Technical Memorandum
Evaluation of Naturally Occurring Uranium and Thorium Decay Chain Radionuclides in Santa Susana Field Laboratory Area IV Soils

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Background

The U.S. Environmental Protection Agency (USEPA) in its final report[1] of soil radionuclide sampling in Area IV of the Santa Susana Field Laboratory (SSFL) indicated that the uranium and thorium decay series radionuclides that were above the radiological trigger level (RTL) were mostly from naturally occurring radioactive material (NORM) origin and not related to site contamination. The report stated the following:

> "For Round 1 sample results, only four NORM RTL exceedances warranted collection of step-out samples during Round 2. Several instances were identified where NORM RTL exceedances were associated with collocated site-related radionuclides. In these instances, Round 2 step-out samples were collected and analyzed to characterize potential site-related contamination."

and:

> "The evaluation of NORM RTL exceedances produced few results considered potentially site related,"

USEPA did not provide a list of samples that exceeded the RTL for the uranium and thorium decay series radionuclides that were or were not considered site related and did not include any results for them in their list of Radiological Areas of Interest. Therefore, this evaluation is being performed to identify which samples that exceed the Look-Up Table (LUT) values for the uranium and thorium decay series radionuclides appear to be NORM origin and which appear to be site related.

Methodology

The USEPA said they used a procedure for assessing the presence of NORM that included evaluation of the consistency of the U-238 and Th-232 decay series radionuclide activities within each series and the isotopic ratio of concentrations of U-235 and U-234 with U-238. The decay series for the U-238, U-235, and Th-232, showing half-lives for each member, are shown in Figures 1 through 3 below.

[1] *Final Radiological Characterization of Soils, Area IV and the Northern Buffer Zone, Area IV Radiological Study, Santa Susana Field Laboratory, Ventura County, California*, HydroGeoLogic, Inc., December 21, 2012.
Ventura County, California

Site-process-related uranium and thorium were chemically purified prior to their introduction onsite, which removes the decay series daughters. The speed at which the daughters grow back in to equilibrium (same activity) with the decay series parent is dependent on the half-life of the daughter. Short half-life daughters grow into equilibrium with longer half-life parents quickly (short ingrowth time) while long half-life daughters do not (long ingrowth time). This fact can be used to determine if elevated concentrations of the parent are due to variations in NORM concentrations or are site related for the uranium decay series because of the long half-life (77,000 years) of the Th-230 daughter for the U-238 series and the long half-life (32,800 years) of the Pa-231 daughter for the U-235 series. Radionuclides in the series before those daughters would be expected to be in equilibrium with the series parent for both site-process-related contamination and for NORM. However, those long half-live radionuclides and their daughters would not be expected to be anywhere near equilibrium with the parent for site-process-related contamination, but would be in equilibrium for NORM. Unfortunately, this is not true for the Th-232 decays series since the longest half-life daughter is only 5.8 years and the entire decay series would be nearing equilibrium in the after the 35 years since site process-related operations ceased.

The ratio of U-234 and U-235 to U-238 activities can also give an indication of site-process-related contamination. In NORM, the ratio of U-234 to U-238 activities should be close to 1 since they are in equilibrium naturally. The ratio of U-235 to U-238 should be close to 0.057 (1/18) based on their natural abundances. Uranium fuel used in reactors onsite was enriched (higher ratio) in the U-235 and U-234 in relationship to the U-238 isotope anywhere from 3 % to near 90%, which means the ratios will be higher. Therefore, if the ratios are higher, it indicates that the concentrations are from site-process-related contamination. However, the converse is not true since site processes may have also involved natural or depleted uranium and site related contamination could have natural ratios.

Evaluation

Only U-238, U-234, U-235, and Th-232 of the radionuclides in the NORM decay series need to be reviewed against their LUT values since their short ingrowth time (short-half-life) daughters can be assumed to be in equilibrium with them and the long ingrowth time (longer half-life) daughter decay series radionuclides will not be site-process related. The USEPA soil data from their SSFL Area IV radiological survey were used to compare the U-238, U-234, U-235, and Th-232 results against their LUT values. Fortunately, no Th-232 results exceeded its LUT value. Eight locations exceeded the LUT for U-238 and 11 locations exceeded the LUT for U-234. The total number of locations that exceeded one or both LUT values was 13. No locations exceeded the LUT for U-235; however, some of the locations that exceeded the LUT for U-238 and/or U-234 were also showed results for U-235 elevated above average backgrounds by a similar ratio as the U-234 and/or U-238 values. See Table 1 for a listing of all uranium decay series data for these locations.

