ADVISORY BOARD ON
RADIATION AND WORKER HEALTH

National Institute for Occupational Safety and Health

SC&A REVIEW OF DOSIMETRY CODING METHODS FOR IDENTIFYING NEPTUNIUM WORKERS AT SAVANNAH RIVER SITE

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Prepared by

Bob Barton, CHP

SC&A, Inc.
2200 Wilson Boulevard, Suite 300
Arlington, Virginia 22201-3324

Saliant, Inc.
5579 Catholic Church Road
Jefferson, Maryland 21755

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PROJECT MANAGER:	John Stiver, MS, CHP [signature on file]
DOCUMENT REVIEWER(S):	John Stiver, MS, CHP [signature on file] Joe Fitzgerald [signature on file]

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ABBREVIATIONS AND ACRONYMS

ABRWH	Advisory Board on Radiation and Worker Health
Am	americium
CAM	Continuous Air Monitor
CATI	computer-assisted telephone interview
CDC	Centers for Disease Control and Prevention
Cf	californium
Cm	curium
CPM	counts per minute
dpm	disintegrations per minute
DOE	U.S. Department of Energy
DOL	U.S. Department of Labor
E&I	Electrical and Instrumentation
EE	energy employee
FP	fission products
HGVC	hot gang valve corridor
HP	Health Physics
HPA	Health Physics Area
HPD	Health Physics Department
HPRED	Health Physics Radiological Exposure Database
µCi	microcurie
mrem	millirem
nCi	nanocurie
NIOSH	National Institute for Occupational Safety and Health
Np	neptunium

O	oxygen
ORAUT	Oak Ridge Associated Universities Team
OW	Open Window
Pu	plutonium
PuFF	235-F Plutonium Fuel Form Fabrication Facility
RCG	Radioactivity Concentration Guideline
RPRT	Report
S	Shielded
SRS	Savannah River Site
TWOPOS	time-weighted one person-one sample
WBC	whole body count

EXECUTIVE SUMMARY

This report presents SC&A's review of ORAUT-RPRT-0077, Revision 00, *Evaluation of Health Physics Area and Health Physics Department Codes to Identify Neptunium Workers at the Savannah River Site* (NIOSH 2016a). In its review, SC&A identified and analyzed the monitoring records provided by the U.S. Department of Energy (DOE) for 86 claimants who had confirmed intakes of neptunium-237 (Np-237) or plutonium-238 (Pu-238).[1] The goal of this evaluation is twofold:

1. Analyze the relationship between Health Physics Area (HPA)/Health Physics Department (HPD) codes and documented intake incidents (see Section 3).
2. Evaluate Savannah River Site (SRS) external dosimetry records for the practical implementation of using HPA/HPD codes to identify neptunium workers for the purpose of assigning unmonitored intakes of neptunium (see Section 4).

The first analysis is useful because it provides an independent verification of the analysis and conclusions in NIOSH 2016a. The second analysis offers perspective on how the proposed methodology for identifying would work in practice. SC&A's review identified eight findings and nine observations. An overall summary of SC&A's conclusions based on these findings and observations is discussed in the remainder of this Executive Summary.

Examination of available HPA and HPD codes for dosimetry cycles related to documented intakes showed reasonable agreement with the codes identified in NIOSH 2016a. SC&A agrees with the main conclusions of NIOSH 2016a that the most frequently encountered HPA and HPD codes represent the groups of workers most likely to have exposure potential to neptunium. However, SC&A also identified cases where intake incidents were associated with areas and departments not directly related to neptunium operations (e.g., construction and maintenance codes). Although these types of area and department codes were observed at a much lower frequency when compared with the more common neptunium operational codes, SC&A does not necessarily agree that they represent little or no exposure potential. However, the issue of what constitutes suitable worker coverage for assigning unmonitored intakes of neptunium is inherently subjective and requires professional judgment. Therefore, the SRS Work Group should carefully consider what constitutes a sufficient cohort for coworker dose assignment.

Based on the review of currently available DOE monitoring records for the 86 claimants identified as having confirmed intakes of Np-237 or Pu-238, it is SC&A's opinion that there is considerable uncertainty in using HPA and HPD codes for assigning coworker intakes during some time periods. This is especially true for workers who might change work location on a semiregular basis but whose external dosimetry files may not adequately reflect such changes. SC&A would note that many of the concerns discussed in Section 4 of this report may be partially or completely alleviated by obtaining a complete set of dosimetry records for the affected workers at SRS. This would include not only quarterly summary reports but also the actual individual cycle dosimetry reports. However, absent additional dosimetric information,

[1] Pu-238 exposures were included in the analysis because workers who had significant exposure potential to plutonium would have also had exposure potential to neptunium.

SC&A recommends that the default approach be to automatically assign coworker intakes unless it can be clearly established that the energy employee (EE) could not have been exposed.

Summary Recommendation: *SC&A believes that the exclusion of workers who do not fit the HPA and HPD criteria described in in the concluding section of NIOSH 2016a from assignment of unmonitored neptunium coworker doses may be too restrictive and not claimant favorable in at least some cases. Furthermore, because of the uncertainty in the availability of HPA and HPD codes used to identify work locations during significant operational periods at SRS, it would be claimant favorable to automatically assign unmonitored intakes unless clear and convincing evidence exists that the EE could not have been exposed.*

1.0 INTRODUCTION AND BACKGROUND

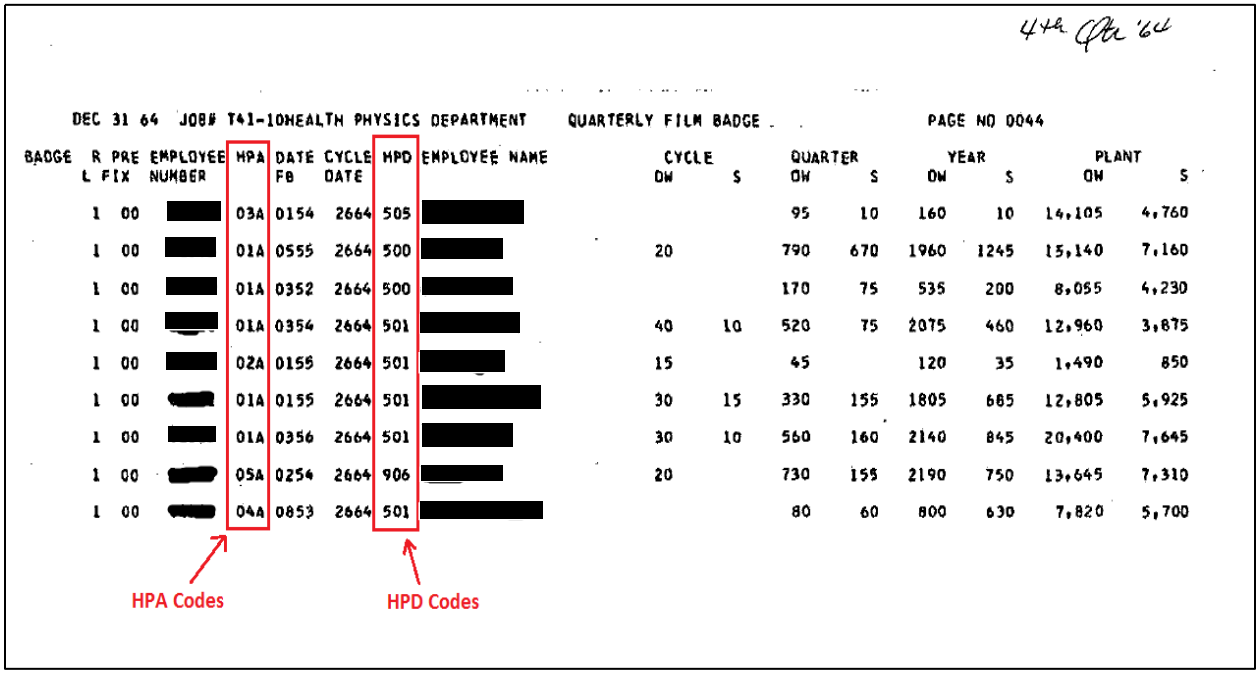
NIOSH released Revision 0 of ORAUT-RPRT-0077, *Evaluation of Health Physics Area and Health Physics Department Codes to Identify Neptunium Workers at the Savannah River Site* (NIOSH 2016a), on November 8, 2016. The stated purpose of this report is as follows:

> [evaluate] *the usefulness of Health Physics Area (HPA) and Health Physics Department (HPD) codes to identify workers associated with the ^{237}Np processes at Savannah River Site (SRS) from 1973 through 1989.* [page 5]

This report presents SC&A's review of the HPA and HPD code methodology presented in NIOSH 2016a. The remainder of this section briefly summarizes the proposed methodology for identifying workers potentially exposed to neptunium. Section 2 provides some general comments on the proposed approach as well as a description of SC&A's evaluation methods. Sections 3 and 4 present the results of SC&A's review.

HPA and HPD codes most often appear in certain formats of external dosimetry records found in claimant monitoring files that DOE supplies. Figure 1 shows an example of HPA and HPD code listings in a dosimetry report. NIOSH 2016a, Tables 2-1 and 3-1, list of HPA and HPD code interpretations. Interpretation of HPA codes was based on direct communication with the SRS Dosimetry Records Manager (NIOSH 2014), and interpretation of HPD codes was based on a list of DuPont department codes dated April 1977 (DuPont 1977).

