DOE Review Release 11/26/2013

Document Title:	Document Number:	ORAUT-OTIB-0084
Internal Coworker Dosimetry Data for Nuclear Metals, Inc.	Revision:	00
	Effective Date:	11/15/2013
	Type of Document:	OTIB
	Supersedes:	None

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Approval:	Signature on File Matthew G. Arno, Document Owner	Approval Date:	10/29/2013
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Approval:	Signature on File James W. Neton, Associate Director for Science	Approval Date:	11/15/2013

☒ New ☐ Total Rewrite ☐ Revision ☐ Page Change

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PUBLICATION RECORD

EFFECTIVE DATE	REVISION NUMBER	DESCRIPTION
11/15/2013	00	New technical information bulletin to provide internal coworker data for Nuclear Metals, Inc. workers. Incorporates formal internal and NIOSH review comments. Training required: As determined by the Objective Manager. Initiated by Matthew G. Arno.

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ACRONYMS AND ABBREVIATIONS

d	day
DOE	U.S. Department of Energy
dpm	disintegrations per minute
GSD	geometric standard deviation
ICRP	International Commission on Radiological Protection
IMBA	Integrated Modules for Bioassay Analysis
L	liter
m	meter
mg	milligram
mL	milliliter
NIOSH	National Institute for Occupational Safety and Health
NMI	Nuclear Metals, Inc.
ORAU	Oak Ridge Associated Universities
OPOS	one-person, one-sample
pCi	picocurie
TIB	technical information bulletin
U.S.C.	United States Code
µCi	microcurie
µg	microgram
µm	micrometer
§	section or sections

1.0 INTRODUCTION

Technical information bulletins (TIBs) are not official determinations made by the National Institute for Occupational Safety and Health (NIOSH) but are rather general working documents that provide historical background information and guidance to assist in the preparation of dose reconstructions at particular sites or categories of sites. They will be revised in the event additional relevant information is obtained about the affected site(s). TIBs may be used to assist NIOSH staff in the completion of individual dose reconstructions.

In this document the word "facility" is used as a general term for an area, building, or group of buildings that served a specific purpose at a site. It does not necessarily connote an "atomic weapons employer facility" or a "Department of Energy (DOE) facility" as defined in the Energy Employees Occupational Illness Compensation Program Act of 2000 [42 U.S.C. § 7384l(5) and (12)].

2.0 PURPOSE

Some employees at DOE sites were not monitored for potential intakes of radioactive material, or the records of such monitoring are incomplete or unavailable. In such cases, data from monitored coworkers can be used to assign an internal dose to address potential intakes of radioactive material. The purpose of this TIB is to provide monitored coworker information for calculating and assigning occupational internal doses to employees at Nuclear Metals, Inc. (NMI) for whom no or insufficient monitoring records exist.

ORAUT-OTIB-0019, *Analysis of Coworker Bioassay Data for Internal Dose Assignment* (ORAUT 2005), describes the general process used to analyze bioassay data for the assignment of doses to individuals based on coworker results. ORAUT-PLAN-0014, *Coworker Data Exposure Profile Development* (ORAUT 2004), describes the approach and processes to develop reasonable exposure profiles based on available dosimetric information for workers at DOE sites and was used in conjunction with site specific information in ORAUT (2012b).

A statistical analysis of NMI bioassay data was performed according to ORAUT-OTIB-0019 (ORAUT 2005) and ORAUT-PROC-0095, *Generating Summary Statistics for Coworker Bioassay Data* (ORAUT 2006), as well as the statistical methods in ORAUT-RPRT-0053, *Analysis of Stratified Coworker Datasets* (ORAUT 2012a). The results were entered in the Integrated Modules for Bioassay Analysis (IMBA) computer program to obtain intake rates for the assignment of dose distributions.

3.0 DATA OVERVIEW

This section provides information on the general selection characteristics of the data and the methods of analysis. More detailed radionuclide-specific information is provided in Section 4.0.

3.1 BIOASSAY DATA SELECTION

Urinalysis bioassay data were obtained from NMI historical documents (see the Data References listing in the References section). These records contain data from NMI and from analytical laboratories that performed the urinalyses. Ideally, for a given bioassay sample, there would be only one record. However, many instances were noted where a given bioassay result was reported multiple times. Other instances were identified where many names (particularly last names) were spelled incorrectly, either in the original records or during the data entry process. First names were also entered as a combination of initials, full names, and nicknames. The bioassay data records were reviewed by a Project health physicist to exclude duplicates and to uniquely identify the individual for each record. This was necessary both to exclude the duplicates and for further statistical analysis as discussed below. The review was conducted with a combination of professional judgment and "fuzzy matching" techniques. The software package R has a function called "agrep" that searches for approximate matches. This function was applied to each record name. For a single last name, the function computes a distance measure (based on the minimum number of insertions, deletions, and substitutions needed to change one last name into the other) for each of the other last names. The function returns all of the last names that are within a certain distance of the last name of interest. The same technique was used for the first and middle names. After matching using the R code, manual matching was performed, then duplicates were identified and excluded.

Little data is available prior to 1978. In 1978, the amount of bioassay data increased substantially due to a recommendation to increase urinalysis frequency and the receipt of a large contract to supply depleted uranium (ORAUT 2012b). Data from before January 1, 1978, and after December 31, 2000 (the last year with a complete dataset) were not used. Only uranium fluorometric bioassay data were evaluated. Records for other radionuclides or uranium activity data were excluded. Uranium activity data is redundant to fluorometric data for the same samples and therefore excluded. Before the statistical analysis, the data were converted from mass units (µg/L or mg/L) to activity units (pCi/L) using a uranium-specific activity of 0.36 pCi/µg. This specific activity was used because this is the specific activity noted in the NMI bioassay results that were reported both in µg/L and µCi/L. In addition, all sample results were adjusted based on a daily urinary excretion of 1,400 mL to yield data in pCi/d.

The data sources are believed to result in a complete or nearly complete data set for the years evaluated. Any missing data is presumed to be missing at random, permitting statistical analysis of the data. No attempt was made to identify or exclude data based on incidents which may have occurred.

3.2 ANALYSIS

Bioassay data were analyzed by year since there was sufficient data to evaluate it on an annual basis for the time span evaluated. A lognormal distribution was assumed. After log-transforming the data, the 50th and 84th percentiles were determined for each period through the use of the methods described in ORAUT (2012a).

In ORAUT-OTIB-0075, *Use of Claimant Datasets for Coworker Modeling* (ORAUT 2009), arguments were presented to support the practice of treating a claimant dataset as a simple random sample from the population of all monitored workers. One potential issue posed by using a claimant dataset is that the workers who are involved in incidents usually submit more samples than workers who submit only routine (non-incident related) samples. This can skew the results because a small number of workers who are involved in incidents can dominate the claimant sample in a given year through the sheer number of samples and because the samples in the dataset are no longer independent of each other. At NMI, the small population of workers subject to bioassay testing resulted in a similar problem. To compensate for the unequal number of samples from the workers, the "one-person, one-sample" (OPOS) technique was used, where only one result was used for each person for each radionuclide for a given year. The OPOS statistic is calculated using the maximum possible mean methodology in ORAUT-RPRT-0053 (ORAUT 2012a). Table A-1 shows the number of workers with a given number of samples per year for each year evaluated.

