8. Quality Assurance

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Quality assurance (QA) is a system of activities and processes put in place to ensure that products or services meet or exceed customer specifications. Quality control (QC) consists of activities used to verify that deliverables are of acceptable quality and meet criteria established in the quality planning process.

8.1 Quality Assurance Activities

Nonconformance reporting and tracking is a formal process used to ensure that problems are identified, resolved, and prevented from recurring. The Lawrence Livermore National Laboratory (LLNL) Environmental Functional Area (EFA) and Environmental Restoration Department (ERD) track problems using the LLNL Institutional Tracking System (ITS). ITS items are initiated when items or activities are identified that do not comply with procedures or other documents that specify requirements for EFA operations or that cast doubt on the quality of regulatory reports, integrity of samples, or data, and that are not covered by other reporting or tracking mechanisms. Nonconformances involving EFA are captured and used to provide trending information for environmental compliance evaluations. There were no laboratory data nonconformances affecting the quality of data used for reporting purposes documented in 2017. Many minor sampling or data problems are resolved without generating an ITS item. The LLNL quality assurance requirements stipulate that laboratories generating data must have a formal nonconformance program to track and document issues in their analyses. Such programs are separate from the LLNL ITS.

LLNL averts sampling problems by requiring formal and informal training on sampling procedures. Errors that occur during sampling generally do not result in lost samples but may require extra work on the part of laboratory or sampling and data management personnel to correct the errors.

LLNL addresses commercial analytical laboratory problems as they arise. Many of the problems concern minor documentation errors and are corrected soon after they are identified. Other problems, such as missed holding times, late analytical results, incorrect analysis and typographical errors on data reports, account for the remaining issues and are not tracked as nonconformances. These problems are corrected by the commercial laboratory reissuing reports or correcting paperwork and do not affect associated sample results.

LLNL participates in the Department of Energy Consolidated Auditing Program (DOECAP). Annual onsite visits to commercial laboratories under contract to LLNL are part of the auditing program to ensure that accurate and defensible data are generated. The audit program is based on DOECAP requirements under The National Environmental Laboratory Accreditation Conference (NELAC) Institute (TNI). All commercial laboratories used by LLNL are LLNL-qualified vendors and are National Environmental Laboratory Accreditation Program (NELAP) certified or California Department of Health Services Environmental Laboratory accredited. Audit reports,

checklists, and Corrective Action Plans are maintained under the DOECAP program for commercial labs.

The following six areas pertain to the services provided by a particular external analytical laboratory:

- QA management systems and general laboratory practices
- Organic analyses
- Inorganic and wet chemistry analyses
- Radiochemical analyses
- Laboratory information management systems and electronic deliverables
- Hazardous and radioactive materials management

LLNL has qualified auditors under the national DOECAP program in the areas of quality assurance, organic chemistry, inorganic chemistry, laboratory information management, and hazardous material management.

In FY2017, the laboratories certified by the State of California operating at LLNL as government owned and contractor operated were not internally assessed, but are subject to assessment by the State of California under the Environmental Laboratory Accreditation Program (ELAP).

Analytical laboratories routinely perform QC tests to document and assess the quality and validity of their sample results. Each set of data received from the analytical laboratory is systematically evaluated and compared to establish measurement-quality objectives before the results can be authenticated and accepted into the monitoring database. Categories of measurement quality objectives include accuracy, precision, and comparability. When possible, quantitative criteria are used to define and assess data quality.

8.2 Analytical Laboratories and Laboratory Intercomparison Studies

In 2017, LLNL had Blanket Service Agreements (BSAs) with six commercial analytical laboratories. All analytical laboratory services used by LLNL are provided by facilities certified by the State of California. LLNL works closely with these analytical laboratories to minimize problems and ensure that QA/QC objectives are maintained.

