Assessment of Certain Special Exposure Cohort-Related Issues for the Hanford Site

White Paper

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INTRODUCTION

This document presents the status of the assessment of dose reconstruction feasibility for several Special Exposure Cohort (SEC)-related issues for the Hanford site. It reflects the current state of knowledge based on extensive site research actions accomplished since the approval of SEC petition SEC-00201 in 2012.

This document addresses only SEC issues and only those that are not dependent on the implementation of the revised guidance for co-worker methods. The evaluations apply only to employees of Hanford prime contractors, including the Department of Energy (DOE) and Pacific Northwest Laboratory (PNL), during the period January 1, 1984 through December 31, 1990 (the definition of the Hanford site for EEOICPA purposes includes all of the Pacific Northwest National Laboratory [formerly PNL] through calendar year 2004).

An overall synopsis of site operations is not included. It is assumed that the reader is familiar with Hanford site operations and the high-level areas of responsibility for the site prime contractors during the period 1984 – 1990. Such information may be found in the SEC evaluation reports (ERs) for petitions SEC-00201 and SEC-00226. A summary of the extensive site research activities represented in this document is presented in Attachment A.

BACKGROUND

The SEC issues addressed in this document are rooted in SEC-00057, which proposed a class for all employees in all areas of the Hanford site from January 1, 1942 through December 31, 1990. The SEC-00057 evaluation was subsequently split into two components (SEC-00057-1 and SEC-00057-2). SEC-00057-1 added a class from October 1, 1943 through August 31, 1946. SEC-00057-2 added a class for 300 Area workers through December 31, 1961 and for 200 Area workers through December 31, 1968. This was followed by 83.14 (Form A) petition SEC-00152 that extended the SEC-00057-2 class definition and removed its Area-specific constraints. As a result, the SEC class for Hanford became all workers in all areas for the period October 1, 1943 through June 30, 1972. SEC-00152 was followed by 83.14 petition SEC-00201, which added a class for July 1, 1972 through December 31, 1983 for all Hanford workers in all areas.

The basis for the class established by SEC-00201 was that NIOSH lacked sufficient information, including biological monitoring data, sufficient air monitoring information, or sufficient process and radiological source information, to allow it to estimate with sufficient accuracy the potential internal exposures to purified highly-enriched uranium, U-233, neptunium, or thorium to which the proposed class may have been subjected. The SEC-00201 ER was approved by NIOSH on June 1, 2012. The Advisory Board on Radiation and Worker Health (ABRWH) accepted the NIOSH recommendation on July 27, 2012. This action left the period January 1, 1984 through December 31, 1990 to be investigated within the context of Petition SEC-00057-2.

During site research activities conducted subsequent to the approval of SEC-00201, NIOSH recognized that the radiological monitoring for certain subcontractors (i.e., employees of other than prime contractors) who performed work at Hanford from 1984 through 1990 was not sufficient for dose reconstruction purposes. Furthermore, it could not be assumed that the existing Hanford co-worker models encompassed the potential internal exposures for those individuals. As a result, in March 2015, NIOSH initiated an 83.14 petition evaluation (SEC-00226) to recommend adding a class for contractors and subcontractors who were not employees of named prime contractors during the period January 1, 1984 through December 31, 1990. The rationale for this SEC class was recognition that "construction trades workers' fundamental type of work, as well as radiological monitoring practices, were substantively different from other Hanford operational workers," and that NIOSH lacked "sufficient radiobioassay monitoring data for construction trades workers, and sufficient workplace monitoring and source term data, that would allow it to estimate with sufficient accuracy the potential internal doses from radionuclides associated with fuel handling, reactor operations, fuel reprocessing, or research activities to which the proposed class may have been exposed during the period from January 1, 1984 through December 31, 1990." The energy employees covered by this SEC class were Hanford workers who did not work for one of the site prime contractors, the Department of Energy, or the Pacific Northwest Laboratory. These were primarily construction and trades workers, but also included all subcontractors.

The approval of the SEC-00226 ER left one group remaining to be evaluated for the period 1984-1990: the employees of the named prime operating contractors excluded by SEC-00226. Consequently, the evaluations and conclusions presented in this document apply only to the prime contractors, as identified in the SEC-00226 class definition. These entities and corresponding operating periods were: Battelle Memorial Institute (i.e., Pacific Northwest Laboratory), January 1, 1984 through December 31, 1990; Rockwell Hanford Operations, January 1, 1984 through June 28, 1987; Boeing Computer Services Richland, January 1, 1984 through June 28, 1987; UNC Nuclear Industries, January 1, 1984 through June 28, 1987; Westinghouse Hanford Company, January 1, 1984 through December 31, 1990; and Hanford Environmental Health Foundation, January 1, 1984 through December 31, 1990.

A consolidation took place in mid-1987 whereby the prime contractor responsibilities formerly executed by Rockwell Hanford, Boeing Computer Services, and United Nuclear were all brought under a single contract executed by Westinghouse Hanford Company. Previously, United Nuclear was the operating contractor for the N Reactor and associated facilities in 100 Area; Rockwell managed operations in 200 Area, including the PUREX Plant and the Plutonium Finishing Plant.

The SEC-00201 ER determined that dose reconstruction was feasible from 1984 onward. This echoed the same conclusion previously drawn in the SEC-00057-2 ER. The bases for this conclusion were: (1) Hanford isotopic uranium analysis records available by the end of 1983 were sufficient to differentiate HEU and U-233 exposures from exposures to natural or slightly-enriched uranium; (2) Hanford work practices and programs had matured; and (3) changes in the nature of work performed after 1983 were such that dose from potential intakes of thorium or neptunium could be bounded with sufficient accuracy. NIOSH initiated the 83.14 class defined by petition SEC-00226 when it was recognized that the improvements in monitoring cited in SEC-00201 as one of the bases for ending its 83.14 class after 1983 did not apply to a subset of workers (i.e., employees of the construction/trade contractor or subcontractors). Otherwise, the determination of dose reconstruction feasibility in SEC-00201 is still applicable for the prime contractor employees not included in the 83.14 class from SEC-00226. That determination of dose reconstruction feasibility is the subject of the current SEC issue evaluations presented in this document.

HANFORD SEC ISSUES CONSIDERED

Following the addition of the 83.14 class from petition SEC-00226 to the SEC in 2015, NIOSH and the ABRWH contractor engaged in a number of exchanges and discussions for the purpose of consolidating all dose reconstruction and SEC issues that remained open. A principal goal for this effort was to develop updates on each of these issues for the Work Group's consideration that reflected the SEC period currently under evaluation, the site research progress made since the last WG updates, and the entry of the SEC-00226 class into the Board Review System (BRS) for tracking.

In November 2017, NIOSH and the ABRWH contractor provided to the Hanford WG a document presenting their consensus recommendations regarding the status of outstanding Hanford issues. That document served two purposes: (1) to capture all unresolved dose reconstruction and SEC-related issues; and (2) to provide a recommended scope and status for each issue within the context of the 1984-1990 period under evaluation.

The Hanford WG met on October 26, 2018 to consider the joint recommendations. Each issue and recommendation was discussed individually, followed by input from the WG regarding concurrence, requested changes, or other actions. Some issues were also closed. In November 2018, NIOSH incorporated the WG input into the Board Review System (BRS).

The current status of all outstanding dose reconstruction and SEC-related issues for Hanford is defined in the BRS. This white paper addresses only SEC issues and only those that are not dependent on the implementation of the revised guidance for co-worker methods. Some of these issues listed below, notably Issues 3 (Th-232), 4 (HEU), 7 (U-233), and 9 (Np-237), are legacy items from earlier periods when chronic sources of these materials were present. No chronic sources for these materials have been identified for the period 1984 through 1990. Much of the site research performed in support of this evaluation was focused on possible source terms for these materials.

The Hanford SEC issues addressed in this document and their respective scopes (per the BRS) are:

Issue 3: Thorium-232 Internal Exposure from January 1, 1960 Onward

This SEC issue relates to: (1) potential thorium exposures during remediation of certain areas; (2) the potential use of thorium in nuclear fuel fabrication and related operations within the 300 Area during 1984 through 1990; and (3) possible thorium use in other areas at Hanford during that time.

Issue 4: HEU - Uranium Intake Estimation

This SEC issue pertains to whether workers who potentially received intakes of HEU during the post-1983 period were monitored by alpha spectrometry (for urinalysis) or by other appropriate means. This issue is contingent upon the identification of a potential source of HEU intakes by Hanford workers from 1984 through 1990.

Issue 7: U-233 Intakes

This SEC issue pertains to potential sources of U-233 intakes during 1984 through 1990, and the adequacy of Hanford's internal monitoring practices for U-233 in the event such sources existed. This issue is contingent upon the identification of a potential source of U-233 intakes by Hanford workers from 1984 through 1990.

Issue 9: Np-237 Intakes

Additional work is needed to address the question of the potential for Np-237 intakes at PUREX from 1984 through 1990. This issue *[of Np-237 intakes generally]* is resolved otherwise.

Issue 10: Tritium Intake Estimation from 1949 Onwards

This SEC issue pertains to tritium dose assignment in the event that sources of Special Tritium Compounds (STCs) are identified that present a potential for worker intakes during the period 1984 through 1990. The issue is resolved until 1983, and for some workers until 1990, through the approval of various SEC classes.

Issue 20: Skin Contamination

This SEC issue pertains to the adequacy of monitoring data for skin contamination resulting from radiological incidents involving primary cooling water at the Hanford N Reactor. This issue pertains to refueling, maintenance, and other activities in support of N Reactor operations. Site data indicate considerable potential for skin contamination during such activities. This contamination potential was not limited to just maintenance workers (i.e., it also existed for operations personnel and other employees).

Issue 22: Radiological Incidents

This SEC issue pertains to the question of whether sufficient bioassays were taken for potential worker internal exposures from minor radiological incidents during the 1984-1990 time period.

Issue 27: Building 324 Leaks

There were leaks of high-level waste in B-Cell, Building 324 (including a major spill), reportedly in 1986. Decontamination of B cell began in the late 1980s. There were earlier leaks under A-Cell and C-Cell. The soil under B-Cell was found to be contaminated in 2010.

The adequacy and completeness of monitoring data have been evaluated and determined to be sufficient for dose reconstruction. Documentation of those findings is pending.

OVERALL CONCLUSIONS

Regarding the issues considered in this document, the overall conclusion is that the ORAU Team has found nothing contrary to the determination made in the SEC-00201 ER that dose reconstruction was feasible from 1984 onward for employees of the prime contractor organizations, as defined in the SEC-00226 class definition. Specific determinations made in support of this conclusion are:

- Extensive site research completed subsequent to SEC-00201 has not identified any evidence of large-scale use of radionuclides of concern (ROCs) or any cases where any of those materials would represent a potential chronic source of intake. ROCs were used infrequently and there was little potential for internal exposure. This prompts the conclusion that internal exposure from ROCs would only have occurred as a result of radiological incidents.

- A lack of nuclide-specific routine monitoring data for a non-chronic source does not portend a dose reconstruction infeasibility. The existence of nuclide-specific data for non-chronic sources indicates that a radiological incident occurred.

- Internal dose evaluations documented by the Hanford internal dosimetry program during the evaluation period indicated that minor workplace incidents were not significant internal dose contributors (i.e., did not produce doses in excess of 1% of applicable radiation protection standards).

- Workplace monitoring with the intent of identifying and reporting radiological incidents of potential internal dose significance appeared sufficient across the site prime contractors. Site-wide guidance for consulting the internal dosimetry program in cases of suspected or indicated radiological intake was in place and followed. Appropriate bioassay methods were available for all ROCs and were used when needed.

