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Soils Activity
Quality Assurance Plan

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SOILS ACTIVITY
QUALITY ASSURANCE PLAN

U.S. Department of Energy,
Environmental Management Nevada Program
Las Vegas, Nevada

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SOILS ACTIVITY
QUALITY ASSURANCE PLAN

Approved by: /s/ Kevin J. Cabble Date: 12/05/2017

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EM Nevada Program

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List of Acronyms and Abbreviations

General Acronyms and Abbreviations

Am	Americium
ASTM	ASTM International
CADD	Corrective action decision document
CADD/CAP	Corrective action decision document/Corrective action plan
CADD/CR	Corrective action decision document/Closure report
CAIP	Corrective action investigation plan
CAP	Corrective action plan
$CaSO_4$	Calcium sulfate
CFR	*Code of Federal Regulations*
COPC	Contaminant of potential concern
COTS	Commercial off the shelf
CR	Closure report
Cu	Copper
DOE	U.S. Department of Energy
DOELAP	U.S. Department of Energy Laboratory Accreditation Program
DQA	Data quality assessment
DQI	Data quality indicator
DQO	Data quality objective
EM	Environmental Management
EPA	U.S. Environmental Protection Agency
FAL	Final action level
FFACO	*Federal Facility Agreement and Consent Order*
GC	Gas chromatography
GC/MS	Gas chromatography/mass spectrometry

List of Acronyms and Abbreviations *(Continued)*

GPS	Global Positioning System
HPLC	High-performance liquid chromatography
keV	Kiloelectron volt
LCS	Laboratory control sample
LQC	Laboratory quality control
MDC	Minimum detectable concentration
MeV	Megaelectronvolt
mg/cm^2	Milligrams per square centimeter
mm	Millimeter
MSD	Matrix spike duplicate
mrem/yr	Millirem per year
M&TE	Measuring and test equipment
N/A	Not applicable
NCR	Nonconformance report
NDEP	Nevada Division of Environmental Protection
NIST	National Institute of Standards and Technology
$Li_2B_4O_7$	Lithium borate
NNSA/NFO	U.S. Department of Energy, National Nuclear Security Administration Nevada Field Office
NNSS	Nevada National Security Site
NTTR	Nevada Test and Training Range
PAL	Preliminary action level
Pu	Plutonium
QA	Quality assurance
QAP	Quality Assurance Plan
QC	Quality control

List of Acronyms and Abbreviations *(Continued)*

RBCA	Risk-based corrective action
RL	Reporting limit
RPD	Relative percent difference
RRMG	Residual Radioactive Material Guideline
SAFER	Streamlined Approach for Environmental Restoration
SOP	Standard Operating Procedure
SOW	Statement of work
TBD	Technical Basis Document
TL	Thermoluminescent
TLD	Thermoluminescent dosimeter
Tm	Thulium
TTR	Tonopah Test Range
VOA	Volatile organic analysis
°C	Degrees Celsius
%R	Percent recovery

Definitions

Accuracy

The degree of agreement between an observed value (sample result) and an accepted reference value. (IDQTF, 2005)

Bias

The systematic or persistent distortion associated with a measurement process. (IDQTF, 2005)

Acquired Software

Software that is supplied through basic procurements, two-party agreements, or other contractual arrangements. Acquired software includes commercial off-the-shelf (COTS) software such as operating systems, database management systems, compilers, software development tools, and commercial calculation software and spreadsheet tools (e.g., Microsoft Excel). Downloadable software that is available at no cost to the user (referred to as freeware) is also considered acquired software. Firmware is acquired software. Firmware is usually provided by a hardware supplier through the procurement process and cannot be modified after receipt. (DOE, 2005)

Activity

An all-inclusive term describing a specific set of operations or related tasks to be performed, either serially or in parallel (e.g., research and development, field sampling, analytical operations, equipment fabrication), that in total result in a product or service. (ANSI/ASQ, 2004)

Assessment

The evaluation process used to measure the performance or effectiveness of a system and its elements. Assessment is an all-inclusive term used to denote any of the following: audit, performance evaluation, management systems review, peer review, inspection, or surveillance. (ANSI/ASQ, 2004)

Calibration

Comparison of a measurement standard, instrument, or item with a standard or instrument of higher accuracy to detect and quantify inaccuracies, and to report or eliminate those inaccuracies by adjustments. (ANSI/ASQ, 2004)

Closure Report (CR)

Verifies that the completed corrective action was conducted in accordance with the approved action plan and provides (to the State) necessary support data to confirm the appropriate action took place. (FFACO, 1996; as amended)

Definitions (Continued)

Comparability

The degree to which different methods or data agree or can be represented as similar. It describes the confidence that two datasets can contribute to a common analysis and interpolation. (IDQTF, 2005)

Completeness

A measure of the amount of valid data obtained from a measurement system. (IDQTF, 2005)

Corrective Action Decision Document (CADD)

Provides a summary of the corrective action investigation; and describes the selected remedy and the rationale for its selection, documenting remedial alternatives ranging from no action to clean closure. (FFACO, 1996; as amended)

Corrective Action Decision Document/Closure Report (CADD/CR)

Developed when results from the corrective action investigation are sufficient to evaluate and select corrective action alternatives. The document provides the rationale for the selection and implementation of corrective action alternatives and justifies that no further corrective action is needed. (FFACO, 1996; as amended)

Corrective Action Decision Document/Corrective Action Plan (CADD/CAP)

Combines both the results of the corrective action investigation (normally presented in the CADD) and the remediation plan (normally presented in the CAP). The document is developed as a time-saving method when the compliance boundary is well defined, and the remediation alternatives are limited. (FFACO, 1996; as amended)

Corrective Action Investigation Plan (CAIP)

Provides or references all specific information for planning investigation activities associated with corrective action units or corrective action sites. (FFACO, 1996; as amended)

Corrective Action Plan (CAP)

Prepared when the CADD requires a corrective action. The CAP outlines the method for implementing the selected corrective action alternative and explains how the action will be completed. (FFACO, 1996; as amended)

Definitions (Continued)

Data Quality Indicators (DQIs)

The quantitative statistics and qualitative descriptors that are used to interpret the degree of acceptability or utility of data to the user. The principal DQIs are precision, accuracy/bias, representativeness, completeness, comparability, and sensitivity. (IDQTF, 2005)

Data Quality Objectives (DQOs)

Qualitative and quantitative statements derived from the DQO process that clarify technical and quality objectives, define the appropriate types of data, and specify tolerable levels of potential decision errors that will be used as the basis for establishing the quality and quantity of data needed to support decisions. (ANSI/ASQ, 2004)

Data Usability

The process of ensuring or determining whether the quality of the data produced meets the intended use of the data. (ANSI/ASQ, 2004)

Deficiency

An unauthorized deviation from acceptable procedures or practices, or a defect in an item. (ANSI/ASQ, 2004)

Document

Any written or pictorial information describing, defining, specifying, reporting, or certifying activities, requirements, procedures, or results. (ANSI/ASQ, 2004)

Environmental Data

Any measurements or information that describe environmental processes or conditions, or the performance of environmental technology. (ANSI/ASQ, 2004)

Inspection

An activity such as measuring, examining, testing, or gauging one or more characteristics of an entity and comparing the results with specified requirements in order to establish whether conformance is achieved for each characteristic. (ANSI/ASQ, 2004)

Item

An all-inclusive term used in place of any of the following: appurtenance, facility, sample, assembly, component, equipment, material, module, part, product, structure, subassembly, subsystem, system, unit, documented concepts, or data. (ANSI/ASQ, 2004)

Definitions *(Continued)*

Measuring and Test Equipment (M&TE)

Tools, gauges, instruments, sampling devices, or systems used to calibrate, measure, test, or inspect in order to control or acquire data to verify conformance to specified requirements. (ANSI/ASQ, 2004)

Method

A body of procedures and techniques for performing an activity (e.g., sampling, chemical analysis, quantification) systematically presented in the order in which they are to be executed. (ANSI/ASQ, 2004)

Nonconformance

A deficiency in characteristic, documentation, or procedure that renders the quality of an item or activity unacceptable or indeterminate; nonfulfillment of a specified requirement. (ANSI/ASQ, 2004)

Precision

The degree to which a set of observations or measurements of the same property, obtained under similar conditions, conform to themselves. Precision is usually expressed as standard deviation, variance, percent difference, or range, in either absolute or relative terms. (IDQTF, 2005)

Procedure

A written document that details the method for an operation, analysis, or action with thoroughly prescribed techniques and steps, and that is officially approved as the method for performing certain routine or repetitive tasks. (ANSI/ASQ, 2004)

Process

A set of interrelated or interacting activities that transform inputs into outputs. (ANSI/ASQ, 2004)

Quality

The totality of features and characteristics of a product or service that bear on its ability to meet the stated or implied needs and expectations of the user. (ANSI/ASQ, 2004)

Quality Assurance (QA)

An integrated system of management activities involving planning, implementation assessment, reporting, and quality improvement to ensure that a process, item, or service is of the type and quality needed and expected by the customer. (ANSI/ASQ, 2004)

Definitions *(Continued)*

Quality Control (QC)

The overall system of technical activities that measures the attributes and performance of a process, item, or service against defined standards to verify that they meet the stated requirements established by the customer; operational techniques and activities that are used to fulfill requirements for quality. (ANSI/ASQ, 2004)

Quality Improvement

A management program for improving the quality of operations. Such management programs generally entail a formal mechanism for encouraging work recommendations with timely management evaluation and feedback or implementation. (ANSI/ASQ, 2004)

Record

A document stating results achieved or providing evidence of activities performed. A record is a document that furnishes objective evidence of the quality of items or activities and that has been verified and authenticated as technically complete and correct. Records may include photographs, drawings, magnetic tape, and other data recording media. (ANSI/ASQ, 2004)

Representativeness

A qualitative term that describes the extent to which a sampling design adequately reflects the environmental conditions of a site. It takes into consideration the magnitude of the site area represented by one sample and indicates the feasibility and reasonableness of that design rationale. Representativeness also reflects the ability of the sample team to collect samples and the ability of the laboratory personnel to analyze those samples so the generated data accurately and precisely reflect site conditions. (IDQTF, 2005)

Service

The result generated by activities at the interface between the supplier and the customer, and by supplier internal activities to meet customer needs. Such activities in environmental programs include design, inspection, laboratory and/or field analysis, repair, and installation. (IDQTF, 2005)

Streamlined Approach for Environmental Restoration (SAFER) Plan

Provides a process for initiating and completing corrective actions at units where enough information exists to select the appropriate remedy before completing an investigation. (FFACO, 1996; as amended)

