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Review of SEC Petition Evaluation Report: Petition SEC-00188, Addendum 2 (1977–2011), for Sandia National Laboratories – Albuquerque

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Abbreviations and Acronyms

Advisory Board, ABRWH	Advisory Board on Radiation and Worker Health
ACRR	Annular Core Research Reactor
BZ	breathing zone
CEDE	committed effective dose equivalent
CEP	Controls for Environmental Pollution
CFR	Code of Federal Regulations
D&D	decontamination and decommissioning
DAC	derived air concentration
DOE	U.S. Department of Energy
EEOICPA	Energy Employees Occupational Illness Compensation Program Act
ER	evaluation report
ES&H	environment, safety, and health
GERT	general employee radiation protection training
H-3	tritium
HEU	high-enriched uranium
KIVA	critical assembly facility
mrem	millirem
NIOSH	National Institute for Occupational Safety and Health
NOCTS	NIOSH DCAS Claims Tracking System
Np	neptunium
NTS	Noncompliance Tracking System
ORAUT	Oak Ridge Associated Universities Team
ORPS	Occurrence Reporting System
PPE	personal protective equipment
Pu	plutonium
RCT	Radiological Control Technician
RMWMF	Radioactive and Mixed Waste Management Facility
RPID	Radiation Protection Internal Dosimetry
RPP	Radiation Protection Program
RPPM	Radiological Protection Procedures Manual

RWP	radiological work permit
SEC	Special Exposure Cohort
SI	Security Inspector
SNL, SNL-A	Sandia National Laboratories-Albuquerque
SRDB	Site Research Database
SNM	special nuclear material
SPR	Sandia Pulse Reactor
TBD	technical basis document
Th	thorium
TLD	thermoluminescent dosimeter

1 Executive Summary

This review of Sandia National Laboratories-Albuquerque (SNL-A or SNL) represents the first opportunity for SC&A to assess Special Exposure Cohort (SEC)-related issues for this site, given the prior National Institute for Occupational Safety and Health (NIOSH) evaluations that led to three successive SEC classes being defined under paragraph 83.14 for all employees for 1949 through 1996. Accordingly, SC&A reviewed (1) the assessment and conclusion for internal dose reconstruction in ER Addendum 2 for post-1996 (NIOSH, 2019a) and (2) remaining issues related to the assessment and conclusion reached for occupational medical dose, environmental occupational dose, and external dose reconstruction in NIOSH's SEC-00188 petition evaluation report (ER) for 1963–1994 (NIOSH, 2012; "SEC ER").

For external doses, SC&A found no evident issues that would preclude dose reconstruction with sufficient accuracy, although there still remain questions about how exposures by personnel to severe radiation gradients at the Sandia Pulse Reactor (SPR) were handled by SNL, and how NIOSH will apply the available dosimetry data for such exposures to dose reconstruction. For internal dose, the weight of evidence supports the feasibility of dose reconstruction with sufficient accuracy for the time period in question.

For workers who were not internally monitored or solely monitored via breathing zone (i.e., workers not on the routine SNL bioassay program), NIOSH has proposed to apply 100 millirem (mrem) committed effective dose equivalent (CEDE) per year as a maximum bounding estimate. SC&A concludes this approach is supported from a programmatic standpoint based on its review of program implementation experience and oversight results before and after the end of 1996.

Regarding NIOSH's reliance on personnel air sampling results to justify the annual assignment of 100 mrem (CEDE) internal dose for workers who were not monitored, partially monitored, or solely monitored via breathing zone (BZ) results, SC&A concluded that the weight of evidence supports that application. However, SC&A was unable to validate fully this conclusion due to lack of certain records pertaining to total number of workers monitored and BZ samples issued and processed. These shortcomings are mitigated by the conservatism taken in NIOSH's approach, including (1) conservative selection of radionuclides of interest (e.g., plutonium-239), (2) no credit taken for respiratory protection, and (3) the observed number of BZ samples per worker, which fell far short of the 200 events calculated in Addendum 2 as necessary to exceed the 100 mrem upper bound.

Based on extensive interviews with security guards who worked at SNL during 1997–2011, an onsite tour of security surveillance locations, review of relevant records pertaining to radiological incidents, and a review of internal intakes of bioassayed personnel at SNL facilities, SC&A concurs with the conclusions of ER Addendum 2 that it is unlikely that security personnel would have received an intake for which a 100 mrem annual dose (CEDE) would have been exceeded.

Overall, SC&A agrees with the conclusion of ER Addendum 2 regarding the feasibility of dose reconstruction for SNL during 1997–2011 based on the weight of available evidence.

2 Introduction and Background

SC&A was tasked with reviewing Addendum 2 of the Petition SEC-00188 ER, regarding SNL-A for 1997–2011, and related SEC issues, at the Advisory Board on Radiation and Worker Health (Advisory Board) meeting in Pittsburgh, PA on April 17, 2019 (ABRWH, 2019). The Addendum 2 report provides continued site and program assessments by NIOSH at SNL-A that were "previously unevaluated in the SEC Petition Evaluation Report for petition SEC-00188, covering 1963–1994 (NIOSH, 2012) and in an Addendum to that report, covering 1995–1996 (NIOSH, 2018)" (NIOSH, 2019a, p. 3).

In its original evaluation under Title 42 of the Code of Federal Regulations (42 CFR) 83.14, NIOSH concluded that it was unable to perform dose reconstruction with sufficient accuracy. Therefore, NIOSH established an SEC class for all employees at SNL-A because of "limited internal monitoring results, limited program documentation availability, the existence of a relatively-underdeveloped internal monitoring record database during that period, and the use of Controls for Environmental Pollution (CEP) analytical services for bioassay well into 1994" (NIOSH, 2019a, p. 3). In Addendum 1 to the ER, NIOSH extended the existing class to December 31, 1996, "due to concerns with air monitoring data availability and uncertainties associated with the transitional and developmental nature of SNL-A's internal monitoring program" (NIOSH, 2019a, p. 3).

2.1 SC&A review approach

This review of the SNL-A SEC-00188, Addendum 2, ER represents the first opportunity for SC&A to assess SEC-related issues for the site, given the prior NIOSH evaluations that led to three successive SEC classes being defined for all employees for 1949 through 1996.[1] Accordingly, SC&A reviewed the assessment and conclusion reached for occupational medical dose and external dose reconstruction made in the SEC-00188 ER (1963–1994)[2] and reviewed the corresponding assessment and conclusion for internal dose reconstruction in Addendum 2 (post-1996). In Addendum 2, NIOSH concluded that "considering the potential exposure scenarios, program policies, procedures, and monitoring data availability, NIOSH finds it is able to estimate . . . internal exposures with sufficient accuracy for the period from January 1, 1997 through May 21, 2011" (NIOSH, 2019a, p. 4).

To support its assessment, SC&A reviewed relevant SNL-A program documentation, monitoring records, and operational information, including incident and compliance tracking reports. SC&A also conducted an interview on January 15, 2020, with Sandia security guards whose tenure included the SEC time period in question, as well as participating in an onsite tour of

[1] The SEC-00162 ER recommended an SEC class for all employees at SNL-A for the early years of 1949–1962, based on "lack of available monitoring program details, process information, and internal monitoring data" (NIOSH, 2011a, p. 3). The SEC-00188 ER extended the time frame with an SEC class for all employees at SNL-A for 1963–1994 based on "the lack of internal monitoring program documentation" (NIOSH, 2012, p. 3). This SEC was further extended to December 31, 1996, in Addendum 1, given the lack of "adequate information necessary to complete individual dose reconstructions with sufficient accuracy for internal radiological exposure to plutonium, tritium, and other radionuclides during the period in question" (ABRWH, 2018, p. 1).

[2] NIOSH notes in Addendum 2 that its dose reconstruction feasibility findings for external radiation exposure are based on the earlier SEC-00188 ER's conclusions about occupational medical dose and all sources of external radiation, including "exposures to beta, gamma, and neutron radiation" (NIOSH, 2019, p. 4).

surveillance routes (appendix 1 provides the interview and tour summary). This is in addition to previous interviews at SNL-A conducted by both NIOSH and SC&A for both the site profile and prior SEC class reviews.

SC&A's lines of inquiry are directed at responding to the following four questions:

1. Is the weight of evidence presented by NIOSH in Addendum 2 (as supported by Addendum 1 and the original SEC-00188 ER) sufficient to support dose reconstruction with sufficient accuracy for external doses by December 31, 1994, and for internal doses by December 31, 1996?

2. Was the implementation of 10 CFR Part 835 requirements for internal exposure monitoring sufficiently adequate by December 31, 1996, to provide assurance that a 100-mrem (CEDE) annual radiation monitoring requirement was being adequately implemented at SNL-A such that use of that value as a bounding dose in NIOSH's co-exposure model is supported?

3. Are there any limitations or uncertainties related to dose reconstruction as a result of SNL-A reliance on personnel air sampling results as indicators for bioassay sampling?

4. Is there evidence and a likelihood that security guards at SNL-A were potentially exposed to radioactive intakes of radionuclides that could have been in excess of 100 mrem CEDE per year that would not have been monitored?

To accomplish this assessment, SC&A focused on Sandia's internal radiation dose monitoring programs for 1997–2011 and, in particular, the adequacy and completeness of corresponding monitoring data to support dose reconstruction with sufficient accuracy. A specific objective was to review the exposure potential of security inspector personnel during that timeframe and to gauge whether they would have likely experienced radiation intakes resulting in internal doses in excess of 100 mrem CEDE.[3]

3 Implementation of Internal Dose Monitoring Program

3.1 Internal dose monitoring program and 10 CFR Part 835 implementation

In its conclusion regarding internal dose reconstruction feasibility, NIOSH noted the following.

> It is NIOSH's position that, regardless of whether Sandia could be shown to be in full compliance with 10 C.F.R. pt. 835, the salient sections of the regulation regarding monitoring and record retention (10 C.F.R. § 835.402 and 10 C.F.R. § 835.702) were in fact bounding of the actual exposure conditions at SNL-A for individuals without monitoring data indicating otherwise. Therefore, in the absence of internal dosimetry records, NIOSH may assume that intakes by

[3] As noted in Addendum 2, NIOSH would apply 100 mrem CEDE as a "bounding dose" for any unmonitored workers at Sandia for the time period in question, based on an assumption that the site's screening review of potential exposures under 10 CFR Part 835 would have identified and provided monitoring to any workers at or in excess of that dose threshold (NIOSH, 2019a).

> workers lacking monitoring data to the contrary did not result in doses exceeding 0.1 rem CEDE. [NIOSH, 2019a, p. 32]

As a means to review the basis of this key conclusion, SC&A evaluated (1) the extent to which Sandia defined and implemented its internal dosimetry program in conformance with 10 CFR Part 835 prior to the end of 1996 and (2) the program implementation experience following 1996 in terms of self-assessment, inspections, incident reporting, and Price-Anderson Amendments Act[4] enforcement findings as they pertain to radiation exposure monitoring and recordkeeping. This would be accomplished with an objective of validating NIOSH's assumption that "intakes by workers lacking monitoring data to the contrary did not result in doses exceeding 0.1 rem CEDE."

3.1.1 Sandia internal dosimetry program

In its original SEC-00188 ER for 1963–1994, NIOSH acknowledged data-retrieval problems at Sandia that existed into the early 1990s which is "due primarily to the absence of internal monitoring program documentation for this period and compounded by the lack of source term information, data retrieval problems known to exist into the very early 1990s, and the use of CEP analytical services for bioassay well into 1994" (NIOSH, 2012, p. 50). In its first Addendum to that ER, NIOSH extended the class to December 31, 1996 due to "concerns with air monitoring data availability and uncertainties associated with the transitional and developmental nature of SNL-A's internal monitoring program" (NIOSH, 2018, p. 5). For this review, SC&A evaluated whether these programmatic concerns were resolved by the end of 1996 and in section 4, whether the original concerns regarding limited internal monitoring results at Sandia have been resolved as manifest in data availability and completeness.

As NIOSH notes in section 7.1.1.1 of Addendum 2, "Sandia implemented a radiation protection program that included baseline, termination, and routine internal monitoring" (NIOSH, 2019a, p. 18). A description of that program and its implementation is detailed in Sandia's Radiation Protection Program (RPP) plan for compliance with the U.S. Department of Energy's (DOE's) then newly promulgated rule for occupational radiation protection, 10 CFR Part 835 (SNL, 1994). This RPP plan was required by DOE to ascertain the compliance status of the then-current Sandia occupational Radiation Protection Program and its commitment, including milestones and actions, necessary to bring the laboratory into full compliance by December 31, 1995. Sandia indicated "partial compliance" with 10 CFR Part 835 requirements for internal dose evaluation (835.402 (c) and (d)) and confirmed that revisions to its technical basis document (TBD) and procedures would be completed by the compliance deadline (SNL, 1994).

The Sandia TBD was revised and issued on October 31, 1995. The TBD confirmed that Sandia's Radiation Protection Internal Dosimetry (RPID) project "will meet, or exceed, the requirements specified in the Department of Energy (DOE) Radiological Control Manual (DOE/EH-0256C) and promulgated under Title 10 of the Code of Federal Regulations Part 835 (10 CFR 835)" (SNL, 1995a). It noted that Sandia's laboratory-based operations differed markedly from those of DOE's production facilities and that these "fundamental differences in work activities dictate

[4] Under the Price-Anderson Amendments Act of 1988, DOE was required to implement an enforcement program based on federal regulations for nuclear safety (10 CFR Parts 820 and 830) and occupational radiation protection (10 CFR Part 835).

that the focus of internal dose monitoring be shifted from a routine basis to a job related basis," with more reliance on short-term radiological work permits (RWPs) for which conservative assumptions regarding radionuclide "physical/chemical form or particle size" are frequently needed due to incomplete source-term information (SNL, 1995a, pp. 1, 2).

The TBD also emphasized that "chronic intakes of radioactive materials are not expected to occur at SNL" (SNL, 1995a, p. 16), and that, accordingly:

> Internal exposures at SNL are expected to result from radiological incidents (e.g., accident situations, failure to follow procedures, etc.) resulting in acute exposures which may or may not be detected. Therefore because of the workplace controls currently in place, the RPID Project is based on the assumption that only acute exposures result in significant doses. [SNL, 1995a, p. 16]

As noted by NIOSH, Sandia identified a "technology shortfall" for specific radionuclides[5] for which air sampling offered a more sensitive means for monitoring in compliance with 10 CFR Part 835 (SNL, 1995a, PDF p. 203). However, the TBD also included the following admonition about use of air sampling in this manner:

> Care should be taken when assessing dose from air sample data. Airborne release events should be collaborated with positive measurements from other air samplers located in the facility. Contamination of the air sample from external sources should be ruled out. All measurements should be compensated for the presence of naturally occurring radon and thoron progeny. In addition, air sample results which indicate potential intakes that are detectable via bioassay should be compared to the intake estimates from bioassay. All recorded doses calculated from air sampling results in the RPID Project will be noted as such. [SNL, 1995a, PDF p. 204]

Added to these "technology" considerations for using air sampling in place of bioassays was the impracticality, including cost, of maintaining the original larger-scope bioassay program at Sandia given the small potential for radionuclide intakes at the site ([redacted], 2017). Beginning in the mid-1990s, many workers were dropped from the internal dosimetry program, and the program was revised to focus on individuals with a higher risk of exposure ([redacted], 2017). These "philosophical changes" were reflected in a revised RPID (issue 04) (SNL, 1996, p. 11) and supported by an independent assessment conducted by an outside expert in 1996, who recommended the use of "DAC-hr tracking (using personal air samples) as the primary method of internal exposure monitoring (with the exception of tritium, for which routine bioassay sampling was retained)" (NIOSH, 2019a, p. 18; Skrable, 1996).

As summarized by a Sandia health physicist:

> The SNL Bioassay Program is confirmatory in nature. The Bioassay Program confirms the results and effectiveness of contamination control and other personnel protection activities. It also serves to detect unwitting intakes. Since

[5] These radionuclides were class W and Y plutonium isotopes, class Y uranium isotopes, and class Y thorium-232 (Th-232) and Th-228.

> Radiological Control Technicians (RCTs) must be present in all work activities where the possibility of meaningful intakes is credible, their bioassay serves as a good proxy indicator for potentially exposed line personnel, while keeping the total monitoring burden low. [[redacted], 2001]

This established SNL internal dosimetry policy and practice provides the program philosophy and context within which SC&A has reviewed NIOSH's evaluation.

3.1.2 RPP and RPID reviews and audits

SC&A reviewed subsequent revisions of these internal dosimetry policy documents and found (as NIOSH documented) that the site updated and improved them based on field implementation and experience. SC&A also reviewed available program self-assessments and appraisals of the Sandia internal dose evaluation program during the SEC period in question (a total of 20 internal and external assessments are listed in Attachment One of Addendum 2). SC&A found several key assessments to be of particular relevance in its review, as follows:

- "Radiation Protection Self-Assessment" (SNL, 1997a)

  As a result of identified program deficiencies in the implementation of the RPP, Sandia conducted a laboratory-wide self-assessment of its radiological operations in July 1996, with data collection, reduction, and followup completed by December 1996. This review was prompted, in part, by an April 4, 1996, memorandum from the DOE Area Office expressing concerns about Sandia line management's "apparent lack of acceptance of responsibility for safe conduct of operations" (DOE, 1996), as well as a recognition by Sandia management that more needed to be done to ensure that the RPP adhered to the full extent of requirements under the new 10 CFR Part 835 rule, as noted in the following 1996 memorandum:

  > Over the last two years, we have seen real improvement in the formality and, indeed, safety of these [radiological] operations thanks to the work of the responsible line organizations, the Radiation Protection support staff, and our ES&H Coordinators. However, we continue to have incidents which indicate we are not yet to the level of formality and control that we must achieve to assure the level of safety we have set as our radiological operations standard. Common factors in these incidents have included: procedures that do not reflect current requirements; operations conducted in non-compliance with existing procedures; and a significant lack of knowledge and understanding of the Sandia Radiation Protection Procedures Manual. [[redacted], 1996, p. 1]

  An assessment tool was developed that included "Self-Assessment Requirements Documents" that recorded the results of each facility or operational assessment. Of 15,125 discrete responses, 144 potential noncompliances with 10 CFR Part 835 were identified, including ones in personnel monitoring. For internal dose evaluation, one noncompliance finding was particularly relevant:

> The referenced procedures do not implement the requirement [10 CFR 835.209(c)]… RPID-20-02, Issue 03, Section 4.2.1, is necessary for the requirement, but is not sufficient. The program needs to specify that bioassay data shall be used, unless bioassay data fit the 10 CFR 835 criteria. The program also needs to give the SNL definition of the nonprescriptive words "unavailable", "inadequate", and "representative". Per interview with [redacted] there were no positive bioassay results in 1994, so no internal dose was assigned. [SNL, 1997a, PDF p. 28]

Based on this self-assessment's overall findings, 16 operations at SNL suspended work until the deficiencies were corrected. All reported potential noncompliances were to be corrected by December 31, 1996, and if not, reported to DOE as an update to the Noncompliance Tracking System (NTS). All findings from this self-assessment were closed by DOE headquarters on December 15, 1997.[6]

- "Monitoring in the Workplace Self-Assessment" (SNL, 1997b)

  This internal review was conducted in May 1997 by Sandia's Radiation Protection Program and focused on monitoring program content and implementation. The review found that what was required by 10 CFR Part 835 (and defined in the Radiological Protection Procedures Manual (RPPM)) was not consistently found in actual facility procedures. A facility review found one operation (in building 884) that was not properly monitored, with another (building 870) having inadequate placement of fixed air monitors. However, it was also observed that the building 884 and 870 air sampling was no longer operationally necessary.