- Workplace monitoring was backstopped with routine bioassay and by the routine *in-vivo* monitoring program in particular.

The bases for these conclusions are detailed in the remainder of this document, beginning with a discussion of the Hanford site radiation protection program and the practices that were in place from 1984 through 1990. That is followed by specific discussions for each SEC issue addressed in this document.

HANFORD RADIATION PROTECTION PROGRAM

This section discusses the elements and practices of the radiation protection program at Hanford from 1984 through 1990 that are germane to the evaluation of the SEC issues addressed in this document. The discussion focuses on the control and monitoring of internal dose since that is the concern for most of the identified issues.

Program Description

Radiation protection at Hanford from 1984 through 1990 (and for many years prior) was implemented as a site-wide services function administered and operated by Pacific Northwest Laboratory (PNL) for DOE-Richland (DOE/RL) and the Hanford site contractors. With respect to internal dosimetry, program practices such as guidance for selection of workers for bioassay monitoring and establishing the type and frequency of bioassay measurements were documented in the "Hanford Internal Dosimetry Program Manual" [Carbaugh et al. 1989] and its predecessors. The "Hanford Dosimetry Evaluation Manual" [Battelle 1982] also provided general guidance and criteria for the development of internal monitoring programs.

Each prime contractor was responsible for its own radiation protection plans and the field portion of its internal monitoring program, following guidance supplied by PNL. The Hanford Internal Dosimetry Program Manual spelled out contractor responsibilities for identifying when bioassays were needed and for which nuclides. PNL was responsible for providing technical guidance and administering the internal dosimetry program. PNL also provided consultation and advisory services to contractors for developing and establishing bioassay programs. PNL would discuss measurement results with workers on an individual basis if so requested by the contractor, and would respond to specific questions if contacted directly by workers [Carbaugh et al. 1989].

The Hanford Internal Dosimetry Program Manual clearly delineated PNL's role as the dosimetry services provider for the site. It stated:

> *The IDP [internal dosimetry program] works closely with Hanford contractor dosimetry organizations to provide a comprehensive internal dosimetry service. However, the IDP has no direct responsibility to ensure the protection of workers, to monitor or conduct surveillance of work environments, to operate facilities, or to assure worker cooperation with bioassay measurement requests. Such items are considered to be the responsibilities of the contractor.* [Carbaugh et al. 1989]

During an interview in December 2014 [ORAUT 2014a], the [REDACTED] stated that the predecessor to the Internal Dosimetry Program Manual was the Hanford Dosimetry Manual published in 1982. That document provided general guidance to site contractors regarding worker bioassay programs until it was replaced by the IDP manual in 1988. During a prior interview in August 2014 [ORAUT 2014b], the [REDACTED] stated that PNL provided guidance to the contractors with respect to their routine bioassay programs, but it was not PNL's role to audit them. The companies made their own determinations of who was monitored and for what. Oversight was ultimately the responsibility of DOE. However, a Hanford dosimetry advisory committee evaluated whether contractors were following PNL's guidance for personnel monitoring, meeting quarterly between the mid-1980s and mid-1990s. During an interview with the [REDACTED] [ORAUT 2014c], the individual stated that contractors would have to provide an explanation to DOE if they did not follow PNL's guidance. During another interview in 2017 [ORAUT 2017a], the [REDACTED] stated their program followed the best practices published by the Institute for Nuclear Power Operations.

Program Bases

A key philosophy of the Hanford IDP was that workplace monitoring, including air sampling and contamination surveys of personnel and work areas, was the primary means for identifying internal exposures. Routine bioassay was considered secondary to workplace monitoring. Because radionuclide intakes were generally prevented by containment or other protective measures, internal exposures were infrequent and typically occurred only as a result of the failure of a protective system. However, there were exceptions identified for certain facilities and operations where low-level chronic exposure conditions existed. These sources of chronic intakes were: (1) operations involving depleted and low-enrichment uranium in the 306-W Specialty Machine Shop, the Uranium Oxide Plant, and the N Reactor Fuel Production Facility; and (2) operations involving tritium in several laboratories [Hanford 1990; Lyon et al. 1988; Lyon et al. 1989]. No chronic sources of Th-232, HEU, or Np-237 were identified.

With the exception of the chronic exposure sources identified above, it was assumed that any internal exposures would occur only as a result of accidental circumstances. Hence, the radiation protection program relied first on workplace monitoring as the means for identifying dosimetrically-significant intakes. PNL's guidance documents defined protocols and investigation levels to be applied in cases where radiological occurrences showed a potential for internal exposure. Cases that required internal exposure investigation were identified by "workplace surveillance (e.g., air sampling, contamination survey, contaminated wound)", routine bioassay, or "other radiation protection considerations" [Lyon et al. 1989].

A routine bioassay was used in cases where chronic intakes were assumed to be a possibility, and to account for potentially undetected, incident-related intakes. Routine bioassay (*in vitro* and *in vivo*) also served to monitor the effectiveness of workplace monitoring methods [Carbaugh et al. 1989].

During an interview in June 2017 [ORAUT 2017a], the [REDACTED] stated that internal monitoring at N Reactor was incident-driven for the most part, but bioassay criteria did exist, as did criteria for responding to skin contamination and puncture wounds. Annual whole-body counts were performed as an element of worker annual physicals.

Workplace Monitoring for Incidents of Potential Internal Dose Significance

Regarding workplace-monitoring practices for identifying potential intakes, PNL's guidance to the contractors was "Internal Dosimetry should be contacted whenever an intake of radioactivity is suspected, or when the dosimetric-significance of an observation or event is in doubt" [Carbaugh et al. 1989]. The following examples were included:

- Suspected intake of radioactive material with the potential for an annual effective dose equivalent of 100 mrem.
- Extended or extensive personal skin contamination.
- Loss of containment or exposure control, such as failure of a ventilation system or respiratory protection, resulting in exposure to high concentrations of airborne radioactivity.
- Spread of contamination that results in levels of radionuclides at or exceeding given levels.
- Unplanned releases of radioactive material to the environment.

Tables were included with criteria such as contamination levels that warranted contacting the IDP.

PNL also recommended that the IDP be included on the distribution for radiation occurrence reports [Carbaugh et al. 1989].

During an interview in August 2014 [ORAUT 2014b], the [REDACTED] stated that the contractors were responsible for identifying whether an incident had occurred, and if so, notifying PNL about who was involved and so forth. PNL provided a response to radiological incidents identified by the contractors and provided guidance on action levels for workplace monitoring (e.g., air sample results). It was the internal dosimetry group's practice to investigate any incidents in which a potential for internal exposure was identified.

IDP annual reports included summary statistics for site-wide incidents that had a potential for internal exposure. PNL began publishing these reports in 1987. Data were presented for each site contractor showing that PNL's guidance for incident reporting was adopted site-wide.

The internal exposure-related incident information from the 1987 through 1990 is summarized below.

- 1987 IDP Annual Report: During 1987, there were 14 reported incidents with potential internal exposure involving 20 workers identified through workplace surveillance (during 1986, there were 44 reported incidents involving 63 workers). Of the 20 persons, 13 were potentially exposed to short-lived fission and/or activation products, four to uranium, two to plutonium, and one to Sr-90. Seventeen of the exposures were via inhalation and three were from minor wounds. None of the individuals involved were determined to have incurred internal doses in excess of 1% of a DOE radiation protection standard [Lyon et al. 1988, PDF p. 39].

- 1988 IDP Annual Report: During 1988, there were 12 incidents of potential internal exposure involving 25 workers identified through workplace monitoring. Of the 25 workers, 14 were potentially exposed to short-lived fission and/or activation products, three to radiostrontium, and eight to transuranic radionuclides. None of the workers received internal doses exceeding 1% of the DOE annual limit [Lyon et al. 1989, PDF p. 27].

- 1989 IDP Annual Report: During 1989, there were 22 incidents of potential internal exposure involving 33 workers identified through workplace monitoring. Of the 33 workers, 13 were potentially exposed to radiostrontium and/or radiocesium, three to radiocobalt, five to uranium, four to tritium, and eight to transuranic elements [Hanford 1990, PDF p. 28].

- 1990 IDP Annual Report: During 1990, there were 14 incidents of potential internal exposure involving 29 workers identified through workplace monitoring. Of the 29 workers, 15 were potentially exposed radiostrontium and/or radiocesium, two to Co-60 and activation products, two to Na-24, seven to transuranic elements, and three to uranium. The bioassays for the 29 workers determined no intake for 14 of them and confirmed intake for eight others. The bioassay results for the other seven workers were pending at the time. Of the eight confirmed intakes, three resulted in a 50-year committed effective dose equivalent (CEDE) in excess of 100 mrem [Hanford 1991, PDF p. 45].

The incident summaries above indicate that the workplace monitoring methods in place at Hanford were capable of identifying radiological occurrences at a threshold below events of internal dose concern and that events of internal dose significance were rare. Radiological occurrences involving internal dose potential would have been substantial events that would have been recognized in the workplace. Further discussion of incident reporting by the Hanford site contractors is provided later in this document.

Routine Internal Monitoring

The Hanford IDP provided for routine bioassay monitoring of potentially-exposed workers via both *in-vivo* measurements and *in-vitro* (excreta) analyses. With respect to determining dose reconstruction feasibility for Hanford workers, routine *in-vivo* monitoring was a key element of the IDP.

Routine *In-Vivo* Monitoring

Routine *in-vivo* bioassay measurements performed for Hanford workers during 1984 through 1990 included both whole-body counts and chest counts. Annual whole-body counts were performed in conjunction with workers' annual medical exams. Routine chest counts were performed when there was potential for lung depositions of radionuclides having gamma energies less than 200 keV. In general, only routine whole-body counts were performed unless an individual worked with transuranic nuclides. Both whole-body and chest counts were performed for employees who worked with transuranics [Lyon et al. 1988]. In addition to those performed during a worker's annual physical, whole-body counts were also performed when employees were newly hired, terminated, or at the beginning or end of special projects [Carbaugh et al. 1989].

The purpose of the routine whole-body counting program was to measure internally-deposited radioactivity in Hanford site contractors "to document the absence of radioactivity in most radiation workers and to determine the amount, distribution, and retention of radioactivity for those few employees who become internally contaminated" [Palmer 1986].

During 1984-1990, whole-body counts were performed primarily using what was known as the "preview counter." The preview counter was a stand-up counter consisting of a column of five sodium iodide detectors mounted in a shielded booth. Data from the preview counter were recorded as the sum from all five detectors plus independent results from the three upper detectors and the sum from the two lower detectors. The data from the individual detectors were used to measure the distribution of radioactivity in the body [Palmer 1990]. As of 1983, PNL asserted that the preview counter detectors were 10 times more sensitive to radioactivity in the body than the shadow-shield counter also in use during that time, meaning a 200-second count in the preview counter was twice as sensitive as the 10-minute counts used for the shadow-shield counter [Palmer et al. 1983].

Internal Monitoring Data 1984-1990

This section provides summaries of the internal monitoring data for Hanford prime contractor employees from 1984 through 1990 for analyses pertinent to the SEC issues under consideration. References to the "REX database" refer to results obtained from the frozen version of the Hanford Radiation Exposure (REX) database that was provided to the ORAU Team in 2014.

In-Vivo Bioassay Data

Tables 1 through 7 below show the number of whole-body counts seen in the REX database for each Hanford site prime contractor from 1984 through 1990. In mid-1987, the previous site prime contracts executed by United Nuclear and Rockwell were consolidated under a single contract with Westinghouse Hanford Company. Hence, there are two sets of data for Westinghouse (one before and one after the consolidation), and data for United Nuclear and Rockwell essentially cease after 1987. Each table shows the subdivision of the reason codes included in the REX database for each entry. Reason codes were not routinely used prior to 1987 so the data for 1984 through 1986 show a number of null entries for that field.

