DEVELOPMENT AND USE OF RADIONUCLIDE REFERENCE CONCENTRATIONS

1.0 INTRODUCTION

The term radiological trigger level (RTL) was used in previous technical memoranda, documents, and presentations associated with the Santa Susana Field Laboratory (SSFL) Area IV Radiological Study. Radiological trigger levels were used as a decision level (DL) value against which laboratory results may be compared to determine whether a predetermined action level (AL), which is the expected limit of background activity, is likely to have been exceeded in a soil sample collected from the Area IV Study Area. The Area IV Study Area is defined as Area IV and the Northern Buffer Zone.

The RTLs were derived from a limited set of available analytical laboratory sampling results (primarily from Subareas 5C and 6) and were used to determine whether specific locations in the study area required additional sampling, called "step-out" sampling. The step-out sample locations were sampled to further characterize and more accurately delineate areas of <u>potential</u> contamination. Actual contamination will be identified by the State of California's Department of Toxic Substances Control (DTSC) after it develops Look-up Table (LUT) values. These values will be derived from data provided by their radiochemical laboratory contractor.

After completion of the step-out sampling and review of the associated radioanalytical results, the RTLs were not used for any other purpose. However, a typographical error of an equation used to calculate the RTLs was discovered after all soil samples had been collected, analyzed, and evaluated, and this memorandum describes the error. Correcting the RTLs had no negative impact on the project.

To provide the most defensible and technically sound advice to project stakeholders, in particular the DTSC, radionuclide reference concentrations (RRC) were developed from the entire Round 1 and Round 2 dataset of soil and sediment sample analytical results after data validation was completed. These RRCs were developed in a similar methodology as the RTLs but with enhancements to provide valuable qualitative and quantitative parameters for guiding the future development of decision-making criteria (LUT values) related to the procurement of analytical services for future assessments, remediation, and closure phases of the SSFL. Radionuclide reference concentrations are not DL values or ALs and should not be used as such. This document presents the RRCs and describes the development, appropriate uses, and limitations of the RRCs and the associated calculation parameters.

1.1 ADMINISTRATIVE ORDER ON CONSENT

An agreement (Docket No. HSA-CO 10/11-037) between the Department of Energy (DOE) and the DTSC promulgated an Administrative Order on Consent (AOC) for Remedial Action, dated December 6, 2010 (DTSC, 2010). Although the AOC does not explicitly guide the development of RTLs or RRCs, it does provide specific direction related to the development of

LUT values for the assessment of radiological contamination in the soil of the Area IV Study Area. The methodology used to develop RTLs and RRCs is the same as that recommended by HGL to develop LUT values. Consequently, the RRCs may serve as a basis for comparison or evaluation in the development of certain components of the LUT values, as discussed later in this paper. However, it is not appropriate to apply either RTLs or RRCs directly for use as LUT values in future phases of radiological assessments, remediation, or closure at the SSFL.

1.2 DEVELOPMENT OF BACKGROUND THRESHOLD VALUES

Background threshold values (BTV) were determined during the U.S. Environmental Protection Agency's (USEPA) SSFL Radiological Background Study. Background threshold values are radioactivity concentrations in soil that were determined to represent an upper limit of background activity for each radionuclide of concern in the study, above which remedial action is expected to be taken, based on the AOC. The BTVs, therefore, represent the basis of ALs for the Area IV Radiological Study.

A detailed analysis of the development of the BTVs is included in the Final Radiological Background Study Report (HGL, 2011). The selection process of the final BTV for each radionuclide of concern is summarized in the Radiological Characterization of Soils report.

1.3 USE OF THE MINIMUM DETECTABLE CONCENTRATION AS AN ALTERNATE ACTION LEVEL

In cases where the quality of the radioanalytical data received from a laboratory does not support the use of the BTV as the AL in the decision-making process, an alternate AL must be selected. The AOC states that in cases where a laboratory's minimum detectable concentration (MDC) is greater than the BTV, the MDC shall become the AL. The selection of the MDC as an alternate AL, when the MDC is greater than the BTV, was also employed in the determination of RTLs and RRCs.

