8%	1.4E-1+/-32%
5	1.9E4+/-1%	5.4E0+/-2%	1.6E1+/-14%	5.7E-1+/-13%	4.7E-1+/-20%
6	6.8E3+/-1%	3.8E0+/-2%	1.9E1+/-8%	6.4E-1+/-11%	4.5E-1+/-13%
7	6.0E3+/-1%	4.1E0+/-2%	2.2E1+/-7%	7.2E-1+/-11%	7.6E-1+/-12%
8	5.1E3+/-1%	2.4E0+/-3%	1.5E1+/-10%	6.2E-1+/-12%	6.6E-1+/-10%
9	4.0E3+/-1%	9.7E-1+/-5%	1.3E1+/-9%	6.3E-1+/-11%	5.2E-1+/-12%
10	3.8E3+/-2%	1.5E0+/-4%	1.4E1+/-9%	6.7E-1+/-12%	6.8E-1+/-9%
12	3.3E3+/-2%	7.5E-1+/-7%	8.7E0+/-13%	5.7E-1+/-10%	6.2E-1+/-11%
14	3.4E3+/-2%	7.2E-1+/-7%	1.1E1+/-12%	7.7E-1+/-10%	7.2E-1+/-10%
16	3.2E3+/-2%	7.7E-1+/-8%	8.3E0+/-15%	8.5E-1+/-9%	5.7E-1+/-12%
18	3.2E3+/-2%	8.7E-1+/-6%	1.1E1+/-11%	7.7E-1+/-10%	7.6E-1+/-10%

Table 4, cont.

Borehole #7

Depth	Gross NaI Counts/Min	U-235	U-238	Pb-212	Pb-214
0	2.4E3+/-2%	2.3E-1+/-15%	6.7E0+/-13%	3.3E-1+/-13%	3.0E-1+/-15%
1	2.9E3+/-2%	5.9E-2+/-43%	8.4E0+/-11%	4.2E-1+/-9%	7.1E-1+/-12%
2	2.7E3+/-2%	5.6E-2+/-51%	4.8E0+/-18%	9.8E-2+/-24%	3.5E-1+/-17%
3	2.5E3+/-2%	6.7E-2+/-42%	4.9E0+/-17%	1.1E-1+/-29%	3.7E-1+/-23%
4	2.3E3+/-2%	1.0E-1+/-27%	6.3E0+/-13%	1.6E-1+/-16%	4.6E-1+/-12%
5	1.6E3+/-3%	2.3E-1+/-12%	2.3E0+/-30%	1.4E-2+/-85%	1.8E-1+/-27%
6	1.3E3+/-3%	4.9E-1+/-7%	1.6E0+/-41%	8.9E-2+/-37%	1.4E-1+/-30%
8	2.4E3+/-2%	9.3E-1+/-5%	7.3E0+/-12%	3.1E-1+/-12%	5.4E-1+/-10%
10	3.1E3+/-2%	3.1E-1+/-12%	5.7E0+/-15%	8.3E-2+/-32%	3.9E-1+/-11%
12	3.0E3+/-2%	1.0E-1+/-29%	6.0E0+/-16%	2.8E-1+/-12%	4.9E-1+/-10%
14	3.0E3+/-2%	1.7E-1+/-21%	7.6E0+/-12%	2.5E-1+/-11%	5.3E-1+/-10%
16	3.0E3+/-2%	3.2E-1+/-14%	8.9E0+/-11%	4.8E-1+/-10%	8.1E-1+/-9%
18	3.4E3+/-2%	------------	------------	------------	------------

Borehole #8

Depth	Gross NaI Counts/Min	U-235	U-238	Pb-212	Pb-214
0	2.6E3+/-2%	6.0E-2+/-77%	------------	4.3E-1+/-13%	5.6E-1+/-12%
2	3.1E3+/-2%	2.0E-1+/-20%	------------	4.0E-1+/-14%	6.1E-1+/-13%
4	3.1E3+/-2%	1.6E-2+/-302%	------------	2.5E-1+/-29%	5.9E-1+/-12%
6	3.3E3+/-2%	8.5E-2+/-41%	------------	4.2E-1+/-15%	5.8E-1+/-14%
8	3.2E3+/-2%	9.7E-2+/-35%	------------	4.7E-1+/-12%	7.5E-1+/-10%
10	3.1E3+/-2%	2.7E-2+/-176%	------------	2.4E-1+/-26%	7.4E-1+/-10%
12	3.1E3+/-2%	1.2E-1+/-31%	------------	4.5E-1+/-14%	5.6E-1+/-12%
14	3.1E3+/-2%	7.2E-2+/-47%	------------	1.1E-1+/-68%	6.8E-1+/-11%
16	3.1E3+/-2%	4.8E-2+/-125%	------------	3.5E-1+/-18%	8.0E-1+/-9%
18	3.1E3+/-2%	2.7E-2+/-200%	------------	7.3E-1+/-9%	7.7E-1+/-9%

Table 4, cont.

Borehole #10

Depth	Gross NaI Counts/Min	U-235	U-238	Pb-212	Pb-214
0	2.3E3+/-2%	1.7E-1+/-18%	-----------	3.3E-1+/-22%	7.8E-1+/-8%
2	3.1E3+/-2%	2.6E-2+/-140%	-----------	6.9E-1+/-9%	9.4E-1+/-7%
4	3.2E3+/-2%	3.9E-2+/-115%	-----------	4.4E-1+/-14%	5.8E-1+/-13%
6	3.4E3+/-2%	5.8E-2+/-955%	-----------	5.4E-1+/-14%	9.8E-1+/-6%
8	3.4E3+/-2%	1.2E-1+/-34%	-----------	6.8E-1+/-10%	9.3E-1+/-7%
10	3.3E3+/-2%	6.8E-2+/-900%	-----------	4.9E-1+/-15%	8.8E-1+/-9%
12	3.4E3+/-2%	4.0E-2+/-538%	-----------	6.0E-1+/-11%	8.0E-1+/-9%
14	3.2E3+/-2%	1.4E-2+/-26%	-----------	5.6E-1+/-14%	9.6E-1+/-7%
16	3.2E3+/-2%	4.9E-2+/-101%	-----------	3.7E-1+/-20%	8.3E-1+/-9%
18	3.1E3+/-2%	1.9E-1+/-25%	-----------	4.3E-1+/-15%	9.7E-1+/-7%