Table 1. Whole-body counts and reason codes shown in the REX database for Rockwell Hanford during 1984 through 1990.

Year	Null	Baseline	Contractor Request	End Assignment	Routine	Special	Termination	Total
1984	2866	0	1	0	0	0	0	2867
1985	2960	1	8	1	1	0	1	2972
1986	1536	274	6	9	833	7	154	2819
1987	0	330	4	0	1025	2	185	1546
1988	0	0	0	0	0	0	0	0
1989	0	1	0	0	0	0	0	1
1990	0	0	0	0	0	0	0	0

Table 2. Whole-body counts and reason codes shown in the REX database for Boeing Computer Services during 1984 through 1990.

Year	Null	Baseline	Contractor Request	End Assignment	Routine	Special	Termination	Total
1984	8	0	0	0	0	0	0	8
1985	11	0	0	0	0	0	0	11
1986	9	0	0	0	3	0	1	13
1987	0	3	0	1	17	0	10	31
1988	0	5	0	0	23	0	4	32
1989	0	41	0	2	93	0	11	147
1990	0	44	0	2	117	0	2	165

Table 3. Whole-body counts and reason codes shown in the REX database for DOE during 1984 through 1990.

Year	Null	Baseline	Contractor Request	End Assignment	Routine	Special	Termination	Total
1984	10	0	0	0	0	0	0	10
1985	2	1	1	0	0	0	0	4
1986	4	0	1	0	0	0	0	5
1987	0	11	1	0	7	0	0	19
1988	0	9	8	0	5	0	0	22
1989	0	33	15	1	32	0	2	83
1990	0	24	285	2	107	0	2	420

Table 4. Whole-body counts and reason codes shown in the REX database for United Nuclear Industries during 1984 through 1990.

Year	Null	Baseline	Contractor Request	End Assignment	Routine	Special	Termination	Contract Work	Total
1984	2545	3	14	3	0	0	0	0	2565
1985	2878	7	19	30	0	0	0	0	2934
1986	1434	207	47	12	849	11	263	6	2829
1987	0	269	81	6	905	1	296	0	1558
1988	0	1	4	0	0	0	0	0	5
1989	0	1	0	0	0	0	0	0	1
1990	0	0	0	0	0	0	0	0	0

Table 5. Whole-body counts and reason codes shown in the REX database for PNL during 1984 through 1990.

Year	Null	Baseline	Contractor Request	End Assignment	Routine	Re-analysis	Special	Termination	Total
1984	1098	0	0	7	0	0	0	0	1105
1985	1062	0	20	7	0	0	0	0	1089
1986	585	97	27	11	262	0	4	73	1059
1987	0	98	25	24	780	0	5	94	1026
1988	0	76	5	5	877	0	4	106	1073
1989	0	186	117	2	949	0	11	123	1388
1990	0	226	30	4	1014	3	16	85	1378

Table 6. Whole-body counts and reason codes shown in the REX database for Westinghouse Hanford Company (pre-consolidation) during 1984 through 1990.

Year	Null	Baseline	Contractor Request	End Assignment	Routine	Special	Termination	Total
1984	886	1	0	0	0	0	0	887
1985	764	0	0	0	0	0	0	764
1986	417	19	1	3	290	0	25	755
1987	0	44	2	4	358	1	6	415
1988	0	0	0	0	0	0	0	0
1989	0	2	0	0	0	0	0	2
1990	0	0	0	0	0	0	0	0

Table 7. Whole-body counts and reason codes shown in the REX database for Westinghouse Hanford Company (post-consolidation) during 1984 through 1990.

Year	Null	Base-line	Contractor Request	End Assignment	Routine	Re-analysis	Special	Termi-nation	Contract Work	Total
1984	0	0	0	0	0	0	0	0	0	0
1985	0	0	0	0	0	0	0	0	0	0
1986	0	0	0	0	0	0	0	0	0	0
1987	1	210	49	5	1955	1	10	398	0	2629
1988	0	239	51	29	3788	0	10	698	0	4815
1989	0	779	169	47	4827	2	13	465	0	6302
1990	0	1141	821	74	5426	7	18	260	1	7748

The data presented in Tables 1 through 7 show that all prime contractors participated in the routine whole-body count program. The relatively fewer numbers of participants for Boeing Computer Services and DOE are expected, given the largely non-radiological nature of their operations.

Tables 8 through 14 show the number of chest counts seen in the REX database for each Hanford site prime contractor from 1984 through 1990. The data are subdivided by reason code, with null entries meaning the reason code was not populated in REX.

Table 8. Chest counts and reason codes shown in the REX database for Rockwell Hanford during 1984 through 1990.

Year	Null	Baseline	Contractor Request	End Assignment	Routine	Special	Termination	Total
1984	500	0	0	0	0	1	0	501
1985	590	0	0	1	0	0	0	591
1986	380	4	1	0	296	22	9	712
1987	0	6	0	0	389	9	14	418
1988	0	0	0	0	0	0	0	0
1989	0	0	0	0	0	0	0	0
1990	0	0	0	0	0	0	0	0

Table 9. Chest counts and reason codes shown in the REX database for Boeing Computer Services during 1984 through 1990.

Year	Null	Baseline	Contractor Request	End Assignment	Routine	Special	Termination	Total
1984	0	0	0	0	0	0	0	0
1985	0	0	0	0	0	0	0	0
1986	0	0	0	0	0	0	0	0
1987	0	0	0	0	2	0	0	2
1988	0	1	0	0	2	0	0	3
1989	0	0	0	0	1	0	0	1
1990	0	0	0	1	0	0	0	1

Table 10. Chest counts and reason codes shown in the REX database for DOE during 1984 through 1990

Year	Null	Baseline	Contractor Request	End Assignment	Routine	Special	Termination	Total
1984	1	0	0	0	0	0	0	1
1985	2	0	0	0	0	0	0	2
1986	0	0	0	0	0	0	0	0
1987	0	0	0	0	0	0	0	0
1988	0	0	0	0	0	0	0	0
1989	0	0	1	0	0	0	0	1
1990	0	3	0	0	0	0	0	3

Table 11. Chest counts and reason codes shown in the REX database for United Nuclear Industries during 1984 through 1990.

Year	Null	Baseline	Contractor Request	End Assignment	Routine	Special	Termination	Total
1984	51	0	0	0	0	0	0	51
1985	117	0	0	0	0	0	0	117
1986	93	2	13	0	64	10	11	193
1987	0	1	3	3	53	1	2	63
1988	0	0	0	0	0	0	0	0
1989	0	0	0	0	0	0	0	0
1990	0	0	0	0	0	0	0	0

Table 12. Chest counts and reason codes shown in the REX database for PNL during 1984 through 1990.

Year	Null	Baseline	Contractor Request	End Assignment	Routine	Re-analysis	Special	Termination	Total
1984	301	0	0	0	0	0	0	0	301
1985	313	0	20	1	0	0	0	1	335
1986	161	12	13	3	88	0	7	8	292
1987	0	27	7	1	227	0	9	4	275
1988	0	9	3	0	178	0	6	8	204
1989	0	55	0	0	233	0	4	21	313
1990	0	27	2	0	263	10	2	13	317

Table 13. Chest counts and reason codes shown in the REX database for Westinghouse Hanford Company (pre-consolidation) during 1984 through 1990.

Year	Null	Baseline	Contractor Request	End Assignment	Routine	Special	Termination	Total
1984	643	0	0	0	0	0	0	643
1985	514	0	0	0	0	0	0	514
1986	267	12	0	0	186	1	16	482
1987	0	8	0	1	226	2	3	240
1988	0	0	0	0	0	0	0	0
1989	0	1	0	0	0	0	0	1
1990	0	0	0	0	0	0	0	0

Table 14. Chest counts and reason codes shown in the REX database for Westinghouse Hanford Company (post-consolidation) during 1984 through 1990.

Year	Null	Baseline	Contractor Request	End Assignment	Routine	Re-analysis	Special	Termination	Total
1984	0	0	0	0	0	0	0	0	0
1985	0	0	0	0	0	0	0	0	0
1986	0	0	0	0	0	0	0	0	0
1987	0	6	5	1	520	0	14	44	590
1988	0	42	4	7	1018	0	21	133	1225
1989	0	139	1	7	1073	0	24	86	1330
1990	0	378	2	24	1387	13	30	51	1885

The chest count data in Tables 8 through 14 show participation by all prime contractors in the routine chest-counting program. The relatively fewer numbers of participants for Boeing Computer Services and DOE are expected, given the largely non-radiological nature of their operations, and the lack of operations involving transuranic materials in particular. The pre- and post-consolidation totals shown for Westinghouse Hanford Company in Tables 13 and 14 are designated in the REX database via different contractor codes. It is unknown why the database shows a baseline count for a Westinghouse worker under the pre-consolidation designation that took place in 1989 (in the post-consolidation era).

Regarding *in-vivo* bioassay results for specific radioisotopes of interest for the SEC issues under consideration during 1984 through 1990, *in-vivo* bioassay data are seen for Th-232 and U-235.

- *In-Vivo* Bioassay Data for Th-232: There are 16 *in-vivo* bioassay results for Th-232 in REX during 1984-1990. Three of those counts were for the same individual: two on September 25, 1986 (an initial count and then apparently a confirmatory count) and a third count on September 30, 1986. The first two counts showed a Th-232 result slightly above the minimum detectable amount (MDA); the third count did not. The first two counts were coded as routine. The follow-up count on September 30 was coded as Special. The results for the three counts were 0.68 nCi, 0.53 nCi, and non-detect with corresponding MDAs of 0.48 nCi, 0.51 nCi, and 0.49 nCi, respectively. The worker was a Rockwell employee with a work location of 272S in the 200 West Area. 272S was a maintenance shop. A second individual associated with the 272S location was chest-counted for Th-232 on October 3, 1986. That count was a Contractor Request. No activity was detected. It is important to note that Th-232 was not routinely reported in *in-vivo* counting results, so the fact it was noted in the initial routine count on September 25, 1986 shows the *in-vivo* bioassay program was indeed sensitive to the presence of unexpected nuclides. Overall, it appears that the initial count results were anomalous and appropriate follow-up measures were taken to verify that no intake had occurred.

  The other 12 *in-vivo* bioassay results for Th-232 in REX for 1984-1990 show a contractor code for PNL but appear to be from counts performed on off-site visitors. All 12 were Contractor Requests for 12 different individuals (i.e., no multiple counts). Five of the counts were performed in September 1985, five were performed in October 1985, and two were performed in March 1986. For all 12 of the individuals, the 1985 and 1986 *in-vivo* bioassay results seen in REX are the only dosimetry data that appear. There are no other internal monitoring entries for those individuals and none at all for external monitoring. The work locations listed for those individuals include National Lead of Ohio and the U.S. Bureau of Mines. All of their Hanford ID codes begin with "V", which is atypical and likely indicates they were visitors. The evidence suggests that the 12 *in-vivo* bioassay results for Th-232 seen in REX for PNL workers during 1984-1990 were, in reality, counts for off-site visitors and not indicative of any Th-232 work taking place at Hanford.

- *In-Vivo* Bioassay Data for U-235: All chest count results in REX for prime contractor employees from 1984 through 1990 include U-235 among the reported isotopes. In addition, there were four entries in REX for prime contractors during 1984 through 1990 where U-235 was associated with a whole-body count. Those results also included Th-234, and three of the four included Am-241. None of the other whole-body count results for those individuals included U-235. None of the results exceeded the reported MDAs, which ranged from 0.1 nCi to 0.61 nCi. Hence, it does not appear that U-235 was reported due to positive indications.