Definitions *(Continued)*

Traceability

The ability to trace the history, application, or location of an entity by means of recorded identifications. In a calibration sense, traceability relates measuring equipment to national or international standard, primary standards, basic physical constants or properties, or reference materials. In a data collection sense, it relates calculations and data generated throughout the project back to the requirements for quality for the project. (IDQTF, 2005)

Validation

Confirmation by examination and provision of objective evidence that the particular requirements for a specific intended use are fulfilled. Data validation is a sampling and analytical process evaluation that includes evaluating compliance with methods, procedures, or contracts, and comparison with criteria based upon the quality objectives. (IDQTF, 2005)

Verification

Confirmation by examination and provision of objective evidence that specified sampling and analytical requirements have been completed. This is to be a completeness check. (IDQTF, 2005)

Revision History

Revision	Effective Date	Description of Revision
Rev. 0	05/2012	Initial Issue
Rev. 1	10/2017	**Throughout document** • Updated acronyms and definitions. • Updated references. • Globally changed "U.S. Department of Energy, National Nuclear Security Administration Nevada Site Office (NNSA/NSO) Nevada Environmental Management Operations Activity" references to "U.S. Department of Energy (DOE) Environmental Management (EM) Nevada Program Soils Activity" along with corresponding changes in personnel titles. **Section 1.0** Clarified responsibility for this QAP: "The EM Nevada Program owns and is responsible for maintaining this QAP. Individual participants are responsible for implementing the requirements of this QAP in accordance with their own approved programs, processes, plans, and procedures. If a participant's requirement document differs from this QAP, the stricter requirement will take precedence." **Sections 1.5.1 through 1.5.4** Removed text dealing with COPCs and action levels, as this is duplicative of what is contained in the Soils Activity RBCA document. **Section 1.5.1.3** Added the methodology for inferring Pu activities in soil samples based on Am-241 activities and the ratios of Am-241 to the Pu isotopes to produce Pu isotope activities that are more representative of the sampled area. **Section 1.6.1** Clarified the requirements for revising this QAP, and added the flowdown of requirements to subcontractors. **Sections 2.0, 2.5, 2.6, and 2.7** Clarified the definition of data quality levels. **Section 2.1.1** Defined key personnel. **Section 2.5.1** Added text to address quality issues concerning the use of TLDs to estimate external dose. **Section 3.1** Clarified responsibilities for conducting assessments. **Appendix A** Replaced contents of Appendix A with a discussion addressing quality issues concerning the use of TLDs to estimate external dose. Prior text addressing chemical COPCs and action levels is contained in the Soils Activity RBCA document. **Appendix B** Removed Appendix B from the document, as the discussion addressing radiological COPCs is contained in the Soils Activity RBCA document. **Appendix C** Removed NDEP comments.

1.0 Management

This Quality Assurance Plan (QAP) provides the overall Quality Assurance (QA) program requirements, technical planning, and general quality practices to be applied to the U.S. Department of Energy (DOE) Environmental Management (EM) Nevada Program Soils Activity. The QAP requirements are consistent with the *Quality Systems for Environmental Data and Technology Programs–Requirements with Guidance for Use* (ANSI/ASQ, 2004); the Intergovernmental Data Quality Task Force Uniform Federal Policy for Quality Assurance Project Plans (IDQTF, 2005); and 10 *Code of Federal Regulations* (CFR) 830.120, *Quality Assurance* (CFR, 2017a), which apply to specific activities performed under the Soils Activity. The EM Nevada Program owns and is responsible for maintaining this QAP. Individual participants are responsible for implementing the requirements of this QAP in accordance with their own approved programs, processes, plans, and procedures. If a participant's requirement document differs from this QAP, the stricter requirement will take precedence.

The EM Nevada Program, or designee, will review the QAP every two years for adequacy and for changing objectives or regulatory requirements. Changes not affecting the overall activity scope or a requirement will not require a QAP revision but will be incorporated into a subsequent revision.

This QAP provides for the evaluation of environmental, safety, and health risks associated with the activities to be performed by using the graded approach to determine the required QA level. The graded approach must be applied with varying degrees of rigor, control, documentation, and actions commensurate with the risks to personnel safety, the public, and the environment. When determining the level of rigor required, the following issues must be taken into consideration:

- The environmental decision to be made
- The impact on human health and the environment
- The regulatory requirements for the site-specific environmental problem

Section 1.0 describes Soils Activity objectives, participant roles and responsibilities, and administrative and management quality requirements (i.e., training, records, procurement). Section 1.0 also details data quality indicators (DQIs), data management, computer software, and procurement requirements. Section 2.0 establishes the requirements to ensure newly collected data

are valid and are managed appropriately. Section 3.0 provides feedback loops through assessments and reports to management as well as the framework for correcting deficiencies in data quality. Section 4.0 provides the requirements for assessing the validity and usability of the data. Section 5.0 provides references for this document.

1.1 Problem Definition and Background

In 1996, the DOE, U.S. Department of Defense, and the State of Nevada entered into the *Federal Facility Agreement and Consent Order* (FFACO) (1996, as amended), which describes the strategies employed to plan, implement, and complete environmental corrective action activities.

The Soils Activity is responsible for evaluating sites identified in the FFACO with surface and shallow subsurface soil contamination resulting from various types of nuclear experiments or testing at the Nevada National Security Site (NNSS), the Nevada Test and Training Range (NTTR), and the Tonopah Test Range (TTR). To evaluate the need for (and extent of) corrective action required at these sites, the Soils Activity assesses impacts to public health and the environment by comparing measurements of soil contaminant levels to risk-based (chemical) and dose-based (radionuclide) action levels. As established in the *Soils Risk-Based Corrective Action* (RBCA) *Evaluation Process* (NNSA/NFO, 2014b), radiological risk is evaluated by using radiological dose as a surrogate. Preliminary action levels (PALs), are established as part of the data quality objectives (DQO) process and are documented in the applicable FFACO planning document. PALs are not remediation standards but are used for contaminant screening purposes. Site contaminants that do not exceed PALs are removed from further corrective action evaluations.

For site contaminants that exceed PALs, appropriate final action levels (FALs) are determined in a risk evaluation documented in the applicable FFACO report. FALs (i.e., remediation standards) are established by conducting an RBCA site evaluation using ASTM International (ASTM) Method E1739-95 (ASTM, 1995) or an equivalent method. ASTM Method E1739-95 uses a three-tiered approach in evaluating the DQO decisions. Action levels established based on successive tiers use increasingly sophisticated (and site-specific) calculations. The Tier 1 action levels are the PALs established in the DQOs, while the action levels for Tier 2 and Tier 3 are site-specific calculations. This process for the Soils Activity is defined in the Soils RBCA document (NNSA/NFO, 2014b).

To evaluate site contamination levels against these remediation standards, data are gathered or generated as part of a corrective action investigation that is designed and implemented using the DQO process as presented in Section 1.5. The results of the investigations are evaluated and corrective action decisions are determined using the data quality assessment (DQA) process as presented in Section 4.3.

1.2 Schedule

The EM Nevada Program and the Nevada Division of Environmental Protection (NDEP) establish milestones and schedules for Soils activities in accordance with the FFACO (1996, as amended). Part XII.4 of the FFACO requires annual meetings to establish priorities, milestones, and due dates for the current fiscal year. Monthly progress reports and lifecycle schedules must be posted to the Environmental Management Information System website.

1.3 Roles and Responsibilities

EM Nevada Program personnel are responsible for achieving quality within the specific tasks they manage. Roles and responsibilities for EM Nevada Program personnel and supporting contractors (referred to as participants) are described in the following subsections.

1.3.1 Deputy Program Manager, Operations

The Deputy Program Manager, Operations is responsible for the administration of the program and reports to the EM Nevada Program Manager. The Operations Manager has oversight and management responsibilities for environmental restoration, and is responsible for ensuring that quality requirements are established and implemented.

1.3.2 Activity Lead

The EM Nevada Program Activity Lead reports to and is the prime point of contact for the Operations Manager. The Activity Lead has day-to-day management responsibilities for technical, financial, and scheduling aspects; and monitors contractor performance. The Activity Lead is also responsible for ensuring effective communication between participants.

1.3.3 Participants

Participants (support contractors) are responsible for developing the procedures for their assigned scope of work and ensuring that work is performed in accordance with applicable federal, state, and local regulations; and with plans and procedures consistent with individual contracts. To fulfill QA responsibilities, participants must, at a minimum, be responsible for the following duties:

- Report information regarding scope, schedule, cost, technical execution, and quality achievement of task order activities to the Activity Lead.
- Implement individual quality programs and procedures that demonstrate the requirements of this QAP are met.
- Ensure the proper resources are provided for QA activities and that QA activities are integrated into operations.
- Evaluate activities to ensure requirements are implemented.
- Implement applicable procedures and instructions.
- Verify that work is technically sound, defensible, consistent with objectives, and conducted in accordance with this QAP.
- Ensure personnel are trained and qualified to achieve initial proficiency; maintain proficiency; and adapt to changes in technology, methods, or job responsibilities.
- Perform assessments to verify compliance with applicable requirements in accordance with Section 3.1.1.
- Identify deficient areas and nonconformances; correct deficiencies; and verify effectiveness.
- Notify the Activity Lead and other involved personnel of significant conditions adverse to quality, safety, health, the environment, or any adverse trends.

1.4 Qualifications and Training

The EM Nevada Program and participants' management must ensure that personnel are qualified and knowledgeable in the activities they perform. Training should emphasize correct performance of assigned work and provide an understanding of why quality requirements exist. Personnel qualification and training records must be maintained as records in accordance with Section 1.7.

1.4.1 Personnel

Participant personnel must be trained and qualified to perform the tasks to which they are assigned. Objective evidence of qualifications may include academic credentials; individual resumes; registrations; and/or certifications, licenses, and training records. Participants will evaluate personnel qualifications against assigned responsibilities and address identified training needs. Training should be provided to achieve and maintain proficiency; adapt to changes in technology, methods, or job description; and allow for feedback and effectiveness of job performance. Qualifications for specific job categories are based on requirements established by the participating organization's personnel management, DOE directives, or other requirement documents.

Training may take the form of orientation and/or indoctrination, formal classroom training, self study, reading, or on-the-job training. Training should include regulatory requirements, scopes of work, QA/quality control (QC) requirements, and applicable work instructions.

1.4.2 Subcontracts

Subcontractor personnel must be qualified and trained to perform the duties for which they were contracted. The contracting organization is responsible for verifying the qualifications of their subcontractors using the same criteria and objective evidence required for their own personnel.

1.5 Data Quality Objectives

The U.S. Environmental Protection Agency's (EPA) DQO process (EPA, 2006c) will be used as guidelines for planning and assessing investigation results. Participants, including EM Nevada Program and NDEP personnel, must establish DQOs for each site.