Borehole #11

Depth	Gross NaI Counts/Min	U-235	U-238	Pb-212	Pb-214
0	2.3E3+/-2%	1.0E-1+/-45%	-----------	3.8E-1+/-16%	5.6E-1+/-13%
2	2.9E3+/-2%	1.2E-1+/-40%	-----------	7.6E-1+/-9%	6.2E-1+/-12%
4	3.1E3+/-2%	5.3E-2+/-423%	-----------	2.6E-1+/-24%	7.0E-1+/-10%
6	3.4E3+/-2%	4.9E-3+/-970%	-----------	5.9E-1+/-12%	9.4E-1+/-8%
8	3.3E3+/-2%	1.2E-3+/-3700%	-----------	5.0E-1+/-11%	6.5E-1+/-12%
10	3.3E3+/-2%	4.5E-2+/-190%	-----------	5.8E-1+/-12%	7.3E-1+/-10%
12	3.2E3+/-2%	8.6E-3+/-530%	-----------	3.9E-1+/-16%	7.6E-1+/-10%
14	3.0E3+/-2%	9.3E-2+/-50%	-----------	3.9E-1+/-16%	4.7E-1+/-16%
16	3.0E3+/-2%	1.1E-1+/-31%	-----------	4.6E-1+/-14%	6.9E-1+/-10%
18	3.0E3+/-2%	2.4E-2+/-173%	-----------	3.2E-1+/-17%	9.2E-2+/-8%

Table 4, cont.

Borehole #13

Depth	Gross NaI Counts/Min	U-235	U-238	Pb-212	Pb-214
0	2.2E3+/-2%	2.1E-1+/-19%	6.0E0+/-16%	3.5E-1+/-17%	3.9E-1+/-15%
2	3.1E3+/-2%	9.9E-2+/-44%	2.9E0+/-38%	4.0E-1+/-16%	5.2E-1+/-13%
4	3.0E3+/-2%	3.9E-3+/-120%	4.3E0+/-26%	3.3E-1+/-21%	6.3E-1+/-10%
6	2.8E3+/-2%	8.0E-1+/-7%	4.9E0+/-22%	3.4E-1+/-15%	4.8E-1+/-10%
8	3.1E3+/-2%	2.1E-1+/-23%	1.1E1+/-10%	4.9E-1+/-12%	4.8E-1+/-14%
10	3.2E3+/-2%	7.7E-2+/-65%	1.1E1+/-10%	3.7E-1+/-18%	7.9E-1+/-8%
12	3.2E3+/-2%	1.8E-1+/-30%	1.3E1+/-99%	6.3E-1+/-11%	6.0E-1+/-10%
14	3.3E3+/-2%	2.4E-1+/-20%	1.4E1+/-8%	6.8E-1+/-10%	7.7E-1+/-8%
16	3.1E3+/-2%	1.5E-1+/-34%	6.9E0+/-16%	5.0E-1+/-13%	7.3E-1+/-10%
18	3.2E3+/-2%	2.7E-1+/-18%	3.6E0+/-32%	5.8E-1+/-12%	6.7E-1+/-11%

Table 5

In situ bore hole measurements vs core sample analyses
(pCi/g +/- % counting error)

Borehole 7 2 foot	*In situ* Gamma Spectroscopy	Core Sample Gamma Spectroscopy On Site	Core Sample Gamma Spectroscopy RMC Labs	Core Sample Alpha Spectroscopy
U-234				1.1E1+/-15%
U-235	5.6E-2+/-51%	8.4E-2+/-170%		3.3E-1+/-98%
U-238	4.8E0+/-18%	2.4E0+/-78%		2.3E0+/-29%
Pb-212	9.8E-2+/-24%	9.1E-1+/-25%		
Pb-214	3.5E-1+/-17%	1.2E0+/-37%	9.2E-1+/-13%	
Bi-214		5.9E-1+/-53%	6.5E-1+/-17%	
K-40		9.2E30+/-32%	2.0E1+/-10%	
Borehole 7 8 foot				
U-234				3.5E1+/-10%
U-235	1.0E0+/-5%	1.4E0+/-64%	2.2E0+/-27%	1.2E1+/-23%
U-238	6.2E0+/-13%	3.0E0+/-61%	<1.0E1	3.2E1+/-16%
Pb-212	3.0E-1+/-19%	8.0E-1+/-43%	<1.2E0	
Pb-214	5.0E-1+/-12%	9.0E-1+/-43%	8.0E-1+/-16%	
Bi-214		7.0E-1+/-45%	7.0E-1+/-17%	
K-40		1.3E1+/-26%	2.0E1+/-10%	
Borehole 7 10 Foot				
U-234				1.5E1+/-10%
U-235	3.0E-1+/-12%	8.0E-1+/-12%	1.5E0+/-27%	5.0E-1+/-39%
U-238	5.7E0+/-14%	1.5E0+/-120%	<1.1E1	1.1E0+/-25%
Pb-212	8.0E-1+/-10%	6.0E-1+/-31%	<1.3E0	
Pb-214	4.0E-1+/-15%	1.0E0+/-38%	9.0E-1+/-13%	
Bi-214		6.0E-1+/-50%	7.0E-1+/-14%	
K-40		1.2E1+/-28%	1.9E1+/-10%	
Borehole 7 11 Foot				
U-234				3.0E0+/-15%
U-235		1.0E-1+/-130%	<5.0E-1	<9.0E-1
U-238		1.4E0+/-120%	<1.1E1	5.0E-1+/-40%
Pb-212		6.0E-1+/-30%	<1.9E0	
Pb-214		1.2E0+/-44%	9.0E-1+/-18%	
Bi-214		7.0E-1+/-44%	1.2E0+/-25%	
K-40		9.5E0+/-32%	1.8E1+/-10%	

Table 6

Water sample analyses (pCi/l +/- counting error)

