Appendix A:

USEPA Guidance states the following:

> "Background radiation levels will generally be determined as background levels are determined for other contaminants, on a site-specific basis. In some cases, the same constituents are found in on-site samples as well as in background samples. The levels of each constituent are compared to background to determine its impact, if any, on site- related activities." (USEPA, 1997)

Accordingly, at HPNS, workplans describe the procedures for determining radiological background levels based on reference areas. See, for example, the 2015 *Final Work Plan, Basewide Radiological Support*, which states the following:

> "The reference area is a geographical area or structure from which representative radioactivity measurements are performed for comparison with measurements performed in an impacted area. The reference area selected should have physical, chemical, radiological, and biological characteristics similar to the impacted area(s) being investigated. The reference area must not be identified as impacted by the HRA [Historical Radiological Assessment]." (Navy, 2015b)

As one example of this approach, recent measurement of background for a Parcel C cleanup effort found the following:

> "Background activity for $_{226}$Ra, based on the mean of the greater of the reported activity or minimum detectable activity (MDA), measured by a minimum of a 21-day in-growth of the 609.31 keV gamma energy peak for bismuth-214 ($_{214}$Bi), was determined to be 1.057 pCi/g. This places the release criterion at 2.057 pCi/g of $_{226}$Ra for final definitive data." (Navy, 2015a)

Table A-1 gives a summary of the findings that are presented in more detail in Table 3-3 from the original document, which follows.

Table A-1

Radionuclide of Concern	Mean background (pCi/g)	Standard deviation (pCi/g)	Remedial Goal (RG) (pCi/g)	Background + RG (pCi/g)
Ra-226	1.057	0.118	1.0	2.057
Cs-137	-0.002	0.010	0.113	0.113
Th-232	1.489	0.190	1.69	3.179
U-235	0.121	0.042	0.195	0.316

Commented [LL2]: Why is this negative?

Commented [LL3]: Should I just add the negative background to the RG?

Note: The values shown subtract instrument background. When count time for instrument background is longer than for the soil sample, then negative or zero values can occur.

Commented [LL4]: Tracy is speculating this possible explanation but needs to check further.

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TABLE 3-3

NCBJB Fill Material Reference Area Soil Measurements (Definitive)

Sample No.	Date	Time	Results (pCi/g)																	
			^{137}Cs	MDA	2σ Total	^{137}Cs	MDA	2σ Total	^{137}Cs	MDA	2σ Total	^{232}Th	MDA	2σ Total	^{232}Th	MDA	2σ Total	^{232}Th	MDA	2σ Total
1	12/03/2013	10:29:00	0.000	0.192	0.238	0.013	0.035	0.036	0.001	0.025	0.031	1.166	0.046	0.129	1.536	0.076	0.202	0.408	0.193	0.262
2	12/03/2013	10:27:00	0.008	0.172	0.209	0.017	0.037	0.037	0.018	0.017	0.028	1.175	0.056	0.147	1.622	0.030	0.206	0.204	0.149	0.197
3	12/03/2013	10:32:00	0.021	0.214	0.261	0.016	0.049	0.052	0.000	0.026	0.030	1.062	0.062	0.108	1.465	0.046	0.160	0.109	0.216	0.261
4	12/03/2013	10:38:00	0.116	0.160	0.229	0.010	0.028	0.035	0.005	0.027	0.030	1.060	0.063	0.133	1.487	0.074	0.179	0.139	0.201	0.261
5	12/03/2013	10:31:00	0.008	0.216	0.262	0.002	0.043	0.045	0.003	0.015	0.031	0.963	0.059	0.128	1.379	0.085	0.204	0.129	0.202	0.275
6	12/03/2013	10:30:00	0.003	0.159	0.194	0.006	0.025	0.031	0.001	0.012	0.019	0.924	0.054	0.102	1.165	0.079	0.150	0.079	0.187	0.242
7	12/03/2013	10:31:00	0.000	0.177	0.216	0.004	0.027	0.031	0.001	0.016	0.022	0.945	0.066	0.125	1.392	0.073	0.207	0.154	0.182	0.231
8	12/03/2013	10:34:00	0.040	0.198	0.248	0.010	0.028	0.031	0.011	0.018	0.025	1.074	0.058	0.142	1.390	0.073	0.172	0.181	0.171	0.218
9	12/03/2013	10:35:00	0.005	0.178	0.217	0.009	0.026	0.033	0.001	0.012	0.021	0.967	0.053	0.127	1.406	0.077	0.200	0.037	0.160	0.242
10	12/03/2013	10:36:00	0.006	0.207	0.260	0.008	0.036	0.038	0.000	0.026	0.036	1.091	0.060	0.139	1.706	0.069	0.193	0.068	0.210	0.249
11	12/03/2013	10:37:00	0.000	0.175	0.216	0.012	0.024	0.032	0.000	0.024	0.030	1.112	0.064	0.134	1.808	0.075	0.165	0.135	0.193	0.248
12	12/03/2013	10:38:00	0.000	0.199	0.198	0.006	0.026	0.032	0.000	0.027	0.036	0.987	0.057	0.144	1.368	0.078	0.208	0.139	0.180	0.248
13	12/03/2013	10:39:00	0.000	0.202	0.237	0.006	0.026	0.032	0.000	0.027	0.036	1.015	0.054	0.133	1.486	0.068	0.185	0.183	0.171	0.234
14	12/03/2013	10:40:00	0.000	0.203	0.271	0.000	0.024	0.029	0.000	0.019	0.029	0.980	0.049	0.123	1.565	0.069	0.193	0.076	0.150	0.203
15	12/03/2013	10:41:00	0.000	0.208	0.250	0.010	0.026	0.032	0.000	0.027	0.032	0.968	0.049	0.128	1.685	0.061	0.203	0.116	0.228	0.268
16	12/03/2013	10:42:00	0.040	0.208	0.265	0.007	0.029	0.032	0.000	0.024	0.030	1.103	0.062	0.133	1.286	0.069	0.188	0.108	0.207	0.246
17	12/03/2013	10:43:00	0.001	0.172	0.211	0.012	0.026	0.036	0.000	0.024	0.030	1.061	0.059	0.131	1.166	0.069	0.185	0.129	0.212	0.248
18	12/03/2013	10:44:00	0.000	0.207	0.255	0.000	0.025	0.030	0.000	0.024	0.030	1.177	0.059	0.140	1.969	0.080	0.191	0.123	0.197	0.249
		mean	0.008			0.002			0.000			1.002			1.488			0.135		
		std dev	0.040			0.010			0.006			0.118			0.195			0.042		
		median	0.000			0.003			0.000			1.001			1.465			0.137		

