Draft

ADVISORY BOARD ON
RADIATION AND WORKER HEALTH

National Institute for Occupational Safety and Health

DOSE RECONSTRUCTION TEMPLATE REVIEW FOR THE PEEK STREET FACILITY, SCHENECTADY, NEW YORK

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ABBREVIATIONS AND ACRONYMS

ABRWH	Advisory Board on Radiation and Worker Health
AEC	U.S. Atomic Energy Commission
AP	anterior-posterior
Ce	cerium
DOE	U.S. Department of Energy
DCF	dose conversion factor
dpm	disintegrations per minute
DR	dose reconstruction
EE	energy employee
HRE	Homogeneous Reactor Experiment
GDP	Gaseous Diffusion Plant
GM	geometric mean
GSD	geometric standard deviation
HRT	Homogeneous Reactor Test
ICRP	International Commission on Radiological Protection
IMBA	Integrated Modules of Bioassay Analysis
IREP	Interactive RadioEpidemiological Program
KAPL	Knolls Atomic Power Laboratory
keV	kiloelectron volt
LOD	limit of detection
MDA	minimum detectable activity
MED	Manhattan Engineer District
MeV	mega-electron volt
µCi/L	microcuries per liter
MTU	metric ton(s) of uranium
Nb	niobium
NCRP	National Council on Radiation Protection and Measurements
NIOSH	National Institute for Occupational Safety and Health
NOCTS	NIOSH/OCAS Claims Tracking System
OCAS	Office of Compensation Analysis and Support
ORAUT	Oak Ridge Associated Universities Team

ORNL	Oak Ridge National Laboratory
OTIB	ORAUT technical information bulletin
pCi	picocurie
Pm	promethium
ppb	parts per billion
ppm	parts per million
Pr	praseodymium
PSF	Peek Street Facility
PSL	physically significant level
Pu	plutonium
Ru	ruthenium
RU	recycled uranium
SPRU	Separations Process Research Unit
Sr	strontium
SRDB	Site Research Database
SRS	Savannah River Site
TBD	technical basis document
Tc	technetium
TRU	transuranic
U	uranium
UO_3	uranium oxide
Y	yttrium
Zr	zirconium

1 SUMMARY BACKGROUND INFORMATION

On December 3, 2018, the Advisory Board on Radiation and Worker Health tasked SC&A with a technical review of the current dose reconstruction (DR) template used by the National Institute for Occupational Safety and Health (NIOSH) to reconstruct radiation doses for employees of the Peek Street Facility (PSF) located in Schenectady, New York. No technical basis document has been developed for DRs of workers at PSF. In lieu of a technical basis document, NIOSH has developed a DR methodology guideline document and DR template that contain facility-specific data, assumptions, and list of documents that provide the basis for the facility-specific data and assumptions.

This report presents SC&A's review of the current PSF DR template, "DR Draft PSF 3.0.doc" (hereafter the "DR Template") and the DR methodology guideline report, *Dose Reconstruction Methodology for the Peek Street Facility* (NIOSH 2009).

1.1 SC&A DR TEMPLATE APPROACH

In the PSF DR Template, NIOSH has color-coded the text to indicate the type of information or to provide direction to the dose reconstructor. The color schemes are:

- Black text is wording that is typically unchanged.
- Blue text is wording that is optional and may need to be deleted.
- Red text indicates wording where a change is needed.
- Blue text with yellow highlight indicates a description of an optional section.
- Red text with yellow highlight indicates directions to the dose reconstructor.
- Turquoise highlight over black or blue text is a field code that is populated when a claim-specific field is imported from workbook tools.
- Text enclosed in angle brackets (< >) represents fields in the report that must be filled in by the dose reconstructor.

SC&A reviewed the statements and assumptions pertaining to the facility information, external dose determination, and the internal dose determination. In this report, each statement is presented, followed by SC&A's evaluation of the statement and a determination of the adequacy of the statement. When an issue was identified, SC&A consulted NIOSH 2009 for additional information that might resolve the concern.

2 FACILITY DESCRIPTION

SC&A reviewed the facility information in the DR Template and was able to verify all of the PSF site information contained in the template. The specific statements are discussed below.

The DR Template states the main purpose of the PSF was to provide a temporary location for the work of the Knolls Atomic Power Laboratory (KAPL) until facilities being constructed at the KAPL Site in Niskayuna, New York, were ready to accept the Peek Street Facility work (KAPL 1994, KAPL 1979). SC&A verified the purpose of PSF based on the information on page 99 of KAPL 1994.

The DR Template states the PSF operated during the years 1947–1954. The *Certification Docket for the Remedial Action Performed at the Peek Street Site Property in Schenectady, New York* (KAPL 1994) states the General Electric Company operated the PSF as a temporary home for the KAPL during the period 1947–1955. The operational period is further clarified on PDF pages 22 and 23 of KAPL 1994:

> Transfer of activities to the current KAPL facility located on River Road in Niskayuna, New York, occurred during the period from early 1949 until late 1954….
>
> In October 1955, the site was sold by the US Government to the private sector.

SC&A concurs with the DR Template that the operational period at PSF was from 1947 through 1954.

The DR Template (page 5) gives the facility description of the PSF as:

> The Peek Street Facility Site consisted of approximately 4.5 acres of land that was located at 425 Peek Street in Schenectady, New York. The major structure on the site was a 75,000 square foot L-shaped building. In 1947, the main building was renovated to house most elements of the Peek Street Facility, including administrative offices, library, laundry, security, drafting, design, engineering, maintenance, health physics, chemistry laboratories, metallurgy areas, machine shops, pile reactor, vault, metal oxidation area, etc. There were also several other smaller buildings that were separate from the main building. Those buildings were used for security, storage, garage, carpentry, laboratory, and fire protection. Three of the buildings included a Laboratory Building, Waste Storage Building, and a Fire House.[KAPL 1994, KAPL 1979]

SC&A found this facility description given on PDF page 22 of KAPL 1994.