Sample No.	Sample Location	Gross Alpha (pCi/l)	Gross Beta (pCi/l)
1	Borehole #6-3/26/82	1.3E1+/-27%	4.2E1+/-16%
2	100H	2.2E0+/-86%	1.5E1+/-39%
3	Standing #20 near trucks	9.0E0+/-31%	8.8E1+/-9%
4	Small creek near H55R	1.2E0+/-140%	5.6E0+/-90%
5	Stream SE of plant	1.2E0+/-140%	1.6E0+/-338%
6	Joachim Creek upstream	5.0E-1+/-260%	4.2E1+/-16%
7	Borehole #2-4/2/82	1.7E0+/-110%	2.0E1+/-30%
8	Borehole #7-3/26/82	8.8E0+/-32%	1.4E1+/-31%
9	Joachim Creek downstream	1.0E0+/-160%	3.1E1+/-20%
10	Small creek upstream	8.3E-1+/-200%	7.9E0+/-590%
11	Joachim Creek midstream	1.7E-1+/-56%	9.1E0+/-268%
12	Borehole #9 4/2/82	2.3E0+/-80%	3.2E2+/-4%
13	Borehole #12 4-2-82	1.1E1+/-28%	6.1E0+/-90%
14	Borehole #1 3/24/82	1.8E2+/-6%	1.3E2+/-7%
15	Borehole #2 4/16/82	8.3E-1+/-200%	1.7E1+/-27%
16	Borehole #3 4/16/82	1.2E0+/-140%	8.9E0+/-56%
17	Borehole #9 4/16/82	1.7E0+/-110%	4.7E2+/-3%
18	Borehole #12 4/16/82	2.7E0+/-73%	2.3E0+/-230%
19	Borehole #2 4/22/82	2.0E0+/-91%	8.8E0+/-56%
20	Borehole #3 4/22/82	1.5E0+/-120%	2.1E1+/-29%
21	Borehole #9 4/23/82	2.0E0+/-91%	5.0E2+/-3%
22	Borehole #12 4/22/82	1.0E0+/-160%	2.5E1+/-24%

Table 7

Gamma spectroscopy analysis of selected water samples

		Isotopic Results (pCi/l +/- counting error)				
Sample No.	Sample Location	U-238 (pCi/l)	U-235 (pCi/l)	Th-232 (pCi/l)	Ra-226 (pCi/l)	K-40 (pCi/l)
14	Borehole #1 3/24/82	5.3E1+/-53%	6.8E0+/-66%	1.9E1+/-46%	-6.7E0+/-77%	8.0E1+/-43%

Table 8

Particulate high volume air samples, long lived activity
(uCi/ml +/- % counting error)

Date	Location	Gross Alpha Activity (uCi/ml)	Gross Beta Activity (uCi/ml)
4/7/82	NW fence line	1.8E-14+/-49%	6.0E-14+/-33%
4/14/82	15 m N of NW fence post	2.3E-14+/-36%	6.4E-14+/-25%
4/14/82	3 m downwind of borehole #1	1.1E-14+/-58%	3.9E-14+/-38%
4/15/82	South of plant	5.8E-15+/-149%	2.8E-14+/-99%
4/15/82	South of parking lot	2.7E-14+/-49%	3.7E-14+/-75%

Table 9

Summary of offsite background radiological measurements

Type of Measurement	Value
External exposure rate one meter above ground	12 uR/hr
Beta-gamma count rates at surface	35/32
Long lived airborne particulate activity	Gross alpha 5.8E-15 uCi/ml +/- 150% Gross beta 2.8E-14 uCi/ml +/- 99%
Soil radionuclide concentrations	U-238 3.6E-1(pCi/g)+/-460% U-235 1.5E-1(pCi/g)+/-130% Ac-238 1.1E-1(pCi/g)+/-330% Pb-212 2.4E-1(pCi/g)+/-70% Pb-214 8.5E-1(pCi/g)+/-48% Bi-214 4.9E-1(pCi/g)+/-65% K-40 8.7E0(pCi/g)+/-37%

Water Activities	Gross alpha	Gross beta
Small creek upstream	8.3E-1+/-200	7.9E0+/-590%
Small creek downstream	1.2E0+/-140%	5.6E0+/-90%
Joachim Creek upstream	5.0E-1+/-260%	4.2E1+/-15%
Joachim Creek downstream	1.0E0+/-100%	3.1E1+/-20%
Joachim Creek midstream	1.7E-1+/-56%	9.1E0+/-268%

Table 10

Target criteria and measurement LLD's for Combustion Engineering Facility burial site.

Soil Contaminants

Nuclide	Target Criteria	LLD
Ra-226	5pCi/g	1pCi/g
Total U	15pCi/g	3pCi/g
U-238	30pCi/g	6pCi/g
U-235	30pCi/g	6pCi/g
Th-232 *	5pCi/g	1pCi/g
Th-230	15pCi/g	3pCi/g

Water and Airborne Contaminants

Nuclide	Target Criteria	LLD
All	MPC Unrestricted	20% MPC
Ra-226 (water)	3E-8 uCi/ml	6E-9 uCi/ml

External Radiation

Nuclide	Target Criteria	LLD
All	20 uR/hr	4 uR/hr

* Th-232 in equilibrium with daughters

APPENDIX I

Radiological Survey Instruments and Methods

A. Portable Survey Instrument

The portable survey instruments used at the C-E facility burial site included two complete sets of Wm. B. Johnson & Associates equipment, which consist of battery operated rate meters, scalers and alpha, beta and gamma probes, and an Eberline PRS-1 ratemeter scaler and detectors. These systems (see Fig. I-1) are totally portable and can be used in the field for both measurements and sample counting.

The alpha probes use a ZnS(Ag) scintillation detector; the beta detector is a thin window (1.4mg/cm2 mica) GM tube, and the gamma detectors are NaI(Tl) crystals. The alpha and beta probes were calibrated with "NBS traceable" sources at the RMC calibration facility in Philadelphia and the gamma scintillator was cross-calibrated with a primary ionization chamber system, described below.

B. Ionization Chamber System

External gamma dose rates were accurately measured with the RMC constructed Tissue Equivalent Ionization Chamber System (Fig. I-2). This system consisted of a 16 liter tissue equivalent, gas filled ionization chamber (Shonka chamber), a Keithley vibrating capacitor electrometer, a printer and battery pack. It is capable of measuring dose rates at background levels to a precision of a few percent.

Since this system is bulky and somewhat fragile, it is not as suited for extensive field measurements as a smaller, lightweight NaI(Tl) portable survey instrument. Therefore, the NaI(Tl) detector was used for the majority of the field gamma measurements. Since this detector's response is energy dependent, it cannot be used as a "micro R meter" unless it is initially calibrated for such use.