In accordance with the graded approach referred to in Section 1.0, the DQO process will determine which measurements are (1) required to make critical decisions about health, the environment, and regulatory compliance; (2) used to support such decisions; and (3) provided for informational purposes only. Critical decision measurements will undergo closer scrutiny during the data gathering and review processes. DQO participants will determine and define the required data quality for each type of measurement in the planning documents.

During the DQO process, representatives from the involved organizations will perform the following:

- Clarify the study objective.
- Develop a conceptual site model.
- Identify critical decisions.
- Identify data needs.
- Determine data use.
- Determine what the data represent.
- Define appropriate type of data to collect.
- Specify tolerable limits on decision errors that will be used as the basis for establishing the quantity and quality of data needed to support the decision.

During the DQO process, criteria for selecting sample locations will be identified, and contaminants of potential concern (COPCs) and PALs will be defined. Sampling and thermoluminescent dosimeter (TLD) placement plans will be developed after the DQOs are established. At the end of investigations, a DQA must be conducted and documented in the applicable FFACO report.

1.5.1 Data Quality Indicators

DQIs are qualitative and quantitative descriptors used in interpreting the degree of acceptability or utility of data. DQIs include precision, accuracy/bias, representativeness, completeness, comparability, and sensitivity. DQI criteria must be established during the site-specific DQO process to properly support the overall activity or sampling task objectives. For each investigation, the data must be assessed against the DQI criteria. The assessment results must be reported in the applicable FFACO report. If any of these criteria are not met, an impact assessment will be conducted, and target analyte results affected will be listed in the FFACO report. Sample results identified as rejected or estimated values during the data validation process are considered qualified data. The label "qualified" is used in this document to identify those results.

1.5.1.1 Precision

The performance criteria for precision is that no more than 20 percent of sample results for each measured COPC are qualified due to duplicate results with a relative percent difference (RPD), normalized difference, or absolute difference exceeding its respective acceptance limits (see Section 4.2.1).

1.5.1.2 Accuracy/Bias

The performance criteria for accuracy is that no more than 20 percent of sample results for each measured COPC are qualified for accuracy (see Section 4.2.2).

1.5.1.3 Representativeness

To ensure representativeness, probabilistic and judgmental sampling designs and sample collection standard operating procedures (SOPs) are used.

Judgmental sampling will be designed to collect samples and place TLDs in locations of particular interest (e.g., background locations, locations most likely to contain the maximum contaminant concentrations, or at locations designed to produce a range of results). This design identifies locations of potential contamination based on biasing information.

Probabilistic sampling schemes will be designed to collect samples from, and place TLDs at, unbiased locations that represent contamination levels within the population of interest.

Special consideration is needed for Americium (Am) and Plutonium (Pu) isotope concentrations related to representativeness. This is due to the nature of these contaminants in soil (Bernhardt, 1976). These isotopes may be present in soil in the form of small particles that may or may not be captured in a small soil sample of 1 to 2 grams. As individual particles of these radionuclides can make a significant impact on analytical results, small soil samples taken from the same site can produce analytical results that are very different (i.e., poor accuracy). However, the Am and Pu isotopes are co-located (e.g., Am-241 is a daughter product of Pu-241), and the relative concentrations between different samples from the same site (i.e., the ratio of Am to Pu isotope concentrations) should be equal. Based on process knowledge and demonstrated by analytical results from previously sampled

Soils sites, the ratios between Am and Pu isotopes in soil contamination from any given source is expected to be the same throughout the contaminant plume at any given time. Therefore, if the ratios are known and one of these isotopic concentrations is known, the concentrations of the other isotopes can be estimated.

Am-241 is reported by the gamma spectrometry method as well as the isotopic Am method. As the gamma spectrometry measurement is based on a much larger soil sample (usually 1 liter), the particle distribution problem discussed above is greatly diminished and the probability of the result being representative of the sampled site is much improved. Therefore, the ratios between the Am and Pu isotopes will be established using the isotopic analytical results and these ratios will be used to infer concentrations of Pu isotopes using the gamma spectrometry results for Am-241. These inferred Pu values will be more representative of the sampled area than the isotopic results. The isotopic ratios of Am-241 to Pu-238, Pu-239/240, and Pu-241 will be calculated for sites identified as containing a Pu-239/240 activity greater than 5 percent of the Residual Radioactive Material Guideline (RRMG) in any sample (NNSA/NFO, 2014b). The calculated ratios and the inferred activities will be reported in the FFACO report document.

1.5.1.4 Completeness

Completeness will be achieved when 80 percent of the environmental sample and TLD results are valid, or sufficient information is acquired to resolve DQO decisions.

1.5.1.5 Comparability

The comparability criteria is that sampling, handling, preparation, analysis, reporting, and data validation were performed and documented in accordance with procedures based on standard methods.

1.5.1.6 Sensitivity

Sensitivity is the capability of a method or instrument to discriminate between measurement responses representing different levels of a variable of interest. Analytical methods must be sufficient to detect COPCs present in the samples at concentrations less than or equal to the corresponding RRMGs. The TLD sensitivity must be less than the FAL.

1.6 Document Control

Systems and controls must be implemented by participants for identifying, preparing, reviewing, approving, revising, collecting, indexing, filing, storing, maintaining, retrieving, distributing, and disposing of pertinent quality documentation and records. Documents that prescribe technical processes, specify quality requirements, or establish management controls must be developed, reviewed, and approved in accordance with the participants' procedures. For characterization and remediation at Soils Activity sites located in the state of Nevada, the following reports (as applicable) may be developed in accordance with FFACO outlines:

- Corrective Action Investigation Plan (CAIP)
- Streamlined Approach For Environmental Restoration (SAFER) Plan
- Corrective Action Decision Document (CADD)
- Corrective Action Decision Document/Corrective Action Plan (CADD/CAP)
- Corrective Action Decision Document/Closure Report (CADD/CR)
- Corrective Action Plan (CAP)
- Closure Report (CR)

Plans and reports must be reviewed for quality requirements, technical adequacy, completeness, and accuracy before approval and issuance. A system or process for identifying documents that require control, and for controlling those documents, must be implemented to ensure that the latest revision of a document is used. The participant management is responsible for ensuring that personnel who perform work are in possession of the most current version of the documents applicable to the activities being conducted. Revisions to controlled documents must be approved by the same level of authority or organization as the original. Documents no longer in use should have their status clearly indicated, and record copies should be maintained in accordance with DOE Order 243.1B Admin Chg. 1, *Records Management Program* (DOE, 2013), and the applicable records. Records disposition schedules are defined in Att. 2 of DOE O 243.1B.

1.6.1 Revisions

Changes or modifications to procedures or plans may become necessary to adjust to actual field conditions or revise programmatic methods. Participants must have procedures to ensure changes are properly identified, documented, approved, and controlled. Verbal authorization of changes must be documented and followed up with a written change notice as soon as practicable. Changes must be

approved commensurate with the original document before the change is implemented. The EM Nevada Program must be notified of changes that impact the technical scope, cost, or schedule.

Revisions and changes to this QAP, other than minor editorial changes, will be communicated to the participants by the EM Nevada Program Activity Lead, or designee. Changes that impact the scope, cost, or schedule must be coordinated with appropriate EM Nevada Program and Participant Contracting Officers before their effective date. Participants are responsible for flowing down new requirements to their subcontractors.

1.6.2 Information Protection

Documents, plans, procedures, presentations, and data must be reviewed in accordance with DOE Order 475.2B, *Identifying Classified Information* (DOE, 2014).

1.7 Records Management

Records of Soils activities must be prepared, reviewed, and maintained. Participants must maintain their records, or submit their records to a storage and retrieval system that is consistent with applicable environmental regulations and DOE Order 243.1B Admin Chg. 1 (DOE, 2013). Such systems will allow for the retrieval of records and must be protected from loss, compromise, or catastrophic events. Storage/documentation systems for computer-based information (e.g., software, models and data) must be designed in accordance with DOE Order 241.1B Admin Chg. 1 (DOE, 2016). Records and metadata must include sufficient detail to allow for the reconstruction of activities as well as provide traceability. Participants' plans, procedures, and program documents must identify the resultant records, appropriate storage, and retention time frames.

Participants should consider the following when identifying a document, including electronic information, as a record:

- Is the document a specific and original source?
- Does the document support a regulatory decision?
- Is the document valuable for assessments?
- Does the document support other documents?
- Is the document a deliverable?
- Does the document describe work performed (e.g., completed forms, field logbooks)?
- Does the document support functions such as training, procurement, or accounting?

- Does the document require action?
- Does the document reflect a decision, action, or lack of action?
- Is the document necessary to understand a decision, action, or non-action?
- Does the document provide context of a decisional document?

The following controls must be applied to records. This is not intended to be an exhaustive list, and additional controls may be applied:

- Do not use whiteout, correction tape, or black permanent markers to correct errors.
- If an error is made on a record, draw a single line through the error; note the correction; then initial and date the correction.
- Take necessary actions to ensure records are not damaged or susceptible to loss, liquid/food spillage, or weather elements.
- Maintain records at job sites in a manner that facilitates ease of retrieval.
- Use indelible ink to enter information into handwritten logs, logbooks, and forms.
- Number each page of logbooks sequentially.
- When handwriting information, draw a diagonal line through a page or portion of a page if it is intentionally left blank, then initial and date the page.
- Back up electronic records on a regular cycle, and store backup media in a separate location or in a two-hour fire-rated safe to safeguard against the loss of information due to equipment malfunctions or human error.

Participants must ensure that records are legible and complete. Incomplete information within a record reduces its overall value. For example, meeting minutes without a date or list of attendees have little value when establishing events.

1.8 Software

Computer software is subjected to controls if it (1) performs hazard analysis; (2) models environmental contaminant migration to determine dose and exposure consequences; (3) provides any other function that could impact worker and/or public safety or health; or (4) manages or analyzes data. The Soils Activity does not anticipate the need to develop software; if a need is

identified, the Underground Test Area Activity Quality Assurance Project Plan (NNSA/NFO, 2015) will be followed.

Acquired software is supplied through basic procurements, two-party agreements, or other contractual arrangements. Acquired software includes commercial off-the-shelf (COTS) software such as operating systems, database management systems, and commercial calculation software and spreadsheets. Downloadable software that is available at no cost to the user (referred to as freeware) is also considered acquired software.

Calculation applications are user-developed algorithms or data structures using COTS software. The use of web-based calculators must be documented in accordance with Section 1.8.5.

1.8.1 Verification

Software and calculation applications must be verified for use based on their ability to provide acceptable results for the intended use. The extent of verification required will depend on the complexity, risk, and uniqueness of the application. Verification documentation must include the following, at a minimum:

- Description and equations of mathematical models, algorithms, and numerical solution techniques, as applicable
- Software and version
- Description of test case(s) and results
- Range of input parameter values for which results were verified
- Identification of any limitations on applications

Software or calculation modifications must be verified in accordance with the same requirements as the original. Verification of changes may be limited to the scope of the modification.