- "Report of Assessment of Sandia National Laboratory Radiation Protection Program" (Lockheed Martin, 1998)

  This May 1998 assessment by a third-party reviewer addressed the documentation (RPP, RPPM, procedures) "that directs and supports the Sandia Radiation Protection Program" (Lockheed Martin, 1998, PDF p. 3). The assessment found, in part, that the RPP was not updated ("maintained current") and there was "no effective system to assure that the requirements of 10CFR835 are implemented in SNL procedures" (Lockheed Martin, 1998, PDF p. 7). However, this assessment did find that, in terms of the RPPM and implementing procedures, "the detailed procedures provide appropriate direction for the accomplishment of processes and tasks" (PDF p. 8).

- Interim report – "Internal Independent ES&H and Quality Appraisal of the Occupational Radiation Protection Program at Sandia National Laboratories, New Mexico" (SNL, 1998a)

  This self-assessment by Sandia, performed from June through September 1998, focused on programmatic effectiveness and evaluated how the radiation protection program was

[6] Based on SC&A's onsite review of the NTS at DOE's Germantown facility on January 10, 2020.

administered. The review found the RPPM to be improving "as an effective source of radiological requirements and guidance," and that the "list of Radiation Protection procedures is comprehensive and covers all topical areas of 10 CFR 835" (SNL, 1998a, p. ii). The concerns cited included timely submittals of RPP revisions to DOE, better definition of organizational roles and responsibilities (and their reflection in procedures), and self-assessments grounded in good practices, not merely regulatory compliance.

- "Radiation Protection Safety Committee Self-Assessment Report" (SNL, 1999)

  This review was conducted by Sandia in 1997–1998 in conformance with the triennial audit requirement of 10 CFR 835.102, under which all functional elements of the radiation protection program must be audited every three years. For "Monitoring in the Workplace," 13 findings were made, with 10 deficiencies related to either area or individual monitoring not being performed. Most deficiencies were attributed to "personnel error," with lessons learned being given to the line managers involved. No findings involving personnel monitoring were significant from a systemic or programmatic standpoint. The findings from this assessment were entered into DOE's NTS and closed on February 20, 2001, based on SC&A's review of the NTS on January 10, 2020.

- "Radiation Protection Safety Committee Triennial Self-Assessment Report" (SNL, 2002)

  This review was conducted by Sandia in 2000–2001 as a second triennial audit of the radiation protection program against 10 CFR Part 835 requirements. This self-assessment found no "systemic or programmatic issues" based on the RPP program and procedures reviewed (SNL, 2002, p. 4).

- "Independent Oversight Inspection of Environment, Safety, and Health Programs at the Sandia National Laboratories" (DOE, 2005)

  DOE's Office of Independent Oversight and Performance Assurance inspected environment, safety, and health (ES&H) programs at SNL during March and April 2005. This review used a "selective sampling approach to evaluate a representative sample of activities . . . at SNL, including its management systems, programmatic research and development, facilities operations, maintenance, construction, and engineered safety systems" (DOE, 2005, vol. 1, p. 1). Review criteria focused on effective implementation of the Department's "integrated safety management" system, the functionality of key facility safety systems, and effective management of safety-critical programs. While weaknesses were noted in hazard recognition programs, construction safety, waste management, and safety engineering analysis, the one with particular relevance for 10 CFR Part 835 and RPP implementation was a finding that "Line management at Z Machine has not applied a sufficient level of rigor in analyzing radiological hazards associated with operations at the facility as necessary to meet institutional requirements and verify the adequacy of radiological controls and practices" (DOE, 2005, vol. 1, p. 6). It was emphasized that "increased management attention is needed to ensure appropriate worker protection" (p. 9). However, while the formality and rigor of SNL workplace hazard analysis and management corrective action were seen as program weaknesses, no concern was cited for occupational radiological monitoring specifically or 10 CFR Part 835 compliance in general.

SC&A's review of these and other self-assessment reviews (including minutes of Sandia's External Advisory Board) for the immediate years following implementation of the RPID in 1995 found no significant issues. However, there were apparent program "rollout" challenges regarding (1) consistent and updated procedures and (2) actual implementation against those procedures that may have persisted into 1997–1998 (for example, as noted by the 1997 self-assessment (SNL, 1997a) that led to operational suspensions, with closure in December 1997). However, none of those appear to have hampered the internal dosimetry program, in terms of its capability to monitor for radionuclide intakes at administrative levels and particularly for 100 mrem CEDE per year.

3.1.3 Price-Anderson compliance findings

SC&A also reviewed the DOE NTS to ascertain the history of Sandia compliance with 10 CFR Part 835 for the SEC period in question (1997–2011). This review (similar to one conducted by NIOSH and reflected in Attachment Two of Addendum 2) was conducted at the offices of DOE's Office of Enforcement on January 10, 2020, and focused on findings and corrective actions related to internal dosimetry program compliance, including use of RWPs, given their importance in stipulating bioassay and other monitoring requirements.[7] Based on a search conducted with DOE of all reported noncompliance issues for 1997–2011, the following NTS reports were considered by SC&A to be relevant.

- "Missing Radiological Protection Records" (1999)

  Sandia conducted a self-assessment in 1998 of its Radiological Protection Records Management System and found overall program accuracy, with the exception of records generated by an individual RCT. Corrective actions taken and closed in 2000. ([redacted])

- "Deficiencies Related to Use of Radiological Work Permits" (2000)

  Through its internal review activities, Sandia identified a number of programmatic deficiencies related to its RWP implementation, including failure to sign in, performing work on an expired RWP, and missing sign-in sheets. These concerns were addressed through a series of program and procedural upgrades, and this finding was closed in 2001. ([redacted])

- "Lapel Monitoring Not Performed during Waste Sorting Activities, Radiological Work Permit Violations" (2002)

  This was apparently an isolated incident wherein sorters at the Radioactive and Mixed Waste Management Facility (RMWMF) failed to wear their lapel samplers as required by

[7] NTS reports regarding the results of self-assessments are addressed in the section 3.1.2. Reported findings related to noncompliance concerns for training, source control, posting, deficiencies in work controls, RWP sign-in lapses, personnel contamination, and other like operational deficiencies were not addressed, other than to confirm their closure in NTS.

the applicable RWP. No programmatic changes were found necessary, although one procedure (involving pre-start review) was revised. Corrective actions taken and closed in 2004. ([redacted])

- "Internal Dosimetry Process" (2012)

  Two nonconformances were identified: (1) failure to review 50 anomalous bioassays for 24 individuals from 2009 to 2012; and (2) BZ sampling results not being transmitted to the Dosimetry Program, as required. No exceedance of administrative dose limits was determined. Corrective actions taken and closed in 2015. ([redacted])

Other than the 1996 self-assessment (reported as NC ID 821), and based on its review of NIOSH's listing of seven pertinent NTS reports, SC&A finds no reported noncompliances with 10 CFR Part 835 to have implications for NIOSH's conclusion regarding the adequate implementation of Sandia's internal dose evaluation program by the end of 1996. Even for that 1996 self-assessment, it is clear that the preponderance of 10 CFR Part 835 compliance issues were for programmatic deficiencies in training, source control, posting, and contamination control, with those relating to dosimetry or monitoring confined to procedural formality or conformance, not actual implementation. The only systemic concern identified was for the last NTS report cited regarding a failure by the health physics program to review anomalous bioassays for 24 individuals spanning the years 2009–2012. In that case, while no administrative reporting levels were exceeded, procedures were apparently not followed and annual dose reports needed to be amended.

3.1.4 DOE Occurrence Reporting System (ORPS) reports

NIOSH reviewed the ORPS for SNL-A for 10 CFR Part 835 violations and found none for which dose reconstruction feasibility would be problematic. SC&A similarly reviewed this record system for 1997–2011, with a scope of review that included any reports of radiation exposure, radioactive contamination, and radiation protection violations. A total of 104 reports resulted from a keyword search of ORPS conducted at the DOE Germantown, MD facility in early January 2020 and were reviewed. SC&A downloaded all reports where uncontrolled radioactive contamination or contamination outside of controlled areas were cited, as well as any procedural violations. Based on this review, SC&A concurs with NIOSH's conclusion that no reports were identified for which a dose construction feasibility issue would be a concern.

4 Breathing Zone Data Evaluation and Completeness

The following subsections evaluate the completeness and adequacy of BZ records used in NIOSH's ER Addendum 2 (NIOSH, 2019a) to justify the assignment of 100 mrem internal dose for workers who were not internally monitored or solely monitored via BZ results.

"Data completeness" refers to the extent to which the available internal monitoring data consist of the entirety of the monitoring results for the affected worker population or, alternately, establishing that the available monitoring data are sufficiently representative of those workers for whom monitoring data have not been captured or are otherwise unavailable. Sections 4.1–4.4 of this report evaluate the completeness and adequacy of BZ records used by NIOSH (2019a, 2019b, 2020) to justify the assignment of 100 mrem internal dose for workers who were not monitored, partially monitored, or solely monitored via BZ results. It is important to note that the 100 mrem CEDE dose assignment would not necessarily apply to workers who were monitored via bioassay or in vivo methods either on a routine or incident/special basis. NIOSH (2019a) reports over 2,000 non-tritium bioassay samples (covering 317 individual workers) and over 1,000 whole-body/thyroid in vivo results (covering 207 individual workers) during the evaluated SEC period. Many of the workers identified in the captured BZ results (~41 percent) also participated in the non-tritium bioassay program (refer to section 4.2).

Perhaps most importantly, SC&A was unable to locate any captured references to indicate how many breathing zone samples were taken during the period of interest and thus should be available for SEC evaluation. In general, such references might include periodic health physics reports or other summary reports that indicate the number of BZ samples processed or, alternately, the number of workers monitored during a given period. However, absent such information, more subjective judgments must be made about data completeness.

Finding 1: SC&A was unable to locate references, such as periodic health physics reports, that tabulate the total number of workers monitored via breathing zone nor the total number of breathing zone samples issued and processed. Thus, a direct evaluation of the completeness of captured breathing zone results is not currently feasible.

Section 4.1 evaluates the temporal completeness of the available captured records on an annual and monthly basis. It must be noted that after the release of NIOSH (2019a) and NIOSH (2019b), NIOSH released a white paper (NIOSH, 2020) that included additional BZ data captured by NIOSH. Section 4.1 evaluates both the NIOSH (2019a, 2019b) data and the added data analyzed in NIOSH (2020). After section 4.1, all SC&A analysis in this report involves all captured data to date and does not delineate between NIOSH (2019a) and NIOSH (2020).

Section 4.2 presents the results of SC&A's evaluation of the number of workers monitored via BZ in the available records. SC&A also evaluated its independent compilation of the BZ data by the site area of work, general work description, radionuclide of concern, and any respiratory protection utilized. This discussion can be found in section 4.3. In addition, SC&A evaluated the magnitude BZ sample results in terms of exposure potential for individual years and work locations (section 4.4). Section 4.4 also provides SC&A's review of the NIOSH (2019a) and (2020) data evaluations, which determined it would take approximately 200 separate exposure events to exceed the 100 mrem threshold value. Finally, section 4.5 summarizes SC&A's review and evaluation of the BZ data.

4.1 Temporal evaluation of completeness

NIOSH (2019a) reports the total number of captured BZ results by year, as shown in figure 1 below. NIOSH also presented these totals to the Advisory Board during its April 2019 meeting in Pittsburgh, PA. For comparison, table 1 shows the independent SC&A-compiled total, which includes the SC&A total as a percentage of the results reported in NIOSH (2019a). As shown in both the figure and table, there were significant differences when comparing the SC&A and NIOSH totals based on the references cited in Addendum 2. This was particularly true in the latter period (2002–2010), where the SC&A totals ranged from 39 percent to 75 percent of the NIOSH-reported total. NIOSH provided SC&A with its compiled BZ database in March 2020 for comparison to identify the source of the apparent discrepancies. Table 1 provides an explanation of the observed differences by year.

Figure 1. Total number of captured breathing zone results by year in NIOSH (2019a) and SC&A compilation

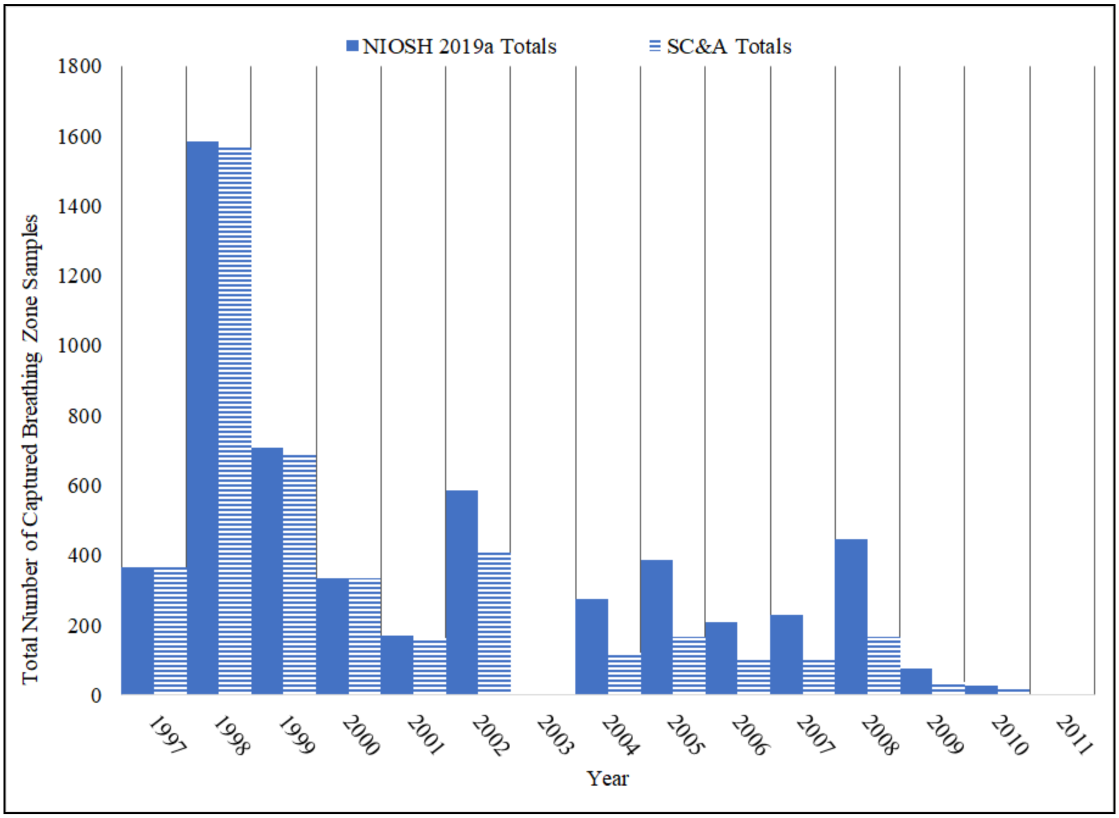


Table 1. Comparison of NIOSH (2019a) and SC&A totals for identified BZs by year

Year	NIOSH total	SC&A total	Percent (SC&A/ NIOSH)	Notes on discrepancy
1997	367	367	100%	No discrepancy identified.
1998	1,583	1,568	99%	Small discrepancy that was not investigated further.
1999	708	687	97%	Small discrepancy that was not investigated further.
2000	336	336	100%	No discrepancy identified.
2001	172	164	95%	Small discrepancy that was not investigated further.
2002	585	436	75%	SC&A identified 151 apparent duplicate results in the NIOSH compilation. The cause for the duplication was that some 2002 references only provided numerical results and did not always provide other identifiable information such as the run number, names of participants, or the location. Removal of these results decreases the NIOSH total to 434. The remaining difference is that the SC&A compilation contained two additional BZ results: one result was on 11/5/2002 that appears to have erroneous measurement results, and the other was a BZ result in which two names were listed for the same BZ result.
2003	0	0	—	Not applicable.

Year	NIOSH total	SC&A total	Percent (SC&A/ NIOSH)	Notes on discrepancy
2004	274	128	47%	SC&A found that tritium (H-3) measurements were counted as separate BZ results in the NIOSH compilation despite being part of the same operation, location, time, and monitored worker as the other gross alpha and gross beta measurements. Additionally, in some cases the gross beta and gross alpha measurement for a single BZ were counted as distinct separate BZ samples. Finally, SC&A found one apparent duplicate sample included in the NIOSH compilation. Adjusting for these observed entries decreases the NIOSH total to 128, which matches the SC&A total.
2005	388	176	45%	Similar issues identified as described for 2004, above. SC&A also identified one BZ that was expressed in units of air concentration in NIOSH's compilation that appeared to be a duplicate. Correction of these observations decreases the NIOSH total to 176, which matches SC&A's total.
2006	208	108	52%	Similar issues identified as described for 2004, above. S&A also found that one of the samples was a high-volume air sample incorrectly labelled as a BZ. Combining these measurements into a single BZ decreased the NIOSH total to 75. The SC&A total (108) also contained 34 measurements that only measured tritium that, when removed, decreased the SC&A total to 74, which is very close to the NIOSH total.
2007	231	111	48%	Similar issues identified as described for 2004, above. SC&A would also note that several BZ samples contained both a gross beta and a low-energy beta measurement. The low-energy beta measurements were also often considered distinct BZ samples. Combining these measurement results into a single BZ result decreases the NIOSH total to 111, which matches SC&A's total.
2008	445	174	39%	Similar issues as identified as described for 2004. This included 167 distinct low-energy beta measurements. Nine BZ samples in the NIOSH compilation appear to be recounts, and four BZ samples are dated 1998 and not 2008. Correction for these observed samples decreases the NIOSH total to 174, which matches the SC&A total.
2009	76	38	50%	NIOSH compilation considered low-energy beta measurements as distinct BZ samples from the gross alpha/beta BZ entries for the purpose of tallying the annual total. Correction of these entries decreases the NIOSH total to 38, which matches the SC&A total.
2010	26	20	77%	NIOSH total contains three low-energy beta measurements that were counted as distinct BZ samples. In addition, three samples represented repeated counts of the same sample. Correction of these observed entries decreases the NIOSH total to 20, which matches the SC&A total.
2011	0	0	—	Not applicable.

As noted in the table 1 entries, the major difference between the NIOSH and the SC&A totals was the manner in which different measurement types were tallied. The SC&A totals considered a single BZ sample to be a unique sampler worn by a single worker for a period of time and evaluated individually by the site for various types of radiation. In the NIOSH compilation, often times (but not always) a single BZ zone result counted toward the annual totals multiple times for each type of radiation measured (gross beta, gross alpha, H-3, low-energy beta). It is SC&A's opinion that the "multiple counting" of BZ samples based on this method is misleading in that it artificially inflates the total number of BZ samplers that were actually worn by workers at Sandia. SC&A recommends that reported totals in the official ER be corrected to represent the single worker/location/event evaluated via breathing zone by the site regardless of the different radiation "types" for which it was analyzed.