LLNL uses the results of nationally recognized intercomparison performance evaluation program data to identify and monitor trends in performance and to draw attention to the need to improve laboratory performance. If a laboratory performs unacceptably for a particular test in two consecutive performance evaluation studies, LLNL may stop work and select another laboratory to perform the affected analyses until the original laboratory has demonstrated that the problem has been corrected. If an offsite laboratory continues to perform unacceptably or fails to prepare and implement acceptable corrective action responses, the LLNL Supply Chain Management Department formally notifies the laboratory of its unsatisfactory performance. If the problem persists, the offsite laboratory's BSA could be terminated for that test. If an onsite laboratory continues to perform unacceptably, use of that laboratory could be suspended until the problem is

corrected. In 2017, all contracted commercial labs were successful in participation in performance evaluation studies and where there were individual failures to perform, the commercial labs were verified to have corrective actions in place.

Although laboratories are also required to participate in laboratory intercomparison programs, permission to publish their accreditation results for comparison purposes was not granted for 2017. To obtain DOE Mixed Analyte Performance Evaluation Program (MAPEP) reports that include the results from all participating laboratories, see http://www.inl.gov/resl/mapep/reports.html. MAPEP is a DOE program and the results are publicly available from laboratories that choose to participate.

8.3 Duplicate Analyses

Duplicate (collocated) samples are distinct samples of the same matrix collected as closely as possible to the same point in space and time. Collocated samples that are processed and analyzed by the same laboratory provide information about the precision of the entire measurement system, including sampling, homogeneity, handling, shipping, storage, preparation, and analysis. Collocated samples that are processed and analyzed by different laboratories provide information about the precision of the entire measurement system that also captures interlaboratory variation (U.S. EPA 1987). Collocated samples may also identify errors such as mislabeled samples or data entry errors. **Tables 8-1**, **8-2**, and **8-3** present summary statistics for collocated sample pairs, grouped by sample matrix and analyte. Samples from both the Livermore Site and Site 300 are included. **Tables 8-1** and **8-2** are based on data pairs in which both values are considered "detections" as described in **Section 8.4**. **Table 8-3** is based on data pairs in which either or both values are considered "nondetections" (see **Section 8.4**).

Table 8-1. Quality assurance collocated sampling: Summary statistics for analytes with more than eight pairs in which both results were above the reporting limit.

Media	Analyte	N [a]	%RSD [b]	Slope	r^2 [c]	Intercept
Air	Gross beta	49	18.6	0.877	0.88	4.95×10^{-5} Bq/m^3
Air	Beryllium [e]	14	15.2	0.312	0.54	2.77 pg/m^3
Air	U235 by mass	12	8.6	1.01	0.98	3.64×10^{-9} µg/m^3
Air	U238 by mass	12	10.3	0.967	0.97	1.09×10^{-6} µg/m^3
Air	Tritium	39	29.3	0.974	0.96	0.00238 Bq/m^3
Direct radiation	90 day Rad dose	21	3.71	0.858	0.82	1.78 mrem
Ground water	Gross alpha [e]	9	32.3	0.351	0.04	0.151 Bq/L
Ground water	Gross beta [d]	28	37.7	0.52	0.22	0.116 Bq/L
Ground water	Arsenic	26	14.7	1.05	0.98	-0.000555 mg/L
Ground water	Barium	17	4.56	0.985	1	0.000359 mg/L
Ground water	Carbon tetrachloride	39	12.5	1.17	0.91	0.472 µg/L
Ground water	Chloroform	65	7.86	0.975	0.99	0.417 µg/L
Ground water	1,1-Dichloroethane	23	8.46	1	1	0.0724 µg/L
Ground water	1,2-Dichloroethane	32	11.5	1.1	0.83	0.733 µg/L
Ground water	1,1-Dichloroethene	67	14.1	1.07	0.98	-0.158 µg/L
Ground water	cis-1,2-Dichloroethene	37	13.7	1.02	0.98	-0.603 µg/L
Ground water	1,2-Dichloroethene (total)	26	12.9	1.05	0.98	-1.64 µg/L
Ground water	Fluoride	9	4.29	1.01	1	-0.00546 mg/L
Ground water	Freon 113	46	19.1	1.04	0.92	0.539 µg/L
Ground water	Nitrate (as NO3)	71	4.16	0.995	1	0.5 mg/L

