Draft

Advisory Board on Radiation and Worker Health
National Institute for Occupational Safety and Health

Summary of Key Issues Concerning Internal Monitoring Completeness and Representativeness for SRS Subcontractor Construction Trade Workers

Contract No. 75D30119C04183
Document No. SCA-TR-2021-SEC002, Revision 0

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March 8, 2021

SC&A, Inc. technical support for the Advisory Board on Radiation and Worker Health's review of NIOSH dose reconstruction program

Document title	Summary of Key Issues Concerning Internal Monitoring Completeness and Representativeness for SRS Subcontractor Construction Trade Workers
Document number	SCA-TR-2021-SEC002
Revision number	0 (Draft)
Supersedes	NA
Effective date	March 8, 2021
Task manager	Joe Fitzgerald, MS, MPH [signature on file]
Project manager	Gregory P. Beronja, PE [signature on file]
Document reviewer(s)	Rose Gogliotti, MS [signature on file]

Record of revisions

Revision number	Effective date	Description of revision
0 (Draft)	3/8/2021	Initial issue

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Abbreviations and Acronyms

ABRWH, Board	Advisory Board on Radiation and Worker Health
Am	americium
Cf	californium
Cm	curium
CTW	construction trade worker
DCAS	Division of Compensation Analysis and Support (NIOSH)
DOE	U.S. Department of Energy
dpm/L	disintegrations per minute per liter
DPSOL	DuPont Standard Operating Logsheet
EE	energy employee
FP	fission product
GSD	geometric standard deviation
MPPF	Multi-Purpose Processing Facility
NIOSH	National Institute for Occupational Safety and Health
NOCTS	NIOSH DCAS Claims Tracking System
non-H3	non-tritium
Np	neptunium
ORAUT	Oak Ridge Associated Universities Team
Pu	plutonium
RWP	Radiological Work Permit
sCTW	subcontractor construction trade worker
SEC	Special Exposure Cohort
Sr	strontium
SRDB	Site Research Database
SRS	Savannah River Site
SWP	Standing Work Permit
Th	thorium
TRU	transuranic
U	uranium
WBC	whole-body count
WSRC	Westinghouse Savannah River Company

1 Executive Summary

On October 21, 2020, the Savannah River Site (SRS) Work Group tasked SC&A to review ORAUT-RPRT-0094, revision 00, "Bioassay for Subcontractor Construction Trade Workers at the Savannah River Site from 1972 to 1997" (NIOSH, 2019b; hereafter "RPRT-0094"). RPRT-0094 is the National Institute for Occupational Safety and Health's (NIOSH's) September 13, 2019, overview and evaluation of SRS internal monitoring data for all subcontractor claimant records in the NIOSH DCAS Claims Tracking System (NOCTS) database. SC&A scanned this report when it was originally issued. However, ORAUT-RPRT-0092, revision 00, " Evaluation of Bioassay Data for Subcontracted Construction Trade Workers at the Savannah River Site" (NIOSH, 2019a; hereafter "RPRT-0092"), which addressed the completeness and representativeness of subcontractor bioassay data as they related to permitted work, was considered the more relevant review and was given priority by the work group at the time.

However, NIOSH's presentation before the full Advisory Board on Radiation and Worker Health (ABRWH, Board) on December 9, 2020 (NIOSH, 2020c), made RPRT-0094 and plutonium logbook data a central part of its new "weight-of-evidence" argument for dose reconstruction feasibility for SRS subcontractor internal dose, along with RPRT-0092. Therefore, the work group asked SC&A to consider this additional information in the context of a now-expanded basis for NIOSH's conclusion that all these data would support a co-exposure model for SRS subcontractors, consistent with the guidelines in DCAS-IG-006, revision 00, "Criteria for the Evaluation and Use of Co-Exposure Datasets" (NIOSH, 2020a).

SC&A's review of RPRT-0094 confirms SC&A's original, informal assessment: While a considerable amount of data covers the timeframe and facilities in question, it suffers from two basic flaws: (1) it homogenizes all forms of SRS internal monitoring data into a single metric for application, which precludes a definitive treatment of data completeness for specific radionuclide source terms; and (2) more fundamentally, it does not substantiate the actual representativeness of the claimant data sample collected as compared to that of the overall site worker population.

As pointed out by NIOSH itself at the December 2019 work group meeting, "there is a potential detriment" to a NOCTS-based approach, in that "we can't directly compare coworkers, therefore, the data completeness must be inferred." (ABRWH, 2019a, p. 216). While a NOCTS-based approach does offer some advantages in its simplicity, timeliness, and resource efficiency, SC&A continues to conclude that it does not meet the intent of DCAS-IG-006 that data completeness be determined from sufficient measurements established from monitored workers with comparable activities and relationships to the radiation environment.[1]

For the plutonium logbook bioassay data presented by NIOSH (2020c), SC&A likewise finds that while there is a considerable amount of data covering the timeframe and facilities in question, it consists almost exclusively of routine bioassay samples. Such information does not

[1] DCAS-IG-006 (NIOSH, 2020a) stipulates that "co-exposure datasets should be established from monitored workers with comparable activities and relationships to the radiation environment" (p. 4) and that "the amount of available monitoring data must be evaluated to determine if there are sufficient measurements to ensure that the data are either bounding or representative of the exposure potential for each job/exposure category at the facility" (p. 6).

address permit-driven, job-specific bioassays and would not serve to either bound or represent those nonroutine exposures for the years in question.

As emphasized in its December 2019, November 2020, and December 2020 presentations before the work groups and full Board (SC&A, 2019b, 2020b, 2020c), SC&A continues to view RPRT-0092 as the only assessment that gives due focus and treatment of the central issue for which the Board requested NIOSH's attention in 2017. That issue is the completeness and representativeness of subcontractor permit-driven, job-specific bioassays in light of substantial gaps in such bioassays confirmed by both Westinghouse Savannah River Company (WSRC) and the U.S. Department of Energy (DOE) in 1997. The carefully designed NIOSH sampling plan (NIOSH 2018) and extensive data captures in 2016–2019 were directed at answering that question. However, in SC&A's estimation, they came up short due to a lack of identifiable, representative job-specific bioassay data, particularly for the 1972–1990 period. NIOSH's conclusions from RPRT-0092 and SC&A's review of it have been discussed extensively before the work group and full Board and are summarized in attachment A of this report.

In conclusion, SC&A does not find that the analysis of claimant subcontractor data in RPRT-0094 and the evaluation of the captured plutonium logbook data for subcontractors adequately address the original concerns about permit-driven, job-specific bioassay monitoring. It is SC&A's position that the original concerns related to the job-specific bioassay program can only be adequately addressed through a direct connection between available internal monitoring data and Radiological Work Permit (RWP) monitoring requirements as analyzed in RPRT-0092.

2 Introduction and Background

The issue of job-specific, permit driven bioassay completeness for subcontractor construction trade workers (sCTWs) has been the central topic of discussion about Special Exposure Cohort (SEC) Petition SEC-00103 since at least 2017. The issue was promulgated on the basis of a 1998 DOE citation and fine of the WSRC for inadequate monitoring of workers performing radiation work under job-specific RWPs (DOE, 1998a, 1998b). Subsequent deliberations by the Board in concert with NIOSH and SC&A ultimately resulted in a full evaluation of RWP-driven internal monitoring requirements in comparison to actual available monitoring data. NIOSH presented this evaluation in RPRT-0092. This report has undergone technical review by SC&A (2019), with subsequent exchanges of two response papers (NIOSH, 2020b; SC&A, 2020a). Discussions of this issue were held by the joint SRS-SEC Issues work groups and the whole Board on several occasions (ABRWH, 2019a, 2019b, 2020a, 2020b, 2020c).

As a supplemental analysis of internal monitoring for subcontractors, NIOSH released RPRT-0094 in September 2019. This NIOSH report documents a thorough overview and evaluation of all the available internal monitoring data for all subcontractor claimant records contained in the NOCTS database at the time of its writing. However, it is important to note that SC&A does not believe RPRT-0094 provides any additional information about the direct connection between the requirements of job-specific, permit-driven internal monitoring and the completeness of such monitoring records, as was the original concern posited by the Board as far back as 2017 (ABRWH, 2017). Due to general timing of the report, as well as questions related to the relevancy of the contents of RPRT-0094 regarding the evaluation of job-specific

bioassays, RPRT-0094 was not discussed during the joint meeting of the SRS and SEC Issues work groups that occurred in December 2019 (ABRWH, 2019a, 2019b).

However, during the subsequent joint videoconference of the SRS and SEC Issues work groups in November 2020 (ABRWH, 2020a, 2020b) and full Board teleconference meeting in December 2020 (ABRWH, 2020c), SC&A was formally tasked with reviewing this information in the focused context of SEC-00103 discussions regarding job-specific monitoring of subcontractors. This report contains SC&A's review of RPRT-0094 in that specified context. SC&A's review also contains a more detailed evaluation of the subcontractor claimant monitoring data to provide a clearer picture on subcontractor monitoring in general; however, this evaluation does not add any new information pertinent to job-specific monitoring. SC&A's general review approach for RPRT-0094 is described in section 3, with subsequent analyses and discussion in sections 4–8.

In addition to the review of RPRT-0094, SC&A was tasked with evaluating additional information and analysis provided by NIOSH in its 2020 presentation to the Board (NIOSH, 2020c) about captured plutonium urinalysis results; section 9 presents this analysis. Finally, attachment A summarizes the issues, respective findings, and conclusions reached by SC&A and NIOSH that are directly related to the job-specific monitoring of subcontractors (as analyzed during the RWP evaluation in RPRT-0092), for ease of reference. The information in attachment A is of particular import due to the fact that the RWP analysis in RPRT-0092 is the only direct evaluation of permit-driven, job-specific monitoring completeness for subcontractors.

3 SC&A Review Approach for RPRT-0094 and Associated Material

SC&A's review of RPRT-0094 focused on providing granularity and perspective to the available claimant internal monitoring dataset in context of the sufficiency and completeness of the overall routine/incident-based monitoring program for subcontractors. However, it must be stressed that this review and its conclusions do not obviate, amend, or replace SC&A's original concerns about the job-specific bioassay program at SRS expressed in SC&A (2019, 2020). SC&A's main concern specific to the RPRT-0094 evaluation is that the percentage of internally monitored workers indicated in RPRT-0094 tacitly implies that any internal monitoring coverage represents appropriate internal monitoring coverage. This includes the issue of whether routine internal monitoring is sufficient to represent nonroutine (e.g., job-specific) internal monitoring coverage, about which SC&A continues to have significant concerns.

As such, SC&A evaluated the claimant subcontractor data to identify individual analytes in bioassay data rather than combining multiple types of internal monitoring into a single metric (refer to sections 4–7). Section 4 discusses the impact of including tritium bioassay data in total internal monitoring totals. Section 5 separates the remaining, non-tritium bioassay data into separate radionuclide categories. Section 6 examines available in vivo monitoring results to adequately differentiate the two main in vivo methods and their capability to measure the analyte of interest and then discusses the implications for the monitoring totals provided in RPRT-0094. Finally, section 7 provides an overall analysis of general internal monitoring coverage by radionuclide category and year by combining both in vitro and in vivo records for the available subcontractor claimants.

As a secondary review topic directly applicable to RPRT-0094, SC&A would like to highlight prior concerns regarding the sole use of claimant data to represent an entire site population. SC&A notes that the use of subsets of claimants to effectively represent an entire site workforce has not been sufficiently vetted and accepted by the Board. These open issues, which are currently under discussion by the Board concerning the review of ORAUT-OTIB-0075, revisions 00 and 01 (NIOSH, 2009, 2016; "OTIB-0075")), are summarized and discussed in section 8.

It should be noted that at the outset of both reviews contained in this report (RPRT-0094 and the discussion of plutonium logbook data in section 9), SC&A concurred with NIOSH's general assertion that there are a significant number of internal monitoring results for sCTWs at SRS. However, SC&A does not believe that the total amount of data necessarily speaks to their completeness or representativeness under the auspices of the co-exposure guidelines outlined in DCAS-IG-006 (NIOSH, 2020a).

