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Background Radiation Survey of the Radiological/Nuclear Countermeasures Test and Evaluation Center

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Introduction

In preparation for operations at the Radiological/Nuclear Countermeasures Test and Evaluation Complex (Rad/NucCTEC), the Department of Homeland Security Domestic Nuclear Detection Office (DHS/DNDO) requested that personnel from the Remote Sensing Laboratory (RSL) conduct a survey of the present radiological conditions at the facility. The measurements consist of the exposure rate from a high-pressure ion chamber (HPIC), high-resolution spectra from a high-purity germanium (HPGe) system in an *in situ* configuration, and low-resolution spectra from a sodium iodide (NaI) detector in a radiation detection backpack. Measurements with these systems were collected at discrete locations within the facility. Measurements were also collected by carrying the VECTOR backpack throughout the complex to generate a map of the entire area. The area was also to be surveyed with the Kiwi (an array of eight-2” × 4” × 16” NaI detectors) from the Aerial Measuring Systems; however, conflicts with test preparation activities at the site prevented this from being accomplished.

Measurements

Measurements were collected at the fixed locations on June 9–10, 2009. Measurements were performed with the VECTOR backpacks on June 11, 2009.

Figure 1: Setup for performing the static measurements. The HPIC and VECTOR are on top of the cart while the HPGe is on the tripod. Batteries on the bottom of the cart were used to power the various systems throughout the day.

The positions for the discrete locations were recorded by collecting the coordinates reported from the GPS receiver contained within a ruggedized PDA which was used to interact with the radiation backpack. When the instruments had a clear view of the sky, the GPS coordinates were fluctuating at the 0.001' level (precision of approximately 6 feet). Because all of the measurements at the fixed locations were performed simultaneously, the accuracy of the position information is no better than 10 feet.

The exposure rate measurements were collected with an RSS-131 from GE/Reuter-Stokes. The RSS-131 is a 10"-diameter chamber filled with argon gas at a pressure of 25 atmospheres. Gamma-rays passing through the argon gas produce ions which provide a measure of the exposure rate. The interface to the RSS-131 was through a numerical display on a laptop computer. The measurements were performed by allowing the system to adjust to each new location before the exposure rate was recorded.

A VECTOR backpack was used to produce a gross count rate survey of the area and to collect mid-resolution NaI spectra. The VECTOR has a 2" × 2" × 8" NaI detector for gamma-ray detection and spectrum capture. The system is usually used in a mode where it is writing the gamma-ray spectra and GPS location second-by-second to internal data storage. This normal mode was used for the area survey where two backpacks were pushed or carried at a walking pace, in a methodical fashion, throughout the area. For the spectra collected at the discrete locations, the one-second spectra were transmitted to a PDA where they were summed to produce a spectrum integrated over several minutes. The detector in the VECTOR was not gain stabilized, thus the energy calibration varies for the collected spectra. This can be seen by the comparison shown in Figure 2.

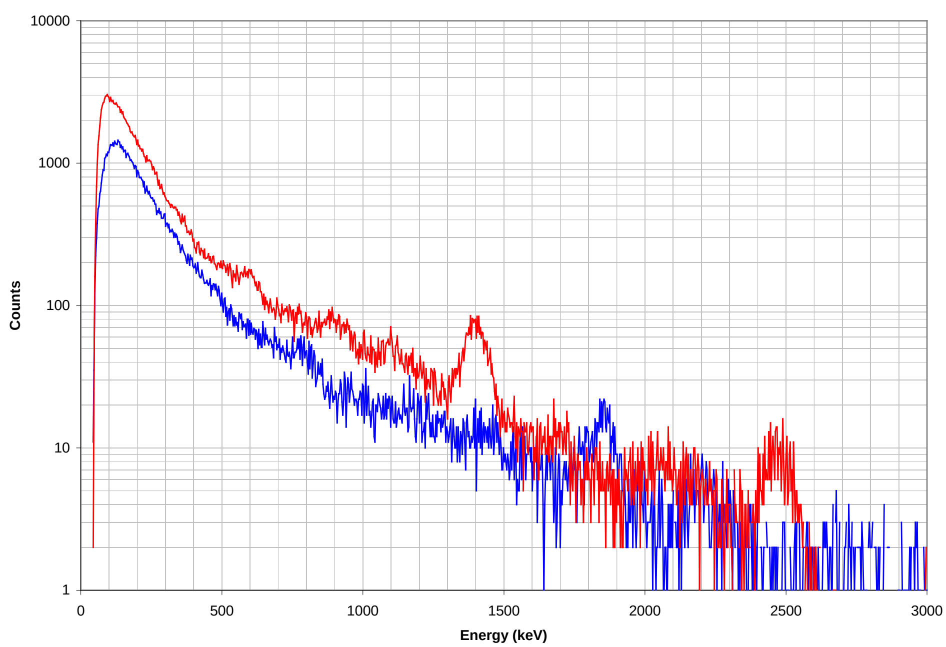

Figure 2: Illustration of the gain changes seen in the backpack detector. The spectrum in red (Location 26) shows the 40K peak around 1400 keV, while the blue spectrum (Location 3) shows ^{40}K around 1870 keV.