Locations 5DS-00018 and 5DS-00019 both exceeded the LUT values for U-238. While the U-234 results did not exceed its LUT for these locations, they were in reasonable agreement with the U-238 results. The long-ingrowth daughters (Th-230, Bi-214, and Pb-214) were also in reasonable agreement with the U-238 results. Therefore, the concentrations at these two locations should be considered from NORM origin.

Locations 6-00045, 7-00017, 7-00052, 7-00066, and NBZ-00017 all exceeded the LUT values for both U-238 and U-234. The U-235 results were also elevated by a similar ratio. The U-238 and U-234 values are in reasonable agreement with each other and with the short-ingrowth daughter (Th-234) but not in agreement with the long-ingrowth daughters (Th-230, Bi-214, and Pb-214). Therefore, the concentrations at these five locations should be considered to be from site processes even though the isotopic ratios look to be normal or only slightly enriched above that of natural uranium.

Locations 7-00022, 7-00090, 7/00151, and 7-00184 all exceeded the LUT values for U-234. The U-235 results were also elevated by a similar ratio but the U-238 results were not. This is an indication of process related enriched uranium. The U-234 values are also not in agreement with the long-ingrowth daughters (Th-230, Bi-214, and Pb-214). Therefore, the concentrations at these four locations should be considered to be from site processes.

Locations 7-00188 and NBZ-00124 exceeded the LUT values for both U-238 and U-234. The U-235 results were also elevated by a similar ratio. The U-238 and U-234 values are in reasonable agreement with each other, with the short-ingrowth daughter (Th-234), and with the long-ingrowth daughters (Th-230, Bi-214, and Pb-214). Therefore, the concentrations at these two locations should be considered from NORM origin.

Summary

Of the 13 locations that exceeded the LUT values for U-234, U-238, or both, 4 were determined to be from NORM origin and 9 were determined to be from site processes based on their ratios with long-ingrowth daughters and/or ratios of the uranium isotopes. Seven of the nine locations whose concentrations were determined to be from site processes were from Subarea 7; one was from Subarea 6 and one was from the Northern Boundary Zone. The results for all but one of the locations were from surface soil. The one exception was from a sample taken from the 1 to 2.3 foot depth.