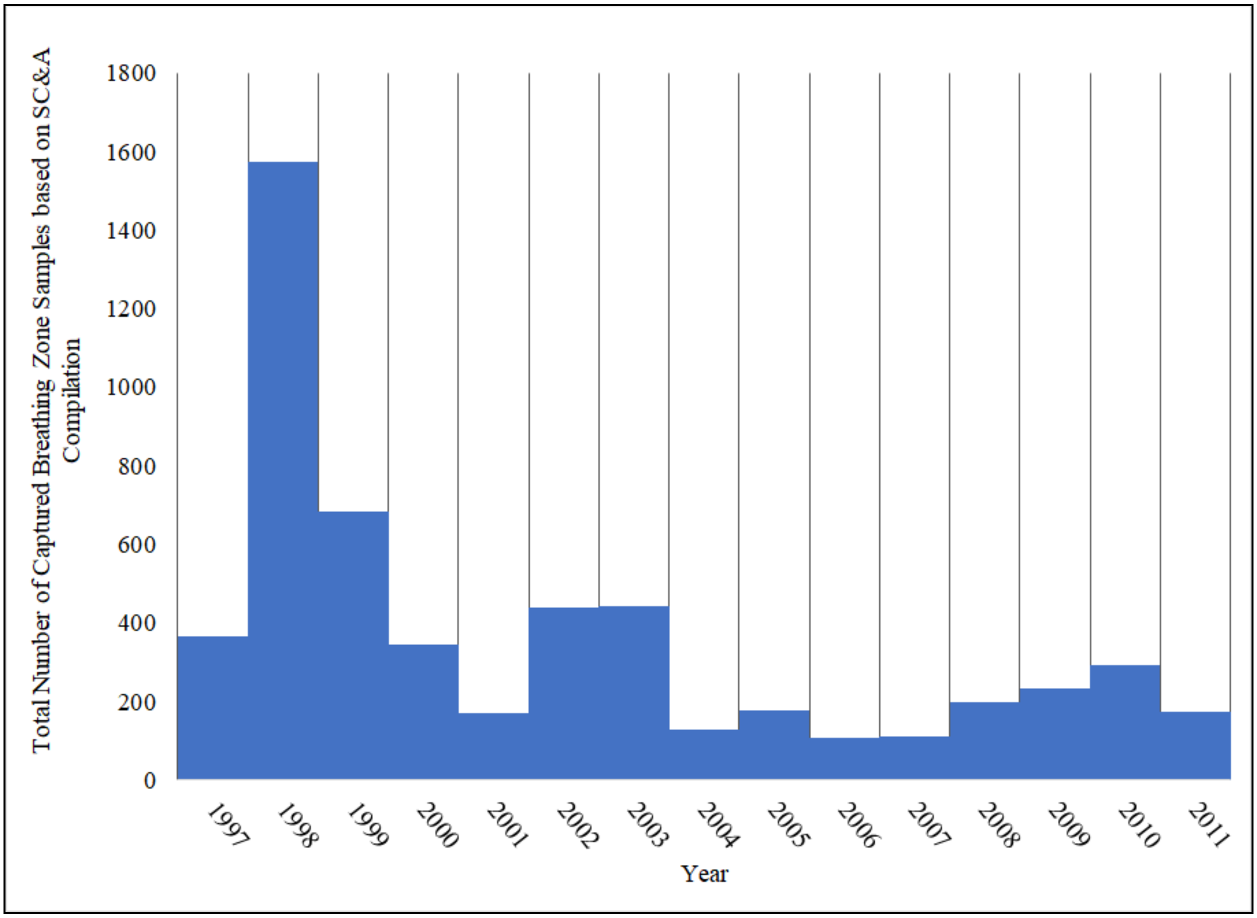
Additionally, in a few cases, repeat measurements of the same BZ sample were included (refer to table 1 entries for 2004 through 2008), or duplicates of the same sample from different references were counted as distinct BZ results (refer to table 1 entry for 2002).

Observation 1: SC&A identified 151 duplicate samples analyzed for 2002 in NIOSH (2019a). These samples should not be included in reported BZ totals and should be removed from any exposure estimates. Furthermore, when reporting the total number of BZ samples, the distinct measurements (gross alpha, gross beta, low-energy beta, and tritium) should not be counted as separate and distinct BZ samplers. These totals should be corrected in any subsequent revisions to the evaluation report to accurately reflect the number of individual workers/events who were monitored via BZ samplers.

Furthermore, as noted for 2007–2010, low-energy beta measurements were considered as separate BZ results and grouped together with the gross beta measurements. SC&A does not believe it is technically appropriate to combine low-energy beta and gross beta measurements into a single distribution for the purposes of quantifying the magnitude of beta exposure potential. SC&A believes a more technically appropriate approach would be to evaluate the low-energy beta component using a separate distribution. However, given the relative magnitude of these results, SC&A does not believe this technical alteration to the exposure evaluation would have a significant effect on the magnitude of resultant beta exposures nor the ER's conclusions.

As noted in section 4, subsequent to the release of Addendum 2 of the ER, additional data were made available for analysis, which were then analyzed and discussed in NIOSH (2020). NIOSH provided these additional raw data to SC&A in March 2020. SC&A found that low-energy beta measurements were treated in a similar manner as the original addendum. A combination of the additional NIOSH (2020) data and the original NIOSH (2019a, 2019b) data is shown in figure 2. All analyses presented from this point forward consider the combined NIOSH (2019a, 2019b) and (2020) datasets.

Figure 2. Total number of captured breathing zone results by year compiled by SC&A using both NIOSH (2019a), NIOSH (2019b), and NIOSH (2020) datasets



As shown in figure 2, there are significant changes in the number of captured BZ results from year to year, ranging from a high of nearly 1,600 results in 1998 to a slightly more than 100 BZ results in 2006 and 2007. While some variability would be expected from year to year given presumed changes in project mission and evolving radiological conditions, SC&A believes the observed variation shown in figure 2 suggests that the captured BZ records are likely not complete for each year in which results were identified and captured. However, absent specific knowledge of all relevant radiological processes, work areas, number of workers involved, and duration of the projects, it is difficult to establish what level of completeness the captured records represent. Therefore, SC&A's conclusion regarding completeness based on annual temporal variation remains subjective.

Although annual variation in the total number of BZ results is informative, a more granular look at variation within each year would also be instructive as to the relative completeness of the captured dataset. SC&A evaluated the captured BZ records on a monthly basis as shown in appendix 2, tables 2A, 2B and 2C. A summary of all 15 years evaluated is shown in appendix 2, table 2D. Figures 2A and 2B show the total number of BZ samples per month and the percentage of annual samples per month, respectively.

Per the analysis shown in appendix 2, the relative amount of captured BZ samples per month (ignoring months with no identified samples) could constitute as little as 1 percent of the annual total (e.g., October 1999) to nearly one-third of the annual total (31.1 percent in July 2004). The average over all months is 8.3 percent, with an arithmetic median value of 7.3 percent and a rank-ordered 95th percentile of 21.1 percent.

The analysis in appendix 2 also provides the total number of unique days per year that had at least one BZ sample captured, as well as the average and maximum number of observed days between BZ samples (refer to table 2D, appendix 2). It must be noted that weekend days were not subtracted when evaluating the number of days between observed BZ samples. Interestingly, aside from 1997 and 1998, nearly all the captured BZ samples were taken on Monday through Thursday.

The total number of unique days per year with captured BZ data varied from a low of 39 in 2007 to a high of 213 in 1998. The average over all evaluated years was 100 unique days per year with at least one BZ sample captured. The average number of days between successive BZ samples ranged from approximately 2.8 in 1998 to 9.8 in 2007. The maximum number of days observed between successive BZ samples ranged from 17 in 1998 to 231 in 2007.

Observation 2: It is SC&A’s opinion that the observed temporal variation in the number of captured BZ samples suggests that the available dataset does not represent a complete set of monitoring records for the affected worker population. Therefore, any conclusions regarding the exposure potential reflected in captured BZ samples are likely based on incomplete data. However, as stated previously, the level of incompleteness is not known at this time.

4.2 Evaluation of the number of individual monitored workers in captured BZ data

In addition to the total number of observed samples, another measure of completeness is to examine the total number of workers monitored via BZ over time. Although NIOSH (2019a, 2019b, 2020) does not specifically tabulate the number of workers monitored via BZ per year, section 6.1.3.1 of the SEC ER provides a summary of the number of monitored workers as found in the SNL “WebDose” dosimetry database (WebDose, 2018). The WebDose total number of workers is shown in figure 3, along with SC&A’s tabulation of the total number of workers by year as contained in captured hardcopy BZ logbooks. From figure 3, it is apparent that many more workers were identified in the captured BZ records than were contained in the SNL electronic WebDose database. During the entire SEC-00188 period, WebDose reported 116 individuals, while SC&A’s review of captured hardcopy records identified 194 unique individuals. SC&A further observes that most of the entries that are contained in WebDose indicate zero dose assigned. Therefore, one can conclude that WebDose was not solely used for documenting positive dose assignment.

Observation 3. Comparison of BZ entries contained in WebDose to captured hardcopy records demonstrates that WebDose does not represent a complete data source reflecting who was monitored via BZ at SNL. Therefore, the use of WebDose to support the 100 mrem dose threshold may not be appropriate.

Figure 3. Total number of individuals monitored via BZ for both WebDose database and SC&A's review of captured BZ records

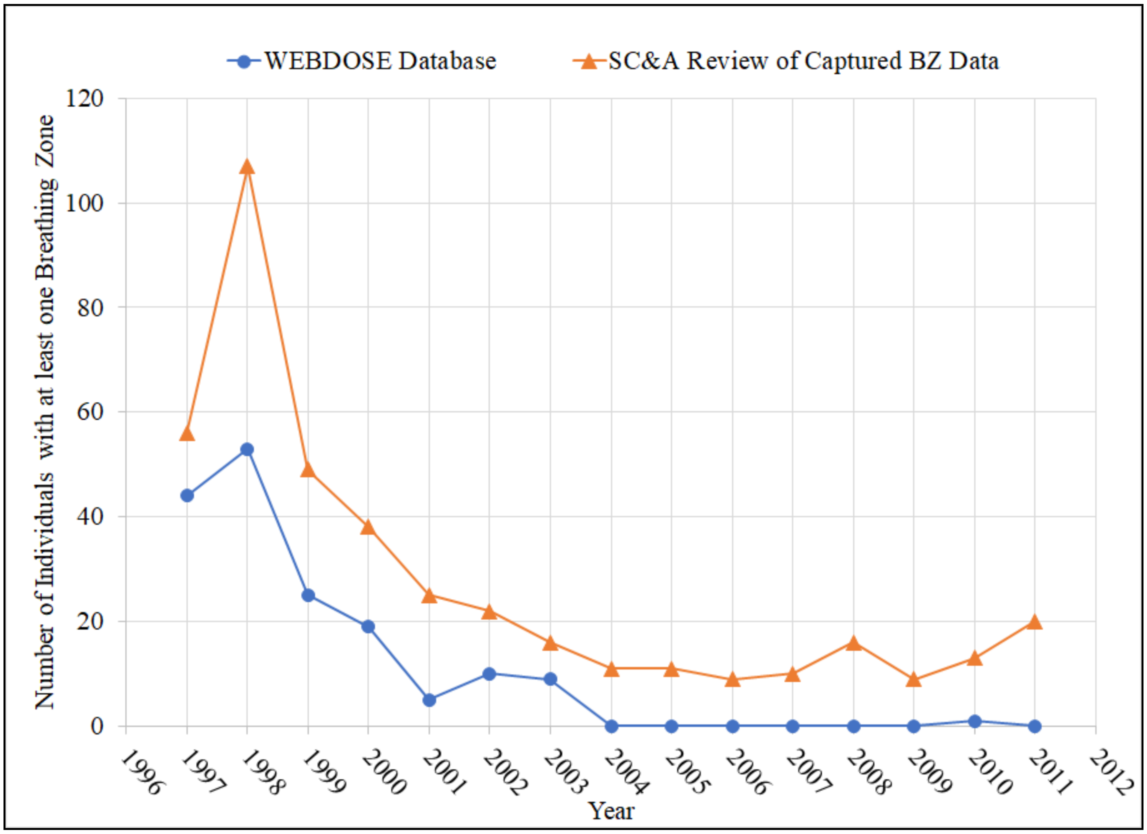


Table 2 shows an overview of the number of individuals monitored and the number of BZs per year associated with those individuals. As shown, the number of individuals identified in the captured BZ records ranged from a low of 9 in 2006 and 2009 to a high of 107 in 1998. The average number of BZ samples per individual worker per year ranged from a low of 6.6 in 1997 to a high of 27.8 in 2003. A rank order of the number of samples per individual worker per year is shown in figure 4. As shown in this figure (and also indicated in table 2), a large portion of the available BZ samples per year are often assigned to just a few individuals.

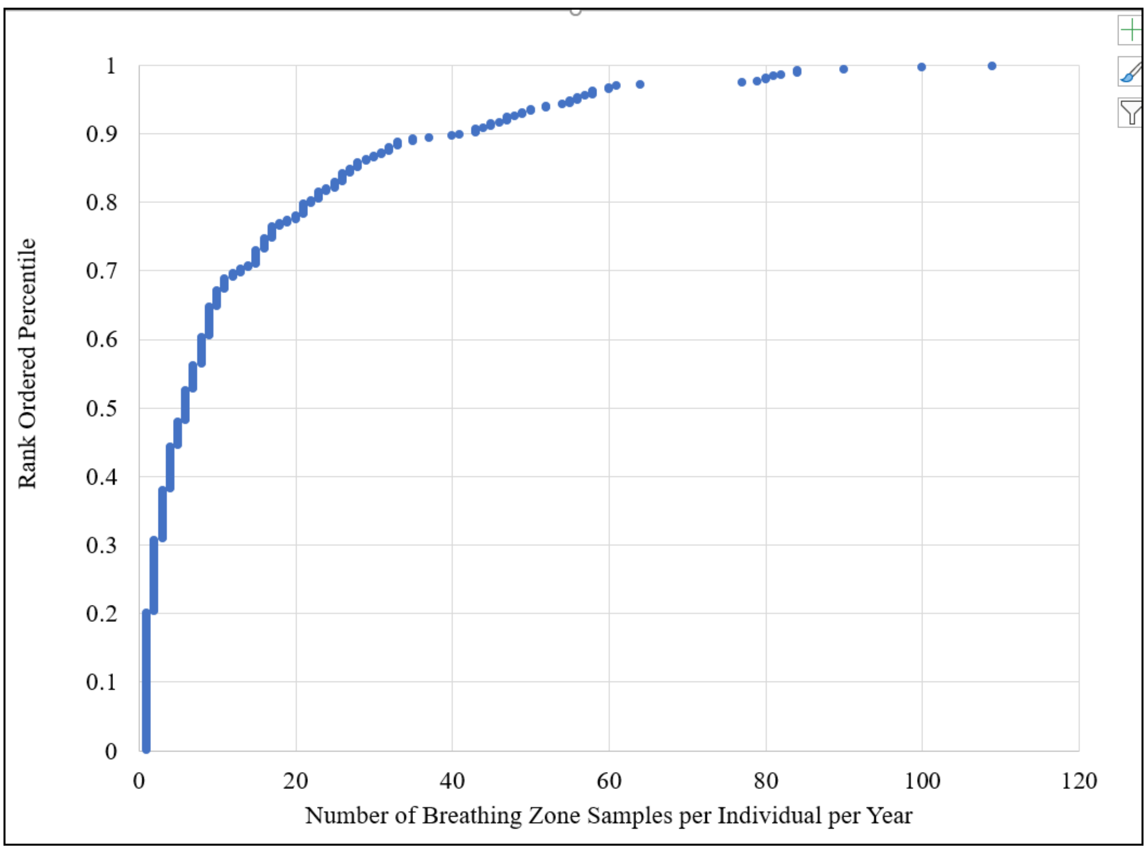
Approximately 8 percent (438 of 5,574) of all captured BZ samples were associated with just one individual who consistently worked in the same area (Building 6920, room 120) performing the same general type of work task (treatment operations). This EE also had the highest number of results per year in 2001 (55), 2002 (109), and 2010 (79).

Observation 4. A substantial portion of the available BZ samples per year are often assigned to just a few individuals. Approximately 8 percent of the total BZ samples were associated with just a single individual, though over 195 monitored individuals were identified. Nearly 80 percent of the identified individual workers in a given year had 20 BZ samples or less.

Table 2. Overview of the number of individuals monitored by year

Year	Total BZ samples	Individuals monitored	Maximum BZ samples per worker	95th percentile BZ samples per worker	Average BZ samples per worker	Median BZ samples per worker
1997	367	56	25	23	6.6	3.5
1998	1,572	107	84	63.1	14.7	7
1999	685	50	58	44	13.7	6
2000	345	38	49	28.45	9.1	5
2001	171	25	55	19.8	6.8	3
2002	439	22	109	57.8	20.0	7
2003	444	16	80	65	27.8	20
2004	128	11	32	29.5	11.6	6
2005	176	11	47	46	16.0	9
2006	108	9	56	40.8	12.0	6
2007	111	10	37	29.8	11.1	6.5
2008	200	16	52	43	12.5	5
2009	234	9	60	56	26.0	19
2010	292	13	100	94	22.5	4
2011	307	20	79	77.1	15.4	6
All years combined	5,579	194	438	124.3	28.7	7

Figure 4. Rank ordering of the number of BZ samples per individual worker per year



Finally, it is worth noting that 79 of the 194 individual workers identified in the BZ records (~41 percent) also submitted non-tritium bioassay samples during the evaluated SEC period. SC&A identified approximately 903 samples associated with these workers, including analyses for plutonium-238/239 (Pu-238/239) (455 measurements), uranium-238/235/234 (368 measurements), americium-241 (351 measurements), thorium-232/230/228 (Th-232/230/228) (91 measurements), neptiunium-237 (Np-237) (3 measurements), and various fission products (370 measurements).

The worker identified with the highest number of BZ results per year also was included in the non-tritium bioassay program. This includes the 11 workers with the highest number of captured BZ results for the entirety of the evaluated period (1997–2011). Therefore, it is reasonable to conclude that workers who were monitored via BZ more frequently were also monitored via urinalysis.

Observation 5: Seventy-nine of the 194 identified individuals in the captured BZ records also participated in the non-tritium bioassay program during the evaluated SEC period. This includes the identified workers with the highest number of BZ results per year as well as the 11 workers with the highest number of BZ results over the entire period. Therefore, evidence suggests that workers who were most often monitored via BZ were also often monitored via non-tritium bioassay.

4.3 Evaluation of temporal trends in work location, general task, limiting radionuclides, and respiratory protection

In addition to evaluating observed trends for total BZ samples and individual workers monitored, SC&A compiled information about the work location (figure 5), general task (figure 6), limiting radionuclides identified (figure 7), and any respiratory protection required (figure 8). Figure 5 shows the general work areas identified in the BZ records. As shown in the figure, a large portion of BZ samples were associated with "TA-II/Site 2" up until 2001, when a significant majority of the BZ records were associated with the "6920/6921" site area.

For the TA-II/Site 2 location, the actual work task was not often reported. However, when the task was identified, it was usually associated with intrusion into contaminated soil piles (refer to figure 6). When radionuclides were specified with this work, transuranic material (generally listed as Pu-239) and thorium were often the primary nuclides of interest (refer to figure 7). During this period (1997–2000), the primary form of respiratory protection was standard air purifying respirators, though air supplied respirators were also utilized to some extent. Overall, the use of respiratory protection ranged from approximately 40 percent (1997) to as high as 90 percent (1999).

For the 6920/6921 location, work tasks were primarily associated with sorting and treatment campaigns (refer to figure 6). In general, transuranic material was the primary radionuclide of interest, though for some years, uranium was indicated most commonly (2001, 2002, and 2007). For the final 3 years of the SEC period (2009–2011), fission and activation products were most commonly identified (refer to figure 7).

As shown in figure 8, 2002 and 2003 saw a marked increase in the use of bubble hoods for respiratory protection. Most commonly, these respirators were associated with the sorting and treatment operations occurring in the 6920/6921 area. From 2004 to the end of the period, respiratory protection was used generally 40 to 60 percent of the time (refer to figure 9). However, for sorting and treatment operations, respiratory protection was used over 62 percent of the time (over 66 percent of the time when transuranic material was identified as a contaminant of interest).