The HPGe measurements were performed with an ORTEC Detective-EX100 (Serial Number 7464039) in an *in situ* configuration (i.e., the detector was on a tripod, facing toward the ground, with the face of the end cap 1 meter above the ground). This unit has an efficiency of 43.9% relative to a 3” × 3” NaI detector. The angular response and efficiency, as a function of energy for this system, were measured with ^{241}Am, ^{152}Eu, and ^{228}Th sources in April 2009. The angular efficiency, as a function of energy, was translated into a conversion to activity uniformly mixed in the soil for the *in situ* geometry. The coefficients for the conversion are given in Table 1.

Table 1: Coefficients for converting counts from *in situ* HPGe measurements to activity in the soil. The count rate in the spectrum peaks are corrected by the expected yield per decay and multiplied by the efficiency derived from this table to get pCi/g.

Energy (keV)	Efficiency ((pCi/g)/cps)
45	1.7056E+1
60	3.4228E+0
100	7.8275E-1
200	4.6472E-1
300	4.6675E-1
500	5.4242E-1
661	6.0197E-1
900	6.2384E-1
1000	6.3921E-1
1500	7.3007E-1
2000	7.9035E-1
2614	8.6326E-1

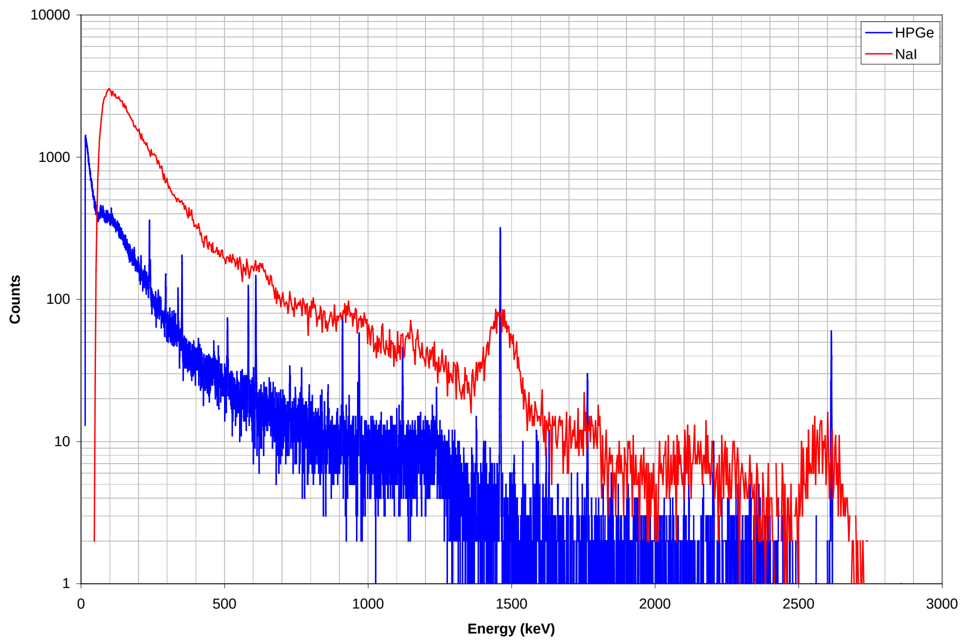

Figure 3: Comparison of spectra collected with the NaI detector in the VECTOR backpack and the *in situ* HPGe detector at Location 26. The energy calibration of the NaI spectrum has been corrected for this plot.