The calibration performed by RMC consisted of accurately measuring the exposure rate at several locations at the C-E facility burial site using the Tissue Equivalent Ionization Chamber, then recording NaI(Tl) measurements at the same location. In this manner a set of NaI(Tl) count-rate versus exposure rates were obtained and a uR/hr calibration factor established, as shown in Fig. I-3.

Due to the energy dependence of the NaI detector, this conversion factor will apply only to the radionuclides and geometries for which the calibrations were made. In the case of the C-E facility burial site, it is known that only naturally occurring nuclides and U-238 and U-235 are likely to be present. Therefore, the conversion factor established at this site, will apply only to naturally occurring radionuclides distributed in soil.

C. Mobile Lab Gamma Analysis System

The mobile lab gamma analysis system (Fig. I-4) consists of a PGT 15% efficient (relative to a 3" x 3" NaI(Tl) crystal) intrinsic germanium (IG) detector, shield and Tennecomp TP-50 laboratory computer data acquisition module. The analysis system was calibrated for all counting geometries with an NBS supplied Eu-152 source.

Each count was analyzed by a computer program for determination of gamma energies and peak areas. All results were printed out immediately following analysis on-site, and data was stored on floppy discs for future analysis, as needed.

Typical LLDs for U-235 and U-238 in soil are 1 and 2 pCi/g, respectively.

D. Auger Hole Logging System

Detailed logging of selected auger holes was performed with the system shown in Fig. I-5. This system consists of a custom designed EG&G Ortec intrinsic germanium detector (10% eff) with a narrow dewar, coupled to a Tracor-Northern 1750 MCA used for data acquisition and initial field evaluations. Data were stored on a tape cassette recorder, then transferred to the lab computer system for final analysis. The entire system, including an NIM module power supply with a bias power supply and amplifier, was powered in the field by a portable 5000 watt gasoline-driven generator.

The logging system was calibrated as described in Attachment 1. Field counting times were normally 10 minutes at each location. Typical LLDs for this system for a 10 minute count are 0.1 pCi/g for U-235 1 pCi/g for U-238, 0.2 pCi/g for Pb-212 and 0.1 for pCi/g Pb-214.

E. Alpha-Beta Counting System.

All particulate air samples and evaporated water samples were counted for gross alpha or beta activity on the Gamma Products low background gas flow proportional counter, shown in Fig. I-6. The system is automatic and can be programmed for a variety of counting parameters.

ATTACHMENT 1 TO APPENDIX I

INTRINSIC GERMANIUM WELL LOG

DETECTOR CALIBRATION

The intrinsic germanium detector was connected to the pulse height analysis system consisting of the following components:

Ortec Model 459 High Voltage Power Supply

Canberra 2011 Spectroscopy Amplifier

Tracor Northern 1750 MCA

Teletype Model 43 Printer

Gain and voltage supply settings were adjusted to obtain an energy spectrum of 0 to 2000 keV, which corresponds to approximately one keV per channel.

Calibration of the well logging system was performed using the calibration rig shown in Fig. I-7. This rig is constructed as a series of four concentric rings surrounding a six inch PVC casing. Each ring contains thin plastic tubes 1-1/4" diameter by 36" long. A set of "source rods" and "background rods" were prepared and loaded into these tubes in a variety of configurations for the various calibration and test counts.

The geometry of the rig is such that the distance from the center of the casing (or detector) to the center of the innermost ring is 3.75 inches, to the center of the second ring is 5.0 inches, to the center of the third ring is 6.25 inches, and to the center of the fourth ring is 7.50 inches. All voids between tubes were filled with low background sand. It was determined that the ratio of source volume in each ring to the total ring area was about 0.6. Hence, when source rods were fully loaded into a given ring, the activity counted represented approximately 60% of the total area (volume) the detector viewed, and counts were adjusted accordingly.

Each source tube is a twelve inch high by one inch diameter tube filled with a material containing Eu-152. The source material was prepared by mixing the standard Eu-152 source solution with plaster of paris, at a constant ratio designed to give a uniform specific activity of 440 pCi/gram. Background rods were filled with "clean" plaster of paris. Plaster of paris was chosen because of its ease of handling, ability to uniformly distribute the source throughout the material, and its density, which approximates that of common soil. (Density of soil, 1.7-2.3 g/cubic cm; density of plaster, 1.5 g/cubic cm; density of sand, 1.4 g/cubic cm)

Four different configurations of source and blank tubes were used for the calibration. Source tubes were placed three high in one of the four concentric rings of the rig for each count while the balance of the rig was filled with blanks. These configurations correspond to the source material being a radial distance of 3.75, 5.00, 6.25 and 7.50 inches from the detector.

Each configuration was counted for 900 seconds, and the area under each of the eight major Eu-152 photopeaks determined for each count.

As a calibration check for the low energy U-238 photons, a second set of calibration rods containing Cd-109 (E =88 keV), was prepared and counted in a similar manner.

Calculation of counts per gamma per gram was determined by the following method (for the Eu-152 rods):

NCNTS/GAMMA/GRAM =

[NCNTS]/[(440pCi/g)(3.7E-2d/s/pCi)(900s)(ABUNDANCEgamma/d)]

For each gamma energy, the net counts/gamma/gram vs distance from the center of the detector was listed. These response curves were then plotted for each energy, for distances and activities which extend to zero net counts. This represents an "infinite" distance from the detector. Using these curves, the total counts from the detector to an infinite distance was calculated by integrating the area under the curve using Simpson's rule for approximating integrals. Of prime importance is the integral from 2 inches to infinity, since this is the area the detector will view when placed inside a four-inch PVC casing.

Finally, the integrated net count/gamma/gram, from two inches to infinity, was plotted vs energy, for each of the Eu-152 photons. With this efficiency curve, a specific activity in soil (pCi/gram) can be determined from a bore hole count, assuming the radionuclide can be identified and its gamma abundance determined. The calculation is:

SPECIFIC ACTIVITYpCi/gm(in soil) =

[NETCOUNTS]/[(ABUNDANCEgamma/dis)(2.22 dis/min/pCi)

(MINUTES COUNTED)(EFFICIENCYcounts/gamma/gm)]

This determination will be valid so long as the radioactive material is uniformly distributed to an "infinite" distance in soil, and the detector is in a four-inch PVC (or similar material) casing. Although soil should be at the surface of the casing, the data indicate that small voids will not produce significant errors in activity estimations.