Media	Analyte	N [a]	%RSD [b]	Slope	r^2 [c]	Intercept
Ground water	Perchlorate	31	9.97	0.987	0.98	-0.077 µg/L
Ground water	Selenium	9	11.8	0.808	0.93	0.000678 mg/L
Ground water	Tetrachloroethene	84	12	1	0.98	0.662 µg/L
Ground water	Trichloroethene	174	11.2	1.08	1	14.8 µg/L
Ground water	Trichlorofluoromethane	9	12.6	0.925	0.91	0.385 µg/L
Ground water	Tritium	23	8.94	1.07	0.99	2.84 Bq/L
Ground water	U234+U233	19	16.1	0.98	0.98	0.00171 Bq/L
Ground water	U235+U236 [e]	13	37.6	0.557	0.85	0.00137 Bq/L
Ground water	U238	22	11.3	0.998	0.99	-0.0168 Bq/L
Sewer	Gross beta [d]	12	17.2	0.426	0.18	0.000373 Bq/mL

(a) Number of collocated pairs included in regression analysis.

(b) 75th percentile of percent relative standard deviations (%RSD) where $\%RSD = \left(\frac{200}{\sqrt{2}}\right)\frac{|x_1 - x_2|}{x_1 + x_2}$ and x_1 and x_2 are the reported concentrations of each routine–collocated pair.

(c) Coefficient of determination.

(d) Outside target range of slope or r^2 because of high variability.

(e) Outside target range of slope or r^2 because of outliers.

Table 8-2. Quality assurance collocated sampling: Summary statistics for selected analytes with eight or fewer pairs in which both results were above the reporting limit.

Media	Analyte	N [a]	Minimum ratio	Maximum ratio
Air	Gross alpha	6	0.83	1.9
Aqueous	Gross alpha	1	0.94	0.94
Aqueous	Gross beta	1	0.96	0.96
Aqueous	Uranium 234 and 233 (in activity)	1	0.94	0.94
Aqueous	Uranium 235 and 236 (in activity)	1	1	1
Aqueous	Uranium 238 (in activity)	1	1	1
Drinking water	Gross beta	1	1.5	1.5
Ground water	Radium 226	2	0.15	0.81
Ground water	Uranium 238 (in mass)	6	0.04	1.1
Other water	Gross beta	1	0.95	0.95
Rain	Tritium	1	1.3	1.3
Runoff (from rain)	Gross alpha	1	1.6	1.6
Runoff (from rain)	Gross beta	3	0.43	1.8
Runoff (from rain)	Tritium	2	0.92	0.97
Soil	Cesium 137	3	0.84	1.2
Soil	Potassium 40	3	0.88	1.1
Soil	Plutonium 238	2	0.82	0.87
Soil	Plutonium 239+240	2	0.92	1
Soil	Radium 226	3	0.9	1.2
Soil	Radium 228	3	0.87	1.1
Soil	Thorium 228	3	0.79	1.1
Soil	Uranium 238 (in activity)	3	0.69	1.1
Sewer	Tritium	6	0.72	1
Vegetation	Tritium	7	0.7	23
Wine	Tritium	2	0.51	1.2

(a) Number of collocated pairs used in ratio calculations.

Table 8-3. Quality assurance collocated sampling: Summary statistics for analytes with at least four pairs in which one or both results were below the reporting limit.

Media	Analyte	Number of inconsistent pairs [a]	Number of pairs	Percent of inconsistent pairs
Ground water	Gross alpha	2	20	10
Ground water	Arsenic	1	11	9.1
Ground water	Carbon tetrachloride	1	311	0.32
Ground water	Chloroform	4	285	1.4
Ground water	Chromium	1	26	3.8
Ground water	Total Coliform	1	8	12
Ground water	Dichlorodifluoromethane	1	349	0.29
Ground water	1,1-Dichloroethene	2	283	0.71
Ground water	cis-1,2-Dichloroethene	3	313	0.96
Ground water	1,2-Dichloroethene (total)	2	324	0.62
Ground water	Freon 113	2	304	0.66
Ground water	Nitrate (as NO3)	1	81	1.2
Ground water	Trichloroethene	2	176	1.1
Ground water	Trichlorofluoromethane	1	341	0.29

(a) Inconsistent pairs are those for which one of the results is more than twice the reporting limit of the other.