In a broader sense, it is SC&A's opinion that the evaluation of SEC-00103 regarding sCTWs hinges on the effectiveness of the internal dosimetry program to execute appropriate job-specific bioassay for workers performing nonroutine radiological tasks and who were not on a routine monitoring program for all relevant radionuclides. Or, absent direct monitoring, that such nonroutine tasks and exposures are adequately represented by subsequent co-exposure intake assignment. This is especially important when considering subcontractor workers whose employment was transient (and thus unlikely to have been enrolled in a routine monitoring program) or was otherwise not routinely monitored for all relevant nuclides related to the task. Such monitoring was to be covered under SRS's job-specific monitoring program, which NIOSH specifically analyzed in RPRT-0092 (refer to attachment A).

Therefore, SC&A contends that while the evaluation of the total number and percentage of monitored subcontractors in RPRT-0094 is useful in establishing the effectiveness of the routine monitoring program, it does little to answer the primary question regarding the completeness and representativeness of available internal monitoring data for nonroutine radiological work for which the application of appropriate job-specific internal monitoring is of primary concern. In SC&A's opinion, this strict evaluation of the amount, or proportion, of the internal monitoring data for the subset of subcontractor workers loses the unambiguous connection between nonroutine radiological work and the appropriate administration of job-specific bioassay. Such unambiguous connections were investigated and evaluated under the aforementioned response papers and associated discussions concerning RPRT-0092 (rather than RPRT-0094). RPRT-0092 remains the most focused attempt to answer the Board's original concerns over the completeness and representativeness of subcontractor job-specific bioassay data.

4 Impact of Including Tritium Bioassays in RPRT-0094

The purpose of RPRT-0094 was to use the claims in the NOCTS database to estimate the numbers and fractions of sCTWs who were monitored by SRS for external and internal exposure during 1972 through 1997. However, the numbers and fractions (usually stated in percentages) of sCTWs monitored for internal intakes are often clouded by the inclusion of tritium bioassays in the analysis presented in RPRT-0094, and they are occasionally averaged over multiple years. SC&A finds that (1) SRS tritium bioassays were generally performed on a routine basis and (2)

including them artificially inflates the percentage of subcontractors internally monitored and obscures evaluation of the real percent monitored for other dosimetrically significant radionuclides that would be encountered while working under a job plan or RWP. The following analyses provide the page numbers in RPRT-0094 where the use of tritium bioassays is discussed and points out the problems associated with including tritium bioassays and averaging the percentages over multiple years, as was done in RPRT-0094.

4.1 Page 12 of RPRT-0094

RPRT-0094 states on page 12:

> For all sCTW, 774 or **87%** had internal records and 783 or 88% had external records. [Emphasis added.]

However, the 87 percent value just indicates that there was at least one internal monitoring record in the energy employee's (EE's) NOCTS files (and includes tritium bioassays) for the period 1972 through 1997, not that the EE was monitored for all intakes necessary for all years of exposure according to a job plan or RWP. Therefore, this is not a percentage that decisions should be based on.

4.2 Page 13 of RPRT-0094

Table 5-1 on page 13 of RPRT-0094 lists the number of SRS claimants with external and internal monitoring by year. However, note that the internal monitoring referred to in columns 8 and 9 includes tritium (column 6). For some years (e.g., 1977 and 1978), almost all the monitoring consisted of tritium bioassays. These data are used in some of the tables following table 5-1 to derive the percents of sCTWs with internal monitoring.

4.3 Page 14 of RPRT-0094

Table 5-2 on page 14 of RPRT-0094 lists the fraction of SRS sCTW claimants with external and internal monitoring by year. However, note that the internal monitoring referred to in columns 4 and 5 used the data from table 5-1 that include tritium, which for some years (e.g., 1977 and 1978) consist of almost all tritium bioassays.

4.4 Page 15 of RPRT-0094

Figure 5-3 on page 15 of RPRT-0094 shows the fraction of externally monitored sCTWs with internal monitoring records and with whole-body count (WBC) records. The internal monitoring data are taken from column 3 of table 5-3, which includes tritium bioassays.

4.5 Page 16 of RPRT-0094

Table 5-3 on page 16 of RPRT-0094 lists the fraction of externally monitored sCTWs with internal monitoring by any method (column 3), WBC (column 4), tritium bioassay (column 5), and urine bioassay for non-H3 (non-tritium) nuclides (column 6). In considering the adequacy of required monitoring according to job plans and RWPs, the statement following table 5-3 is misleading in that the percentages (28 percent and 98 percent) given include tritium bioassays:

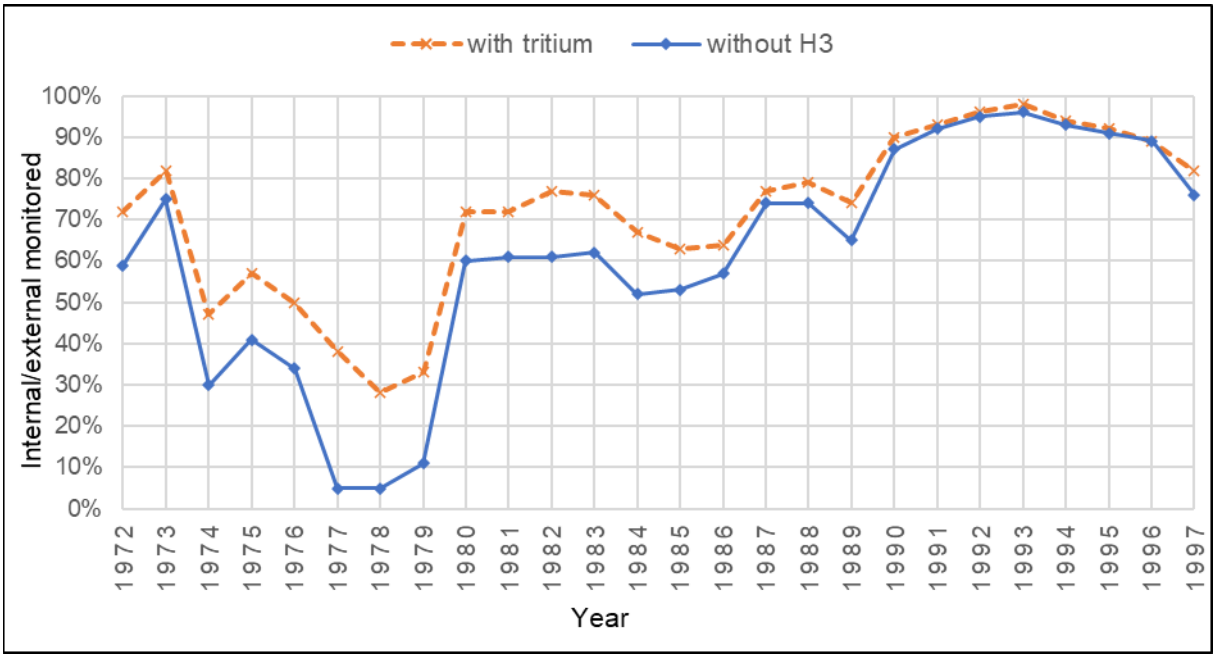
> These fractions, listed in Table 5-3, ranged from **28%** in 1978 to **98%** in 1993. [Emphases added.]

4.6 Page 17 of RPRT-0094

Table 5-4 on page 17 of RPRT-0094 lists the fraction of externally monitored sCTWs with internal monitoring by means of WBCs or non-H3 bioassays within 1 year (column 2) and within 3 years (column 3).

To clarify the fraction of sCTWs monitored for non-tritium intake, SC&A analyzed the data in tables 5-3 and 5-4 of RPRT-0094. Figure 1 shows the percent of sCTWs with external monitoring who also were monitored for internal intakes (with and without tritium bioassay).

Figure 1. Fraction of sCTWs monitored for non-H3 radionuclides compared to total including tritium



Note that for a significant number of years, the fraction of sCTWs internally monitored decreased when going from using all internal monitoring methods, which includes tritium bioassays (top plot), to non-H3 monitoring (bottom plot), especially during the 1970s and 1980s.

4.7 Page 17 of RPRT-0094

In the conclusions in section 6.0, RPRT-0094 states:

> Although not all sCTW were found to have internal monitoring records for each year of employment at SRS, for the years after 1979, **63%** or more of externally monitored sCTW had internal monitoring records. The lowest fraction of externally monitored sCTW with internal records was **28%** in 1978. [Emphases added.]

It should be noted that tritium bioassays were included in deriving the 63 percent and 28 percent values. In fact, for 1978, 25 percent of the sCTWs had tritium bioassays and only 5 percent had non-H3 monitoring (some workers had both tritium and non-H3 monitoring; therefore, the total does not add up to 30 percent).

4.8 Page 19 of RPRT-0094

In the data trends conclusions in section 6.2, NIOSH states:

> For externally monitored sCTW, a requirement prior to entry in radiologically controlled areas, the annual fractions of those with internal monitoring records ranged between **28%** and **98%**. The lowest fractions were in the latter 1970's and generally increased over time. Between 1972 and 1979 the average of the fractions is **51%**, for the 1980's it is 72%, and for 1990 through 1997 it is 92%. [Emphases added.]

As previously pointed out, the 28 percent and 98 percent values quoted are misleading because they include tritium bioassays, which is not useful when considering the adequacy of required monitoring according to job plans and RWPs. Additionally, the percentage values obtained from averaging fractions over the 1970s, 1980s, and 1990s given in the quoted statement are also misleading because (1) they include tritium bioassays (as shown in column 3 of table 5-3), and (2) averaging the fractions obscures issues in annual monitoring results. For example, while the quoted passage claims an average of 51 percent over the period 1972–1979, there were only 5 percent monitored by WBCs or for non-H3 nuclides for the years 1977 and 1978 and 11 percent for 1979 (table 5-4, column 2).

4.9 SC&A summary position regarding evaluation of tritium bioassays

SC&A finds that removing tritium bioassays and not averaging the analysis over multiple years provides a better analysis of the true percentage of sCTWs monitored for internal intakes pertinent to evaluating dosimetrically significant radionuclides that would be encountered while working under a job plan or RWP at SRS. Furthermore, it should be noted that the evaluation of tritium bioassay was specifically omitted from the prior evaluation of RWPs and followup job-specific bioassay monitoring in RPRT-0092. Therefore, it is not clear to SC&A why tritium monitoring was included in the RPRT-0094 assessment.

Finding 1: SC&A does not believe it is appropriate to combine tritium bioassay monitoring with other dosimetrically significant radionuclide monitoring, nor does SC&A feel it is appropriate to average values over multiple years in assessing the general completeness of internal monitoring for the subcontractor claimant population. Internal tritium monitoring was specifically omitted from the RPRT-0092 analysis of RWPs and followup job-specific monitoring as not relevant.

5 SC&A Evaluation of Non-Tritium Bioassay Data in RPRT-0094

RPRT-0094 also provides an evaluation of claimant subcontractor bioassay data for non-tritium data as a combined group. Non-tritium bioassay data consist of plutonium, fission product, uranium, neptunium, and americium monitoring. However, SC&A believes that a more meaningful evaluation of the monitoring practices and coverage for subcontractors would

involve an analysis of the individual radionuclides sampled via bioassay rather than combining all non-tritium bioassay into a single group. In this section, SC&A examined the 886 subcontractor claimants to separate each bioassay type by year to determine the actual coverage by appropriate analyte for subcontractors.

Finding 2: SC&A does not believe combining all non-tritium bioassay into a single metric for evaluation of the general completeness of subcontractor claimant monitoring to be technically appropriate.

As part of its analytical process, RPRT-0094 uses evidence of external monitoring during the given year as the trigger to determine whether associated internal monitoring is present. The underlying logic is that if there is no external monitoring then it can be assumed the worker did not enter radiological areas. This would logically be the case for subcontractors performing new construction in clean areas for which internal and external monitoring is likely unnecessary. SC&A concurs with this approach. Therefore, the analysis in this section only considers externally monitored subcontractors in the evaluation of non-tritium bioassay.

However, another facet of the RPRT-0094 analytical process involves the acceptable timeframe for non-tritium bioassay. Table 5-4 of RPRT-0094 appears to consider any non-tritium bioassay within 3 years of the year in which external monitoring data exist to be evidence of appropriate internal monitoring coverage for the specific year in which external monitoring was observed. SC&A does not believe this is an appropriate or claimant favorable assumption for evaluating the completeness of monitoring practices for subcontractors.

Appendix C to ORAUT-OTIB-0081 (NIOSH, 2020d) summarizes historical monitoring frequencies for a variety of different worker types and timeframes. Examination of these tables indicates that only certain worker categories for plutonium were prescribed a monitoring frequency of one sample every 3 years. For example, those workers designated as “minimum potential” were to be sampled once every 3 years. However, the frequency of plutonium bioassay could also be at a rate of once, twice, or four times per year depending on the worker type, area, and timeframe. For example, a 1976 bioassay schedule listed maintenance personnel in 773-A as requiring four plutonium bioassays per year. For the other types of non-tritium bioassay, sampling of monitored workers was required at a minimum of once per year. Therefore, SC&A’s analysis has assumed a monitoring frequency of once per year for all non-tritium bioassay types.