Results of this calibration indicate that an "infinite" thickness in soil for a bore hole logging device is about 10 inches from the center of the detector. Thus, for a four-inch hole, gamma logging will only "see" activity out to about seven or eight inches from the hole. For low energies (e.g. 100 keV), 50 to 60% of the total activity seen is in the interval of two to four inches. For energies above 500 keV, this value is 40 to 50%. While this volume may not seem large, it represents several thousand (2000 to 4000) grams of soil, which is much larger than typical core samples, and is therefore more representative of the actual soil activity.

This calibration indicates that the sensitivity of the IG well logging system is such that the Ra-226 daughter Bi-214, as measured by the 47% abundant 609 keV peak, can be easily detected at one pCi/gram in soil, in a five minute count, with a 95% confidence level and precision of 0.4 pCi/g.

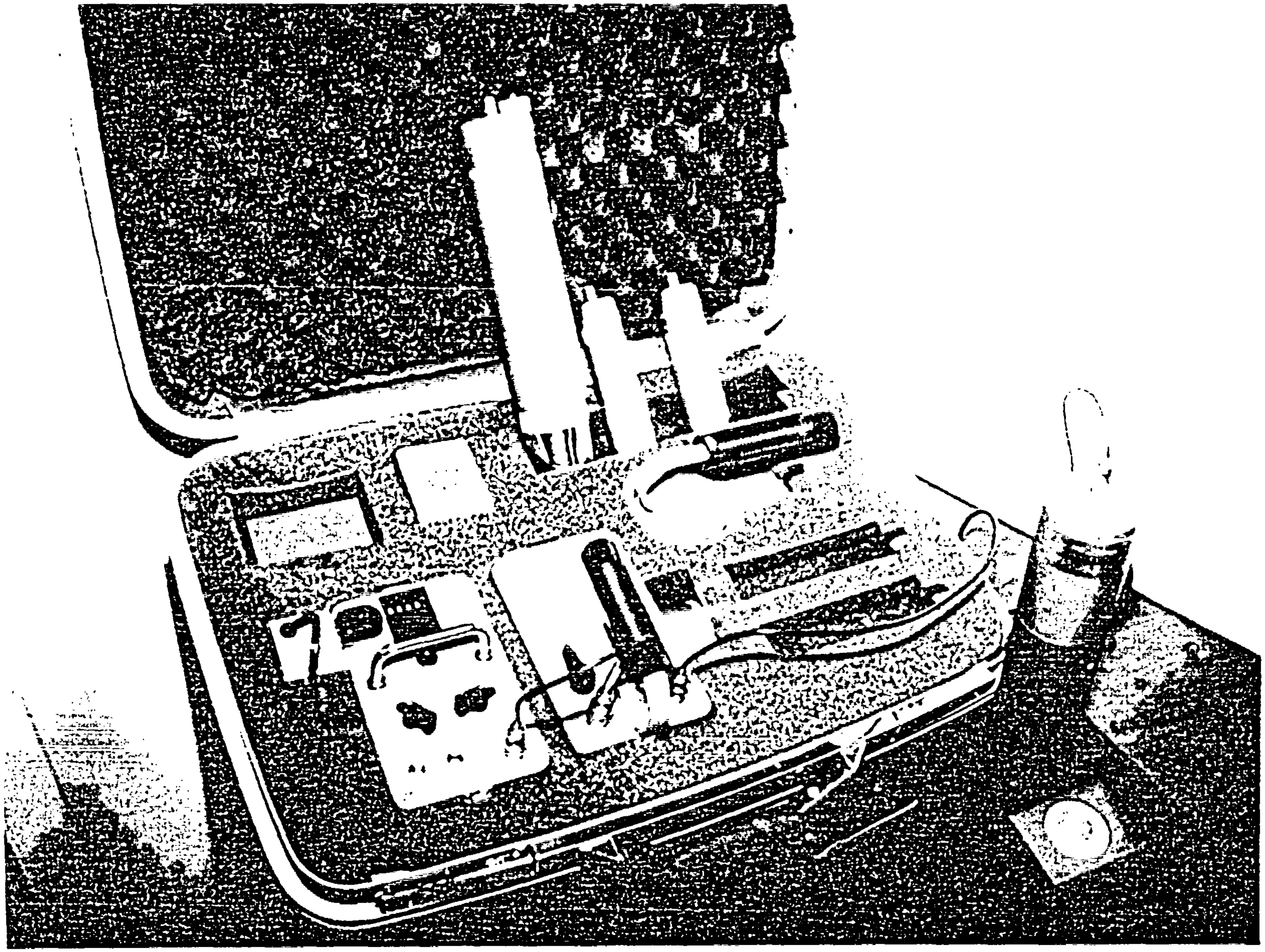


Figure I-1. Portable Survey Instrument Kit.