For data prior to October 14, 1994, results of 1 µg/L were treated as censored results. Depending on the format of the data source, "<" symbols were not always used, especially for results on computerized printout. This permits consistent treatment of the data.

To permit lognormal fitting, zero values were considered to be censored values that were censored at the smallest positive value in the records for the period being evaluated.

Two high results were excluded from the analysis. One result was inconsistent with other bioassay results for the same individual shortly after the high result, and the second was noted in the records as being an error.

4.0 INTAKE MODELING

This section discusses intake modeling assumptions, intake fitting, and intake materials.

4.1 ASSUMPTIONS

Each result that was used in the intake calculations was assumed to have a normal distribution. A uniform absolute error of 1 was applied to all results to assign the same weight to each result. Because of the nature of work at NMI, intakes could have been chronic or acute. However, a series of acute intakes can be approximated as a chronic intake. Therefore, intakes were assumed to be chronic and to occur through inhalation with a 5-µm activity median aerodynamic diameter particle size distribution.

A specific activity of 0.36 pCi/g, the conversion factor used in the source bioassay records, was used to convert fluorometric data to data in units of activity.

For intake modeling, all uranium activity was assumed to be ^{234}U. This assumption does not affect the fitting of the data for intake determination because all uranium isotopes have the same biokinetic behavior and the isotopes that were considered in this analysis all have long half-lives in relation to the assumed intake period. The International Commission on Radiological Protection (ICRP) Publication 68 dose coefficients (also referred to as dose conversion factors) for ^{234}U are 7% to 31% larger than the dose coefficients for ^{235}U, ^{236}U, and ^{238}U (ICRP 1995). Therefore, the assumption that the intake is 100% ^{234}U provides a result that is favorable to claimants.

4.2 BIOASSAY FITTING

IMBA was used to fit the bioassay results to a series of inhalation intakes. Data for each radionuclide were fit as a series of chronic intakes. The intake assumptions were based on observed patterns in the bioassay data. Periods with constant chronic intake rates were chosen by the selection of periods in which the bioassay results were similar. A new chronic intake period was started if the data indicated a significant sustained change in the bioassay results. By this method, the years were divided into multiple chronic intake periods for each radionuclide (ORAUT 2005).

Because the uranium isotopes that were present at NMI have very long radiological half-lives, and because the material is retained in the body for long periods, excretion results are not independent. For example, an intake in the 1970s could contribute to urinary excretion in the 1990s and later. To avoid potential underestimation of intakes for people who worked at NMI for relatively short periods, each chronic intake was fit independently using only the bioassay results from the single intake period for type S solubility. This method results in an overestimate of intakes for exposures that extended through multiple assumed intake periods. However, these intake rates are to be considered best-estimate intake rates. Only the results in the intake period were selected for use in the fitting of each period. Excluded results are shown in light gray or red in the figures in Attachment A. Included results are dark gray or blue. For type M and F solubility, this approach was not used. The results of the uranium statistical analysis that was used to calculate the intakes are provided in Table A-2.

Uranium Type F: The solid lines in Figures A-1 and A-2 in Attachment A show the fits to the 50th- and 84th-percentile excretion rates, respectively, for type F materials. Table A-3 lists the 50th- and 84th-percentile intake rates that were determined from the uranium urinalysis along with the associated geometric standard deviations (GSDs).

Uranium Type M: The solid lines in Figures A-3 and A-4 in Attachment A show the fits to the 50th- and 84th-percentile excretion rates, respectively, for type M materials. Table A-4 lists the 50th- and 84th-percentile intake rates that were determined from the uranium urinalysis along with the associated GSDs.

Uranium Type S: The solid lines in Figures A-5 to A-10 in Attachment A show the individual fits to the 50th- and 84th-percentile excretion rates, respectively, for type S materials. The same intake periods were applied for both percentiles because the values followed a similar pattern. Figures A-11 and A-12 show the 50th- and 84th-percentile predicted excretion rates, respectively, from all type S intakes. Table A-5 lists the 50th- and 84th-percentile intake rates that were determined from the uranium urinalysis along with the associated GSDs.

5.0 ASSIGNMENT OF INTAKES AND DOSES

This section describes the derived intake rates and provides guidance for assigning doses. For the calculation of doses to individuals from bioassay data, a minimum GSD of 3 has been used to account for biological variation and uncertainty in the models. It was considered inappropriate to assign a value less than 3 for the coworker data. Therefore, a GSD of at least 3 was assigned for each of the intake periods. The original GSDs are provided in the tables for each radionuclide and solubility type in Attachment A. The 95th-percentile values are based on the adjusted GSD for the intake period. For cases in which there is justification that the individual might have had larger intakes than the 50th-percentile intake rates, dose reconstructors should use the 95th-percentile intake rates input into IREP as a constant

Tables 5-1 to 5-3 list the uranium intakes and associated GSDs to be used for each year of potential uranium exposure. The 2000 intake rates can be extended past 2000 as a measure favorable to claimants.

Table 5-1. Type F uranium intake rates (pCi/d).

Start	End	50th percentile	GSD	95th percentile
1/1/1978	12/31/1983	7.83	3.00	47.7
1/1/1984	12/31/1994	3.98	3.00	24.2
1/1/1995	12/31/2000	0.899	3.00	5.48

Table 5-2. Type M uranium intake rates (pCi/d).

Start	End	50th percentile	GSD	95th percentile
1/1/1978	12/31/1983	32.6	3.00	199
1/1/1984	12/31/1994	15.9	3.00	97.0
1/1/1995	12/31/2000	3.26	3.05	20.4

Table 5-3. Type S uranium intake rates (pCi/d).

Start	End	50th percentile	GSD	95th percentile
1/1/1978	12/31/1983	574	3.00	3,497
1/1/1984	12/31/1994	243	3.00	1,479
1/1/1995	12/31/2000	69.7	3.00	425

6.0 ATTRIBUTIONS AND ANNOTATIONS

All information requiring identification was addressed via references integrated into the reference section of this document.

REFERENCES

ICRP (International Commission on Radiological Protection), 1995, *Dose Coefficients for Intakes of Radionuclides by Workers*, Publication 68, Pergamon Press, Oxford, England.

ORAUT (Oak Ridge Associated Universities Team), 2004, *Coworker Data Exposure Profile Development*, ORAUT-PLAN-0014, Rev. 00, Oak Ridge, Tennessee, November 24.

ORAUT (Oak Ridge Associated Universities Team), 2005, *Analysis of Coworker Bioassay Data for Internal Dose Assignment*, ORAUT-OTIB-0019, Rev. 01, Oak Ridge, Tennessee, October 7.

ORAUT (Oak Ridge Associated Universities Team), 2006, *Generating Summary Statistics for Coworker Bioassay Data*, ORAUT-PROC-0095, Rev. 00, Oak Ridge, Tennessee, June 5.

ORAUT (Oak Ridge Associated Universities Team), 2009, *Use of Claimant Datasets for Coworker Modeling*, ORAUT-OTIB-0075, Rev. 00, Oak Ridge, Tennessee, May 25.