Finding 3: SC&A believes that it is technically inappropriate and inconsistent with established SRS procedure to assume that that all claimant subcontractors who were monitored externally in a given year would have been assigned to the minimum bioassay frequency of once every 3 years for all non-tritium radionuclides. SC&A’s analysis assumed a minimum requirement of annual bioassay (once per year) to evaluate general subcontractor monitoring coverage in accordance with routine SRS monitoring guidelines.

SC&A examined the DOE-supplied dosimetry files for each of the 886 claims and noted what radionuclides were monitored in any given year. SC&A then examined the NIOSH-supplied

compilation of annual external dosimetry[2] for each claim. If external dosimetry was indicated in the specific year of the NIOSH compilation, SC&A examined available claimant-specific urinalysis for plutonium, fission products, uranium, neptunium, and americium[3] during that same year. Table 1 shows the results of this evaluation. In addition, Figures 2–4 display the percentage of internally monitored subcontractors by year for plutonium, fission products, and uranium, respectively. Additional discussion of americium monitoring can be found later in this section.

Table 1. SC&A evaluation of non-tritium bioassay results for subcontractor claims monitored externally during year (percentage of externally monitored subcontractor claims with internal monitoring in same year)

Year	External dosimetry and plutonium urinalysis	External dosimetry and fission product urinalysis	External dosimetry and uranium urinalysis	External dosimetry and neptunium urinalysis	External dosimetry and Am/Cm/Cf/Th urinalysis	RPRT-0094 percentage for all non-H3 bioassay
1972	18 (26.1%)	39 (56.5%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	59%
1973	17 (24.6%)	50 (72.5%)	1 (1.4%)	0 (0.0%)	0 (0.0%)	75%
1974	16 (20.5%)	17 (21.8%)	2 (2.6%)	0 (0.0%)	0 (0.0%)	30%
1975	18 (17.6%)	29 (28.4%)	15 (14.7%)	0 (0.0%)	0 (0.0%)	41%
1976	18 (16.1%)	28 (25.0%)	2 (1.8%)	0 (0.0%)	0 (0.0%)	34%
1977	3 (2.5%)	1 (0.8%)	3 (2.5%)	0 (0.0%)	1 (0.8%)	4%
1978	4 (2.4%)	1 (0.6%)	2 (1.2%)	0 (0.0%)	0 (0.0%)	5%
1979	12 (6.7%)	2 (1.1%)	1 (0.6%)	0 (0.0%)	1 (0.6%)	8%
1980	67 (32.8%)	74 (36.3%)	2 (1.0%)	0 (0.0%)	0 (0.0%)	60%
1981	76 (31.0%)	128 (52.2%)	1 (0.4%)	0 (0.0%)	0 (0.0%)	61%
1982	46 (23.1%)	107 (53.8%)	3 (1.5%)	0 (0.0%)	0 (0.0%)	59%
1983	49 (20.6%)	123 (51.7%)	5 (2.1%)	0 (0.0%)	3 (1.3%)	54%
1984	50 (19.9%)	122 (48.6%)	1 (0.4%)	0 (0.0%)	1 (0.4%)	50%
1985	61 (20.0%)	136 (44.6%)	13 (4.3%)	1 (0.3%)	2 (0.7%)	51%
1986	83 (23.4%)	192 (54.1%)	2 (0.6%)	0 (0.0%)	0 (0.0%)	55%
1987	74 (21.6%)	171 (50.0%)	8 (2.3%)	0 (0.0%)	0 (0.0%)	55%
1988	98 (27.8%)	62 (17.6%)	19 (5.4%)	0 (0.0%)	0 (0.0%)	40%
1989	111 (26.9%)	9 (2.2%)	11 (2.7%)	0 (0.0%)	1 (0.2%)	29%
1990	132 (27.6%)	7 (1.5%)	7 (1.5%)	0 (0.0%)	2 (0.4%)	30%
1991	212 (50.8%)	164 (39.3%)	83 (19.9%)	5 (1.2%)	1 (0.2%)	65%
1992	255 (73.1%)	214 (61.3%)	183 (52.4%)	8 (2.3%)	0 (0.0%)	76%
1993	149 (53.2%)	111 (39.6%)	94 (33.6%)	6 (2.1%)	0 (0.0%)	58%
1994	104 (57.8%)	90 (50.0%)	67 (37.2%)	7 (3.9%)	0 (0.0%)	61%
1995	75 (46.6%)	72 (44.7%)	60 (37.3%)	1 (0.6%)	0 (0.0%)	53%

[2] These data were supplied by NIOSH in two spreadsheets transmitted on December 28, 2020.

[3] Although available dosimetry records generally only list these urinalysis samples as "Am" (americium), the bioassay extraction method was intended to capture americium, curium, californium, and thorium.

Year	External dosimetry and plutonium urinalysis	External dosimetry and fission product urinalysis	External dosimetry and uranium urinalysis	External dosimetry and neptunium urinalysis	External dosimetry and Am/Cm/Cf/Th urinalysis	RPRT-0094 percentage for all non-H3 bioassay
1996	67 (47.5%)	70 (49.6%)	50 (35.5%)	2 (1.4%)	4 (2.8%)	51%
1997	70 (55.1%)	57 (44.9%)	43 (33.9%)	2 (1.6%)	5 (3.9%)	56%

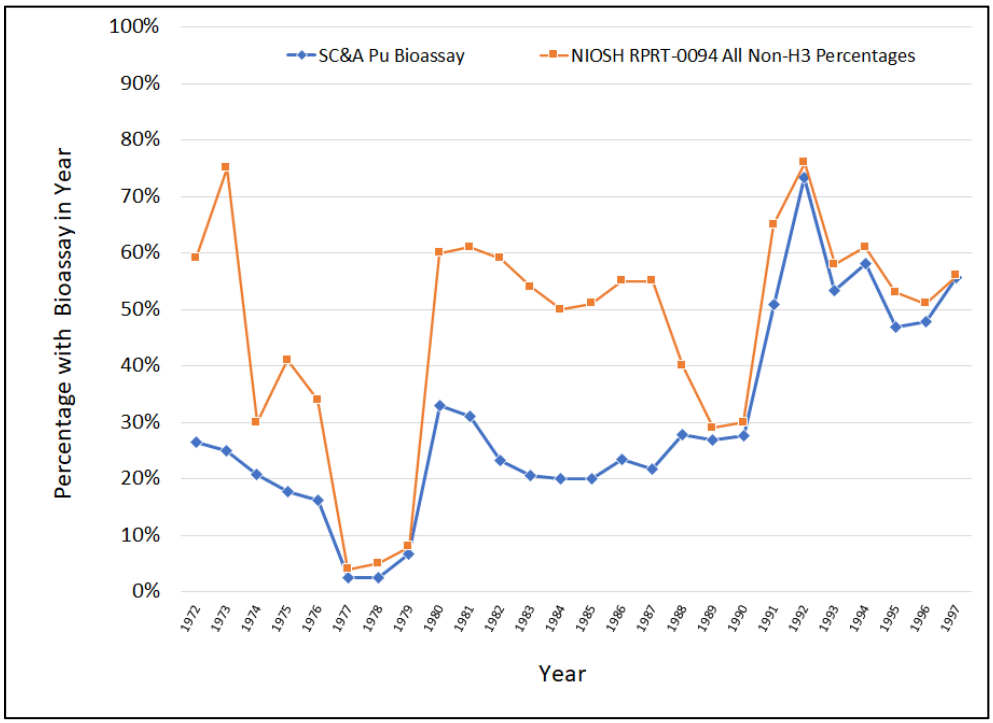
As shown in figure 2, plutonium bioassay coverage ranged from 2.4 percent in 1978 to 73.1 percent in 1992; however, if only the DuPont era[4] of interest is considered, the maximum percentage drops to 32.8 percent in 1980. Figure 3 shows that fission product bioassay coverage ranged from 0.6 percent in 1978 to 72.5 percent in 1973. Figure 4 shows that uranium bioassay coverage ranged from 0.0 percent in 1972 to 52.4 percent in 1992; however, if only the DuPont era of interest is considered, the maximum percentage drops to 14.7 percent in 1975. For comparison, the far-right column of table 1 (column 7) shows the percentage of workers monitored for all non-tritium bioassay as provided in table 5-3 of RPRT-0094. The RPRT-0094, table 5-3, results are also plotted in figures 2–4 to illustrate the individual differences for these radionuclides.

Not surprisingly, the RPRT-0094 percentages for all non-H3 bioassay are significantly higher than the SC&A evaluation for many years and radiation types. This is particularly evident for many years during the DuPont era. However, beginning in 1988, the bioassay percentages calculated by SC&A show significantly better agreement with the RPRT-0094 percentages for non-H3 bioassay. SC&A observes that during this latter period, often plutonium, uranium, and fission product bioassay were all collected on the same date for the individual worker.

Finding 4: When non-tritium bioassay is separated into the individual radiological assay components (plutonium, fission products, uranium, neptunium, and americium), the percentage of monitored subcontractor workers decreases markedly for many years during the DuPont era.

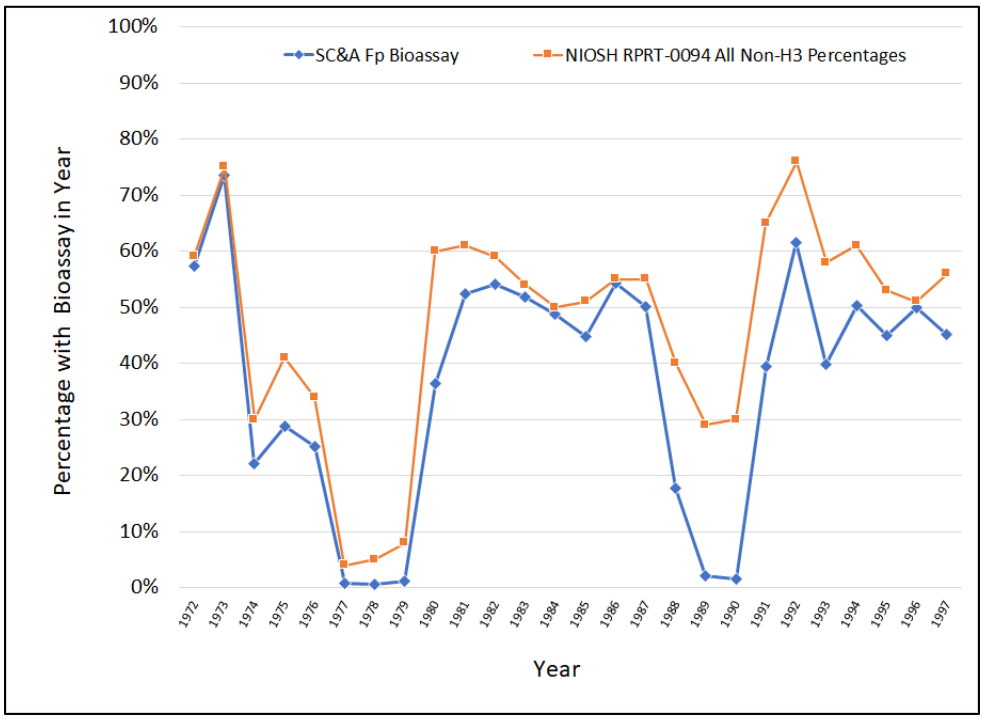
[4] SC&A assumed the DuPont era to be 1972–1990 for consistency with the RPRT-0092 analysis (NIOSH, 2019a), SC&A review (SC&A, 2019a), and subsequent discussions (NIOSH, 2020b; SC&A, 2020a; ABRWH, 2019a, 2019b, 2020a, 2020b, 2020c).