Figure 1. Example Dosimetry Record Showing HPA and HPD Codes (Employee Names and Numbers Have Been Redacted)



4th Qtr '64

DEC 31 64 JOB# T41-10HEALTH PHYSICS DEPARTMENT QUARTERLY FILM BADGE PAGE NO 0044

BADGE	R L	PRE FIX	EMPLOYEE NUMBER	HPA	DATE FB	CYCLE DATE	HPD	EMPLOYEE NAME	CYCLE DW	CYCLE S	QUARTER DW	QUARTER S	YEAR DW	YEAR S	PLANT DW	PLANT S
	1	00	[redacted]	03A	0154	2664	505	[redacted]			95	10	160	10	14,105	4,760
	1	00	[redacted]	01A	0555	2664	500	[redacted]	20		790	670	1960	1245	15,140	7,160
	1	00	[redacted]	01A	0352	2664	500	[redacted]			170	75	535	200	8,055	4,230
	1	00	[redacted]	01A	0354	2664	501	[redacted]	40	10	520	75	2075	460	12,960	3,875
	1	00	[redacted]	02A	0155	2664	501	[redacted]	15		45		120	35	1,490	850
	1	00	[redacted]	01A	0155	2664	501	[redacted]	30	15	330	155	1805	685	12,805	5,925
	1	00	[redacted]	01A	0356	2664	501	[redacted]	30	10	560	160	2140	845	20,400	7,645
	1	00	[redacted]	05A	0254	2664	906	[redacted]	20		730	155	2190	750	13,645	7,310
	1	00	[redacted]	04A	0853	2664	501	[redacted]			80	60	800	630	7,820	5,700

HPA Codes

HPD Codes

The main objective of NIOSH 2016a is to correlate HPA and HPD codes with workers who are assumed to have the highest risk of neptunium exposure. Specifically, Section 5.0 of NIOSH 2016a states:

> *The analysis in this report shows that HPA and HPD codes for operations and maintenance workers have a correlation in terms of neptunium facilities.*
> [page 11]

To correlate HPD and HPA codes that are likely associated with neptunium exposure, the National Institute of Occupational Safety and Health (NIOSH) examined the records of workers who had one or more of the following characteristics:

- Were assigned HPD Code 205 (designating a subgroup of the separations department associated with the 235-F Plutonium Fuel Form Fabrication Facility, also known as "PuFF").
- Were monitored internally via Pu-238 and/or Np-237 bioassay (both claimants and nonclaimants).
- Were identified with specific Np-237 contamination incidents.

Based on the subsequent analysis, Section 8.0 of NIOSH 2016a concludes the following:

> *All workers associated with HPD 205 are assumed to have had a significant exposure potential due to the mission of the group and the location of the work.*
>
> - *92% of the intake monitoring was associated with only five HPA codes: 2F, 2H, 3M, 5A, and 4H.*
> - *71% of the intake monitoring was associated with only seven HPD codes: 205, 500, 503, 209, 300, 601, and 300*
>
> *Most (66%) of the intake monitoring for ^{238}Pu and ^{237}Np is associated with seven combinations of HPA and HPD codes:*
>
> - *HPA 2F and HPD 205 (235-F PuFF) = 43%,*
> - *HPA 2H and HPD 205 (235-F PuFF) = 5.6%,*
> - *HPA 3M and HPD 503 (Works Technical: Reactor Technology) = 4.3%,*
> - *HPA 2F and HPD 500 (Works Technical: HP) = 4.0%,*
> - *HPA 2H and HPD 209 (Separations: HB Line) = 3.8%,*
> - *HPA 2F and HPD 601 (Works Engineering: E&I) = 2.4%, and*
> - *HPA 3M and HPD 300 (Raw Materials) = 2.4%.*
>
> *This indicates that there was little or no known intake potential in other combinations of location and functional department. It suggests that the combination of HPA and HPD code is a powerful predictor of the recognized need for intake monitoring for ^{238}Pu and ^{237}Np. Personnel dosimetry exposure records contain these HPD and HPA codes for the workers. Works Technical*

> *Reports and site Special Hazard Investigations reports contain documentation of radiological worker incidents and events that occurred in the various work areas. When necessary, these documents can be references to determine HPD and HPA codes for workers.* [page 18]

Although not explicitly stated, it is apparent that NIOSH intends to use the HPA and HPD codes (or combinations of them) shown above as a trigger for the application of unmonitored neptunium coworker doses. The assumed corollary is that other observed HPA and HPD codes would not be considered neptunium workers and, thus, would preclude the application of coworker intakes.

2.0 GENERAL COMMENTS AND REVIEW APPROACH

As described in Section 1.0, NIOSH 2016a evaluated the correlation between HPA and HPD codes among workers who were likely to have the greatest exposure potential to neptunium. In its concluding section, NIOSH 2016a lists the HPA and HPD codes that were most often associated with those workers. SC&A assumes that the intent is to use only those codes (or the combination of them) to assign coworker intakes to unmonitored workers. However, SC&A believes that the report would benefit from more specific and explicit instructions to the dose reconstructor on how NIOSH plans to implement the proposed approach. For example, is a single HPA or HPD code sufficient to assign neptunium doses, or is the combination of codes required? Would neptunium intakes be assigned only for that badging period in which the code designations are identified, or would they be assigned for a longer period (such as the whole year)? If the EE indicates neptunium exposure but does not have dosimetry records with the identified codes, are unmonitored neptunium exposures still applicable? Often, such questions can be answered with hypothetical dose reconstructions[2]; however, explicit instructions to the dose reconstructor would also provide clarity on how neptunium coworker intakes will be implemented.

Observation 1: Section 8.0 of NIOSH 2016a would benefit from explicit instructions or descriptions, or both, on how NIOSH plans to implement the proposed approach of using HPA and HPD codes to assign Np-237 coworker intakes. Additionally, an example dose reconstruction using actual claimant records would help illustrate how the methodology would function in practice.

In principle, SC&A agrees that the combinations of HPA and HPD codes identified in NIOSH 2016a represent "powerful indicators" of the group of workers most likely to have exposure potential to neptunium. However, SC&A does not a priori agree that these codes (or combinations of codes) preclude other HPA and HPD designations from having "little or no known" exposure potential and thus being deemed inappropriate for coworker intake assignment. The fact that workers with other combinations of HPA and HPD codes were monitored for Pu-238/Np-237, and in some cases have confirmed intakes of these radionuclides, indicates that other types of workers could have been exposed, even if such exposures were less probable than code designations presented in Section 8.0 of NIOSH 2016a.

Clearly, the issue of what constitutes appropriate worker coverage is a matter of professional judgment and not necessarily a technical determination. Such philosophical judgments are common in any coworker model application and can vary significantly from site to site. Thus, SC&A feels the issue of worker coverage is of particular import and should be carefully considered by the SRS Work Group.

Observation 2: The issue of what constitutes appropriate worker coverage for applying coworker intakes of neptunium is central to NIOSH 2016a. Such judgments are not necessarily technical in nature but are common in the practical implementation of any

[2] SC&A understands that at the time of the release of NIOSH 2016a, the neptunium coworker model was still under development. However, an example dose reconstruction with placeholder intake values would still be beneficial and provide clarity.

unmonitored dose assignment. Thus, the issue of sufficient worker coverage in the context of using HPA and HPD codes for dose assignment should be carefully considered by the SRS Work Group.

As stated in Section 1.0 of NIOSH 2016a:

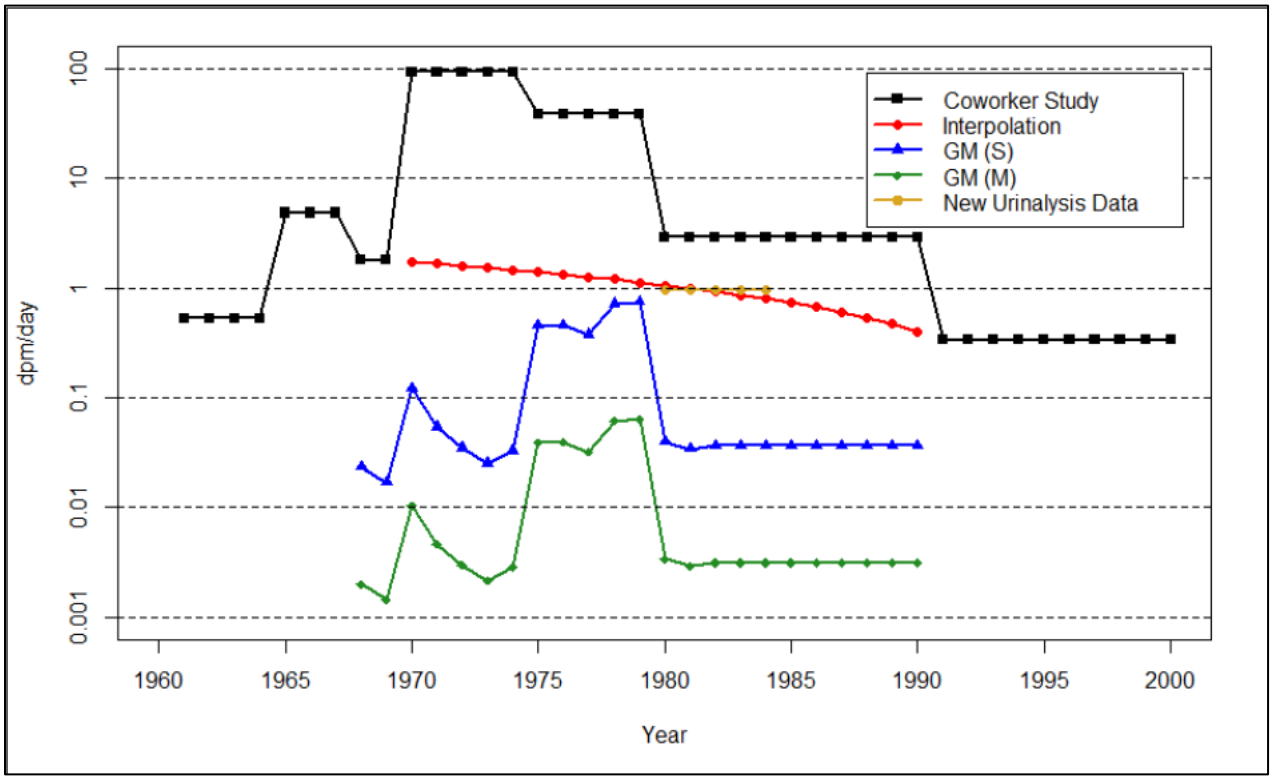
> *Separations processes associated with ^{237}Np are closely related to similar processes involving ^{238}Pu; therefore, monitoring for exposure to ^{238}Pu is assumed to be an indicator of a potential for ^{237}Np intake.* [page 5]

SC&A agrees that, because of the purpose of the operation of interest and the proximity of specific activities involving Np-237 and Pu-238, exposure potentials to both contaminants are closely correlated. Therefore, SC&A examined the SRS Transuranic Internal Dose Registry to identify claimants who had confirmed uptakes of Np-237, or Pu-238, or both. NIOSH 2016a restricted its analysis to the period from 1973 to 1989; however, SC&A expanded the timeframe for evaluation to the period from 1959 to 2000. The rationale for expanding the period for evaluation is based on ORAUT-RPRT-0065, Revision 00, *An Evaluation of Neptunium Operations at Savannah River Site* (NIOSH 2016b), which contains the following concluding statement:

> *Final sets of stratified coworker intakes will be derived using neptunium urinalysis **through 1969 and 1990 through 1995**, and WBC data through 1989 using TWOPOS calculation methods….* [emphasis added] [page 42]

Notably, the statement does not specify an exact start date for the application of neptunium intakes and only states the proposed method utilizes "*urinalysis through 1969*." Based on that same statement, it appears coworker intake assignment is to end in 1995. However, NIOSH 2016b also provides a timeline of derived coworker intakes (shown as Figure 8-15 in NIOSH 2016b and as Figure 2 below) that spans the years from approximately 1960 to 2000. Documentation suggests that pilot-scale separations activities involving Pu-238 and Np-237 began in 1959 and included at least some bioassay monitoring (Coogler et al. [n.d.]). Therefore, SC&A chose 1959 as the start for its analysis and 2000 as the final year evaluated.