ORAUT (Oak Ridge Associated Universities Team), 2012a, *Analysis of Stratified Coworker Datasets*, ORAUT-RPRT-0053, Rev. 01, Oak Ridge, Tennessee, July 16.

ORAUT (Oak Ridge Associated Universities Team), 2012b, *SEC Petition Evaluation Report Petition SEC-00195*, Oak Ridge, Tennessee, August 30.

DATA REFERENCES IN CHRONOLOGICAL ORDER

NMI (Nuclear Metals, Inc.) and Bolton, M. M. Jr., 1959–1982, NMI: collection of “Medical Sample” forms, Concord, Massachusetts; Bolton: collection of untitled letters to NMI, Boston, Massachusetts. [SRDB Ref ID: 26863]

Bolton, M. M. Jr., 1978–1979, collection of untitled letters to Nuclear Metals, Inc., Cambridge, Massachusetts. [SRDB Ref ID: 113312]

Bolton, M. M. Jr., 1980–1981, collection of untitled letters to Nuclear Metals, Inc., Cambridge, Massachusetts. [SRDB Ref ID: 29174]

Kinneman, J. D., 1981, “Evaluation of Bioassay Data,” memorandum to A. W. Grella, U.S. Nuclear Regulatory Commission, Region 1, King of Prussia, Pennsylvania, December 8. [SRDB Ref ID: 107973]

Bolton, M. M. Jr., 1981–1982, collection of untitled letters to Nuclear Metals, Inc., Cambridge, Massachusetts. [SRDB Ref ID: 29175]

NMI (Nuclear Metals, Inc.), 1981–1992, collection of “Urinalysis History Form,” H. P. Form No. 25, and “Personnel Exposure Information Annual Summary,” HP Form No. 36A, Concord, Massachusetts. [SRDB Ref ID: 113397]

Bolton, M. M. Jr., 1982, collection of untitled letters to Nuclear Metals, Inc., Cambridge and Boston, Massachusetts. [SRDB Ref ID: 28443]

Bolton, M. M. Jr., 1983–1984, collection of untitled letters to Nuclear Metals, Inc., Boston, Massachusetts. [SRDB Ref ID: 113271]

Bolton, M. M. Jr., 1983–1984, collection of untitled letters to Nuclear Metals, Inc., Boston, Massachusetts. [SRDB Ref ID: 25074]

Bolton, M. M. Jr., 1984, collection of untitled letters to Nuclear Metals, Inc., Boston, Massachusetts. [SRDB Ref ID: 113213]

NMI (Nuclear Metals, Inc.), 1984, “NMI - Health Physics Urinalysis Data Listing,” Concord, Massachusetts, August 9. [SRDB Ref ID: 113590]

NMI (Nuclear Metals, Inc.), 1984, “NMI - Health Physics Urinalysis Data Listing,” Concord, Massachusetts, August 9. [SRDB Ref ID: 24979]

NMI (Nuclear Metals, Inc.) and Bolton, M. M. Jr., 1984, NMI: collection of “Urine Sample Collection Form,” H.P. Form No. 20, Concord, Massachusetts; Bolton: collection of untitled letters to NMI, Boston, Massachusetts. [SRDB Ref ID: 25075]

NMI (Nuclear Metals, Inc.) and B&G (Bolton and Galanek), 1984–1985, NMI: collection of “Urine Sample Collection Form,” H.P. Form No. 20, Concord, Massachusetts; B&G: untitled letter to D. Allard (NMI), Boston, Massachusetts (B&G), June 28. [SRDB Ref ID: 113211]

NMI (Nuclear Metals, Inc.), 1985, “NMI - Health Physics Urinalysis Data Listing,” January 8. [SRDB Ref ID: 113403]

NMI (Nuclear Metals, Inc.) and Bolton, M. M. Jr., 1985, NMI: collection of Urine Sample Collection Form,” H.P. Form No. 20, Concord, Massachusetts; Bolton: collection of untitled letters to NMI, Boston, Massachusetts. [SRDB Ref ID: 113457]

NMI (Nuclear Metals, Inc.), and Bolton, M. M. Jr., 1985–1986, NMI: collection of “Urine Sample Collection Form,” H.P. Form No. 20, Concord, Massachusetts; Bolton: collection of untitled letters to NMI, Boston, Massachusetts. [SRDB Ref ID: 25006]

NMI (Nuclear Metals, Inc.), 1986, “NMI - Health Physics Urinalysis Data Listing,” Concord, Massachusetts, January 27. [SRDB Ref ID: 25083]

NMI (Nuclear Metals, Inc.) and Bolton, M. M. Jr., 1986–1987, NMI: collection of “Urine Sample Collection Form,” H.P. Form No. 20, Concord, Massachusetts; Bolton: collection of untitled letters to NMI, Boston, Massachusetts. [SRDB Ref ID: 25007]

NMI (Nuclear Metals, Inc.), 1987, collection of “Urine Sample Collection Form,” H.P. Form No. 20, and Fluorometric Laboratory Environmental Sample Analysis Report, Concord, Massachusetts. [SRDB Ref ID: 113217]

NMI (Nuclear Metals, Inc.), 1987, “NMI - Health Physics Urinalysis Data Listing,” Concord, Massachusetts, January 15. [SRDB Ref ID: 25031]

NMI (Nuclear Metals, Inc.), 1987–1988, collection of “Urine Sample Collection Form,” H.P. Form No. 20, and Fluorometric Laboratory Environmental Sample Analysis Report, Concord, Massachusetts. [SRDB Ref ID: 24980]

NMI (Nuclear Metals, Inc.), 1988, “NMI - Health Physics Urinalysis Data Listing,” Concord, Massachusetts, January 20. [SRDB Ref ID: 29147]

NMI (Nuclear Metals, Inc.) and Bolton, M. M. Jr., 1988–1989, NMI: collection of “Urine Sample Collection Form,” H.P. Form No. 20, Concord, Massachusetts; Bolton: collection of untitled letters to NMI, Boston, Massachusetts. [SRDB Ref ID: 113139]

NMI (Nuclear Metals, Inc.) and B&G (Bolton and Galanek), 1988–1989, NMI: collection of “Breathing Zone Air Sample Record,” Health Physics Form 97, and associated memoranda, Concord, Massachusetts; B&G: collection of untitled letters to NMI, Boston, Massachusetts. [SRDB Ref ID: 113252]

NMI (Nuclear Metals, Inc.), and Bolton, M. M. Jr., 1988–1989, NMI: collection of “Urine Sample Collection Form,” H.P. Form No. 20, Concord, Massachusetts; Bolton: collection of untitled letters to NMI, Boston, Massachusetts. [SRDB Ref ID: 24999]

NMI (Nuclear Metals, Inc.), 1989, “NMI - Health Physics Urinalysis Data Listing,” Concord, Massachusetts, January 26. [SRDB Ref ID: 24990]

NMI (Nuclear Metals, Inc.), 1989–1990, collection of “Urine Sample Collection Form,” H.P. Form No. 20, Concord, Massachusetts. [SRDB Ref ID: 26872, p. 3]