In-Vitro Bioassay Data

In-vitro bioassay results in REX for specific radioisotopes of interest to the SEC issues under consideration during 1984 through 1990 included those for U-235 and Np-237.

- *In-Vitro* Bioassay Data for U-235 and Uranium Isotopic: There are 111 *in-vitro* bioassay results for U-235 in REX for prime contractor workers during 1984-1990. Twenty-seven were for Rockwell employees and the remaining 84 were for PNL employees. All of the analyses for Rockwell workers were Baseline, Contractor Requests, or Special bioassay. None of them was routine. All but one of the U-235 analyses for PNL workers were routine, with the other being a termination assay.

  There were also 32 *in-vitro* bioassay records in REX that included a result for U-233, but they were all associated with uranium isotopic analyses, which show results for all uranium isotopes. Twenty-five of the results were for Rockwell employees and the remaining seven were for PNL workers.

- *In-Vitro* Bioassay Data for Np-237: There are 12 *in-vitro* bioassay records in REX for prime contractor employees from 1984-1990. All of them appear to be associated with a radiological incident that occurred in July 1989. The timing of the incident suggests it was associated with the Multi-Isotope Production Test that is discussed later in this paper under the dose reconstruction feasibility assessment for Issue 9. All 12 were Special bioassay requests for two individuals, six bioassays each. All of the samples that were submitted for analysis were noted as split samples.

  The REX database shows that two urine and four fecal samples were requested from each individual. Each of the individuals provided two urine samples. One individual provided three of the requested fecal samples and the other provided two. The urine samples from the two individuals were provided on July 22 and July 25, 1989.

  The results from the initial urinalyses were negative for one individual and slightly positive for the other. The slightly positive result was 0.03 ± 0.01 nCi with a detection limit of 0.02 nCi. The results from the second set of urine samples collected three days later were negative for the individual whose initial result was slightly positive and positive for the individual whose initial result was non-detect. The positive result was 0.07 ± 0.02 nCi with a detection limit of 0.02 nCi.

All the fecal-sampling results were non-detect relative to a detection limit of 0.1 nCi. The individual whose initial urine result showed slightly positive provided a fecal sample that same day. The individual whose initial urine result was non-detect provided fecal samples the following two days, on July 23 and July 24. Both individuals provided fecal samples on July 26, the day after the second urine samples were collected.

Discussion of Internal Dosimetry Program Practices

Regarding the SEC issues under consideration, a number of observations may be drawn from the internal dosimetry program practices in place at Hanford from 1984 through 1990.

- With respect to specific radioisotopes of interest, no sources of those materials representing a potential for chronic intake were identified by the IDP during that time. Any previously unknown sources of chronic intake would have been apparent in routine bioassay results.
- Appropriate bioassay methods were in place for all ROCs.
- Prime contractors reported incidents of potential internal dose significance to PNL for evaluation. Minor incidents were not of internal dose significance and workplace monitoring was backstopped by the routine bioassay program.
- There was broad participation in the routine *in-vivo* monitoring program across the site prime contractors, particularly those responsible for radiological operations.
- The routine *in-vivo* monitoring program was sensitive to the presence of unexpected radionuclides in monitoring results, such as Th-232.

The absence of routine *in-vitro* bioassay data for radionuclides of concern is due to there being no chronic sources of those materials. Hence, bioassays collected specifically for those materials would imply that an incident had occurred. The *in-vitro* bioassay data for Np-237 from July 1989 are an example of this.

ASSESSMENT OF DOSE RECONSTRUCTION FEASIBILITY FOR EACH ISSUE

This section details the information obtained relevant to each of the SEC issues addressed in this document through the extensive site research activities completed since the approval of SEC-00201. It also provides a corresponding assessment of dose reconstruction feasibility. The information and feasibility determinations are limited in scope to employees of the Hanford site prime contractors only for the period 1984 through 1990. Construction trade workers and site subcontractors are not considered in these discussions or in the determinations of dose reconstruction feasibility.

Issue 3: Thorium-232

Th-232 Sources and Inventories

Throughout 1984 through 1990, the largest inventory of thorium at Hanford was held by PNL in the 306-W Building where earlier operations involving Th-232 are known to have taken place. While the total amount of Th-232 held in the 306-W was large (over 800 kg), site research activities completed to date have not identified any large variances that would be indicative of significant processing. At any given time during 1984 through 1990, the Th-232 held in 306-W Building was roughly 85% of the total Th-232 possessed by PNL. The next-largest inventory was a total of 115 kg of Th-232 associated with spent fuel held in the 324 Building. The inventories held at 306-W and 324 Buildings collectively accounted for approximately 97% of the total Th-232 held by PNL.

Specific information regarding PNL's Th-232 inventory identified in references captured to date include:

- A total of 802.9 kg of Th-232 in the 306-W Building as of January 1985 [Dickman 1985].
- A total inventory of 947.7 kg of Th-232 within PNL as of October 31, 1987. 813.7 kg of that was in 306-W [Battelle 1987-1988a].
- A total inventory of 947.9 kg of Th-232 within PNL as of January 31, 1988. The 306-W inventory was unchanged from October 1987 [Battelle 1987-1988a].
- A total inventory of 945.5 kg of Th-232 within PNL as of September 30, 1988. The 306-W inventory was unchanged from October 1987 [Battelle 1987-1988a].
- A total inventory of 945.5 kg of Th-232 within PNL as of December 31, 1988. This was the same as the total on September 30, 1988 but the total for 306-W had increased by 1.4 kg to 815.1 kg [Battelle 1988-1989]. The increase was due to a furnace tube transferred to 306-W from 308 Building on October 4, 1988 (see below, and [Battelle 1988-1989, PDF p. 203].
- A total inventory of 945.2 kg of Th-232 within PNL as of September 30, 1989. The inventory for 306-W was 804.2 kg, 10.9 kg less than it was at the end of calendar year 1988 due to a transfer to Building 329 [Battelle 1988-1989].
- A total inventory of 945.9 kg of Th-232 within PNL as of January 31, 1990. The inventory in 306-W was unchanged from September 30, 1989 [Battelle 1989-1990].
- A total inventory of 945.2 kg of Th-232 within PNL as of October 29, 1990. The inventory in 306-W was unchanged at 804.2 kg [Battelle 1989-1990].

- A static inventory of 115.3 kg of Th-232 associated with spent fuel held in the 324 Building from October 31, 1987 through October 29, 1990 [Battelle 1987-1988a; Battelle 1988-1989].

- During an interview in June 2017, the former radiological lead for the 308 Building indicated that there might also have been Th-232 present in the 325 Building. That was confirmed from the subsequent review of material control and accountability (MC&A) records from PNL. Specifically, there was an inventory of 10.8 kg of Th-232 in the 325 Building from December 21, 1987 through March 24, 1989 [Battelle 1987; Battelle 1989]. As of April 26, 1988, that amount decreased by 2.1 kg to 8.7 kg [Battelle 1989].

Transactions Involving Thorium

Examples of transfers or other transactions involving thorium from 1984 through 1990 include:

- June 23, 1986: Approval was given to ship sintered tiles containing 492 g of thorium from 306-W to the Chalk River Lab in Canada [Dickman 1986].

- August 1987: A project number change for 200 g of thorium was made "to reflect use on PNL programs." The 200 g of thorium had been obtained from the Westinghouse contract consolidation process [Amacker 1987].

- October 16, 1987: 140 grams of thorium contained in glass was sent from Chemical Systems Analysis in 308 Building to the Engineering Development Laboratory at PNL [Battelle 1987-1988a, PDF p. 256].

- May 3, 1988: It appears that 200 g of thorium was transferred from PNL (325 Building) to Westinghouse Waste Systems Operations in Building 340 [Battelle 1987-1988a].

- October 4, 1988: Transfer of a furnace tube containing 1.4 kg of thorium from 308 Building (Chemical Systems Analysis) to the 306-W Building [Battelle 1988-1989, PDF p. 203].

- April 12, 1989: Glass monoliths (11 bars) containing 3.6 weight-percent thorium oxide were received at 325 Building from NY State Alfred University. The thorium was contained in the glass, which also contained depleted uranium. The items were associated with the West Valley Vitrification Project [Battelle 1988-1989, PDF p. 101].

- August 3, 1989: 10.9 kg of thorium oxide powder was sent from 306-W Building to Chemical Sciences in Building 329 [Battelle 1988-1989, PDF p. 39]. Building 329 was a low-level chemical sciences laboratory so it is doubtful the thorium powder was used in an uncontained manner with regard to facility contamination or potential intakes.

- September 28, 1989: 100 grams of thorium sent from 325 Building to the 224-T waste facility in 200 Area [Battelle 1988-1989, PDF p. 21].

Radiological Occurrence Involving Thorium

In December 1990, a radiological occurrence was documented for the 3720 Building when a "rigorous" radiation survey of several rooms identified contamination "outside of normal containment" in two of them. The contamination was presumed to be legacy Th-232 from historical operations in Building 3720 and was described as "either fixed, inaccessible to normal operations, or of reasonably low levels and presented no safety, health, or environmental concerns." The contamination was found "within the radiation area and in locations not routinely accessed by personnel." Maximum levels were 100,000 dpm beta/gamma and 3,000-dpm alpha [PNL 1988-1991, PDF pp. 429-433].

Th-232 Discussion

The site research actions represented in this document have not identified any processes or operations involving Th-232 at Hanford from 1984 through 1990. In particular, no large-scale operations that would represent a source of chronic intakes have been identified. A review of large volumes of MC&A data provided indications that occasional work involving small amounts of thorium may have taken place within PNL facilities in the 300 Area during 1984 through 1990. However, any such work would have involved small amounts of thorium where the potential for intake, if any, would be associated with radiological incidents. No such incidents have been identified to date, and the [REDACTED] has previously stated he did not recall any intakes or investigations involving thorium taking place [ORAUT 2014b].

Another source of potential Th-232 internal exposure at Hanford during 1984 through 1990 was performing radiological surveys or similar activities in facilities where legacy contamination from past thorium processing was present. A radiological occurrence documented for the 3720 Building in December 1990 serves as an example. In prior submittals to the Hanford WG, the ABRWH contractor stated that exposure potential from such activities was "likely very intermittent" during 1984-1990 and that internal exposure potential from legacy thorium during that time "may have been limited, except where soil or residual matter was disturbed" [SC&A 2011b]. Significant clean-up work did not begin at Hanford until after 1990 and was performed by prime contractors other than those considered within this document. Any thorium present in the soil or residual matter would likely have been commingled with other radioactive materials, notably uranium. If any such work was performed during 1984-1990 it would have been limited in scope and likely would have been performed by individuals already covered by the 83.14 class created by SEC-00226.

As discussed previously, the routine bioassay program, and the routine *in-vivo* monitoring element of that program in particular, served as backstops to workplace monitoring methods for identifying radiological intakes associated with non-chronic sources. The applicability of whole-body counting to detecting otherwise unknown intakes of Th-232 is discussed in Section 5.3.4 of the Hanford site profile [ORAUT 2015]. It should be noted that the Th-232-to-Ac-228 activity ratios provided in the site profile represent recently-separated Th-232 and are, therefore, extremely conservative. In reality, if any intakes of Th-232 occurred at Hanford during

1984-1990, the material would have been many years post-purification and would have contained much more Ac-228 than what was assumed in the site profile. The site profile also assumes a chronic intake.