Figure 2. Screenshot of Figure 8-15 from NIOSH 2016b



SC&A identified 86 claimants who were employed during this expanded period and had confirmed uptakes of Pu-238, Np-237, or both, in the SRS Transuranic Internal Dose Registry. SC&A's evaluation of these 86 claims focused on two facets:

1. Characterization of the intake incident and the correlation between the badging records (HPD and HPA codes) associated with the incident (see Section 3).

2. Evaluation of the monitoring practices and available dosimetry records supplied by DOE in the context of using the HPA/HPD dosimetry codes to identify potentially exposed workers (see Section 4).

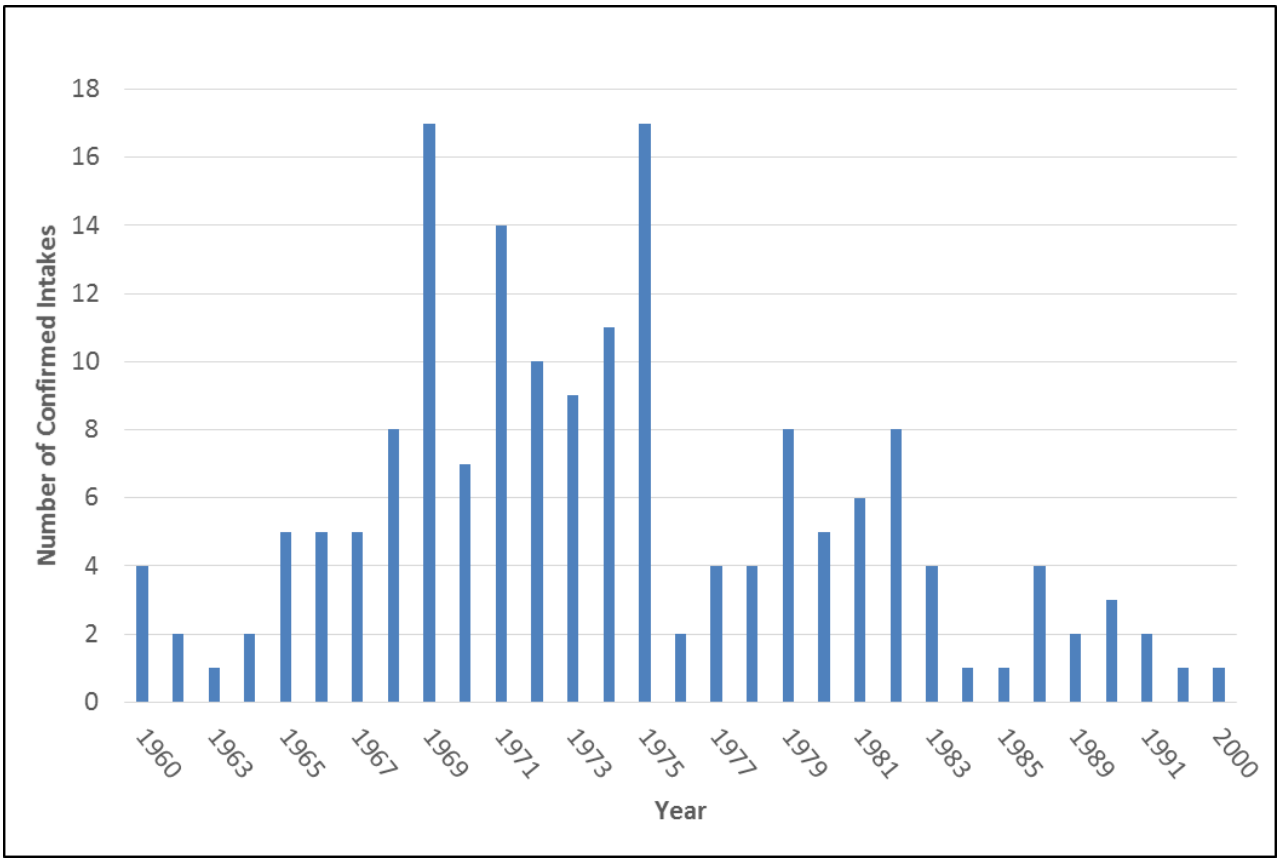
The first facet is intended provide a comparison similar to the evaluation presented in NIOSH 2016a. The second facet is intended to demonstrate and characterize the practical implementation of using dosimetry codes to establish work areas in general.

3.0 EVALUATION OF HPA AND HPD CODES ASSOCIATED WITH DOCUMENTED UPTAKES OF Np-237 AND Pu-238 IN IDENTIFIED CLAIMANT RECORDS

SC&A examined the claim files for each of the 86 EEs who were identified as having positive uptakes of Np-237, Pu-238, or both, during the period of interest (1959–2000). For each intake, SC&A reviewed (1) available monitoring records for the associated dosimeter badge codes and (2) related internal monitoring information, which very often contained the location of the incident. Appendix A has a detailed listing of all 86 claimants and associated intake incidents.

In total, there were 173 intake incidents involving Np-237 or Pu-238 for the 86 identified claimants. The number of confirmed intakes by year is shown in Figure 3. Only 10 of the 173 total intake incidents involved a confirmed intake of Np-237; the remaining 163 were related to Pu-238.

Figure 3. Number of Confirmed Pu-238 and Np-237 Intakes by Year (1960–2000)



Examination of the DOE dosimetry records for the claimants involved in identified intake incidents revealed that only 99 of 173 (~57%) contained a dosimetry record that listed a specific

HPD code.[3] Table 1 shows a breakdown of HPD codes identified with the intake incidents and also presents the percentages in NIOSH 2016a, Section 5.2, for comparison.

As seen in Table 1, the HPD code most commonly identified in both the SC&A and NIOSH 2016a analyses was 205, which represents the Separations Department located at the 235-F PuFF area. However, SC&A identified other HPD codes that were not directly identified in NIOSH 2016a, Section 5.2, but were associated with confirmed intakes of Np-237 or Pu-238. These codes represent the Works Technical Department (Laboratory Personnel), the Separations Department (F and H Canyons), and the Technical Department (Miscellaneous). Also identified in the SC&A analysis was the department Code 40 (which represents the Construction department). This department code would be particularly important for transient workers doing irregular jobs around potentially contaminated equipment, such as decontamination and repair activities. Additionally, SC&A identified the HPD Code 000, which is not listed in either NIOSH 2016a or the underlying reference used to identify the department with a specific HPD code (DuPont 1977).

Table 1. HPD Codes Identified Among 99 Intake Incidents for Claims with Confirmed Intakes of Np-237 or Pu-238

SC&A Identified HPD Code	SC&A Total Number (Percentage)	HPD Description	NIOSH Identified Percentage
205	39 (39.4%)	Separations – 235-F PuFF	50%
209	18 (18.2%)	HB-Line	4.0%
203	12 (12.1%)	Separations – H Canyons	Not Listed
501	10 (10.1%)	Works Technical – Laboratory	Not Listed
500	7 (7.1%)	Works Technical – Health Physics	5.4%
906	3 (3.0%)	Miscellaneous Technical	Not Listed
000	3 (3.0%)	Unknown Department Code	Not Listed
601	2 (2.0%)	Works Engineering – Electronics and Instrumentation	2.4%
602	1 (1.0%)	Works Engineering – Maintenance	2.2%
200	1 (1.0%)	Separations – F Canyons	Not Listed
703	1 (1.0%)	Service – Traffic and Transportation	Not Listed
201	1 (1.0%)	Separations – FB Line	Not Listed
40	1 (1.0%)	Construction	Not Listed

Approximately 75% (129 of 173) of the intake incidents had an associated dosimetry record that listed an HPA code.[4] Table 2 shows a breakdown of HPA codes identified with the intake incidents and also shows the percentages presented in NIOSH 2016a, Section 5.1, for comparison.

As seen in Table 2, the majority of HPA codes identified with Np-237 and Pu-238 exposure were for the general areas of 200-H and 200-F. Interestingly, the SC&A analysis found 200-H to be

[3] The discussion of dosimetry records that do not contain an HPD code can be found in Section 4.
[4] The discussion of dosimetry records that do not contain an HPA code can be found in Section 4.

the most frequently identified code (60.5% of the total), with codes associated with 200-F showing the next highest percentage (25.5% of the total). Conversely, the analysis in NIOSH 2016a showed the opposite, with 200-F codes constituting the majority (62%) and 200-H codes observed at the next highest frequency (12%). It is important to note that for at least two cases reviewed, SC&A identified area codes that are reflective of construction and maintenance workers (HPA codes for Carpenters and the South Gate of Central Shops). This demonstrates that there was exposure potential to Np-237 and Pu-238 despite the EE's HPA code not comporting with the locations most commonly associated with the operations of interest.

Table 2. HPA Codes Identified Among 129 Intake Incidents for Claims with Confirmed Intakes of Np-237 or Pu-238

SC&A Identified HPA Code	SC&A Total Number (Percentage)	HPA Description	NIOSH Identified Percentage
2A, 2H	78 (60.5%)	200-H	12%
1A, 2F, 1F	33 (25.6%)	200-F, 200-F Main Gate, 200-F North Entrance	62%
5A	5 (3.9%)	773-A	8.1%
4H	3 (2.3%)	232-234 F	1.9%
A03, H02	2 (1.6%)	703-A (B Wing), 200-H Main Gate	Not Listed
3M	2 (1.6%)	300-M	9.2%
F02, H02, HB2	1 (0.8%)	200-F Main Gate, 200-H Main Gate, Unknown*	Not Listed
H1	1 (0.8%)	200 Effluent Treatment Facility**	Not Listed
7A	1 (0.8%)	South Gate of Central Shops	Less than 1%
8C	1 (0.8%)	Carpenters	Not Listed
F8	1 (0.8%)	235-F Not Construction	Not Listed
F3	1 (0.8%)	241-F Construction	Not Listed

*HPA code HB2 is not listed in NIOSH 2014.
**According to NIOSH 2014, this code was no longer in use after 1992; however, the dosimetry record in question was dated January 1995. The designation "200 Effluent Treatment Facility" was in use before 1992.