NMI (Nuclear Metals, Inc.), 1990, collection of “Urine Sample Collection Form,” H.P. Form No. 20, Concord, Massachusetts. [SRDB Ref ID: 25077]

NMI (Nuclear Metals, Inc.), 1990–1991, collection of “Urine Sample Collection Form,” H.P. Form No. 20, Concord, Massachusetts. [SRDB Ref ID: 25060]

NMI (Nuclear Metals, Inc.), 1991, “NMI - Health Physics Urinalysis Data Listing,” Concord, Massachusetts, January 28. [SRDB Ref ID: 25061]

NMI (Nuclear Metals, Inc.), 1991–1992, collection of “Urine Sample Collection Form,” H.P. Form No. 20, Concord, Massachusetts. [SRDB Ref ID: 25066]

NMI (Nuclear Metals, Inc.) and Bolton, M. M. Jr., 1991–1992, NMI: collection of “Urine Sample Collection Form,” H.P. Form No. 20, Concord, Massachusetts; Bolton: collection of untitled letters to NMI, Boston, Massachusetts. [SRDB Ref ID: 29177]

Vumbaco, F. J., 1992, untitled letter to J. Kinneman (U.S. Atomic Energy Commission), Nuclear Metals, Inc., Concord, Massachusetts, March 10. [SRDB Ref ID: 110113]

NMI (Nuclear Metals, Inc.), 1992, “NMI - Health Physics Urinalysis Data Listing,” Concord, Massachusetts, January 24. [SRDB Ref ID: 29148]

NMI (Nuclear Metals, Inc.), 1992–1993, collection of “Urine Sample Collection Form,” H.P. Form No. 20, Concord, Massachusetts. [SRDB Ref ID: 28590]

NMI (Nuclear Metals, Inc.), 1993, “NMI - Health Physics Urinalysis Data Listing,” Concord, Massachusetts, February 1. [SRDB Ref ID: 29157]

NMI (Nuclear Metals, Inc.), 1994–1995, collection of “Urine Sample Collection Form,” H.P. Form No. 20, Concord, Massachusetts. [SRDB Ref ID: 25068]

NMI (Nuclear Metals, Inc.), 1994–1995, collection of “Bioassay Sample Collection Form,” Health and Safety Form 20, Concord, Massachusetts. [SRDB Ref ID: 29167]

NMI (Nuclear Metals, Inc.), 1995–1996, collection of bioassay records, Concord, Massachusetts. [SRDB Ref ID: 25064]

NMI (Nuclear Metals, Inc.) and VGK (V. G. Khlopin Radium Institute), 1995–1996, NMI: collection of "Bioassay Sample Collection Form," Health and Safety Form 20, Concord, Massachusetts; VGK: collection of "Report of Analytical Results," St. Petersburg, Russia. [SRDB Ref ID: 113449]

NMI (Nuclear Metals, Inc.), 1996, "NMI - Health Physics Urinalysis Data Listing," Concord, Massachusetts, February 8. [SRDB Ref ID: 29165]

NMI (Nuclear Metals, Inc.), 1996, "NMI - Health Physics Urinalysis Data Listing," Concord, Massachusetts, January 9. [SRDB Ref ID: 29166]

VGK (V. G. Khlopin Radium Institute) and NMI (Nuclear Metals, Inc.), 1996, VGK: collection of "Report of Analytical Results," St. Petersburg, Russia; NMI: collection of "Bioassay Sample Collection Form," Health and Safety Form 20, Concord, Massachusetts. [SRDB Ref ID: 29193]

NMI (Nuclear Metals, Inc.), 1996, "NMI - Health Physics Urinalysis Data Listing," Concord, Massachusetts, January 9. [SRDB Ref ID: 113377]

Starmet, 1999–2000, collection of "Bioassay Sample Collection Form," Health and Safety Form 20, and "Report of Chemical Analysis," Concord, Massachusetts, and Barnwell, South Carolina. [SRDB Ref ID: 113421]

Starmet, 1999–2001, collection of bioassay sample reports, Concord, Massachusetts, and Barnwell, South Carolina. [SRDB Ref ID: 113569]

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Table A-1. Worker urinalysis sampling frequency.

# samples per year	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
1	72	14	185	245	256	252	227	271	213	224	208
2	30	1	69	100	83	40	57	86	63	48	31
3	11	0	35	45	42	27	27	27	24	27	16
4	2	0	26	30	21	14	14	10	13	12	14
5	0	0	11	22	24	15	10	9	19	11	5
6	2	0	14	23	12	11	10	7	8	14	8
7	1	0	9	16	15	9	16	12	8	17	13
8	1	0	11	9	22	16	12	3	6	11	11
9	1	0	6	11	19	18	19	6	11	15	9
10	2	1	3	10	35	13	18	8	6	12	20
11	2	0	0	9	52	30	19	17	18	13	22
12	4	0	5	8	72	72	26	27	20	33	47
13	2	0	1	8	51	101	66	47	57	76	54
14	1	0	3	9	41	55	73	49	44	60	47
15	0	0	4	5	25	36	37	46	19	22	24
16	0	0	3	5	35	18	24	11	16	8	5
17	1	1	2	8	26	6	8	16	10	5	9
18	0	0	1	8	5	4	6	7	3	4	2
19	0	1	0	4	10	1	3	5	3	3	3
20	0	0	3	9	5	4	3	2	7	2	0
21	0	0	0	4	4	1	0	2	1	2	1
22	0	0	1	12	3	0	0	2	1	1	0
23	0	0	1	4	0	1	1	0	1	0	0
24	0	0	4	3	2	0	0	1	1	0	1
25	0	0	4	4	0	1	1	1	2	0	0
26+	0	1	16	45	3	2	2	2	9	7	6

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# samples per year	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1990	2000
1	60	201	189	147	11	75	97	117	2	60	53	7
2	12	26	23	76	0	14	11	23	0	21	12	3
3	3	7	5	9	0	4	5	5	0	12	11	1
4	3	28	8	1	0	3	4	4	0	2	4	4
5	1	17	1	4	0	2	2	4	0	0	3	2
6	2	3	2	5	0	7	3	1	0	0	7	1
7	1	7	2	8	0	6	3	2	0	1	2	5
8	1	2	1	14	0	6	0	4	0	1	1	2
9	0	5	5	14	0	3	3	1	0	0	0	2
10	0	5	0	10	0	4	1	5	0	0	5	5
11	0	7	10	12	0	3	8	7	0	0	3	0
12	0	17	28	19	0	6	14	14	0	0	0	0
13	0	67	56	27	0	8	7	10	0	0	0	0
14	0	34	42	21	0	10	7	7	0	0	1	0
15	0	14	15	6	0	6	2	1	0	0	0	0
16	0	12	5	7	0	3	0	1	0	0	0	0
17	0	3	2	1	0	2	2	0	0	0	0	0
18	0	3	2	4	0	0	0	1	0	0	0	0
19	0	2	1	0	0	1	0	0	0	0	0	0
20	0	1	0	0	0	1	0	0	0	0	0	1
21	0	0	0	2	0	0	0	1	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0
23	0	1	0	0	0	0	0	0	0	0	0	0
24	0	2	0	0	0	0	1	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0
26+	0	9	9	2	0	3	3	1	0	0	0	0

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Table A-2. 50th- and 84th-percentile urinary excretion rates of uranium, 1978 to 2000 (pCi/d).