2.0 DEVELOPMENT OF RADIOLOGICAL TRIGGER LEVELS

The RTL was the DL value against which laboratory results from the Area IV Radiological Study Round 1 soil sampling event were compared to determine whether the AL was likely to have been exceeded. The RTLs were calculated and evaluated only during the Round 1 sampling event, and their use was limited to determining whether step-out sampling (Round 2) was warranted at specific locations.

Decisions regarding the possible exceedance of an AL should take into account the overall uncertainty of the analytical method, as well as the data user's tolerance for making decision errors. These parameters influence the likelihood that a particular laboratory result is consistent with the true sample concentration in excess of the AL. Radiological trigger levels were calculated as follows (USEPA, 2004):

$$RTL = AL + 1.645*U_M$$

Where:

AL	=	the greater of the BTV or the laboratory's method MDC
U_M	=	the laboratory's method uncertainty for results at the AL
1.645	=	the normal distribution quantile consistent with a 5 percent decision error rate

There were two laboratories involved in the analysis of samples collected for the Area IV Radiological Study, and each laboratory provided different MDC and method of uncertainty (U_M) values for each radionuclide of concern. Therefore, laboratory-specific RTLs were calculated independently for each laboratory and the higher of the two values was used as the project RTL for the sole purpose of determining the need for step-out sampling (Round 2). These RTLs are named "Original RTLs" and are summarized in Attachment A.

2.1 ESTIMATION OF METHOD UNCERTAINTY

For each laboratory, U_M was determined, wherever feasible, by a power regression of the relative uncertainty verses the sample activity. Although a robust dataset was desired, this regression was performed for each radionuclide on a relatively small ($n < 60$) initial set of validated samples, which were available at the time the RTLs were needed for evaluation of Round 1 samples. The resulting regression equation was used to identify the activity level, which is called the Laboratory Action Level (LAL), for each radionuclide at which the project-required 10 percent maximum relative uncertainty was achieved. Per the analytical statement of work, results above the LAL were required to have a maximum relative uncertainty of 10 percent and results below the LAL were required to have a maximum relative uncertainty of 10 percent of the LAL. For each radionuclide, the AL (greater of the BTV or MDC) was compared to the LAL to determine U_M (HGL, 2012).

In cases where the methodology described above was not feasible, generally a result of insufficient data or a lack of adequately predicting the LAL from the derived regression equation, an estimate of the LAL was made based on a technical review of the individual analytical method. For all methods, a multiplication factor was determined that, when applied to the average MDC for that method, provided a reasonable estimate of the LAL, which in turn enabled calculation of U_M.

2.2 ESTIMATION OF METHOD MINIMUM DETECTABLE CONCENTRATION

Minimum detectable concentrations are calculated by the laboratory for each sample result. Minimum detectable concentrations are determined, in part, by routine analytical parameters such as count time and sample size, but are also influenced by sample-specific issues such as matrix interference, chemical yield, and other factors. The mean and standard deviation of the achieved sample-specific MDCs were calculated from the entire dataset for each laboratory. Where necessary, the mean MDC was used in the estimation of the LAL, as described above. For all radionuclides, the mean MDC plus twice the standard deviation of the mean MDCs were used as a reliable estimate of the *method* MDC; that is, an MDC value that could be expected to be achieved by the laboratory approximately 97.7 percent of the time. This *method MDC* was then compared to the BTV for each radionuclide to determine the appropriate AL.

2.3 ERROR IN THE CALCULATION OF RADIOLOGICAL TRIGGER LEVELS

After the RTLs were developed and used in the selection of Round 2 step-out sample locations, a typographical error in an equation was discovered in the RTL calculation in which the value for U_M was consistently underestimated. The consequence of this error was an underestimation of most RTLs and overestimation of a few RTLs used to determine Round 2 step-out sample locations. As a result, there may have been step-out samples that were collected unnecessarily. There were no cases, however, where step-out sampling was not performed when it otherwise should have been. Disclosure of the error was made to USEPA on August 21, 2012, and the calculation error was corrected. The corrected RTLs were not used for any purpose other than to determine if any additional step-out sample would have been warranted, which was not the case. These RTLs are named "corrected RTLs" and are summarized in Attachment A.