The DR Template (page 5) describes the purpose and types of work performed at the PSF:

> The Peek Street Facility was used for two basic purposes: (1) the design of an intermediate breeder reactor concept, which was later converted to the design of the S1G/S2G submarine reactor plan for the Navy; and (2) the design of a chemical process for the recovery of uranium and plutonium from irradiated

> nuclear reactor fuel. As related to the work of developing and supporting these designs, beryllium and radioactive materials were used in the Chemistry and Metallurgy Areas of the main building. Radioactive material was also worked with in the Metal Oxidation Facility, which was attached to the easterly side of the main building, and a Laboratory Building that was located away from the main building on its westerly side. Pending preparation for disposal, radioactive liquids were stored in the Laboratory Building; solid wastes were stored in the Waste Storage Building and alongside the exterior of the Waste Storage Building in large metal-lined wood boxes.[KAPL 1979]

SC&A reviewed *History and Radiological Status of the KAPL Peek Street Site and the KAPL Sacandaga Site* (KAPL 1979) and found information describing the function and use of the PSF on PDF page 99.

The DR Template (page 5) provides a description of the types and quantities of radioactive materials used at PSF:

> Based on record reviews, the maximum quantities of radioactive materials that were present at the Peek Street Facility at any one time were estimated to be approximately 500 kg of natural uranium, 65 kg of enriched uranium, 300 g of plutonium, 3 g of encapsulated radium, a few grams of polonium, and as much as a few curies of fission products.[KAPL 1979]

SC&A found the information confirming the DR Template's description on PDF page 100 of KAPL 1979:

> It is reasonable to estimate, based on record reviews, that the maximum quantities of radioactive materials mentioned in A, B, and C above at the Peek Street Site at any one time consisted of about 500 kilograms of natural uranium, 65 kilograms of enriched uranium, 300 grams of plutonium, a few grams of polonium, as much as a few curies of fission products, 3 grams of radium (this was contained in capsules and not altered), and 100 kilograms of beryllium.

Finally, the DR Template (pages 5–6) describes the material removal and facility survey and release.

> By the end of October 1949, the entire area previously occupied by the Chemistry Division at the Peek Street Facility had been surveyed and released for future use…. In February 1950, the radioactive material and beryllium in the vault area were moved to the KAPL Site…. In April 1950, the Metallurgy Area was unconditionally released…. In June 1950, the Laboratory Building was unconditionally released. In July 1950, the Waste Storage Building was removed and the Oxidation Building that was attached to the main building was also removed…. In November 1953, the vault area was unconditionally released.[KAPL 1979]

On PDF pages 101–102 of KAPL 1979, SC&A found the chronology of decontaminating and decommissioning events from the phase out of the Chemistry Area operations in October 1949 through the final release of the site in October 1955.

3 EXTERNAL DOSE

SC&A reviewed the external dose information in the DR Template regarding dosimeter type, recorded, missed, and unmonitored photon, neutron, and electron doses, ambient doses, and occupational medical doses. During review of the external dose information, SC&A identified six findings and one observation. The specific assumptions and SC&A's evaluation are discussed below.

3.1 DOSIMETER

The DR Template states:

> Because information provided in the dosimetry records indicated that the Hanford type dosimeters were used at the Peek Street Facility, the distribution of [the energy employee's] exposure geometry was assumed to be consistent with the specific dosimetry parameters applicable to the Technical Basis Document for the Hanford Site – Occupational External Dose.[ORAUT-TKBS-0006-6] This exposure assumes 100% anterior-posterior (AP) geometry.

SC&A reviewed "Excerpts from KAPL Radiological History Report" (ORAUT 1997). Table 4-1 on PDF page 73 of that document shows the history of personnel film dosimeters used at KAPL facilities. For the PSF operational period, 1947–1954, Table 4-1 indicates a Hanford-type holder with a 39 mil silver filter was used. Section 6.4.2.1 of ORAUT-TKBS-0006-6 describes the two-element dosimeter used at Hanford from 1944 to 1957 (page 25):

> **Two-Element Film Dosimeter, October 1944 to March 1957.** Hanford implemented a two-element beta/photon dosimeter in 1944 based on the design developed by Pardue, Goldstein, and Wollan (1944) at the Metallurgical Laboratories. This basic dosimeter design was used at the Clinton Laboratory (now ORNL) and later by many other MED/AEC/DOE laboratories. The Hanford design consisted of an open window and a 1-mm silver shield.

SC&A agrees that the PSF used Hanford-type dosimeters during the operational period from 1947 to 1954.

3.2 RECORDED PHOTON DOSE

The DR Template addresses the photon energy distribution used for unmonitored workers, monitored plutonium workers, and monitored workers (other than plutonium). Unmonitored works are assigned onsite ambient dose and occupational medical doses assuming 100% 30–250 kiloelectron volts (keV) photons. Monitored plutonium workers are assigned recorded photon doses assuming 100% of the nonpenetrating dose is attributed to <30 keV photons and 100% of the penetrating dose is attributed to 30–250 keV photons. The photon doses for monitored workers not handling plutonium are assigned assuming 100% 30–250 keV photons.

SC&A agrees that assigning ambient and occupational medical doses using the energy distribution of 30–250 keV photons is consistent with the guidance in ORAUT-PROC-0060,

Revision 01 (2006), *Occupational Onsite Ambient Dose Reconstruction for DOE Sites*, and ORAUT-PROC-0061, Revision 04 (2017), *Occupational Medical X-Ray Dose Reconstruction*. SC&A also agrees that the nonpenetrating dose for plutonium workers should be attributed to <30 keV photons as described in ORAUT-OTIB-0017, Revision 01 (2005), *Interpretation of Dosimetry Data for Assignment of Shallow Dose*.

The DR Template (page 9) contains the following statement regarding the penetrating photon energy assumption:

> Because there was more than one photon energy distribution associated with the photon radiation source terms at the Peek Street Facility and because it cannot be determined which source term a worker was exposed to at this small facility, a photon energy distribution of 100% 30–250 keV photons was applied to the measured and missed penetrating photon doses.

No basis is provided or referenced. Table 6-7 of ORAUT-TKBS-0006-6 lists the photon energy distribution for reactor and plutonium processing facilities as attributed to 25% 30–250 keV and 75% >250 keV photons. NIOSH 2009 (page 4) contains a similar paragraph:

> Because there was more than one photon energy distribution associated with the photon radiation source terms at the Peek Street Facility and because it cannot be determined which source term a worker was exposed to at this small facility, all exposures to photon radiation will be assumed to have the most claimant-favorable photon energy distribution that was possible at the site. Therefore, a photon energy distribution of 100% 30–250 keV photons will be used for all Peek Street Facility photon exposures.