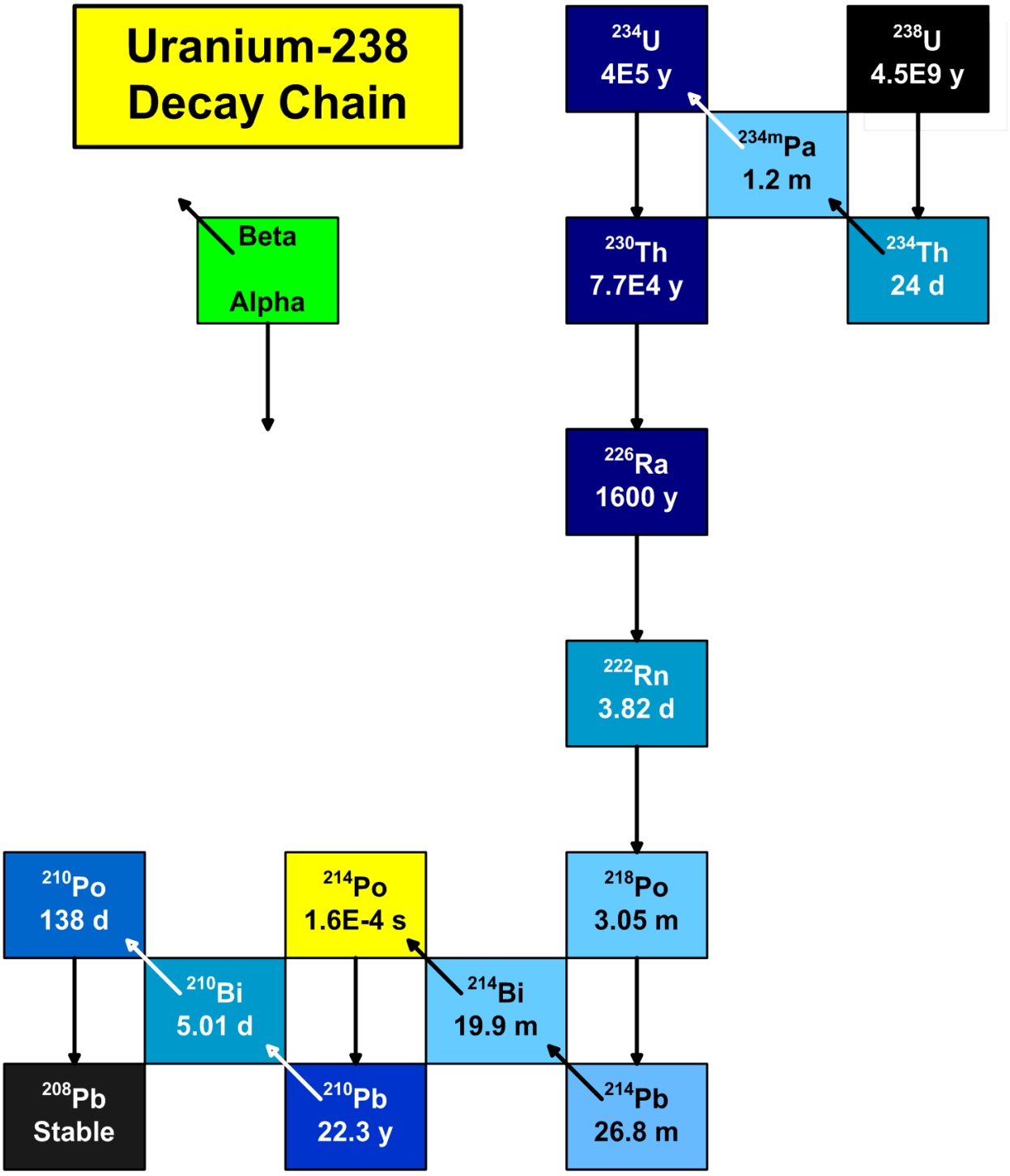

Figure 1. Uranium-238 Decay Series

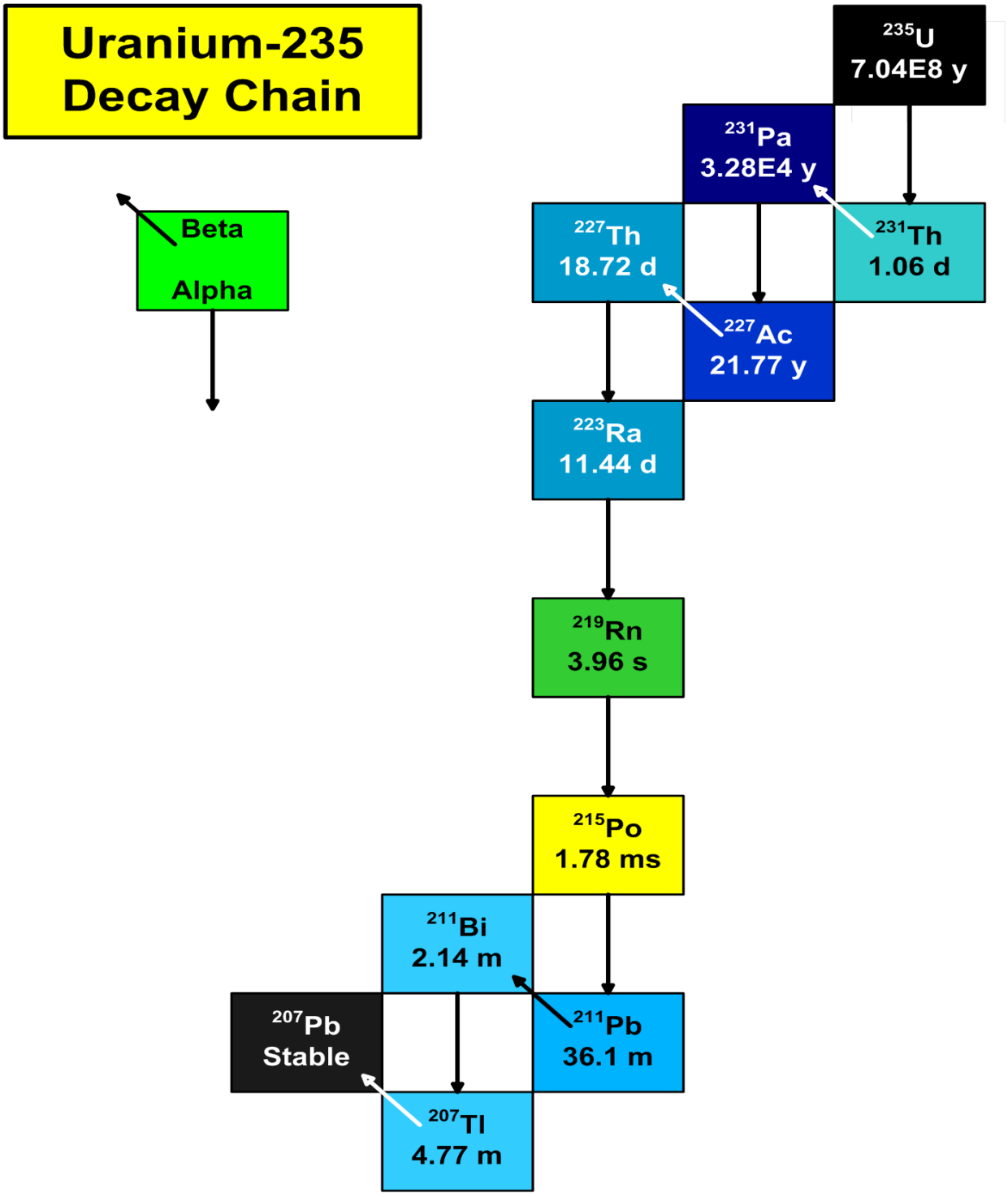

Figure 2. Uranium-235 Decay Series