Figure 2. Percentage of externally monitored subcontractor claims with plutonium bioassay in same year



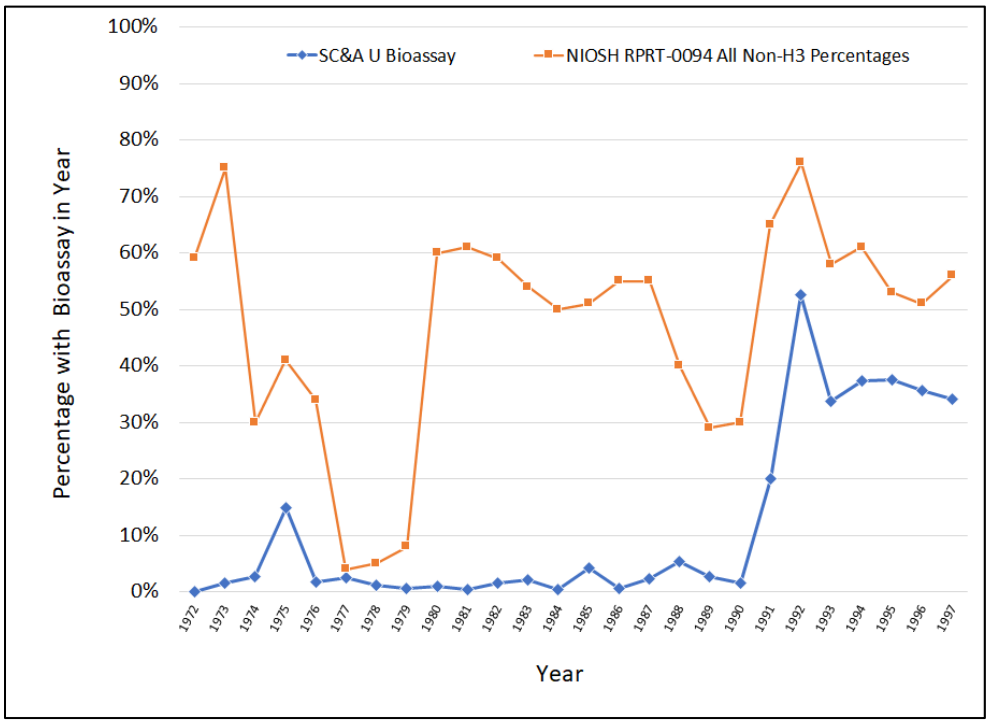
Source: NIOSH (2019b).

Figure 3. Percentage of externally monitored subcontractor claims with fission product bioassay



Source: NIOSH (2019b).

Figure 4. Percentage of externally monitored subcontractor claims with uranium bioassay



Source: NIOSH (2019b).

As seen in table 1, SC&A observed only a handful of neptunium and americium bioassays in the subcontractor claimant population, which indicates extremely low percentages of monitoring (i.e., bioassay percentages ranged from 0 to 3.9 percent by year for both neptunium and americium). However, this is to be expected, because these isotopes were handled on a much smaller scale than the other primary contaminants. Specific to americium, SC&A attempted to gain a better characterization of the monitoring coverage by further restricting comparisons to only workers who had observed dosimetry codes associated with areas where separated americium had the potential to be handled. Per information provided by NIOSH (2020b), separated americium was handled in the F-Wing of 773-A and the Multi-Purpose Processing Facility (MPPF) located in F-Area. Per table 5-1 of ORAUT-OTIB-0081, revision 05 (NIOSH, 2020d), there do not appear to be specific dosimetry codes for F-Wing and the MPPF; therefore, SC&A used the generic dosimetry codes for 773-A[5] and F-Area.[6] SC&A observed 978 dosimeter cycles that were labelled with one of these health physics area codes.

The percentage of workers with observed dosimetry and bioassay results for americium is shown in figures 5 and 6 for 773-A and F-Area, respectively. As seen in figure 5, americium bioassay and 773-A dosimetry matches were only observed in 1990 (16.7 percent), 1996 (40 percent), and 1997 (57.1 percent). It is noteworthy that the percentage of monitored workers in 773-A in 1990 (16.7 percent) reasonably matches the percentage of monitored workers identified with 773-A F-

[5] General 773-A codes observed in subcontractor claimant records are: 1A, 5A, and A01.

[6] General F-Area codes observed in subcontractor claimant records are: 1F-5F, F01-F03, F05, F2, F08, and F09.

Wing area radiation work permits analyzed in RPRT-0092 for the DuPont era (20 percent directly monitored 1981–1988) (NIOSH, 2019a).

Specific to the F-Area (figure 6), external dosimetry and americium bioassay matches were only observed in 1984 (2.1 percent), 1985 (1.8 percent), 1990 (1.0 percent), and 1991 (1.4 percent). It should be noted that while the MPPF was constructed in 1972, the facility did not appear to start full operations until approximately 1978. It is also not clear what level of operation occurred at the MPPF throughout the period of interest and whether there were significant periods where the facility was shut down and/or placed in standby mode.

Observation 1: A limited, area-specific analysis of dosimetry codes with americium bioassay showed a very low percentage of bioassay coverage with the exception of 1996 and 1997 (40 percent and 57.1 percent monitored via bioassay, respectively) for the 773-A area. The other year in which 773-A specific dosimetry and bioassay matches were identified (~17 percent in 1990) showed a reasonably similar percentage to the RWP analysis described in RPRT-0092 during the DuPont era (20 percent directly monitored via urinalysis or chest count for 1981–1988).

Figure 5. Comparison of the number of subcontractor claims with external dosimetry associated with 773-A versus those also monitored via americium urinalysis per year

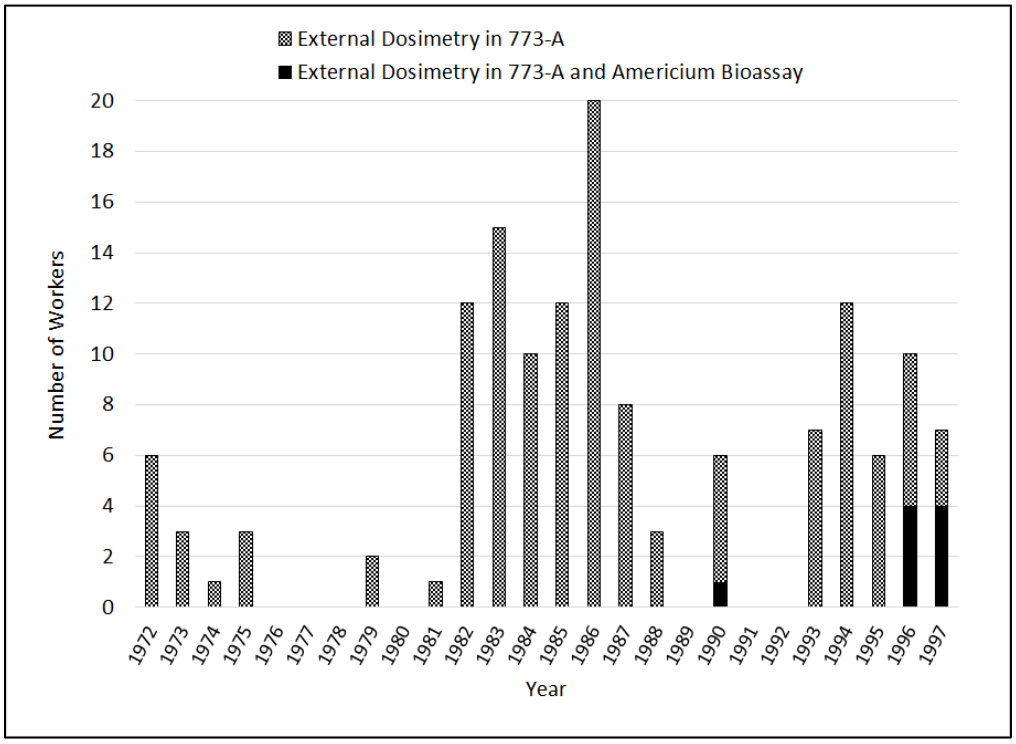
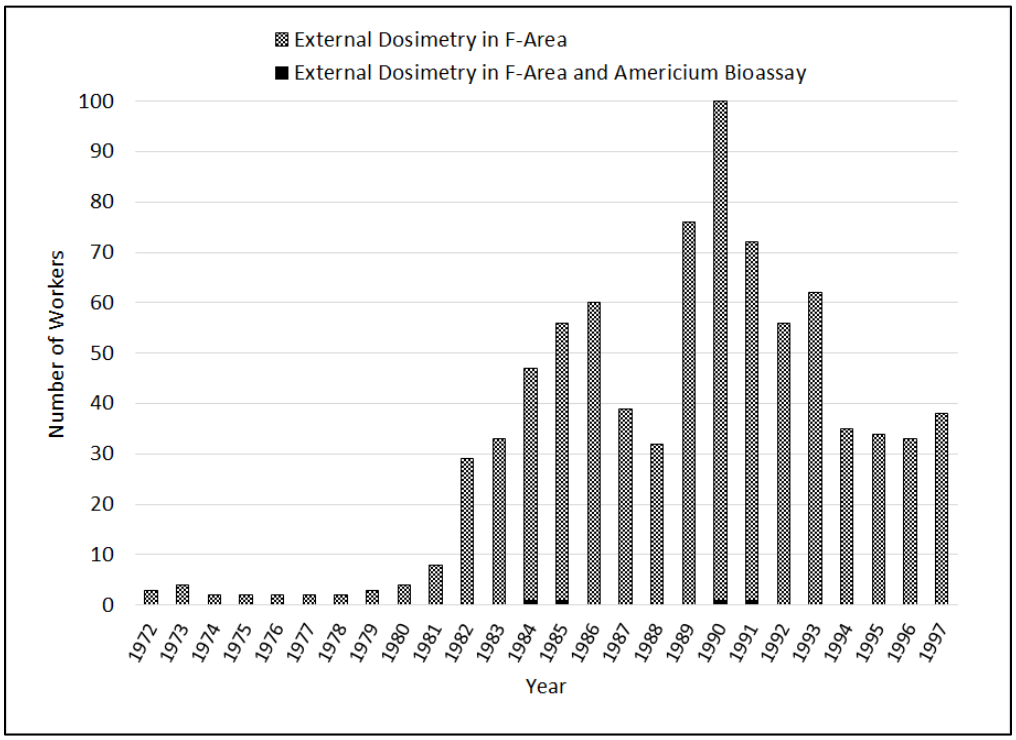


Figure 6. Comparison of the number of subcontractor claims with external dosimetry associated with F-Area versus those also monitored via americium urinalysis per year



6 Differentiation of In Vivo Techniques Observed in Subcontractor Claimant Data

In addition to separating non-tritium bioassay into its component parts as discussed in the previous section, SC&A believes it is appropriate to separate the two main in vivo methods in use at SRS during the period of interest:

1. **Whole body counting (WBC)/FASTSCAN:** uses sodium-iodide detectors generally to detect fission and activation products. WBC technology may have been able to directly detect uranium-235 (U-235) and also detect neptunium-237 (Np-237) via measurement of the daughter product palladium-233. However, it is not clear to SC&A to what extent measurements of U-235 and Np-237 were made using the FASTSCAN in vivo counter.

2. **Chest counts:** uses phoswich or germanium detectors for low-energy photons capable of detecting actinides (plutonium, americium, curium).

Observation 2: It is not clear to SC&A whether the FASTSCAN in vivo counter, which represents the majority of available in vivo monitoring data, was used to measure U-235 and Np-237. However, for the analysis presented in this section, SC&A assumed that such measurements were made.

A breakdown, by year, of the number of claimants with external dosimetry and in vivo monitoring is shown in table 2 and plotted in figure 7. As seen in the table, overall in vivo

monitoring was somewhat infrequent until 1987 (generally less than 5 percent of the externally monitored population). The marked increase in 1987 coincides with the implementation of the FASTSCAN counter, which was capable of performing diagnostic measurements of individuals in a matter of 1–2 minutes but was not capable of measuring lower energy photons associated with the actinides of plutonium and americium. Chest counting (which is capable of measuring actinide material) during the DuPont era was also relatively infrequent, with the percentage monitored ranging from lows of 0 percent in 1973, 1975, and 1976 to a high of 8.9 percent in 1983. The percentage monitored via chest count was less than 5 percent for all other years during the DuPont era.

The overall effect of combining the in vitro and in vivo data for each of the five major radionuclide categories (plutonium, fission products, uranium, neptunium, and americium) is discussed in section 7.

