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PUBLICATION RECORD

EFFECTIVE DATE	REVISION NUMBER	DESCRIPTION
03/14/2014	00	New technical information bulletin to provide internal coworker data for SSFL 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

CEP	Controls for Environmental Pollution, Inc.
d	day
DOE	U.S. Department of Energy
dpm	disintegrations per minute
GM	geometric mean
GSD	geometric standard deviation
ICRP	International Commission on Radiological Protection
IMBA	Integrated Modules for Bioassay Analysis
L	liter
m	meter
MDA	minimum detectable activity
mL	milliliter
NIOSH	National Institute for Occupational Safety and Health
OPOS	one person–one sample
ORAU	Oak Ridge Associated Universities
pCi	picocurie
SRDB Ref ID	Site Research Database Reference Identification (number)
SSFL	Santa Susana Field Laboratory
TIB	technical information bulletin
U.S.C.	United States Code
µCi	microcurie
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)].

Attributions and annotations, indicated by bracketed callouts and used to identify the source, justification, or clarification of the associated information, are presented in Section 6.0.

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 coworker intake data for Area IV of the Santa Susana Field Laboratory (SSFL) and the De Soto Avenue Facility (sometimes referred to as the Energy Technology Engineering Center or Atomics International). This document does not apply to the Canoga Avenue Facility and Downey Facility because their covered periods end before the periods that are addressed in this document.

ORAUT-OTIB-0019, *Analysis of Coworker Bioassay Data for Internal Dose Assignment* (ORAUT 2005), describes the general process for analyzing 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.

The analysis used internal exposure bioassay data from SSFL. A statistical analysis of the data was performed according to ORAUT-OTIB-0019 (ORAUT 2005), its implementing procedure, ORAUT-PROC-0095, *Generating Summary Statistics for Coworker Bioassay Data* (ORAUT 2006), and the statistical methods in ORAUT-RPRT-0053, *Analysis of Stratified Coworker Datasets* (ORAUT 2012). 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 directly from the SSFL in the form of electronic scans of hard-copy bioassay data records. These records contain data from SSFL internal records and records from the analytical laboratories that performed the urinalyses. SSFL received urinalysis data from the laboratories and transcribed that data onto internal forms, which SSFL referred to as "8X11" and "McBee cards." The methods of recording the data differed between the laboratories and SSFL

internal records. In general, data from the laboratories were recorded in a consistent manner with few legibility issues. In the 1960s, the laboratory data were recorded based on the date the sample was received at the laboratory, which was generally within 2 weeks of the sample collection date. The McBee cards and 8X11 forms dated the records based on the sample collection date. In the 1990s and after, the laboratory data appear to use the same date as the McBee cards. The data sources can be divided into two broad categories, laboratory data and facility data, with the facility data consisting of the McBee cards and the 8X11 forms.

The facility data do not contain as much information as the laboratory data. Many positive results were indicated as a "+" with no value. Data indicating less than the minimum detectable activity (MDA) were recorded either as a zero (earlier years) or as being less than a generic MDA. In contrast, the laboratory data report the positive values and commonly report MDAs.

Ideally, for a given bioassay sample, there should be both a laboratory record and a facility record that provide the results of the analysis. However, this is not always the case. In addition, it is not possible to establish a 100%-certain one-to-one correlation between facility and laboratory data. It is possible, especially with reported positive results in the facility data, to individually correlate records by hand based on professional judgment. Examination of the different data sources does reveal that neither source can be considered complete. There are laboratory data for which no facility data can be found and vice versa. This is most easily demonstrated by observed instances where a given tracking number (a unique number for an individual) appears only in one of the data sources for a given year. Therefore both data sources were used with identified duplicates excluded as discussed below.

For most of the 1960s, both data sources are available and the number of records from each source is comparable. Only facility data are available for February 14, 1968, through July 19, 1989. From July 20, 1989, forward, there are more laboratory data available than facility data.

The sample receipt date on the laboratory data form is usually a few days after the sample collection date on the facility form. The bioassay data records were reviewed by a Project health physicist and in those instances where a reasonable correlation between the facility data and the laboratory data could be made, the facility data was excluded as duplicate, especially because the facility data typically contain less detail about a given sample.

During the review, multiple results from the same date (based on sample collection date) with the same result or where a zero and a less-than result were reported were excluded to remove duplicates and leave only one result for statistical analysis. In addition, questionable reported activity units were encountered, such as results in units of µCi/L when pCi/L would be consistent with contemporaneous data or dpm/mL instead of dpm/sample. The reported units were altered to be consistent with the contemporaneous reporting units. As part of this, results marked as "ND," "NDA," or "Neg" were set to zero, illegible results were excluded, and the date the sample was received by the laboratory was used as the sample date if no sample date was available.

Data from before January 1, 1965 (the end of the Special Exposure Cohort period) or after December 31, 2005 (the last year with a complete dataset) were not used. Other records were excluded from the analysis for the following reasons:

- Results with volume or mass units of grams were assumed to be fecal samples.
- Controls for Environmental Pollution, Inc. (CEP)-derived data, including all data from August 4, 1991, through June 1, 1993, and on June 20, 1993, were suspect due to quality issues with the laboratory. This period encompasses all CEP-derived data.
- Data with a blank or "?" for analysis type were not usable.

Some of the records have individual fields that are blank or illegible but contain sufficient information to proceed with the analysis. The following rules were used to adjust for blank or unusable fields [1]:

- Volumes were assumed to be 1,500 mL, and
- Units were assumed to be dpm/sample.

In addition, all sample results were adjusted from a daily urinary excretion of 1,500 mL to 1,400 mL.

3.2 ANALYSIS

Bioassay data were analyzed by year or multiyear span depending on the amount of data available for each radionuclide during a given period and the expected biokinetics of each radionuclide. 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-RPRT-0053 (ORAUT 2012).

In ORAUT-OTIB-0075, *Use of Claimant Datasets for Coworker Modeling* (ORAUT 2009), arguments are presented to support the practice of treating a claimant dataset as a simple random sample from the population of all monitored workers. A potential problem in using a claimant dataset is that the workers who were involved in incidents usually submitted more samples than workers who submitted only routine (not incident-related) samples. This is problematic because a small number of workers who were 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. To compensate for the unequal number of samples from the workers, the one person–one sample (OPOS) technique was used, in which only one result is used for each person for each radionuclide for a given year. The OPOS statistic was calculated using the maximum possible mean methodology in ORAUT (2012).

3.3 PLUTONIUM

Two analytical techniques were used for plutonium bioassay – autoradiography (labeled “PUA”) and gas-flow proportional counting (labeled “PUB”). The two techniques were distinguished beginning in 1974. Previous results were only indicated as “PU,” which was presumed to be indicative of autoradiography based on the earlier use of this procedure. It was assumed the A and B designations were added with the introduction of the gas-flow proportional counting procedure. Analysis type designations that were used for this study were “PUA” (autoradiography), “PU,” and “Pu” (unknown analytical technique, presumed to be autoradiography). No results were identified with an analysis type of “PUB.” Sufficient bioassay data were available to perform a statistical analysis for 1965 through 1986. Although plutonium bioassay data are available through 1994, there were insufficient data to perform a statistical analysis after 1986.

3.4 URANIUM

Uranium data are presented as fluorometric (mass) and radiometric (activity) results. Samples analyzed fluorometrically were also analyzed radiometrically. Only the data that were reported in activity units were used. The analysis type designation that was used was “UR.” Sufficient bioassay data were available to perform a statistical analysis for 1965 through 1988. Although uranium bioassay data are available through 1993, there were insufficient data to perform a statistical analysis after 1988.