Effective bioassay date	50th percentile	84th percentile	No. of employees
1/1/1979	0.910	6.194	145
7/1/1980	1.777	5.405	417
7/1/1981	3.454	7.729	656
7/1/1982	2.514	4.763	863
7/1/1983	2.038	4.002	747
7/1/1984	1.413	2.717	679
7/1/1985	0.693	1.660	674
7/1/1986	1.549	3.101	583
7/1/1987	1.125	1.928	627
7/1/1988	1.343	2.278	556
7/1/1989	0.812	2.160	83
7/1/1990	1.028	1.777	473
7/1/1991	0.785	1.492	406
1/1/1993	1.323	2.644	390
7/1/1994	1.072	2.829	167
7/1/1995	0.341	0.935	173
7/1/1996	0.283	0.686	209
1/1/1998	0.244	0.801	97
7/1/1999	0.214	0.630	102
7/1/2000	0.287	0.825	33

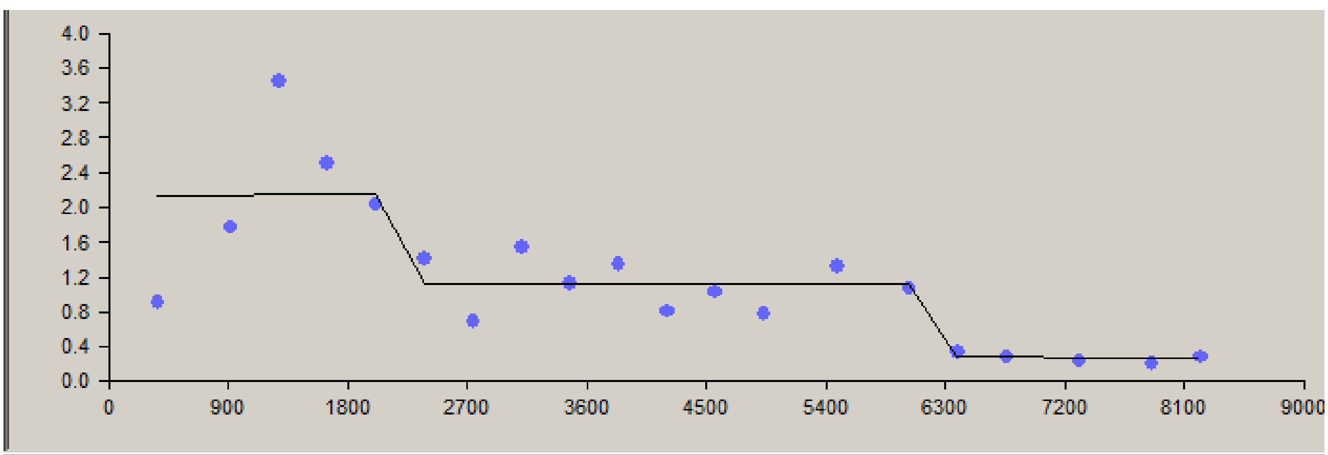

Figure A-1. Predicted uranium bioassay results calculated using IMBA-derived uranium intake rates (line) compared with bioassay results (dots), 50th percentile, all years, type F.

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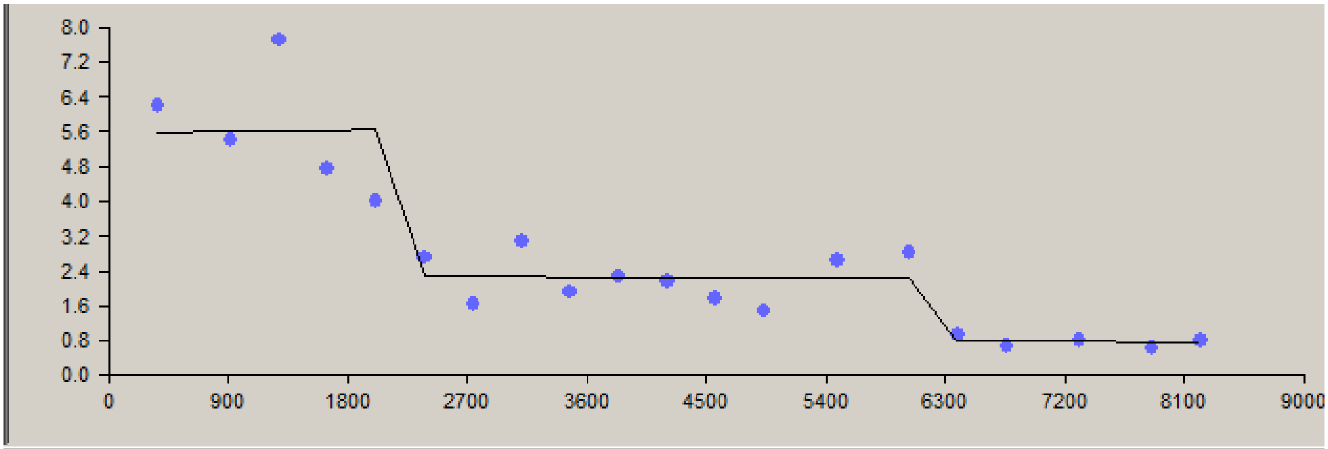

Figure A-2. Predicted uranium bioassay results calculated using IMBA-derived uranium intake rates (line) compared with bioassay results (dots), 84th percentile, all years, type F.

Table A-3. Type F uranium intake modeling results (dpm/d).

Year(s)	50th percentile	84th percentile	GSD	Adj. GSD	95th percentile
1978–1983	7.83	20.5	2.62	3.00	47.7
1984–1994	3.98	8.01	2.02	3.00	24.2
1995–2000	0.899	2.61	2.91	3.00	5.48

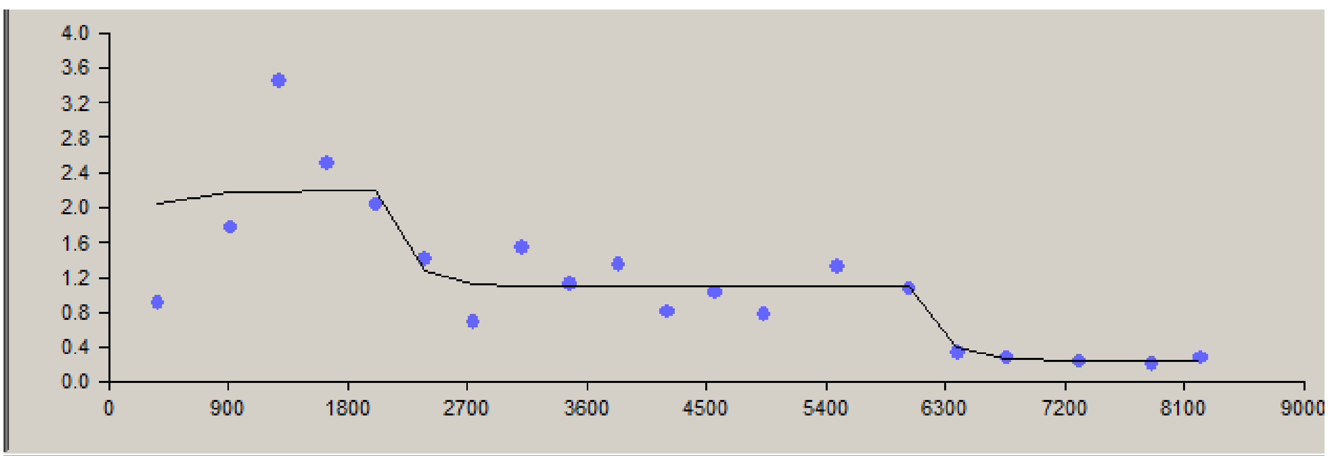

Figure A-3. Predicted uranium bioassay results calculated using IMBA-derived uranium intake rates (line) compared with bioassay results (dots), 50th percentile, all years, type M.