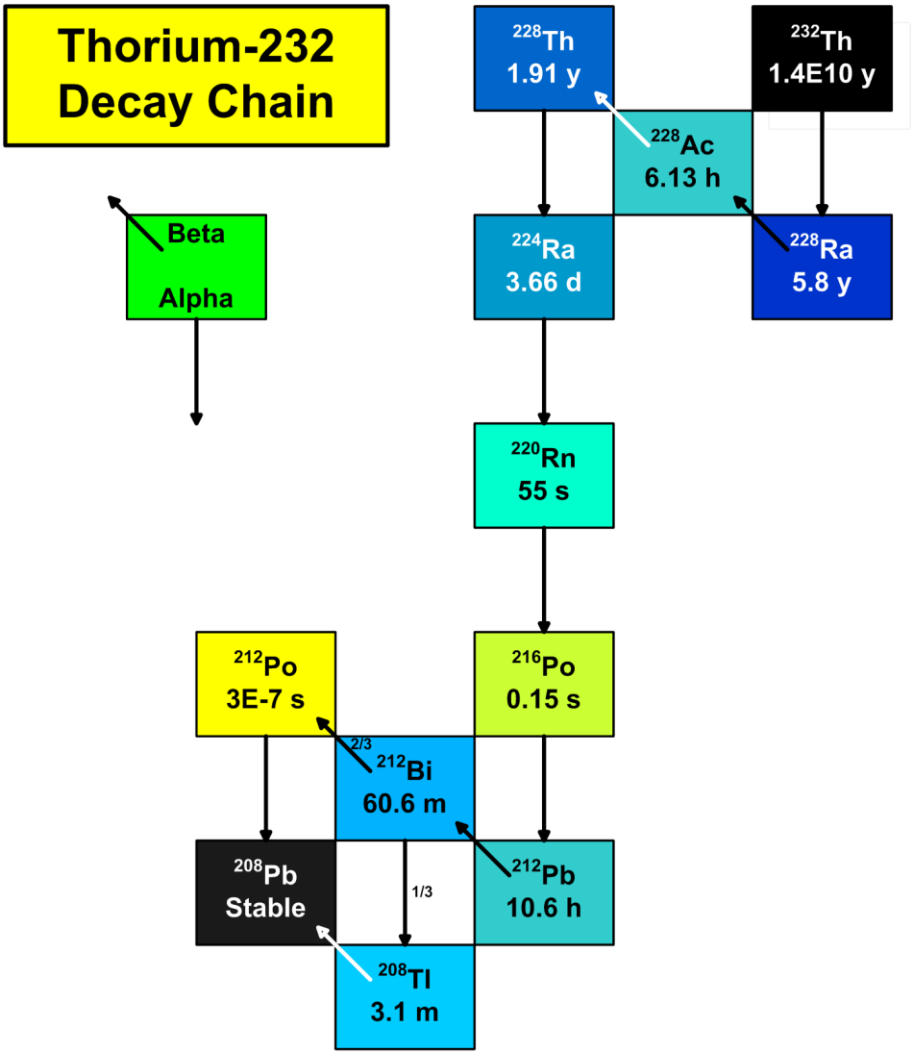

Figure 3. Thorium-232 Decay Series

Table 1. Soil Uranium Decay Series Results for Locations with Results Above LUT Values