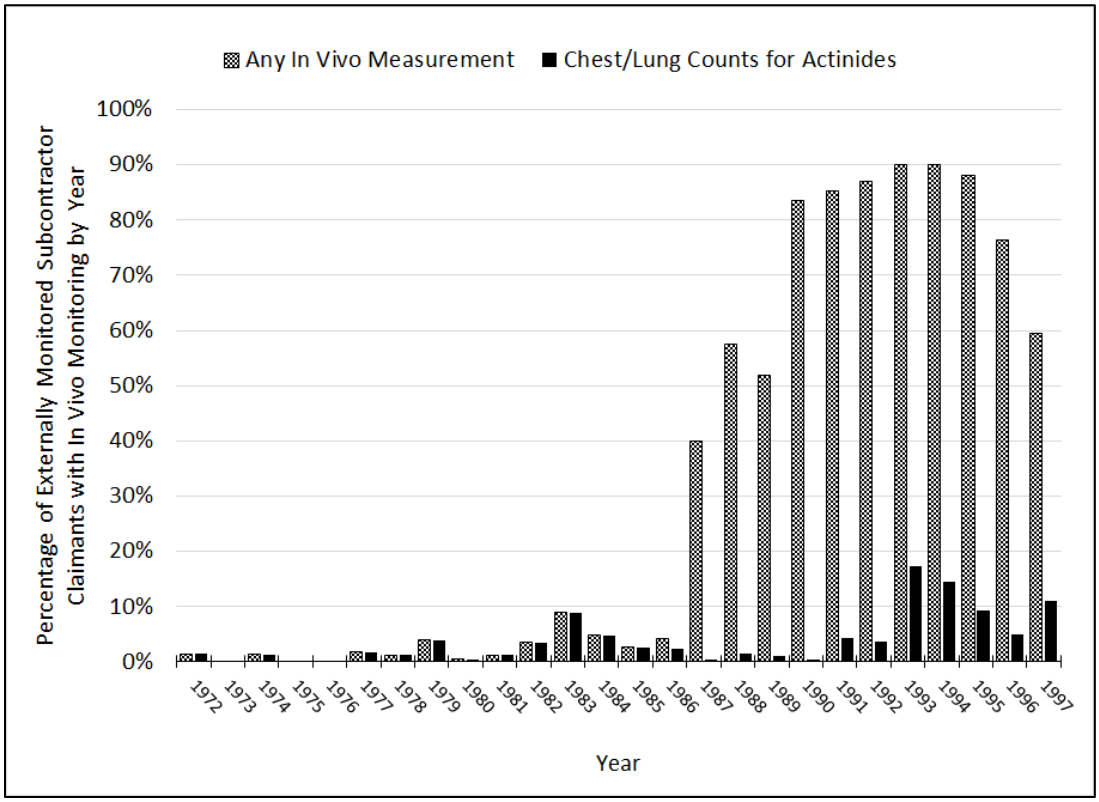
Observation 3: Chest counting capable of measuring actinide material, such as americium and plutonium, was relatively infrequent during the DuPont era and was generally less than 5 percent of the externally monitored population. Therefore, the effect on the monitoring totals for these contaminants is minimal for most years (refer to section 7 for a full analysis).

Table 2. Overview of in vivo monitoring for externally monitored subcontractors by year (number and percentage of externally monitored subcontractor claims with in vivo monitoring in same year)

Year	External dosimetry and WBCs, FASTSCAN, and chest counts	External dosimetry with only FASTSCAN results	External dosimetry and chest/lung counts for actinides
1972	1 (1.5%)	0 (0.0%)	1 (1.5%)
1973	0 (0.0%)	0 (0.0%)	0 (0.0%)
1974	1 (1.3%)	0 (0.0%)	1 (1.3%)
1975	0 (0.0%)	0 (0.0%)	0 (0.0%)
1976	0 (0.0%)	0 (0.0%)	0 (0.0%)
1977	2 (1.7%)	0 (0.0%)	2 (1.7%)
1978	2 (1.2%)	0 (0.0%)	2 (1.2%)
1979	7 (3.9%)	0 (0.0%)	7 (3.9%)
1980	1 (0.5%)	0 (0.0%)	1 (0.5%)
1981	3 (1.2%)	0 (0.0%)	3 (1.2%)
1982	7 (3.5%)	0 (0.0%)	7 (3.5%)
1983	21 (8.9%)	0 (0.0%)	21 (8.9%)
1984	12 (4.8%)	0 (0.0%)	12 (4.8%)
1985	8 (2.6%)	0 (0.0%)	8 (2.6%)
1986	15 (4.2%)	7 (2.0%)	8 (2.3%)
1987	136 (39.9%)	135 (39.6%)	1 (0.3%)
1988	202 (57.5%)	197 (56.1%)	5 (1.4%)

Year	External dosimetry and WBCs, FASTSCAN, and chest counts	External dosimetry with only FASTSCAN results	External dosimetry and chest/lung counts for actinides
1989	214 (51.9%)	210 (51.0%)	4 (1.0%)
1990	399 (83.5%)	397 (83.1%)	2 (0.4%)
1991	355 (85.3%)	337 (81.0%)	18 (4.3%)
1992	303 (87.1%)	290 (83.3%)	13 (3.7%)
1993	251 (90.0%)	203 (72.8%)	48 (17.2%)
1994	161 (89.9%)	135 (75.4%)	26 (14.5%)
1995	141 (88.1%)	126 (78.8%)	15 (9.4%)
1996	107 (76.4%)	100 (71.4%)	7 (5.0%)
1997	74 (58.7%)	60 (47.6%)	14 (11.1%)

Figure 7. Summary of in vivo counting methods



7 Combination of In Vivo and In Vitro Monitoring Methods

To gain a complete picture of subcontractor internal monitoring practices for non-tritium radionuclides, SC&A combined the in vitro and in vivo monitoring data for each of the primary radionuclides of interest: plutonium, fission products, uranium, neptunium, and americium. For fission products, uranium, and neptunium, all in vivo results were included along with the specific urinalysis results for these contaminants. As noted in section 6, observation 2, SC&A is not certain whether the FASTSCAN WBCs actually performed measurements of U-235 and Np-237. Since FASTSCAN measurements represent the overwhelming majority of available in vivo data beginning in 1987, exclusion of FASTSCAN as a viable method for detecting uranium and neptunium would significantly decrease the results reported in this section during this post-1986 period evaluated.

For plutonium and americium, only chest counts were considered in addition to radionuclide-specific urinalysis results. The increase in monitoring percentage by inclusion of chest count data for plutonium and americium is presented in table 3. As shown in the table, there was often no increase in the monitored percentage for these radionuclides for many years. The increase in monitored percentage was less than 2 percent for 19 of 26 years for plutonium and 13 of 26 years for americium.

Observation 4: Combination of relevant in vitro and chest count monitoring for plutonium and americium resulted in only modest increases in the internally monitored population for most years when compared to in vitro alone

Table 3. Increase in monitoring percentage by combining urinalysis and chest count data

Year	Pu	Am
1972	0.0%	1.5%
1973	0.0%	0.0%
1974	0.0%	1.3%
1975	0.0%	0.0%
1976	0.0%	0.0%
1977	0.9%	0.9%
1978	0.6%	1.2%
1979	3.4%	3.9%
1980	0.5%	0.5%
1981	0.8%	1.2%
1982	3.0%	3.5%
1983	8.4%	8.9%
1984	1.6%	4.4%
1985	1.6%	2.3%
1986	1.7%	2.3%
1987	0.0%	0.3%
1988	0.6%	1.4%

Year	Pu	Am
1989	0.0%	0.7%
1990	0.2%	0.4%
1991	1.0%	4.3%
1992	0.0%	3.7%
1993	5.0%	17.2%
1994	0.0%	14.5%
1995	0.0%	9.4%
1996	0.0%	5.0%
1997	0.0%	10.3%

Table 4 summarizes the range of monitoring coverage by radionuclide category for the DuPont era (1972–1990), WSRC era (1991–1997), and the entire evaluated period (1972–1997). As shown in table 4, the range of monitoring coverage for some radionuclides during the DuPont era, such as plutonium and americium, is significantly lower (3–34 percent and 0–10 percent, respectively) than the estimate in RPRT-0094 for all non-tritium bioassay (5–87 percent).

Finding 5: When considering both relevant in vitro and in vivo data, the percentage of plutonium and americium monitoring coverage during the DuPont era (1972–1990) only ranged 3–34 percent and 0–10 percent, respectively. This can be compared to the range of 5–87 percent calculated for all non-tritium bioassay in RPRT-0094.

Table 4. Comparison of SC&A's range of monitoring coverage for key radionuclide categories versus all non-tritium bioassay presented in RPRT-0094 (percentage of externally monitored subcontractors with internal monitoring records in the same year)

Radionuclide category	SC&A percentage range during DuPont era (1972–1990)	RPRT-0094 percentage range of all non-tritium monitoring during DuPont era (1972–1990)	SC&A percentage range during WSRC era (1991–1997)	RPRT-0094 percentage of all non-tritium monitoring during WSRC era (1991–1997)	SC&A percentage range for all years evaluated (1972–1997)	RPRT-0094 percentage of all non-tritium monitoring for all years evaluated (1972–1997)
Plutonium	3–34%	5–87%	47–73%	76–96%	3–73%	5–96%
Fission products	2–84%	5–87%	73–94%	76–96%	2–94%	5–96%
Uranium	2–84%	5–87%	71–94%	76–96%	2–94%	5–96%
Neptunium	0–84%	5–87%	60–90%	76–96%	0–90%	5–96%
Americium	0–10%	5–87%	4–17%	76–96%	0–17%	5–96%

Table 5 and figure 8 present the combined internal monitoring coverage by year. They show that, on a year-by-year basis, plutonium bioassay coverage was generally less than 30 percent of the NOCTS subcontractor population until 1991. For the other radionuclides (excluding americium),

the monitoring coverage increased markedly in 1987, which coincides with increased in vivo monitoring methods that could potentially be used to detect uranium, neptunium, and fission products.

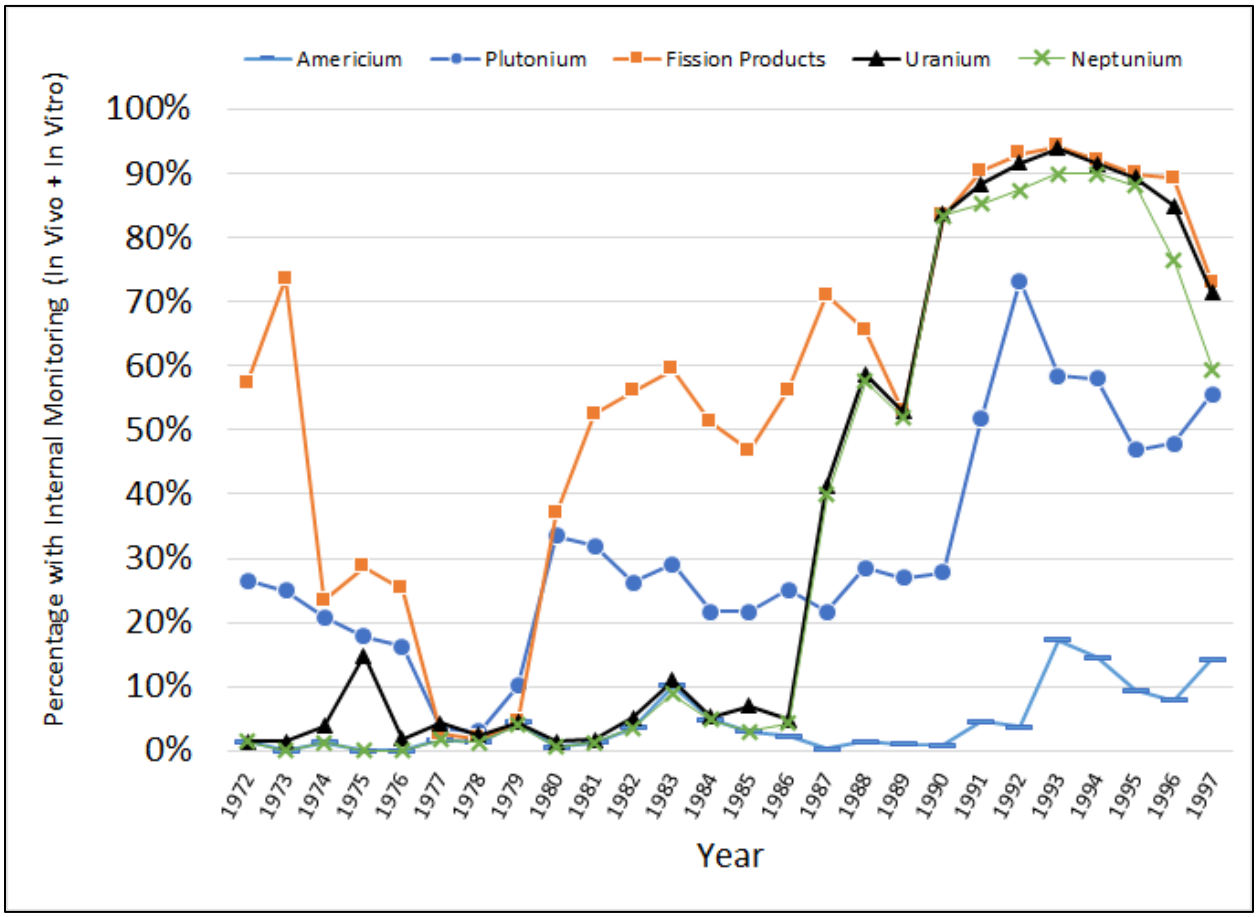
Finding 6: When considering the combination of radionuclide-specific in vitro data and applicable in vivo measurements, the percentage of externally monitored subcontractor claims with internal monitoring per year did not markedly increase until 1991 (plutonium) and 1987 (uranium and neptunium). Monitoring percentages for americium were less than ~17 percent for all years and less than ~10 percent for the DuPont era years. These values are significantly lower than the all non-tritium monitoring percentages calculated in RPRT-0094 for many years during the DuPont era.