3.5 FISSION PRODUCTS

Beta emitter bioassay data were used to represent mixed fission products. These bioassay data should be evaluated in accordance with the latest revision of ORAUT-OTIB-0054, *Fission and Activation Product Assignment for Internal Dose-Related Gross Beta and Gross Gamma Analyses* (ORAUT 2014) and, specifically, the data should be considered to be chemically processed beta samples in accordance with Table 7-2 of that document. This is consistent with some of the analytical techniques that were used by SSFL or is favorable to claimants for the other analytical techniques that were used by SSFL. Because data from the different techniques were merged for analysis, the categorization of the different analytical techniques most favorable to claimants was used for application of ORAUT-OTIB-0054.

The analysis type designations that were used were "MFP" (mixed fission product, chemical separation of alkaline earths and rare earths including strontium) if the method type was "B" for beta counting (which excludes gamma-counting data), "MFPB," and "MFP(B)," and "FP" if the method type was "3A" (mixed fission products less cesium and volatiles, assumed to indicate strontium). Sufficient bioassay data were available to perform a statistical analysis for 1965 through 1991. Although fission product bioassay data is available through 1993, there was insufficient data to perform a statistical analysis after 1991.

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, assigning the same weight to each result. Because of the nature of work at SSFL, 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.

For intake modeling, all plutonium activity was assumed to be ^{239}Pu. This assumption did not affect the fitting of the data for intake determination because all plutonium isotopes have the same biokinetic behavior and the isotopes this analysis considered all have long half-lives in relation to the assumed intake period.

For intake modeling, all uranium activity was assumed to be ^{234}U. This assumption did not affect the fitting of the data for intake determination because all uranium isotopes have the same biokinetic behavior and the isotopes this analysis considered all have long half-lives in relation to the assumed intake period. 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 was 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 and sustained change in the bioassay results. By this method, the years were divided into multiple chronic intake periods for each radionuclide.

4.3 PLUTONIUM

Because the plutonium isotopes at SSFL 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 1960s could contribute to urinary excretion in the 1980s and later. To avoid potential underestimation of intakes for people who worked at SSFL for relatively short periods, each chronic intake was fit independently using only the bioassay results from the single intake period for types M and S solubility. This method resulted in an overestimate of intakes for exposures that extended through multiple assumed intake periods; however, these intake rates are to be considered best estimates. Only the results in the intake period were selected for use in the fitting for each period. Excluded results are shown in light gray or red in the figures in Attachment A. Included results are dark gray or blue. The results of the plutonium statistical analysis that was used to calculate the intakes are provided in Table A-1.

Insufficient bioassay data were available for 1965 and 1966 to perform a statistical analysis. The Nuclear Materials development facility began operation in 1967, which led to an increase in potential plutonium exposure and therefore plutonium urinalysis data. The 1967-to-1968 data was used to back-extrapolate for 1965 and 1966, when the potential plutonium exposure was less. This assumption is favorable to claimants.

Plutonium Type M: The solid lines in Figures A-1 to A-4 in Attachment A show the individual fits to the 50th- and 84th-percentile excretion rates, respectively, for type M materials. Figures A-5 and A-6 show the predicted 50th- and 84th-percentile excretion rates, respectively, from all type M intakes. Table A-4 lists the 50th- and 84th-percentile intake rates determined from statistical analysis of the plutonium urinalysis data along with the associated geometric standard deviations (GSDs).

Plutonium Type S: The solid lines in Figures A-7 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 predicted 50th- and 84th-percentile excretion rates, respectively, from all type S intakes. Table A-5 lists the 50th- and 84th-percentile intake rates determined from statistical analysis of the plutonium urinalysis data along with the associated GSDs.

4.4 URANIUM

Because the uranium isotopes at SSFL 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 1950s could contribute to urinary excretion in the 1980s and later. To avoid potential underestimation of intakes for people who worked at SSFL 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 estimates. Only the results in the intake period were selected for use in the fitting for 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 types M and F solubility, this approach was not used. In 1974, the excretion rates from the statistical analysis were inconsistent with the contemporaneous years and were excluded to be favorable to claimants. In 1984 and 1985, the results are zero (statistical analysis not possible) and were similarly excluded. 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-13 and A-14 in Attachment A show the fit to the 50th- and 84th-percentile excretion rates, respectively, for type F materials. Table A-6 lists the 50th- and 84th-percentile intake rates determined from statistical analysis of the uranium urinalysis data along with the associated GSDs.

Uranium Type M: The solid lines in Figures A-15 and A-16 in Attachment A show the fit to the 50th- and 84th-percentile excretion rates, respectively, for type M materials. Table A-7 lists the 50th- and 84th-percentile intake rates determined from statistical analysis of the uranium urinalysis data along with the associated GSDs.

Uranium Type S: The solid lines in Figures A-17 to A-24 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-25 and A-26 show the 50th- and 84th-percentile predicted excretion rates, respectively, from all type S intakes. Table A-8 lists the 50th- and 84th-percentile intake rates determined from statistical analysis of the uranium urinalysis along with the associated GSDs.

4.5 FISSION PRODUCTS

The fission product bioassay data is a beta emitter analysis and was assumed to be ^{90}Sr for the purposes of intake modeling. The results of the statistical analysis of fission product bioassay data that were used to calculate the intakes are provided in Table A-3. The solid lines in Figures A-27 and A-28 in Attachment A show the individual fits to the 50th- and 84th-percentile excretion rates, respectively, from all type F intakes. Table A-9 lists the 50th- and 84th-percentile intake rates the determined from statistical analysis of the beta-emitter urinalysis data 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 was 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 95th-percentile values were 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. The original GSDs are provided in the tables for each radionuclide and solubility type in Attachment A.

The following subsections list the intake rates that should be used for each radionuclide and the period of applicability of each intake rate.

5.1 PLUTONIUM

Tables 5-1 and 5-2 list the plutonium intakes and associated GSDs to be used for each year of potential plutonium exposure. All data derive from urinalysis bioassay results and should be treated as plutonium gross alpha intakes, which can be considered to be 100% ^{239}Pu. If evaluation of Type Super S solubility is necessary, ORAUT-OTIB-0049, *Estimating Doses for Plutonium Strongly Retained in the Lung* (ORAUT 2010a), should be applied accordingly. The 1986 intake rates can be extended past 1986 as a measure favorable to claimants.

Table 5-1. Type M plutonium gross alpha intake rates (dpm/d).

Start	End	50th percentile	GSD	95th percentile
1/1/1965	12/31/1968	13.12	5.15	195
1/1/1969	12/31/1986	3.018	3.00	18.4

Table 5-2. Type S plutonium gross alpha intake rates (dpm/d).

Start	End	50th percentile	GSD	95th percentile
1/1/1965	12/31/1968	329	5.15	4,880
1/1/1969	12/31/1986	41.62	3.00	254

5.2 URANIUM

Tables 5-3 to 5-5 list the uranium intakes and associated GSDs to be used for each year of potential uranium exposure. The 1988 intake rates can be extended past 1988 as a measure favorable to claimants.

Table 5-3. Type F uranium intake rates (dpm/d).

Start	End	50th percentile	GSD	95th percentile
1/1/1965	12/31/1968	17.6	3.00	107
1/1/1969	12/31/1972	8.91	3.00	54.3
1/1/1973	12/31/1979	18.87	3.00	115
1/1/1980	12/31/1988	5.666	3.00	34.5

Table 5-4. Type M uranium intake rates (dpm/d).