While NIOSH 2009 states that a photon energy of 30–250 keV is the most claimant favorable, no reference is provided in NIOSH 2009 or the DR Template, and SC&A did not find this guidance in OCAS-IG-001, Revision 3 (2007), *External Dose Reconstruction Implementation Guideline*. SC&A believes NIOSH should include either the basis or a reference for the basis of the penetrating photon energy distribution.

Finding 1: The assumption of 100% 30–250 keV for the penetrating photon energy distribution is unsupported and inconsistent with assumptions used in the Hanford technical basis document.

Also related to the penetrating photon dose, the DR Template goes on to state:

> In addition, an uncertainty factor of 1.3 has been applied to the measured penetrating photon doses to account for the uncertainty in dosimeter response.[ORAUT-TKBS-0006-6]

Table 6-25 of ORAUT-TKBS-0006-6 lists the overall bias and uncertainty of the Hanford dosimeters. The systematic uncertainty for the two-element film dosimeter, like those used at the PSF, is listed as 1.2. The Hanford Calculation Workbook 4.16 also list the dosimeter uncertainty as 1.2 through 1956. NIOSH 2009 does not provide information on dosimeter uncertainty. However, NIOSH 2009 (page 4) does state the following:

> There is no site-specific information regarding dosimeter limits of detection, uncertainty, and bias; therefore, it will be assumed that the Hanford Site's information regarding those dosimeter parameters is applicable to the Peek Street Facility. The dose reconstructors shall obtain the applicable dosimeter parameters from the *Technical Basis Document for the Hanford Site – Occupational External Dosimetry*.[ORAUT-TKBS-0006-6, Rev. 02]

SC&A believes NIOSH should provide a basis for the uncertainty factor of 1.3 or use the uncertainty factor of 1.2 that is given in their cited reference.

Finding 2: The assumption of an uncertainty factor of 1.3 is unsupported and inconsistent with the cited reference.

The DR Template also contains two notes, directions to the dose reconstructor, regarding the photon doses. The first note states (page 8):

> (NOTE: For the <30 keV photons energy group, the organ DCFs in Table 4.1a of IG-001 [i.e., for the <20 keV Pu photons] should be used instead of the App B organ DCFs. Because Table 4.1a does not provide 20 keV photon organ DCF values for the esophagus or the ovaries, the <30 keV photon DCFs should be used, in accordance with the Table 4.1a recommendations. It should also be noted that the Table 4.1a based values for the <30 keV photon energy group have been programmed into the tool that was created for the PSF.)

Table 4.1a of OCAS-IG-001, Revision 3, contains special dose conversion factors (DCFs) for plutonium that were calculated assuming AP geometry and 20 keV mono-energetic photons. SC&A agrees that applying the 20 keV photon DCFs is appropriate for PSF plutonium workers. However, SC&A was unable to locate any PSF-specific tool containing the DCFs from Table 4.1a.

Observation 1: SC&A did not locate a PSF-specific tool containing the preprogrammed plutonium DCFs.

The second note (page 8) reads:

> (NOTE: Also, a correction factor to account for the dosimeter's over-response to low energy photons should not be used for the <30 keV photons energy group in PSF cases, because the Pu workers were likely exposed to a combination of electron and low energy photon emitting source terms. Due to the small size of the PSF, the Pu workers' exposures were not likely limited to Pu. In addition, the bioassay data for some of the Pu workers indicate that some were also exposed to sources of electron radiation, such as uranium. Applying such a correction factor for a PSF worker could result in a worker's non-penetrating doses being underestimated.)

According to ORAUT-TKBS-0006-6 and the Hanford Calculation Workbook 4.16, the dosimeter correction factor is also applied to the <30 keV photon doses. However, SC&A agrees with NIOSH's basis for not applying the correction factor to the <30 keV photon doses.

3.3 ELECTRON DOSES

For non-plutonium workers, the DR Template (page 10) attributes the recorded nonpenetrating doses to >15 keV electrons:

> An electron energy distribution of 100% >15 keV electrons was applied to the measured and missed electron doses. Because both photon and electron doses were measured by the same dosimeter, when both a zero electron dose and a zero photon dose were reported, the zeros were assigned as single missed photon dose, in accordance with the Technical Information Bulletin: Interpretation of Dosimetry Data for Assignment of Shallow Dose.[ORAUT-OTIB-0017]

This is a common DR practice and is consistent with the guidance in ORAUT-OTIB-0017.

3.4 UNMONITORED NEUTRON DOSE

As previously described, the PSF used a two-element beta/photon film dosimeter to monitor employees. Unmonitored neutron doses are assigned using an assumed neutron energy distribution and applying a neutron-to-photon ratio to the penetrating dosimeter reading. The DR Template (page 9) states:

> Because the neutron energy distribution was mostly unknown, a neutron energy distribution of 100% 0.1 to 2 MeV neutrons was applied to all of the unmonitored neutrons doses that were estimated using a neutron-to-photon ratio, in accordance with the recommendations in the Technical Information Bulletin: Technical Basis for Conversion from NCRP Report 38 Neutron Quality Factors to ICRP Publication 60 Radiation Weighting Factors for Respective IREP Input Neutron Energy Ranges.[ORAUT-OTIB-0055] In accordance with the recommendation in this same document, the unmonitored neutron doses were multiplied by a factor of 2.

SC&A finds this consistent with guidance found on page 11 of ORAUT-OTIB-0055, Revision 00 (2006):

> If sufficiently detailed information on neutron energies is not available, dose reconstructors should use the following claimant-favorable recommendations: (1) assume the corrected dose equivalent to be twice the measured dose, missed dose, or dose based on neutron-to-photon ratios; and (2) assume the neutron energies are in the range from 0.1 to 2 MeV.

The DR Template (page 11) states the neutron-to-photon ratio to be used for the PSF was determined from facilities with similar neutron producing activities.