Results

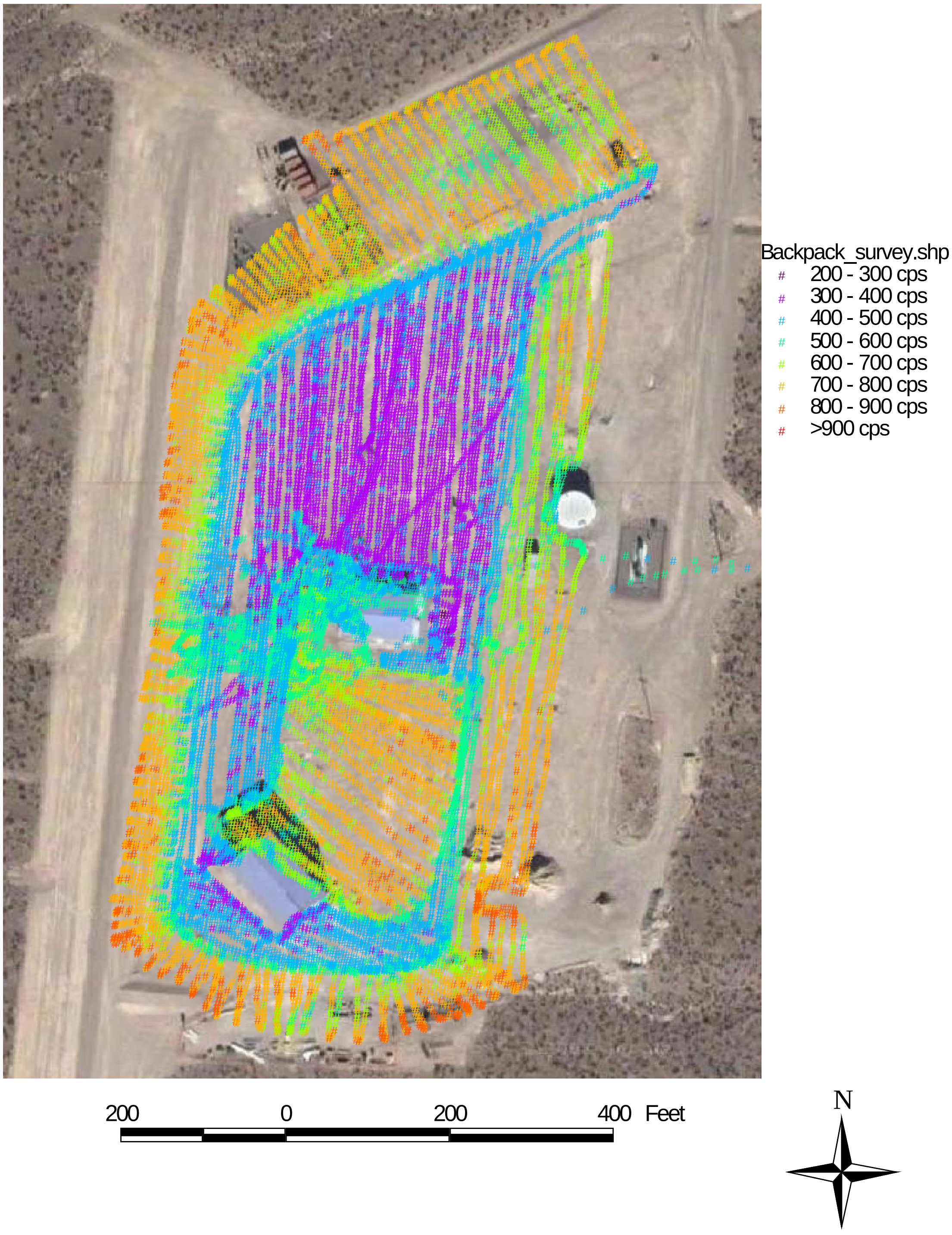

Figure 4: Survey of the Rad/NucCTEC facility as performed with the VECTOR backpacks. Only the gross count rate from the NaI detector in the backpack is plotted. The paved areas show a lower background than the unpaved areas. The image under the data was taken prior to laying down the asphalt in the complex.

Table 2: Locations and exposure rates of the static measurements. The filenames for the NaI spectra collected with the VECTOR backpack are also listed. The GPS information for the measurements collected in the Active Interrogation Building is suspect, so they have been highlighted.