Acquired software may be used without verification if the code has widespread use, verification, and documentation (often referred to as industry standard or industry proven). There must be a method for error reporting and configuration control. The intended use of the software must be within the applications identified capabilities and constraints (usually identified in user's manuals). Acquired

software used without modification must have operational checks performed to verify that the software is installed and functioning as intended.

1.8.2 Control

Participants must maintain a configuration management process to identify and define the configuration items in a system. The system must control the release and change of these items throughout the system lifecycle, record and report the status of configuration items and change requests, and verify the completeness and correctness of configuration items. The process must address the following:

- Determine and identify those portions of the software product that need to be controlled.
- Ensure those entities have necessary and accurate documentation.
- Ensure changes are made to the entities in a controlled manner.
- Ensure that the correct version of the entities/software product are being used.
- Ascertain, at any point in time, the status of the entity.

1.8.3 Storage

The design and maintenance of systems that house electronic information and records must be managed in accordance with DOE Order 200.1A (DOE, 2008). The physical media on which software is stored must be controlled and protected so that software and data are physically retrievable and protected from loss or compromise by catastrophic events. Backup copies must be maintained so that a single event will not cause a significant loss of software or data.

1.8.4 Documentation

Acquired software must be uniquely identified. Software documentation must be maintained with associated calculations and reference material. Documentation will consist of reference material, verification/validation records, operational test records, and user-oriented information.

1.8.5 Operational Use

Operational use of software must be documented. The minimum information should include the version of software used, input, output, and the date. If input parameters other than those in the Soils

RBCA document (NNSA/NFO, 2014b) are used, the justification for use must be documented in the applicable FFACO reports.

1.9 Procurement

Procurement of items and services must be consistent with Federal Acquisition Regulations and purchase order terms and conditions. Vendors must meet the requirements of their subcontracts or agreements.

1.9.1 Procurement Control

Vendors must meet or exceed specifications delineated in the subcontract/purchase order documents. Vendors must adhere to the contractor's requirements mandated by General Services Administration Federal Acquisition Regulations Standard Form 33; the Schedule, Part I, Section H "Special Contract Requirements" for the procurement of quality affected items and services.

The procuring contractor will assess the capabilities of subcontractor key personnel to verify qualifications and determine whether any training is needed for environmental restoration activities. Subcontractors should be evaluated for prior experience, the ability to perform specific tasks, and cost.

1.9.1.1 Subcontracts

Participants' subcontracts must define prices/costs, specifications/statement of work (SOW), packaging/marking, inspection/acceptance, deliveries or performance, special contract requirements, contract clauses, list of attachments, and evaluation factors for award of the item or service being procured. Subcontract documents must be reviewed for accuracy and completeness by qualified technical personnel before award. Changes to a subcontract require the same level of review and approval as the original document.

1.9.1.2 Measuring and Test Equipment

Participants subcontracts must also require that purchased and rented measuring and test equipment (M&TE) is compliant with existing National Institute of Standards and Technology (NIST) standards before acceptance and that calibration certification documentation is provided. Instrument

manufacturers' manuals should be available. Schedules for recalibration must be established and adhered to for M&TE.

1.9.2 Laboratory Performance

Participant's subcontracts with commercial analytical laboratories must ensure that samples are received, handled, stored, and analyzed in accordance with the analytical laboratory's QA program and the contractor's statement of work. Verification of laboratory conformance is the responsibility of the contracting organization. Subcontracts must incorporate the requirements found in Section 2.5.2.

1.9.3 Verification of Quality Conformance

The contractor must require access to the subcontractor's or vendor's facilities, including their subtier facilities, work areas, and records for assessments to verify acceptability. Upon receipt, procured items or services must be inspected for conformance to specifications and requirements before items are released or placed into service. Procured items must be evaluated for suspect/counterfeit parts. Personnel have the authority to stop work if significant quality problems are identified.

1.9.4 Inspection and Acceptance Testing

Inspections and acceptance testing must be accomplished in accordance with inspection documents and test procedures that reflect acceptance and performance criteria. Individuals performing inspections and acceptance testing must be independent of those who performed the work. Quality-affecting materials used during characterization, corrective action, or sampling activities must be inspected upon receipt for adequacy. M&TE used in the performance of inspections or acceptance tests must be calibrated and properly maintained. Any item or work determined to be defective must be controlled to avoid inadvertent use.

1.10 Identification and Control of Items

Participants must establish and document sufficient controls to ensure that quality-affecting items (e.g., equipment, components, and material) can be readily identified. These controls must be established to prevent incorrect use, retain integrity of materials, and preserve the desired operating characteristics of equipment.

1.10.1 Suspect and Counterfeit Items

Participants must establish effective controls to prevent, detect, and dispose of suspect and counterfeit items (such as bolts and lifting straps) when such items could lead to unexpected equipment failures or to negative impacts to mission, the environment, or personnel. Trend analyses for improving the suspect/counterfeit item prevention process must be performed.

1.11 Measuring and Test Equipment

Participants must uniquely identify and control their M&TE, and establish a system of calibration and preventive maintenance to ensure proper operation. Reference standards of the correct type and range must be used for collecting data consistent with objectives. M&TE records must be maintained in accordance with Section 1.7.

1.11.1 Calibration

Participants must calibrate M&TE in accordance with their procedures or the manufacturer's instructions. The frequency of periodic or factory calibrations will be based on the manufacturer's recommendations, national standards of practice, equipment type and characteristics, and past experience. Calibrations must be performed on M&TE before work begins and at intervals prescribed by participant organization procedures.

Equipment that becomes inoperable, fails calibration, or is past its calibration expiration date must be tagged "out of service" and, when possible, segregated to prevent inadvertent use. Results of activities performed using equipment that is out of calibration must be evaluated for adverse affects and the appropriate personnel notified.

Physical and chemical standards must have certifications traceable to NIST, EPA, or other nationally recognized agencies. Supporting documentation on reference standards and equipment must be maintained.

1.11.2 Preventive Maintenance

Participants will perform periodic preventive maintenance on field and laboratory equipment in accordance with manufacturers' specifications and warranties. The frequency of preventive maintenance will be based on manufacturers' recommendations and the users' professional knowledge and experience.

2.0 Work and Data Processes

Details of specific environmental data-collection activities will be discussed in the applicable site-specific planning documents. Appropriate technical methods or a scientific rationale must be employed. Activities must be performed in accordance with procedures and site-specific plans that comply with the applicable requirements of DOE orders, procedures, this QAP, and planning documents. Upon request, participants must supply the EM Nevada Program with copies of applicable procedures. Deviations from plans and procedures must be documented and approved from the original approving organization.

The quality required of a dataset is determined by its actual use in the decision-making process. The quality of the data used to resolve DQO decisions must be justified in the DQA. The required level of quality will depend on the use of the data (e.g., to directly make a decision, to indirectly make a decision, or to support assumptions in the conceptual site model). Data will be classified into one of three categories: decisional, decision supporting, and informational. Decisional data will be used to make primary decisions on environmental contaminant action levels or closure standards being met; decision-supporting data will contribute to such decisions; and informational data will support conceptual models or guide investigations related to such decisions. Descriptions of these categories and how they relate to data quality are discussed in Sections 2.5 through 2.7.

2.1 Planning

Participants must perform fieldwork safely and within the controls established by Real Estate/Operations Permits and Work Packages or equivalent. Activities must be documented in the associated task plans, activity plans, field instructions, and/or SOPs. Data acquisition methods for which a procedure does not exist (those that are unique, experimental, or under development) must be detailed in field documentation. Field sampling and laboratory analytical procedures must incorporate QC criteria.

Personnel responsible for data collection must verify that activities are defined, controlled, verified, and documented. Planning must incorporate the principles of Integrated Safety Management to mitigate hazards to workers. Work assignments must be clearly communicated with lines of

communication established among all participants. Organizations that are assigned lead responsibilities must coordinate planning with decision-makers and participants.

2.1.1 Task Planning

Key personnel must be briefed on the purpose, expected outcome, schedule, and responsibilities when assigned tasks. Responsible managers must monitor the planning process to ensure communication of status, assess progress and, if necessary, implement issue resolution.

Key personnel are those who perform any of the following activities:

- Collect, generate, or analyze data.
- Plan or approve work.
- Define DQOs.
- Oversee QC or safety.
- Manage or supervise activities covered by this QAP.

2.1.2 Readiness Determination

Readiness reviews must be performed as required by participating organizations before work resumes (after stop work orders) to verify and document that planning and prerequisites have been satisfactorily completed. At a minimum, readiness reviews must verify that the following issues have been addressed:

- Scope of work is defined and understood.
- Planned work is appropriate to meet DQO objectives.
- Work instructions have been approved and issued to personnel.
- Hazards have been identified and analyzed, and controls have been implemented.
- Proper resources (e.g., personnel, equipment, and materials) have been identified and are available.
- Assigned personnel have been trained and qualified.
- Internal and external interfaces have been defined.
- Work authorizations and permits have been obtained.

- M&TE calibration is current.
- A feedback mechanism has been established to facilitate process improvement.

2.2 Field Documentation

Participants' procedures must include field documentation of sufficient detail to facilitate the reconstruction of field activities. Instrument identification numbers and applicable calibration must be documented. Field personnel must document activities in a notebook, logbook, or form as required by the participant organization. The field documentation must be reviewed (i.e., with an initial and date) for completeness and accuracy by someone, other than those performing the work, who is knowledgeable in the area being reviewed. Field records and related documentation must be developed and maintained in accordance with Section 1.7.

Participants taking photographs must have EM Nevada Program approval and be in compliance with NNSS and U.S. Air Force requirements (if on the NTTR). The photographs must be processed and stored in accordance with DOE Order 471.6 Admin Chg. 2, *Information Security* (DOE, 2015) and DOE Order 475.2B, *Identifying Classified Information* (DOE, 2014).

2.3 Decontamination

Equipment parts in contact with samples must be decontaminated to prevent cross-contamination. Contractor procedures should address decontamination methods for the sample matrices involved and the potential contaminants of concern.

2.4 Investigation-Derived Waste

Investigation-derived waste must be managed in accordance with DOE orders, U.S. Department of Transportation regulations, *Resource Conservation and Recovery Act* regulations, Nevada laws and regulations, the FFACO (1996, as amended), State and DOE agreements, relevant permits, and site-specific requirements.

2.5 Decisional Data

Decisional data are used to directly resolve DQO decisions (i.e., the data are directly compared to FALs). These data require the highest level of QA/QC in collection and measurement systems because the data are used to resolve primary decisions (i.e., rejecting or accepting the null hypothesis), and/or to verify that closure standards have been met. Environmental TLD and media analytical data are classified as decisional data when used in this manner. If other methods of collecting decisional data are identified, they will be addressed in the applicable FFACO report. Decisional data documentation must be maintained as records in accordance with Section 1.7.