Location Name	Begin Depth	End Depth	Lab Sample ID	Analyte	Activity	Units	MDC	DV Qualifier	Total 1 Sigma Propagated Uncertainty	Critical Level
5DS-00018	1	2.5	293876006	Ac-227	0.0184	pCi/g	0.21	U	0.0733	0.104
5DS-00018	1	2.5	293876006	Bi-214	2.94	pCi/g	0.0378		0.122	0.0186
5DS-00018	1	2.5	293876006	Pa-231	-0.187	pCi/g	0.877	UJ	0.293	0.434
5DS-00018	1	2.5	293876006	Pb-214	3.07	pCi/g	0.0388		0.131	0.0191
5DS-00018	1	2.5	293876006	Th-230	1.67	pCi/g	0.069		0.132	0.0258
5DS-00018	1	2.5	293876006	Th-234	3.74	pCi/g	0.24		0.23	0.434
5DS-00018	1	2.5	293876006	U-233/U-234	1.82	pCi/g	0.0651		0.154	0.0278
5DS-00018	1	2.5	293876006	U-235/U-236	0.065	pCi/g	0.0486		0.0226	0.0172
5DS-00018	1	2.5	293876006	U-238	2.07	pCi/g	0.0543		0.17	0.022
5DS-00019	1	3.17	293876007	Ac-227	-0.172	pCi/g	0.274	U	0.0916	0.135
5DS-00019	1	3.17	293876007	Bi-214	2.36	pCi/g	0.0434		0.103	0.0212
5DS-00019	1	3.17	293876007	Pa-231	0.0423	pCi/g	1.14	UJ	0.348	0.56
5DS-00019	1	3.17	293876007	Pb-214	2.62	pCi/g	0.0494		0.12	0.0243
5DS-00019	1	3.17	293876007	Th-230	1.66	pCi/g	0.0597	L	0.133	0.0211
5DS-00019	1	3.17	293876007	Th-234	4.35	pCi/g	0.408		0.335	0.56
5DS-00019	1	3.17	293876007	U-233/U-234	2	pCi/g	0.0631	J	0.182	0.0238
5DS-00019	1	3.17	293876007	U-235/U-236	0.0628	pCi/g	0.0549		0.0255	0.017
5DS-00019	1	3.17	293876007	U-238	2.22	pCi/g	0.0189	J	0.197	0
6-00045	0	0.5	289304011	Ac-227	-0.128	pCi/g	0.208	U	0.0702	0.103
6-00045	0	0.5	289304010	Ac-227	-0.172	pCi/g	0.262	U	0.0896	0.129
6-00045	0	0.5	289304011	Bi-214	0.935	pCi/g	0.0326		0.0459	0.0159
6-00045	0	0.5	289304010	Bi-214	1.49	pCi/g	0.0422		0.0703	0.0205
6-00045	0	0.5	289304011	Pa-231	0.142	pCi/g	0.875	U	0.271	0.43
6-00045	0	0.5	289304010	Pa-231	-0.403	pCi/g	1.1	U	0.374	0.541
6-00045	0	0.5	289304011	Pb-214	1.03	pCi/g	0.038		0.0502	0.0187
6-00045	0	0.5	289304010	Pb-214	1.68	pCi/g	0.0479		0.0812	0.0235
6-00045	0	0.5	289304011	Th-230	1.19	pCi/g	0.0642	L	0.126	0.0203
6-00045	0	0.5	289304010	Th-230	1.24	pCi/g	0.049		0.116	0.0155
6-00045	0	0.5	289304011	Th-234	1.45	pCi/g	0.398	J	0.372	0.197
6-00045	0	0.5	289304010	Th-234	2.45	pCi/g	0.439	J	0.276	0.541
6-00045	0	0.5	289304011	U-233/U-234	2.16	pCi/g	0.0328	J	0.19	0.0102
6-00045	0	0.5	289304010	U-233/U-234	2.48	pCi/g	0.0249	J	0.247	0
6-00045	0	0.5	289304010	U-235/U-236	0.0794	pCi/g	0.0307		0.0307	0
6-00045	0	0.5	289304011	U-235/U-236	0.14	pCi/g	0.0173		0.0316	0
6-00045	0	0.5	289304011	U-238	2.23	pCi/g	0.0406	J	0.195	0.0144
6-00045	0	0.5	289304010	U-238	2.34	pCi/g	0.0585	J	0.236	0.0181
7-00017	0	0.5	289196011	Ac-227	0.0327	pCi/g	0.275	U	0.0828	0.136
7-00017	0	0.5	289196011	Bi-214	0.778	pCi/g	0.0371		0.0394	0.0182
7-00017	0	0.5	289196011	Pa-231	-0.0563	pCi/g	1.16	U	0.405	0.576
7-00017	0	0.5	289196011	Pb-214	0.845	pCi/g	0.0501		0.0469	0.0248
7-00017	0	0.5	289196011	Th-230	0.641	pCi/g	0.0507	L	0.0769	0.016
7-00017	0	0.5	289196011	Th-234	2.55	pCi/g	0.387		0.246	0.127
7-00017	0	0.5	289196011	U-233/U-234	3.08	pCi/g	0.0348		0.261	0.0108
7-00017	0	0.5	289196011	U-235/U-236	0.196	pCi/g	0.0183		0.0391	0
7-00017	0	0.5	289196011	U-238	2.65	pCi/g	0.0148		0.229	0
7-00022	0	0.5	289304003	Ac-227	0.0111	pCi/g	0.168	U	0.0515	0.0827
7-00022	0	0.5	289304003	Bi-214	0.83	pCi/g	0.0305		0.0409	0.0149
7-00022	0	0.5	289304003	Pa-231	-0.0214	pCi/g	0.715	U	0.221	0.351
7-00022	0	0.5	289304003	Pb-214	0.884	pCi/g	0.0303		0.0427	0.0148
7-00022	0	0.5	289304003	Th-230	0.673	pCi/g	0.0192	L	0.0796	0
7-00022	0	0.5	289304003	Th-234	1.18	pCi/g	0.189		0.0999	0.0785
7-00022	0	0.5	289304003	U-233/U-234	2.33	pCi/g	0.0358		0.206	0.0111
7-00022	0	0.5	289304003	U-235/U-236	0.104	pCi/g	0.0188		0.028	0
7-00022	0	0.5	289304003	U-238	1.1	pCi/g	0.0152		0.113	0
7-00052	0	0.5	289196009	Ac-227	0.11	pCi/g	0.217	J	0.0709	0.107
7-00052	0	0.5	289196010	Ac-227	-0.0174	pCi/g	0.243	U	0.074	0.12
7-00052	0	0.5	289196009	Bi-214	0.661	pCi/g	0.0356		0.0349	0.0174
7-00052	0	0.5	289196010	Bi-214	0.777	pCi/g	0.0352		0.0381	0.0173
7-00052	0	0.5	289196009	Pa-231	-0.325	pCi/g	0.897	U	0.291	0.442