Location	Latitude	Longitude	Exposure Rate (µR/hr)	VECTOR filename
1	36° 53.4137	116° 1.8375	8.5	LV_06092009_1627_XX.dat
2	36° 53.4441	116° 1.8361	8.5	LV_06092009_1648_XX.dat
3	36° 53.4743	116° 1.8283	8.2	LV_06092009_1708_XX.dat
4	36° 53.4824	116° 1.8338	8.3	LV_06092009_1728_XX.dat
5	36° 53.4858	116° 1.8393	8.1	LV_06092009_1744_XX.dat
6	36° 53.4604	116° 1.864	7.6	LV_06092009_1807_XX.dat
7	36° 53.4686	116° 1.8764	8.2	LV_06092009_1821_XX.dat
8	36° 53.4334	116° 1.8906	8.5	LV_06092009_1839_XX.dat
9	36° 53.4322	116° 1.8851	8.3	LV_06092009_1858_XX.dat
10	36° 53.4299	116° 1.8924	8.5	LV_06092009_1915_XX.dat
11	36° 53.4265	116° 1.8814	8.8	LV_06092009_1932_XX.dat
12	36° 53.4464	116° 1.8654	8.1	LV_06092009_1951_XX.dat
13	36° 53.4332	116° 1.8484	8.5	LV_06092009_2010_XX.dat
14	36° 53.3949	116° 1.8947	8.4	LV_06092009_2028_XX.dat
15	36° 53.3595	116° 1.9038	10.9	LV_06092009_2106_XX.dat
16	36° 53.3562	116° 1.8791	8.6	LV_06092009_2125_XX.dat
17	36° 53.3615	116° 1.8855	8.1	LV_06092009_2143_XX.dat
18	36° 53.3656	116° 1.8956	9.1	LV_06102009_1554_XX.dat
19	36° 53.3581	116° 1.8965	8.8	LV_06102009_1614_XX.dat
20	36° 53.3545	116° 1.913	10.1	LV_06102009_1631_XX.dat
21	36° 53.3858	116° 1.9011	11.1	LV_06102009_1664_XX.dat
22	36° 53.3297	116° 2.0018	10.7	LV_06102009_1708_XX.dat
23	36° 53.3855	116° 1.8434	10	LV_06102009_1725_XX.dat
24	36° 53.3544	116° 1.848	9.2	LV_06102009_1745_XX.dat
25	36° 53.3853	116° 1.8425	9.2	LV_06102009_1803_XX.dat
26	36° 53.3881	116° 1.8562	13.0	LV_06102009_1823_XX.dat
27	36° 53.4588	116° 1.8443	7.5	LV_06102009_1844_XX.dat
28	36° 53.5025	116° 1.8306	12.5	LV_06102009_1925_XX.dat
29	36° 53.475	116° 1.8878	13.2	LV_06102009_1945_XX.dat
30	36° 53.4158	116° 1.9016	12.8	LV_06102009_2004_XX.dat
31	36° 53.3631	116° 1.9107	12.4	LV_06102009_2023_XX.dat
32	36° 53.3395	116° 1.8663	10.3	LV_06102009_2042_XX.dat
33	36° 53.3752	116° 1.8343	12.4	LV_06102009_2111_XX.dat
34	36° 53.4265	116° 1.8306	12.3	LV_06102009_2130_XX.dat
35	36° 53.4844	116° 1.8192	12.0	LV_06102009_2149_XX.dat