Finding 1: Of the 173 documented intakes of Np-237 and Pu-238 identified among the claimant population, 43% had associated dosimetry records that did not identify an HPD code and 25% that did not identify an HPA code.

Observation 3: When HPA and HPD codes were provided in the available external dosimetry records associated with confirmed intakes, the codes showed reasonable agreement with the analyses in Sections 5-1 and 5-2 of NIOSH 2016a. SC&A agrees that, in general, these codes represent the cohort of workers most likely to have been exposed to neptunium. However, the SC&A analysis identified HPD and HPA codes associated with construction trades that are likely important for the assignment of coworker doses despite not being seen as frequently as the HPA and HPD codes typically associated with operations personnel.

4.0 OBSERVATIONS CONCERNING SAVANNAH RIVER SITE MONITORING PRACTICES AND AVAILABLE DOE CLAIMANT RECORDS

To understand and characterize the potential use of HPA and HPD codes to identify neptunium workers for the purpose of administering unmonitored coworker intakes, SC&A analyzed the available monitoring records for the 86 claimants who had confirmed intakes of Np-237 or Pu-238, or both. Specifically, SC&A examined the radiation monitoring records supplied by DOE for these claims to understand the availability and completeness of the HPA and HPD codes found in such records. SC&A made nine observations related to monitoring practices and currently available records contained in the claimant files. These observations and associated discussion are organized by the time periods that generally reflect changes in external monitoring reporting practices and formats. These time periods are as follows:

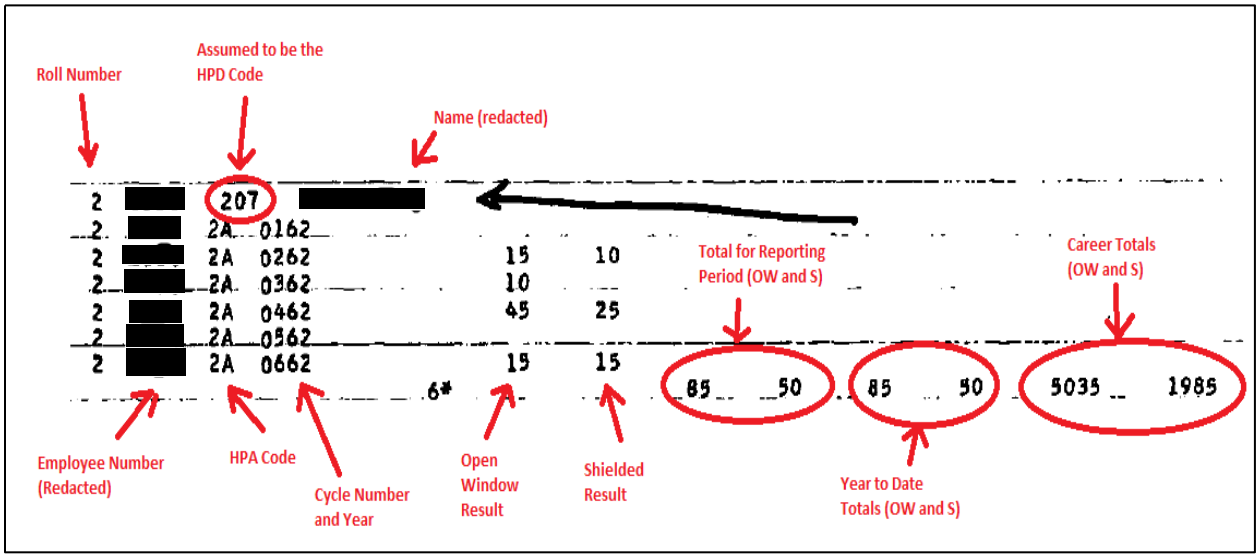
- January 1959–March 1963 (see Section 4.1)
- April 1963–December 1972 (see Section 4.2)
- January 1973–December 1981 (see Section 4.3)
- January 1982–December 1988 (see Section 4.4)
- January 1989–December 1989 (see Section 4.5)
- January 1990–December 2000 (see Section 4.6)

Section 4.7 provides a general overview and summary of the observed changes in monitoring practices as seen in the reviewed claim files.

4.1 JANUARY 1959–MARCH 1963

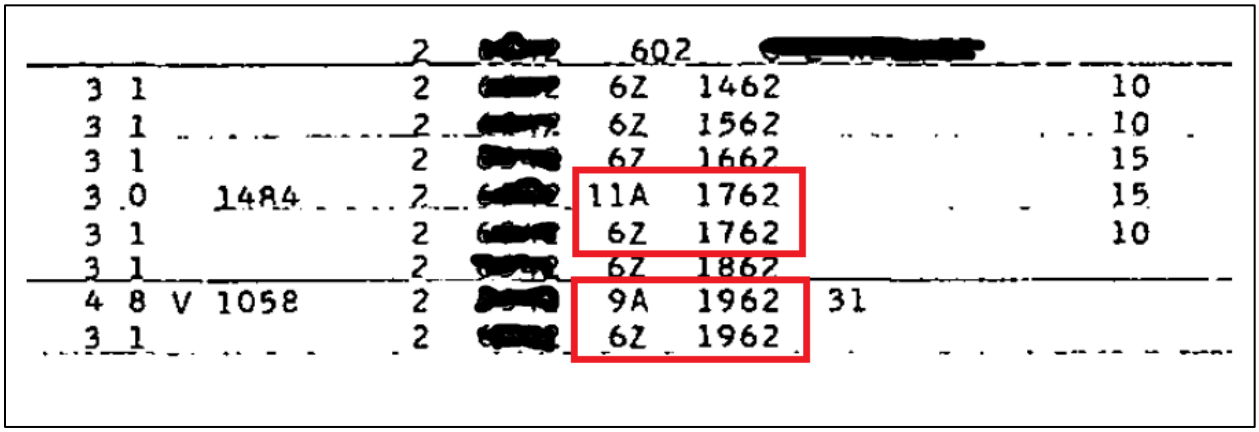
From 1959 through the first quarter of 1963, the dosimetry exchange cycle was on a biweekly basis for all 57 claims with employment during this period. Figure 4 shows an example screenshot of available external dosimetry during this period. It should be noted that the “cycle numbers” shown in Figure 4 are sequential but actually represent 2-week periods, because the total number of cycles in a year was consistently 26. Also of note is that a single HPD code appears to be used to represent a group of cycle exchanges (in this case, cycles 1–6).

Figure 4. Example Screenshot of Dosimetry Records Format in Use from 1959 to March 1963



Importantly, SC&A observed instances in which it is documented in the record that the EE was assigned to multiple areas during the same badging cycle (i.e., multiple HPA codes are indicated). This was observed to some extent in more than 80% (46 of 57) of the cases with employment during this period. An example of a badging period containing multiple HPA codes is shown in Figure 5. As seen in Figure 5, the entries for the 17th and 19th cycles have two HPA codes. This characteristic is especially important because it indicates that if monitored workers were in multiple areas during a given cycle, that information is documented in the dosimetry record.

Figure 5. Example of a Dosimetry Record that Indicates Two Different HPA Codes for the Same Cycle



Observation 4: For the period from 1959 through March 1963, badges were exchanged on a biweekly frequency. Approximately 80% of the cases examined during this period contained examples in which multiple HPA codes were identified for the same badging

cycle. This indicates that changes in work area were being tracked by the dosimetry branch and that information is available in the claimant monitoring records supplied by DOE.

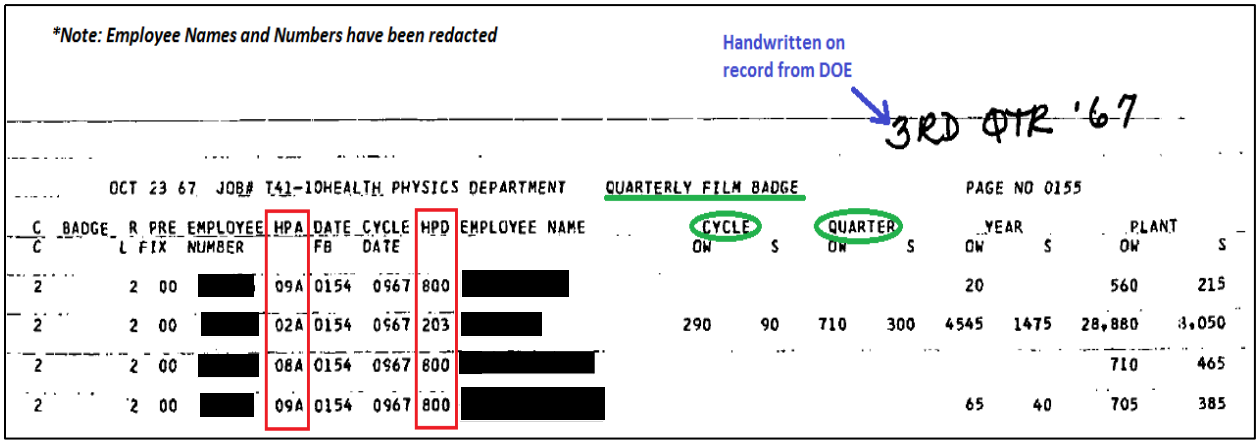
4.2 APRIL 1963–DECEMBER 1972

Beginning in April 1963 and extending through 1964, dosimeters continue to be exchanged on a biweekly basis, as evidenced by the cycle numbering scheme. However, DOE-supplied monitoring records provide only quarterly summaries of these cycle reports. Beginning in 1965 and extending through 1972, the badging exchange frequency appears to switch to monthly. As was the case for the earlier period, DOE provided only quarterly summary records. An example of the quarterly records available from April 1963 to December 1972 is shown in Figure 6. As seen in Figure 6, the record is identified as a "quarterly" record; however, an individual exposure for the "cycle" is reported in addition to the quarterly total. Each entry represents a single worker and contains an HPA and an HPD code.

Of the 86 claimants identified in the SRS Transuranic Internal Dose Registry, 67 were employed during the period from April 1963 to December 1972. More than 95% of those claims (64 of 67) contained only quarterly exposure summaries in their DOE-supplied monitoring records (the three remaining claims are discussed later in this section). This indicates that, at minimum, any change in singular work location might be noted only on a quarterly basis for these workers.