Figure 5. General work areas found in the captured BZ records (1997–2011)

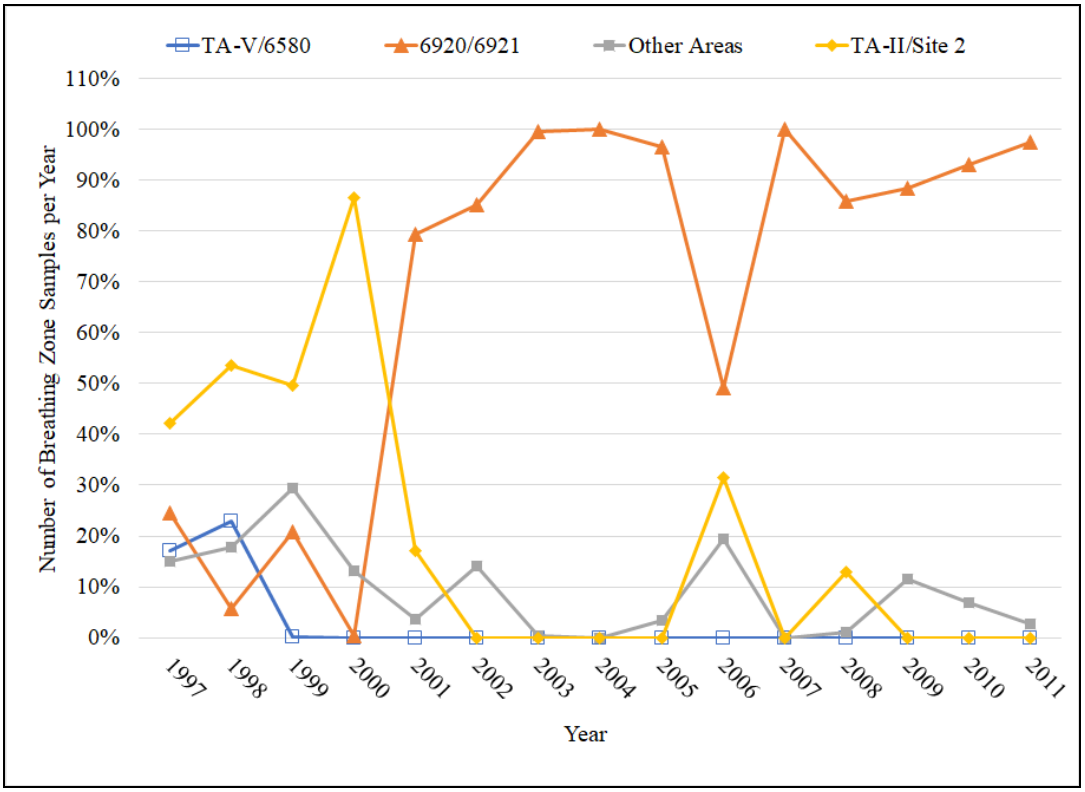


Figure 6. General work tasks identified in captured BZ records

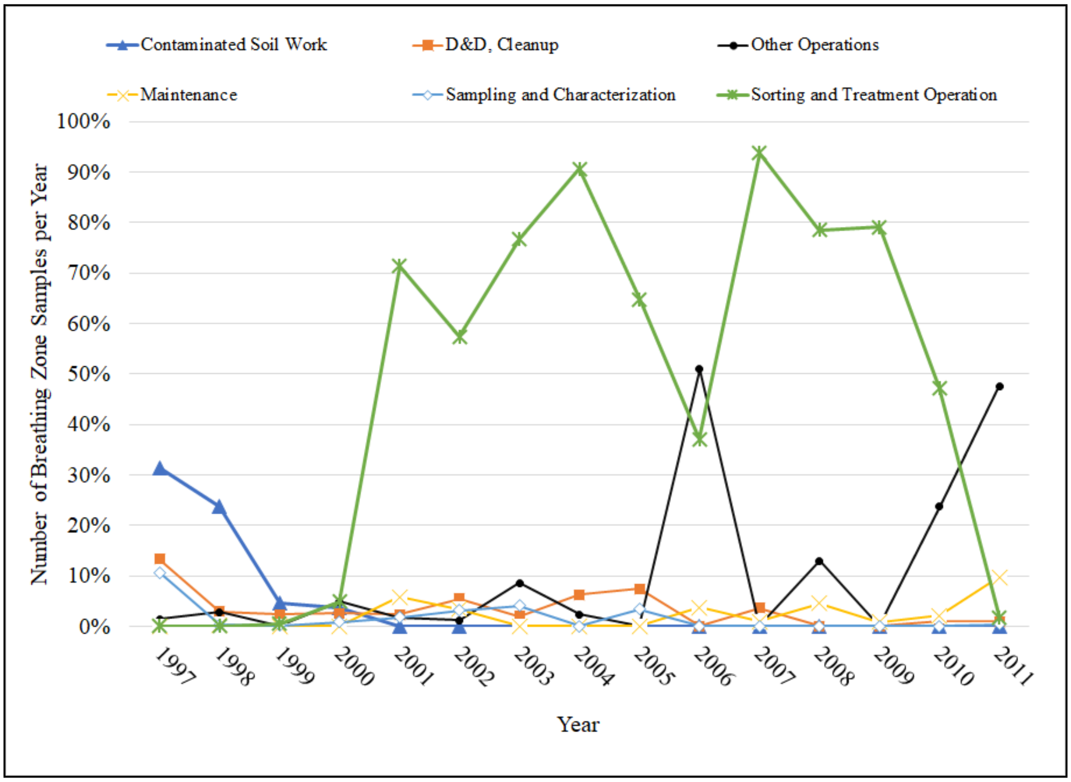


Figure 7. Primary radionuclide of interest identified with BZ operation

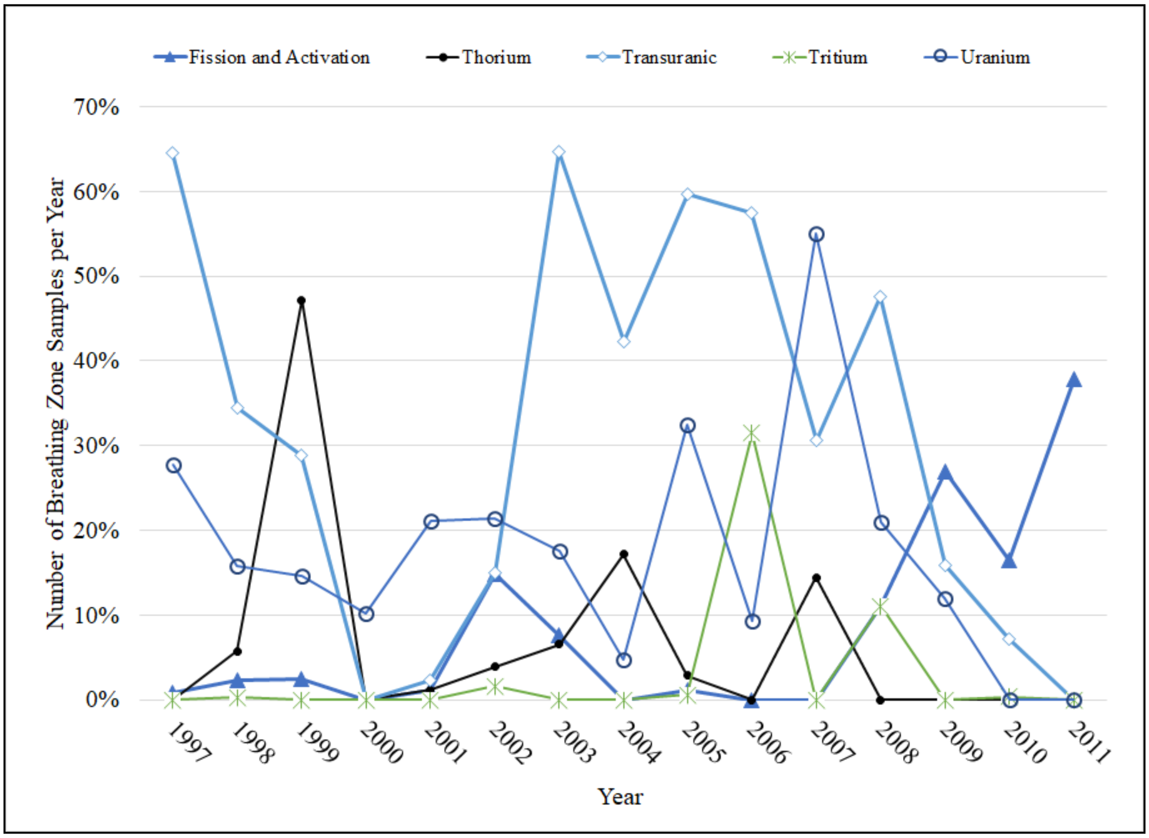


Figure 8. General types of respiratory protection used by workers identified with BZ operation

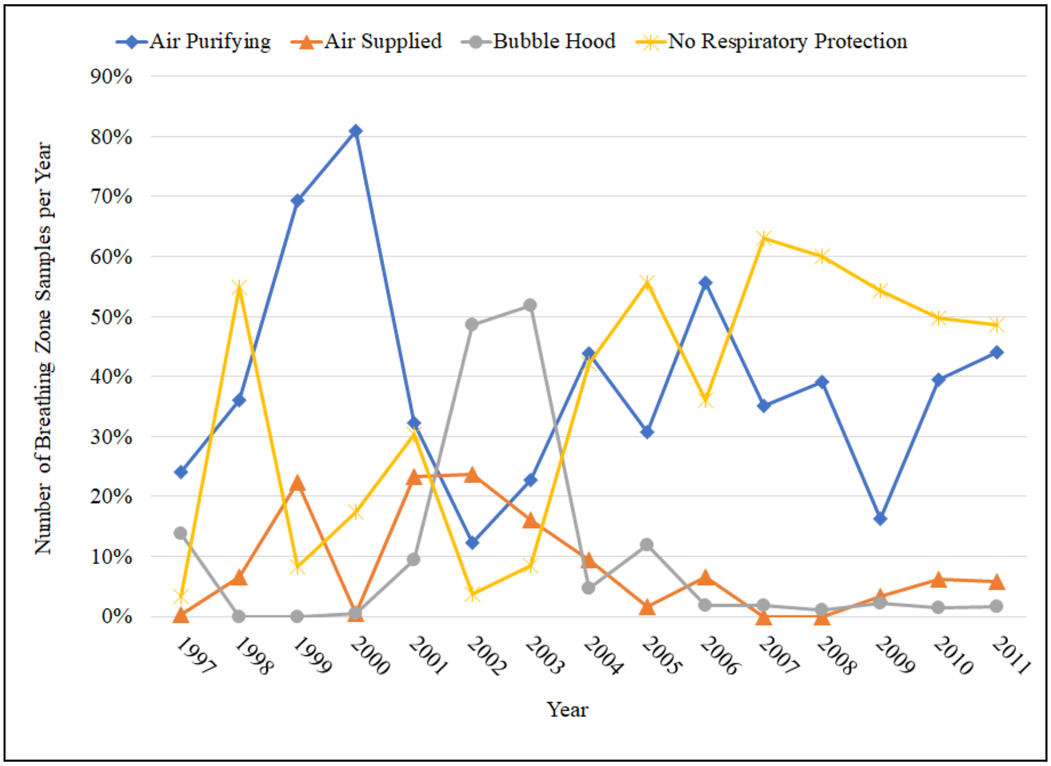
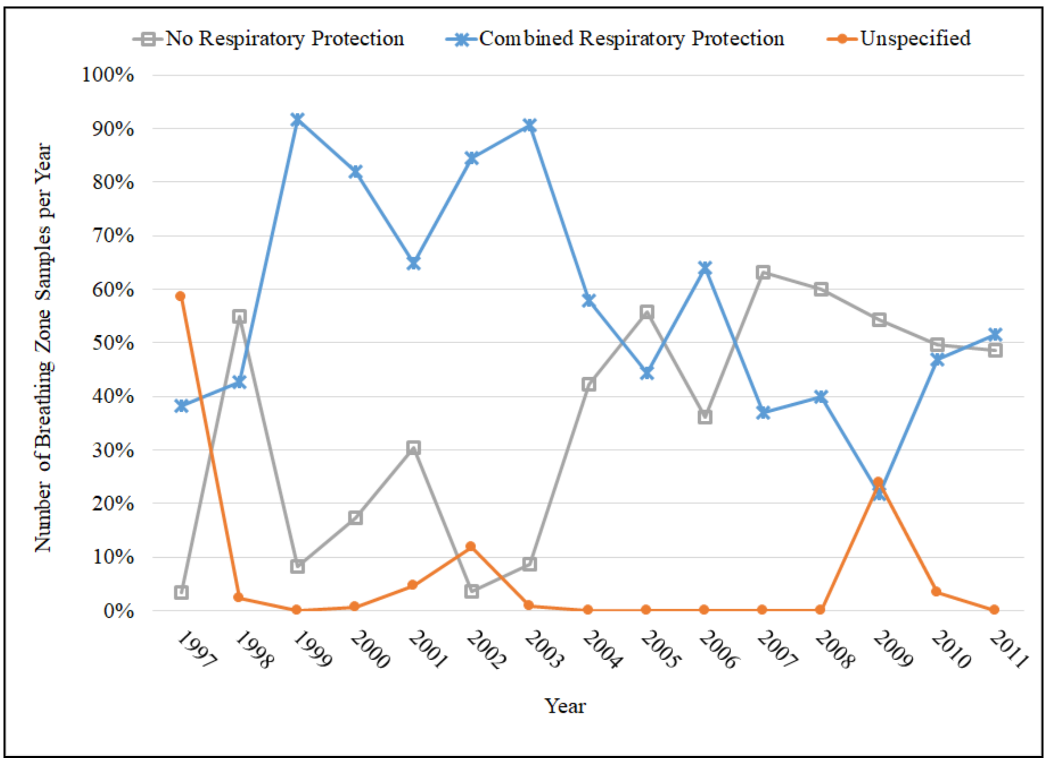


Figure 9. Overall respiratory protection used by workers identified with BZ operation



4.4 Characterization of exposure potential

The main purpose of analyzing the BZ data in the evaluation of SEC-00188 is to characterize the exposure potential for workers involved in the BZ program in relation to the proposed maximum dose assignment of 100 mrem for unmonitored or partially monitored workers. In support of the 100 mrem maximum dose assignment, NIOSH provides an analysis of gross alpha, gross beta, and tritium doses over the entire SEC-00188 period (NIOSH 2019b, 2020). The NIOSH method utilizes multiple imputation methods[8] to modify BZ samples that resulted in doses that were less than 1 mrem. These actual and imputed results were then fit to a lognormal distribution to obtain the basic dose parameters. The results of this method yielded the following ranges of median doses per BZ event: 0.482–0.490 mrem (gross alpha), 0.00054 mrem (gross beta), and 0.00066 to 0.00069 mrem (tritium). Based on this analysis, NIOSH (2019a) concludes:

> it is not likely that an individual would be able to receive 100 mrem per year of internal exposure under these conditions (i.e., an individual would have to be present for 200 events, based on the median dose, to receive an exposure in excess of 100 mrem in a year. [NIOSH, 2019a, p. 31]

SC&A believes the NIOSH analysis correctly identifies that the alpha component is by far the dosimetric quantity of interest. Therefore, the analysis in this section focuses solely on the dose from alpha-emitting radioisotopes. However, SC&A is concerned that an analysis that focuses on only on the median doses over all work locations and the entire SEC-00188 timeframe may not sufficiently characterize the inherent temporal and job-specific variations. Therefore, SC&A performed a separate analysis that considered these factors.

While NIOSH utilized multiple imputation to replace dose values that were less than 1 mrem, SC&A used all calculated doses as is with the exception of negative values, which were set to zero. Furthermore, due to the number of alpha BZ results that were negative or zero, fitting the BZ derived doses to lognormal distributions becomes problematic. Therefore, SC&A used the basic metrics of arithmetic median, average, rank-ordered 95th percentile, and maximum dose. Finally, to assure some level of consistency with the NIOSH analysis, SC&A did not make any alterations to the "raw" data in NIOSH's calculation files (e.g., apparent duplicates were not removed).

Table 3 shows the basic dose metrics as a function of each year during the SEC-00188 period. As shown in the table, the arithmetic median dose per breathing zone sample for all years during the SEC-00188 period (0.39 mrem) is reasonably close to the NIOSH-derived values (0.482–0.490 mrem). However, SC&A-derived average doses were consistently higher than the NIOSH range, with the exception of 2004 and 2008. Rank-ordered 95th percentile BZ results on an annual basis were a factor of 2–44 times higher than the NIOSH generated median value. However, it is important to note that these results reflect a single BZ result, or work event, within the year rather than a consistent date rate or annual dose total typically considered in co-exposure dose assignment.

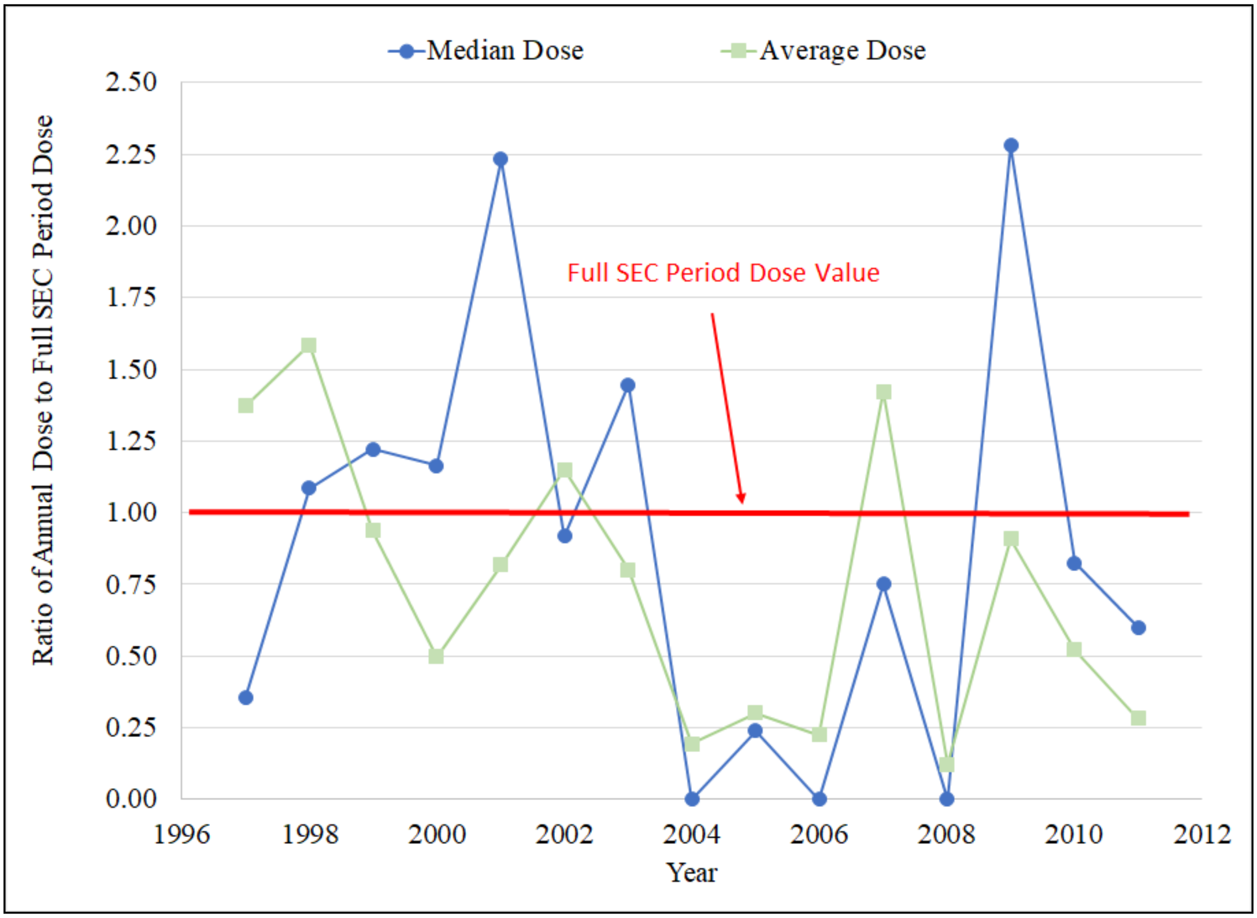
[8] The process of using multiple imputation values on censored data is currently under review by SC&A and the Savannah River Site and SEC Issues Work Groups.