Th-232 Summary

The likelihood of intakes of Th-232 at Hanford during 1984-1990 appears small and the prior IDP manager did not recall any incidents or exposure concerns involving thorium. If an intake potential existed, any dosimetrically-significant intakes would have resulted from incidents that would have been recognized in the field. Further, as previously discussed, there is an example in the REX database of what appears to be follow-up from a routine chest count where positive Th-232 was indicated. Two subsequent chest counts were performed, and a second individual from the same work location was also counted. Hence, the *in-vivo* bioassay program was sensitive to the presence of unexpected radioisotopes, including those present in background. Any intakes of Th-232 at Hanford during 1984-1990 would have involved aged material, meaning it would have contained ample quantities of gamma-emitting progeny (notably Ac-228 and Pb-212) relative to Th-232.

Site research to investigate the potential for unmonitored intakes of Th-232 by Hanford prime contractor employees during 1984 through 1990 has not identified any information contrary to the determination made in SEC-00201 that dose reconstruction is feasible for those workers during that time.

Issue 4: HEU

HEU Sources from 1984 through 1990

Earlier reviews of MC&A records at Hanford identified what appeared to be potential sources of HEU within 200 Area, and the Plutonium Finishing Plant (PFP) in particular, during 1984 through 1990. Site research activities completed since those earlier MC&A reviews, including numerous interviews with Hanford staff, determined that there were no significant operations involving HEU within the 200 Area. The vaults at PFP were used to store HEU materials on behalf of others, including feedstock for nuclear fuels research at the 308 Building, HEU fuel pins, and an HEU fuel assembly [ORAUT 2017b]. There was no processing of HEU at PFP or the PUREX plant [ORAUT 2017c].

The only HEU sources identified at Hanford during 1984 through 1990 that represented a potential for internal exposure were associated with nuclear fuels research and development (R&D) activities that took place in the 300 Area, and in the 308 Building in particular. Operations in the 308 Building included fabricating nuclear fuel pins from fuel pellets and associated activities, such as welding. It appears that fuel-pin-closure welding operations were performed in a glovebox [Hanford 1988]. Historically, pressing of powders into fuel pellets was also performed in the 308 Building. However, it is unknown if this was done during 1984 through 1990. MC&A data indicated the presence of HEU powders in 308 Building during that time: an assay of a 6 kg supply of 93%-enriched uranium oxide powder was performed in June 1984 [Sherman 1984] and what appear to be additional enriched-uranium powders were noted on an inventory from 1986 [Hanford 1986]. However, no records indicating the use of these materials were identified.

As of the late 1980s, most of the nuclear fuel R&D performed in the 308 Building appears to have been in support of the development of enriched uranium mixed oxide, enriched uranium oxide, and enriched uranium metal fuels for use in fast reactors (in the Fast Flux Test Facility [FFTF] in particular). The mixed oxide fuels are not directly pertinent to this evaluation since the plutonium content would have driven the radiation protection measures and the internal monitoring. However, it should be noted that individuals who worked with plutonium-bearing fuels would have received routine chest counts that were likewise sensitive to U-235.

The uranium enrichments involved in the oxide and metallic fuels assembled in 308 Building during the late 1980s were nominally 38% and 43% (e.g., see [Westinghouse 1988, PDF p. 5; Van Keuren 1989, PDF p. 7]. The metal fuels were 90% uranium and 10% zirconium. The fuel pellets used in the metal fuel pins were manufactured by Argonne National Laboratory - West (ANL-W) [Westinghouse 1988, PDF pp. 5, 11]. Whether ANL-W also made the pellets for enriched uranium oxide fuel is currently unknown. Fuel pellets from Los Alamos were also used in the 308 Building, but these were mixed oxide materials that also contained plutonium (e.g., see [Rasmussen 1989, PDF pp. 4, 31-40].

Following test irradiations, enriched uranium fuels would sometimes be sent to the 327 Building for testing (including destructive testing) in the hot cells there. The likelihood seems remote that an unrecognized intake, consisting solely of enriched uranium, would result from such an operation given the other contaminants (e.g., fission products) that would have been present.

Radiation Protection in the 308 Building

In June 2017, an interview was held with the [REDACTED] for Westinghouse facilities in the 300 Area from [REDACTED]. The individual stated that nuclear materials in the 308 Building included plutonium in addition to uranium, and the building was primarily controlled as an alpha-contaminated facility. Various types of air monitoring were used. The 308 Building was solely a Westinghouse facility (i.e., not shared with PNL). The individual stated that Westinghouse radiological control staff was well aware of the radiological source terms and complexities that existed in the 308 Building environment and their monitoring practices were correspondingly stringent. Workers at 308 Building received routine whole-body and chest counts, *in-vitro* bioassay, and nasal smears when needed. Procedures were in place for responding to incidents, which included sending individuals to PNL for *in-vivo* or wound counting, as required [ORAUT 2017d].

Another interview in July 2013 [ORAUT 2013a] involved several workers from 308 Building who covered a period from the 1970s through the 1980s. The individuals stated that operations in the 308 Building were performed in gloveboxes and that contamination surveys and air monitor testing were performed daily. NIOSH has obtained a collection of radiation work permits that specify requirements for radiological surveys, personnel contamination monitoring, and other radiation protection practices for internal dose control for the various operations performed in the 308 Building [Hanford 1987-1988].

HEU Summary

It is unknown how frequently operations involving enriched uranium took place in 308 Building, but it appears that the only internal exposure potential from HEU would have been associated with radiological incidents. Operations were performed in gloveboxes in what was described as a well-controlled environment that included daily surveys and various types of air monitoring. It seems unlikely that an incident would have gone unrecognized; especially given that 308 Building was considered an alpha facility. Procedures were in place for responding to incidents, including sending individuals for *in-vivo* counting, as needed.

Workers in the 308 Building received routine bioassays including whole-body and chest counting. U-235 was one of the isotopes routinely reported in chest-count results. The presence of transuranic materials in the 308 Building would have meant a rigorous internal monitoring and workplace surveillance program. Appropriate bioassay measures (both *in vivo* and *in vitro*) were available in the event of an incident involving HEU, and any otherwise, unknown intake would have been apparent in the routine chest count.

Site research to investigate the potential for unmonitored intakes of highly-enriched uranium by Hanford prime contractor employees during 1984 through 1990 has not identified any information contrary to the determination made in SEC-00201 that dose reconstruction is feasible for those workers during that time.

Issue 7: U-233

With respect to intake potential, no indications of any sources or usage of U-233 from 1984 through 1990 have been identified to date. A recommendation to the Hanford WG is that this issue be closed would, therefore, seem appropriate.

Issue 9: Np-237

Investigations into possible sources of Np-237 intakes at Hanford during 1984 through 1990 have focused on the following sources:

- Potential exposures associated with the Multi-Isotope Production (MIP) Test performed in the FFTF.
- Potential exposures associated with nuclear waste characterization research.
- Potential exposures at the PUREX plant associated with the side-pocketing of impure neptunium solutions, and from legacy materials in Q Cell.

Each of these potential sources is discussed below.

MIP Test

In May 1989, a short-duration test irradiation known as the MIP test was performed in the FFTF. The test ran for 10.49 effective full-power days starting on May 21, 1989 and ending on June 2, 1989 [Schmittroth ed. 1989]. The primary purposes of the MIP test were: (1) to generate nuclear physics data needed to improve the predictive accuracy of plutonium isotope production in the FFTF; and (2) to demonstrate the production of Pu-238 containing low amounts of the Pu-236 impurity [Rawlins 1988]. The MIP test also served to demonstrate the production of other radioisotopes in the FFTF.

The MIP test involved a single test assembly that contained numerous target materials. Among these were pins and dosimetry targets of neptunium oxide. The assembly contained 15 vanadium capsules each containing 8.5 milligrams of neptunium oxide, for a total of 127.5 mg [Morford 1988]. The neptunium used in the MIP test came from neptunium oxide wire that had been obtained from Oak Ridge National Laboratory in the early 1980s [ORNL 1982]. The wire was installed in the vanadium test capsules at Hanford, presumably in the 308 Building. It appears that the neptunium target fabrication for the MIP test was completed in April 1989 [Rawlins 1989].

Following irradiation, the initial disassembly of the MIP test assembly was performed in the FFTF's Interim Examination and Maintenance (IEM) Cell. The pins were removed in the IEM Cell and sent to the 324 Building. At 324, the dosimeter capsules were removed and sent to the 325 Building for radiochemical analysis. By mid-July 1989, the irradiated test capsules had decayed sufficiently to allow chemical separations and alpha spectrometric analyses [Schmittroth ed. 1989].

Hanford [1990, PDF p. 36] alludes to an incident involving Np-237 that occurred during 1989. The *in-vitro* bioassay data associated with this incident were described earlier in this document. The timing of the incident (the first bioassays were ordered on July 22, 1989) suggests strongly that it was associated with the analysis of the neptunium oxide dosimeter wires from the MIP test. An incident report or other details surrounding the event have not yet been identified.

Nuclear Waste Characterization Research

Dickman [1984] refers to a project to encapsulate 6.1 grams of Np-237 in an inert, simulated nuclear waste glass and to fabricate it into specific shapes and forms. The simulated waste was also to contain depleted uranium, plutonium, and americium. The intent was to distribute the simulated waste material to other national laboratories involved in nuclear waste research. The Np-237 appears to have been located in 325 Building. A Nuclear Material Transaction Report dated October 9, 1984 documents a project number change for the 6.1 grams of Np-237 [Dickman 1984]. A similar transaction involving 0.3 grams of Np-237 in glass took place in

December 1984 [Scott 1984]. That material belonged to the Materials Department in the 308 Building.

The incorporation of Np-237 into a simulated waste glass was part of PNL's role as the Nuclear Waste Materials Characterization Center. It is presently unknown how long that role lasted. Battelle [1987-1988b, PDF p. 52] includes an inventory listing several items of neptunium in glass in Building 3764 as of July 18, 1988.

PUREX Plant

The PUREX plant was shut down in September 1972 and did not resume operation until November 1983. Side-pocketing of low-concentration neptunium solution from back-cycle waste streams in J Cell resumed in 1985 [Bouse and Nichols 1988]. Neptunium followed the uranium product stream in the PUREX process and was present in the waste stream from the final uranium cycle. This stream also contained plutonium and fission products. Neptunium would be separated and concentrated from the uranium waste stream until about 2 kg were present. It would then be sent to Tank J2 for storage. Details of the neptunium separation process carried out in J Cell may be found in the PUREX Neptunium Recovery and Purification Information Manual [Duckworth 1963, PDF pp. 13-20].

As of March 1988, approximately 12.6 kg of neptunium was present in Tank J2 awaiting final disposition [Bouse and Nichols 1988]. This material was a dilute product, containing more than 40 grams per liter of neptunium [Bouse and Nichols 1988, PDF p. 10]. It also contained uranium, plutonium, and fission products [Duckworth 1963, PDF p. 21]. Due to differences in specific activity, even trace quantities of plutonium represented significant alpha activity overall. In September 1992, DOE issued a concurrence with Westinghouse Hanford Company's recommendation that the dilute neptunium solution stored in J Cell be sent to the 200 Area tank farms as waste [Halsted 1992]. The PUREX plant was identified for closure shortly thereafter (in December 1992) [Westinghouse 1995].

Neptunium purification operations (formerly conducted in Q Cell) never resumed after PUREX restarted in 1983. The SRDB includes records showing entries being made into Q Cell in March 1981 to perform activities such as glovebox work and leak repairs [PNL 1981]. It is reasonable to assume such activities may also have taken place during the period 1984-1990, but it seems unlikely such activities would have resulted in unknown intakes of purified Np-237 even if such sources existed.