3.0 CALCULATION AND USE OF RADIONUCLIDE REFERENCE CONCENTRATIONS

At the time of the discovery and disclosure of the calculational error described in Section 2.3, all step-out sampling had been completed and the majority of project data had been validated. After the remaining project data were validated, RRCs were derived in the same manner as the corrected RTLs. The only exception to this statement is that independent RCCs were calculated for each of the two laboratories used during the Area IV study, and the entire set of Round 1 and Round 2 sample data from each laboratory was used. Radionuclide reference concentrations are included in Attachment B of this paper.

The comparison of study sample results to the RRCs is <u>not</u> an appropriate basis for assessment, remediation, or closure decisions in future phases of this project; that is, RRCs should not be used as LUT values. Those issues are addressed in the LUT technical memorandum and are outside the scope of this paper. The appropriate use of the RRCs and the associated method MDCs are discussed below.

3.1 APPROPRIATE USE OF RADIONUCLIDE REFERENCE CONCENTRATIONS

The Area IV Radiological Study sample data may be compared to the RRCs to determine which radionuclides are *likely* to be associated with actual LUT exceedances in future phases of radiological assessments, remediation, or closure at the SSFL.

The delineation of specific areas that might be considered contaminated in future phases is dependent on the measurement quality objectives (MQO) obtained during the future procurement of laboratory services. However, USEPA believes that the qualitative assessment of which radionuclides represent site-related contamination is not likely to significantly change. It may be useful, therefore, to consider radionuclides that currently exceed the RRCs to represent a priority group of analytes on which future phases might concentrate and focus resources. The list of Priority One Radionuclides for which any Round 1 or Round 2 sample result exceeded the RRCs is shown in Section I of Table 1 in Attachment B. Unlike the RTLs, all sample results from each laboratory contracted during the Area IV Radiological Study were compared to the respective laboratory's calculated RRCs; that is, the greater of the two RRCs was not selected for comparison to the sample results.

3.2 APPROPRIATE USE OF METHOD MINIMUM DETECTABLE CONCENTRATIONS

In the determination of input parameters for RRCs, method MDCs were calculated as the two sigma (that is, 97.7 percent confidence level of the standard normal cumulative probability) upper confidence limit of the laboratory-specific and analyte-specific MDCs achieved by the laboratories during the Area IV Radiological Study. As such, the method MDCs represent a reliable estimate of laboratory MDCs that, at a minimum, should be technologically and practically feasible to achieve during future phases of radiological assessments or remediation at the SSFL.

The method MDCs are considered to be established, reasonably achievable MQOs, available from existing contract radioanalytical laboratories. The lesser of the values between the two laboratories used during the Area IV Radiological Study should be considered one of several critical MQOs for future procurement of laboratory analytical services. These method MDCs are provided in Attachment B.

4.0 REFERENCES

California Department of Toxic Substances Control (DTSC), 2010. Administrative Order On Consent For Remedial Action, Santa Susana Field Laboratory, Simi Hills, Ventura County, California. December.

HydroGeoLogic, Inc. (HGL), 2011. Final Radiological Background Study Report, Santa Susana Field Laboratory, Ventura County, California. October.

HGL, 2012, Final Quality Assurance Project Plan for Soil Sampling, Area IV Radiological Study, Santa Susana Field Laboratory, Ventura County, California, Revision 01. March.

U.S. Environmental Protection Agency (USEPA), 2004. Multi-Agency Radiological Laboratory Analytical Protocols Manual (MARLAP). July.

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ATTACHMENT A

TABLE OF ORIGINAL AND CORRECTED RADIOLOGICAL TRIGGER LEVELS

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Attachment A
Original and Corrected Radiological Trigger Levels