Start	End	50th percentile	GSD	95th percentile
1/1/1965	12/31/1968	75.91	3.00	463
1/1/1969	12/31/1972	34.92	3.00	213
1/1/1973	12/31/1979	78.02	3.00	475
1/1/1980	12/31/1988	21.92	3.00	134

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

Start	End	50th percentile	GSD	95th percentile
1/1/1965	12/31/1968	1,592	3.00	9,701
1/1/1969	12/31/1972	744.4	3.00	4,536
1/1/1973	12/31/1979	1,266	3.00	7,714
1/1/1980	12/31/1988	389	3.00	2,370

5.3 MIXED FISSION PRODUCTS

Intake rates in Table 5-6 were calculated from the fission product urine sample results, assuming a ^{90}Sr biokinetic model. Because the urine results were based on gross activity analyses, a number of mixed fission products were included in the analysis; therefore, these intake rates must be adjusted to account for the fraction of activity attributable to ^{90}Sr. The intake rates should be treated as samples following major chemical processing. The resulting intake rates should then be used to assign intakes for all mixed fission products in accordance with ORAUT-OTIB-0054 (ORAUT 2014). The 1991 intake rate can be extended past 1991 as a measure favorable to claimants.

Table 5-6. Unadjusted Type F ^{90}Sr intake rates (dpm/d) based on mixed fission product bioassay.

Start	End	50th percentile	GSD	95th percentile
1/1/1965	12/31/1991	61.05	3.00	372

6.0 ATTRIBUTIONS AND ANNOTATIONS

Where appropriate in this document, bracketed callouts have been inserted to indicate information, conclusions, and recommendations provided to assist in the process of worker dose reconstruction. These callouts are listed here in the Attributions and Annotations section, with information to identify the source and justification for each associated item. Conventional References, which are provided in the next section of this document, link data, quotations, and other information to documents available for review on the Project's Site Research Database (SRDB).

[1] Arno, Matthew. ORAU Team. Dose Reconstructor. January 21, 2011.
These rules were developed based on examination of the data for trends in how the data was recorded, review of the internal dose technical basis document for SSFL (ORAUT 2010b) to determine default, and/or assumed analytical techniques and reporting conventions.

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ICRP (International Commission on Radiological Protection), 1995, *Dose Coefficients for Intakes of Radionuclides by Workers*, Publication 68, Pergamon Press, Oxford, England. [SRDB Ref ID: 22731]

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

ORAUT (Oak Ridge Associated Universities Team), 2014, *Fission and Activation Product Assignment for Internal Dose-Related Gross Beta and Gross Gamma Analyses*, ORAUT-OTIB-0054, Rev. 02, Oak Ridge, Tennessee, March 6.

ATTACHMENT A
COWORKER DATA FIGURES
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Table A-1. 50th- and 84th-percentile urinary excretion rates of plutonium gross alpha, 1968 to 1986 (dpm/d).

Effective bioassay date	50th percentile	84th percentile	No. of employees
1/1/1968	0.064	0.328	34
1/1/1970	0.026	0.097	31
1/1/1974	0.013	0.040	28
1/1/1976	0.037	0.049	48
1/1/1980	0.022	0.034	30
1/1/1984	0.040	0.053	48
1/1/1986	0.020	0.031	53

Table A-2. 50th- and 84th-percentile urinary excretion rates of uranium gross alpha, 1965 to 1988 (dpm/d).

Effective bioassay date	50th percentile	84th percentile	No. of employees
7/1/1965	2.90	8.33	470
7/1/1966	4.52	10.83	298
7/1/1967	5.47	14.69	338
7/1/1968	6.22	14.05	269
7/1/1969	2.50	8.60	153
7/1/1970	3.41	7.79	164
7/1/1971	2.35	5.09	135
7/1/1972	1.68	5.67	122
7/1/1973	4.99	7.09	88
7/1/1974	5.95	7.53	86
7/1/1975	0.23	1.13	135
7/1/1976	5.77	8.03	166
7/1/1977	4.52	6.68	95
7/1/1978	4.89	14.14	147
7/1/1979	5.14	6.52	124
7/1/1980	1.76	3.66	109
7/1/1981	1.34	2.08	104
7/1/1982	0.22	0.86	75
7/1/1983	3.17	3.41	57
7/1/1986	2.05	3.18	34
7/1/1987	1.48	2.29	59
7/1/1988	1.44	2.24	63

ATTACHMENT A
COWORKER DATA FIGURES
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Table A-3. 50th- and 84th-percentile urinary excretion rates of fission products, 1965 to 1990 (dpm/d).

Effective bioassay date	50th percentile	84th percentile	No. of employees
7/1/1965	26.06	58.88	321
7/1/1966	21.04	38.26	216
7/1/1967	20.99	44.65	221
7/1/1968	19.63	30.48	154
7/1/1969	10.07	24.71	116
7/1/1970	19.34	24.40	125
7/1/1971	16.54	28.26	84
7/1/1972	14.67	23.58	75
7/1/1973	12.90	24.28	66
7/1/1974	4.65	22.27	55
7/1/1975	12.90	20.51	84
7/1/1976	18.72	29.14	67
7/1/1977	6.98	31.58	75
7/1/1978	14.25	30.33	118
7/1/1979	9.06	22.97	84
7/1/1980	5.54	17.07	82
7/1/1981	17.75	33.77	55
7/1/1982	14.67	33.51	65
7/1/1983	15.42	23.90	45
7/1/1984	3.59	14.29	65
7/1/1985	15.89	26.69	67
7/1/1986	16.15	27.12	78
7/1/1987	21.92	38.70	63
7/1/1988	24.52	29.45	65
7/1/1989	22.79	37.83	50
7/1/1990	7.67	45.77	33
3/1/1991	8.08	35.30	27

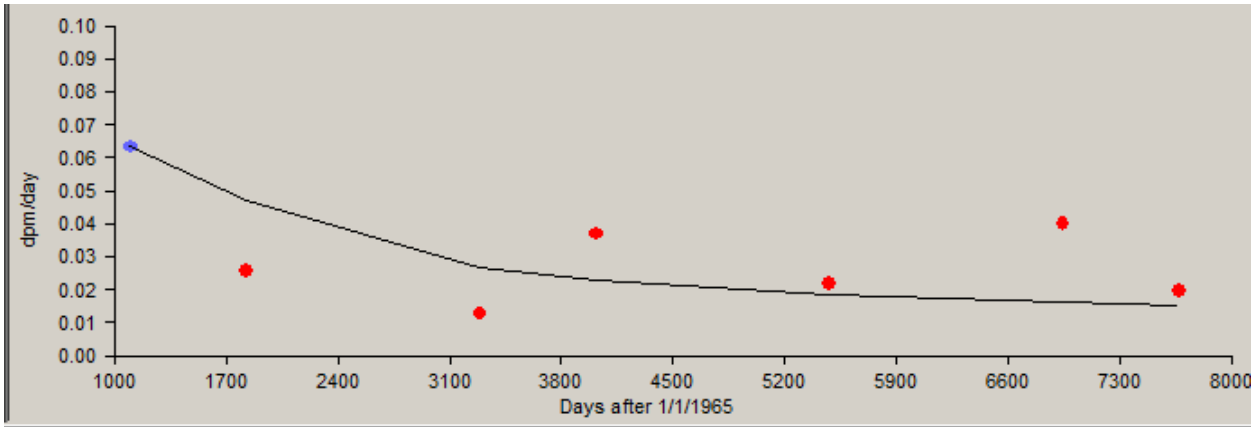

Figure A-1. Predicted plutonium bioassay results calculated using IMBA-derived plutonium intake rates (line) compared with bioassay results (dots), 50th percentile, 1965 to 1968, type M.