Observation 5: Beginning in April 1963 and extending through December 1972, available dosimetry records are reported on a quarterly basis, although dosimeters were exchanged on either a biweekly or monthly basis. Therefore, work location can only be assessed (at a minimum) on a quarterly basis for this period.

Figure 6. Example Screenshot of Quarterly Summary Report in the April 1963–December 1972 Period (Names and Employee Numbers Have Been Redacted)



Unlike dosimetry records from before April 1963, SC&A found no evidence of workers being assigned multiple HPA codes (indicating multiple work areas) for a single badging cycle. Therefore, any variability in work location during a given badging period does not appear to have been tracked by the dosimetry department in the available records. This obviously adds uncertainty in using the available HPA codes for assignment of work area. This is particularly true for transient workers, such as construction and maintenance workers, who may have worked

and been exposed in several work areas during a 3-month period but only have one HPA code designated in the available records.

Finding 2: During the period from April 1963 to December 1972, SC&A found no evidence that multiple HPA codes were being assigned during a given badging cycle, which would allow for identifying worker movements among different areas. Unlike the previous period, it does not appear that the dosimetry department was using the HPA codes to track all worker movements during a given badging cycle.

Table 3 describes the three claims that did not have quarterly dosimetry throughout this period. As seen in Table 3, the first claim had quarterly dosimetry reports except for 1972, in which individual monthly cycles were reported. However, the monthly cycles were contained on a single sheet and no HPA or HPD codes were present for identifying a work area. The other two claims did not have dosimetry cycle information before 1973, although annual summaries indicate positive exposures during these years. It should be noted that NIOSH has independently identified select quarterly reports for these two individuals from 1967 to 1970 through their own research.[5] Therefore, the quarterly reports may be available but were simply not included in the DOE-supplied monitoring records.

[5] This process is known to SC&A as "hotlinking," in which NIOSH provides documents, reports, and other records with the claimant's name that have been uncovered through unrelated site research.

Table 3. Three Reviewed Cases That Have Covered Employment but no Quarterly Exposure Records (April 1963–December 1972)

NOCTS Claim #	Employment	Job Title	Comments
[redacted]	[redacted]/1954–[redacted]/1991	Mechanic and [redacted]	For 1972, dosimetry results for all 12 individual monthly cycles are provided on a single sheet of paper. However, HPA and HPD codes are not included on this 1972 report. Quarterly reports are available for remaining monitoring years during the period of interest.
[redacted]	[redacted]/1952–[redacted]/1986	Construction	No external dosimetry cycle records (monthly or quarterly) are available before 1973. Annual exposure summaries indicate positive external dose was accrued each year from 1956 to 1972. However, annual summaries do not contain HPA or HPD codes that would allow for worker placement. It should be noted that NIOSH has identified quarterly reports for this EE for select quarters from 1967 to 1970; therefore, the missing dosimetry records for this individual may be available.
[redacted]	[redacted]/1954–[redacted]/1996	Lab Tech	Aside from a handful of visitor badges in the 1960s, the EE does not have any regular dosimetry records (individual cycles or quarterly summaries) until 1973. Annual exposure summaries indicate positive doses were accrued every year from 1955 to 1972 except for 1958. However, annual summaries do not contain HPA or HPD codes. It should be noted that NIOSH has identified quarterly reports for this EE for select quarters from 1967 to 1970; therefore, the missing dosimetry records for this individual may be available.

Observation 6: SC&A identified two cases in which no quarterly exposure reports were available from April 1963 to December 1972; however, annual exposure summaries indicate that positive doses were accrued during this timeframe. Through a process known as "hot-linking," NIOSH has identified selected quarterly reports for these two individuals in the years 1967 to 1970. Therefore, the dosimetry records may not be missing; however, they are currently unavailable in the DOE-supplied records.

SC&A notes that for many cases during the period of interest (~64%), a quarterly report was available for each relevant monitoring quarter. However, for 23 of 64 (~36%), at least some of the quarterly reports appear to be missing from their available dosimetry files. For most of these claims with incomplete records (~70%), it is evident that DOE did not supply records for quarters with no accrued external dose. Examination of the remaining cases with incomplete data indicates the missing reports reflected positive exposures.

Finding 3: Several reviewed claims had incomplete quarterly dosimetry records (i.e., a summary report was not supplied for each relevant quarter). For many of those cases, it appears that quarterly reports that reflected no positively accrued dose were omitted by

DOE. In other cases, however, missing quarterly reports are representative of positive exposure periods, as evidenced by comparison with annual totals.

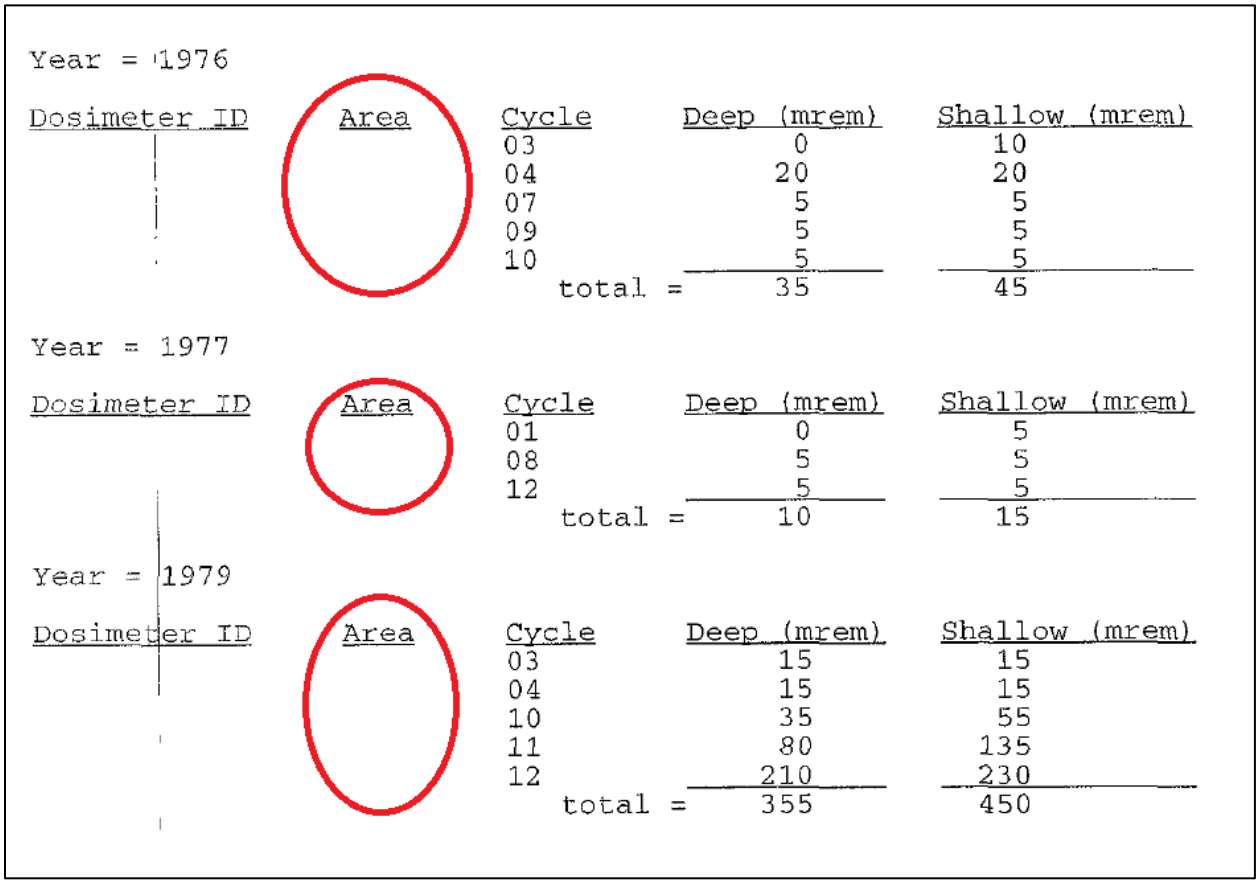
4.3 JANUARY 1973–DECEMBER 1981

Beginning in 1973, the dose of record supplied by DOE comes from the Health Physics Radiological Exposure Database (HPRED). Overall, 78 claimants reviewed had covered employment during this period. Similar to the previous period, it appears dosimeters were exchanged on a monthly basis. Figure 7 shows an example of one such record from HPRED. As seen in Figure 7, the sections of the record where the area is to be specified for each cycle are blank. Additionally, no HPD codes are present in this reporting format.

In some reviewed cases, individual monthly cycle reports or quarterly reports, or both, were supplied in addition to the HPRED entries. However, more than 97% of the reviewed cases from this period (76 of 78 cases) had at least some dosimeter cycles with no area specified and no individual cycle report to supplement with work area information.

Finding 4: External dosimetry cycle data extracted from HPRED for the years 1973–1981 do not contain an area designation (HPA code) or indications of the department (HPD code). Some claims reviewed contained limited individual cycle reports that can be used to supplement the HPRED data. However, 97% of the reviewed claims had at least some dosimetry cycles during which no work area could be determined.

Figure 7. Screenshot of Dosimetry Records from HPRED for the Years 1976, 1977, and 1979



Year = 1976

Dosimeter ID	Area	Cycle	Deep (mrem)	Shallow (mrem)
		03	0	10
		04	20	20
		07	5	5
		09	5	5
		10	5	5
		total =	35	45

Year = 1977

Dosimeter ID	Area	Cycle	Deep (mrem)	Shallow (mrem)
		01	0	5
		08	5	5
		12	5	5
		total =	10	15

Year = 1979

Dosimeter ID	Area	Cycle	Deep (mrem)	Shallow (mrem)
		03	15	15
		04	15	15
		10	35	55
		11	80	135
		12	210	230
		total =	355	450

In addition, it was observed that dosimetry data from HPRED did not include a cycle entry for every month of a given year. For example, in Figure 7, only January, August, and December dosimetry cycles are reported for the year 1977. This does not appear to indicate that the EE was not being monitored during the missing badge cycle; rather, it appears that only badging cycles with positive results for deep and/or shallow dose were reported by HPRED in available records. Overall, only 11 of 78 workers (~14%) had a dosimetry cycle entry for each possible monthly badging cycle during their employment. All badging cycles for these 14 workers reported positive exposures.