Table 3. SC&A-calculated doses per BZ sample per year

Year	Arithmetic median dose (mrem)	Average dose (mrem)	Rank-ordered 95th percentile dose (mrem)	Maximum dose (mrem)
1997	0.14	2.95	15.07	138.78
1998	0.42	3.41	9.34	388.63
1999	0.48	2.02	7.14	176.50
2000	0.46	1.07	3.25	33.14
2001	0.87	1.76	8.21	23.79
2002	0.36	2.48	7.75	366.60
2003	0.57	1.72	7.34	31.50
2004	0.00	0.42	2.09	2.92
2005	0.09	0.65	2.51	10.57
2006	0.00	0.49	2.11	6.16
2007	0.29	3.06	22.29	58.62
2008	0.00	0.26	1.04	2.06
2009	0.89	1.96	4.53	45.58
2010	0.32	1.12	5.55	13.17
2011	0.24	0.61	2.45	14.42
All years combined	0.39	2.15	7.19	388.63

Importantly, the dose estimates per BZ per year fluctuate significantly on an annual basis as shown in figure 10. Notably, the median SC&A value in 2001 and 2009 was over a factor of 2 higher than the SC&A-calculated median for the full SEC period. When considering the average SC&A dose per BZ sample, the annual average was higher for four of the SEC years (1997, 1998, 2002, and 2007).

Figure 10. Ratio of the annual SC&A dose values to the full SEC-00188 SC&A dose values



SC&A also analyzed the relative dose per BZ sample by the major work areas as described in section 4.3 of this report; the results are shown in table 4. As shown in the table, BZ derived doses associated with the TA-V/6580 area were significantly higher than the other main areas evaluated. As shown in figure 5 (in section 4.3), nearly all of the BZ samples associated with this area were in 1997 and 1998 (only three BZ samples were identified outside of these 2 years for this area).

Table 4. Overview of SC&A-calculated dose per BZ sample per general work area

SC&A location designation	Arithmetic median dose (mrem)	Average dose (mrem)	Rank-ordered 95th percentile dose (mrem)	Maximum dose (mrem)
6920/6921	0.40	1.44	5.70	366.60
Other areas	0.37	2.31	9.74	176.50
TA-II/Site 2	0.16	0.75	2.24	123.91
TA-V/6580	3.45	12.74	54.20	388.63
All areas combined	0.39	2.15	7.19	388.63

Figures 11 and 12 display the ratio of the area-specific doses per year versus the doses for all areas over the entire SEC period. Specifically, figure 11 displays the median dose comparison, and figure 12 shows the average dose comparison. Similar to the analysis in table 4, the largest ratios per year were observed for the general area designated by SC&A as “TA-V/6580” in 1997 and 1998. Increased exposure potential (up to a factor of 4 for the arithmetic median) was also observed for other areas and years, such as the following:

- “6920/6921” in 1999–2001, 2003, and 2009
- “TA-II/Site 2” in 2001
- “Other areas” in 1999, 2000, 2001, 2010, and 2011

Figure 11. Ratio of the median annual dose values by general work area to the full SEC-00188 dose values for all areas

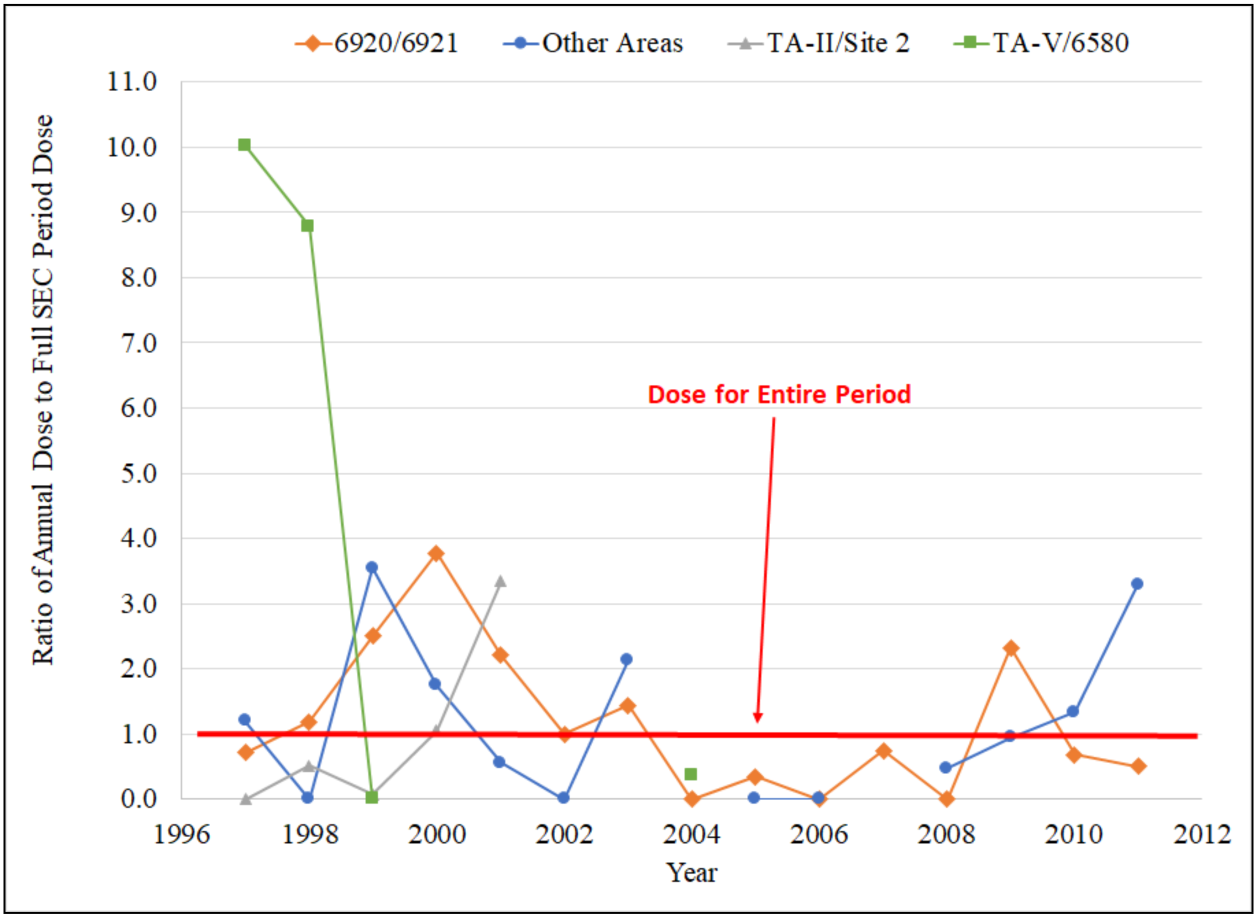
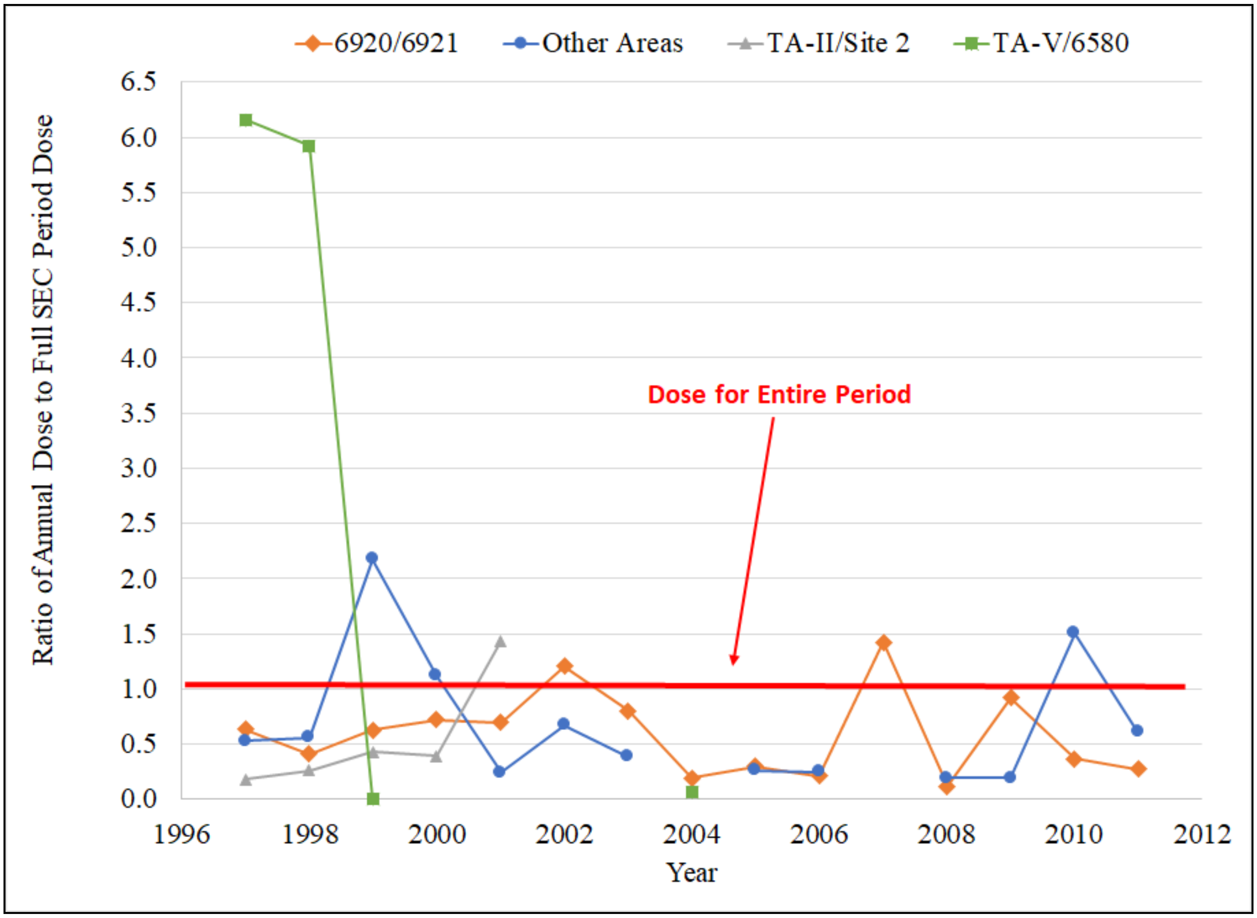


Figure 12. Ratio of the average annual dose values by general work area to the full SEC-00188 dose values for all areas



However, it is important to note that three main mitigating factors are not accounted for in SC&A's analysis that bias the dose estimates much higher than the likely reality of the exposure scenario. These three mitigating factors are discussed in sections 4.4.1, 4.4.2, and 4.4.3 below.

4.4.1 Mitigating factor 1: Selection of the radionuclide of interest

The alpha-emitting radionuclide of interest was assumed to be Pu-239 over 99 percent of the time rather than lower exposure alpha-emitting material identified (e.g., depleted uranium). In both the SC&A and NIOSH analysis, only 53 of 5,858 BZ results evaluated (or less than 1 percent) assumed uranium-238 was the radionuclide of interest, although SC&A's analysis indicates over 16 percent of the available BZ samples mentioned uranium as the limiting alpha-emitting radionuclide. From a dosimetric standpoint, internal exposures assigned using Pu-239 are a factor of 6.67 higher than uranium. Based on the captured BZ records, the only potential contaminants that have a greater exposure per intake than Pu-239 are Np-237 and Th-232. However, Np-237 and Th-232 were only identified for approximately 0.6 percent and 9 percent of the BZ samples, respectively.

SC&A did not observe Np-237 or Th-232 identified as the contaminant of interest in association with BZ samples collected in the TA-V/6580 area. Pu-239 was always assumed when evaluating internal exposure potential for this area, though it comprised just 55 percent of the observed BZ results. The remaining limiting radionuclides identified associated with TA-V/6580 were mixed fission products (~7 percent), unknown/unspecified (~10 percent), and uranium (~28 percent). Therefore, the dose estimates calculated by SC&A for this area are already biased high based on the assumed contaminant of interest.

4.4.2 Mitigating factor 2: Respiratory protection is not considered

Respiratory protection utilized by the workers was not considered in any of the dose evaluations performed by either NIOSH or SC&A. As noted in section 4.3, respiratory protection was used anywhere from 40 to 90 percent of the time on an annual basis (refer to figures 8 and 9). Typical protection factors associated with the respirators in use at Sandia would generally range from 40 (standard air purifying respirator) to 1,000 (air supplied bubble hood).

Specific to the TA-V/6580 area, respiratory protection was worn nearly 86 percent of the time. Table 5 shows the breakdown of respirator use for this area. Sandia reported respiratory protection factors for the "air purifying respirators" in use that ranged from 50 (SNL, 1998b) to 100 (SNL, 2006).

Table 5. Summary of respiratory protection used in the TA-V/6580 area

Respiratory protection type	Percentage of BZ samples
Air purifying respirator	44.0%
Powered air purifying respirator	18.4%
Full face respirator (unknown if powered)	23.4%
Unavailable/unspecified	4.7%
No respiratory protection	9.5%

4.4.3 Mitigating factor 3: Number of exposure events per year

As noted in the NIOSH (2019a) exposure potential analyses, it would take approximately 200 distinct BZ zone exposures/events to surpass the 100 mrem threshold on an annual basis. SC&A's evaluation of the BZ data demonstrates that 200 days of exposure is likely the typical maximum amount in a year that could be experienced, as records indicate that nearly all BZ samples were taken on Monday–Thursday (refer to table 2D in appendix 2).

SC&A's analysis of individuals monitored in the captured BZ records noted that (1) the most individual BZ samples observed in a single year was 109 and (2) at the rank-ordered 95th percentile, workers received between 23 and 77 BZ samples per year (refer to section 4.2). In general, approximately 80 percent of the observed individual workers had 20 BZ results per year or less. However, it must be noted that these numbers are based on likely incomplete data (refer to section 4.1), although the level of incompleteness is not known at this time.

Observation 6: SC&A's analysis of relative exposure potential demonstrates that noteworthy fluctuations in exposure potential can exist by year and by work area. Specifically, work in the general area designated by SC&A as "TA-V/6580" during the years 1997 and 1998 showed significantly elevated exposure potential when compared to all years and areas. However, SC&A does not believe these fluctuations necessarily

obviate the use of 100 mrem as a maximizing dose assignment to unmonitored workers, as several significantly conservative assumptions were included in the dose estimates.

4.5 SC&A summary conclusions regarding breathing zone data

SC&A was unable to provide a direct evaluation of the completeness of the captured BZ data because information about the number of BZ samplers that were issued/processed during the SEC-00188 period is unknown (finding 1). The total number of captured BZ samples reported in the SEC ER Addendum appears to include multiple counts of the same BZ sampler, based on the radiation type that was measured. Therefore, the totals reported by NIOSH (2019a) are artificially inflated in some cases (observation 1).

Subjective evaluation of the data completeness included an analysis of temporal variations on an annual and monthly basis. This analysis indicated significant changes from time period to time period and suggests to SC&A that the captured dataset is likely not complete (observation 2). Comparison of captured BZ samples to available electronic database files (i.e., WebDose) indicates the electronic BZ records are also incomplete (observation 3).

When considering the individual workers monitored, SC&A found that significant portions of the captured BZ samples were attributable to just a few workers. For example, approximately 8 percent of the total captured BZ samples were attributed to just one individual, although 194 unique monitored workers were observed. Approximately 80 percent of the individuals identified in the captured BZ records had 20 BZ samples per year or less (observation 4). In addition, over 40 percent of the identified workers also participated in the non-tritium bioassay program, including workers that had the highest number of captured BZ results (observation 5).

Section 4.3 provides an annual breakdown of work area, general task, radionuclide of interest, and respiratory protection. From 1997 to 1999, the most common work location and task identified was intrusion into contaminated soil piles at TA-II/Site 2. After this period, the most common type of monitored work activity was sorting and treatment operations occurring in the 6920/6921 area. The most common contaminants of interests were transuranic material (e.g., Pu-239), thorium, and uranium (in particular, depleted uranium). Respiratory protection was used approximately 40–90 percent on an annual basis.

Finally, an evaluation of exposure potential showed significant variation among different years and work areas. The most concerning exposure estimates occurred in 1997–1998 in the TA-V/6580 area. Estimates of the average and median doses per event in this location ranged from 6 to 10 times higher than the sitewide dose estimates over the entire SEC-00188 period. However, several factors mitigate the concern over elevated dose potential in this and other site areas. These mitigating factors include:

- conservative selection of the radionuclide of interest (e.g., Pu-239), which likely overestimates the dose estimate by a factor of 6 or more for many exposure events
- no modification of dose estimates for respiratory protection, which likely overestimates the dose estimates by a factor of 40–1,000 depending on the respirator in use

- the observed number of BZ samples per individual worker, which ranged as high as 109 BZ samples per worker per year, which is far short of the 200 events calculated in NIOSH (2019a) necessary to exceed the 100 mrem upper bound

However, it must be noted that the evaluation of the final mitigating factor (number of exposure days) is likely limited by the completeness of the available dataset. The actual level of completeness (or incompleteness) of the dataset is currently unknown. Notwithstanding concerns about the completeness of the captured BZ dataset, SC&A believes the totality of evidence suggests that 100 mrem represents a plausible upper bound internal exposure for workers who were not monitored or who were partially monitored (observation 6).

5 External Dose Monitoring Program

SC&A reviewed the feasibility of reconstructing external dose stated in table 7-2 of Addendum 2 (NIOSH, 2019a, p. 37). Table 7-2 states that it is feasible to reconstruct external doses (to include occupational medical x-ray, environmental, and external exposures) for the period January 1, 1997, through May 21, 2011, for SNL-A workers. SC&A used the following documents in this review:

- the original TBD, ORAUT-TKBS-0037, revision 00, “Site Profile for Sandia National Laboratories in Albuquerque, New Mexico, and the Tonopah Test Range, Nevada” (NIOSH, 2007)
- SC&A’s review, “Site Profile for Sandia National Laboratories in Albuquerque, New Mexico, and the Tonopah Test Range in Nevada,” SCA-TR-TASK1-0022, revision 0 (SC&A, 2009)
- the SEC ER for Petition SEC-00180, Sandia National Laboratories-Albuquerque (NIOSH, 2012)
- the current TBD, ORAUT-TKBS-0037, revision 01, “Site Profile for Sandia National Laboratories in Albuquerque, New Mexico, and the Tonopah Test Range, Nevada” (NIOSH, 2013)
- “SEC Petition Evaluation Report Petition SEC-00188, Addendum (1995–1996)” (NIOSH, 2018)
- “SEC Petition Evaluation Report Petition SEC-00188, Addendum 2 (1997–2011)” (NIOSH, 2019a)

SC&A reviewed the feasibility of reconstructing external dose from an SEC perspective, not necessarily from an aspect of resolving the TBD findings. The following is a summary of SC&A’s review.

5.1 Occupational medical x-ray dose

SC&A reviewed:

- Section 3 (pp. 22–37) of ORAUT-TKBS-0037, revision 01 (NIOSH, 2013)
- Section 7.3.3 (p. 56), section 7.3.4.1 (pp. 57–58), and section 7.6, table 7-2 (p. 62) of the SEC ER
- Table 7-2 (p. 37) of SEC ER Addendum 2 for 1997–2011 (NIOSH, 2019a)
- Samples of SNL-A claim files to observe occupational medical x-ray records

SC&A reviewed 20 SNL-A claims in the NIOSH DCAS Claims Tracking System (NOCTS) for workers employed during the period 1997–2011. SC&A found that some claimants' DOE files contained occupational medical x-ray records. The dose reconstruction reports for the claimants were based on a combination of available occupational medical x-ray records in the DOE files and the recommended x-ray frequency in the SNL-A TBD applicable at the time of the dose reconstruction.