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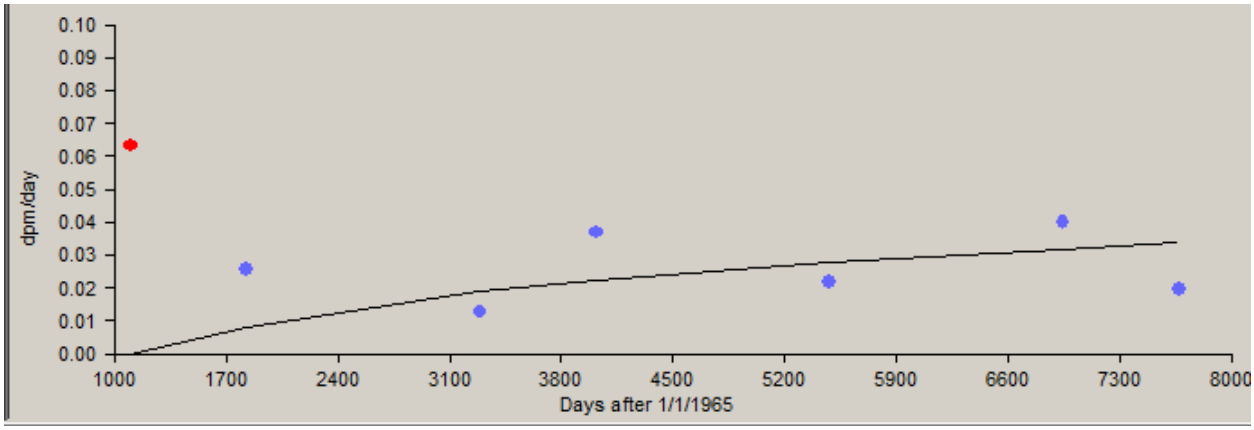

Figure A-2. Predicted plutonium bioassay results calculated using IMBA-derived plutonium intake rates (line) compared with bioassay results (dots), 50th percentile, 1969 to 1986, type M.

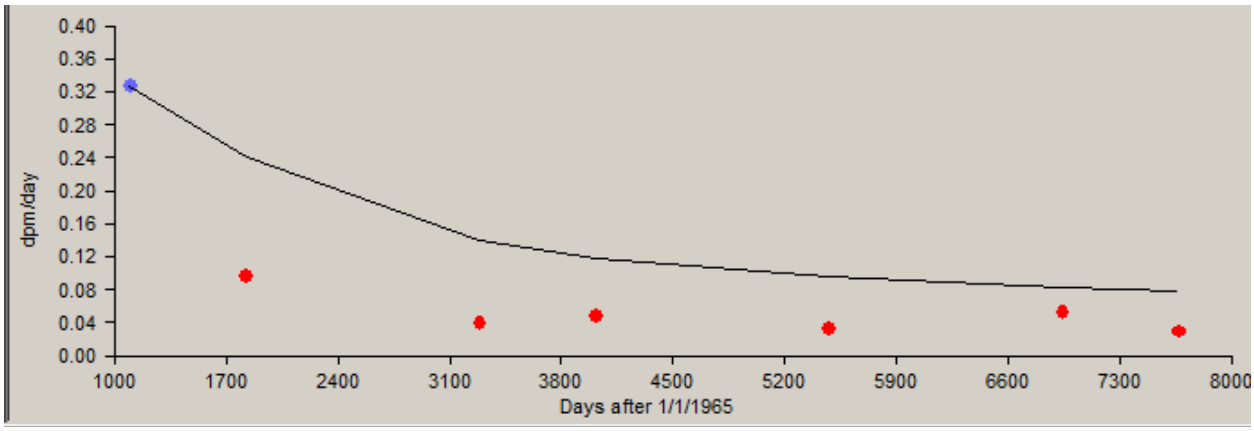

Figure A-3. Predicted plutonium bioassay results calculated using IMBA-derived plutonium intake rates (line) compared with bioassay results (dots), 84th percentile, 1965 to 1968, type M.

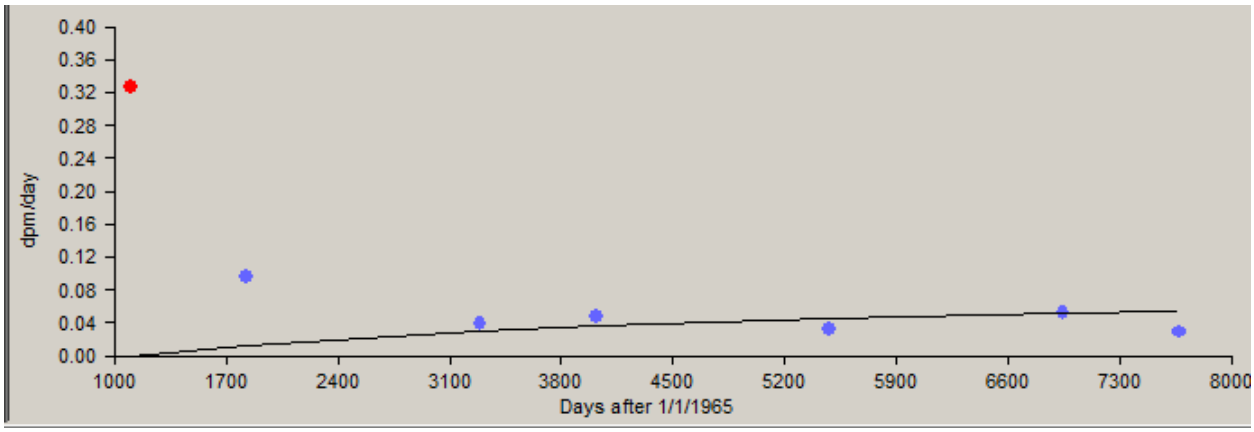

Figure A-4. Predicted plutonium bioassay results calculated using IMBA-derived plutonium intake rates (line) compared with bioassay results (dots), 84th percentile, 1969 to 1986, type M.

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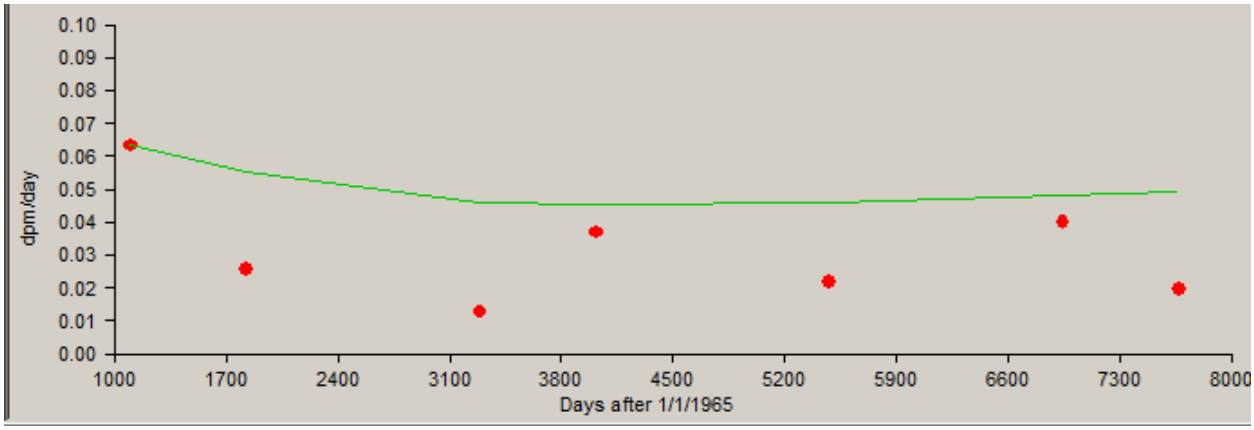

Figure A-5. Predicted plutonium bioassay results calculated using IMBA-derived plutonium intake rates (line) compared with bioassay results (dots), 50th percentile, all years, type M.