Radionuclides	Symbol	Original RTL	Corrected RTL
Actinium-227	Ac-227	0.217	0.287
Actinium-228	Ac-228	2.40	2.68
Americium-241	Am-241	0.0454	0.108
Americium-243	Am-243	0.0401	0.0256
Antimony-125	Sb-125	0.354	0.374
Bismuth-212	Bi-212	2.15	2.38
Bismuth-214	Bi-214	1.59	1.83
Cadmium-113m	Cd-113m	3030	3440
Carbon-14	C-14	2.96	3.25
Cesium-134	Cs-134	0.0864	0.107
Cesium-137	Cs-137	0.207	0.225
Cobalt-60	Co-60	0.0280	0.0363
Curium-243/244	Cm-243/44	0.0443	0.107
Curium-245/246	Cm-245/246	0.0306	0.0695
Curium-248	Cm-248	0.0333	0.0761
Europium-152	Eu-152	0.0566	0.0740
Europium-154	Eu-154	0.150	0.195
Europium-155	Eu-155	0.231	0.237
Holmium-166m	Ho-166m	0.0432	0.0556
Iodine-129	I-129	1.56 (1)	1.92
Lead-212	Pb-212	2.69	3.11
Lead-214	Pb-214	1.70	1.96
Neptunium-236	Np-236	0.0470	0.0606
Neptunium-237	Np-237	0.0401	0.153
Neptunium-239	Np-239	0.139	0.189
Nickel-59	Ni-59	8.39 (2)	8.09
Nickel-63	Ni-63	4.92	2.95
Niobium-94	Nb-94	0.0214	0.0279
Plutonium-236	Pu-236	0.0448 (2)	0.133
Plutonium-238	Pu-238	0.0415	0.123
Plutonium-239/240	Pu-239/240	0.0404	0.0950
Plutonium-241	Pu-241	10.4	6.04
Plutonium-244	Pu-244	0.0313	0.0588
Potassium-40	K-40	32.4	35.5
Promethium-147	Pm-147	17.5	13.8
Protactinium-231	Pa-231	0.936	1.25
Radium-226	Ra-226	2.03	NDC

Attachment A
Original and Corrected Radiological Trigger Levels

Radionuclides	Symbol	Original RTL	Corrected RTL
Sodium-22	Na-22	0.0370	0.0472
Strontium-90/Yttrium-90	Sr-90/Y-90	0.485	0.645
Technetium-99	Tc-99	1.63	2.42
Thallium-208	Tl-208	0.937	1.07
Thorium-228	Th-228	3.98	4.27
Thorium-229	Th-229	0.145	0.371
Thorium-230	Th-230	2.20	2.38
Thorium-232	Th-232	3.10	3.44
Thorium-234	Th-234	3.19	3.54
Thulium-171	Tm-171	72.4	76.7
Tin-126	Sn-126	0.0237	0.0309
Tritium	H-3	11.9	16.7
Uranium-233/234	U-233/234	2.02	2.18
Uranium-235/236	U-235/236	0.151	0.233
Uranium-238	U-238	1.80	1.96

Notes:

All values in picocuries per gram.

(1) - The original RTL for I-129 was developed after the RTL Technical Memorandum was completed.

(2) - The values shown were derived after the RTL Technical Memorandum was completed and were used as a comparison for round 1 soil sample results.

NDC - No data collected at the time the corrected RTLs were calculated, thus the value could not be calculated.

pCi/g - picocuries per gram

RTL - radiological trigger levels

ATTACHMENT B

TABLE OF RADIONUCLIDE REFERENCE CONCENTRATIONS AND MINIMUM DETECTABLE CONCENTRATIONS

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Attachment B
Radiological Reference Concentrations