For claimants with or without x-ray medical records, section 3 of ORAUT-TKBS-0037, revision 01, provides guidelines to the dose reconstructor in the form of:

- Frequency and types of medical x-ray exams (table 3-1)
- X-ray machine manual settings (table 3-4)
- Organ doses as a function of x-ray exam type and year (tables 3-5 and 3-9)
- Skin doses as a function of cancer location, x-ray exam type, and year (table 3-8)

These guidelines are in concurrence with ORAUT-OTIB-0006, revision 04, "Dose Reconstruction from Occupational Medical X-ray Procedures" (NIOSH, 2011b), the version current at the time the TBD was issued.

SC&A found that the occupational medical dose section in revision 01 of ORAUT-TKBS-0037 (NIOSH, 2013) significantly expanded the coverage of x-ray doses compared to revision 00 of ORAUT-TKBS-0037 (NIOSH, 2007). There may remain TBD issues to be addressed; however, in this review SC&A did not find indications that there were issues that would prevent dose reconstruction of occupational medical x-ray doses from an SEC perspective.

5.2 External environmental dose

SC&A reviewed:

- Section 4 (pp. 37–50) of ORAUT-TKBS-0037, revision 01 (NIOSH, 2013)
- Sections 7.3.1.2 and 7.3.2 (p. 56), section 7.3.4.1 (pp. 57–58), and section 7.3.5 (pp. 58–59) of the SEC ER
- Table 7-2 (p. 37) of SEC ER Addendum 2 for 1997–2011 (NIOSH, 2019a)

In SC&A's 2009 review (SC&A, 2009, finding 9, p. 13, and section 3.9, pp. 45–46) of ORAUT-TKBS-0037, revision 00 (NIOSH, 2007), SC&A pointed out the inadequate justification of the environmental external doses recommended in table 4-2. Although the recommended annual doses were stated to be based on thermoluminescent dosimeter (TLD) environmental measurements starting in 1980, there was no supporting detailed data on how the assignment of <1 mrem, 5 mrem, and 10 mrem annual doses for the various technical areas were derived.

Section 4 for occupation environmental external dose in ORAUT-TKBS-0037, revision 01 (NIOSH, 2013), is very similar to section 4 in ORAUT-TKBS-0037, revision 00 (NIOSH, 2007). Table 4-2 contains the same data in both documents. Revision 01 (NIOSH, 2013) contains an additional table of data for 2005–2010 (table 4-3). Again, as in revision 00, revision 01 does not provide supporting detailed data on how the assignments of <1 mrem, 5 mrem, and 10 mrem annual doses for the various technical areas were derived.

This TBD issue has yet to be addressed. However, if adequate TLD data are available, then SC&A did not find indications that there were issues that would prevent dose reconstruction of external environmental doses from an SEC perspective.

5.3 External exposure dose

SC&A reviewed:

- Section 6 (pp. 97–106) of ORAUT-TKBS-0037, revision 00 (NIOSH, 2007)
- SC&A's review, "Site Profile for Sandia National Laboratories in Albuquerque, New Mexico, and the Tonopah Test Range in Nevada," SCA-TR-TASK1-0022, revision 0, (SC&A, 2009)
- Section 6 (pp. 81–92) of ORAUT-TKBS-0037, revision 01 (NIOSH, 2013)
- Section 5.2.2 (pp. 31–33), section 6.0 (pp. 33–34), section 6.2 (pp. 40– 46), section 7.3 (pp. 54–59), and section 7.6, table 7-2 (p. 62), of the SEC ER
- Table 4-1 (p. 7) and table 7-2 (p. 37) of Addendum 2 for 1997–2011 (NIOSH, 2019a)

SC&A analyzed the external monitoring data in table 6-4 (pp. 43–44) of the SEC ER for the period 1990–2010, and Site Research Database (SRDB) 172158 (WebDose, 2018) for the period 2011–2017. SC&A plotted the number of monitored workers at SNL-A as a function of year, as shown in figure 13.

Figure 13. Number of SNL-A workers monitored for external exposure per year

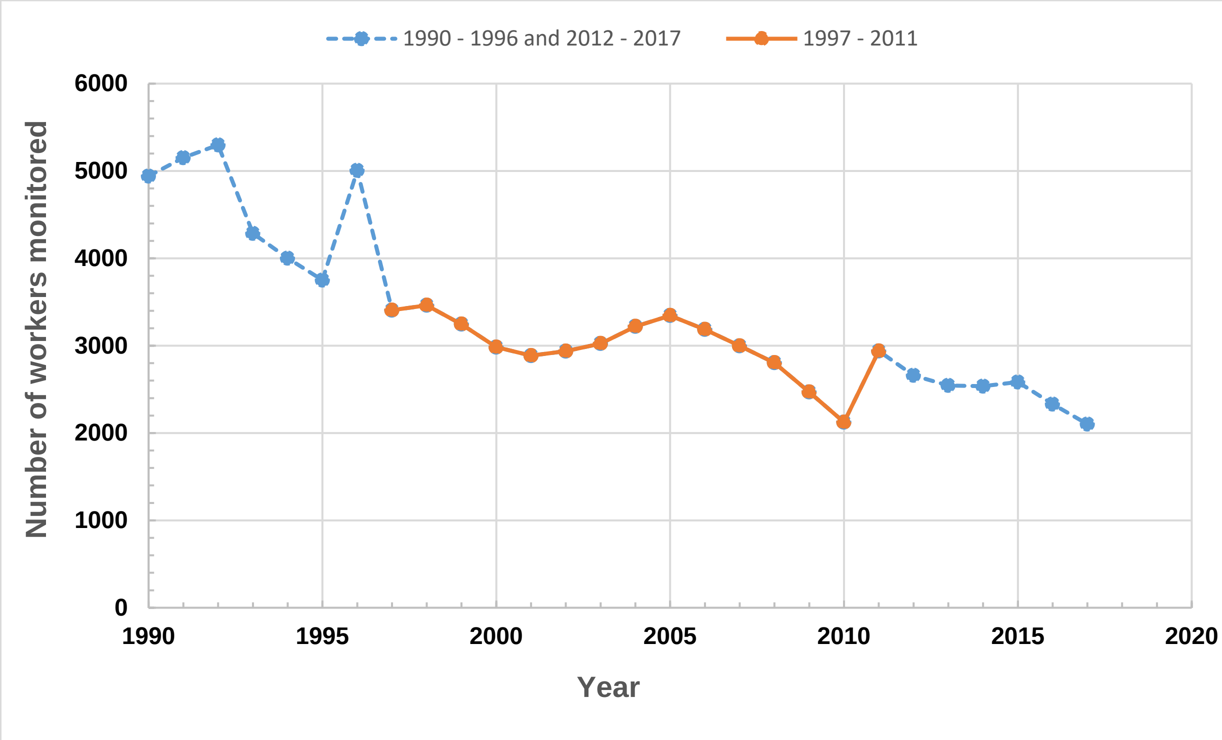


Figure 13 indicates a slowly decreasing monitoring rate during the SEC period under consideration, 1997–2011 (solid line). This trend is consistent with a gradually decreasing monitor rate as seen in the periods (dotted lines) before and after the 1997–2011 period.

SC&A reviewed 20 claim cases in NOCTS with job titles (operator, scientist, security, etc.) that would indicate the potential need for external monitoring during the employment period 1997–2011. SC&A found that, in general, these workers were monitored for photon, shallow, and neutron doses periodically or continuously, as dictated by work location and job duties. During periods of low potential exposure when the worker was not monitored, ambient external dose was assigned in the dose reconstruction report. SC&A also reviewed several other cases where the worker's job title (programmer, staff, etc.) would indicate a low potential for exposure and found these workers were not monitored. These observed monitoring practices would be consistent with a controlled external monitoring program.

In this review, SC&A did not find indications that there were issues that would prevent dose reconstruction of external exposures from an SEC perspective for the SEC period 1997–2011.

However, there could be one relevant TBD issue that has not been clarified that involves inaccurate dose records for reactor personnel, as discussed in section 3.2 of SC&A's (2009) review of the SNL-A TBD, revision 00 (NIOSH, 2007). NIOSH briefly addressed the issue in section 7.5 (p. 60) of the SEC ER as follows:

> *ISSUE: Inaccurate Dose Record for Pulse Reactor Personnel*
>
> RESPONSE: Inaccurate dose records for SPR [Sandia Pulse Reactor] operators resulted from the under-recording of external gamma/neutron dose received during shutdown maintenance activities. This under-recording resulted from inadequate dosimetry at the time for a severe gradient of exposure levels experienced by personnel working beneath the reactor vessel. Workers in this area experienced higher exposures to the head than would have been properly monitored by the badge located on the chest. Survey data from 1961 (paired gamma and neutron measurements) for various locations in the SPR facility have been obtained by NIOSH. The data's usefulness for determining actual worker exposures has been assessed and corrections can be made enabling conservative estimation of bounding exposures. It is noteworthy that wrist badges were used, ostensibly to measure the non-uniform fields. The primary issue associated with severe gradients/non-uniform fields is unmonitored exposure to extremities (normally hands); the wrist badges were likely used to measure that exposure. Additionally, "head" badges were provided to the workers to more accurately monitor the exposure to the head and enable a more accurate determination of eye exposure ([redacted], 1982; [redacted], 1982).

This issue was very briefly mentioned in section 5.1 (page 9) of Addendum 2 for 1997–2011 (NIOSH, 2019a) as follows:

> Notably, discussions with the SEC-00188 petitioner as well as other members of the Security Force revealed concerns with work they performed in the SPR area.

Considering the severe radiation gradient at the SRP, SC&A does not find that external exposures received by the security force and related personnel would have been subject to the gradient because of the workers' physical locations. Therefore, special dosimetry would not have been needed, and the recorded whole-body doses would be appropriately recorded. However, SC&A did have the following observation.

Observation 7: SPR radiation gradient dose issue. The issue of exposure to severe radiation gradients would not be applicable to personnel working outside the immediate area of the bottom of the reactor vessel. However, the potential exposures to maintenance and operating personnel while performing close-up work on the SPR has not been sufficiently addressed and resolved.

The following is a summary of some of the radiation gradient issues to be addressed:

- It has not been established what year multiple dosimeters were required for work near the severe radiation gradients around the SPR.
- The method of recording post-1981 chest, head, and wrist dosimeter results and how they will be used for dose reconstruction has not been addressed.
- It has not been determined if, or how, the multiple-dosimeter data will be used to correct previous single-dosimeter data for dose reconstruction purposes.
- It has not been determined if this issue continued into the 1997–2011 evaluation period.

- A 1998 DOE Occurrence Report System (SNL, 1998c) indicates a dosimetry incident at the SPR involving a dosimeter (TLD) worn on the worker's head reading approximately twice the total dose registered on the electronic dosimeter worn on the chest. However, that report also noted that the dosimetry staff reviewed past data involving multibadging and did not find significant differences between chest and head exposure readings.

Although NIOSH stated in the SEC ER that "The data's usefulness for determining actual worker exposures has been assessed and corrections can be made enabling conservative estimation of bounding exposures" (NIOSH 2012, p. 60), the details of this methodology have not been provided.

While this is not likely a SEC issue because a bounding method could be used, these items need to be addressed and resolved.

6 Petition Basis for SEC-00188 (Petitioner Concerns Regarding Exposure Potential)

The Addendum 2 evaluation addressed the following "assertion" made for petition SEC-00188 on behalf of the petitioner, in Section 7.4.

> Assertion: *The petitioner asserted that* [job title redacted] *working at SNL-A were tasked with working in and around radioactive hazard areas and machines. Duties listed included the* [job duties redacted]. [The petitioner] *(and two other employees via affidavit) asserted that at times external monitoring devices were not properly worn and that no internal monitoring was performed. Additionally, results of requests for external monitoring records have been incomplete.* [NIOSH, 2019a, p. 33]

NIOSH reviewed available documentation regarding this assertion, describing how instances where the question of potential worker exposures for the indicated work by security guards[9] was identified, characterized, and monitored (or not monitored). Based on instances of potential intakes being identified in the early 1990s, Sandia management met with the personnel involved and agreement was reached (as outlined in an October 12, 1992, memorandum; [redacted], 1992) that a baseline urinalysis and whole-body count would be required of all current and new security guards, in addition to other internal dose monitoring provisions. As observed by NIOSH, however, subsequent decisions by Sandia management negated this agreement, and sitewide actions were taken to reduce the number of workers in the bioassay program commensurate with their assessed potential for radiological intakes. What bioassay samples were taken and submitted for analyses were analyzed by CEP. None of these results have ever been made available, with Sandia management ceasing contractual use of CEP services in 1994 because "quality control testing raised questions about the reliability of CEP's reports." (NIOSH, 2019a, p. 35).

As NIOSH noted in its Addendum 2 review, there are no internal monitoring records for any security guards based on a comparison of the listing of these individuals provided by Sandia

[9] Also known as Security Police Officers and Security Inspectors (SIs) during various time periods.

against the WebDose (2018) extract. NIOSH indicated that because security guards are not categorized as radiological workers by Sandia, they are only given general employee radiation protection training (GERT) and are not allowed in radiological control areas where there would be a potential for intakes. As indicated in section 7.2.3 of Addendum 2, exposures of nonradiological workers, including security guards, can be "bounded by application of a presumptive annual exposure of 100 mrem CEDE consistent with the monitoring threshold contained in 10 C.F.R. pt. 835, and as supported by available radiological survey data" (NIOSH, 2019a, p. 35).

For this presumption to be valid, it would need to be validated that security guards, as a worker category, were not potentially exposed to annual intakes that would have exceeded 100 mrem CEDE per year for the time period (1997–2011) in question. Because guards were not monitored for intakes and no records exist of any such measurements, SC&A looked for any evidence of work-related proximity to unsealed radiological sources where unmonitored intakes may have occurred. Instances where guards would have been in close proximity to contamination or operations where contamination potential was recognized would be likewise instructive.

There are indications, as noted in various interviews with security personnel, that because of growing security concerns, guards were moved closer to high-security nuclear and radiological sources and facilities and were posted in proximity to activities involving onsite materials testing of components, pulsed reactor experiments, the shipment of special nuclear components and mixed waste material, and routine surveillance of laboratory spaces. All of these activities carried some exposure potential, but other than an a priori conclusion that security guards were excluded from any locations where that potential was in excess of 100 mrem per year (thereby requiring monitoring under 10 CFR Part 835), no further review had been conducted of the likelihood that potential intakes would have exceeded that threshold internal dose. It is that presumption of minimal or no potential intakes for security guards in the course of their sitewide surveillance activities and facility security functions that has been challenged by the petitioner in previous statements to the Advisory Board and in interviews conducted by both NIOSH and SC&A.

6.1 Contention by security guards regarding potential radiation exposure

SC&A has reviewed documentation and interviews conducted with health physics personnel and security guards in 2011, 2014, and 2018 and agrees with NIOSH's accounting of the radiological exposure history of Sandia security guards outlined in Addendum 2, section 7.4, pp. 33–35 (NIOSH, 2019a). This included how the issue of internal dose evaluation arose in the early 1990s, how it was addressed in bioassay procedural changes in 1992 (wherein all security guards were placed on routine bioassay schedules), and how that policy was discontinued by 1993–1995[10] given concerns over the need for such monitoring and cost.

However, SC&A also determined that further review was warranted and requested an onsite interview and tour with the petitioner, which took place on January 15, 2020, to investigate further the issue of potential intakes during security surveillance work activities. The following is

[10] The precise date of bioassay discontinuation not clear.

a consolidated outline and assessment of information provided by the petitioners and their coworkers, both at this most recent interaction and in previous submissions and interviews.

1. The Sandia security guard force are roving personnel that support many different operational functions on site. The security guard force are not categorized as radiation workers at Sandia, are not trained beyond GERT, and are restricted from entering radiological areas, unless escorted by an RCT or qualified and monitored radiation worker (based on using the "escort in lieu of training" provision in the RPPM) ([redacted], 2014; [redacted], 2018). The guards were required to conduct routine facility surveillance across the site, including radiological laboratories, reactor areas, vaults and waste management sites, but as nonradiological workers, they were excluded from controlled areas.

2. Security guards are badged for external radiation (quarterly TLDs; refer to the 2020 interview summary in appendix 1) but are not categorized as radiation workers based on the RPPM (i.e., with a potential exposure of 100 mrem CEDE per year) and are not on a routine bioassay program or subject to lapel sampling. This RPPM policy is based on 10 CFR Part 835 (promulgated in 1995 and implemented by 1996) and postdates the 1992 initiative that led to temporary routine bioassay of security guards. Special bioassays may be ordered based on incidents; this has occurred with the security guard force on occasion ([redacted], 2018). When posted at and doing surveillance for the SNL reactors—SPR I, II and III and the Annular Core Research Reactor (ACRR)—guards did not normally use the hand and foot counters like the operating staff. Other disparities noted by interviews with the guards included instances where operators were issued pencil dosimeters and were given routine bioassays, whereas the guards had the standard site TLD dosimeter and were not on routine bioassay (refer to the 2020 interview summary in Appendix 1).

3. Movement of security guards was only permitted outside of controlled areas and sometimes in radioactive materials areas, and they would not normally be in a working contamination area or in any areas requiring frisking, such as a radiation buffer zone. Security barriers are typically physical barriers with guards outside the area. Locations posted as "Airborne Radioactive Areas" have been sufficiently characterized so as to demark boundaries within which personnel monitoring and protective equipment are required; the guard force would be restricted to surveillance outside of those boundaries. GERT training was intended to reinforce these restrictions regarding boundaries ([redacted], 2018).

4. Security guards observed that, from their perspective, the preceding boundary restrictions were not always enforced consistently. It was noted that there were situations where security guards were "going into areas they were not supposed to," for example, in Tech Area IV ([redacted], 2014, p. 2). Several provided accounts of entering corridors outside of hot cells where radioactive material was transferred, accessing special nuclear material (SNM) vaults within controlled areas, and escorting vehicles to waste management facilities. Two guards were stationed near the control room for nuclear effects shot sequences and would conduct surveillance in SNM vault areas and for SNM targets being handled (appendix 1).

5. In Tech Area V, security guards would access the vault and staff a guard post near the control room but not enter the KIVA or other contamination zones. Egress monitoring was provided for Tech Area V, but “not in the early days” ([redacted], 2014, p. 2). However, the presence of RCT personnel was acknowledged, and they would check for contamination[11] ([redacted], 2014; [redacted], 2014; [redacted], 2014).

6. In Tech Area III, which included the chemical and mixed waste management facility (RMWMF), guards conducted surveillance from outside the perimeter fence and did not routinely enter the dump area itself. However, based on interviews, guards did, on occasion, enter the RMWMF to conduct surveillance of a vault located on site but with limited entry to roped-off, unrestricted areas.

7. As noted in various interviews, guards were assigned to escort duties related to radiological materials being transported and stored in security bunkers. While exposure potential was primarily external in nature, an incident did occur in June 1992 that involved potential intakes of uranium and entailed special bioassays with urinalyses and whole-body counting. Of the five security guards receiving urinalyses, two had positive results for uranium isotopes, with an assigned dose “less than 1 mrem.” The lung counts performed were negative ([redacted], 1993, PDF p. 57).

8. One instance was found of a reported violation of radiological boundary restrictions by a security guard. In 1995, a guard conducting facility surveillance in a building inadvertently entered a contamination area. Upon being aware of this issue, the guard reported it to their supervisor and self-monitored, determining that contamination had occurred. The guard was subsequently bioassayed, and the results were negative (SNL, 1995b).