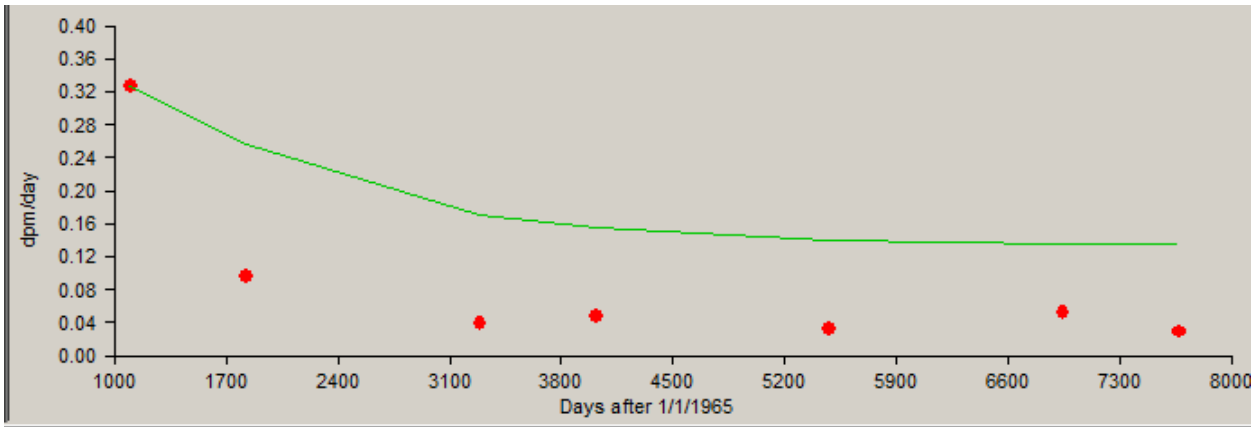

Figure A-6. Predicted plutonium bioassay results calculated using IMBA-derived plutonium intake rates (line) compared with bioassay results (dots), 84th percentile, all years, type M.

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

Year(s)	GM	84th percentile	GSD	Adj. GSD	95th percentile
1965–1968	13.12	67.61	5.15	5.15	195
1969–1986	3.018	4.959	1.64	3.00	18.4

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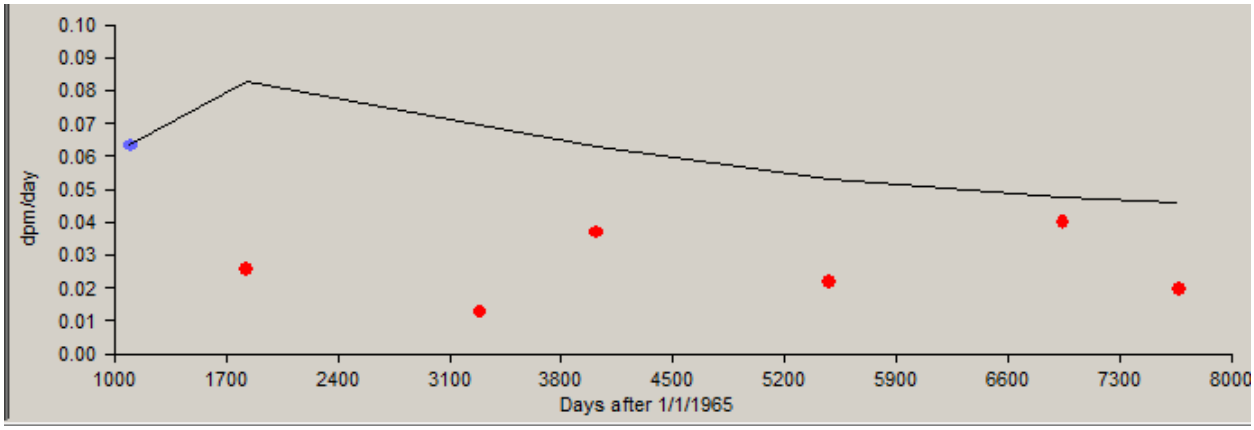

Figure A-7. Predicted plutonium bioassay results calculated using IMBA-derived plutonium intake rates (line) compared with bioassay results (dots), 50th percentile, 1965 to 1968, type S.

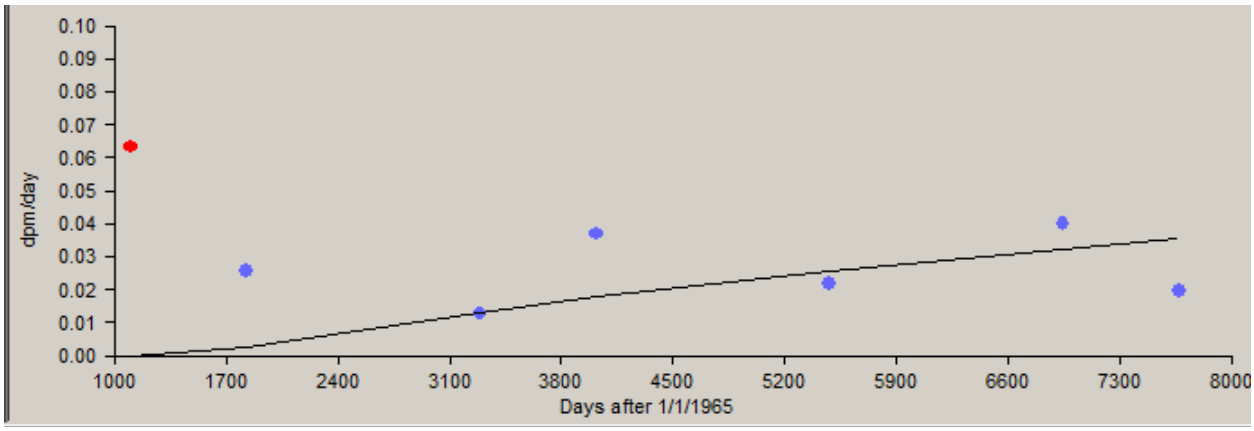

Figure A-8. Predicted plutonium bioassay results calculated using IMBA-derived plutonium intake rates (line) compared with bioassay results (dots), 50th percentile, 1969 to 1986, type S.

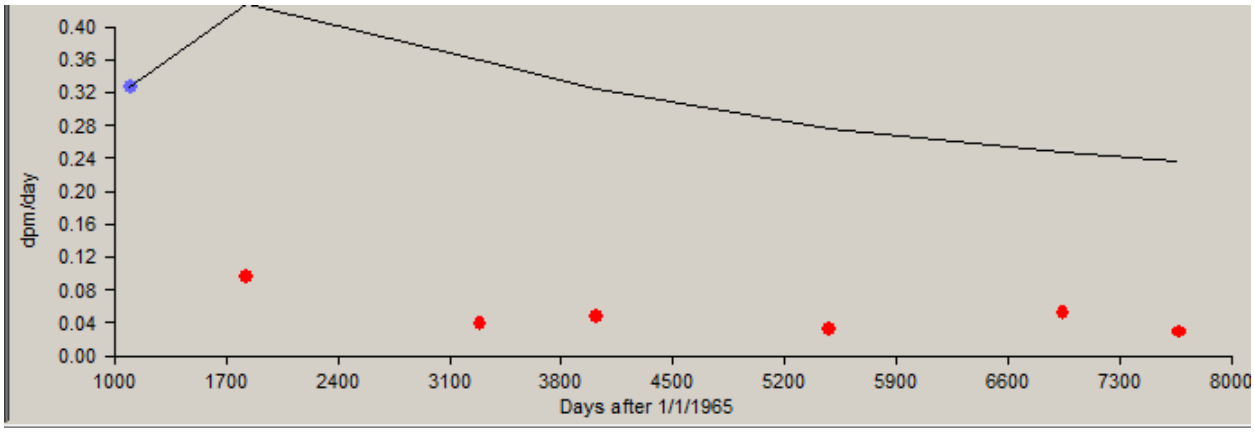

Figure A-9. Predicted plutonium bioassay results calculated using IMBA-derived plutonium intake rates (line) compared with bioassay results (dots), 84th percentile, 1965 to 1968, type S.