2.5.1 Environmental TLDs

When TLDs are used for determining external dose rates, they must be managed to minimize exposure to radioactivity that is not associated with the population of interest. Participants must implement procedures to account for dose other than from the population of interest (e.g., pre- and post-deployment).

TLDs must be placed in accordance with the Soils RBCA document (NNSA/NFO, 2014b) and activity-specific plans (e.g., CAIP, SAFER plan). TLDs must be identified by a unique serial number and a documented anneal date before deployment. Placement and retrieval date and location must be documented for each TLD. Placement coordinates must be obtained for each TLD location. Chain of custody forms must be used to transfer TLDs after collection (see Section 2.5.2.2).

At least one additional TLD must be placed at a location representative of background conditions that are not impacted by the area under investigation to provide background measurements. These areas are selected based on aerial flyover data and radiological maps of the sites.

TLDs must be annealed and processed in accordance with the *Nevada Test Site Routine Radiological Environmental Monitoring Plan* (BN, 2003) or equivalent. The analytical results must include read dates and individual element results, and be documented in a format that facilitates analyses in accordance with the Soils RBCA document (NNSA/NFO, 2014b) and activity-specific plans (e.g., CAIP, SAFER plan).

The determination of the external dose component of the total effective dose by TLDs was determined to be the most accurate method because of the following factors:

- TLDs are exposed at the sample plots for an extended time period that approximates the 2,000 hours of exposure time used for the Industrial Area exposure scenario. This eliminates errors in reading dose-rate meter scale graduations and needle fluctuations that would be magnified when as-read meter values are multiplied from units of "per-hour" to 2,000 hours.

- The use of a TLD to determine an individual's external dose is the standard in radiation safety and serves as the "legal dose of record" when other measurements are available. Specifically, 10 CFR Part 835.402 (CFR, 2017b) indicates that personal dosimeters must be provided to monitor individual exposures and that the monitoring program that uses the dosimeters must be accredited in accordance with a DOE Laboratory Accreditation Program (DOELAP).

Additional information about the TLDs used by the Soils Activity and their performance is provided in Appendix A.

2.5.2 Environmental Media Samples

Sample collection plans must establish proper sampling protocols to ensure that personnel collect representative samples and that cross-contamination is not introduced during collection.

Either composite or grab samples may be collected. If composite samples are collected, the compositing protocol will be established in the sample collection plan and documented in the applicable FFACO report.

2.5.2.1 Labels and Collection Documentation

Sample labels must be affixed to containers in a manner that does not obscure any data preprinted on the containers. The label must be protected to ensure legibility and sample integrity. The unique sample number must be in indelible ink on the label.

Sample collection documentation must include the following information:

- Unique sample number
- Sample location
- Sample date and time
- Sample medium
- Preservation or conditioning of the sample

- Collection method
- Name of individual collecting sample

2.5.2.2 Chain of Custody

For field samples used to generate decisional data, chain of custody must be maintained to provide the traceability of possession from the time the samples are collected until disposition. A sample is considered to be in custody if it meets any of the following criteria:

- Is in a person's physical possession.
- Is in a person's unobstructed view after being in the person's physical possession.
- Is in a secured area to prevent tampering after having been in the person's physical possession.
- Is in a designated secured storage area where access is restricted to authorized personnel only.
- Is in secure packaging and sealed with a custody seal during shipment to laboratory.

Environmental media sample containers must be sealed with a custody seal that is initialed and dated by the sample custodian before it is relinquished (ideally, before it leaves the sample collection site). The seal must be placed such that the container cannot be opened without breaking the seal.

The sample custodian is responsible for sample custody until the sample is relinquished to another individual or a secure storage area via the chain of custody form. The chain of custody form does not document transfers to and from shipping entities; therefore, waybills must be retained and included with sample documentation. This transfer does not interrupt the chain of custody as long as the package remains sealed. Whenever samples are transferred to a new sample custodian, the new custodian must sign his or her name, the company name, and the time and date that the transfer occurred. The chain of custody form must accompany the samples during handling and shipment. The chain of custody forms and shipping papers must be maintained in accordance with Section 1.7.

2.5.2.3 Sample Handling, Preservation, Packaging, and Shipping

The site-specific planning documents must identify the appropriate sample containers, preservation procedures, and holding times for specific analyses. Contractor procedures for sample handling, preservation, packaging, and shipping should include instructions for maintaining the integrity of the samples by the applicable preservation methods. Procedures should specify steps necessary for packing the shipping containers. Procedures for the shipment of samples must comply with 49 CFR,

Parts 171–177 (CFR, 2017e), for the packaging, labeling, and placarding. If temporary secure storage is used, the procedure should state under what conditions the samples may be stored.

2.5.2.4 Field QC Samples

Field QC samples provide a mechanism for assessing and documenting that the sample collection process meets the quality objectives. To minimize handling, analysis, and data evaluation bias, field QC samples must be submitted to the laboratory without indicating they are QC samples (blind). Field QC sample collection and documentation must be in accordance with procedures and plans. Field QC samples include, as applicable, equipment rinsate blanks, field blanks, trip blanks, and field duplicates. The number and type of field QC samples required will be determined during the DQO process for each site. Other types of data collected, such as observational data and measurements, must have the appropriate QC checks applied to ensure the information collected is of a quality that meets the objectives of the activity. Records must be preserved and maintained in accordance with Section 1.7 of this document.

2.5.2.4.1 Blanks

If blank analytical results indicate possible contamination of samples, sample results must be reviewed to determine whether qualifiers should be assigned to the data or whether the source should be resampled. Blank analytical results must be maintained with the corresponding sample data in the laboratory records file and reported in the data package. The following types of blanks should be analyzed when field or shipping events warrant:

- ***Equipment rinsate*** is collected from the final rinse solution in the equipment rinse process to determine the effectiveness of the process. The blanks are analyzed for the same analytes as the corresponding environmental samples.
- ***Field blanks*** should be collected at specified frequencies according to the probability of contamination or cross-contamination. Field blanks should be collected as closely in time and space to the sample as possible. The blanks are analyzed for the same analytes as the corresponding environmental samples.
- ***Trip blank*** is a volatile organic analysis (VOA) container of organic-free water that is shipped to the field along with the other VOA sample containers to determine whether contaminants can enter through the vial during storage and transport.

2.5.2.4.2 Field Duplicate Samples

Field duplicate samples are collected only in coordination with grab samples. They are collected as closely in time and space to the grab sample as possible and used to assess sampling and analytical variability. The field duplicates must follow the original sample collection procedure and analytical profile. The duplicate must be assigned a unique sample number, and duplicate collection must be distributed throughout the sampling.

2.6 Decision-Supporting Data

Decision-supporting data contribute, but are not generally used, to resolve primary decisions and affect DQOs. They are used primarily for sample location planning and preliminary corrective action boundary identification. When decision supporting data are used, limitations and explanations of data quality must be presented in the applicable FFACO reports.

If existing or historical data are part of scoping or design for more data collection, many quality issues can be determined by the resolution of the new effort. If estimates are appropriate, proven reliability of historical or existing data may be unnecessary. This is especially true when additional sampling leads to the decision.

2.6.1 Radiological Land Area Surveys

Radiological land area surveys conducted to characterize radiological conditions at a site must be performed with a radiation detector. Detectors may be linked to a Global Positioning System (GPS) and/or a computer that logs the data at predetermined intervals. Operational methods, calibration, and/or response checks of radiological instruments must be proceduralized to identify criteria for acceptable instrument performance (e.g., control charts and upper confidence levels).

Radiological land area survey documentation must include the following:

- Method of collection, instrument identification and type, and GPS unit
- Coordinate system in which the data have been collected
- Location and/or task-specific information

2.6.2 Geophysical Surveys

Geophysical survey instruments are used to identify subsurface anomalies or buried metallic debris. Operational methods and instrument response checks against a known source before each use must be documented and proceduralized.

2.6.3 Aerial Radiological Surveys

Aerial radiological surveys are conducted periodically on the NNSS and NTTR by multiple organizations. When these data are used as decision-supporting data in an FFACO report, the author must document the limitations of the data and appropriateness for use, and address data quality (including considerations of data accuracy per Section 4.2.2 of this document) in accordance with Section 2.6.

2.7 Informational Data

Informational data do not directly affect DQOs but provide information to support conceptual models and guide investigations. If informational data are extracted from published documents, no quality determination is required. If informational data are generated, the source or process of generation must be documented. Information must be reviewed by someone other than the initiator to ensure correct collection, transcription, and manipulation.

2.7.1 Air Filter Samples

Air filter samples must be collected and analyzed in accordance with requirements of the *Nevada Test Site Routine Radiological Environmental Monitoring Plan* (BN, 2003), Community Environmental Monitoring Program (DRI, 2004), or equivalent.

2.8 Laboratory Types

Laboratories used by the Soils Activity must meet one of the criteria described in the following subsections.

2.8.1 TLD Laboratories

TLD laboratories must maintain a dosimetry accreditation from DOELAP and demonstrate compliance with Subpart C of 10 CFR 835 (CFR, 2017b; NNSA/NFO, 2014b). These laboratories must comply with the requirements of the *Nevada Test Site Routine Radiological Environmental Monitoring Plan* (BN, 2003) or equivalent.

2.8.2 Subcontracted Commercial Analytical Laboratories

Subcontracted commercial laboratories analyzing decisional environmental samples must comply with the following requirements:

- Participate in Performance Evaluation/Proficiency Testing programs appropriate to sample matrices and analyses, and provide performance evaluation results and data deficiency reports for identified deficiencies.
- Participate in the DOE Consolidated Audit Program.
- Be NDEP certified.
- Possess a Radioactive Materials license.
- Be National Environmental Laboratory Accreditation Conference accredited, or equivalent.

These participations, accreditations, and certifications must be maintained throughout the term of the contract.

2.8.3 Other Laboratories

Non-decisional samples may be analyzed using standard methods appropriate to the type of sample and intended use of the data.

2.9 Subcontracted Commercial Laboratory Requirements

Subcontracted commercial laboratories must meet the criteria described in the following subsections.

2.9.1 Sample Storage and Disposal

Samples received at the analytical laboratory that have been entered into the sample tracking system must be placed into a storage refrigerator or secure area. The methods of storage are generally intended to ensure the following:

- Retard biological action.
- Retard hydrolysis of chemical compounds and complexes.
- Reduce volatility of constituents.
- Reduce adsorption effects.
- Reduce light exposure.