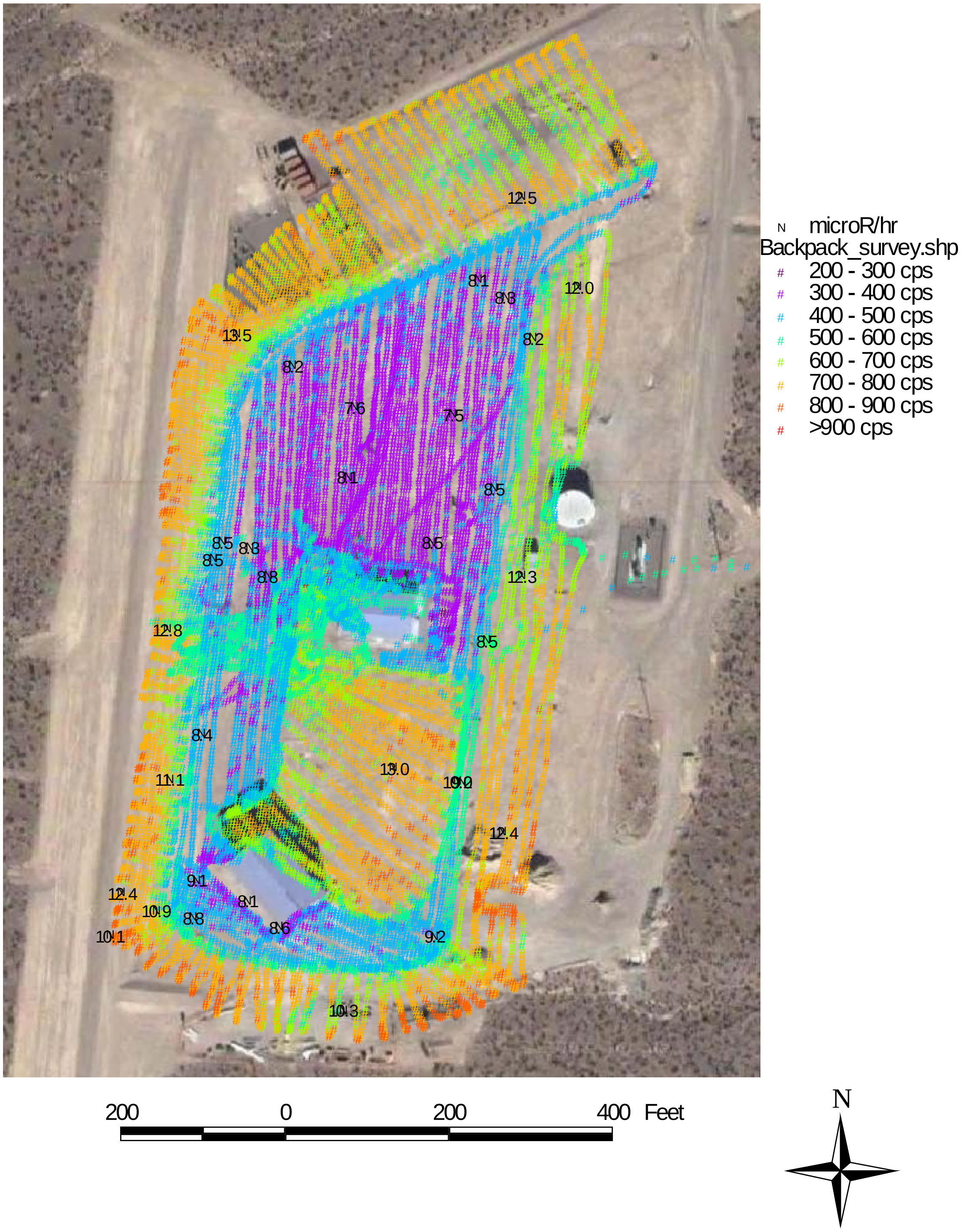

Figure 5: The measurements from the high-pressure ion chamber are shown on top of the backpack survey. The data shows good correlation between the HPIC and backpack. The measurements inside the Active Interrogation Building were excluded.

Table 3: Results from the HPGe measurements. The areas of the peaks in the spectra were calculated, corrected by the yield per decay of the parent isotope, and multiplied by the efficiency of the detector for a source uniformly distributed in the soil. Whenever possible, the results from multiple peaks were combined to produce a weighted average activity concentration. The GPS information for the measurements collected in the Active Interrogation Building is suspect, so they have been highlighted.

Location	Latitude	Longitude	HPGe filename	Ra-226 pCi/g	Th-232 pCi/g	K-40 pCi/g
1	36.890228	-116.030625	090609_01.Spc	0.567±0.024	0.239±0.017	3.725±0.17
2	36.890735	-116.030602	090609_02.Spc	0.544±0.024	0.22±0.017	3.435±0.165
3	36.891238	-116.030472	090609_03.Spc	0.545±0.023	0.187±0.015	2.868±0.15
4	36.891373	-116.030563	090609_04.Spc	0.553±0.023	0.115±0.013	2.586±0.143
5	36.891430	-116.030655	090609_05.Spc	0.499±0.023	0.131±0.013	2.873±0.152
6	36.891007	-116.031067	090609_06.Spc	0.549±0.023	0.129±0.015	2.293±0.133
7	36.891143	-116.031273	090609_07.Spc	0.495±0.022	0.153±0.015	2.787±0.149
8	36.890557	-116.031510	090609_08.Spc	0.594±0.025	0.282±0.02	4.398±0.184
9	36.890537	-116.031418	090609_09.Spc	0.598±0.024	0.182±0.015	2.901±0.151
10	36.890498	-116.031540	090609_10.Spc	0.585±0.024	0.235±0.017	3.238±0.159
11	36.890442	-116.031357	090609_11.Spc	0.591±0.024	0.193±0.016	2.568±0.143
12	36.890773	-116.031090	090609_12.Spc	0.572±0.024	0.13±0.016	2.504±0.14