(b) Does not include count of pairs where both results were detections.

When there were more than eight data pairs with both results in each pair considered detections, precision and regression analyses were performed; those results are presented in **Table 8-1**. When there were eight or fewer data pairs with both results considered detections, the ratios of the individual data pairs for selected analytes were calculated; the minimum and maximum ratios are given in **Table 8-2**. When either of the results in a pair is considered a nondetection, then for consistency the other result should be also be a nondetection, or less than two times the reporting limit. **Table 8-3** identifies the sample media and analytes for which at least one pair failed this criterion. Media and analytes with fewer than four pairs are not included.

Precision is measured by the %RSD; see the EPA's *Data Quality Objectives for Remedial Response Activities: Development Process*, Section 4.6 (U.S. EPA 1987). Acceptable values for %RSD vary greatly with matrix, analyte, and analytical method; however, lower values represent better precision. The results for %RSD given in **Table 8-1** are the 75th percentile of the individual precision values. 95% of the pairs have %RSD of 37% or better.

Regression analysis consists of fitting a straight line to the collocated sample pairs. Good agreement is indicated when the data lie close to a line with a slope equal to 1 and an intercept equal to 0, as illustrated in **Figure 8-1**. Allowing for normal analytical and environmental variation, the slope of the fitted line should be between 0.7 and 1.3, and the absolute value of the intercept should be less than the detection limit. The coefficient of determination (r^2) should be greater than 0.8. These criteria apply to pairs in which both results are considered above the detection limit.

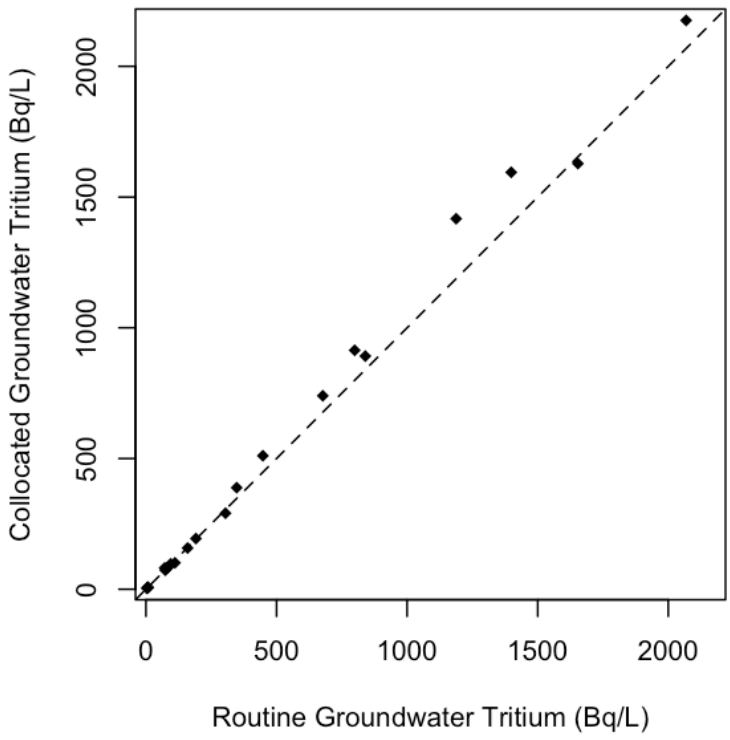

Figure 8-1. Example of good agreement between collocated sample results using groundwater tritium concentrations.

Collocated sample comparisons are more variable when the members of the pair are analyzed by different methods or with different criteria for analytical precision. For example, radiological analyses using different counting times or different laboratory aliquot sizes will have different amounts of variability. Different criteria are rarely, if ever, used with collocated sample pairs in LLNL environmental monitoring sampling. Different criteria are sometimes used in special studies if more than one agency is involved and each sets its own analytical criteria.