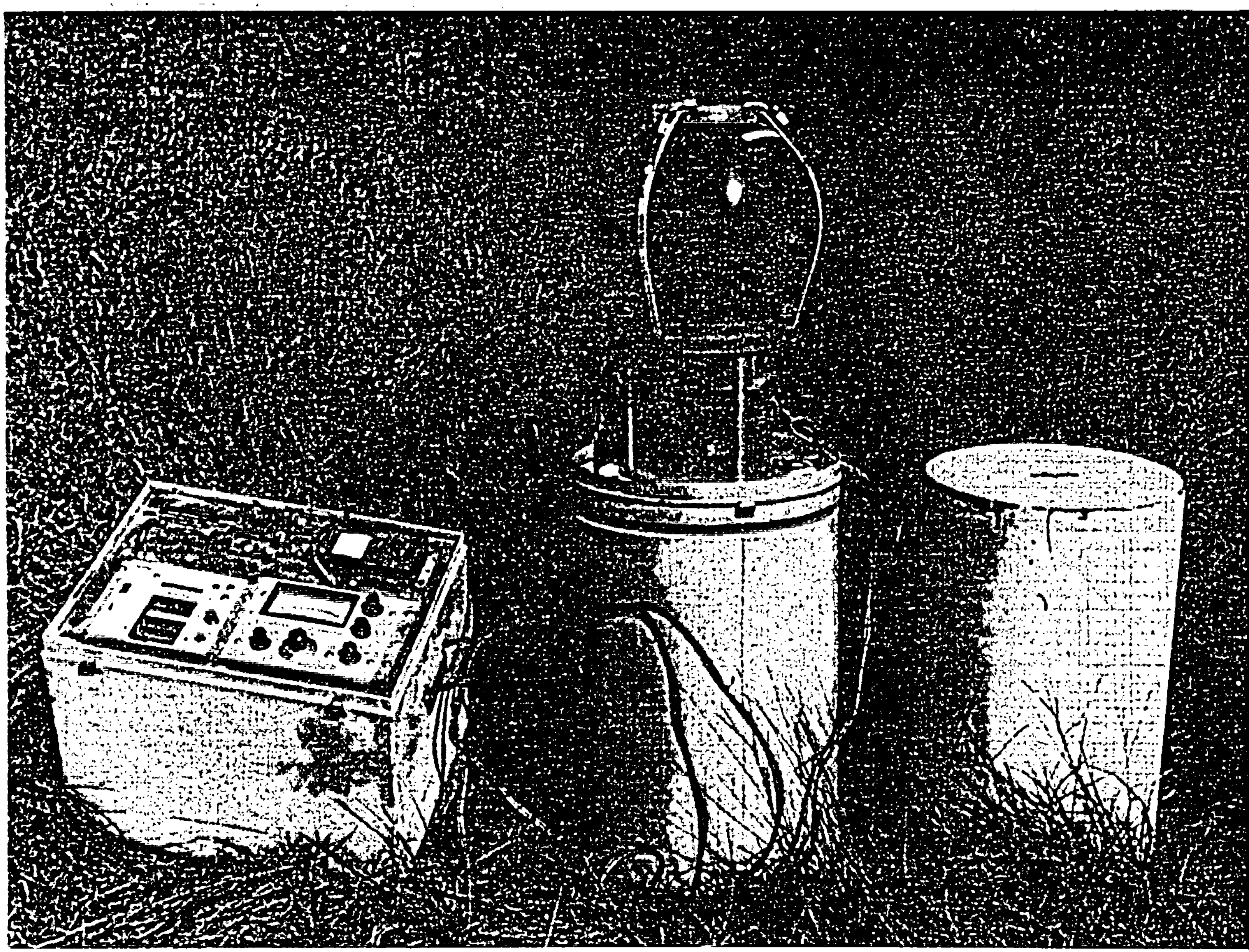


Figure I-2. High sensitivity tissue equivalent ionization chamber system.

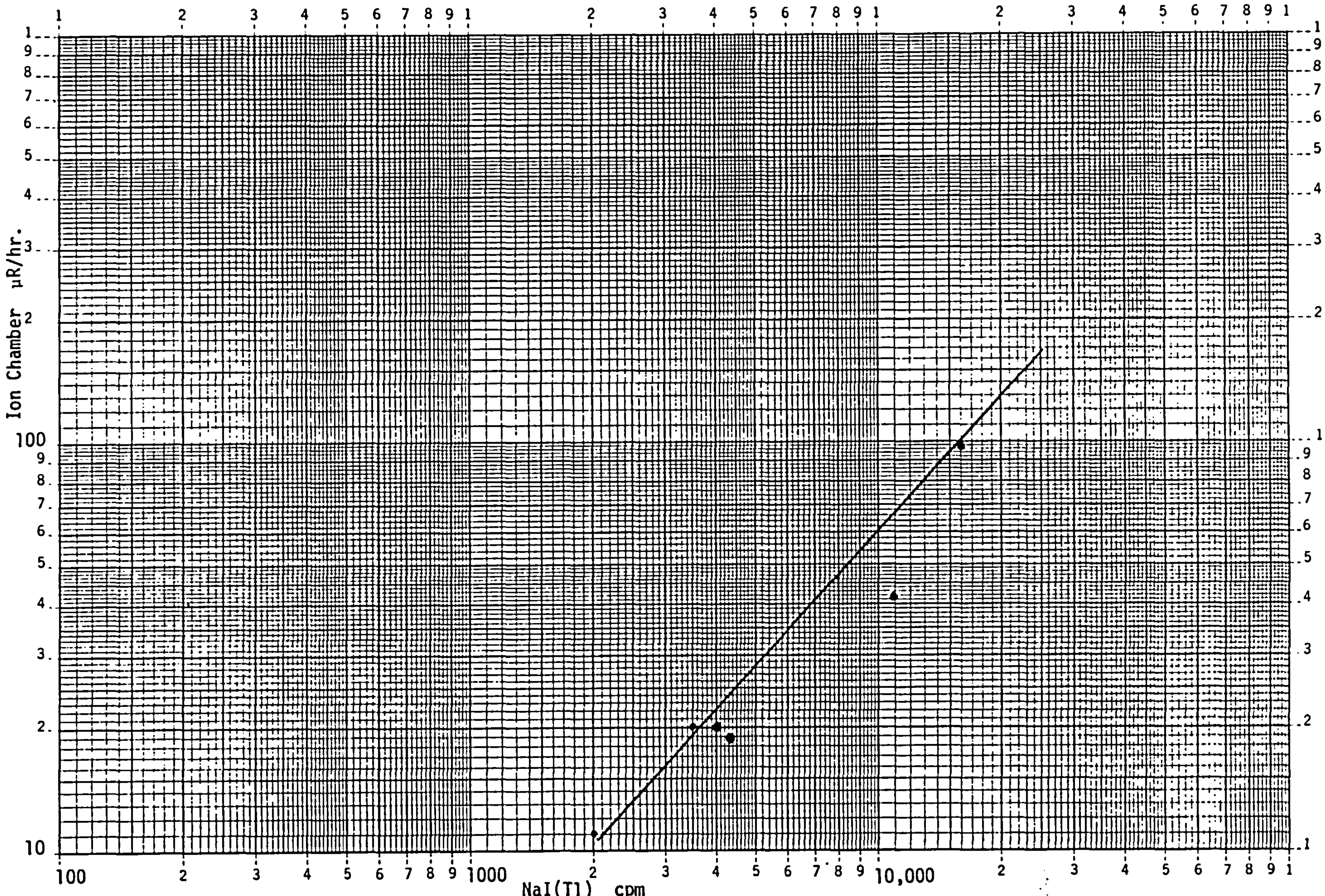


Fig. I-3. Ion chamber exposure rate vs. NaI(Tl) count rate, Combustion Engineering facility burial site.