Preservation methods are generally limited to pH control, preservation, and refrigeration. Radiological samples do not require preservation or refrigeration. The possibility of reanalysis requires that proper environmental control of samples post-analysis be provided. Sample storage procedures must be documented and described in laboratory-specific SOPs. Samples, residual samples, and secondary waste must be disposed of in accordance with 40 CFR Parts 260–268 and 761 (CFR, 2017c and d); 49 CFR Parts 171–177 (CFR, 2017e); and all applicable federal, state, and local statutes, regulations, ordinances, orders, and rules. Disposal must be appropriately documented and copies of disposal records must be made available upon request.

2.9.2 Laboratory Quality Control Samples

Laboratory quality control (LQC) samples must be analyzed using the same analytical procedures used to analyze environmental samples. Each analytical laboratory must generate QC samples during each analytical run to assess and document accuracy and precision associated with each analytical measurement. Data from concurrently analyzed LQC samples and other QC results that are used to demonstrate analytical control must be included in the laboratory's analytical report. The requirements for the types and number of LQC samples will depend on the analytical procedure or method and the laboratory's QA objective for each test.

LQC samples may include method blanks, laboratory control samples (LCSs), surrogate-spike, and matrix spike/matrix spike duplicate (MSD) samples. If LQC sample results are outside statistical control limits, corrections must be made and reported in the analytical report case narrative.

2.9.2.1 Laboratory Control Sample

The LCS is a known matrix spiked with compounds representative of the target analytes. The LCS must be carried throughout the sample preparation and analysis procedures to assess laboratory accuracy and precision. The LCS must be analyzed concurrently with each analytical batch for each analyte of interest and must be prepared from standards independent of the calibration standard. Results of duplicate LCS analyses must be reported as RPD and percent recovery (%R), and included with the associated analytical report.

2.9.2.2 Method Blank

A method blank is an analyte-free matrix to which all reagents are added in the same volumes and proportions as environmental samples. Method blanks must be analyzed by the laboratory to check for instrument contamination and interference from reagents. A method blank must be concurrently prepared and analyzed for each analyte of interest for each analytical batch. Method blank data must be reported in the same units (when applicable) as the corresponding environmental samples, and results must be included with each analytical report.

2.9.2.3 Surrogate-Spike Samples

A surrogate-spike is an organic compound that is similar to the target analyte(s) in chemical composition and behavior in the analytical process, but is not normally found in environmental samples. Surrogate-spike sample analysis must be performed for all samples analyzed by gas chromatography (GC), gas chromatography/mass spectrometry (GC/MS), and high-performance liquid chromatography (HPLC) to monitor the percent efficiency of sample preparation methods on a sample-by-sample basis. Surrogates are nontarget compounds added to GC, GC/MS, and HPLC samples, blanks, and standards before extraction or purging. Surrogate compounds and concentrations added must be those specified in the applicable analytical method. Results of surrogate spike sample analyses must be reported as %R.

2.9.2.4 Matrix Spike/MSD Samples

Matrix spikes/MSDs are aliquots of environmental samples spiked with a known concentration of target analyte(s). The spiking occurs before sample preparation and analysis. Matrix spike/MSD samples must be analyzed by the laboratory to determine interferences of the sample matrix.

2.9.2.5 Laboratory Duplicate Samples

For inorganic analysis, the laboratory must split an environmental sample for each matrix in every batch of up to 20 samples using the same sample preparation and analysis methods.

2.9.3 Documentation

Data documentation requirements, as well as QA and technical requirements, must be specified in the subcontracted laboratory's SOW. Reported analytical data must include the following documentation:

- Sample receipt and tracking documentation, including identification of the organization and individuals performing the analysis and dates of sample receipt, preparation (if applicable), and analysis.
- Results of LCSs, matrix spikes, replicates, laboratory blanks, calibrations, and calibration verifications, as appropriate for the methods used.
- Identification of nonconformances that may affect the laboratory's measurement system during the time period in which the analysis was performed.
- Analytical results or data deliverables, including reduced data, detection limits, and identification of data qualifiers.

2.10 Data Management

Data must be controlled and managed to guarantee data integrity throughout acquisition and development. Systems must be established for directing data into a controlled data management system. Requirements must be established for identification, collection, selection, control, and transfer of data. Data management must include procedures for documenting the origin of data to ensure that data used to support decisions are of known quality. Procedures must be used to optimize the detection and correction of errors and prevent data loss during data reduction, reporting, and data

entry into databases. Participating organizations must have a system in place for the control and transfer of data and interpretive work products, which will provide guidance for gathering, manipulating, and distributing data.

3.0 Assessment and Oversight

3.1 Assessments

Participating organizations are responsible for conducting self-assessments to determine and verify whether requirements are being implemented effectively. Each organization is also subject to independent assessments conducted by, or on behalf of, the EM Nevada Program. Participating organizations are responsible for addressing issues and correcting instances of non-compliance identified during assessments or by other means.

Assessment personnel have authority to suspend or stop work in progress upon detection and identification of an immediate adverse condition affecting quality. Resumption of work must be in accordance with Section 2.1.2.

3.1.1 Participant Assessments

Planned and periodic assessments will be conducted and will involve management participation. Management assessments identify and correct problems that hinder the organization from achieving its objectives. Independent assessments are conducted by qualified individuals or groups that are not a part of the organization directly performing the work being assessed. Independent assessments measure item and service quality, adequacy of work performance, and promote improvement. Assessments should focus on issues such as the following:

- Adequacy of implementation of the QA program, with emphasis on quality improvement
- Management biases or organizational barriers that impede the improvement process
- Adequacy of organization's structure, staffing, and physical facilities
- Training programs
- Compliance with requirements

Results of assessments must be documented in reports and issued to managers. Participants must ensure follow-up of deficiency corrections, including evaluations of effectiveness of management’s actions. Results of management assessments should be entered into a tracking system for the purposes of identifying trends and lessons learned. The responsibilities and authorities of personnel conducting assessments must be defined and documented, particularly for the authority to suspend or stop work

in progress upon detection and identification of an immediate adverse condition affecting the quality of results.

3.1.2 EM Nevada Program Oversight Assessments

Oversight assessments must be performed periodically by EM Nevada Program personnel, or their designees, to verify compliance with applicable quality requirements (including this Soils QAP), policies, and procedures. Assessments must be conducted in accordance with NFO Order 226.X, *Line Oversight (LO) Program* (NNSA/NFO, 2014a).

3.2 Reports to Management

Participants must inform the Activity Lead of planned activities through receipt, review, and/or approval of any of the following:

- Task plans, schedules, and procedures
- Assessment reports
- Issues, deficiency correction requests, deficiency corrections, and schedules
- Nonconformance reports (NCRs)

Participants' procedures must ensure the documentation, reporting, and correction of nonconforming conditions or issues. In addition, periodic assessment of QA/QC activities and data quality parameters must be evaluated and reported.

3.3 Issue Resolution

Soils Activity objectives are to produce quality products and to continuously improve both processes and products. The following subsections establish the methods and responsibilities for identifying, reporting, controlling, and resolving issues for activities performed.

3.3.1 Issues

Issues are any findings, deficiencies, NCRs, incidents, opportunities for improvement, or any other items of interest that warrant or demand management attention. Issues must be resolved and tracked to closure. Issues can also be defined as strengths and noteworthy practices that are tracked and used for process improvement.

Individuals identifying issues are responsible for the appropriate documentation and reporting. Responsible personnel should be notified when issues are identified. Participants must document, resolve, and report issues in accordance with internal procedures.

Issues that cross organizations lines or that have the potential to impact the products of other participants must be communicated to the EM Nevada Program Activity Lead and the affected participants.

3.3.2 Cause

A cause is the most basic element that, if corrected, will prevent recurrence of the same (or similar) issue. Causal analysis should be used where the understanding of the basic underlying cause is important to prevent similar or related issues. The causal analysis should be used to gain an understanding of the deficiency, its causes, and the necessary corrections to prevent recurrence of the deficiency. The level of effort expended should be based on the possible negative consequences of a repeat occurrence of an issue. The analysis must be maintained as a record.

3.3.3 Trend Analysis

Trend analyses should be performed on nonconforming conditions, deficiencies, and causes to identify any possible trends. Participants should bring adverse trends to the attention of the appropriate management. Positive trends, such as improved performance or cost savings resulting from enhancements or the application of new technology, should be shared to facilitate improvement in other areas or projects. As appropriate, information obtained from trend analyses should be included in a lessons learned system.

3.3.4 Lessons Learned

The EM Nevada Program has implemented a lessons learned system as a focal point for reporting and retrieving important information concerning experiences gained through previous activities. Continuous improvement can be fostered through incorporation of applicable lessons learned into work processes and planning activities, including work plan development, budget development, and strategic planning. The lessons learned program should be used interactively with other management tools such as critiques, assessments, readiness reviews, and evaluations of field activities.

4.0 Environmental Data Usability

Analytical data documentation, verification, and validation requirements must ensure that data used in the decision-making process are scientifically valid, defensible, traceable, and of known precision and accuracy. The data should be of sufficient known quality to withstand scientific and legal challenge relative to the use for which the data are obtained.

Analytical data users must assess documentation for acceptability against the requirements stipulated in the following subsections. Analytical reports (printed or electronic) should note any data use limitations. Data usability records must be maintained in accordance with Section 1.7.

4.1 Verification

Analytical data verification must be performed to evaluate the completeness, correctness, and conformance of each dataset. This verification should include a review of sample collection, handling and transfer, and documentation associated with sampling activities. Laboratory results must be checked upon receipt. If there appears to be an error in the analysis, the laboratory must be contacted immediately, and deficiency correction(s) must be taken. If investigation reveals that processes were not in control, actions must be taken to correct the deficiency and the resulting data must be evaluated to determine any impacts.

4.2 Validation

Analytical data validation must be performed on a portion of the environmental sample results to determine the dataset's analytical quality. Data validation criteria must be based upon industry analytical quality standards and methods. Validation should include an evaluation of method and contract compliance, data calculations, QC and calibration verifications, raw data, and data generation methods. Validation can include qualifying data that may restrict or limit data use. Analytical data validation must include DQI criteria as stated below. Five percent of validated sample data results must also be validated by a third party as an assessment of the validation process.

Sample results falling outside acceptable ranges for precision and accuracy (defined in Sections 4.2.1 and 4.2.2) must be evaluated to determine whether deficiency correction is necessary.

4.2.1 Precision

Precision is used to qualify individual parameter results when corresponding QC sample results are not within established control limits. Precision is quantified by the RPD between the samples or the normalized /absolute difference.