Data sets that do not meet LLNL regression analysis criteria fall into one of two categories: outliers and high variability. Outliers can occur because of data transcription errors, measurement errors, or real but anomalous results. Of the 30 data sets reported in **Table 8-1**, three did not meet the target for acceptability because of outliers. **Figure 8-2** illustrates a set of collocated pairs with two outliers.

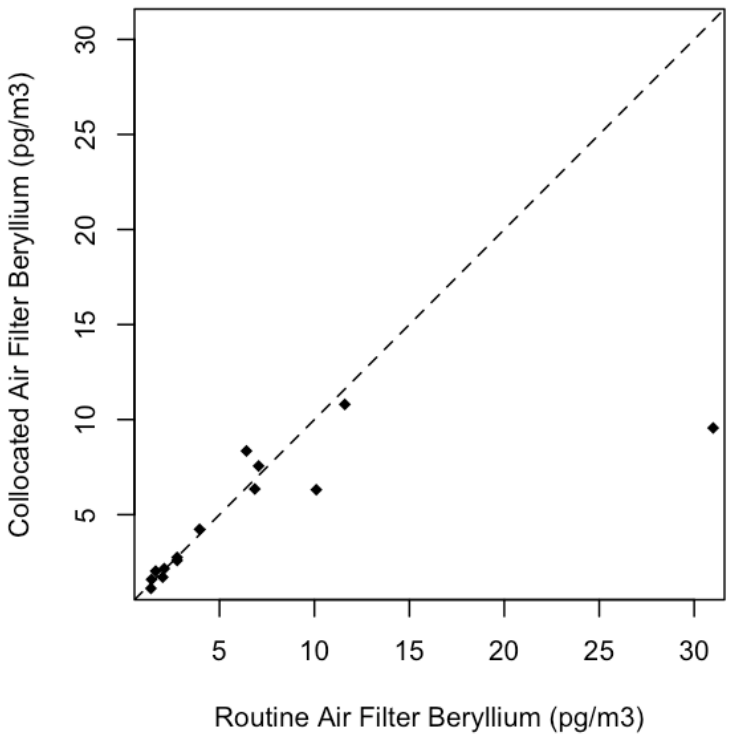

Figure 8-2. Example of data with two outliers using collocated air filter beryllium measurements.

The second category, high variability, occurs when the measurement process inherently has substantial variability (see **Figure 8-3** for an example). This tends to occur at extremely low environmental concentrations. Low concentrations of radionuclides on particulates in air highlight this effect because a small change in the number of radionuclide-containing particles on an air filter can significantly affect results. Analyses of total organic carbon and total organic halides in water are particularly difficult to control. Of the 30 data sets listed in **Table 8-1**, two show sufficient variability in the results to make them fall outside the target range.

8.4 Data Presentation

The data tables in **Appendix A** were created using computer scripts that retrieve data from a database, convert the data into Système International (SI) units when necessary, calculate summary statistics, format the data, organize the data into rows and columns, and present a draft table. The tables are then reviewed by the responsible analyst before inclusion in the Appendix. Analytical laboratory data and values calculated from the data are normally displayed with two, or at most three, significant digits. Significant trailing zeros may be omitted.