Radionuclides	Symbol	GEL Two Sigma UCL MDC	TAL Two Sigma UCL MDC	GEL RRC	TAL RRC
Section I: Priority One Radionuclides					
Actinium-228	Ac-228	0.135	0.108	2.68	2.68
Bismuth-212	Bi-212	0.220	0.163	2.38	2.38
Bismuth-214	Bi-214	0.0419	0.0315	1.83	1.83
Cesium-137	Cs-137	0.0251	0.0198	0.225	0.225
Cobalt-60	Co-60	0.0252	0.0228	0.0400	0.0363
Europium-152	Eu-152	0.0670	0.0459	0.105	0.0739
Lead-212	Pb-212	0.0497	0.0319	3.11	3.11
Lead-214	Pb-214	0.0479	0.0317	1.96	1.96
Nickel-59	Ni-59	7.24	0.648	10.9	0.875
Plutonium-239/240	Pu-239/240	0.0369	0.00664	0.115	0.0230
Strontium-90/Yttrium-90	Sr-90/Y-90	0.387	0.0677	1.02	0.117
Thallium-208	Tl-208	0.0255	0.0213	1.07	1.07
Thorium-230	Th-230	0.123	0.0156	2.38	2.38
Thorium-234	Th-234	0.426	0.222	3.54	3.54
Uranium-233/234	U-233/234	0.0997	0.0172	2.18	2.18
Uranium-235/236	U-235/236	0.0751	0.0149	0.249	0.152
Uranium-238	U-238	0.0718	0.0143	1.96	1.96
Section II: Priority Two Radionuclides					
Actinium-227	Ac-227	0.267	0.169	0.422	0.205
Americium-241	Am-241	0.0410	0.0141	0.0815	0.0386
Americium-243	Am-243	0.0372	0.00686	0.105	0.0252(1)
Antimony-125	Sb-125	0.0695	0.0502	0.374	0.374
Cadmium-113m	Cd-113m	178	47.5	3440	3440
Carbon-14	C-14	0.998	0.0983	3.19	2.96
Cesium-134	Cs-134	0.0231	0.0688	0.0431	0.0801
Curium-243/244	Cm-243/244	0.0466	0.0162	0.123	0.0396
Curium-245/246	Cm-245/246	No data	0.0123	No data	0.0346
Curium-248	Cm-248	No data	0.0110	No data	0.0398
Europium-154	Eu-154	0.136	0.125	0.217	0.198
Europium-155	Eu-155	0.0949	0.0438	0.253	0.231
Holmium-166m	Ho-166m	0.0362	0.0302	0.0581	0.0514
Iodine-129	I-129	0.525	No data	2.42	No data
Neptunium-236	Np-236	0.0495	0.0368	0.0784	0.0599
Neptunium-237	Np-237	0.0542	No data	0.147	No data

Attachment B
Radiological Reference Concentrations

Radionuclides	Symbol	GEL Two Sigma UCL MDC	TAL Two Sigma UCL MDC	GEL RRC	TAL RRC
Section II: Priority Two Radionuclides (Continued)					
Neptunium-239	Np-239	0.177	0.102	0.280	0.167
Nickel-63	Ni-63	1.78	0.843	2.80	1.34
Niobium-94	Nb-94	0.0213	0.0172	0.0339	0.0274
Plutonium-236	Pu-236	0.0510	0.0107	0.137	0.0349
Plutonium-238	Pu-238	0.0480	0.00921	0.122	0.0254
Plutonium-241	Pu-241	3.73	No data	6.04(1)	No data
Plutonium-244	Pu-244	0.0259	0.00526	0.0666	0.0135
Potassium-40	K-40	0.213	0.186	35.5	35.5
Promethium-147	Pm-147	8.62	No data	14.5	No data
Protactinium-231	Pa-231	1.11	0.693	1.75	1.22
Radium-226	Ra-226	0.151	No data	2.19(2)	No data
Sodium-22	Na-22	0.0306	0.0295	0.0485	0.0468
Technetium-99	Tc-99	1.75	0.387	2.76	0.619
Thorium-228	Th-228	0.183	0.0300	4.27	4.27
Thorium-229	Th-229	0.135	0.0165	0.381	0.0741
Thorium-232	Th-232	0.0877	0.0139	3.44	3.44
Thulium-171	Tm-171	23.0	7.63	77.1	76.7
Tin-126	Sn-126	0.0233	0.0195	0.0372	0.0309
Tritium	H-3	9.99	0.284	16.2	8.59

Notes:

All values in picocuries per gram.

(1)Less than 50 results were used in the calculation of the RRC, thus caution is warranted in the use of this value.

(2)Only five results were available to calculate this value, thus comparison of data against the resulting RRC may be subject to uncertainty significantly above the design parameters described in the project QAPP.

GEL - GEL Laboratory, LLC

MDC - minimum detectable concentration

No data - no samples were analyzed thus value is not determined.

RRC - radionuclide reference concentration

TAL - TestAmerica Laboratories, Inc.

Two Sigma UCL MDC - two sigma (97.7 percent confidence level of the standard normal cumulative probability) UCL MDC.

UCL - upper confidence limit