Precision must be determined with field and laboratory duplicate samples. Field duplicate samples will be collected simultaneously with samples from the same source under similar conditions in separate containers. The duplicate samples will be treated independently of the original sample in order to assess field impacts and laboratory performance on precision through a comparison of results. Laboratory sample duplicates are an aliquot, or subset, of a field sample generated in the laboratory. They are not a separate sample but a split, or portion, of an existing sample. Typically, laboratory duplicate QC samples include MSD and LCS duplicate samples for organic, inorganic, and radiological analyses. The following are the criteria for precision:

- ***Inorganic chemical precision criteria***
  - When sample and duplicate results are greater than or equal to 5× the reporting limit (RL), the RPD criteria are 20 and 35 percent for aqueous and soil samples, respectively.
  - When sample or duplicate results are less than 5× the RL, control limits are ±1× RL and ±2× RL for aqueous and soil samples, respectively.
- ***Organic chemical precision criteria***
  - Criteria are based on professional judgment using laboratory-defined control limits.
- ***Radiological precision criteria***
  - When sample and duplicate results are greater than or equal to 5× the minimum detectable concentration (MDC), the RPD criteria are 20 and 35 percent for aqueous and soil samples, respectively.
  - When sample or duplicate results are less than 5× the MDC, the control limit is ±2 for both aqueous and soil samples.
- ***TLD criteria***
  - When the raw read result is greater than 45, the relative standard deviation criterion is 10 percent.

Any values outside the specified criteria do not necessarily result in the qualification of analytical data. It is only one factor in making an overall judgment about the quality of the reported analytical results.

4.2.2 Accuracy/Bias

Accuracy is a measure of the closeness of an individual measurement to the true value. It is used to assess the performance of laboratory measurement processes.

Accuracy is determined by analyzing a reference material of known parameter concentration, or by reanalyzing a sample of known concentration or amount of parameter that has been added (spiked). The %R (measured sample concentration divided by true concentration multiplied by 100) is used to measure accuracy.

Accuracy will be evaluated based on results from three types of spiked samples: matrix spike, LCS, and surrogates (organics). The following are the criteria for accuracy:

- ***Inorganic chemical accuracy criteria*** are 75 to 125 percent for matrix spike recoveries and 80 to 120 percent for LCS recoveries.
- ***Organic chemical accuracy, matrix spike, and LCS laboratory-specific %R criteria*** are developed and generated in-house by the laboratory in accordance with laboratory procedures.
- ***Radiochemical accuracy criteria*** are 80 to 120 percent for LCS and matrix spike recoveries.
- ***Survey data*** must indicate horizontal and vertical accuracy (e.g., spatial data related to sample location, field measurement, boundary, or other spatial feature).

Any values outside the specified criteria do not necessarily result in the qualification of analytical data. It is only one factor in making an overall judgment about the quality of the reported analytical results. Factors beyond laboratory control, such as sample matrix effects, can cause the measured values to be outside the established criteria. Therefore, the entire sampling and analytical process must be evaluated when determining the usability of the affected data.

4.2.3 Sensitivity

Sensitivity is the capability of a method or instrument to discriminate between measurement responses representing different levels of a variable of interest. Analytical methods must be sufficient to detect target compounds present in the samples at concentrations less than or equal to the corresponding FALs.

4.3 Data Quality Assessment

A DQA must be performed to determine whether the data met the performance criteria specified in the DQO process. The DQA considers how the data relate to decisions to be made, the intended use of the data, and whether data are suitable for making those decisions. The DQA must be performed on data of known and documented quality. The DQA must be documented in the applicable FFACO report. Information on DQA can be found in EPA QA/G-9R, *Data Quality Assessment: A Reviewer's Guide* (EPA, 2006a), and its companion document EPA QA/G-9S, *Data Quality Assessment: Statistical Tools for Practitioners* (EPA, 2006b). The DQA process must include the following steps:

- ***Review the DQO process*** to provide context for analyzing the data. State the primary statistical hypotheses; confirm the limits on decision errors for committing false negative (Type I) or false positive (Type II) decision errors; and review any special features, potential problems, or deviations to the sampling design.

- ***Perform a preliminary data review*** by reviewing QA reports and inspecting the data both numerically and graphically, validating and verifying the data to ensure that the measurement systems performed in accordance with the criteria specified, and using the validated dataset to determine whether the quality of the data is satisfactory.

    - When sample results are greater than one-half the FALs and DQIs for those results do not meet established criteria, the data assessment must include explanations or justifications for their use or rejection.

- ***Select the test*** based on the population of interest, population parameter, and hypotheses. Identify the key underlying assumptions that could cause a change in one of the DQO decisions.

- ***Verify the assumptions.*** Perform tests of assumptions. If data are missing or are censored, determine the impact on DQO decision error.

- ***Draw conclusions from the data.*** Document conclusions drawn as a result of the statistical analysis.

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Appendix A

Use of TLDs in the Soils Activity

A.1.0 Background

Panasonic model UD-814 TLDs are used to measure external dose at Soils Activity release sites. They are identical to those used in the routine NNSS environmental monitoring program. These TLDs contain four individual elements that produce four independent estimates of external dose. The readings from each element are compared as part of the routine QA checks during the TLD processing. External dose at each TLD location is determined using the readings from TLD elements 2, 3, and 4.

Environmental TLDs used in the Soils Activity are provided, maintained, and analyzed by the NNSS External Dosimetry Program. This program is administered by the NNSS Radiological Safety Prime Contractor's Radiological Control Department, under contract provisions of the U.S. Department of Energy, National Nuclear Security Administration Nevada Field Office (NNSA/NFO). Demonstration that the External Dosimetry Program meets the requirements in Title 10 CFR Part 835, "Occupational Radiation Protection" (CFR, 2017b) for monitoring the workplace and for assessing external radiation doses to workers is provided in *Radiological Control Technical Basis Document* (TBD)*: External Dosimetry,* TBD-0441-028, Rev. 9 (NSTec, 2014).

According to this TBD, the environmental TLDs (Panasonic UD-814) are calcium sulfate ($CaSO_4$) phosphors under 0.7 millimeter (mm) of lead. These $CaSO_4$ phosphors are elements 2, 3, and 4 in the TLD (the only elements used by the Soils Activity). Each of these elements is considered an independent sample and should provide comparable results. The first element is a lithium borate ($Li_2B_4O_7$) phosphor, but the data from that element are not used.

These TLDs are different than personal TLDs in their element configuration, but the same phosphor materials are used. Personal TLDs (Panasonic UD-802) contain two $Li_2B_4O_7$ phosphors and two $CaSO_4$ phosphors. The configuration of the personal TLDs allows for the estimation of a shallow, eye, and deep tissue dose; whereas, elements 2, 3, and 4 in the environmental TLDs are configured to estimate a deep tissue dose (NSTec, 2014). The configuration of these two types of TLDs are shown in Table A.1-1.

Table A.1-1
Configuration of Panasonic TLDs UD-802 and UD-814

TLD	Element	Phosphor	Density Thickness (mg/cm²)			
			Case	Hanger	Total	Comments
UD-802	E1	$Li_2B_4O_7$:Cu	14	3	17	N/A
	E2	$Li_2B_4O_7$:Cu	160	150	310	
	E3	$CaSO_4$:Tm	160	150	310	
	E4	$CaSO_4$:Tm	87	150	1,025	Including 0.7-mm lead
UD-814	E1	$Li_2B_4O_7$:Cu	14	3	17	N/A
	E2	$CaSO_4$:Tm	900	160	1,060	Including 0.7-mm lead
	E3	$CaSO_4$:Tm	900	160	1,060	
	E4	$CaSO_4$:Tm	900	160	1,060	

Cu = Copper
Tm = Thulium
N/A = Not applicable
mg/cm^2 = Milligrams per square centimeter

The energy responses of the elements in the UD-802 dosimeter shown in Figure A.1-1 were presented in the External Dosimetry TBD (NSTec, 2014). Element 4 from the UD-802 dosimeter (the filtered $CaSO_4$ element) is the same as elements 2, 3, and 4 in the UD-814 dosimeter. This element provides a fairly linear response to energies above 30 kiloelectron volt (keV), although it has some over-response in the lower 30- to 90-keV range. Where Am-241 is the prevalent gamma-emitter (at 60-keV energy), this could have the effect of slightly overestimating dose.

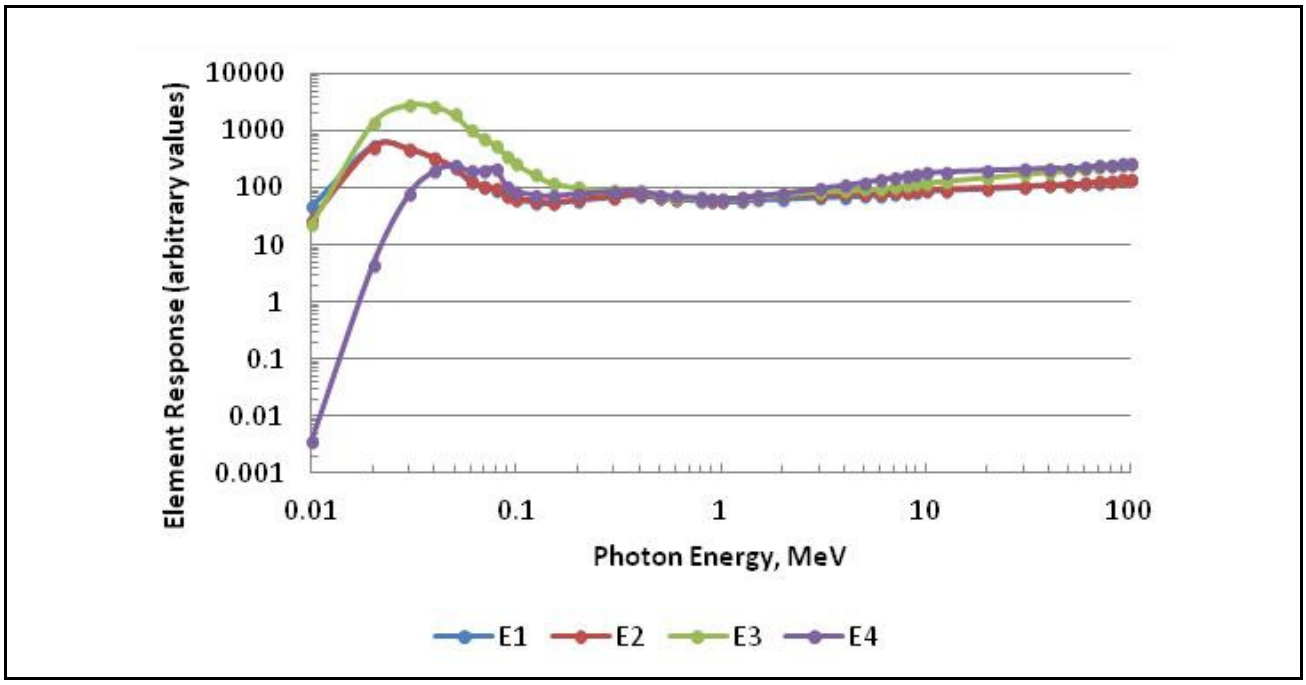

Figure A.1-1
TLD Element Response
Source: NSTec, 2014 (Figure 16)

A.2.0 Quality Assurance

A comprehensive QA Program is maintained by the NNSS Radiological Safety Prime Contractor's Radiological Control Department dosimetry operations in accordance with Title 10 CFR Part 830, "Nuclear Safety Management," Section 122 (CFR, 2017a). The QA Program addresses management, training, and qualification requirements, quality improvement and work processes, record keeping, performance, and program assessment. The effectiveness of the QA Program is demonstrated through satisfactory completion and maintenance of the DOELAP accreditation (NSTec, 2014, Section 9.0).