9. Security training exercises were identified as instances when security guards sometimes found themselves in potentially contaminated areas. For example, during training exercises in Tech Area V, guards recalled moving in and around taped-off radiation areas and using normally restricted entry points ([redacted], 2014).

10. Excess inventory was removed from laboratory spaces sometime around 2004–2007 to lower administrative costs at the laboratory. In interviews, guards mentioned an “Evergreen” initiative that had them perform extensive surveillance and security within facilities during this timeframe, with extended proximity to laboratories containing gloveboxes and sources. It was noted that materials were very well contained at that point, with low exposure potential. However, two buildings, which contained a number of laboratories, had fume hood vents on the roof, which showed some contamination readings in the mid-to-late 1990s. One security guard commented that they had contamination on shoes and more contamination was found in an adjacent roadway ([redacted], 2014; [redacted], 2014).

[11] Regarding Tech Area V, an internal review performed by Sandia health physics staff confirmed that “Since Radiological Control Technicians (RCTs) must be present in all work activities where the possibility of meaningful intakes is credible, their bioassay serves as a good proxy indicator for potentially exposed line personnel, while keeping the total monitoring burden low” ([redacted], 2001).

11. The guards, as a group, did not recall any significant radiological exposure concerns, except for some potential airborne contamination issues. None recalled anyone on the guard force becoming contaminated during surveillance activities, although it was recollected that there was one instance where contamination was claimed at the KIVA in Tech Area IV and another confirmed in an unusual occurrence report (refer to item 7 above). They expressed concern about conducting routine surveillance in facilities and outside areas where contamination or radiological exposure sources were suspected or present, and about not being afforded personal protective equipment (PPE) for protection or routine bioassays. Outside of the KIVA, interviewees claimed that communication with and surveillance by RCTs was minimal. There was concern that in high-security areas (e.g., Tech Area V), operators would vacate the facility upon an alarm going off, but the guards would stay at their posts (appendix 1).

6.2 Assessment of security guard exposure potential

SC&A identified several routine circumstances during which potential radiological contamination may have been present in the proximity of Sandia guards during security posting, training, and surveillance activities. These included laboratory surveillance in Tech Area I buildings, during security details near test shot locations where ground contamination may have been present (e.g., following rocket sled tests), and at the Tech Area V reactors and hot cell, where guards were posted in close proximity to operations and needed to secure material shipments from the Hot Cell area. Training activities at Tech Area V and other locations, as well as surveillance at SNM vaults, would have involved some—albeit infrequent—potential for proximity to low levels of contamination.

However, there is no evidence of any notable intakes by radiological workers or RCTs at any of those locations. For the RMWMF, procedures required continuing contamination surveys and posting. Security personnel would not have been permitted entry to any radiological contamination area where exposures to general employees was prohibited, as illustrated by the SNL (1995b) report submitted for the inadvertent exposure of a security guard in 1995 as discussed in section 6.1 above. SC&A has reviewed incident reporting (e.g., ORPS) for Sandia for 1997–2011: a total of 104 reported radiation protection incidents with 18 involving removable radiological contamination. SC&A has found no instances where the presence of such contamination resulted in worker intakes or where nonradiological workers had potential exposure subject to DOE reporting or bioassay followup. For the several instances where contamination was discovered in noncontrolled areas, the contamination was minimal and limited and not readily available for potential internal exposure.

7 Conclusions

In terms of the four lines of inquiry that were the core basis of SC&A's review of SEC ER Addendum 2, SC&A's conclusions are as follows:

1. **Question 1: Is the weight of evidence presented by NIOSH in Addendum 2 (as supported by Addendum 1 and the original SEC-00188 ER) sufficient to support dose reconstruction with sufficient accuracy for external doses by December 31, 1994, and for internal doses by December 31, 1996?**

SC&A concludes for external doses that there were no evident issues that would preclude dose reconstruction with sufficient accuracy, although there still remain several questions about how exposures by personnel to severe radiation gradients at the SPR were handled by SNL, and how NIOSH will apply the available dosimetry data to dose reconstruction. For internal dose, the weight of evidence supports the feasibility of dose reconstruction with sufficient accuracy for the time period in question.

However, SC&A was unable to verify fully the completeness of BZ monitoring results due to the lack of available records from which the total number of workers monitored via BZ, or the total number of BZ samples issued and processed, could be tabulated. These shortcomings are mitigated by the conservatism in NIOSH's approach, including (1) conservative selection of radionuclides of interest (e.g., Pu-239), (2) no credit taken for respiratory protection, and (3) the observed number of BZ samples per worker, which fell far short of the 200 events calculated in Addendum 2 as necessary to exceed the 100 mrem upper bound.

2. **Question 2: Was the implementation of 10 CFR Part 835 requirements for internal exposure monitoring sufficiently adequate by December 31, 1996, to provide assurance that a 100 mrem (CEDE) annual radiation monitoring requirement was being adequately implemented at SNL-A such that use of that value as a bounding dose in NIOSH's co-exposure model is supported?**

   SC&A concludes that based on documented program implementation experience and oversight results before and after the end of 1996, the 10 CFR Part 835 provisions for radiation exposure monitoring and recordkeeping were adequately implemented to support the application of a 100 mrem (CEDE) maximum dose as a means to bound internal dose in NIOSH's co-exposure model for SNL.

3. **Question 3: Are there any limitations or uncertainties related to dose reconstruction as a result of SNL-A reliance on personnel air sampling results as indicators for assignment of 100 mrem (CEDE) internal dose?**

   From SC&A's assessment, the weight of evidence supports the application of available personnel air sampling results as a means to justify the annual assignment of 100 mrem (CEDE) internal dose for workers who were not monitored, partially monitored, or solely monitored via BZ results. As previously noted, the lack of available BZ monitoring records is mitigated by the conservatism of NIOSH's dose estimation approach.

4. **Question 4: Is there evidence that security guards at SNL-A were potentially exposed to radioactive intakes of radionuclides that could have been in excess of 100 mrem CEDE per year that would not have been monitored?**

   Based on (1) extensive interviews with security guards who worked at SNL during 1997–2011, (2) an onsite tour of surveillance locations, (3) review of relevant records pertaining to radiological incidents, and (4) a review of internal intakes of bioassayed personnel at SNL facilities, SC&A concurs with the conclusions of ER Addendum 2 that it is unlikely that security personnel would have received an intake for which a 100 mrem annual dose (CEDE) would have been exceeded.

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Appendix 1: Interview and Tour Summary

At the April 17, 2019, Advisory Board meeting in Pittsburgh, Pennsylvania, the Sandia National Laboratories petitioner, [redacted], provided a public statement in response to NIOSH's presentation of its Addendum 2 ER for 1997–2011. In that oral statement, [redacted] indicated his disagreement with the NIOSH report. He noted that "nowhere in the report does it mention our [security guards'] concerns. We expressly told NIOSH that none of our officers were ever put on internal or personal air monitoring program" (ABRWH, 2019, p. 39). It was "reported that it would take 200 events in a year to receive a certain dose, I don't remember that. But that was an attainable goal within six months, within four, five, six months with most of our officers" (ABRWH, 2019, p. 39). A Sandia security guard accompanying [redacted], [redacted], also provided a statement that "there's an assumption that's being made that because of a philosophical change there [in 1997] that the program became robust overnight. We actually have . . . information that we got earlier this week, sir, where we know for sure that in 1997, '98 and '99, there were still incidences going on here at the labs, at least in those three years, where 835 was not being followed" (ABRWH, 2019, p. 40).

SC&A was tasked by the Advisory Board at this meeting to review the Addendum 2 report and to follow up on these and other petitioner issues. In subsequent discussions with the petitioners, SC&A agreed to conduct an onsite interview with Sandia security guards and, with NIOSH and members of the Board's Sandia work group, tour specific Sandia facilities and areas pertinent to security guard concerns over past potential radiation exposure.[12] This onsite visit occurred on January 15, 2020. A summary of the interview and tour was compiled by SC&A and reviewed for accuracy and representativeness by [redacted] and other security guard personnel. This summary is provided below.

Interview and Tour Summary SEC-00188 Evaluation Report, Addendum 2 Review, Sandia National Laboratories, 1997–2011

Date of interview and tour: January 15, 2020[13]

Interviewees: Security Guards [five commenting, names redacted]

Interviewers: Henry Anderson and Josie Beach, Advisory Board on Radiation and Worker Health
Joe Fitzgerald, SC&A, Inc. (Board technical contractor)
Chuck Nelson, NIOSH, and Tim Adler, Oak Ridge Associated Universities Team (ORAUT) (NIOSH technical contractor)

Observers: Ted Katz (Advisory Board liaison), Donald Brady (DOE San Francisco Field Office), SNL EEOICPA manager, two security guard managers

[12] Earlier interviews by both NIOSH and SC&A were conducted with Sandia security guards in support of the site profile and earlier SEC evaluation reports, specifically in 2014, 2017, and 2018.
[13] This summary was provided to the interviewees following the onsite interview for validation of its accuracy and representativeness and subsequently underwent DOE Headquarters classification review.

NOTE:

Although an abundance of good information was provided in the interview, this summary concentrates on areas that could potentially impact consideration of SEC status and/or claimants' dose assignments in the radiation dose reconstruction program under the Energy Employees Occupational Illness Compensation Program Act (EEOICPA).

Comments are included in brackets where SC&A has provided clarification to the site expert's statement.

Required Project Statement

Please be informed that your participation in this discussion is voluntary. Information you provide will be treated in a confidential manner and will not be attributed to you in a public manner without your express permission. The information you provide may be shared with officials from NIOSH, other federal agencies, and the Advisory Board on Radiation and Worker Health (ABRWH), who are involved in implementing the Energy Employees Occupational Illness Compensation Program Act (EEOICPA). In addition, information that you provide may be referenced (without identifying your name or personal information) in technical documents that are posted on the NIOSH website and made available to the public. You will have an opportunity to review SC&A's written summary of your interview to ensure that we accurately report the information provided to us in this interview.

Advisory Board Statement

Thank you for taking the time to speak with us today. We really appreciate your help. This interview is being conducted as part of an independent technical review of the SEC Petition Evaluation for the Sandia National Laboratories (SNL). Please note this interview and your responses are not a formal affidavit, or legal document, but a tool to assist the Advisory Board in understanding the site operations and radiation monitoring practices.

Since this site was part of the DOE Nuclear Weapons complex, there are certain restrictions as to what can be discussed here today in an uncontrolled area. We ask that you not disclose any sensitive or potentially sensitive information with us today. If you believe this type of information is necessary to our understanding of the site operations and radiation monitoring practices, we will be happy to arrange a secure follow-up interview where you will be allowed to discuss sensitive information. Do you have any questions?

Lines of Inquiry

The following are advance questions that were provided the interviewees as background for this interview.

1. What was the standing policy or procedure for security guards entering designated radiation areas or zones during routine surveillance or inspections? How were guards trained when it came to radiation protection? What monitoring was prescribed, e.g., BZ (breathing zone; "lapel") air sampling or bioassay monitoring, and did health physics monitors ever accompany guards for particular inspections or surveillance?

2. Were there any radiological areas (including contamination and buffer areas) that you were assigned to provide surveillance? Did any of these involve actually entering a

radiation control zone? Which ones were of most concern to the guard force? Were there any security guard posts located inside of a facility containing radiation sources; which ones were those? Was airborne and/or surface contamination a problem? How often were guards found to be contaminated and was this reported?

3. How often were guards checked for potential intakes via nasal swabs or special urinalyses? Was there any procedure that guards followed at the time when they suspected or were found to be contaminated? Did the guards receive any reporting from Sandia regarding either external or internal radiation exposure, or suspected intakes? Did you receive whole body counting – if so, how often?

4. Do you recall any unusual circumstances, radiation sources, or incidents involving radiation at Sandia after 1995 involving the guard force? Did contamination alarms (CAM alarms) go off in the guards' vicinity – what happened? Were you concerned about potential exposures, particularly intakes, from any of these?

5. Did you ever find yourself in a radiation control zone along side of a worker with personal protective equipment (e.g., respirator, anti-contamination clothing, gloves, etc.)?

6. Did you ever conduct security inspections or perform other duties at the RMWMF (radioactive waste landfill)? How were these conducted? What personal protective equipment was worn, if any, and what procedures were followed for radiation protection purposes? Was any contamination ever detected on your person afterwards?

7. Was there a notable change in radiation monitoring or practice from the early 1990s to the late 1990s? How so? From your recollection, what was the reason for this change?

8. Were you or other security guards present during any testing at Sandia involving radiation sources (e.g., "boom boxes")? If so, we may want to hold a secure interview regarding the radiological monitoring involved.

9. Do you recall if the bioassay monitoring program for security inspectors that was phased out by 1995 ever showed any positive intakes? What was the discussion surrounding both the introduction of bioassay monitoring and its eventual phase out?

10. Is there anything else from your work experience in the late-1990s that would relevant to radiation exposure monitoring, radiological controls, incidents, and dose records? Do you believe potential radiation exposure or intake of radionuclides were missed at the time?

Tour Summary

[An onsite tour of security guard surveillance routes and facility locations at Sandia National Laboratories-Albuquerque was provided the Advisory Board members, SC&A, NIOSH, ORAUT, and other personnel present. The tour was intended to provide background and perspective for the interviewers on the exposure concerns of the petitioners and their coworkers.]

Technical Area I

The "horseshoe" Buildings 805, 806, and 807 included radiation-related work from the first floor to the basement. After 1996, there was a considerable change to facilities, with the three-story buildings being demolished sometime just after 2000. Chemical laboratories were located in the three buildings, with radiological work in one of them. The security guards conducted routine patrols on every floor of this complex, with surveillance focused on ensuring no classified items left out, no coffee pots left on, and generally nothing amiss. Typically, one guard was assigned to each facility. At times, security guards were stationed within these facilities, but that was limited to 6 months to 2 years.

Guards were badged quarterly with TLDs. In the early 1990s, it was revealed that their bioassays were not handled seriously, with CEP [a radiological monitoring vendor] being alleged to have not processed its bioassays correctly.

Two buildings apparently contained special "material," and the security guards had no direct access to one of them, but did patrol the other. Building 867 is illustrative of 8–9 similar buildings that were eventually demolished. When they were being used, the guards conducted considerable surveillance in them and for some, were stationed there. The guards were also stationed adjacent to pools that contained nuclear rods that were roped off.

Technical Area V

There was radiological metal handling in two TA-V buildings. Guards were posted whenever large entry doors were open to the hot cell; sometimes that was "24/7" when testing was being performed. When the gloveboxes adjacent to the hot cell were being used for radiological analyses, the doors were closed and the guards stationed just outside the hot cell area. Radiological material was stored in room 109; components were contaminated, and security was stringent for accountability purposes. They were stationed just inside the door when opened for SNM deliveries, and were reassured that that location was "OK" from a radiation dose standpoint. It usually took as long as a full day (the day shift) to accomplish these operations. The guards would conduct surveillance around the reactors, but did not normally use the hand and foot counters like the operating staff would.

There was a "dirty," dilapidated building that entailed some surveillance and was the location for security guard training on occasion. It was torn down 4–5 years ago but was active as recently as 2004–2005.

The security force also conducted patrolling of received SNM components.

Technical Area IV

Conducted nuclear shots for nuclear effects studies, as well as critical assembly experimentation. Guards were stationed around these operations "24/7" and there were often lengthy "shot" sequences that could take months and even years to complete. Two guards were stationed by a control room bathroom at a point furthest away from the "Kiva," where the reactor irradiations were being done. The guard force also had regularly access to the North Vault within the facility and would man security posts on the grounds. Guards would be called upon to conduct surveillance for any SNM targets before shots took place. Guards were originally stationed outside of the reactor building, adjacent to a “dog run” fenced security corridor, but were moved inside the facility in 2003–2007 (in 2007, all SNM was removed). They would accompany supervisors for “end of shift” sweeps of the area to ensure workers were accounted for. It was noted that a back entrance (“echo door”) was located at the facility, which was used by the security guards during nonoperational hours training exercises (for which no monitoring was performed).

Technical Area III

Includes chemical and radioactive and mixed waste management facility (RMWMF). Waste material comes from entire site, including Area IV reactors. Ten years ago, guards conducted surveillance of gates and fence line from the outside (perimeter fire checks) but did not go into the dump area itself. However, guards did standby as workers sifted through containers of dirt to screen out rocks and other artifacts (the facility manager confirmed that the soil being sifted was from the area of the nearby chemical dump area and had been monitored as nontoxic and nonradioactive. Guards would also respond to entries to the vaults located at the RMWMF but were instructed not to go beyond the yellow ropes where contamination had been identified and would have been distant from any active operations. Typically, the guards would stay away from waste management operations, such as soil sifting and processing, because they tended to be very dusty (although “wet” methods were used to reduce dust). It was known that some of the waste material was from onsite decontamination and decommissioning (D&D) and could include low-level radioactive contamination.

Technical Area II

The buildings in this older area (e.g., 919 and 920) had been demolished and D&D’d years before. However, the guards still had to conduct surveillance in and around the area.

General

The security guards were training at the various area facilities, had moved and even crawled through many of the hallways and floors present, and did not consistently use hand and foot counters to check for contamination. This was also the case when escorting SNM and other radioactive materials out of facilities.

As a function of the security sensitivity of an operation or facility, there may have been additional guards assigned. This was the case with the “Evergreen” project. It was also the case when guards were moved closer to secure facilities and sources, particularly in 2003–2007, as concerns elevated because of terrorist threats.

There seemed to be a disparity in how monitoring was assigned: Operators routinely made use of real-time pencil dosimeters and participated in the routine bioassay program, whereas the guards typically had regular TLDs (albeit, on occasion, the guards apparently were issued pencil dosimeters). In one instance, in the 1990s, a couple of guards were exposed to negative air pressure in a radiological facility and were given special bioassays (which were negative).

There were about 150–200 guards on the force by the 2000s.

Regarding one building, if certain facility alarms went off, the security guard force was required to respond and man specific places in and around the facility.

Group Interview

Security Guard 5. [redacted] as a security inspector in 1992.

Security Guard 6. Has worked at the site for [redacted] years as a security inspector/guard.

Security Guard 7. Has worked on site for [redacted] years as a security inspector/guard in all areas.

Security Guard 8. [redacted] in 1984 as a security inspector.

Security Guard 9. Has worked on site for [redacted] years as a security inspector/guard.

To open the interview, the security guards present were asked whether there were any instances during which they had felt unsafe from a radiation protection standpoint or where their monitoring was not consistent with others in the same location. All three security guards being interviewed at that point stated they were "uncomfortable" working in "dorm south" in TA-V. They were uneasy hearing alarms go off during shots and noted that scientists exited the building [KIVA control room?] while leaving the guards, in place, at their stations. It was noted that radiological monitors were used, and it was likely contamination wipes were also used, but the guards were not sure on that. It was noted by one security guard that he thought some of the RCTs tried to "max" their monthly administratively allowed dose early in the month. None of the guards recall any significant exposure concerns, overall—perhaps, just some potential air contamination. However, they are concerned that their TLDs always read "zero" dose, despite the facility alarms going off regularly.

There was a discussion by one guard of his experiences in one particular building in TA-V. He recalled being stationed in this 8-foot-high posting, with his hand-held monitor alarming during actual testing in the TA-V reactors. The security force did not see any positive results on their TLDs, but it was indicated that they sometimes wore them under their protective vests. Operators would leave the reactor building during shots, leaving the guards stationed there. One area of exposure concern were penetrations ("tubes") that went all the way through the wall of containment. He indicated that they observed stationary TLDs at various building locations, including adjacent to walkways and on the fence. The operators wore pencil dosimeters in addition to their TLDs—some question of whether the external dosimetry would actually detect "pulsed" radiation from test shots and whether TLDs worn by security guards were appropriate for the pulsed radiation they may have been exposed to. The security guards walked near hot cells all the time. They were required to be present in the exchange room when SNM material was being transferred. It was recalled there were frequent alarms in that area; RCTs were getting "overused" monitoring in this area.