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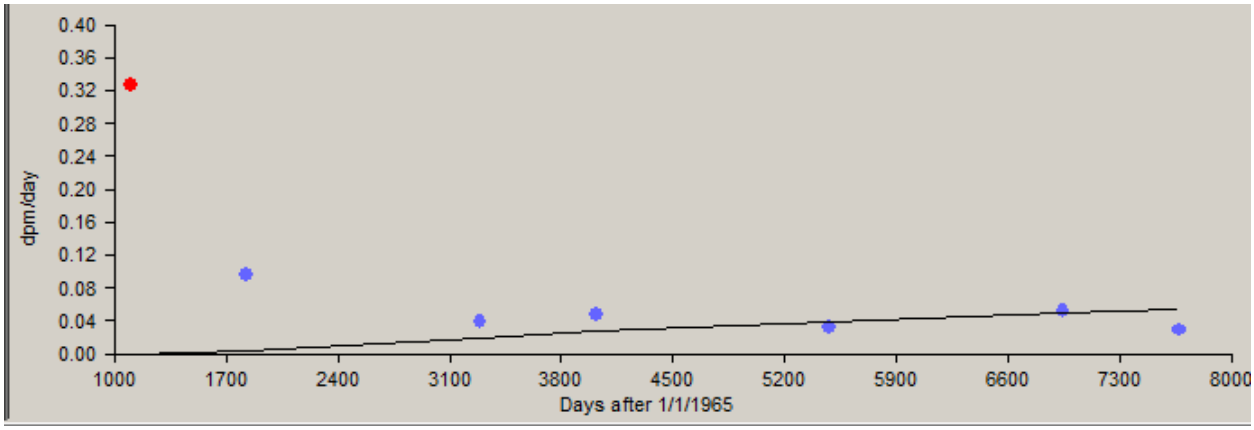

Figure A-10. Predicted plutonium bioassay results calculated using IMBA-derived plutonium intake rates (line) compared with bioassay results (dots), 84th percentile, 1969 to 1986, type S.

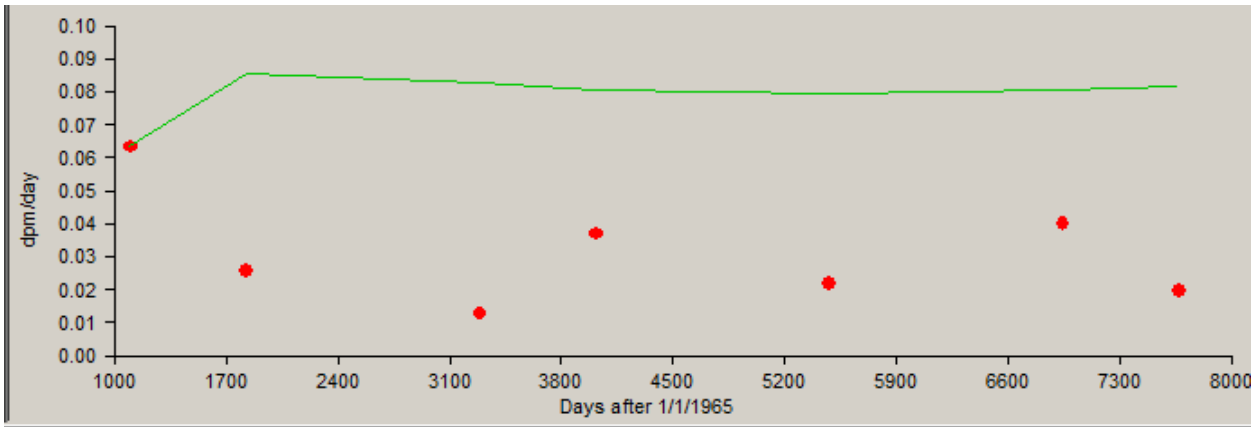

Figure A-11. Predicted plutonium bioassay results calculated using IMBA-derived plutonium intake rates (line) compared with bioassay results (dots), 50th percentile, all years, type S.

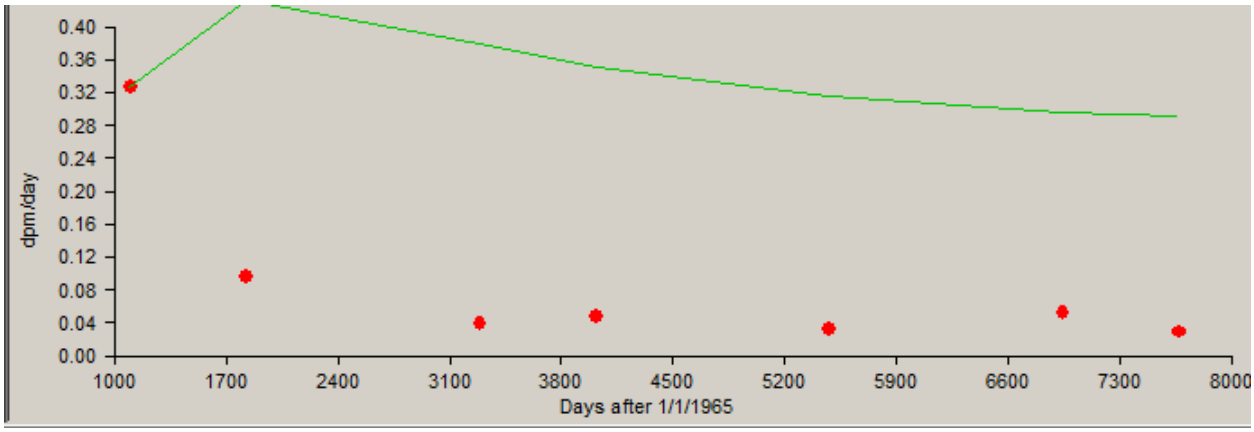

Figure A-12. Predicted plutonium bioassay results calculated using IMBA-derived plutonium intake rates (line) compared with bioassay results (dots), 84th percentile, all years, type S.

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

Year(s)	GM	84th percentile	GSD	Adj. GSD	95th percentile
1965–1968	329	1,695	5.15	5.15	4,880
1969–1986	41.62	64.15	1.54	3.00	254

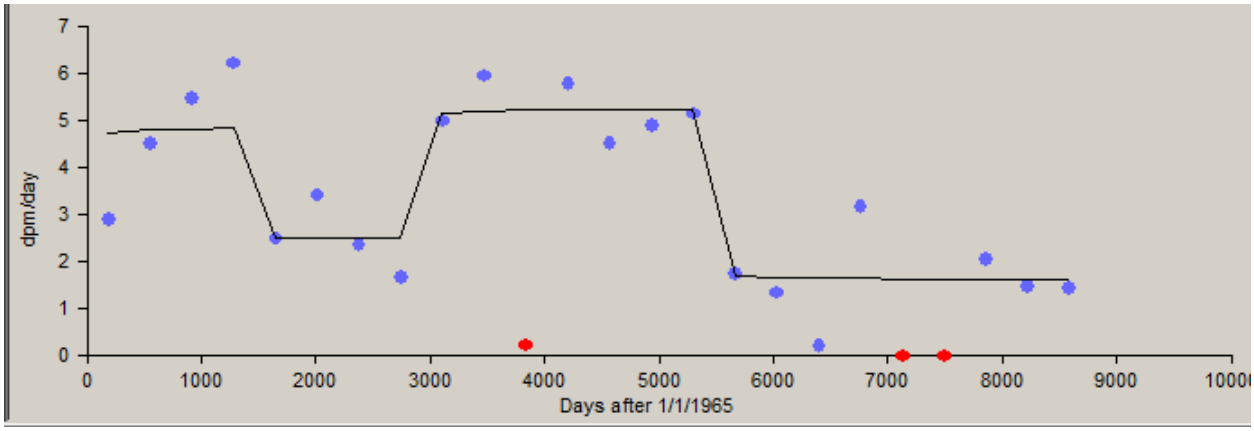

Figure A-13. Predicted uranium bioassay results calculated using IMBA-derived uranium intake rates (line) compared with bioassay results (dots), 50th percentile, all years, type F.