Notes:

Information concerning flags associated with the on-site laboratory data can be found in Section 4.3.

Abbreviations and Acronyms:

^{137}Cs – cesium-137
MDA – minimum detectable activity
MDC – minimum detectable concentration
pCi/g – picocuries per gram
^{226}Ra – radium-226
std dev – standard deviation
^{232}Th – thorium-232

(Navy, 2015a)

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Appendix B: Converting 6-inch Asphalt to a Soil Depth

The basic shielding calculation is:

$$I_f = I_0 e^{-\mu_L t}$$

Where I_f is the final intensity of radiation,
I_0 is the original intensity of radiation
μ_L is the linear attenuation coefficient of the material attenuating the radiation, and
t is the thickness of the attenuator

If we divide by I_0, we get the fraction of intensity that has been attenuated when passing through a specific absorber of a specific thickness (t).

$$\frac{I_f}{I_0} = e^{-\mu_L t}$$

If we use soil, the fraction of intensity equation would look like the following:

$$\frac{I_{f,soil}}{I_{0,soil}} = e^{-\mu_{L,soil} t_{soil}}$$

Likewise, if we use asphalt, the fraction of intensity equation would look like the following:

$$\frac{I_{f,asphalt}}{I_{0,asphalt}} = e^{-\mu_{L,asphalt} t_{asphalt}}$$

For Hunter's Point, we want to determine how much soil would give us the same fraction of intensity as 6 inches of asphalt. To determine the depth of soil needed, we will set both the fraction of intensity of soil and asphalt equal to each other as followed:

$$e^{-\mu_{L,soil} t_{soil}} = \frac{I_{f,soil}}{I_{0,soil}} = \frac{I_{f,asphalt}}{I_{0,asphalt}} = e^{-\mu_{L,asphalt} t_{asphalt}}$$

If we cancel out the intensity fraction, this would give us:

$$e^{\mu_{L,soil} t_{soil}} = e^{\mu_{L,asphalt} t_{asphalt}}$$

To eliminate the exponential, we multiply each side by natural log of each side.

$$ln(\ \mu_{L,soil} t_{soil}) = ln(e^{\mu_{L,asphalt} t_{asphalt}})$$

This would give us:

$$\mu_{L,soil} t_{soil} = \mu_{L,asphalt} t_{asphalt}$$

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If we solve to t_{soil}, this would give us the equation needed to determine the depth of soil needed to equal 6 inches of asphalt.

$$t_{soil} = \frac{\mu_{L,asphalt} t_{asphalt}}{\mu_{L,soil}}$$

In order to solve the above equation, we must know the linear attenuation coefficient for soil and asphalt. The linear attenuation coefficient is determined by specific energies. If we look at a lower energy such as 0.186MeV for Ra-226, we get the following

$$t_{soil} = \frac{\mu_{L,asphalt} t_{asphalt}}{\mu_{L,soil}}$$

where the $t_{asphalt}$=6 inches = 15.24 cm
$\mu_{L,asphalt} = 0.307\ cm^{-1}$
$\mu_{L,soil} = 0.195\ cm^{-1}$

$$t_{soil} = \frac{0.307\ cm^{-1} \times 15.24\ cm}{0.195\ cm^{-1}}$$

$$t_{soil} = 23.99$$

If we look at a higher energy such as 2.614MeV for Tl-208, we get the following:

$$t_{soil} = \frac{0.0916 cm^{-1} \times 15.24 cm}{0.0541\ cm^{-1}}$$

$$t_{soil} = 25.79$$

DRAFT

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