Table 5. SC&A evaluation of internal monitoring for subcontractor claims monitored externally during year (percentage of externally monitored subcontractors with internal monitoring in year)

Year	External dosimetry and monitored for plutonium	External dosimetry and monitored for fission products	External dosimetry and monitored for uranium	External dosimetry and monitored for neptunium	External dosimetry and monitored for Am/Cm/Cf/Th	RPRT-0094 percentage for all non-H3 bioassay
1972	26.5%	57.4%	1.5%	1.5%	1.5%	59%
1973	25.0%	73.5%	1.5%	0.0%	0.0%	75%
1974	20.8%	23.4%	3.9%	1.3%	1.3%	30%
1975	17.8%	28.7%	14.9%	0.0%	0.0%	41%
1976	16.2%	25.2%	1.8%	0.0%	0.0%	34%
1977	3.4%	2.6%	4.3%	1.7%	1.7%	5%
1978	3.0%	1.8%	2.4%	1.2%	1.2%	5%
1979	10.1%	4.5%	4.5%	3.9%	4.5%	11%
1980	33.5%	36.9%	1.5%	0.5%	0.5%	60%
1981	32.0%	52.5%	1.6%	1.2%	1.2%	61%
1982	26.3%	56.1%	5.1%	3.5%	3.5%	61%
1983	29.1%	59.5%	11.0%	8.9%	10.1%	62%
1984	21.6%	51.2%	5.2%	4.8%	4.8%	52%
1985	21.7%	46.7%	6.9%	3.0%	3.0%	53%
1986	25.1%	56.2%	4.8%	4.2%	2.3%	57%
1987	21.7%	71.0%	41.3%	39.9%	0.3%	74%
1988	28.5%	65.5%	58.7%	57.5%	1.4%	74%
1989	26.9%	52.9%	52.9%	51.9%	1.0%	65%
1990	27.8%	83.5%	83.7%	83.5%	0.8%	87%
1991	51.9%	90.4%	88.5%	85.3%	4.6%	92%
1992	73.3%	93.1%	91.7%	87.4%	3.7%	95%
1993	58.4%	94.3%	93.9%	90.0%	17.2%	96%
1994	58.1%	92.2%	91.6%	89.9%	14.5%	93%

Year	External dosimetry and monitored for plutonium	External dosimetry and monitored for fission products	External dosimetry and monitored for uranium	External dosimetry and monitored for neptunium	External dosimetry and monitored for Am/Cm/Cf/Th	RPRT-0094 percentage for all non-H3 bioassay
1995	46.9%	90.0%	89.4%	88.1%	9.4%	91%
1996	47.9%	89.3%	85.0%	76.4%	7.9%	89%
1997	55.6%	73.0%	71.4%	59.5%	14.3%	76%

Figure 8. Combined monitoring coverage (in vitro plus in vivo) for major radionuclide categories



Similar to the analysis in section 5, SC&A performed an area-specific analysis for americium based on external dosimetry codes for 773-A and F-Area. The results are shown in figures 9 and 10. As seen in the figures, the inclusion of chest count data had a significant effect for the 773-A area during certain years of the WSRC era, with americium monitoring percentages ranging from 40 percent to 70 percent in the years 1994–1997. For the F-Area analysis, americium monitoring coverage ranged from 0 percent (1972–1981, 1987, and 1988) to

28.6 percent in 1994. The maximum observed percentage during the DuPont era was 12.1 percent in 1983.

Observation 5: Similar to observation 1, a limited, area-specific analysis of dosimetry codes with americium bioassay showed a very low percentage of bioassay coverage, with the exception of the late 1990s for the 773-A area. For the F-Area analysis, monitoring percentages were zero for 12 of 26 years evaluated and less than 20 percent for 22 of 26 years (including the 12 zero percentage years).

Figure 9. Comparison of the number of subcontractor claims with external dosimetry associated with 773-A versus those also monitored via americium urinalysis or chest counts per year

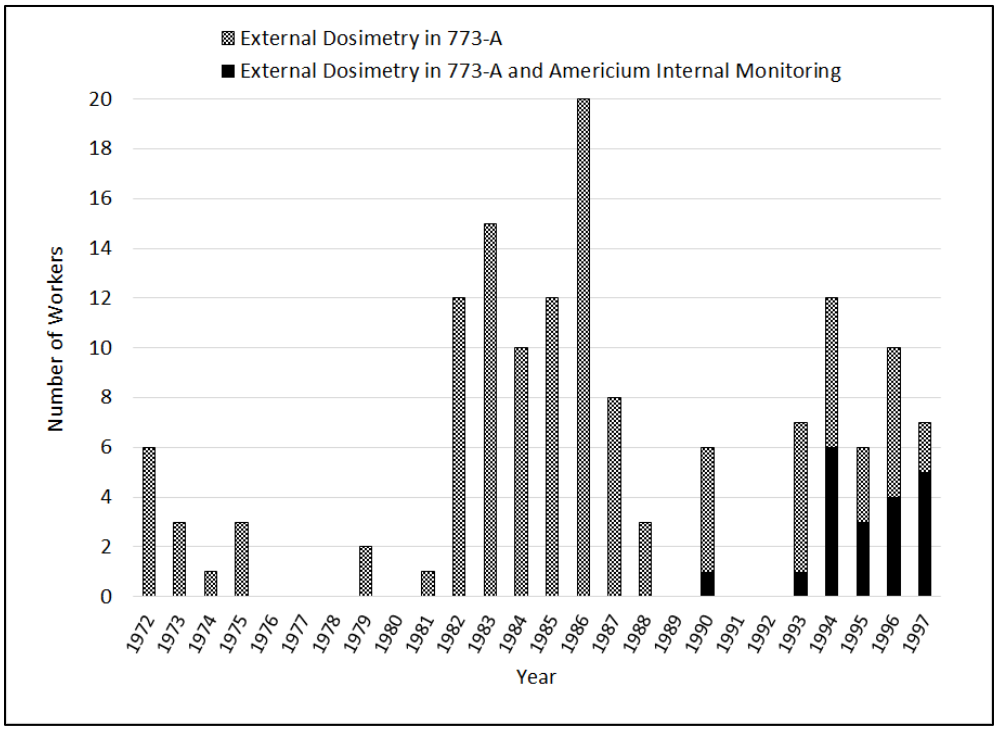
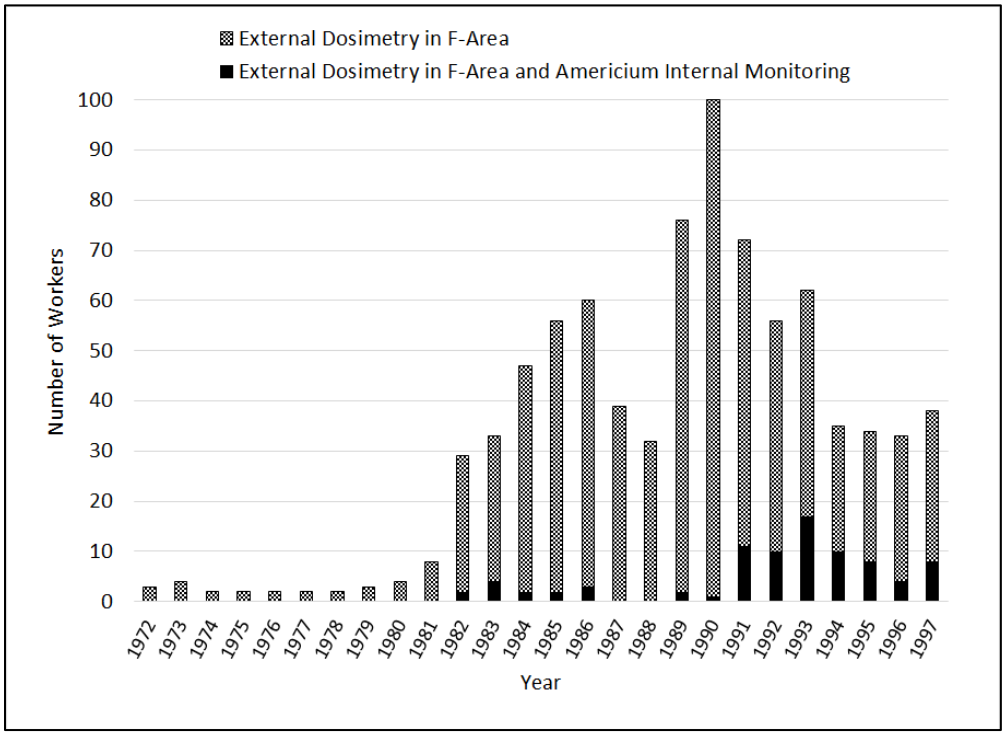


Figure 10. Comparison of the number of subcontractor claims with external dosimetry associated with F-Area versus those also monitored via americium urinalysis or chest counts per year



8 Evaluation of ORAUT-OTIB-0075 SRS Findings Applicable to RPRT-0094

The concluding paragraph on page 19 of RPRT-0094 states the following:

> The overall trend observed in these data is that the subcontractor construction trade workers who were monitored were represented as least as well as other SRS workers. The completeness of the data is more than adequate for dose reconstruction and for the basis of the SRS coworker model.

In this statement, it appears that NIOSH is assuming that NOCTS data are an acceptable representative sample of the population for SRS subcontractors. However, this assumption has not been validated in the past and has been contested in SC&A's (2010, 2017) reviews of OTIB-0075 (NIOSH, 2009, 2016). The purpose of this section is to summarize SC&A's SRS-related concerns about OTIB-0075 that are applicable to RPRT-0094 and the above assumption.

The following documents were used in this review:

- ORAUT-OTIB-0075, revision 00, May 25, 2009 (NIOSH, 2009)
- SC&A review of ORAUT-OTIB-0075, revision 00, January 2010 (SC&A, 2010)
- ORAUT-OTIB-0075, revision 01, June 17, 2016 (NIOSH, 2016)

- SC&A review of ORAUT-OTIB-0075, revision 01, October 9, 2017 (SC&A, 2017)
- ORAUT-RPRT-0094, revision 00, September 13, 2019 (NIOSH, 2019b)

The material in OTIB-0075, revisions 00 and 01, involved using bioassay data from NOCTS in modeling coworker data for several DOE sites. SC&A's overall conclusions about using NOCTS data for SRS coworker modeling is found on page 56 of SC&A's (2010) review of OTIB-0075, revision 00:

> The overall conclusion of this analysis for the SRS coworker model is that, contrary to NIOSH's proposal in its Evaluation Report (NIOSH, 2008), the NOCTS claimant dataset is inadequate for dose reconstruction with sufficient accuracy for SRS construction workers. A more complete compilation of the data and analyses by area, radionuclide, and job type are necessary to determine whether dose reconstruction with sufficient accuracy is feasible for SRS construction workers.

SC&A's OTIB-0075 finding 11 is specifically applicable to internal exposures of SRS construction workers and RPRT-0094 (SC&A, 2010, p. 46):

> Finding #11: At SRS, the 84th percentile of exposures to tritium and plutonium for construction workers in specific work areas show considerable differences from the 84th percentile of site-wide exposures to construction workers. Similar results are observed for the corresponding ratio of the GSDs. In many cases, there are insufficient data for construction workers to make a comparison for uranium, enriched uranium and fission products.