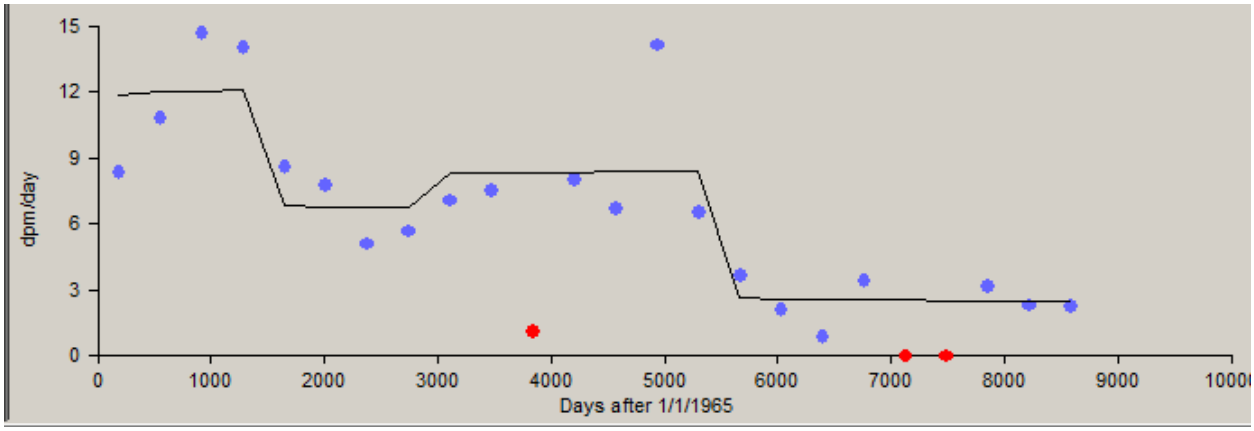

Figure A-14. Predicted uranium bioassay results calculated using IMBA-derived uranium intake rates (line) compared with bioassay results (dots), 84th percentile, all years, type F.

Table A-6. Type F uranium intake modeling results (dpm/d).

Year(s)	GM	84th percentile	GSD	Adj. GSD	95th percentile
1965–1968	17.6	44.09	2.51	3.00	107
1969–1972	8.91	24.35	2.73	3.00	54.3
1973–1979	18.87	30.03	1.59	3.00	115
1980–1988	5.666	8.652	1.53	3.00	34.5

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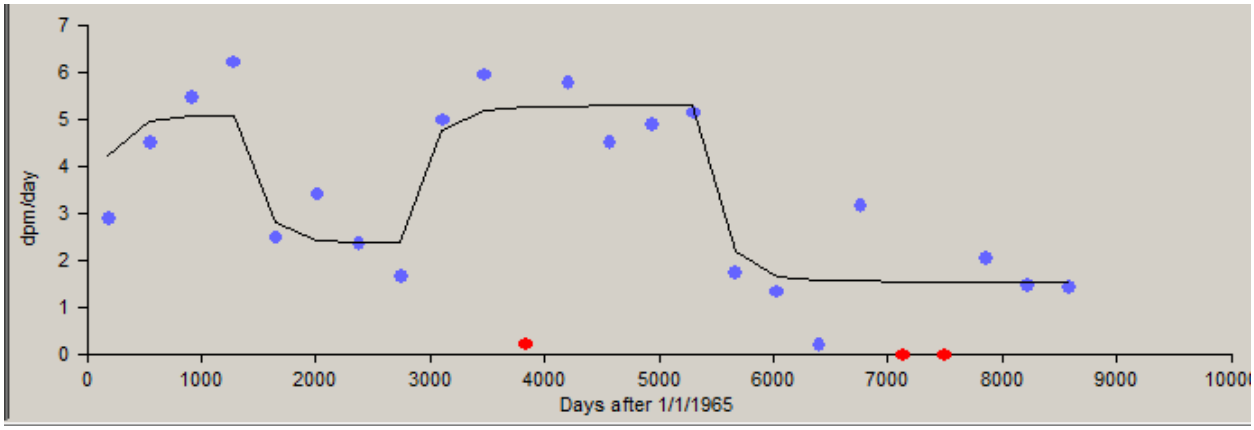

Figure A-15. Predicted uranium bioassay results calculated using IMBA-derived uranium intake rates (line) compared with bioassay results (dots), 50th percentile, all years, type M.

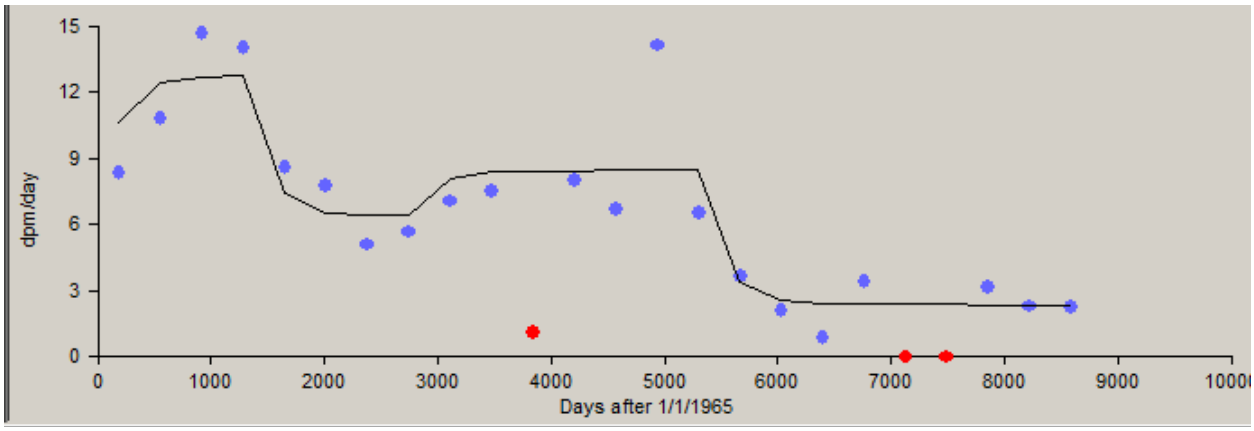

Figure A-16. Predicted uranium bioassay results calculated using IMBA-derived uranium intake rates (line) compared with bioassay results (dots), 84th percentile, all years, type M.

Table A-7. Type M uranium intake modeling results (dpm/d).