SC&A compared the number of available badging cycle records against the number of potential badging cycles based on the covered employment for each reviewed claimant. For example, the worker's records shown in Figure 7 indicate five dosimetry cycles in 1976. If the worker was employed for all of 1976, then the expected number of badging cycles would be 12. Therefore, 5/12 (or ~42%) of the worker's expected dosimetry cycle records were contained in the available records.

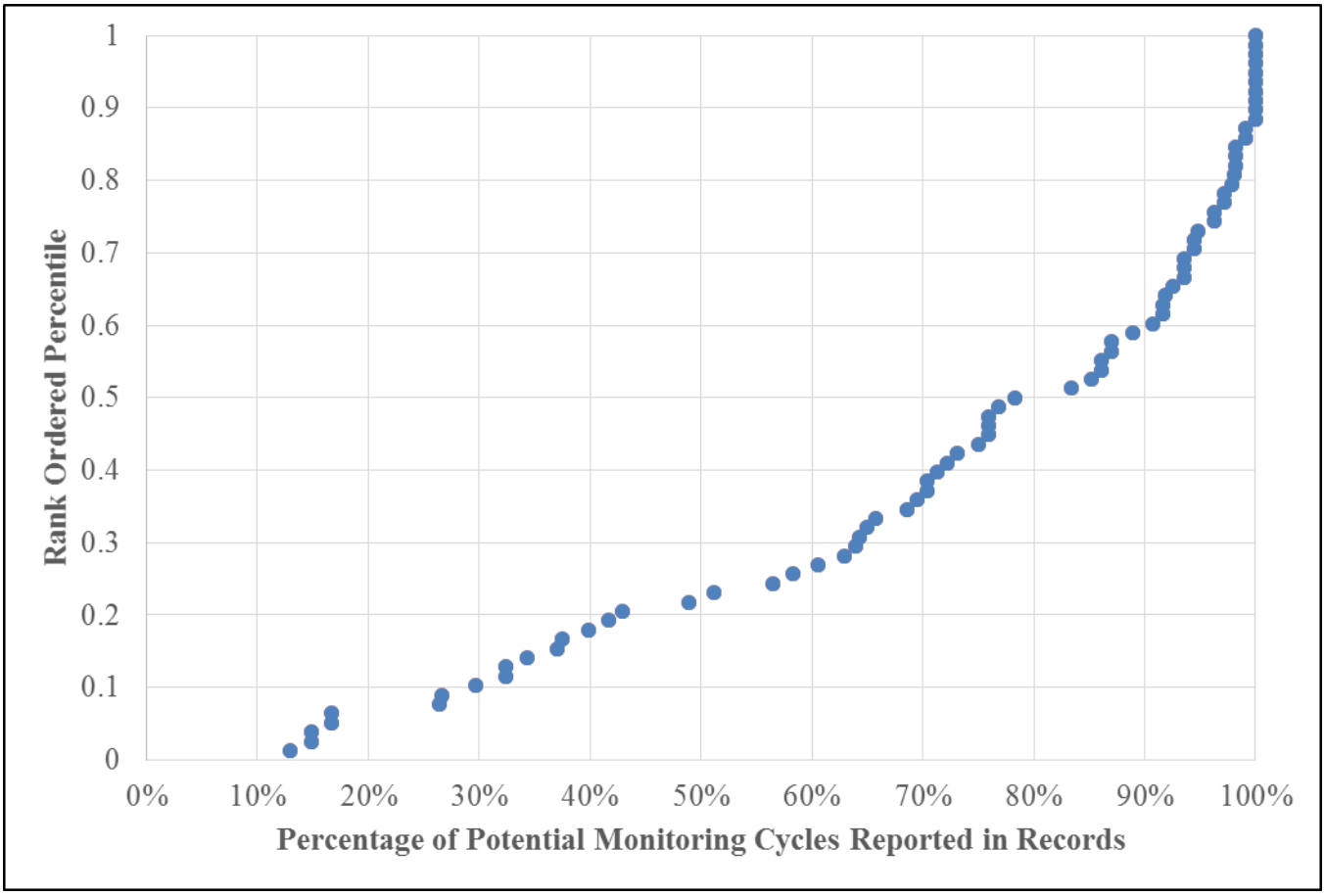
During the period of interest, the average percentage of expected dosimetry cycle reports per worker that were in the workers' monitoring files was 73% (i.e., reviewed workers had, on average, 73% of their expected dosimetry records in their files). The median percentage is

slightly higher, at approximately 81%. Figure 8 shows the rank-ordered percentage of available dosimetry cycle reports for each of the 78 claims reviewed.

SC&A recognizes that the issue of missing dosimetry cycles in which no dose was accrued is somewhat mitigated because neptunium work generally involves relatively high external exposure potential. However, work that was short term, such as maintenance and construction activities, may still have involved intake potential without correspondingly high dosimeter results.

Finding 5: From 1973 to 1981, the primary external dosimetry record format is from HPRED. SC&A observed that some dosimetry cycles appeared to be missing for this period. Based on a review of the 78 claimant monitoring records with employment during this period, it is apparent that dosimetry cycles without a positive external dose recorded are not reported by HPRED. Only 14% of the reviewed claims had dosimetry cycle reports for each relevant monitoring cycle. For these claims, every dosimetry entry for these workers contained a positive result.

Figure 8. Rank Order of the Percentage of Available Dosimetry Cycle Records for 78 Reviewed Claimants (1973–1981)



Finally, SC&A did not observe any evidence of multiple HPA codes being assigned for the same dosimetry cycle. This was consistent with both the earlier period (April 1963–December 1972; see Section 4.2) and the period after (January 1982–June 1989; see Section 4.4).

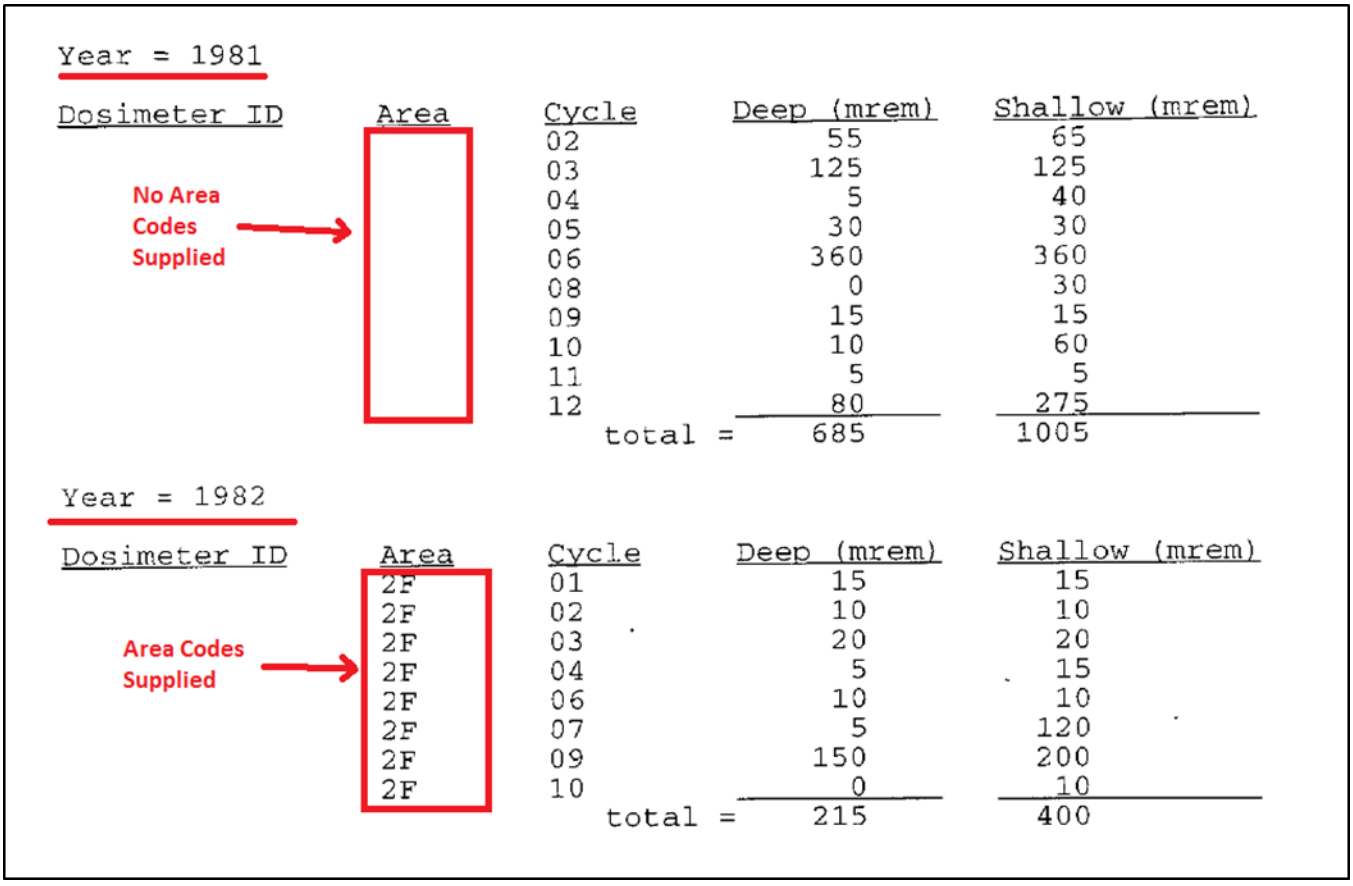
Finding 6: For the period from January 1973 to December 1981, SC&A found no evidence that multiple HPA codes were being assigned during a given badging cycle that would allow for identifying worker movement among different work areas. Unlike the previous period, it does not appear the dosimetry department was using the HPA codes to track all worker movements during a given badging cycle.

4.4 JANUARY 1982–DECEMBER 1988

The same general record format utilizing HPRED was used for the period of 1982–1988 as was used for the previous period (1973–1981), with the notable difference that the area code is specified for all listed dosimetry cycles (see Figure 9).

Observation 7: Beginning in January 1982 and ending in December 1988, all listed HPRED dose entries contain an associated area (HPA) code. No HPD codes were identified in the HPRED dosimetry records.