Figure I-4. Interior of mobile lab showing gamma counting system and other equipment.

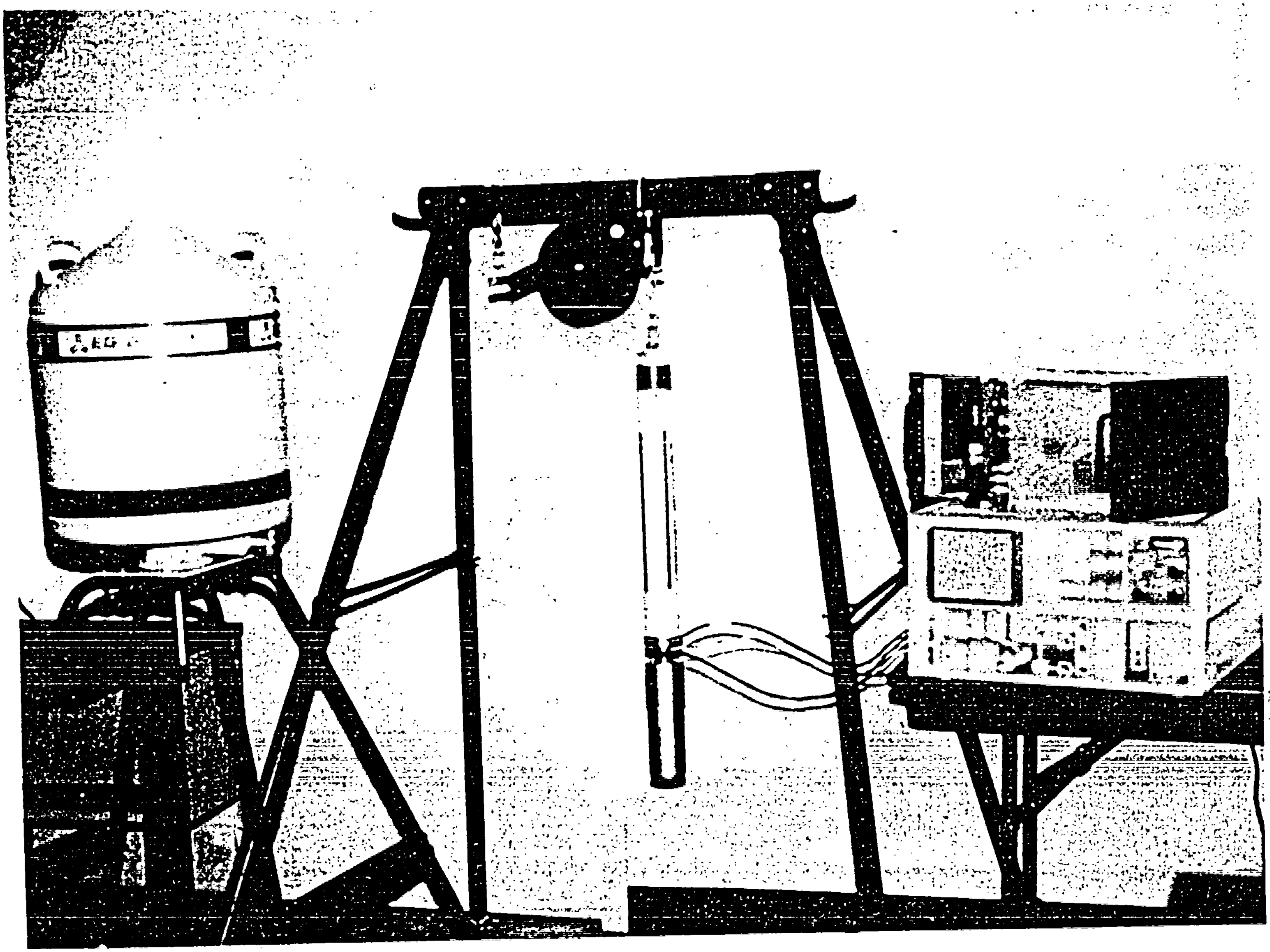


Figure I-5 In-situ auger hole logging system with intrinsic germanium detector and narrow dewar assembly, data acquisition equipment and storage/ fill dewar.