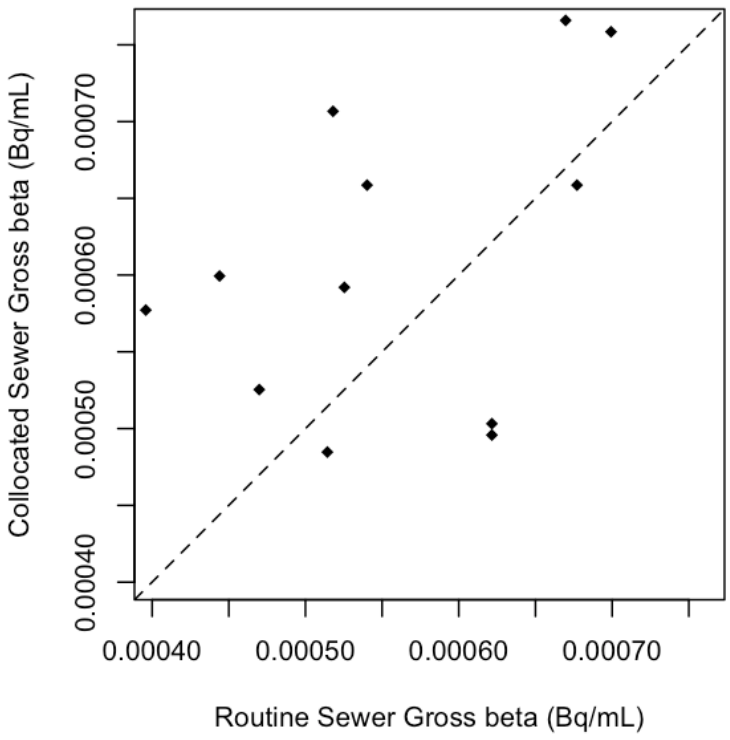

Figure 8-3. Example of high variability using collocated sewer effluent gross beta concentrations.

8.4.1 Radiological Data

Most of the data tables in **Appendix A** that have radiological data display the result plus or minus (±) an associated 2σ (two sigma) uncertainty. This measure of uncertainty represents intrinsic variation in the measurement process, most of which is due to the random nature of radioactive decay (see **Section 8.6**). The uncertainties are not used in summary statistic calculations. Any radiological result exhibiting a 2σ uncertainty greater than or equal to 100% of the result is considered a nondetection, whereas any radiological result exhibiting a 2σ uncertainty less than 100% of the result is considered a detection, whether above or below the analytical contract reporting limit.

Some radiological results are derived from the number of sample counts minus the number of background counts inside the measurement apparatus. In such cases, samples with a concentration at or near background sometimes have more background counts than sample counts, and thus a negative value. Such results are reported in the data tables and used in the calculation of summary statistics.

Some data tables provide a limit-of-sensitivity value instead of an uncertainty when the radiological result is below the detection criterion. Such results are displayed with the limit-of-sensitivity value in parentheses.

8.4.2 Nonradiological Data

Nonradiological data reported by the analytical laboratory as being below the analytical contract reporting limit is displayed in tables with a less-than symbol (<) and referred to as a "nondetection." Reporting limit values are used in the calculation of summary statistics, as explained below.

8.5 Statistical Comparisons and Summary Statistics

Standard statistical comparison techniques such as regression analysis, *t*-tests, and analysis of variance are used where appropriate to determine the statistical significance of trends or differences between means. When a statistical comparison is made, the results are described as either "statistically significant" or "not statistically significant." Other uses of the word "significant" in this report do not imply that statistical tests have been performed but relate to the concept of practical significance and are based on professional judgment.

Summary statistics are calculated according to Gallegos (2016). The usual summary statistics are the median, which is a measure of central tendency, and interquartile range (IQR), which is a measure of dispersion (variability). However, data tables may present other measures at the discretion of the analyst. In this report, at least four values are required to calculate the median and at least six values are required to calculate the IQR.

The median indicates the middle of the data set (i.e., half of the measured results are above the median, and half are below). The IQR is the range that encompasses the middle 50% of the data set. The IQR is calculated by subtracting the 25th percentile of the data set from the 75th percentile of the data set. When necessary, the percentiles are interpolated from the data. Different software vendors may use slightly different formulas for calculating percentiles. Radiological data sets that include values less than zero may have an IQR greater than the median.

Summary statistics are calculated from values that, if necessary, have already been rounded, such as when units have been converted from picocuries (pCi) to Becquerels (Bq), and are then rounded to an appropriate number of significant digits. The calculation of summary statistics may be affected by the presence of nondetections. A nondetection of the form "less than the reporting limit" indicates that a measured value is not available; instead, the best information available is that the actual value is less than the contract reporting limit. Adjustments to the calculation of the median and IQR for data sets that include such nondetections are described below.