Location Name	Begin Depth	End Depth	Lab Sample ID	Analyte	Activity	Units	MDC	DV Qualifier	Total 1 Sigma Propagated Uncertainty	Critical Level
7-00052	0	0.5	289196010	Pa-231	0.0922	pCi/g	1.02	U	0.312	0.505
7-00052	0	0.5	289196009	Pb-214	0.726	pCi/g	0.0429		0.0377	0.0211
7-00052	0	0.5	289196010	Pb-214	0.875	pCi/g	0.0453		0.0466	0.0224
7-00052	0	0.5	289196010	Th-230	0.607	pCi/g	0.0185	L	0.0735	0
7-00052	0	0.5	289196009	Th-230	0.623	pCi/g	0.0516	L	0.0762	0.0163
7-00052	0	0.5	289196009	Th-234	2.08	pCi/g	0.226		0.143	0.0929
7-00052	0	0.5	289196010	Th-234	2.45	pCi/g	0.316		0.182	0.505
7-00052	0	0.5	289196010	U-233/U-234	2.57	pCi/g	0.0388		0.229	0.012
7-00052	0	0.5	289196009	U-233/U-234	2.67	pCi/g	0.0148		0.231	0
7-00052	0	0.5	289196010	U-235/U-236	0.121	pCi/g	0.0204		0.0314	0
7-00052	0	0.5	289196009	U-235/U-236	0.171	pCi/g	0.0431		0.037	0.0134
7-00052	0	0.5	289196010	U-238	2.19	pCi/g	0.0481		0.2	0.017
7-00052	0	0.5	289196009	U-238	2.29	pCi/g	0.0495		0.202	0.0187
7-00066	1	2.3	289196003	Ac-227	-0.00332	pCi/g	0.204	U	0.0606	0.1
7-00066	1	2.3	289196003	Bi-214	0.799	pCi/g	0.0329		0.0398	0.0161
7-00066	1	2.3	289196003	Pa-231	-0.132	pCi/g	0.845	U	0.265	0.415
7-00066	1	2.3	289196003	Pb-214	0.919	pCi/g	0.0348		0.0465	0.0171
7-00066	1	2.3	289196003	Th-230	0.844	pCi/g	0.0147	L	0.083	0
7-00066	1	2.3	289196003	Th-234	2.85	pCi/g	0.325		0.234	0.102
7-00066	1	2.3	289196003	U-233/U-234	2.61	pCi/g	0.0387		0.221	0.0137
7-00066	1	2.3	289196003	U-235/U-236	0.177	pCi/g	0.0386		0.0359	0.012
7-00066	1	2.3	289196003	U-238	2.47	pCi/g	0.0133		0.211	0
7-00090	0	0.5	289300009	Ac-227	0.054	pCi/g	0.226	U	0.0703	0.112
7-00090	0	0.5	289300009	Bi-214	0.728	pCi/g	0.0316		0.0359	0.0154
7-00090	0	0.5	289300009	Pa-231	-0.167	pCi/g	0.935	U	0.294	0.461
7-00090	0	0.5	289300009	Pb-214	0.788	pCi/g	0.0427		0.0413	0.0211
7-00090	0	0.5	289300009	Th-230	0.587	pCi/g	0.111	L	0.09	0.0415
7-00090	0	0.5	289300009	Th-234	1.73	pCi/g	0.3		0.168	0.1
7-00090	0	0.5	289300009	U-233/U-234	4.09	pCi/g	0.0511	J	0.348	0.0181
7-00090	0	0.5	289300009	U-235/U-236	0.304	pCi/g	0.0217		0.0544	0