This technical basis document is reviewed triennially and all implementing documents are reviewed biennially and updated as necessary. Overall program operations are routinely reviewed and improved through the use of the Blind Audit Program, DOELAP performance testing, onsite audits, and internal assessments. Quality processes are in place to ensure that personnel radiation equivalent dose results are reviewed, investigated, and reported accurately. This includes review and approval of all quality-related data such as daily QC tests, reader calibration, reader linearity, reader crossover, and reader heating tests.

Process variances and the necessary corrective actions are tracked, and activities are implemented to approve, evaluate, and resolve process variances and control nonconforming items until corrective actions are completed. Processes are reviewed for improvement during the execution of the process and also from internal or external assessment findings.

A.3.0 Temperature Effects

An evaluation was conducted to determine whether the high ambient temperatures typical of NNSS summers could affect the dose readings of the TLDs. This question was evaluated based on two independent lines of inquiry: (1) the physical properties of the TLD materials associated with radiation measurement, and (2) the observed performance of TLDs subjected to different ambient temperatures.

A.3.1 TLD Properties

The first evaluation was based on the theoretical mechanisms used to measure radiation with TLDs. Radiation causes electrons in the phosphor crystal's atoms to jump to higher energy states where they are trapped due to intentionally introduced impurities (for the UD-814 TLDs, the impurity is thulium). When exposed to sufficient heat, the electrons are released to a lower energy state, which causes a photon of energy to be released that is equal to the energy difference between the two energy states. A paper titled "Environmental Dosimetry Using High-Sensitivity TL Detectors" published in *Radiation Physics and Chemistry* (Katona et al., 2007) demonstrates the relationship between temperature and photon light emissions for three types of TLD substrate materials, including the $CaSO_4$:Tm that is used in the Panasonic model UD-814 TLDs for environmental monitoring at the NNSS. Figure A.1-2 was extracted from this document and shows the relationship between temperature and photon light emissions for the $CaSO_4$:Tm phosphor (shown as Type 2 in the figure). As demonstrated by Figure A.1-2, there were no significant measurable photon emissions from the $CaSO_4$:Tm TLD material at temperatures below approximately 120 degrees Celsius (°C). As this temperature is well over twice the highest observed temperature at the NNSS, it is reasonable to assume that ambient temperatures at the NNSS are not causing significant release of trapped electrons in the TLD material.

A.3.2 Seasonal Effects

The second evaluation is based on observed performance of TLDs at the NNSS. In November 2009, 22 TLDs were placed at the Little Feller II site (NNSA/NSO, 2011). Due to the accumulation of snow at this site, these TLDs could not be collected until April 2010, well after the planned 2,000 hours of exposure. Therefore, another set of 22 TLDs was placed at the same locations and exposed during the

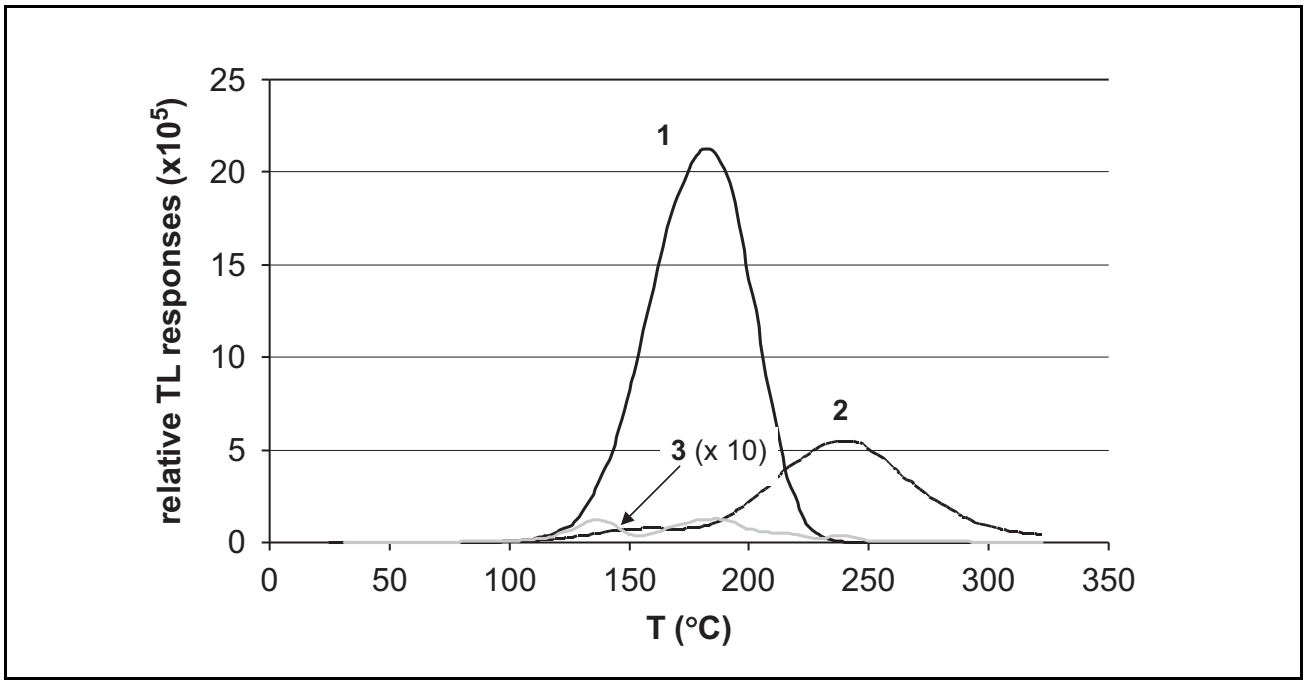

Figure A.1-2
Relationship between Temperature and Photon Light Emissions for 3 Types of TLD Phosphors
Source: Katona et al., 2007 (Fig. 1)

summer months of June, July, and August. The results of the summer and winter deployments are compared in Figure A.1-3. These results show a very high correlation between the two sets of data. This demonstrates that ambient temperatures at the NNSS have no significant effect on TLD readings.

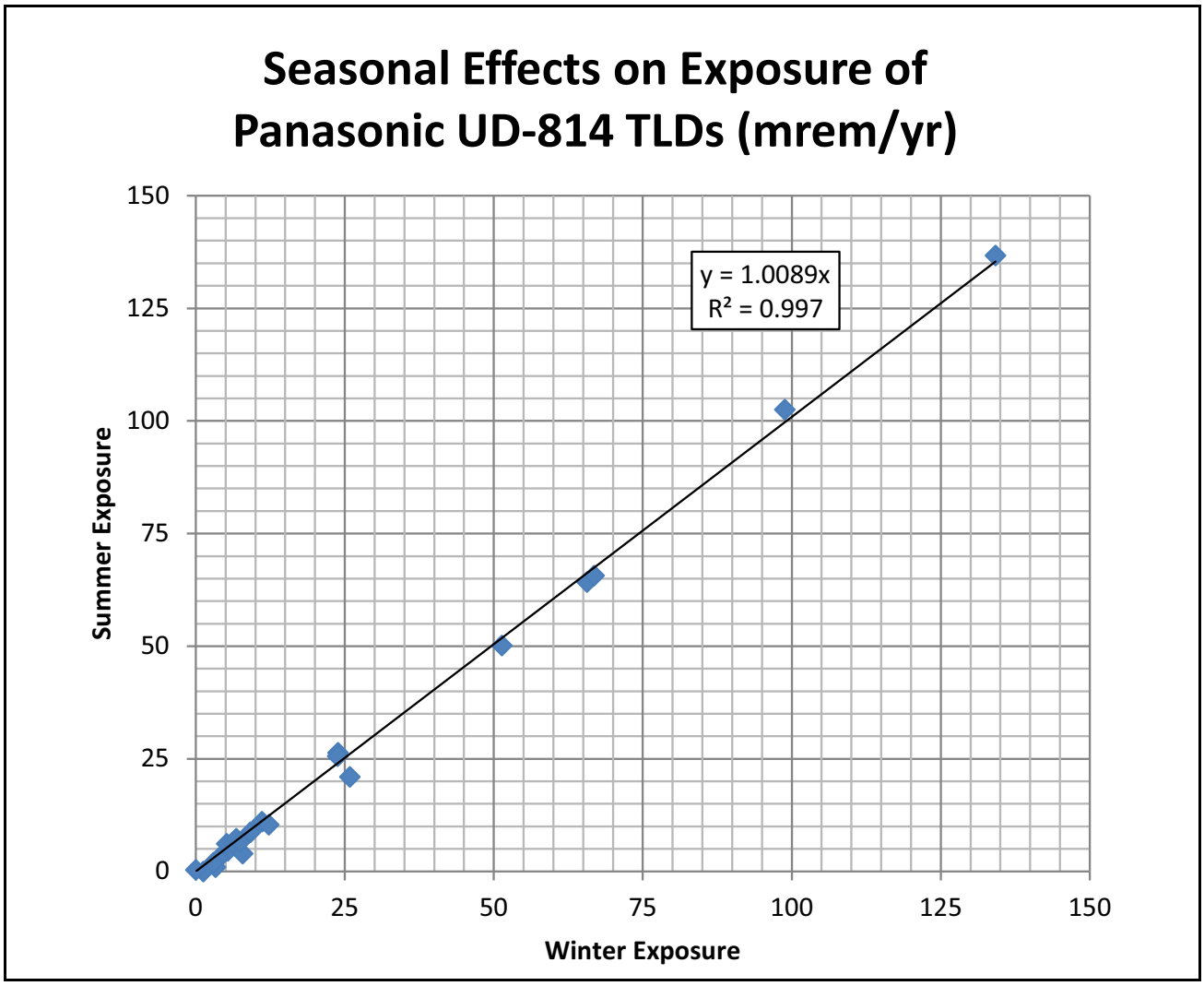

Figure A.1-3
Comparison of Seasonal Effects on
Exposure of Co-Located Panasonic UD-814 TLDs

A.4.0 References

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