> The technical basis documents for the following reactor and critical assembly sites were reviewed to determine an appropriate neutron-to-photon ratio for the Peek Street Facility: Hanford, Savannah River Site, Oak Ridge National Laboratory, Idaho National Engineering Laboratory, Los Alamos National Laboratory, Argonne National Laboratory East, Brookhaven National Laboratory, and the Energy Technology Engineering Center…. Based on the information

provided in these technical basis documents, a neutron-to-photon ratio of 1.2:1 is likely claimant-favorable for facilities with critical assemblies and small-scale research reactors. It should also be noted that the technical basis documents for the following sites did not provide any neutron-to-photon ratios: Idaho National Engineering Laboratory, Argonne National Laboratory East, Brookhaven National Laboratory, and the Energy Technology Engineering Center.

SC&A reviewed the neutron-to-photon ratios in the external technical basis documents for Hanford (ORAUT-TKBS-0006-6, Revision 04), Savannah River Site (ORAUT-TKBS-0003, Revision 03), Oak Ridge National Laboratory (ORAUT-TKBS-0012-6, Revision 01), and Los Alamos National Laboratory (ORAUT-TKBS-0010-6, Revision 03). Table 3-1 lists the neutron-to-photon ratios for reactors and critical assemblies.

Table 3-1. Neutron-to-Photon Ratios for Reactors and Critical Assemblies

Site	Description	GM	GSD	Reference
Hanford Site	B, D, F, H, DR, C, KW, KE Reactors	0.8	3.0	ORAUT-TKBS-0006-6, Table 6-22
Hanford Site	N Reactor	0.06	3.1	ORAUT-TKBS-0006-6, Table 6-22
Hanford Site	300 Area Test Reactors (305, 309, 318, 326)	0.8	3.0	ORAUT-TKBS-0006-6, Table 6-22
Hanford Site	Critical Mass Laboratory 120, 209E	1.1	2.3	ORAUT-TKBS-0006-6, Table 6-22
Savannah River Site	105C, K, L, P, R	0.18	2.52	ORAUT-TKBS-0003, Table E-9
Oak Ridge National Laboratory	3005 Low Intensity Test Reactor	1.2	2.2	ORNL-TKBS-0012-6, Section 6.3.4.2.3.9, X-10 Calculation Workbook 2.12
Oak Ridge National Laboratory	3010 Bulk Shielding Reactor	1.2	2.2	ORNL-TKBS-0012-6, Section 6.3.4.2.3.9, X-10 Calculation Workbook 2.12
Oak Ridge National Laboratory	3042 Oak Ridge Research Reactor	1.2	2.2	ORNL-TKBS-0012-6, Section 6.3.4.2.3.9, X-10 Calculation Workbook 2.12
Oak Ridge National Laboratory	7500 Homogeneous Reactor Experiment (HRE) Facility	1.2	2.2	ORNL-TKBS-0012-6, Section 6.3.4.2.3.9, X-10 Calculation Workbook 2.12
Oak Ridge National Laboratory	7503 Molten Salt Reactor Experiment	1.2	2.2	ORNL-TKBS-0012-6, Section 6.3.4.2.3.9, X-10 Calculation Workbook 2.12
Oak Ridge National Laboratory	7710 Health Physics Research Reactor Facility	1.2	2.2	ORNL-TKBS-0012-6, Section 6.3.4.2.3.9, X-10 Calculation Workbook 2.12
Oak Ridge National Laboratory	7500 HRE/HRT Reactors	1.2	2.2	ORNL-TKBS-0012-6, Section 6.3.4.2.3.9, X-10 Calculation Workbook 2.12
Oak Ridge National Laboratory	9213 Critical Experiments Facility neutron source	1.2	2.0	ORNL-TKBS-0012-6, Section 6.3.4.2.3.9, X-10 Calculation Workbook 2.12

Site	Description	GM	GSD	Reference
Los Alamos National Laboratory	Reactor Operations	2.3	1.05	ORAUT-TKBS-0010-6, Table 6-22, LANL Calculation Workbook 3.04
Los Alamos National Laboratory	Criticality Experiments	2.3	1.05	ORAUT-TKBS-0010-6, Table 6-22, LANL Calculation Workbook 3.04

Using the information in Table 3-1, SC&A calculated average neutron-to-photon ratios of 1.05 and 1.53 for reactor facilities and critical assemblies, respectively. The average of these values is 1.29.

NIOSH 2009 also specifies the neutron-to-photon ratio of 1.2, citing the same references as the DR Template.

SC&A was unable to verify the neutron-to-photon ratio of 1.2 using the cited references and believes NIOSH should provide a basis for their decision. The basis may be as simple as citing the ORNL neutron-to-photon information given in Section 6.3.4.2.3.9 of ORAUT-TKBS-0012-6, Revision 01 (2007).

Finding 3: SC&A was unable to verify the neutron-to-photon ratio of 1.2 using the cited references.

3.5 MISSED DOSE

The missed photon and neutron doses are determined based on the number of zero photon dosimeter cycles. Depending on the type of DR, the maximum or actual number of zero dosimeter cycles may be used. For the maximum number of dosimeter cycles, the DR Template (page 12) states:

> The total number of dosimeter cycles assigned was 338 for photons. This number was based on a claimant-favorable assumptions of 52 (1947, 1948, and 1952–1954)[ORAUT 1997] and 26 (1949–1951)[ORAUT 1997] photon dosimeter exchanges for each full or partial year of monitored employment, up to the date of diagnosis, to ensure that all possible instances of a zero dosimeter reading were accounted for in this dose reconstruction. Based on the minimum reporting level information associated with the Hanford type dosimeters,[ORAUT-TKBS-0006-6] a potential missed photon dose of 8.409 rem was calculated.

Table 4-9 of ORAUT 1997 provides the dosimeter exchange frequencies used at KAPL facilities. A biweekly exchange frequency was used from 1949–1951 and a weekly exchange frequency for the other years from 1947 to 1954, resulting in a maximum of 338 dosimeter cycles. Applying the two-element dosimeter limit of detection (LOD) of 0.040 rem, shown in Table 6-13 of ORAUT-TKBS-0006-6, results in a maximum missed photon dose of 6.760 rem.

NIOSH 2009 does not address the dosimeter exchange frequency or dosimeter LOD.