Several of the Hanford staff interviews completed as part of the site research represented in this document addressed the potential for Np-237 intakes, and radionuclides in general, in the PUREX plant. An interview in July 2013 [ORAUT 2013b] that included the individual responsible for [REDACTED] Np-237 process at PUREX was particularly insightful. He confirmed that the impure neptunium solution in J Cell contained plutonium and other impurities. Respirators were used in Q Cell when bagging equipment in or out of a hood, or during activities with a potential for airborne contamination, and swipe samples were used to determine if respiratory protection was needed. Most glovebox work did not require a respirator. The individual stated that [REDACTED] from his work at PUREX and he would know if anyone else had. He added that internal exposure was a "big deal" and *in-vitro* bioassay samples were collected every six to twelve months. Workers had annual whole-body counts and the few individuals working with neptunium may also have had lung counts, but he could not recall. The individual stated he [REDACTED] from [REDACTED] onward. When there was contamination, they were aware of it and dealt with it. Routine swipe samples were taken in Q Cell and there were continuous air monitors (CAMs) in place. He did not recall any incidents or problems.

Other individuals associated with PUREX were also interviewed. The [REDACTED] stated that supplied-air respiratory protection was used in the Q Cell [ORAUT 2014c]. A former [REDACTED] from PUREX during the 1980s stated that internal monitoring for PUREX workers was primarily *in-vitro* bioassay and chest counts. He was monitored annually. He stated there was never a need to monitor workers for Np-237 during the time he worked at PUREX, and that PUREX workers were essentially monitored internally by default [ORAUT 2017e].

Additional MC&A Reviews

Reviews of MC&A records obtained more recently show varying inventories of Np-237 up to approximately 60 grams in 325 Building during the late 1980s. This instance of Np-237 appears to have been associated with liquid wastes or other similar materials present in the 325 Building in support of its various radiochemical research missions. As such, it would not represent a pure source of Np-237 intake if an intake potential existed. MC&A data often are compiled for a single accountable material, so mixtures are not always apparent. In addition, MC&A data show only accountable materials, not fission products or other radioactive materials, in general, that might also be present.

Np-237 Discussion

- MIP Test: The only internal exposure potential associated with the MIP Test would have been during the post-irradiation chemical separations of the neptunium dosimeters and would have been associated with a radiological incident. The Np-237 incident indicated in the REX database during July 1989 appears to confirm that such an incident did indeed occur. The bioassays associated with that incident are direct evidence of the points emphasized in this document regarding non-chronic sources. The circumstances surrounding the determination that a potential intake of Np-237 occurred are currently unknown, but it appears the affected individuals were referred for internal dosimetry follow-up in accordance with established practices. Appropriate bioassay methods were available and used when needed. The brief discussion of that evaluation in the site services annual report for 1989 indicates that such an incident involving Np-237 had not occurred at Hanford for a long time [Hanford 1990, PDF p. 36].

- Nuclear Waste Characterization Research: Information regarding the incorporation of Np-237 into glass has not been identified beyond the fact it appears those activities if performed at Hanford, may have occurred in the 325 Building. Given the small amounts involved, it is assumed that such operations would have been a batch process. There was no intake potential once the material was incorporated into the glass matrix.

- PUREX: The only potential source of pure Np-237 at PUREX during 1984 through 1990 was legacy contamination in the Q Cell from when PUREX was shut down in 1972. It is unknown if such sources actually existed, but even if they did, the lead individual for neptunium activities at PUREX during 1984 through 1990 was adamant that no such intakes occurred.

Np-237 Summary

With respect to chronic intake potential, there were no significant sources of purified Np-237 at Hanford from 1984 through 1990. Any intakes, therefore, would have been the result of radiological incidents. What little intake potential that existed for purified Np-237 during that time appears to have been limited to infrequent activities involving small quantities within the 300 Area.

An incident involving a potential intake of Np-237 that apparently occurred in July 1989 exemplifies the points raised in this document regarding internal monitoring for non-chronic sources and incident-related intakes. A potential intake was recognized and the affected individuals were referred for internal monitoring. Appropriate bioassay methods were available and used. The brief description of the incident from the Radiation Protection Support Services Annual Report for 1989 suggests that it was the first Np-237-related incident that had occurred at Hanford in a long time [Hanford 1990, PDF p. 36]. The timing of the incident suggests it was associated with chemical separations work for the neptunium dosimeters from the MIP Test.

Site research completed to investigate the potential for unmonitored intakes of purified Np-237 by Hanford prime contractor employees during 1984 through 1990 has not identified any information contrary to the determination made in SEC-00201 that dose reconstruction is feasible for those workers during that time.

Issue 10: Special Tritium Compounds

As it pertains to the period 1984 through 1990, this issue was prompted by a statement in the Hanford site profile that metal tritides were potentially present as part of the Tritium Target Program that began in 1988 [ORAUT 2015, PDF p. 37]. Presumably, this refers to post-irradiation examinations of test assemblies for light water reactor-based tritium production performed by PNL in 300 Area.

NIOSH has not identified any references indicating that dissolving or other post-irradiation examinations of irradiated tritium target rods took place at Hanford during 1984 through 1990. PNL did begin testing of light water reactor-type tritium target rods in 1989, but the initial test irradiation was not completed until December 1990. The irradiation was performed in the Advanced Test Reactor at Idaho National Laboratory beginning in November 1989.

The site research activities represented in this document have not identified any sources of metal tritide exposure at Hanford from 1984 through 1990. Tritium workers were monitored by routine urinalysis. No dose reconstruction infeasibility related to intakes of special tritium compounds has been identified. NIOSH has developed methods for assigning dose from intakes of special tritium compounds if a potential source of such intakes is ever identified [ORAUT 2007]

Issue 20: Skin Contamination at N Reactor

Skin Contamination Evaluation

A formal, mandatory process for documenting skin contamination events at N Reactor was in place long before 1984. As of 1974, this included the use of a standard form to record “the level and exact location of radioactive skin contamination on a person's body” [UNI 1980, PDF p. 389]. The same reference (implementing procedure) stated, “All cases of personnel skin contamination are to be recorded.” A personnel decontamination procedure from 1979 established a limit for beta-gamma contamination of 200 cpm per probe area when using a portable GM survey probe [UNI 1980, PDF p. 535].

UNI [1984a] and UNI [1985a] are collections of skin-contamination survey forms from N Reactor from 1984 and 1985, respectively. A review of these records showed that portal monitors were in use at N Reactor as of January 1984 and appeared to be the means by which many cases of skin contamination were identified. All of the forms reviewed included maximum contamination levels, the instrument used (e.g., “GM”), and an indication (checkbox) if the individual was sent for whole-body counting. Most also included an estimate of how long the contamination had been on the skin. UNI [1988] contains skin-contamination survey forms from N Reactor from calendar-year 1988. Additional collections of these forms exist at Hanford and could be retrieved if necessary.

To augment the review of the skin contamination forms currently in the Site Research Database (SRDB) a review of Hanford claim records was also performed. A total of 2,200 claims that showed Hanford employment from 1984 through 1990 were reviewed to identify those that included skin contamination reports during that period. The review revealed that significant skin contamination cases appear to have been infrequent, and when such cases did occur, the workers were sent for whole-body counting or bioassay sampling. Pisarcik [1985, PDF p. 8] is a November 25, 1985 memo from United Nuclear (prime contractor for N Reactor from 1984 until 1987) documenting guidance for follow-up bioassay via whole-body counting in cases of contamination events where a radiological intake was indicated. A field on the skin-contamination survey form for denoting whether an individual had been sent for whole-body counting was in place by January 1984 (see [UNI 1984a]).

The N Reactor was shut down in 1987 due in part to the Chernobyl nuclear accident in April 1986.

Skin Contamination Summary

Formal monitoring and recording of skin contamination events at N Reactor were in place prior to 1984, including a requirement that all cases of skin contamination be recorded. Portal monitors were in use as of 1984 and appeared to be the means by which many cases of skin contamination were detected. The skin contamination forms included maximum contamination levels and most included an estimate of how long the contamination had been present on the skin. The forms also included a checkbox to denote if an individual had been sent for whole-body counting. Numerous examples of these skin contamination forms are available in the SRDB and include the calendar years 1984 and 1985.

A review of Hanford claim files that included skin-contamination cases from 1984 through 1985 concluded that significant skin contaminations cases appear to have been infrequent, and when such cases did occur, the workers were sent for whole-body counting or bioassay sampling.

Typical skin contamination events do not result in significant dose rates to the skin. However, the information on the individual skin contamination survey forms could be used to estimate a skin dose if desired.

No internal or external dose reconstruction infeasibility associated with insufficient monitoring for skin contamination events at N Reactor has been identified.

Issue 22: Internal Monitoring Associated with Minor Radiological Incidents

As currently stated in the BRS, the question asked by Issue Number 22 is whether sufficient bioassays were taken to account for potential worker internal exposures from minor radiological incidents during 1984-1990. Some history of the evolution of this issue is provided below for context.

Minor Radiological Incidents Background

In 2011, the ABRWH contractor stated, "Individual DOE-supplied claimant records examined contain almost all incidents mentioned in CATIs or in REX database. The REX database is not detailed regarding incidents. No pattern of omitting incidents from personnel records was detected" [SC&A 2011a]. In April 2013, the ABRWH contractor concluded that employees involved in serious incidents were monitored, but added that "it may be worthwhile to review less significant incidents (not rising to the level of formal investigation at B and C) for further insights regarding incidental exposures that may have taken place" [SC&A 2013a]. The ABRWH contractor provided further elaboration in October 2013, stating, "It will be useful to review incident records for 1984-1990 for affected operations and buildings to determine whether event-driven bioassays were taken for potential exposures" [SC&A 2013b].

Minor Radiological Incidents Evaluation

Hanford's guidance to site contractors was to refer employees for internal dosimetry evaluation any time there was an incident or workplace indication that suggested a potential for a radiological intake. In short, the IDP was to be informed any time an intake of radioactive material was suspected based on workplace monitoring data (air sampling, personnel contamination surveys, etc.) or other radiation protection considerations. The review of numerous site references (e.g., the Radiation Protection Support Services Annual Reports and related documents) and discussions with the [REDACTED] (e.g., see [ORAUT 2014b]) provided confidence that the IDP was indeed diligent in evaluating incidents of potential internal exposure when notified. The evaluation of Issue 22, therefore, evolved into a determination of whether the site contractors were likewise diligent in recording and reporting radiological incidents and notifying PNL in cases where a radiological intake was suspected.

As previously noted, the Radiation Protection Support Services Annual Reports contain information such as how many potential internal exposure incidents were identified through workplace monitoring and the nuclides involved. Those discussions indicate that the threshold for radiological incidents of internal dose significance was high in terms of incident severity. Typical workplace radiological occurrences did not reach that threshold.

The site research activities represented in this document include the collection of numerous radiological incident reports and related documents. The SRDB contains numerous examples of such documentation, but the available references are not believed to reflect the entirety of incident reports contained in Hanford's record holdings. In 1988, PNL stated it had compiled "A centralized file of Hanford radiological incidents since 1945" from a search performed to locate as many of such records as possible. Copies or originals of all identified radiological incidents were placed in a chronological file in the records library [Lyon et al. 1989]. In a memo dated February 28, 1989, PNL refers to this collection as the "Hanford Radiological Incident File" [Lyon 1989, PDF p. 24].

A search of the SRDB for the words "incident" and "accident" for the activity period of January 1, 1984 through December 31, 1990 returned 339 individual references. They included radiation occurrence reports, event fact sheets, Off-Normal Condition/Event reports, monthly reports, worker interview notes/communications, the Hanford Radiological Protection Support Services Annual Reports for 1987-2001, copies of Procedure-Radiation Incident Correction Report forms, incident investigation reports, programmatic appraisal reports, and several daily/shift activity logbooks. These files document follow-ups to personnel contaminations, contaminated or potentially-contaminated injuries and wounds, dosimetry issues such as damaged, lost, or forgotten dosimeters, and procedural violations.