13	36.890553	-116.030807	090609_13.Spc	0.528±0.022	0.15±0.016	2.402±0.137
14	36.889915	-116.031578	090609_14.Spc	0.562±0.024	0.286±0.019	3.753±0.172
15	36.889325	-116.031730	090609_15.Spc	0.88±0.031	0.796±0.03	10.497±0.287
16	36.889270	-116.031318	090609_16.Spc	0.56±0.024	0.169±0.015	3.055±0.155
17	36.889358	-116.031425	090609_17.Spc	0.544±0.023	0.179±0.015	2.828±0.151
18	36.889427	-116.031593	090610_18.Spc	0.591±0.024	0.183±0.018	2.949±0.153
19	36.889302	-116.031608	090610_19.Spc	0.613±0.026	0.295±0.019	3.993±0.178
20	36.889242	-116.031883	090610_20.Spc	0.849±0.03	0.728±0.028	9.204±0.267
21	36.889763	-116.031685	090610_21.Spc	0.907±0.032	0.79±0.029	10.277±0.282
22	36.888828	-116.033363	090610_22.Spc	0.758±0.029	0.644±0.027	9.573±0.269
23	36.889758	-116.030723	090610_23.Spc	0.769±0.029	0.674±0.027	8.534±0.257
24	36.889240	-116.030800	090610_24.Spc	0.51±0.023	0.196±0.017	2.89±0.152
25	36.889755	-116.030708	090610_25.Spc	0.573±0.024	0.299±0.019	4.61±0.191
26	36.889802	-116.030937	090610_26.Spc	1.057±0.036	1.181±0.037	16.045±0.354
27	36.890980	-116.030738	090610_27.Spc	0.519±0.023	0.138±0.016	2.341±0.138
28	36.891708	-116.030510	090610_28.Spc	1.018±0.035	1.171±0.036	15.556±0.348
29	36.891250	-116.031463	090610_29.Spc	1.084±0.035	1.316±0.038	16.405±0.356
30	36.890263	-116.031693	090610_30.Spc	1.083±0.035	1.191±0.036	15.627±0.351
31	36.889385	-116.031845	090610_31.Spc	1.033±0.035	1.156±0.036	14.831±0.34
32	36.888992	-116.031105	090610_32.Spc	0.645±0.028	0.692±0.028	9.216±0.266
33	36.889587	-116.030572	090610_33.Spc	1.024±0.035	1.175±0.036	14.963±0.343
34	36.890442	-116.030510	090610_34.Spc	1.001±0.034	1.109±0.035	14.617±0.338
35	36.891407	-116.030320	090610_35.Spc	0.881±0.032	0.891±0.032	12.024±0.307