7-00090	0	0.5	289300009	U-238	1.68	pCi/g	0.0176		0.164	0
7-00151	0	0.5	288930001	Ac-227	-0.0243	pCi/g	0.236	U	0.0699	0.116
7-00151	0	0.5	288930001	Bi-214	0.938	pCi/g	0.042		0.0498	0.0203
7-00151	0	0.5	288930001	Pa-231	0.0511	pCi/g	0.989	U	0.315	0.484
7-00151	0	0.5	288930001	Pb-214	0.991	pCi/g	0.0434		0.05	0.0212
7-00151	0	0.5	288930001	Th-230	0.848	pCi/g	0.0794	L	0.0951	0.0297
7-00151	0	0.5	288930001	Th-234	1.73	pCi/g	0.328		0.173	0.11
7-00151	0	0.5	288930001	U-233/U-234	4.07	pCi/g	0.0158		0.339	0
7-00151	0	0.5	288930001	U-235/U-236	0.218	pCi/g	0.0455		0.0436	0.0141
7-00151	0	0.5	288930001	U-238	1.65	pCi/g	0.0456		0.157	0.0161
7-00184	0	0.5	289304004	Ac-227	-0.00136	pCi/g	0.218	U	0.0641	0.107
7-00184	0	0.5	289304004	Bi-214	0.685	pCi/g	0.039		0.0405	0.0188
7-00184	0	0.5	289304004	Pa-231	-0.182	pCi/g	0.923	U	0.3	0.451
7-00184	0	0.5	289304004	Pb-214	0.79	pCi/g	0.041		0.0413	0.02
7-00184	0	0.5	289304004	Th-230	0.582	pCi/g	0.0516	L	0.073	0.0163
7-00184	0	0.5	289304004	Th-234	1.56	pCi/g	0.307	J	0.163	0.103
7-00184	0	0.5	289304004	U-233/U-234	2.61	pCi/g	0.0607	J	0.246	0.0215
7-00184	0	0.5	289304004	U-235/U-236	0.107	pCi/g	0.0606		0.0347	0.0188
7-00184	0	0.5	289304004	U-238	1.03	pCi/g	0.0607		0.12	0.0215
7-00188	22	23	296352013	Ac-227	-0.121	pCi/g	0.26	U	0.0831	0.128
7-00188	22	23	296352013	Bi-214	1.63	pCi/g	0.0426	Y	0.0787	0.0206
7-00188	22	23	296352013	Pa-231	-0.164	pCi/g	1.1	U	0.356	0.539
7-00188	22	23	296352013	Pb-214	1.74	pCi/g	0.0495	Y	0.081	0.0242
7-00188	22	23	296352013	Th-230	2.31	pCi/g	0.093	LY	0.169	0.0376
7-00188	22	23	296352013	Th-234	1.95	pCi/g	0.372		0.193	0.124
7-00188	22	23	296352013	U-233/U-234	2.29	pCi/g	0.0597	Y	0.19	0.0242
7-00188	22	23	296352013	U-235/U-236	0.171	pCi/g	0.0431	Y	0.0367	0.0134
7-00188	22	23	296352013	U-238	2.23	pCi/g	0.0349	Y	0.185	0.0108
NBZ-00017	0	0.5	303592013	Ac-227	-0.0905	pCi/g	0.201	U	0.0719	0.0987
NBZ-00017	0	0.5	303592013	Bi-214	1.2	pCi/g	0.0363		0.0569	0.0176
NBZ-00017	0	0.5	303592013	Pa-231	0.532	pCi/g	0.908	J	0.291	0.445