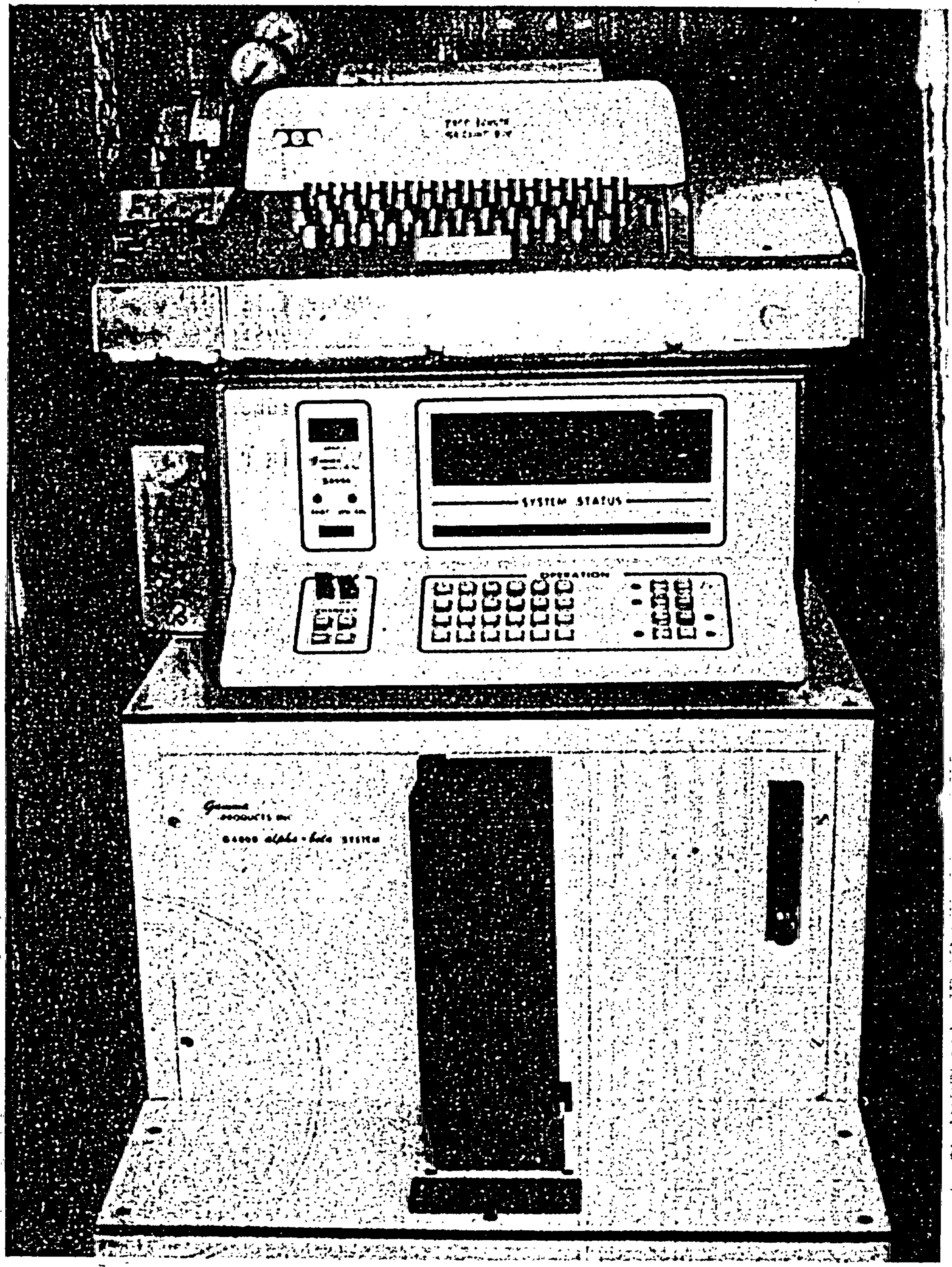


Figure I-6. Automatic beta-gamma gas flow proportional counter.

Figure I-7

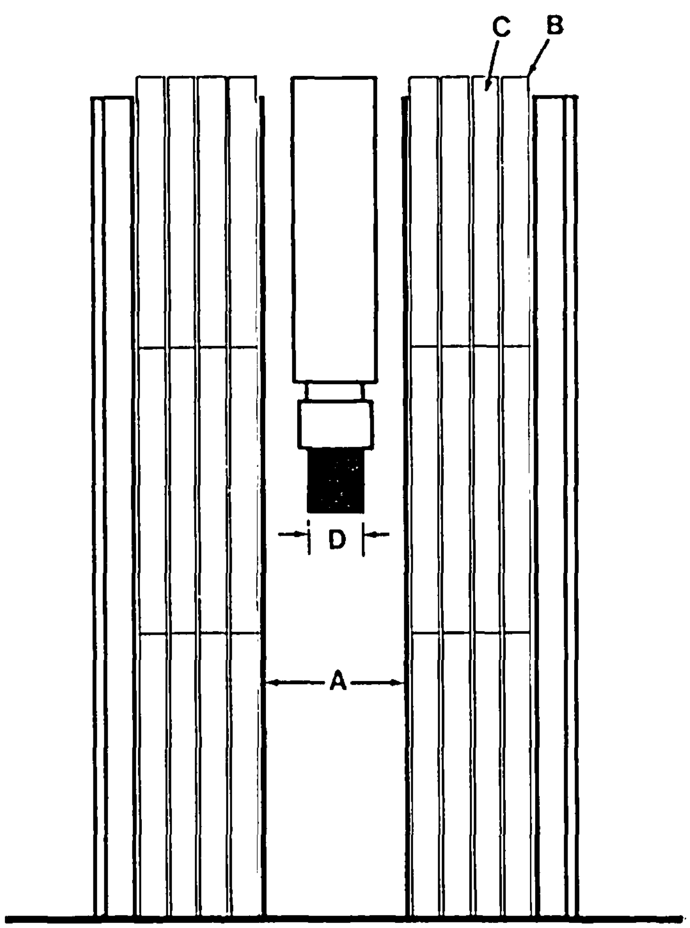
CALIBRATION RIG ASSEMBLY

"A" - 6" I.D. PVC Pipe

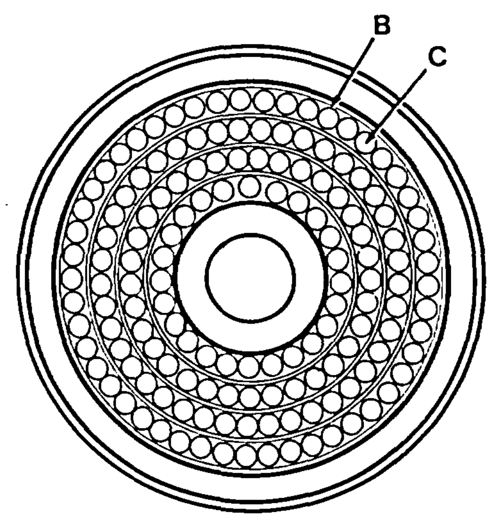
"B" - 1.25" diameter x 36" long butyrate source holder tubes

"C" - 1" diameter x 12" long source tubes. 3 per holder tube

"D" - IG Detector



Cross Section



Top View

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16. ABSTRACT (200 words or less)

This report presents the results of a radiological survey of the burial site adjacent to the Combustion Engineering (C-E) plant in Hematite, Missouri, performed by Radiation Management Corporation (RMC) in the spring and summer of 1982. Measurements were made to determine external radiation levels, surface and subsurface radionuclide concentrations and radioactivity in air and water. Results show uranium concentrations in burial pits as high as 38 and 21 pCi/g for U-238 and U-235 respectively. Results also show uranium concentrations in surface soils as high as 4.7 and 1.1 pCi/g for U-238 and U-235 respectively. Based on an estimated U-234/U-238 activity ratio of about 10 to 1, the highest U-234 activity in the burial pits is estimated to be approximately 400 pCi/g, and in surface soils approximately 47 pCi/g. Radium and thorium concentrations did not exceed background levels. Radioactivity in water which exceeded EPA drinking water standards was found in two onsite monitoring wells.

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