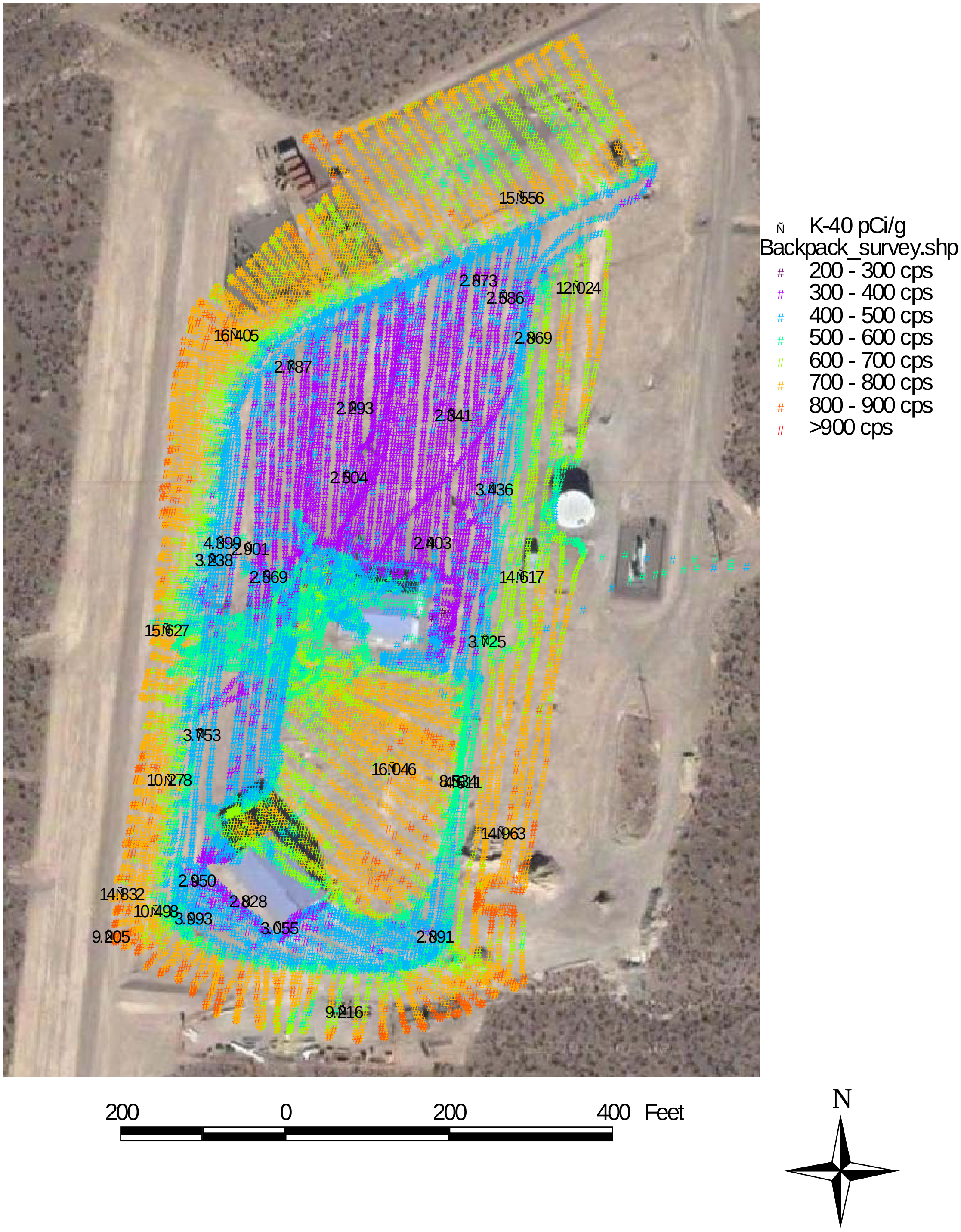

Figure 6: The results of the analysis of the HPGe spectra for ^{40}K activity in the ground are shown on top of the backpack survey. The measurements inside the Active Interrogation Building were excluded.

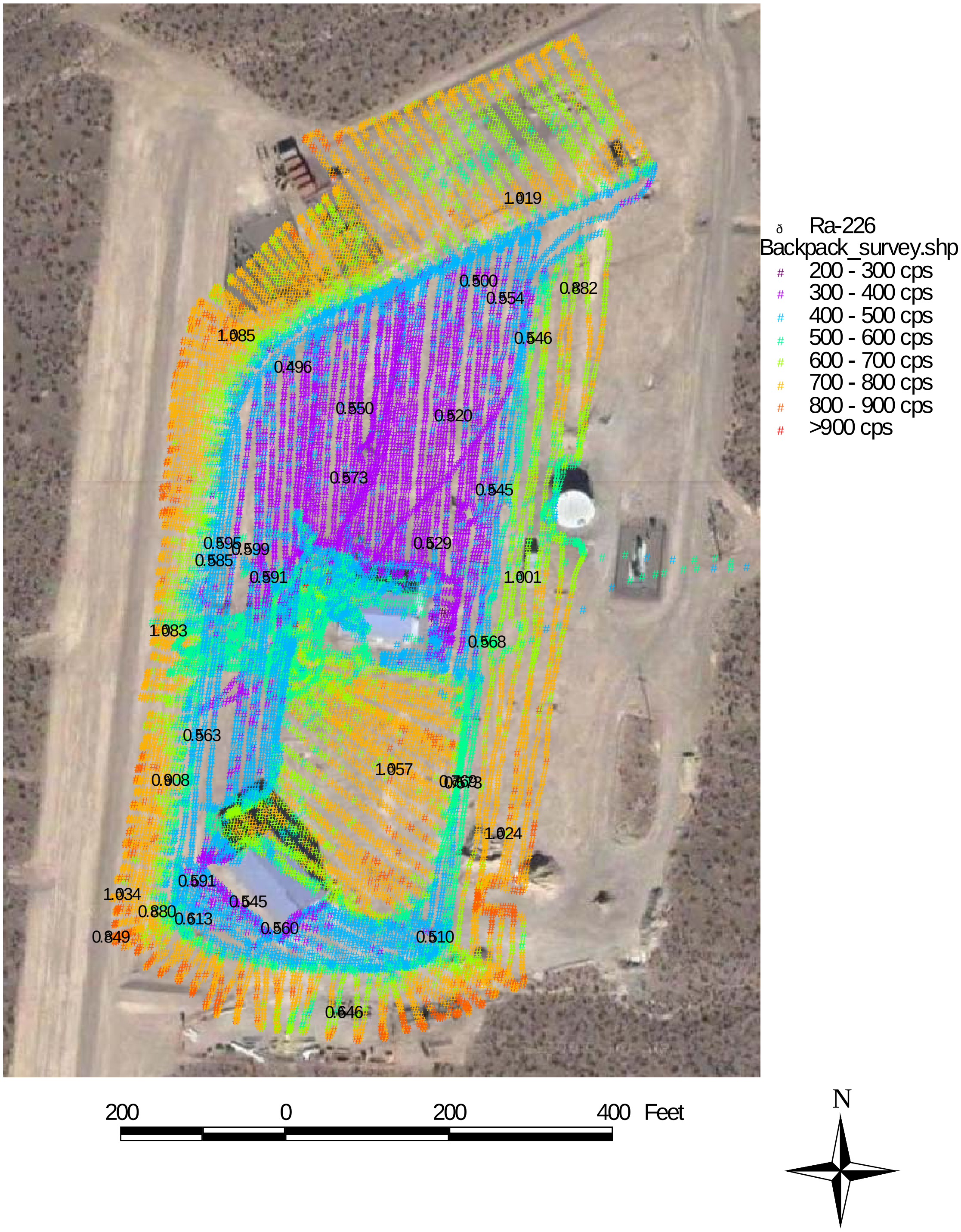

Figure 7: The results of the analysis of the HPGe spectra for ^{226}Ra activity in the ground are shown on top of the backpack survey. The measurements inside the Active Interrogation Building were excluded.