Although not stated in the DR Template, it appears NIOSH used a dosimeter LOD of 0.050 rem to calculate the missed photon dose. As shown above, this is not consistent with the dosimeter LOD information in the Hanford technical basis document.

Finding 4: The dosimeter LOD used in the DR Template is not specified in the template, and the value of 0.050 rem assumed based on NIOSH's calculation is not consistent with the Hanford dosimeter information.

3.6 ONSITE AMBIENT DOSE

Onsite ambient doses are assessed as part of the DR for monitored and unmonitored periods of employment. The maximum ambient dose would be assigned for an unmonitored period covering the entire PSF operating period from 1947 to 1954, 8 years. The DR Template (page 13) states:

> Therefore, annual on-site ambient doses were assigned for each full or partial year of employment, up to the date of diagnosis. The doses assigned were based on a review of the on-site ambient radiation levels at other sites with similar activities,[ORAUT-PROC-0060] which determined that the maximum annual on-site ambient radiation levels did not likely exceed 0.423 rem per year at the Peek Street Facility. Therefore, a likely claimant-favorable **<OR>** reasonable annual dose of 0.423 rem was assigned for each full or partial year of employment at the Peek Street Facility. This results in a total on-site ambient dose of 3.384 rem being assigned to the <organ>.

SC&A reviewed the "Maximizing Dose Summary," Attachment B of ORAUT-PROC-0060. Table 3-2 shows the 1947–1954 annual maximum ambient doses for the Hanford Site, Oak Ridge National Laboratory, and Idaho Engineering Laboratory.

Table 3-2. Maximum Ambient Dose (from ORAUT-PROC-0060, Attachment B)

Year	Hanford Site	Oak Ridge National Laboratory	Idaho Engineering Laboratory
1947	0.157	0.473	NA
1948	0.150	0.980	NA
1949	0.205	1.555	NA
1950	0.072	0.270	NA
1951	0.072	0.372	NA
1952	0.125	0.946	0.159
1953	0.082	0.710	0.159
1954	0.282	0.473	0.159

NA = not listed in Attachment B.

Using the data above, SC&A calculated the average maximum annual ambient dose for each site as 0.143 rem, 0.772 rem, and 0.159 rem for Hanford, Oak Ridge, and Idaho, respectively. The average of these three values is 0.342 rem. The average of the Oak Ridge and Hanford values is 0.433 rem.

NIOSH 2009 (page 6) states:

> During the years of 1947–1954, the Hanford Site and the Oak Ridge National Laboratory (ORNL) were the only sites performing similar types of activities and working with similar radionuclides. Using the doses provided in Attachment B,[ORAUT-PROC-0060] an annual on-site ambient dose assignment of 0.423 rem was calculated for the Peek Street Facility, and will be assigned for each full year of Peek Street Facility employment. A dose of 0.423 rem represents average of the annual maximizing on-site ambient doses for the Hanford Site and the ORNL for the years of 1947–1954.

SC&A was unable to verify the annual maximum ambient dose value of 0.423 rem stated in the DR Template.

Finding 5: SC&A was unable to verify the PSF annual maximum ambient dose value using the cited reference.

3.7 OCCUPATIONAL MEDICAL DOSE

For the occupational medical doses, the DR Template references ORAUT-OTIB-0006, Revision 04 (2011), *Dose Reconstruction from Occupational Medical X-Ray Proced*ures, and ORAUT-PROC-0061, Revision 03 (2010), *Occupational Medical X-Ray Dose Reconstruction for DOE Sites*. The DR Template states the basis for determining the occupational medical dose for PSF employees as:

> Based on the information in Table 6-5 of the Technical Information Bulletin: Dose Reconstruction from Occupationally Related Diagnostic X Ray Procedures[ORAUT-OTIB-0006, Rev. 04] and an assumed annual chest X-ray procedure for each full or partial year of employment up to the date of diagnosis...

NIOSH assumed an annual chest x-ray frequency for each year of employment at the PSF. SC&A found information supporting this assumption on PDF page 80 of ORAUT 1997, which indicates that in November 1947, KAPL implemented safety rules that included "Chest X-Ray and urine examination are to be taken once a year and as indicated by pertinent findings."

Revision 04 of ORAUT-OTIB-0006, *Dose Reconstruction from Occupational Medical X-Ray Procedures*, became effective June 20, 2011, and does not contain a Table 6-5 as stated in the DR Template. The text in the DR Template most likely refers to Table 6-5, "Organ doses for default entrance kerma values," in Revision 03 PC-1, effective December 21, 2005. SC&A believes the correct reference is ORAUT-OTIB-0006, Revision 05, Attachment B, "Organ Dose Equivalent Tables," effective August 13, 2018.

The DR Template also states that the medical doses include a factor of 1.3 to account for uncertainty or an uncertainty of ± 30%.

> This X-ray dose incorporates a factor of 1.3 to account for uncertainty and likely exceeds the true X-ray dose to the <organ>.[ORAUT-PROC-0061, Rev. 03] **<OR>** The

> assigned X-ray doses were applied as a normal distribution with an uncertainty of ± 30%.[ORAUT-PROC-0061, Rev. 03]

Upon review of Revision 03 of ORAUT-PROC-0061, SC&A found that Section 6.2.1, "Overestimate Approach," contains the following guidance:

> Unless otherwise noted in Table A-1, doses from the TBDs should be multiplied by 1.3 (1.35 for some TBDs) to account for uncertainty in an overestimate (and the doses treated as constants in IREP), or doses may be assigned as a normal distribution in IREP Parameter 1 and multiplied by 0.3 (0.35 for some TBDs) in Parameter 2.

Section 6.2.2, "Best-Estimate Approach," states:

> Unless otherwise noted, assigns the doses from the TBD as a normal distribution in IREP Parameter 1 and assigns the doses from the TBD multiplied by 0.3 in Parameter 2.

However, SC&A believes the correct reference is ORAUT-PROC-0061, Revision 04 (2017), which does not include guidance to use factor of 1.3 to account for uncertainty. For overestimates, best estimates, and underestimates, the Revision 04 guidance states (page 7):

> Assigns the doses in IREP with a normal distribution in IREP Parameter 1 and an uncertainty of the dose multiplied by 0.3 in Parameter 2.