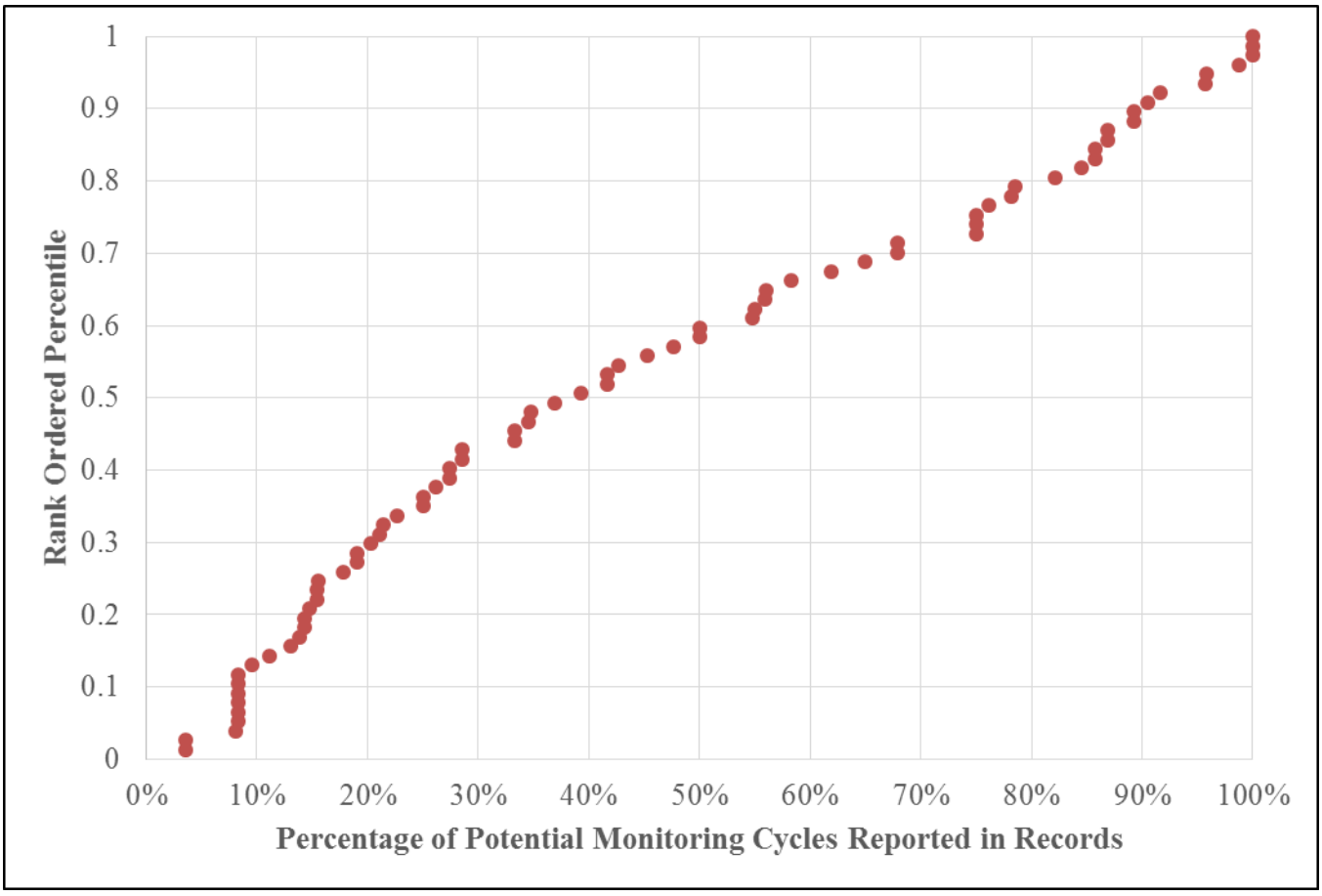
Figure 9. Screenshot of HPRED Dosimetry Record from 1981 and 1982 Showing the Transition from Not Reporting the Area (1981) to Reporting the Area (1982)



Finding 5 from Section 4.3 is also relevant to the records from 1982 to 1988. Specifically, SC&A observed apparent gaps in the reported cycle dosimetry reports supplied for the reviewed claimants during this period. Only 4 of the 77 workers (~5%) from the period of interest had a complete set of dosimetry cycle reports during their relevant employment. The records for all four of these individuals showed a positive entry for every monthly dosimetry cycle. Similar to Finding 5, the missing cycles for the remaining workers appear to be for months in which no external dose was accrued.

Similar to the analysis in Section 4.3, SC&A compared the number of reported dosimetry cycles to the number expected based on the EE's employment. For the average worker, approximately 46% of the expected monitoring cycles were included as entries in the EE's dosimetry file (median percentage 39%). Figure 10 shows a rank order of each of the reviewed claimants by the percentage of expected dosimetry cycles that were actually reported in the individual's monitoring record.

Figure 10. Rank Order of the Percentage of Available Dosimetry Cycle Records for 77 Reviewed Claimants (1982–1988)



Finding 7: For 1982 to 1988, the primary external dosimetry record format is from HPRED. SC&A observed that some dosimetry cycles appeared to be missing during the period. Based on a review of the 77 claimant monitoring records with employment during this period, it appears that dosimetry cycles without a positive external dose recorded are

not reported by HPRED. Only 5% of the reviewed claims had dosimetry cycle reports for each relevant monitoring period, and every dosimetry entry for these workers contained a positive result.

Finding 6 from Section 4.3 is also relevant to the records from 1982 to 1988. SC&A did not observe any instances in which multiple area codes were listed for the same dosimetry cycle. This is consistent with the two prior evaluated periods: April 1963 to December 1972 and January 1973 to December 1981.

Finding 8: For the period from January 1982 to December 1988, SC&A found no evidence that multiple HPA codes were being assigned during a given badging cycle, which would allow for identifying worker movement among different work areas. It is apparent that the dosimetry department was not using the HPA codes to track worker movements during a given badging cycle.

4.5 JANUARY 1989–DECEMBER 1989

Available dose records beginning in 1989 also utilize HPRED, as was done from 1973 to 1988. Somewhat uncharacteristically, there were no reported dosimetry cycles in 1989 until April, and no HPA codes were used until July. The year 1989 appears to be a transition year for record-keeping practices, including the practice of reporting of zero dose cycles. In addition, the practice of reporting multiple HPA codes for the same dosimetry cycle was observed beginning in 1989. Figures 11 and 12 show two 1989 dose records that illustrate these changes.

Figure 11. Screenshot of 1989 Dosimetry Record (1 of 2)

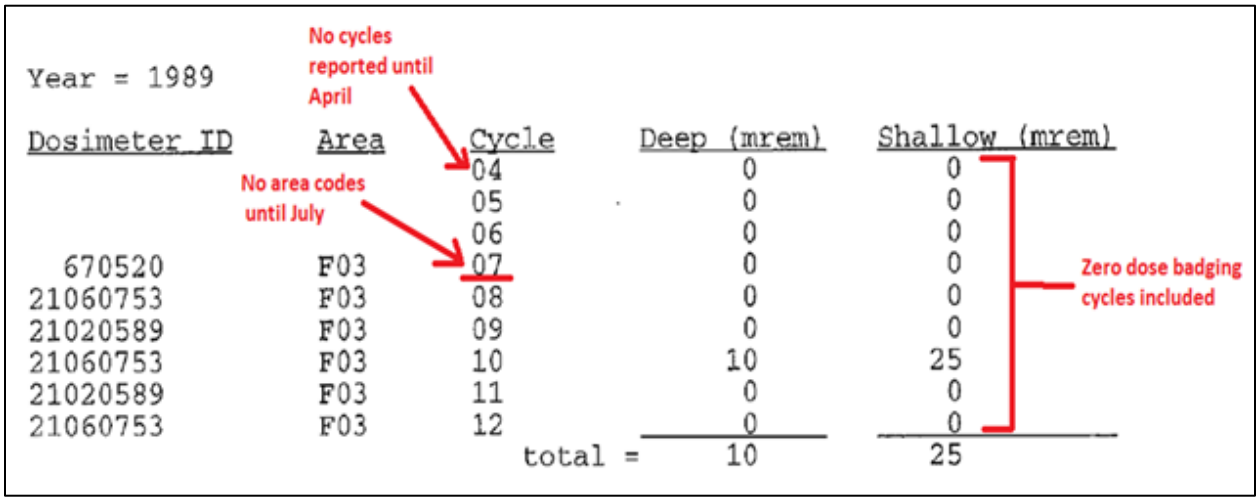
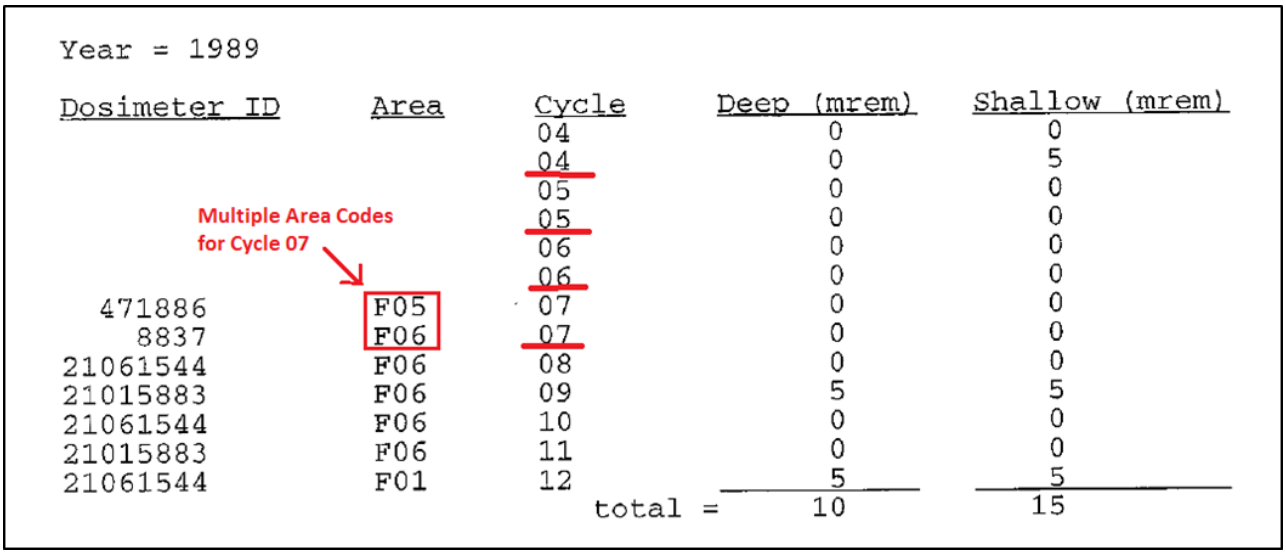


Figure 12. Screenshot of 1989 Dosimetry Record (2 of 2)



Observation 8: Dosimetry record keeping appears to go through a transition in 1989. Dosimetry cycles generally were not reported in HPRED until April of that year, and HPA codes are not included until July. In addition, zero dose cycles were reported and multiple HPA codes can be observed for the same dosimetry cycle.