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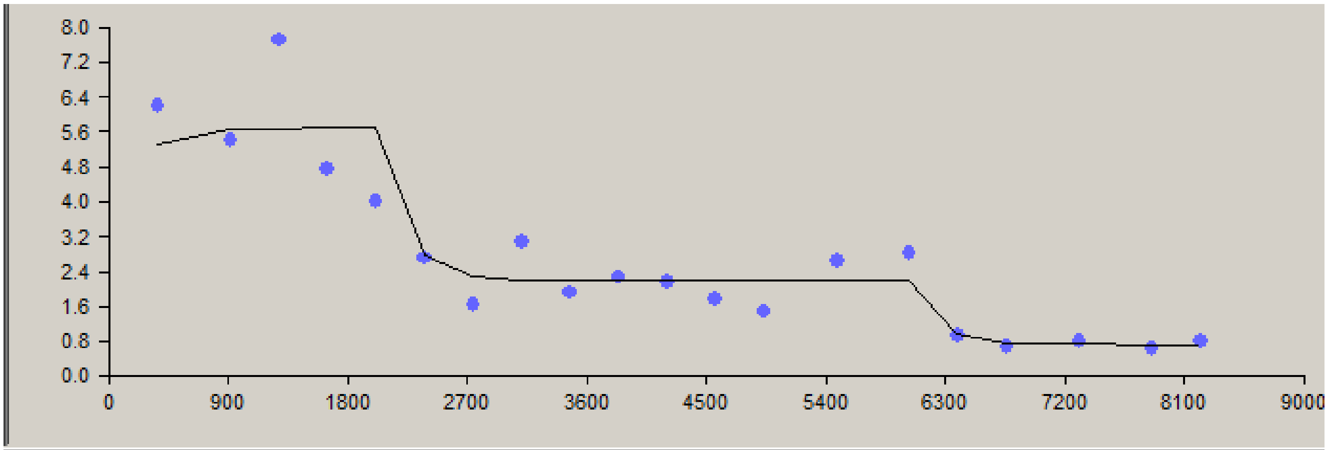

Figure A-4. Predicted uranium bioassay results calculated using IMBA-derived uranium intake rates (line) compared with bioassay results (dots), 84th percentile, all years, type M.

Table A-4. Type M uranium intake modeling results (dpm/d).

Year(s)	50th percentile	84th percentile	GSD	Adj. GSD	95th percentile
1978–1983	32.6	84.6	2.60	3.00	199
1984–1994	15.9	31.8	2.00	3.00	97.0
1995–2000	3.26	9.95	3.05	3.05	20.4

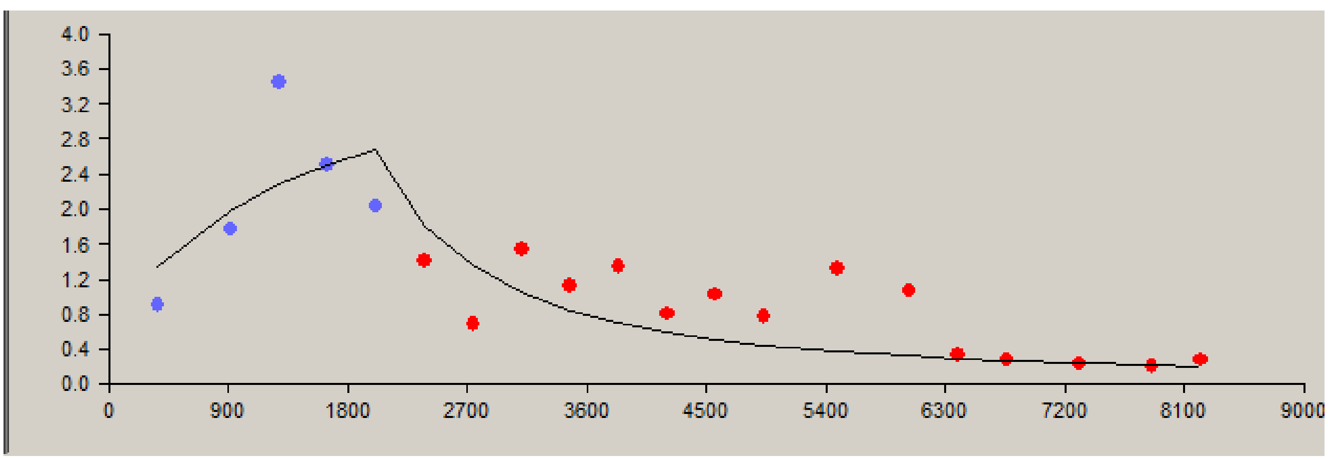

Figure A-5. Predicted uranium bioassay results calculated using IMBA-derived uranium intake rates (line) compared with bioassay results (dots), 50th percentile, 1978–1983, type S.

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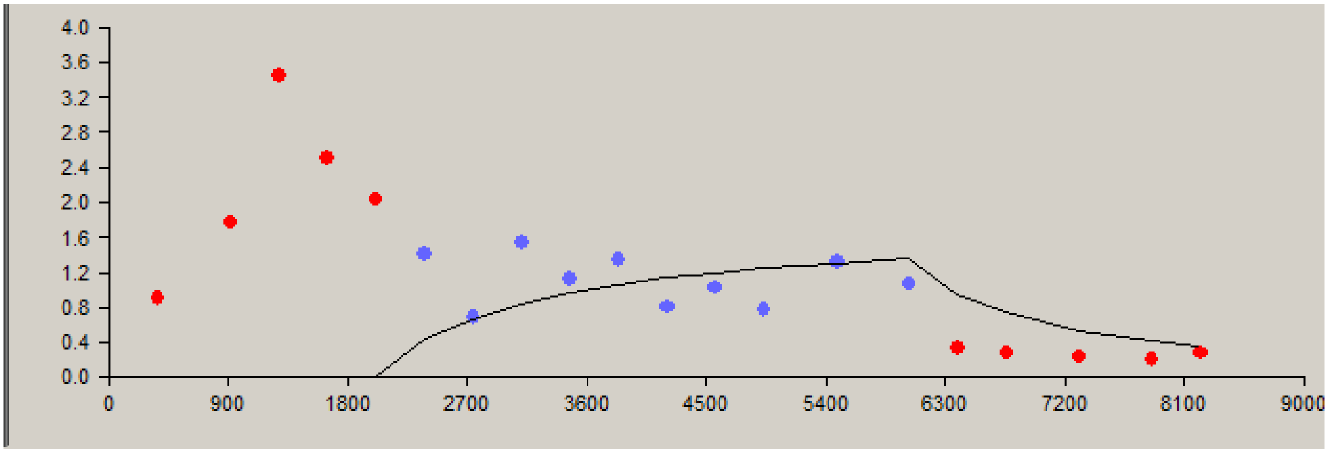

Figure A-6. Predicted uranium bioassay results calculated using IMBA-derived uranium intake rates (line) compared with bioassay results (dots), 50th percentile, 1984–1994, type S.