The PSF occupational medical dose methodology described in NIOSH 2009 is similar and references ORAUT-OTIB-0006, Revision 03 PC-1.

SC&A believes the DR Template information regarding occupational medical doses is not consistent with current approved guidance.

Finding 6: The DR Template occupational medical dose basis contains incorrect information and outdated references.

4 INTERNAL DOSE

SC&A reviewed the internal dose information in the DR Template regarding detection limit and the parameters used to assign internal doses from fission product, plutonium, enriched uranium, natural uranium, and tritium. During review of the internal dose information, SC&A identified two findings and two observations. The specific assumptions and SC&A's evaluation are discussed below.

4.1 BIOASSAY DETECTION LIMITS

According to ORAUT 1997, KAPL employees submitted urine samples that were analyzed for fission products, plutonium, enriched uranium, natural uranium, and tritium, as appropriate. NIOSH complied the bioassay data and calculated intakes for 29 employees in a PSF coworker study.[1] Table 4-1 shows the analyses and number of bioassay samples contained in the PSF coworker study.

Table 4-1. PSF Bioassay Coworker Study

Bioassay Analysis	Sample Dates	Number Samples	PSL (dpm/day)	Results >PSL
Enriched uranium	1950–1961	29	5	1
Fission products	1953–1955	16	50	0
Plutonium	1949–1956	53	0.33	1

PSL = physically significant level.

PDF page 94 of ORAUT 1997 describes the physically significant level (PSL) as follows:

> The term physically significant level refers to the minimum practical lower limit of reliable analytical and counting detectability of uranium in urine

The DR Template (page 15) discusses the PSL and its relationship to the minimum detectable activity (MDA):

> The internal dosimetry records indicated that the physically significant level (PSL) for a given analysis technique was an empirically derived value at the 95% confidence level (i.e., at a level providing a 5% false positive rate), which is similar to currently used decision levels (L_ds). However, given that the minimum detectable activity (MDA) and a decision level are related by the equation MDA = L_d/E_c, where E_c is the counting efficiency, and given the units of measure reported for the PSL, the PSL values are more closely related to the currently used MDA values. Because all measurement results for non-naturally occurring radionuclides showed an activity less than the PSL for the given radionuclides and bioassay methods, only missed internal doses were assessed.

[1] NIOSH's Excel files for the coworker study are stored on the Division of Compensation Analysis and Support internal server at [redacted].

The PSLs stated in the DR Template are 50 disintegrations per minute (dpm)/day, 0.33 dpm/day, 5 dpm/day, 5 µg/day, and 1 microcurie per liter (µCi/L) for fission products, plutonium, enriched uranium, natural uranium, and tritium, respectively. With the exception of the PSL for natural uranium, SC&A found these same values in Figure 5-23 on PDF page 120 of ORAUT 1997. The table on PDF page 120 of ORAUT 1997 lists the PSL for natural uranium at 3 µg/day.

NIOSH 2009 provides a discussion of PSL and references ORAUT 1997. However, it does not provide specific PSLs for fission products, plutonium, enriched uranium, natural uranium, or tritium.

Observation 2: The natural uranium PSL in the DR Template is not consistent with information in ORAUT 1997 and is not referenced.

4.2 FISSION PRODUCT DOSE

For the fission product dose assessment, the DR Template (pages 15–16) states:

> A 10-day decay period was used for the activation and fission product intake calculations, in accordance with the Technical Information Bulletin: Fission and Activation Product Assignment for Internal Dose-Related Gross Beta and Gross Gamma Analyses[ORAUT-OTIB-0054, Rev. 00 PC-1] because the Peek Street Facility was equipped with a zero pile reactor and a critical assembly. The fraction of the gross beta radioactivity in the urine sample that was attributable to strontiumn-90 was assumed to be 0.037, based on the information in Table 7-2 of the Technical Information Bulletin: Fission and Activation Product Assignment for Internal Dose-Related Gross Beta and Gross Gamma Analyses.[ORAUT-OTIB-0054, Rev. 00 PC-1] Using that fraction, a missed strontium-90 intake rate was calculated using the IMBA computer model and an excretion rate of 0.93 dpm/day. Because lung absorption Type F (i.e., very soluble) was likely the only form of strontium-90 that was likely present at the Peek Street Facility, the evaluation was only performed for Type F material. Based on the information and assumptions above, a missed internal strontium-90 intake rate of 2.5 dpm/day was calculated.
>
> Intakes for the other radionuclides that may have been associated with the fission product analysis were estimated using the strontium-90 intake and the associated radionuclide ratios provided in Table 7-3 of the Technical Information Bulletin: Fission and Activation Product Assignment for Internal Dose-Related Gross Beta and Gross Gamma Analyses.[ORAUT-OTIB-0054, Rev. 00 PC-1] A summary of the estimated fission product and activation product radionuclide intake rates is provided in Table 1 below.

Table 1. Radionuclide Intake Rates for Urine Samples Analyzed for Fission Products

Fission Product or Activation Product	Ratio Applied[a]	Intake Rate (dpm/day)
Strontium-90	1:1	2.5E+00
Barium-140	26:1	6.5E+01
Cerium-141	30:1	7.5E+01
Cerium-144	16:1	4.0E+01
Cesium-134	0.30:1	7.5E-01
Cesium-137	1.3:1	3.2E+00
Europium-155	0.072:1	1.8E-01
Iron-55	1.7:1	4.2E+00
Iodine-131	532:1	1.3E+03
Lanthanum-140	30:1	7.5E+01
Niobium-95	28:1	7.0E+01
Promethium-147	3.4:1	8.5E+00
Ruthenium-103	23:1	5.7E+01
Ruthenium-106	5.5:1	1.4E+01
Strontium-89	19:1	4.7E+01
Yttrium-91	23:1	5.7E+01
Zirconium-95	31:1	7.7E+01

[a.] Ratios applied are relative to strontium-90 for 10-day old reactor fuel, per ORAUT-OTIB-0054.[Rev. 00 PC-1]

SC&A was able to find the Tables 7-2 and 7-3 information cited in the DR Template. ORAUT-OTIB-0054, Revision 00 PC-1, became effective on November 19, 2007. Since that date, there have been several revisions. The current version is ORAUT-OTIB-0054, Revision 04, effective August 27, 2015; this version does not contain the fission product information in the tables cited.