For data sets with all measurements above the reporting limit and radiological data sets that include reported values below the reporting limit, all reported values, including any below the reporting limit, are included in the calculation of summary statistics.

For data sets that include one or more values reported as "less than the reporting limit," the reporting limit is used as an upper bound value in the calculation of summary statistics.

If the number of values is odd, the middle value (when sorted from smallest to largest) is the median. If the middle value and all larger values are detections, the middle value is reported as the median. Otherwise, the median is assigned a less-than (<) sign.

If the number of values is even, the median is halfway between the middle two values (i.e., the middle two when the values are sorted from smallest to largest). If both of the middle two values and all larger values are detections, the median is reported. Otherwise, the median is assigned a less-than (<) sign.

If any value used to calculate the 25th percentile is a nondetection, or any value larger than the 25th percentile is a nondetection, the IQR cannot be calculated and is not reported.

The median and the IQR are not calculated for data sets with no detections.

8.6 Reporting Uncertainty in Data Tables

Measurement uncertainties associated with results from analytical laboratories are represented in two ways. The first of these, significant digits, derives from the resolution of the measuring device. For example, if an ordinary household ruler with a metric scale is used to measure the length of an object in centimeters, and the ruler has tick marks every one-tenth of a centimeter, the length can reliably and consistently be measured to the nearest tenth of a centimeter (i.e., to the nearest tick mark). An attempt to be more precise is not likely to yield reliable or reproducible results because it would require a visual estimate of a distance between tick marks. The appropriate way to report a measurement using this ruler would be, for example, 2.1 cm, which would indicate that the "true" length of the object is nearer to 2.1 cm than to 2.0 cm or 2.2 cm (i.e., between 2.05 and 2.15 cm). A measurement of 2.1 cm has two significant digits. Although not stated, the uncertainty is considered to be ± 0.05 cm. A more precise measuring device might be able to measure an object to the nearest one-hundredth of a centimeter; in that case a value such as "2.12 cm" might be reported. This value would have three significant digits and the implied uncertainty would be ± 0.005 cm. A result reported as "3.0 cm" has two significant digits. That is, the trailing zero is significant and implies that the true length is between 2.95 and 3.05 cm—closer to 3.0 than to 2.9 or 3.1 cm.

When performing calculations with measured values that have significant digits, all digits are used. The number of significant digits in the calculated result is the same as that of the measured value with the fewest number of significant digits.

Most unit conversion factors do not have significant digits. For example, the conversion from milligrams to micrograms requires multiplying by the fixed (constant) value of 1,000. The value 1,000 is exact; it has no uncertainty and therefore the concept of significant digits does not apply.

The second method of representing uncertainty is based on random variation. For radiological measurements, there is variation due to the random nature of radioactive decay. As a sample is

measured, the number of radioactive decay events is counted and the reported result is calculated from the number of decay events that were observed. If the sample is recounted, the number of decay events will almost always be different because radioactive decay events occur randomly. Uncertainties of this type are reported as 2σ (two sigma) uncertainties. A ± 2σ uncertainty represents the range of results expected to occur approximately 95% of the time if a sample were to be recounted many times. A radiological result reported as, for example, "2.6 ± 1.2 Bq/g," would indicate that with approximately 95% confidence, the "true" value is in the range of 1.4 to 3.8 Bq/g (i.e., 2.6 – 1.2 = 1.4 and 2.6 + 1.2 = 3.8).