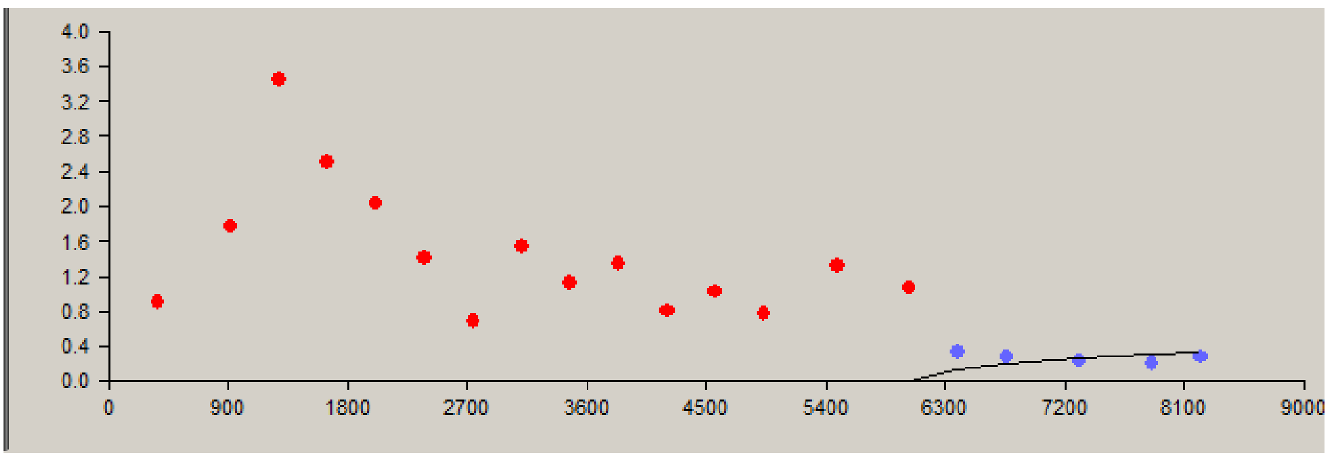

Figure A-7. Predicted uranium bioassay results calculated using IMBA-derived uranium intake rates (line) compared with bioassay results (dots), 50th percentile, 1995–2000, type S.

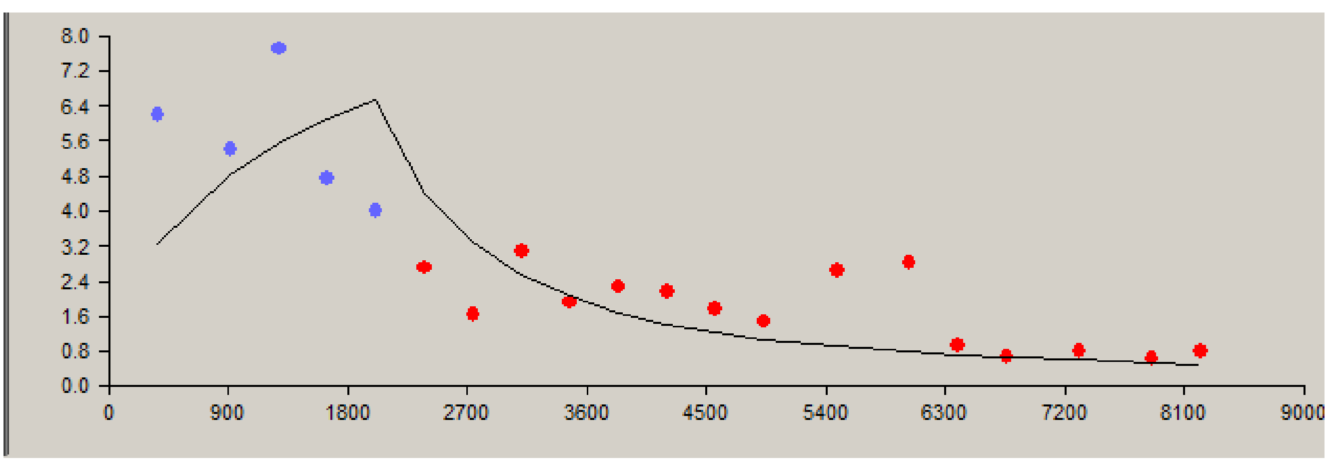

Figure A-8. Predicted uranium bioassay results calculated using IMBA-derived uranium intake rates (line) compared with bioassay results (dots), 84th percentile, 1978–1983, type S.

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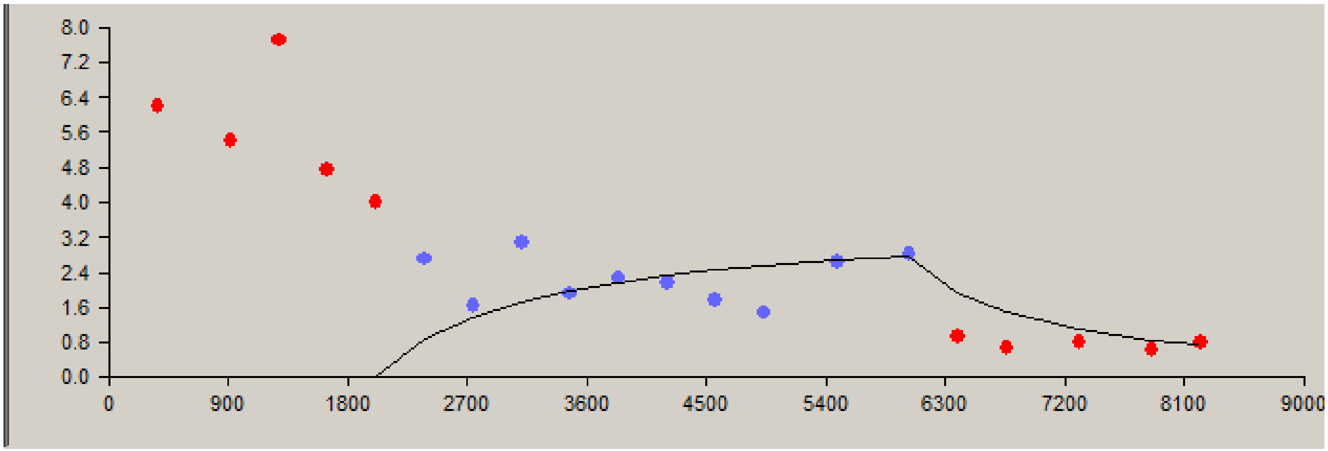

Figure A-9. Predicted uranium bioassay results calculated using IMBA-derived uranium intake rates (line) compared with bioassay results (dots), 84th percentile, 1984–1994, type S.