PNL [1983-1987] and PNL [1988-1991] are incident files obtained from PNL in early 2019. The incident reports they contain span the period from 1983 through 1991. This collection is not believed to represent the Hanford Radiological Incident File that was compiled in 1988, but serves as an example of incident reporting practices by the site contractors, and demonstrates that

PNL was included on the reports distributions. The reports include contamination events, radiation events, environmental releases, administrative control measure violations, criticality protocol violations, loss-of-source control events, and safety concerns from all of the prime contractors for the major Hanford operating areas. The files include reports for facilities across 100, 200, and 300 Areas, the 1100 Area Central Stores, the FFTF (400 Area), PUREX, Richland Research Complex (RRC), and off-site. From 1984 through 1987, the files contain two incident reports from the 100 Area (N Reactor Area), 19 incident reports related to the 200 Area managed by Rockwell, and 32 incident reports for the 300 Area managed by Westinghouse. Following the consolidation of the management contractors in mid-1987, there were three incident reports located in the 100 Area, 24 in the 200 Area, and 34 in the 300 Area through 1990.

Incidents at N Reactor were typically skin contaminations that were documented on a skin-contamination survey form. An implementing procedure from 1974 mandated that all cases of personnel skin contamination are to be recorded [UNI 1980, PDF p. 389]. Thus, requirements for documenting contamination events at N Reactor were in place long before 1984. UNI [1984a] and UNI [1985a] are collections of skin contamination reports from 100 Area from 1984 and 1985, respectively.

UNI [1985b] is an example of a contractor (United Nuclear) procedure from 1985 for creating Radiation Incident Correction Reports. It includes criteria for determining if a radiation incident has occurred (i.e., it provides a definition of a radiation incident). Distribution was required to appropriate management, to Radiological Engineering, and to the incident file, along with copies of relevant radiation surveys. These reports documented less serious radiological events that were often corrected immediately or nearly so. The corrective action was documented on the report form.

UNI [1984b] contains a collection of United Nuclear radiation occurrence reports from 1984. These forms documented actions taken and explicitly required distribution to "PNL Exposure Records." The information included location, date, site classification, and time of major and minor occurrences. The types of information noted included potential internal and external exposures, violations of dosimetry procedures, and notations where contamination was not successfully removed.

Pisarcik [1985, PDF p. 8] is a November 25, 1985 memo from United Nuclear documenting guidance for follow-up bioassay via whole-body counting in cases of contamination events during which a radiological intake was indicated.

During an interview in June 2017 [ORAUT 2017e], a [REDACTED] from the PUREX plant stated that nasal contamination incidents would not necessarily be recorded in incident reports, but would definitely be documented in radiation monitoring logs. He also stated they did not often send people for follow-up bioassay, and that would have been the only weakness in their program. The same individual stated that workers at PUREX were very skilled and were essentially internally monitored by default. There were no cases of workers who should have been monitored internally but were not. PUREX workers received routine urinalysis and chest counts.

Workers from Building 308 interviewed in July 2013 stated that the occurrence reporting process there was "very formalized" in the 1980s, and formal incident reporting had been implemented in the 1970s [ORAUT 2013a].

Minor Radiological Incidents Summary

A review of pertinent SRDB documents identified numerous documents describing radiological incidents involving personnel intakes and associated internal monitoring measures. Documentation of contractor incident reporting requirements, associated reports, and records were also identified. A combined examination and summary of those documents (i.e., both incident/monitoring reports and documents addressing reporting practices and requirements) showed that incidents were reported to the appropriate radiological protection organizations, including PNL dosimetry services. The variety of incident locations, dates, and causes is indicative of a comprehensive reporting system.

Reviews of the numerous examples of contractor radiological incident reports available in the SRDB show that the prime contractors had systems in place for: (1) recognizing and documenting radiological incidents in the field; (2) following through to further investigate exposures; and (3) revising protocols to prevent reoccurrence when warranted. The documentation included indications (e.g., distribution lists, form instructions, bioassay requests, and procedural guidance) of having been distributed across organizations. Hence, no dose reconstruction infeasibility associated with insufficient attention to internal dose from workplace radiological incidents was identified.

Issue 27: Building 324 Leaks

This is a due diligence item regarding the adequacy and completeness of internal monitoring data for workers who may have been affected by radiochemical-cell leakage incidents that occurred within the 324 Building. It was prompted by the publicity surrounding the late-2009 discovery that the Building 324 hot cells had been leaking highly-radioactive liquids into the underlying soil.

Both prior to and during the SEC period under evaluation (calendar-year 1984 through calendar-year 1990), there were numerous cases of high-level radioactive waste being spilled within radiochemical engineering cell B (B-Cell) in the 324 Building. These included a major spill that occurred in 1986. A significant incident occurred in 1989 when radioactive material leaked from B-Cell due to water being applied to interior surfaces during in-cell decontamination activities. There were earlier leaks under A-Cell and C-Cell.

In 2011, SC&A reported to the Hanford WG that it had conducted interviews and that the health physics coverage at 324 Building was reportedly good. Mixed fission product monitoring data were determined to exist for the mid-1980s when the major B-Cell spill occurred, although data may not exist for some specific radionuclides. SC&A recommended that NIOSH verify that sufficient monitoring data existed for workers affected by radiological incidents at 324 Building SC&A [2011a].

In 2018, the BRS entry for this issue was updated to state, “The adequacy and completeness of monitoring data have been evaluated and determined to be sufficient for dose reconstruction. Documentation of those findings is pending.”

Building 324 Incidents

The focus of the evaluation for Issue 27 is radiological incidents that occurred in 1986 and 1989. Another incident occurred in October 1990 that was not related to the cell leakage concern, but it has been included here for completeness.

Personnel did not enter the radiochemistry cells, so they were not directly affected by spills that occurred within those areas or leakage of those materials through the cell liners to the underlying soil. Such events include a major spill that occurred on October 21, 1986 when an estimated more than one million curies of Cs-137 and Sr-90 leaked to the floor of B-Cell.

The three incidents considered in this evaluation are described below. However, only the first two are germane to the Building 324 radiochemistry cells.

- In March 1986, a contaminated HEPA filter from the B-Cell exhaust system was tipped over during a crane-positioning operation resulting in Cs-137 contamination of the 324 Building truck lock (loading/unloading) facility and adjacent areas [Gray 1986; Gerber 1992, PDF p. 246]. Personnel surveys associated with this incident were reported as “within acceptable limits” [Gray 1986].

- In July 1989, water being used for in-cell decontamination operations within B-Cell leaked through cell penetrations causing significant, high-dose-rate contamination of exterior floor areas in Room 1B. It was reported that “No skin or personal effects contamination occurred” as a result of this incident or during the subsequent recovery process [Jarrett 1990].

- In October 1990, Cs-137 contamination occurred in the Shielded Materials Facility operating gallery when a negative air-pressure system failed during a material transfer operation [Gerber 1992, PDF p. 246; Hikido 1991]. Four individuals received skin contamination as a result of this incident. Two of them were sent to the Emergency Decontamination Facility as a precautionary measure. Three of them were sent for whole-body counts. The *in-vivo* bioassay results were characterized as positive, but low-level [Hikido 1991].

Building 324 Evaluation

Documentation for the first two incidents (March 1986 and July 1989) confirms that workplace monitoring was employed in the radiochemical areas with respect to controlling potential internal exposures. No intakes were indicated and no special bioassays were prescribed. The discussion of the October 1990 incident in the Shielded Materials Facility provides another example of a potential intake being identified through workplace monitoring and the affected individuals being referred for internal dosimetry evaluation.

Operations at the 324 Building involved highly-radioactive materials. Contamination incidents, therefore, involved substantial amounts of radioactivity with respect to detecting or recognizing such events. Contamination of accessible areas within the radiochemical cell section of 324 Building contained high concentrations of Cs-137 and Sr-90, which are key radioisotopes considered in the design of internal monitoring programs for fission-product source terms.

Incident reporting by the Hanford prime contractors has been previously established through the evaluation of Issue 22. It should not be arbitrarily assumed that a process upset (e.g., water leakage) meant that radiological intakes must have occurred and special bioassay was therefore warranted.

Building 324 Summary

Evaluation of pertinent radiological incidents that occurred within the 324 Building did not identify any personnel monitoring deficiencies or indications of unmonitored internal dose. No dose reconstruction infeasibility associated with cell leakage events at 324 Building has been identified for Hanford prime contractor employees from 1984 through 1990.

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ATTACHMENT A: SITE RESEARCH ACTIVITIES AND SYNOPSIS

The evaluations presented in this document reflect extensive site research activities accomplished subsequent to the SEC-00201 ER. Actions to obtain additional information for evaluating Hanford SEC issues for 1984-1990 began in April 2012. Information obtained during the early portion of those activities led to a recognition that the radiological monitoring for certain subcontractors (i.e., employees of other than prime contractors) who performed work at Hanford during 1984 through 1990 was not sufficient for dose reconstruction purposes. Therefore, an 83.14 SEC class was added in 2015 that encompassed Hanford non-prime contractor employees for 1984 through 1990. Site research activities subsequent to the addition of the 83.14 class were accomplished with an emphasis on individual site contractor records so that any differences in the implementation of radiation protection practices across the different contractors were sufficiently considered.

Principally, the site research activities accomplished for the evaluation of Hanford SEC issues for 1984 through 1990 consisted of using available finding-aides to identify and review pertinent records, and conducting interviews with current or former Hanford staff with knowledge of the facilities and/or operations of interest. Pertinent records were initially identified using search terms selected to address the outstanding SEC issues and to identify higher-level, program-related records. Keywords and search terms were then expanded and augmented as new information was obtained. These broad site research actions were augmented with searches and reviews that specifically targeted material control and accountability records for the purpose of foot-printing usage of radioactive materials of concern within specific facilities and programs during the period under evaluation.

A secondary source of information pertinent to the various SEC issues under evaluation was the review of the records identified through the principal sources (i.e., searches of finding-aides, interviews, and reviews of material accountability records). The review of a given set of pertinent records often led to the identification of additional, related records that the initial search terms may not have encompassed. Likewise, in addition to directly-applicable information, personnel interviews often also provided information for subsequent actions, such as additional points of contact, report series to look for, or other information regarding pertinent references. Collectively, record reviews and personnel interviews drove an interrelated and iterative site research process.

Once a sufficient volume of potentially-relevant records was identified, NIOSH and contractor staff would travel to Richland, Washington to physically review the identified material at the DOE facilities there. Appropriately-cleared individuals were used so there were no information access restrictions. Most staff interviews were also conducted in person at DOE facilities in Richland. A total of 19 such site visits were completed between April 2012 and April 2019.

The primary finding-aides used for identifying relevant information via search terms were the existing databases of Hanford records maintained by DOE and the site contractors. PNL's electronic records database was also included. Records identified through these database searches included individual documents, boxes of documents, staff or facility logbooks, and other media such as drawings and photographs. An emphasis was placed on obtaining programmatic information from the individual prime contractors. Such records included radiation work permits, radiation protection procedures, manuals, and other contractor-specific records related to radiation protection programs and practices.

Additional records databases beyond those maintained by Hanford or DOE/RL were also searched for Hanford-related documents. These included databases from the Energy Employees Claimant Assistance Project, the National Nuclear Security Administration, the Journal of Occupational and Environmental Hygiene, the Health Physics Journal (HPJ), the Defense Technical Information Center, DOE OpenNet, DOE OSTI Information Bridge, DOE OSTI SciTech Connect, Google, National Academies Press (NAP), NIOSH, and the NRC Agencywide Document Access and Management (ADAMS). A site visit to DOE headquarters was also made to evaluate high-level material accountability records.