4.6 JANUARY 1990–DECEMBER 2000

As discussed in the previous section, a transition in reporting practices appears to have happened in 1989. Most importantly, multiple HPA codes were being reported for a single badging cycle and zero dose cycles were also reported in the HPRED printouts; this practice continued into the period from 1990 to 2000. Overall, 56 workers were employed during the period from 1990 to 2000, and all but one had external dosimetry. SC&A closely examined the 55 remaining workers with external dosimetry to judge its completeness. In SC&A's estimation, 51 of 55 workers (~93%) had complete dosimetry with no observed temporal gaps. The four workers who appear to have at least some gaps in external dosimetry are described in Table 4.

Table 4. Four Reviewed Cases That Appear to Have Gaps in External Dosimetry, 1990–2000

NOCTS Claim #	Relevant Employment	Job Title	Comments
[redacted]	[redacted]/1952–[redacted]/1993	[redacted] Specialist	The last observed badging cycle was in September 1992. The EE had a routine whole body count in May 1993 and a termination whole body count in August 1993. The EE submitted a tritium bioassay as well as termination bioassay for plutonium and neptunium in August 1993. Notably, the EE did not record a positive external dose after September 1990, so the exposure potential may have been very low to nonexistent for the EE during the final year of employment. No additional information was identified in the CATI with the EE or DOL case files relevant to the final year of employment.
[redacted]	[redacted]/1989–[redacted]/1995	Operator	The last reported dosimetry cycle was in January 1993, but covered employment extends through May 1995. The EE was on a regular tritium bioassay schedule up until May 1995 and [redacted] dose reported in 1994. The last routine plutonium bioassay was in 1992; however, there were several follow-up bioassays during 1993–1995. The EE had an investigational whole body count in 1994 [redacted] and a termination whole body count in May 1995. Both whole body counts indicate the work area as 234-H. The CATI with the EE confirms the work locations as 234-H and 235-H during this period. The EE only had one positive dosimetry cycle from January 1990 to January 1993 (10 mrem OW and S in December 1992). So it is possible that the exposure potential for the EE was low enough that external dosimetry was not needed.

NOCTS Claim #	Relevant Employment	Job Title	Comments
[redacted]	[redacted]/1988–[redacted]/1996, [redacted]/1996–[redacted]/1997, [redacted]/1997–[redacted]/1997, [redacted]/1998–[redacted]/1998, [redacted]/1999–[redacted]/2000	Electrician	External badging appears to be intermittent for the EE during the period of interest (sometimes the EE is badged in successive months; other times the badging appears to be quarterly; in still other instances, the gaps are much larger). The EE was on a consistent whole body count schedule throughout relevant employment. The CATI with the EE indicates that badging was worn on a routine basis. Of the 88 dosimetry cycles provided during the period of interest, only 15 registered a positive exposure (~17%). Given the EE's job title as an electrician, it is also possible that the claimant did not consistently work in radiological areas.
[redacted]	[redacted]/1978–[redacted]/2013	Technical Assistant, [redacted]	Monitoring appears sporadic during the period of interest. The EE has no dosimetry from 1993 to 1995. The CATI with EE indicates a badge was worn at all times. There is a gap in routine whole body count monitoring from 1992 to 1996. Routine bioassay was taken in 1991 (Am/Cm/Cf, Pu-238, Pu-239), and then a tritium bioassay sample was taken in 1996. Given the pattern in internal monitoring, it is likely that the EE was not exposed and thus not monitored during portions of the period of interest.

Observation 9: For the 1990–2000 period, SC&A observed that dosimetry dose cycles with no positive exposure were included in the HPRED printouts. SC&A also saw evidence that multiple HPA codes were assigned to the same dosimetry cycle. SC&A's examination of 55 reviewed claims during this period indicates that about 93% of the reviewed case files had complete dosimetry records. The four remaining claims were closely examined, and SC&A believes there are plausible explanations for what appear to be gaps in the dosimetry monitoring (i.e., the EE did not require monitoring).

4.7 SUMMARY OF MONITORING CHARACTERISTICS, 1959–2000

As discussed in Sections 4.1–4.6, the SRS dosimetry and reporting practices for use in workplace assignment changed over time. Ideally, the available dosimetry records would represent a comprehensive history of an individual's work in specific radiological areas, so that any coworker dose assignments accurately reflect the exposure potential encountered by the claimant. To that end, the temporal spacing, record completeness, and indications of worker movement in the available monitoring records are especially important for claimant-favorable implementation of unmonitored intakes. Figure 13, which displays a summary for each period, shows that the available SRS dosimetry records satisfy these criteria to varying degrees.

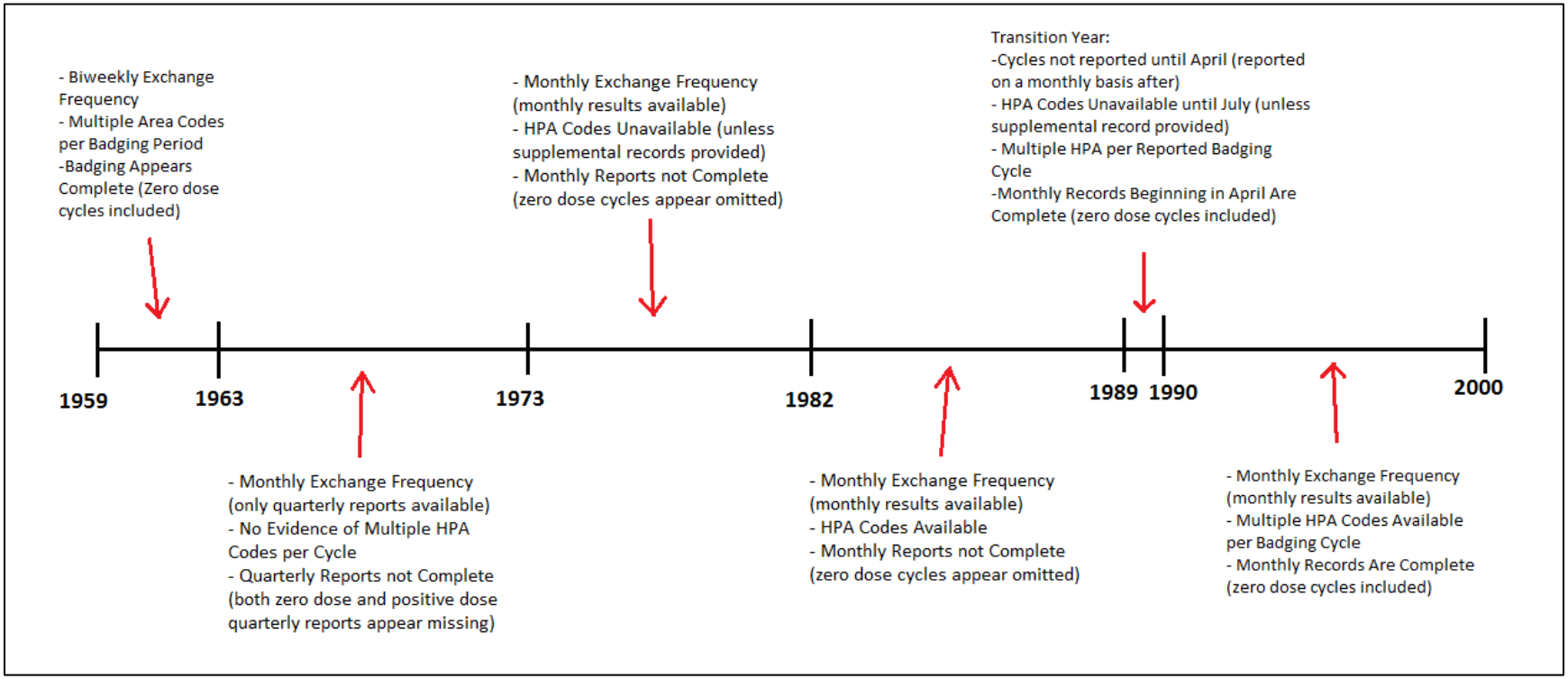
From the beginning of the evaluated period (1959) through March 1963, the records appear to be complete, indicate changes in work area within a single badging cycle, and were reported on a biweekly schedule (the shortest observed exchange frequency; see Section 4.1). The period from July 1989 through December 2002 displayed similar characteristics, except that the exchange frequency was monthly. The characteristics of these two periods represent the ideal situation for correctly and fairly assigning coworker intakes.

For the period of 1982 to 1988, dosimetry is available monthly, with the area specified; however, there is no evidence that changes in work assignment during a given cycle were ever documented. In addition, it appears that dosimetry cycles that did not register a positive exposure were not included in the database printout. The period from 1973 to 1981 had similar characteristics, except that no area designation is provided in the reported cycles from HPRED. In some cases, supplemental records had been provided that designate the area code; however, the reason for inclusion of these supplemental records and their relative completeness could not be established during this evaluation.

Finally, only quarterly summaries are available for the period from April 1963 through 1972, although it is evident that the workers were on either a biweekly or monthly badge exchange frequency. SC&A did not find any instances where it was noted that an employee changed work locations mid-quarter, based on the reporting of HPA codes. It was apparent that some quarterly records were not available for some reviewed claims. The missing records represented periods in which positive dose was accrued and periods in which no dose was accrued.

As noted previously, many of the concerns and limitations of the currently available monitoring records described in Section 4 might be alleviated by obtaining the full set of dosimetry cycle reports for affected claimants. However, at the time of this report, it is not known to SC&A whether such records are complete and available. Nor is it clear whether such records would reflect changes in location for workers who changed specific jobs on a semiregular basis for at least some periods of interest at SRS.

Figure 13. Summary Timeline of Observed External Dosimetry Characteristics and Reporting Practices (1959–2000)



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APPENDIX A: DESCRIPTION OF INTAKE INCIDENTS FOR 86 CLAIMS INCLUDED IN SC&A CLAIMANT STUDY

[Appendix A is withheld in its entirety to prevent the disclosure of Privacy Act protected information.]