NIOSH 2009 contains the same fission product information and references ORAUT-OTIB-0054, Revision 00, effective May 11, 2007.

Finding 7: The fission product information in the DR Template is not consistent with current guidance in ORAUT-OTIB-0054, Revision 04.

4.3 PLUTONIUM DOSE

The assessment of plutonium dose is described in the DR Template (page 17), in part, as follows:

> It was assumed that the plutonium at the Peek Street Facility was weapons-grade plutonium, because the Peek Street Facility was developing methods to separate plutonium from irradiated nuclear reactor fuel for nuclear weapons production. Based on this assumption and given that the plutonium in the urine was freshly separated and analyzed for alpha radioactivity, the composition of the plutonium in the detected in urine sample only consisted of plutonium-238, plutonium-239, plutonium-240, and plutonium-242. The isotopic composition of the alpha-emitting plutonium in the urine is provided in Table 2 below…

> Because the radionuclide composition of plutonium is dependent on its age since separation and because the Peek Street Facility only existed for 7 years, the maximum age of the plutonium that the Peek Street Facility workers were exposed to was assumed to be 7 years old. Table 3 provides the potential radionuclide composition of the plutonium source term that the Peek Street Facility workers were exposed to. For this dose reconstruction, a plutonium-239 intake was calculated based on the bioassay data and Table 2 information, and the intakes of the other radionuclides in the plutonium source term were estimated from the plutonium-239 intake and the ratios provided in Table 3.

SC&A reviewed the information in Tables 2 and 3 of the DR Template. The reference cited for both tables is ORAUT-TBKS-0006-5, Revision 04, effective October 20, 2010. The current revision of that document is ORAUT-TBKS-0006-5, Revision 06, effective November 16, 2015. The specific activities of Hanford weapons-grade plutonium mixture shown in Tables 2 and 3 are contained in Table 5-5 of Revision 06.

The plutonium information in NIOSH 2009 references ORAUT-TKBS-0006-5, Revision 01, effective November 24, 2004.

Observation 3: The plutonium composition information is correct. However, the reference cited is outdated and needs updating.

4.4 URANIUM DOSE

The DR Template (page 19) discusses the assumptions and parameters used to assess doses from enriched uranium as follows:

> Because the Peek Street Facility was involved with developing processes to recycle enriched uranium from irradiated nuclear fuel, [the energy employee] might have been exposed to other non-uranium radionuclides that were associated with recycled uranium. Therefore, potential intakes of the other radionuclides in recycled uranium were estimated from the uranium intakes using the ratios for each of the associated radionuclides provided in Table 5 below.

The DR Template (page 20) also addresses doses from natural uranium as follows:

> Because the Peek Street Facility was involved with developing fast breeder reactor technologies, it may have been involved with developing processes to recycle the natural uranium from an irradiated breeder reactor blanket. Therefore, [the energy employee] might have been exposed to other non-uranium radionuclides that were associated with recycled uranium. The potential intakes of the other radionuclides in recycled uranium were estimated from the uranium intakes using the ratios for each of the associated radionuclides provided in Table 5 above.

Table 5 of the DR Template is reproduced below in Table 4-2. No reference is cited for the radionuclide fractions presented.

Table 4-2. Table 5 from PSF DR Template

Radionuclide	Intake Activity Fraction Relative to Total Uranium
Neptunium-237	1.4E-03
Plutonium-239	8.5E-04
Technetium-99	3.0E-01

SC&A reviewed ORAUT-TKBS-0006-5, Revision 06; ORAUT-TKBS-0017-5, Revision 03, *Feed Materials Production Center – Occupational Internal Dose* (2017); and *Review of Generation and Flow of Recycled Uranium at Hanford* (DOE 2000) but was unable to verify the recycled uranium activity fractions in Table 5.

NIOSH 2009 (pages 14–15) provides a discussion of the recycled uranium basis:

> *Basis for Associated Radionuclides in Recycled Uranium*
> The basis for the associated radionuclides and ratios being used in **Table 3** has been excerpted from the draft of the *Technical Basis Document titled Dose Reconstruction Considerations for Recycled Uranium Contaminants* (OTIB-0053). The excerpted information is intended to provide a stand alone basis for the ratios in Table 3, since plans to issue this technical basis document may have been cancelled.
>
> Recycled uranium (RU) is contaminated with trace levels of actinide and fission product isotopes that could not be completely removed during chemical separation. Contaminants primarily included: Sr/Y-90, Tc-99, Zr/Nb-95, Ru-103, Ru-106, thorium, neptunium, plutonium, and other gamma emitting radionuclides. The major contaminants contaminates with a possible dose impact include: Tc-99, plutonium, and neptunium, since they existed at concentrations that were sufficient to result in internal doses to some organs that were considered to be significant.
>
> The default ratios listed in **Table 3** are intended to be applied to workers of the category of primary chemical separation plants or the primary shipping sites represented only by the four sites that extracted uranium from spent fuels and constituted the supply of recycled uranium to the system.[1] The default ratios are based upon Hanford data, and a more detailed summary of how the default ratios were derived are provided in **Table 4**.[1] Because the Peek Street Facility was involved with developing the chemical processes that were used by the chemical separation plants, the ratios for the chemical separation plants are representative of the composition of the material at the Peek Street Facility."

Table 4
Recycled Uranium Contaminant Levels
for Primary Production Sites[1]

Contaminant	Range of Average Concentrations in Uranium (ppb)	Range of Observed Concentrations in Uranium (ppb)	Default Values		
			(ppb)	(pCi/µg U)	(pCi/pCi U)
Np-237	100–400	3–800	800	5.7E-04	1.4E-03
Plutonium	3–5	0.1–5	5	3.5E-04	8.5E-04
Tc-99	10–5E+03	1–6E+03	6E+03	0.1	3.0E-01

[Note: Original table has been slightly reformatted to comply with Section 508 of the Rehabilitation Act.]