The discussion turned to the radioactive waste dumps. The security guards were involved in perimeter surveillance when the dumps were being cleaned up. The cleanup crews were dressed out in air packs and had worked in "tents" during cleanup work. The guards were only 50 yards away at the fenceline, parked near the rocket sled track, and were scanned by RCTs. At the RMWMF, they conducted routine patrols and building walkthroughs, but they did not enter the

RMWMF when active packaging and processing operations were being conducted. One guard recalls smelling and seeing what he considered to be hazardous materials at the RMWMF, including an instance when a waste container "cracked" and two employees "died within a couple of hours."

Security guards performed surveillance of a long "tin" building in Area V. This building was taped for radiation contamination and cordoned off; was unused for years. They also conducted surveillance activities at nuclear material security bunkers and provided perimeter security.

In SNL laboratories, guard patrols were told to walk down the laboratory spaces but were not informed of what radiological sources or contamination might be present. There was particular concern over two buildings, in particular. There was no protocol for use of hand and foot counters for security guards upon leaving most facilities; they were only required upon egress from the Gamma Irradiation Facility, ACRR, and the KIVA. They were not issued PPE and were rarely scanned by RCTs during their surveillance duties (it was noted that one of the guards had been stationed at the rocket sled area at least 50 times but was only scanned by an RCT once). Communication with RCTs was only routine at the KIVA; otherwise, it was rare. None of the guards recalled anyone on the security force being found contaminated, albeit they recall one guard claiming contamination at the KIVA on one occasion. It was noted that during the tritium gun sight contamination event, bioassay readings were found to be very low.

In surveillance of TA-2, guards frequented a diamond-shaped area, including a hallway to one of the buildings. There was a hot spot near a walkway and guards were advised to walk around it, but none were aware of the 1995–2000 cleanup that had taken place. Depleted uranium was found in an arroyo, stemming from an upstream impact testing site; for that reason, guards tried to walk around the arroyo.

In TA-V, in 1998, Sandia was "running low on radiological isotope," and Sandia was conducting tests on radiological isotope development. Some of these sources were held for some time. It was noted that in one instance, a guard had to be stationed with such a source for 12 hours, and literally sat on the source.

In TA-1, guards needed to check a safe in a contaminated area, and needed to scan their shoes twice during a shift and often had to clean them off. This continued from 1986 into the 1990s until the buildings in question were cleaned up.

In one building, the security guards had to check whether lights were functional and could see "rods" being pulled. Radiological scans were being taken when a tarp was removed, setting off detectors in adjacent buildings.

One guard recalled that in the 1995–1996 timeframe, he had sat too close to a "substance" at KIVA and had to "give up his pants."

Appendix 2: Analysis of BZ Sampling Results by Month

As summarized in section 4.1, SC&A evaluated the captured BZ records on a monthly basis, as shown in tables 2A, 2B, and 2C of this appendix. Table 2D summarizes all 15 years evaluated. Figures 2A and 2B show the total number of BZ samples per month and the percentage of annual samples per month, respectively.

Table 2A. SC&A tabulation of the number of breathing zone results by month, 1997–2001

Month	Total 1997 (% of annual total)	Total 1998 (% of annual total)	Total 1999 (% of annual total)	Total 2000 (% of annual total)	Total 2001 (% of annual total)
January	7 (1.9%)	53 (3.4%)	96 (14.0%)	53 (15.4%)	13 (7.6%)
February	18 (4.9%)	84 (5.3%)	110 (16.1%)	54 (15.7%)	10 (5.8%)
March	26 (7.1%)	342 (21.8%)	147 (21.5%)	0 (0.0%)	36 (21.1%)
April	35 (9.5%)	155 (9.9%)	45 (6.6%)	20 (5.8%)	10 (5.8%)
May	32 (8.7%)	164 (10.4%)	85 (12.4%)	57 (16.5%)	8 (4.7%)
June	41 (11.2%)	150 (9.5%)	32 (4.7%)	43 (12.5%)	12 (7.0%)
July	19 (5.2%)	132 (8.4%)	53 (7.7%)	45 (13.0%)	4 (2.3%)
August	49 (13.4%)	166 (10.6%)	24 (3.5%)	38 (11.0%)	16 (9.4%)
September	44 (12.0%)	106 (6.7%)	31 (4.5%)	22 (6.4%)	2 (1.2%)
October	26 (7.1%)	52 (3.3%)	5 (0.7%)	3 (0.9%)	12 (7.0%)
November	54 (14.7%)	142 (9.0%)	23 (3.4%)	0 (0.0%)	8 (4.7%)
December	16 (4.4%)	26 (1.7%)	34 (5.0%)	10 (2.9%)	40 (23.4%)
Annual total	367	1,572	685	345	171

Table 2B. SC&A tabulation of the number of breathing zone results by month, 2002–2006

Month	Total 2002 (% of annual total)	Total 2003 (% of annual total)	Total 2004 (% of annual total)	Total 2005 (% of annual total)	Total 2006 (% of annual total)
January	19 (4.3%)	38 (8.6%)	0 (0.0%)	16 (9.1%)	0 (0.0%)
February	19 (4.3%)	45 (10.1%)	0 (0.0%)	32 (18.2%)	7 (6.5%)
March	49 (11.2%)	28 (6.3%)	0 (0.0%)	35 (19.9%)	15 (13.9%)
April	18 (4.1%)	16 (3.6%)	13 (10.2%)	21 (11.9%)	14 (13.0%)
May	45 (10.3%)	30 (6.8%)	8 (6.3%)	22 (12.5%)	12 (11.1%)
June	28 (6.4%)	28 (6.3%)	17 (13.3%)	20 (11.4%)	14 (13.0%)
July	52 (11.8%)	73 (16.4%)	40 (31.3%)	6 (3.4%)	8 (7.4%)
August	70 (15.9%)	37 (8.3%)	27 (21.1%)	0 (0.0%)	0 (0.0%)
September	20 (4.6%)	66 (14.9%)	16 (12.5%)	4 (2.3%)	24 (22.2%)
October	63 (14.4%)	30 (6.8%)	4 (3.1%)	6 (3.4%)	12 (11.1%)
November	31 (7.1%)	8 (1.8%)	0 (0.0%)	14 (8.0%)	0 (0.0%)
December	25 (5.7%)	45 (10.1%)	3 (2.3%)	0 (0.0%)	2 (1.9%)
Annual total	439	444	128	176	108

Table 2C. SC&A tabulation of the number of breathing zone results by month, 2007–2011

Month	Total 2007 (% of Annual Total)	Total 2008 BZ's (% of Annual Total)	Total 2009 (% of Annual Total)	Total 2010 (% of Annual Total)	Total 2011 (% of Annual Total)
January	3 (2.7%)	20 (10.0%)	4 (1.7%)	26 (8.9%)	5 (1.6%)
February	0 (0.0%)	12 (6.0%)	3 (1.3%)	30 (10.3%)	28 (9.1%)
March	0 (0.0%)	25 (12.5%)	10 (4.3%)	27 (9.2%)	46 (15.0%)
April	0 (0.0%)	29 (14.5%)	11 (4.7%)	28 (9.6%)	52 (16.9%)
May	0 (0.0%)	42 (21.0%)	7 (3.0%)	20 (6.8%)	42 (13.7%)
June	0 (0.0%)	32 (16.0%)	32 (13.7%)	29 (9.9%)	41 (13.4%)
July	0 (0.0%)	39 (19.5%)	26 (11.1%)	15 (5.1%)	39 (12.7%)
August	9 (8.1%)	0 (0.0%)	51 (21.8%)	21 (7.2%)	33 (10.7%)
September	26 (23.4%)	0 (0.0%)	26 (11.1%)	26 (8.9%)	13 (4.2%)
October	24 (21.6%)	0 (0.0%)	19 (8.1%)	41 (14.0%)	7 (2.3%)
November	26 (23.4%)	0 (0.0%)	20 (8.5%)	16 (5.5%)	1 (0.3%)
December	23 (20.7%)	1 (0.5%)	25 (10.7%)	13 (4.5%)	0 (0.0%)
Annual total	111	200	234	292	307

Figure 2A. Total captured breathing zone samples by month, 1997–2011

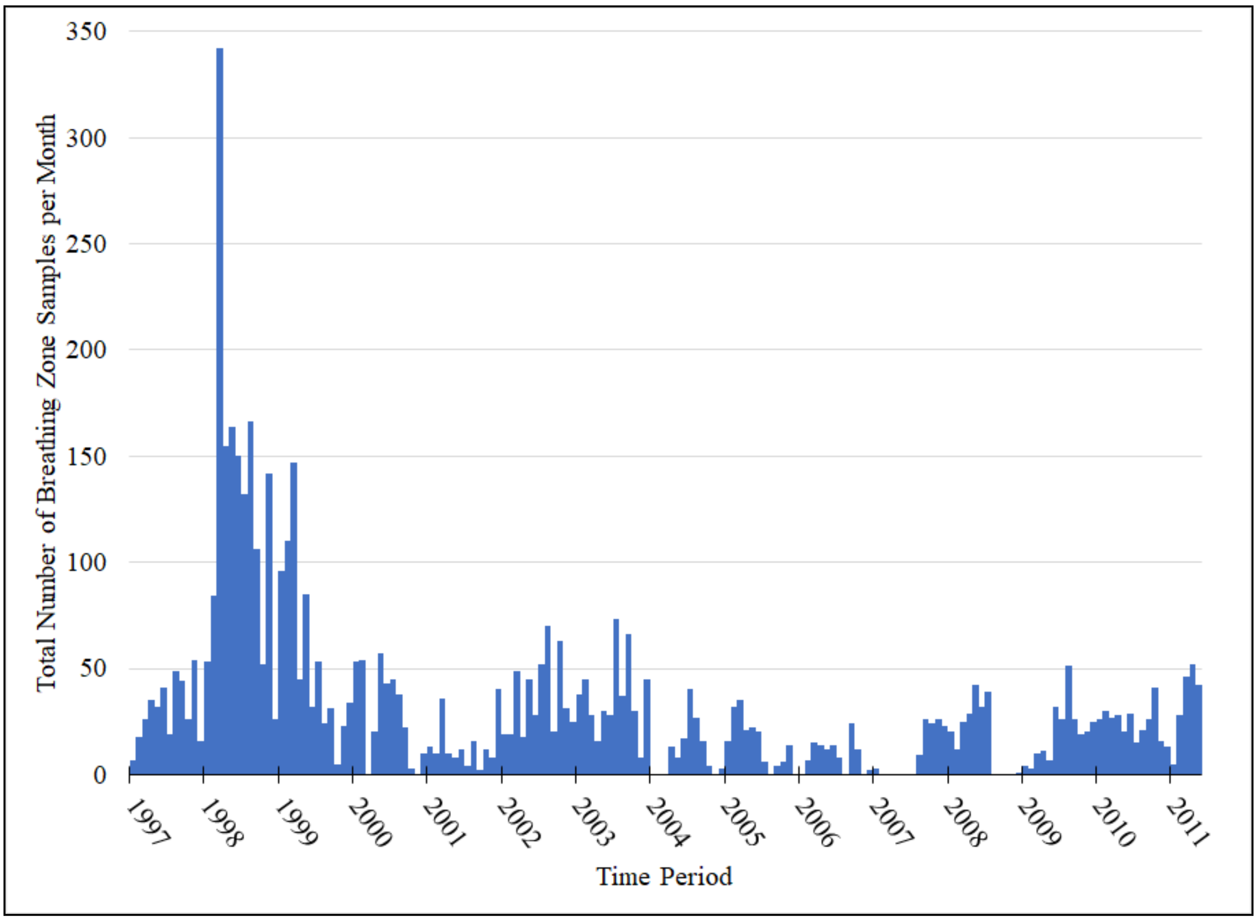
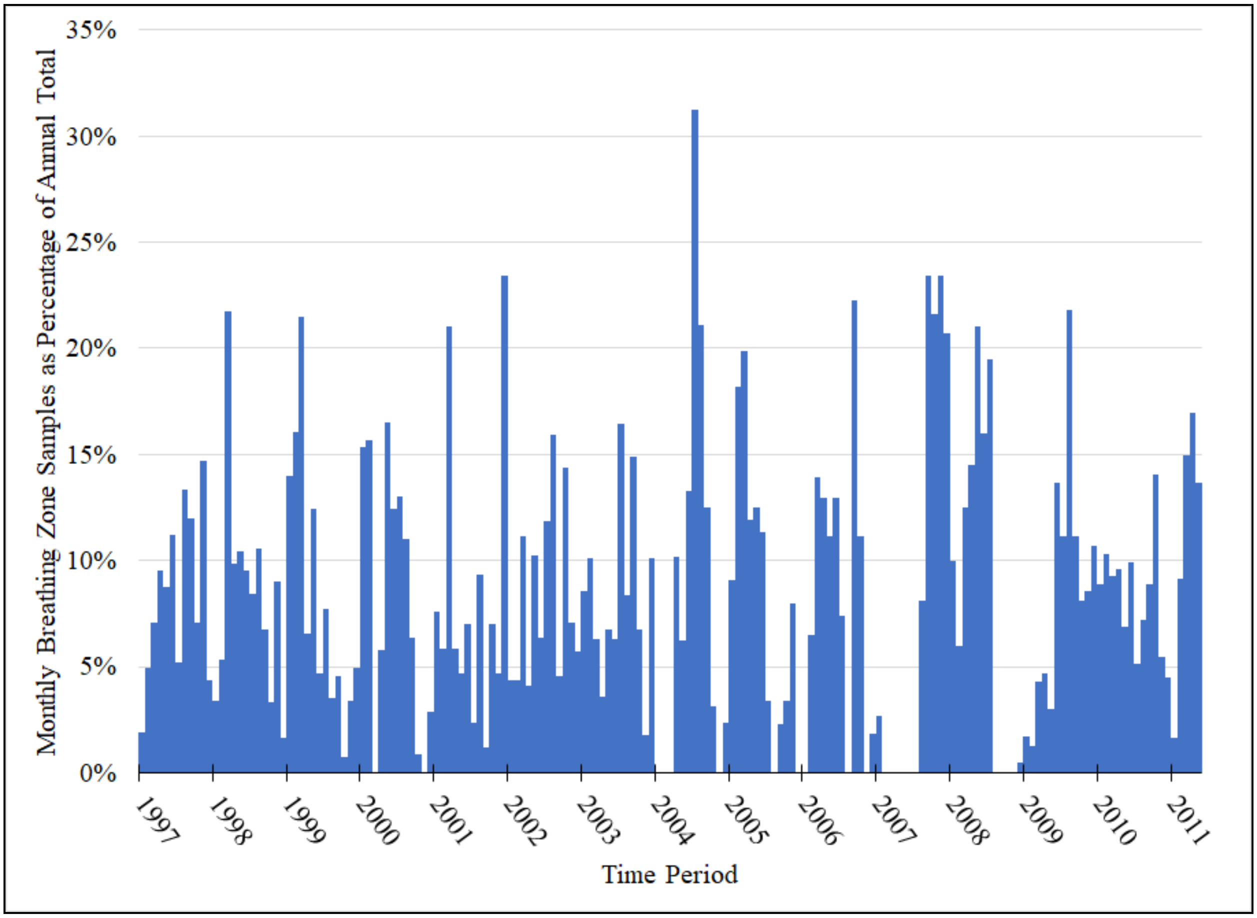


Figure 2B. Captured breathing zone samples by month as a percentage of the annual total, 1997–2011



In addition to a summary of the monthly analysis, table 2D also provides the total number of unique days per year that had at least one BZ sample captured as well as the average and maximum number of observed days between BZ samples. It must be noted that weekend days were not subtracted when evaluating the number of days between observed BZ samples. Interestingly, aside from 1997 and 1998, nearly all the captured BZ samples were taken on Monday through Thursday.

Table 2D. Summary of monthly temporal analysis and overall data gaps

Year	Range of BZ samples by month as a percentage of annual total	Months with no captured BZ results	Total days with BZ samples taken	Average number of days between BZ samples in year [(a)]	Largest number of days between BZ samples in year [(a)]	Additional comments
1997	1.9%–14.7%	None	134	2.8	29	Total unique days with BZ samples taken includes 12 weekend days. The largest gap between samples (29) occurred from January 1 through January 29.
1998	1.7%–21.8%	None	216	1.8	17	Total unique days with BZ samples taken includes 54 weekend days. The largest gap between samples occurred at the end of December and thus might be explained by typical vacation usage. The next largest gap was 8 days occurring in late April.
1999	0.7%–21.5%	None	124	3.1	29	Largest gap between samples (29) occurred from mid-October to mid-November. No BZ samples were identified for weekend days, and BZ samples were only identified for five Fridays during the year.
2000	0.0%–16.5%	March, November	83	4.7	50	For the 2 previous years (1998 and 1999), the largest percentage of samples occurred in March (roughly 22% of the annual total in each year). However, no samples were identified in March 2000. The largest gap between BZ sampling dates was 50, which occurred from late October into mid-December.
2001	1.2%–23.4%	None	84	4.7	25	Largest gap between samples (25) occurred twice: late August–late September and November 1–26. All observed BZ samples occurred on Monday through Thursday.
2002	4.1%–15.9%	None	157	2.5	23	Largest gap between samples (23) occurred between December 2001 and January 8, 2002. No BZ samples were identified for weekend days, and BZ samples were only identified for six Fridays during the year.
2003	1.8%–16.4%	None	127	3.7	105	The observed gap (105 days) occurred from late December 2003 through the beginning of April 2004. Aside from two Saturdays for which BZ data were found, all other BZ results were taken on Monday through Thursday.

Year	Range of BZ samples by month as a percentage of annual total	Months with no captured BZ results	Total days with BZ samples taken	Average number of days between BZ samples in year [(a)]	Largest number of days between BZ samples in year [(a)]	Additional comments
2004	0.0%–31.3%	January–March, November	43	8.9	106	Gap in first 3 months of 2004 continues the gap from 2003 in which no captured data were identified. A gap in November is surrounded by only 4 BZ results in October (3.1%) and 3 BZ results in December (2.3%). All observed BZ samples occurred on Monday through Thursday.
2005	0.0%–19.9%	August, December	65	6.6	85	Largest gap between samples (85) occurred from mid-November through early February 2006. Aside from a single Friday, all BZ samplers occurred Monday through Thursday.
2006	0.0%–22.2%	January, August, November	48	8.7	85	Largest gap between samples (85) occurred from mid-November 2005 through early February. All observed BZ samples occurred on Monday through Thursday.
2007	0.0%–23.4%	February–July	39	9.8	231	Largest gap between samples (231) occurred from early January through late August. All observed BZ samples occurred on Monday through Thursday.
2008	0.0%–21.0%	August–November	74	5.7	134	Largest gap between samples (134) occurred from late July to mid-December. All observed BZ samples occurred on Monday through Thursday.
2009	1.3%–21.8%	None	94	4.3	37	Largest gap between samples (37) spanned from mid-January to mid-February. All observed BZ samples occurred on Monday through Thursday.
2010	4.5%–14.0%	None	125	3.2	28	Largest gap between samples (28) occurred from late December 2010 through mid-January 2011. All observed BZ samples occurred on Monday through Thursday.
2011	0.0%–16.9%	December	87	4.3	42	Largest gap between samples (42) occurred from mid-October through the end of November. However, it should be noted that this falls outside the evaluated SEC period. BZ samples were identified for only 12 Fridays during the year, and none were observed for weekend days.

[(a)] Number of days between samples in these column spans across concurrent months and concurrent years.