When necessary, radiological results are converted from pCi to Bq by multiplying by 0.037. This introduces additional digits that are not significant and should not be shown in data tables (for example, 5.3 pCi/g × 0.037 Bq/pCi = 0.1961 Bq/g). The initial value, 5.3, has two significant digits, so the value 0.1961 would be rounded to two significant digits, that is, 0.20. However, the rounding rule changes when there is a radiological uncertainty associated with a radiological result. In this case, data are presented according to the method recommended in Multi-Agency Radiological Laboratory Analytical Protocols (MARLAP) Section 19.3.7 (U.S. NRC/U.S. EPA 2004). First the uncertainty is rounded to the appropriate number of significant digits, after which the result is rounded to the same number of decimal places. For example, suppose a result and uncertainty after unit conversion are 0.1961 ± 0.05436, and the appropriate number of significant digits is two. First, 0.05436 is rounded to 0.054 (two significant digits) and 0.054 has three decimal places, so 0.1961 is then rounded to three decimal places, i.e., 0.196. These would be presented in the data tables as 0.196 ± 0.054.

When rounding a value with a final digit of "5," the software used to prepare the data tables implements the ISO/IEC/IEEE 60559:2011 rule, which is "go to the even digit." For example, 2.45 would be rounded down to 2.4, and 2.55 would be rounded up to 2.6.

The software that prepares the data tables pays careful attention to the details of rounding for significant digits. It should be noted, however, that these details are of little practical significance. For example, if a result of 5.6 is incorrectly rounded to 5.5 or 5.7, the introduced "error" is less than 2% (0.1/5.6 = 0.018). Such an error will rarely have any effect on the interpretation of the data with respect to human health or environmental impact.

A common activity in environmental monitoring is to compare measurements in an attempt to determine whether the objects being measured are "the same" or "different." For example, measurements of tritium concentration in each of two wine bottles could be compared; if they are not the same, there might be an indication of differences between the regions in which the grapes were grown. Comparisons between samples, particularly for radiological results, must take into account the uncertainty in the measurements of each sample. As mentioned above, the uncertainty interval indicates that the "true" value of the material being measured is not known exactly, but is probably somewhere within the interval. A comparison of measured values, not taking into account the uncertainty intervals, might suggest that the objects being measured are "different," but such a conclusion is not supported when the uncertainty intervals overlap.

8.7 Quality Assurance Process for the Environmental Report

Unlike the preceding sections, which focused on standards of accuracy and precision in data acquisition and reporting, this section describes the actions that are taken to ensure the accuracy of this data-rich environmental report, the preparation of which involves many operations and many people. The key elements that are used to ensure accuracy are described here.

Analytical laboratories send reports electronically, which are loaded directly into a database. This practice should result in perfect agreement between the database and data in printed reports from the laboratories. In practice, however, laboratory reporting is not perfect, so the EFA and ERD Data Management Teams (DMTs) carefully check incoming data throughout the year to make sure that electronic and printed reports from the laboratories agree. This aspect of QC is essential to the environmental report's accuracy. In addition, EFA and ERD technical staff review the analytical laboratories' internal QC results to make sure that analytical QA standards have been met, and to identify potential errors. When necessary, analytical laboratories are asked to review results or reanalyze samples. Results that do not meet QA standards may be flagged as suspect or rejected.

As described in **Section 8.4**, computer scripts are used to pull data from the database directly into the format of the table, including unit conversion and summary statistic calculations. All of the data tables contained in **Appendix A** were prepared in this manner. For these tables, it is the responsibility of the appropriate analyst to check each year that the table is up-to-date (e.g., new locations/analytes added, old ones removed), that the data agree with the data he or she has received from DMT, and that any summary calculations have been done correctly.

For this 2017 environmental report, LLNL staff checked tables and figures in the body of the report. Forms to aid in the QC of tables and figures were distributed along with the appropriate figure, table, and text, and a coordinator kept track of the process. Items that were checked included clarity and accuracy of figure captions and table titles; data accuracy and completeness; figure labels and table headings; units; significant digits; and consistency with text. Completed QC forms and the corrected figures or tables were returned to the report editor, who, in collaboration with the responsible author, ensured that corrections were made.

There are multiple levels of document review performed to ensure the accuracy and clarity of this report. Authors, scientific editors, and the DOE Livermore Field Office (LFO) all participate in multiple review cycles throughout document production.

8.8 Errata

Appendix E contains the protocol for errata in LLNL *Environmental Reports* and the errata for *LLNL Site Annual Environmental Report 2016*.

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