SC&A's (2010) review gives the basis for finding 11 on pages 45 and 46; results are listed in table 4-5 for tritium, plutonium, uranium, enriched uranium, and fission products, and shown in figure 4-15 for plutonium and figure 4-17 for uranium.

NIOSH issued revision 01 of OTIB-0075 in 2016 (NIOSH, 2016). SC&A reviewed the revised technical basis document and found that, while the revised OTIB-0075 contained an increase in the number of claims and corresponding data, it did little to address the original concern about the NOCTS data being unrepresentative of the unmonitored workers. This finding was summarized on pages 11–12 of SC&A's (2017) review report and SC&A's entries into the Board Review System on November 2, 2017:

> The increase in the number of workers in the claimant datasets may have improved the statistics for the claimant dataset but, except for Finding 2, it did little to address SC&A's original concern as expressed in our 2010 review (SC&A 2010) of OTIB-0075, Revision 00. These concerns are (1) the adequacy of the data in the claimant dataset in NOCTS to represent the unmonitored workers (who were subjected to a wide variety of exposure potentials) and (2) in Revision 01 to OTIB-0075, there was no indication in the text or footnotes of how many total claimants there were to compare to the 1,585 claimants who submitted uranium urine samples (as related to the original Finding 6). The datasets may need to be

tested to determine if stratification is needed concerning areas, time, radionuclide, construction versus non-construction workers, subcontractors versus prime, etc.

Therefore, the SRS OTIB-0075 findings have remained unresolved and are still in progress.

There are other SC&A OTIB-0075 findings concerning SRS tritium bioassays. However, as discussed in section 4 of this review, SC&A finds that SRS tritium bioassays were generally performed on a routine basis; including them in determining the adequacy and representativeness of sCTW monitoring artificially inflates the percentage monitored and obscures evaluation of the real percentage monitored for dosimetrically significant radionuclides.

9 Plutonium Logbook Bioassay Samples

In its response to SC&A's (2019) comments on RPRT-0092, NIOSH indicated that it "believes that subCTWs were adequately monitored in areas outside 773-A between 1972 and 1990" and that "additional coding efforts support the representativeness called for in the co-exposure implementation guide" (NIOSH, 2020b, p. 7). NIOSH specifically cited its review of "available plutonium logbooks" for 1972–1990 in order to "ascertain a more complete picture of subCTW bioassay monitoring" (NIOSH, 2020b, p. 7). In its later presentation to the full Board at its December 2020 meeting, NIOSH noted its belief that based on this review, "subCTWs were sufficiently monitored in areas outside of 773-A between 1972 and 1990" (NIOSH, 2020c, slide 61). NIOSH also indicated that a "similar pattern of internal monitoring was observed in the RWP analysis, the NOCTS data analysis, and now the plutonium bioassay logbook analysis" (NIOSH, 2020c, slide 61).

From the December 2020 presentation, two points were seemingly made: (1) that while RPRT-0092's survey of permit-indicated, job-specific bioassay data was confined to only one SRS facility, Building 773-A, the logbook data represented additional facilities at SRS; and (2) that, overall, the historical trends in total plutonium bioassay data resembled those seen in the RPRT-0092 RWP analysis and RPRT-0094 NOCTS data analysis for the 1970s and 1980s. As such, these plutonium logbook data are included by NIOSH in its weight-of-evidence conclusion that the SRS co-exposure model would be representative and bounding for subcontractor bioassay data.

SC&A reviewed all logbook references cited in NIOSH's database and confirmed a timeframe covering various SRS facilities from 1968 to 1990. The bioassay types indicated include routine, special, and termination, with a large number being listed as followup, rerun, recount, and resample. Some were listed as "DTPA," 24 hour, non-scheduled, and by numbered type (e.g., types 1–12, whose meaning is not known).[7] While NIOSH accounted for 11,316 plutonium bioassay samples for sCTWs from these logbooks, it is not clear whether this number includes followups, reruns, recounts, and resamples. However, NIOSH clarified that it believes this figure

[7] An inquiry was made to NIOSH regarding the composition ("type") of the logbook samples cited. Their response (Cardarelli, 2021) indicated that the data presented "do not address the type of sample or why it was collected."

(11,316 samples) underestimates the actual number of sCTW bioassay samples because multiple entries of the same sCTW that appeared on the same logbook page were not included.

From this review, SC&A established that with the possible exception of a relatively small number of bioassay samples being "24 hour" or "non-scheduled," the vast majority of the bioassay samples cited are of a routine or special bioassay type, with some termination bioassays included. There is no listing of subcontractor job-specific bioassays.

Given the common and historical production and use of plutonium at various SRS facilities, and the sitewide routine monitoring requirement for plutonium, the sheer availability of a large number of routine plutonium bioassays for various facilities does not obviate the lack of permit-indicated, job-specific bioassays for subcontractors that is SC&A's and the work group's core concern about the completeness and representativeness of the SRS co-exposure model. Such data are only available for one SRS facility, 773-A, for incomplete periods of time during 1972–1990. At least one facility, F-Wing of 773-A, demonstrates incomplete bioassay data availability for americium-241 (Am-241). The relative completeness of sCTW job-specific bioassay data for plutonium at 773-A for 1972–1990 cannot be extrapolated to other SRS facilities simply based on the availability of a large number of routine plutonium bioassay samples collected for sCTWs performing routine work at those facilities. For that presumption to be valid, it would need to be demonstrated that the exposure source terms for subcontractor work under RWPs, job plans, and Safe Work Permits (SWPs) were similar to, or could be bounded by, those for routine work. That has not been done.

On this last point, WSRC itself emphasized that "it is very important to realize that being on a routine sampling program does not automatically cover the bioassay sampling requirement specified on the RWP. . . . **routine sampling programs may not be appropriate for work involving non-routine mixes or concentrations of radioactive material**" that would be the basis for an RWP or job plan job-specific bioassay requirement (WSRC, 1997, PDF p. 9; emphasis added). WSRC also noted that "certain facilities such as the Savannah River Technology Center (SRTC) [773-A] and the solid waste disposal facilities handle a wide array of radioactive materials, some of which may not be encountered in the typical radiological work environment by workers in those areas" (WSRC, 1998a, p. 2).

Regarding the trends noted by NIOSH in its plotting of the annual number of subcontractors for 1972–1990 from the plutonium bioassay logbooks, it is not clear that there is any relevance for the SEC question at hand. Whether the number of sCTWs with plutonium bioassay monitoring declined or increased during a certain time period would seemingly be a function of both the scale of plutonium-related operations at SRS and changing contractor monitoring policies over time. The fact that the subcontractor numbers are similarly mirrored in the plutonium logbooks, RPRT-0092 survey, and NOCTS, respectively, would make sense for that reason: The number of plutonium bioassay samples would presumably be driven by those common factors.

Regarding the "Defense in Depth" programmatic strength of the SRS bioassay program reiterated by NIOSH in its December 2020 Board presentation (NIOSH, 2020c, slide 14), there have only been a few independent or internal assessments of its claimed effectiveness. One such review, the DOE Tiger Team assessment of the internal radiation dosimetry program in 1990, found that the "technical basis for determining bioassay type and frequency has not been

established for the nuclides encountered at SRS." That assessment, performed by senior health physicists from outside of SRS, also found that "there is no enforcement of [DuPont's policy to remove employees who fail to submit bioassay samples] and some employees ignore requests for bioassay samples." The Tiger Team review also found that, "Procedures require all bioassay results exceeding resample levels to be investigated. At the present time, this is only being done rigorously for plutonium results greater than 0.02 dpm/L." Overall, DOE concluded that "the sitewide internal dosimetry program does not comply with the requirements of DOE 5480.11" (DOE, 1990, PDF pp. 535, 536).

Another review was the WSRC 1998 self-assessment of the SRS bioassay program relative to the DOE enforcement moratorium for DOE-wide bioassay programs to permit necessary corrective actions. In this review, the site contractor found that while the "pre-scheduled" routine bioassay sampling program had adequate compliance (100 percent), the "recent shortcomings [only 21 percent compliance for job-specific bioassays, leading to DOE enforcement penalty] had to do with failures to collect job-specific samples from all workers who were supposed to leave such samples." (WSRC, 1998b, PDF p. 8). While WSRC resampled all workers missed in 1997, no internal assessment or followup bioassays were performed for prior years.

In summary, the fact that there is a large number of routine plutonium bioassays for subcontractors who worked at SRS locations other than 773-A for 1972–1990 is neither relevant nor surprising. Plutonium-related source terms were an exposure potential at a number of SRS facilities and were a prescribed, prescheduled bioassay requirement for most workers in those facilities, including subcontractors. However, job-specific bioassays were required by permit for work involving nonroutine radionuclides, mixes, and concentrations, and it is for that bioassay data category that the Board and SC&A had requested a review by NIOSH of its completeness and representativeness to support a SRS co-exposure model. The absence of RWPs and accountable job-specific bioassays during the 1970s and 1980s and independent findings of significant bioassay programmatic deficiencies at SRS in 1990 and 1997 exacerbate the circumstances of this data gap. SC&A concludes that NIOSH's use of a large number of routine plutonium bioassay samples does not address the issues, findings, and conclusions presented by SC&A regarding RPRT-0092's shortcomings in addressing the completeness and representativeness of subcontractor job-specific bioassays at SRS for at least 1972–1990.

Finding 7. It is not relevant to cite routine plutonium bioassay samples as a basis for NIOSH's conclusion that subCTWs were sufficiently monitored in areas outside of 773-A between 1972 and 1990 when the SEC-relevant question is the completeness and representativeness of job-specific bioassays.

10 Summary and Conclusions

SC&A does not dispute the analysis presented in RPRT-0094, which concluded, in part:

> Although not all sCTW were found to have internal monitoring records for each year of employment at SRS, for the years after 1979, 63% or more of externally monitored sCTW had internal monitoring records. The lowest fraction of externally monitored sCTW with internal records was 28% in 1978. For the subset of internal monitoring records related to other radionuclides with longer

> biological residence times and longer monitoring periods than tritium, the fractions of externally monitored sCTW with either WBC of non-Tritium records are 52% or greater for the years after 1979 with the lowest fraction of 5% in 1977 and 1978. [NIOSH, 2019b, p. 17]

However, SC&A does not believe that combining all forms of internal monitoring into a single metric accurately reflects the completeness of monitoring records for subcontractors. As shown in sections 3–6, for many years, the individual radionuclide analysis is substantially lower than the overall percentage of workers with any form of internal monitoring. For example, the ranges of total monitoring coverage by year (in vivo plus in vitro) during the DuPont era (1972–1990) were 3–34 percent for plutonium and 0–10 percent for americium. These ranges can be compared to the RPRT-0094 estimate for all non-tritium internal monitoring during the DuPont era, 5–87 percent.

In addition, SC&A notes that several issues remain open regarding the use of claimant data as a representative sample for the entire site population (as noted in section 8). Finally, SC&A acknowledges that a significant amount of plutonium data are contained in captured logbooks for subcontractors (as noted in section 9). However, such data do not contain information that would link them to permit-driven, job-specific bioassay compliance in order to determine the completeness of the job-specific monitoring program.

While SC&A agrees that there is a substantial amount of routine and incident/special internal monitoring data as described in RPRT-0094 and presented in NIOSH (2020c), the completeness of internal monitoring records for subcontractors (and in particular those who should have been monitored via the job-specific monitoring program) cannot be established by such an evaluation. The completeness of the job-specific monitoring program was to be established via the evaluation of RWPs as agreed upon by NIOSH, SC&A, and the SRS work group and outlined in RPRT-0092. SC&A's review of RPRT-0092 concluded the following:

> In summary, without the validation of subcontractor data completeness that the RPRT-0092 evaluation was to provide, there has been no substantiation that there are sufficient job-specific bioassay measurements available to ensure that the coworker data in OTIB-0081 are either bounding or representative of the exposure potential of subcontractors performing permit-driven work across the SRS site. [SC&A, 2019a, p. 65]

SC&A does not believe that the analysis of the claimant population of subcontractors (as found in RPRT-0094), nor the evaluation of captured logbook data (as presented in NIOSH (2020c)), sufficiently address the issue of job-specific bioassay completeness for unmonitored subcontractors performing radiological work under an RWP. Therefore, SC&A's conclusions regarding the completeness of job-specific bioassay and, by extension, the adequate representation of job-specific bioassay in any subsequent co-exposure model, remain unchanged.