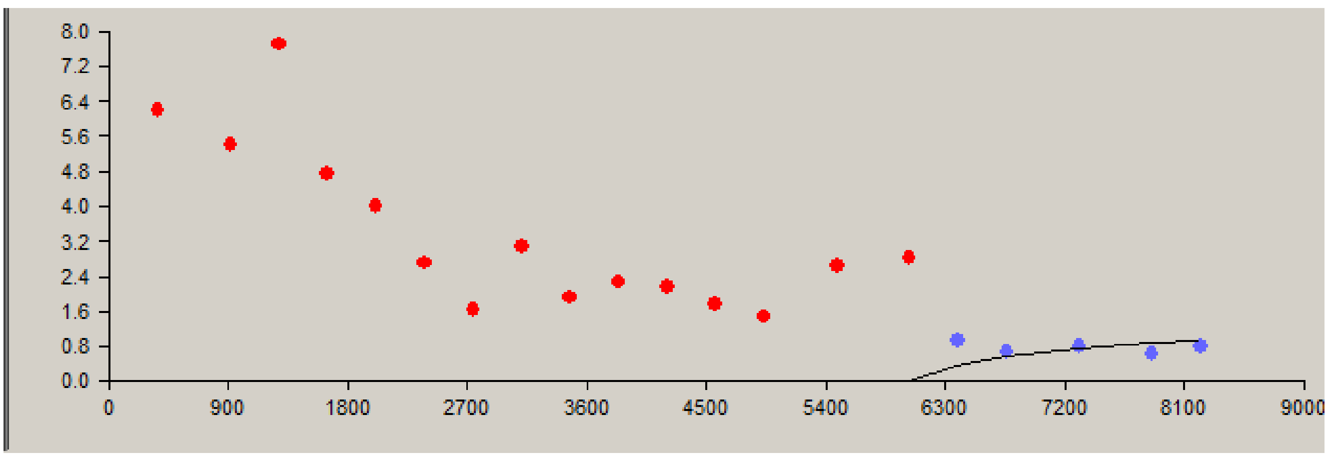

Figure A-10. Predicted uranium bioassay results calculated using IMBA-derived uranium intake rates (line) compared with bioassay results (dots), 84th percentile, 1995–2000, type S.

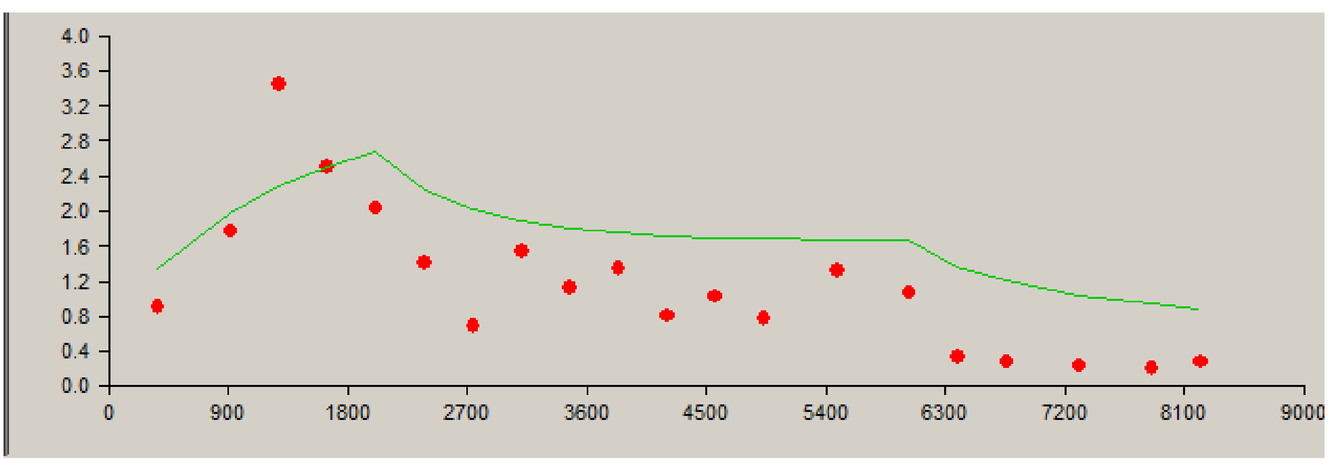

Figure A-11. Predicted uranium bioassay results calculated using IMBA-derived uranium intake rates (line) compared with bioassay results (dots), 50th percentile, all years, type S.

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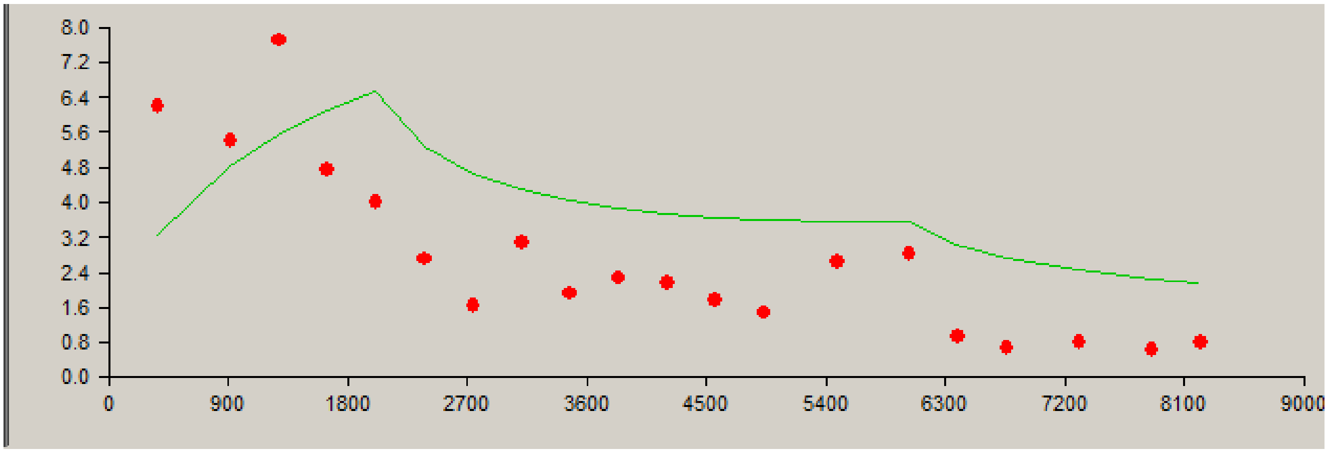

Figure A-12. Predicted uranium bioassay results calculated using IMBA-derived uranium intake rates (line) compared with bioassay results (dots), 84th percentile, all years, type S.

Table A-5. Type S uranium intake modeling results (dpm/d).

Year(s)	50th percentile	84th percentile	GSD	Adj. GSD	95th percentile
1978–1983	574	1,395	2.43	3.00	3,497
1984–1994	243	496	2.04	3.00	1,479
1995–2000	69.7	200	2.88	3.00	425