Reference [1] in the above quote is given in NIOSH 2009 (pages 19–20) as:

> [1] Bryce, Rich L. ORAU Team. Senior Health Physicist. May 2008.
> For the category of facilities defined as primary production sites this includes the four chemical processing plant sites, which dissolved spent fuels and extracted plutonium (in the case of the weapons production plants) and the remaining unused uranium. Of necessity the radiation protection programs for these facilities were extensive as exposure potential was to high levels of fission products, TRU, uranium, and others. For RU considerations the primary exposure source would have been the process to convert uranyl nitrate to UO_3 for shipment. In the case of Hanford and SRS they had fuel fabrication facilities in which RU was received and processed. Notes in the Hanford Mass Balance report indicate that the trace levels of contaminants did not result in detectable levels of TRU, etc. in the bioassay analyses, which indicate in turn that claimants will likely have direct bioassay upon which to perform DR. However, in cases in which uranium bioassay is available and a default for contaminant ratio addition is necessary.
>
> The recommended default of 5 ppm U for Pu is based upon the upper level of the observed range. The limits of 10 ppm U were established from the beginning and throughout the history of the RU period and the analyses were performed on the uranyl nitrate product from the extraction columns and returned if the levels were above or approaching the limits. Records in DOE/RL-2000-43[DOE 2000] indicate that rare shipments (6 in number) above 10 ppb U (12, 13, 16, 19, 22, & 30) in 193 MTU of the total 93,316 MTU (approx. 0.2% by mass) were sent to the Gaseous Diffusion Plants (GDPs). During a 3 yr period (5/64 to 6/67) out of 352 shipment lots 6 exceeded 5 ppb U (6, 6, 6, 7, 7, & 8) for a weight percentage of approx. 1.7%. The average was 2.2 ppb U with a range of <1 – 8). Since the recorded experience of the shipment contaminant levels for Pu indicated that a trivial percentage of the mass exceeded 10 ppb U and <2% exceeded 5 ppbU, with a clear indication that those lots were sporadic in nature rather than extending over a significant time, and with the average a factor of 2 or so below 5 ppb U, a default of 5 ppb U appears to be adequately favorable to claimants with insignificant risk of exposure above this value. Also, the fuel fabrication

> processes were with materials that had been processed through the GDP process with significant contaminant removal and/or through Fernald also with contaminant removal and or dilution mechanisms.

SC&A could not locate a draft, issued, or archived version of ORAUT-OTIB-0053, and NIOSH 2009 did not provide a Site Research Database (SRDB) identifier for the Rich citation. SC&A performed a search of the SRDB for the Rich document and ORAUT-OTIB-0053 but did not find either document.

SC&A believes the DR Template should contain a discussion of the basis for the determination of the recycled uranium contaminants and/or an appropriate reference.

Finding 8: No basis or reference is cited for the recycled uranium activity fractions in Table 5 of the DR Template.

4.5 RARE EARTH DOSE

Although rare earth urinalyses were not performed at PSF, the DR Template provides a discussion of potential doses from rare earth radionuclide produced at the Separations Process Research Unit (SPRU) located at KAPL. The DR Template specifies using the same PSL as for fission products, 50 dpm/day, and also contains two notes relevant to rare earth bioassay evaluation:

> (NOTE: A rare earth urinalysis result is an indicator that there are some potential problems with the covered employment for this case, since this sample was most likely collected as a result of the EE's work at the KAPL or SPRU Site. (SPRU is located on the KAPL Site.) If a rare earth urinalysis is reported for PSF employment period, the DR should carefully review the available claim records to determine if there is an error in NOCTS regarding the EE's covered employment.) [pp. 20–21]

> (NOTE: Because Ce/Pr 144 and Pm-147 are both rare earths and fission products, doses attributable to intakes of these radionuclides are accounted for in both the assessment of the mixed fission products and rare earth urinalyses. Because the rare earth urinalysis implies that these radionuclides may have been separated from the other fission products, the OTIB-0054 approach should not be used for them. Therefore, the potential intakes of Ce/Pr-144 and Pm-147 should be assessed based on the rare earth urinalysis data, for the periods that are covered by that data.) [p. 21]

NIOSH 2009 provides similar information regarding rare earth radionuclides.

SC&A found information on SPRU located at KAPL in ORAUT 1997 and concurs with the information described in the DR Template and NIOSH 2009 regarding rare earth radionuclides.

4.6 TRITIUM DOSE

Should an employee have tritium bioassay data, the tritium dose is assessed assuming a PSL of 1 µCi/L, verified and described in Section 4.1, and the guidance in ORAUT-OTIB-0011, Revision 00, *Technical Information Bulletin: Tritium Calculated and Missed Dose Estimate*s (2004). SC&A concurs with the method described in the DR Template to assess the tritium doses at PSF.

5 SUMMARY CONCLUSIONS

The DR Template for PSF is used by the dose reconstructors in lieu of a technical basis document. The DR Template contains facility-specific data, assumptions, and list of documents that provide the basis for the facility-specific data and assumptions. SC&A's review of the DR Template for PSF identified **eight findings** and **three observations**.

- **Finding 1:** The assumption of 100% 30–250 keV for the penetrating photon energy distribution is unsupported and inconsistent with assumptions used in the Hanford technical basis document.
- **Finding 2:** The assumption of an uncertainty factor of 1.3 is unsupported and inconsistent with the cited reference.
- **Finding 3:** SC&A was unable to verify the neutron-to-photon ratio of 1.2 using the cited references.
- **Finding 4:** The dosimeter LOD used in the DR Template is not specified in the template, and the value of 0.050 rem assumed based on NIOSH's calculation is not consistent with the Hanford dosimeter information.
- **Finding 5:** SC&A was unable to verify the PSF annual maximum ambient dose value using the cited reference.
- **Finding 6:** The DR Template occupational medical dose basis contains incorrect information and outdated references.
- **Finding 7:** The fission product information in the DR Template is not consistent with current guidance in ORAUT-OTIB-0054, Revision 04.
- **Finding 8:** No basis or reference is cited for the recycled uranium activity fractions in Table 5 of the DR Template.
- **Observation 1:** SC&A did not locate a PSF-specific tool containing the preprogrammed plutonium DCFs.
- **Observation 2:** The natural uranium PSL in the DR Template is not consistent with information in ORAUT 1997 and is not referenced.
- **Observation 3:** The plutonium composition information is correct. However, the reference cited is outdated and needs updating.

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