Location Name	Begin Depth	End Depth	Lab Sample ID	Analyte	Activity	Units	MDC	DV Qualifier	Total 1 Sigma Propagated Uncertainty	Critical Level
NBZ-00017	0	0.5	303592013	Pb-214	1.35	pCi/g	0.0373		0.0644	0.0182
NBZ-00017	0	0.5	303592013	Th-230	0.855	pCi/g	0.0662	L	0.0997	0.0209
NBZ-00017	0	0.5	303592013	Th-234	2.94	pCi/g	0.319		0.218	0.105
NBZ-00017	0	0.5	303592013	U-233/U-234	2.4	pCi/g	0.0953		0.228	0.0386
NBZ-00017	0	0.5	303592013	U-235/U-236	0.0973	pCi/g	0.0293		0.0332	0
NBZ-00017	0	0.5	303592013	U-238	2.43	pCi/g	0.0557		0.229	0.0173
NBZ-00124	0	0.5	298466009	Ac-227	0.0292	pCi/g	0.226	U	0.0665	0.111
NBZ-00124	0	0.5	298466009	Bi-214	2.66	pCi/g	0.0327	Y	0.115	0.016
NBZ-00124	0	0.5	298466009	Pa-231	0.263	pCi/g	0.924	U	0.286	0.455
NBZ-00124	0	0.5	298466009	Pb-214	2.87	pCi/g	0.0387	Y	0.121	0.019
NBZ-00124	0	0.5	298466009	Th-230	3.62	pCi/g	0.105	L	0.243	0.0432
NBZ-00124	0	0.5	298466009	Th-234	2.65	pCi/g	0.321	J	0.19	0.455
NBZ-00124	0	0.5	298466009	U-233/U-234	2.28	pCi/g	0.0968		0.186	0.0448
NBZ-00124	0	0.5	298466009	U-235/U-236	0.127	pCi/g	0.04		0.0303	0.0124
NBZ-00124	0	0.5	298466009	U-238	2.67	pCi/g	0.04		0.211	0.0142

Yellow highlights indicate elevated results. Green highlights indicate non-elevated results.