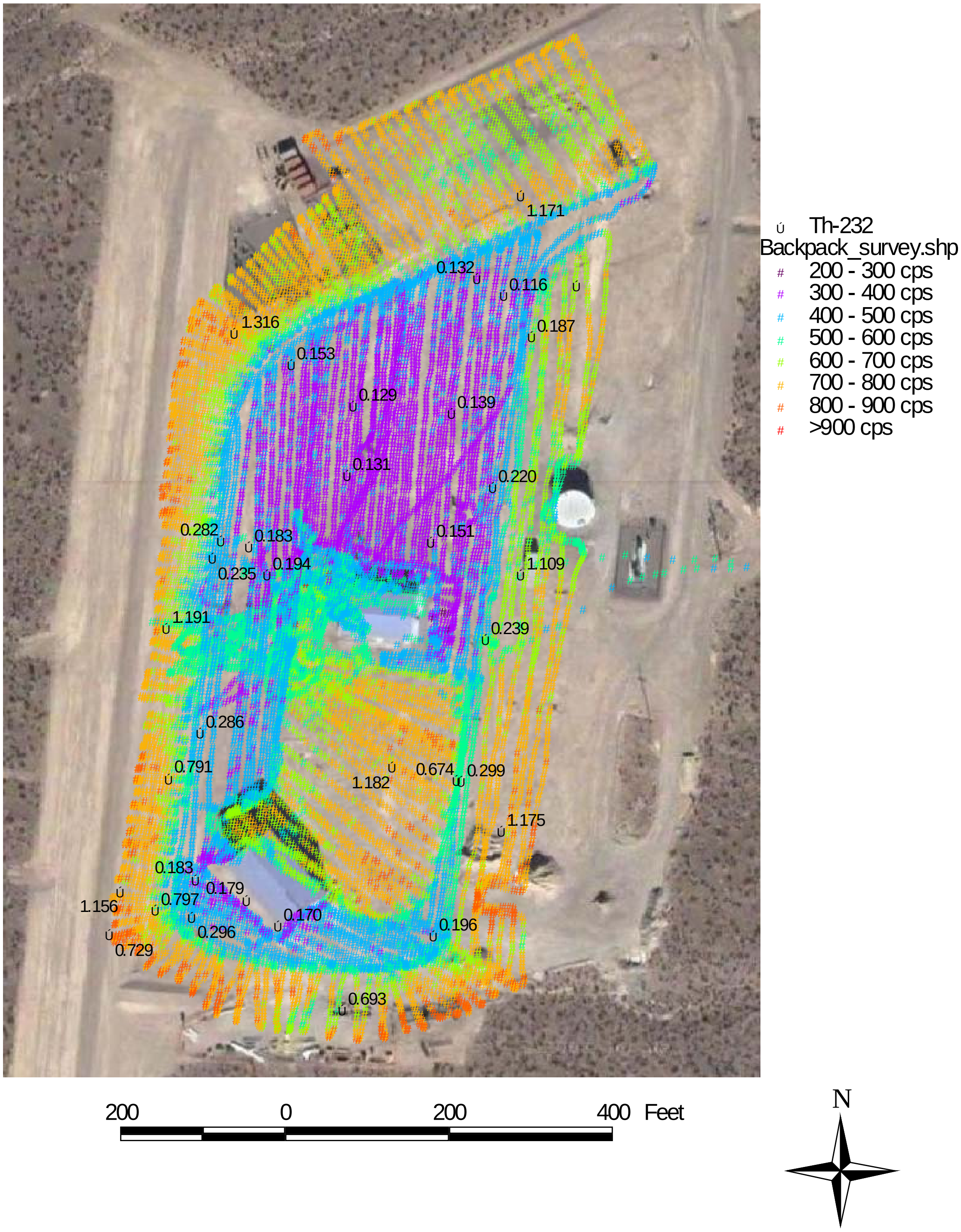

Figure 8: The results of the analysis of the HPGe spectra for ^{232}Th activity in the ground are shown on top of the backpack survey. The measurements inside the Active Interrogation Building were excluded.