Conclusion: SC&A does not find that the analysis of claimant subcontractor data in RPRT-0094 or the evaluation of the captured plutonium logbook data for subcontractors adequately address the original concerns of permit-driven, job-specific bioassay monitoring. It is SC&A's position that the original concerns related to the job-specific

bioassay program can only be adequately addressed through a direct connection between available internal monitoring and RWP monitoring requirements as analyzed in RPRT-0092.

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Attachment A: Matrix of SC&A's RPRT-0092 Findings

SC&A findings (abbreviated) (Nov. 12, 2019) (SC&A, 2019a)	**NIOSH response (SC&A summary) (Aug. 18, 2020)** (NIOSH, 2020b)	**SC&A additional points (summary) (Nov. 5, 2020)** (SC&A, 2020b)	**NIOSH additional points (presentations Nov./Dec. 2020)** (NIOSH, 2020c, 2020e)	**SC&A final conclusion (Feb. 2021)**
1. No SWPs or job plans sampled by NIOSH for 1972–1990 contain any requirements or indications for job-specific bioassays.	Even though bioassay choice not checked nor entered on SWPs and job plans, ample number of bioassays taken for sCTWs and CTWs that could be associated by bioassay data to the date of the SWPs and job plans.	NIOSH emphasizes "ample" *routine* and *special* bioassay data (NIOSH, 2020b, p. 4), particularly in NOCTS claimant database, but still cannot demonstrate data completeness for subcontractor *job-specific* bioassays, at least for 1972–1990.	RPRT-0092 used the era-specific criteria to determine if bioassays should have been taken for the 1972–1989 time period.	NIOSH's proposed use of "ample" (NIOSH 2020b, p. 4) routine, incident, and NOCTS data for subCTWs does *not* address Board's issue of job-specific bioassay data completeness and representativeness.
2. Assumed radionuclides of interest are of questionable accuracy given the lack of source term characterization prior to 1990.	Significant evidence that SRS characterized radiation work environments in multiple ways (various examples given).	For at least the DuPont era, there is a lack of any evidence of consistent, analysis-based radiological source-term characterization based on DPSOL procedures, actual job plans or SWPs sampled, and DOE Tiger Team independent audit of program performance.	SRS maintained inventories of radioactive materials. Examples: isotope production records, TRU and enriched uranium controlled as special nuclear materials, and monthly works technical reports from 1953–1989.	DOE found sitewide facility radiological characterization for bioassays to be deficient at SRS prior to 1990. NIOSH examples are *not* relevant.

SC&A findings (abbreviated) (Nov. 12, 2019) (SC&A, 2019a)	NIOSH response (SC&A summary) (Aug. 18, 2020) (NIOSH, 2020b)	SC&A additional points (summary) (Nov. 5, 2020) (SC&A, 2020b)	NIOSH additional points (presentations Nov./Dec. 2020) (NIOSH, 2020c, 2020e)	SC&A final conclusion (Feb. 2021)
3. Scope of sampling for 1972–1990 is limited to one facility, 773-A.	SCTWs were adequately monitored in areas outside 773-A between 1972 and 1990, as supported by additional coding efforts (e.g., Pu logbooks and incident-based data).	Citing sitewide *routine* sCTW bioassay data for plutonium and fission products, and NOCTS claimant data, is not relevant to RPRT-0092's objective of gauging *job-specific* bioassay data completeness.	Additional reviews of Pu logbooks support representativeness called for in DCAS-IG-006.	NIOSH *not* responsive to Board request for broadened scope of SRS facilities to support *job-specific* bioassay data analysis for completeness.
4. Incident-based bioassays provided on more stringent basis than job-specific ones; should not be used to supplement data completeness survey.	NIOSH has demonstrated that incident-based/special bioassay data should be used to demonstrate data completeness. This is because incident-based/special bioassay data will be bounding.	NIOSH seems to agree, given its statement that the inclusion of these data was "not meant to complement completeness of the non-incident/non-special bioassay data" (NIOSH, 2020b, p. 10).	Incident-based/special bioassay data include positive results making the co-exposure model more bounding or claimant favorable.	Agree that incident-based data should not be used to complement completeness analysis. NIOSH has *not* demonstrated such data bounds SRS-wide sCTW job-specific bioassay results.
5. Incompleteness of SRS dose records for 1972–1990 substantiated by acknowledged destruction of sCTW records.	While permits and other records are lacking, no evidence of missing dosimetry records.	SC&A accepts that, to date, no evidence of missing dosimetry records has been found.	Same	SC&A agrees no evidence exists of missing dosimetry records.

SC&A findings (abbreviated) (Nov. 12, 2019) (SC&A, 2019a)	NIOSH response (SC&A summary) (Aug. 18, 2020) (NIOSH, 2020b)	SC&A additional points (summary) (Nov. 5, 2020) (SC&A, 2020b)	NIOSH additional points (presentations Nov./Dec. 2020) (NIOSH, 2020c, 2020e)	SC&A final conclusion (Feb. 2021)
6. For 1981–1987, only 20% of sCTW Am-241 job plan combinations identified by NIOSH had internal monitoring performed within acceptable timeframe.	sCTWs had limited exposure to americium contamination. Majority of americium incidents/intakes occurred in areas where Am-241 was present in a mixture with Pu. Because workers with known intakes included in co-exposure Am models, NIOSH can bound doses for all workers, including sCTWs.	NIOSH/SC&A appear to agree only 20% of sCTW/job plan combinations directly monitored (in vitro or in vivo). Key Question: Has adequate evidence been established that the job-specific monitoring program was sufficient to detect intakes of separated americium?	NIOSH agrees with SC&A Finding 6 (20% monitored in the 1980s)	SC&A and NIOSH are in agreement.
7. Total "effectively monitored" population for Am-241 during 1980–1989 is approximately 33%.	Total number of effectively monitored workers is not 33%. It is total of those directly monitored with urinalysis bioassays or chest count (20%) plus coworkers indirectly monitored (36%), leading to effectively monitored total of 56%.	Credit for effective monitoring should only include unmonitored workers if monitored worker on same job plan is used in co-exposure modeling. If samples are not used for co-exposure model (i.e., in vivo monitoring for Am-241), the unmonitored worker is not represented.	NIOSH disagrees with SC&A finding 7 (33% effectively monitored). NIOSH may use chest count data for co-exposure modelling if needed.	SC&A agrees that if a co-exposure model were developed using both urinalysis and appropriate in vivo data (i.e., chest count data), then the effectively monitored population would increase. SC&A cautions that any such analysis should not include WBC data and only consider chest count data. To date, no such model has been analyzed or proposed.

SC&A findings (abbreviated) (Nov. 12, 2019) (SC&A, 2019a)	NIOSH response (SC&A summary) (Aug. 18, 2020) (NIOSH, 2020b)	SC&A additional points (summary) (Nov. 5, 2020) (SC&A, 2020b)	NIOSH additional points (presentations Nov./Dec. 2020) (NIOSH, 2020c, 2020e)	SC&A final conclusion (Feb. 2021)
8. Many of workers (70–73%) who should have been monitored for FPs underwent appropriate internal sampling during two periods evaluated prior to 1990 (1972–1974 and 1980–1989). However, very few of these monitored workers underwent in vivo counting for FPs. Thus, they are not included in the coworker model developed for SRS and are not considered representative of the unmonitored worker.	Although sCTWs are underrepresented in the fission product co-exposure model until 1983, the stratified model is valid for sCTWs because the data included for prime CTWs who performed similar work are sufficient.	No analysis of job plans was available for the years 1975–1979. Original sampling plan indicated bioassay would only be considered in evaluation if it was within 1 year. NIOSH dose reconstruction procedures considered periods greater than 2 years (not 3 years) to be unmonitored. SC&A and NIOSH disagree on effectively monitored workers: 70% vs. 94% (1972–1974) and 74% vs. 99% (1980–1989).	Actual fission product urinalysis results reported for individual sCTWs will be used to reconstruct fission product doses. Exposure models are stratified to CTW (prime plus subcontractor). Prime CTWs were routinely monitored during the entire period, while sCTWs were monitored by special urinalysis up to 1982. By 1976, WBCs replaced FP urinalysis to detect FP intakes. The model is valid for sCTWs as the data for all CTWs are sufficient for dose reconstruction purposes.	Similar to the response to finding 7 in the previous row, SC&A agrees that if a co-exposure model were developed using both in vitro and in vivo results, then the effectively monitored population would increase to comparable levels as those presented in RPRT-0092 (NIOSH, 2019a).

SC&A findings (abbreviated) (Nov. 12, 2019) (SC&A, 2019a)	NIOSH response (SC&A summary) (Aug. 18, 2020) (NIOSH, 2020b)	SC&A additional points (summary) (Nov. 5, 2020) (SC&A, 2020b)	NIOSH additional points (presentations Nov./Dec. 2020) (NIOSH, 2020c, 2020e)	SC&A final conclusion (Feb. 2021)
9. SC&A does not find that the data collected as part of the RPRT-0092 review support the premise that subcontractors on job plans that should have required internal monitoring for americium were either directly monitored (around 20%) or, alternately, appropriately represented in the derived coworker models for SRS (around 13%).	Regarding the americium CTW co-exposure model, the stratified model is valid because there are sufficient data to reconstruct doses for all CTWs. NIOSH reaffirms its position that sCTWs performed work and were monitored similarly to prime CTWs. Therefore, the developed co-exposure model can be used to estimate unmonitored sCTWs radiation doses.	Does not answer question of dose reconstruction feasibility for separated Am-241. Effectively monitored population should only consider unmonitored workers on same job plan of monitored worker who is included in co-exposure model; i.e., work is represented in co-exposure estimate, 33% effectively monitored.	The effectively monitored calculation is the total of the directly monitored (20%) and the indirectly monitored or coworkers (36 %), which includes coworkers chest counts made within 2 years from the date of the job plan, for a total effectively monitored worker of 56%, according to SC&A calculations.	See SC&A response to findings 6 and 7 in this table.
10. RWP data for 1990 are lacking.	NIOSH believes that 88% direct monitoring for sCTWs is not demonstrably incomplete (NIOSH, 2019a, PDF p. 38). Satisfies criteria in DCAS-IG-006, the implementation guide for co-exposure models	The 88% NIOSH quoted covers the entire period of 1990–1998 (not just 1990) and addresses the number of bioassays, not RWPs, so it cannot be used to address the lack of RWPs for the one year of 1990.	NIOSH believes that 88% direct monitoring for sCTWs (Pu, Sr, U, Am, Np) is not demonstrably incomplete; these data can be categorized in the 1990 to 1998 timeframe.	The 88% NIOSH quoted is for the number of bioassays averaged over 1990–1998, not the number of RWPs specifying radionuclides to be monitored for the one year of 1990. Bundling 1990 with 1991 indicates a lack of RWP information for 1990.

SC&A findings (abbreviated) (Nov. 12, 2019) (SC&A, 2019a)	NIOSH response (SC&A summary) (Aug. 18, 2020) (NIOSH, 2020b)	SC&A additional points (summary) (Nov. 5, 2020) (SC&A, 2020b)	NIOSH additional points (presentations Nov./Dec. 2020) (NIOSH, 2020c, 2020e)	SC&A final conclusion (Feb. 2021)
11. For both the 1972–1989 and 1990–1998 periods, when considering all radionuclides requiring internal monitoring per work permit, as opposed to "at least one radionuclide" requiring monitoring, the percentage of monitored workers drops significantly (particularly in the earlier periods). Directly monitored workers ranged from 47% to 77% (in comparison to 76% to 96% in RPRT-0092), and effectively monitored workers ranged from 55% to 89% (in comparison to 85% to 99% in RPRT-0092).	NIOSH stands by the results given for effectively monitored workers. Even without consideration of effective monitoring, sufficient numbers of subcontractor trade workers were monitored in the 1972 through 1998 timeframe coupled with internal monitoring data for prime CTWs to develop a co-exposure model for use in reconstructing unmonitored doses.	"monitored for at least one radionuclide" (NIOSH, 2019a, p. 59) should not be used to indicate that a worker was adequately bioassayed as specifically prescribed by a job plan or RWP.	The sampling plan for the Westinghouse era (1990–1998) considered a worker as monitored if they had at least one bioassay results.	An analysis of the percentage of subcontractor workers that were "monitored for at least one radionuclide" (NIOSH, 2019a, p. 59) should not be used to indicate that subcontractors, or any workers, were adequately bioassayed as prescribed by an RWP or job plan.