Among the secondary sources of information identified through the Hanford site research activities were other databases containing information of potential interest. A number of these databases were evaluated for their usefulness to the overall site research process. These included databases of waste disposal information, access control systems, and stores of records related to environmental restoration activities.

Interviewees were identified through the review of program records, by searches of personnel records performed by DOE/RL on behalf of NIOSH, and by the interviewees themselves. Interviewees included radiation control technicians and radiation control managers, material control and accountability staff, process engineers, operations supervisors, waste management staff, dosimetry records managers, and dosimetry program managers. An effort was made to identify individuals who worked in those various areas from each of the three principal prime contractors during 1984 through 1987 (i.e., prior to the consolidation of those operations under the single contract with Westinghouse). However, many of the prime-contractor workers simply transitioned over following the consolidation.

Most interviews were performed in person, using cleared individuals and secure locations (if needed) to ensure that any pertinent information could be provided. In many cases, security clearances were reinstated for retired individuals so they could speak freely. Some individuals were interviewed multiple times to obtain additional information as the site research process progressed. Some of these follow-up interviews were conducted via teleconference.

The following pages provide a custom Hanford Data Capture synopsis (Rev 07). This custom synopsis covers documents captured after 2012 that are specific to the period 1984-1990. Since the last Hanford synopsis (Rev 06), a total of 2,039 documents were site-associated to Hanford. Review of these documents identified 650 additions that met the date criteria. This synopsis reflects the research efforts for each source searched and the number of documents uploaded as a result of the data capture effort discussed in this paper.

Table A-1: Custom Data Capture Synopsis for Hanford, 1984 through 1990

Data Capture Information	General Description of Documents Captured	Date Completed	Uploaded to SRDB
Primary Site/Company Name: Hanford DOE, 1942-present Alternate Site Names: Hanford Engineer Works (HEW) Site Contractors (1984-1990): Westinghouse Hanford Company UNC Nuclear Industries Rockwell Hanford Company Battelle Memorial Institute (Pacific Northwest Laboratory) Physical Size of the Site: The full Hanford site is approximately 586 square miles. Site Population: The entire Hanford workforce in September 1990 was nearly 9,000.	Plutonium fecal sampling and internal dose, multi-isotope production tests, irradiated fuel disposition, special nuclear material disposition, tritium production and bioassay, plutonium scrap declarations, hot cell readiness reviews, Cesium-137 and Sr-90 re-encapsulation, requests for material transfers, neptunium production, environmental impact statements, facility descriptions and photographs, the history of the Hanford internal deposition and organ dose lists, whole body and chest counting issues, uranium bioassay, bioassay monitoring programs, in vivo measurement of Th-232, personnel dosimetry annual reports, personnel dosimetry manual, Personnel Dosimetry Advisory Committee meeting minutes, a list of Hanford contractors, 1985 safety and radiation protection statistics, nuclear materials inventories, document retirement listings, material control and accountability codes, construction management, Pacific Northwest Laboratory monthly reports, documented communications, monthly performance and operational reports, proposed change to plutonium excretion function, bioassay of Iodine-125 workers, radiation surveys, radiation incident reports, radiation incident correction reports, skin contamination surveys, routine surveys, assessments, Nuclear Safety audits, ALARA program reports, radiological control reports, ES&H reports, air sample logs and reports, radiological safety appraisals, functional area appraisals, exposure investigations, health physics shift logs, radiation work permits, organizational charts, analytical laboratory operations, whole body counter activities, operational health physics procedures, Tiger Team follow-up findings and closure records, radiation work requirements and permits, procedure manuals, effluent and stack monitoring, radionuclide reports, inventories, journal entries, and source data, enriched uranium reports, special nuclear material reports, curium reports, radiation control protocol and work procedures, neptunium reports, occurrence reports, safety analyses, test descriptions, and the 1987 whole body counting program plan.	04/17/2019	521
Albany Research Center	Radiation survey of radioactive waste shipment.	11/01/2012	1
Battelle Memorial Institute - King Avenue	Sample analyses of plutonium lab and filter bed sand.	01/10/2013	1

Data Capture Information	General Description of Documents Captured	Date Completed	Uploaded to SRDB
DOE Germantown	Hanford Reporting Information System matrix.	08/26/2014	1
Federal Records Center (FRC) - Lee's Summit	PUREX gaseous effluent sampling, monthly and quarterly West Valley Demonstration Project vitrification, waste characterization, nuclear materials reports, an inductively coupled plasma spectroscopy report, and material transfers to Pacific Northwest Laboratory.	06/13/2016	23
Federal Records Center (FRC) - San Bruno	Radiological calibration and bioassay intercomparisons.	07/31/2014	2
Internet - DOE OpenNet	A 1985 request for safeguards and security field support.	05/24/2017	1
Internet - DOE OSTI Information Bridge	Pacific Northwest Laboratory's 1985 manual on the prompt detection of airborne plutonium in the workplace.	12/30/2012	1
Internet - DOE OSTI SciTech Connect	Radiobioassay laboratory procedures, documentation of Hanford wells, Pacific Northwest Laboratory vitrification and spent fuel consolidation research conducted in support of the West Valley Demonstration Project, and nuclear waste treatment annual reports.	07/02/2015	36
Internet - Google	Reports of plutonium/americium incidents, Pacific Northwest Laboratory's characterization of light water reactor spent fuel, and the treatment of West Valley Demonstration Project alkaline waste and sludge wash waters.	12/29/2014	3
Internet - Hanford	Facility radiological characterizations, radiological waste characterization guidance, the management of plutonium contaminated hydraulic fluid, and release 13 of the Environmental Investigations and Site Characterization Manual.	05/30/2018	5
Internet - Hanford Administrative Record/Public Information Repository	The 1990 Health Physics Procedures Manual.	09/25/2017	1
Internet - Hanford Declassified Document Retrieval System (DDRS)	The measurement of Rocky Flats oxides and material transfers from Idaho National Laboratory.	04/02/2015	2
Internet - Health Physics Journal	A uranium lung burden intercomparison.	08/10/2016	1
Internet - National Academies Press (NAP)	Safety issues at the Hanford N Reactor.	01/06/2015	1
Internet - NIOSH	The SEC-00201 Petition Evaluation Report and suggested updates to dose reconstruction and special exposure cohort issues for consideration by the Hanford Work Group.	10/22/2018	2
Internet - NRC Agencywide Document Access and Management (ADAMS)	The work evaluation of the Basalt Waste Isolation Project and waste vitrification and quality assurance meeting minutes.	12/15/2014	2
Kansas City Plant	Monthly intercomparisons of TMA Eberline dosimeters at Pacific Northwest Laboratory.	10/15/2013	2

Data Capture Information	General Description of Documents Captured	Date Completed	Uploaded to SRDB
NIOSH	Hanford SEC-00155 Petition documentation support and interview notes.	07/17/2014	8
Nuclear Regulatory Commission (NRC) Public Document Room	The 1987 radiological survey of the Exxon Centrifuge Test Facility.	09/14/2012	1
ORAU Team	1985 cesium whole body counts, interview notes, documented communications, and ORAU Team technical basis documents.	01/03/2018	33
Oregon State University	In vivo counting of americium-241 in human lungs and lymph nodes.	02/04/2019	1
US Environmental Protection Agency (EPA)	Documentation of Nuclear Metals waste shipments to Hanford.	02/14/2014	1
TOTAL	N/A	N/A	**650**

Table A-2: Databases Searched for Hanford Custom Search, 1984 through 1990

Database/Source	Keywords / Phrases	Hits	Selected
DOE Comprehensive Epidemiologic Data Resource (CEDR) https://apps.orau.gov/cedr/ COMPLETED 05/12/2010	Database search terms and Internet URL are available in the Excel file called "Hanford Rev 07, (Custom 1984-1990) 10-18-19"	0	0
DOE Hanford Declassified Document Retrieval System (DDRS) and Public Reading Room http://reading-room.labworks.org/Catalog/Search.aspx COMPLETED 05/12/2010	Database search terms and Internet URL are available in the Excel file called "Hanford Rev 07, (Custom 1984-1990) 10-18-19"	168	2
DOE Legacy Management Considered Sites https://www.lm.doe.gov/Considered_Sites/Summary/ COMPLETED 05/12/2010	Database search terms and Internet URL are available in the Excel file called "Hanford Rev 07, (Custom 1984-1990) 10-18-19"	0	0
DOE National Nuclear Security Administration (NNSA) - Nevada Site Office https://nnsa.energy.gov/library COMPLETED 05/12/2010	Database search terms and Internet URL are available in the Excel file called "Hanford Rev 07, (Custom 1984-1990) 10-18-19"	0	0
DOE OpenNet http://www.osti.gov/opennet/advanced-search.jsp COMPLETED 05/14/2010	Database search terms and Internet URL are available in the Excel file called "Hanford Rev 07, (Custom 1984-1990) 10-18-19"	23	1

Database/Source	Keywords / Phrases	Hits	Selected
DOE OSTI Energy Citations (phased out by OSTI SciTech) http://www.osti.gov/energycitations/ COMPLETED 05/12/2010	Database search terms and Internet URL are available in the Excel file called “Hanford Rev 07, (Custom 1984-1990) 10-18-19”	288	0
DOE OSTI Information Bridge (phased out by OSTI SciTech) http://www.osti.gov/bridge/advancedsearch.jsp COMPLETED 05/11/2010	Database search terms and Internet URL are available in the Excel file called “Hanford Rev 07, (Custom 1984-1990) 10-18-19”	528	2
DOE OSTI SciTech Connect http://www.osti.gov/scitech/ COMPLETED 04/14/2014	Database search terms and Internet URL are available in the Excel file called “Hanford Rev 07, (Custom 1984-1990) 10-18-19”	1	1
Energy Employees Claimant Assistance Project (EECAP) http://www.eecap.org COMPLETED 03/28/2014	Database search terms and Internet URL are available in the Excel file called “Hanford Rev 07, (Custom 1984-1990) 10-18-19”	23	13
Google http://www.google.com COMPLETED 05/11/2010	Database search terms and Internet URL are available in the Excel file called “Hanford Rev 07, (Custom 1984-1990) 10-18-19”	2,261,772	40
Health Physics Journal http://journals.lww.com/health-physics/pages/default.aspx COMPLETED 08/20/2016	Database search terms and Internet URL are available in the Excel file called “Hanford Rev 07, (Custom 1984-1990) 10-18-19”	1	1
Journal of Occupational and Environmental Health (Taylor Francis Group) http://www.maneyonline.com/loi/oeh COMPLETED 07/20/2010	Database search terms and Internet URL are available in the Excel file called “Hanford Rev 07, (Custom 1984-1990) 10-18-19”	1	0
National Academies Press http://www.nap.edu/ COMPLETED 07/11/2010	Database search terms and Internet URL are available in the Excel file called “Hanford Rev 07, (Custom 1984-1990) 10-18-19”	36	2
NRC ADAMS Reading Room https://adams.nrc.gov/wba/ COMPLETED 06/14/2011	Database search terms and Internet URL are available in the Excel file called “Hanford Rev 07, (Custom 1984-1990) 10-18-19”	8,511	376
United States Army Corps of Engineers (USACE) http://www.usace.army.mil/ COMPLETED 05/12/2010	Database search terms and Internet URL are available in the Excel file called “Hanford Rev 07, (Custom 1984-1990) 10-18-19”	0	0
U.S. Transuranium & Uranium Registries http://www.ustur.wsu.edu/ COMPLETED 05/12/2010	Database search terms and Internet URL are available in the Excel file called “Hanford Rev 07, (Custom 1984-1990) 10-18-19”	0	0