Year(s)	GM	84th percentile	GSD	Adj. GSD	95th percentile
1965–1968	75.91	190.7	2.51	3.00	463
1969–1972	34.92	93.84	2.69	3.00	213
1973–1979	78.02	124.1	1.59	3.00	475
1980–1988	21.92	33.04	1.51	3.00	134

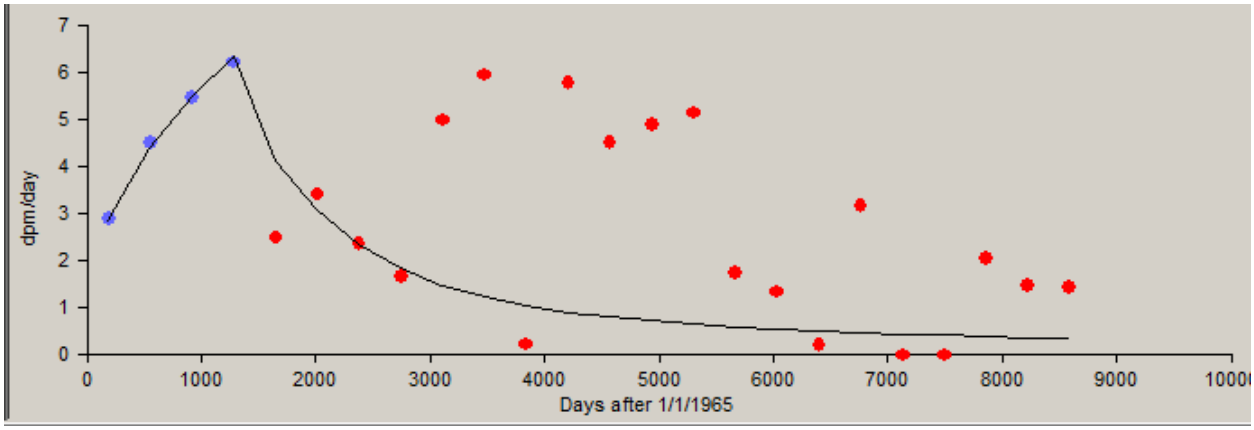

Figure A-17. Predicted uranium bioassay results calculated using IMBA-derived uranium intake rates (line) compared with bioassay results (dots), 50th percentile, 1965 to 1968, type S.

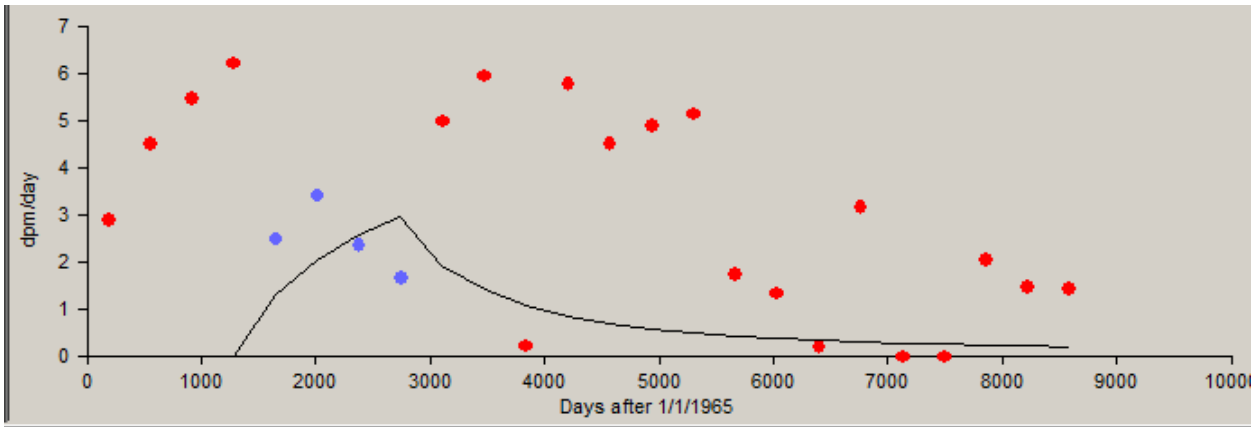

Figure A-18. Predicted uranium bioassay results calculated using IMBA-derived uranium intake rates (line) compared with bioassay results (dots), 50th percentile, 1969 to 1972, type S.

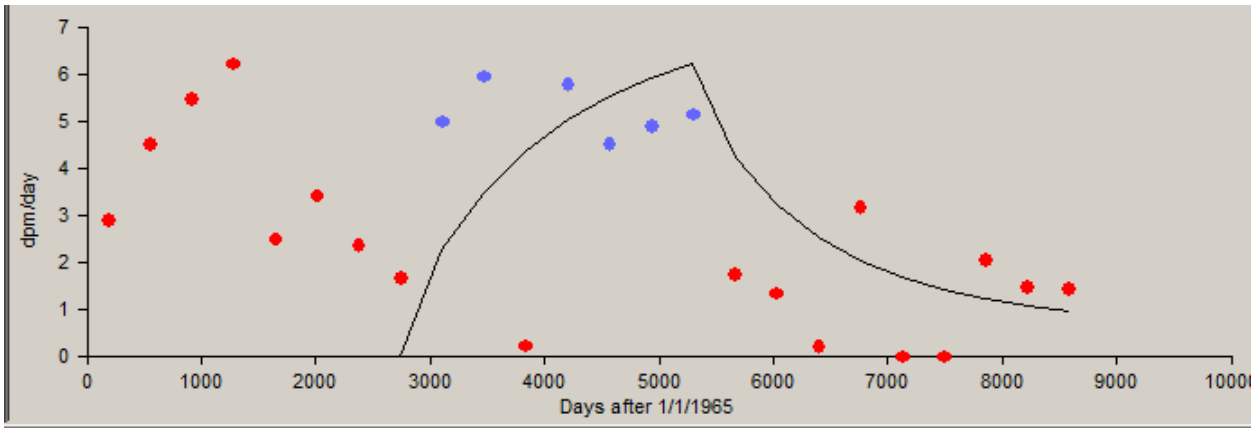

Figure A-19. Predicted uranium bioassay results calculated using IMBA-derived uranium intake rates (line) compared with bioassay results (dots), 50th percentile, 1973 to 1979, type S.

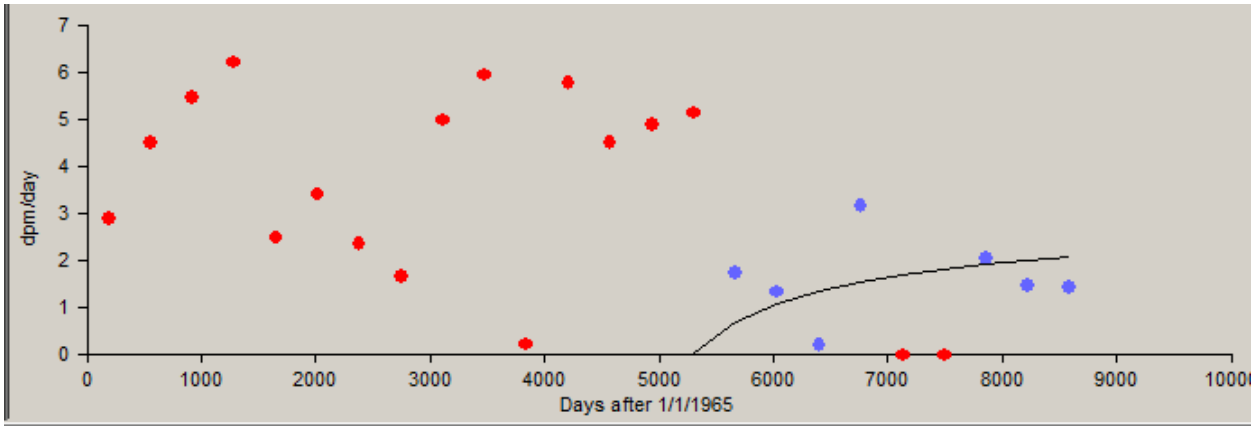

Figure A-20. Predicted uranium bioassay results calculated using IMBA-derived uranium intake rates (line) compared with bioassay results (dots), 50th percentile, 1980 to 1988, type S.

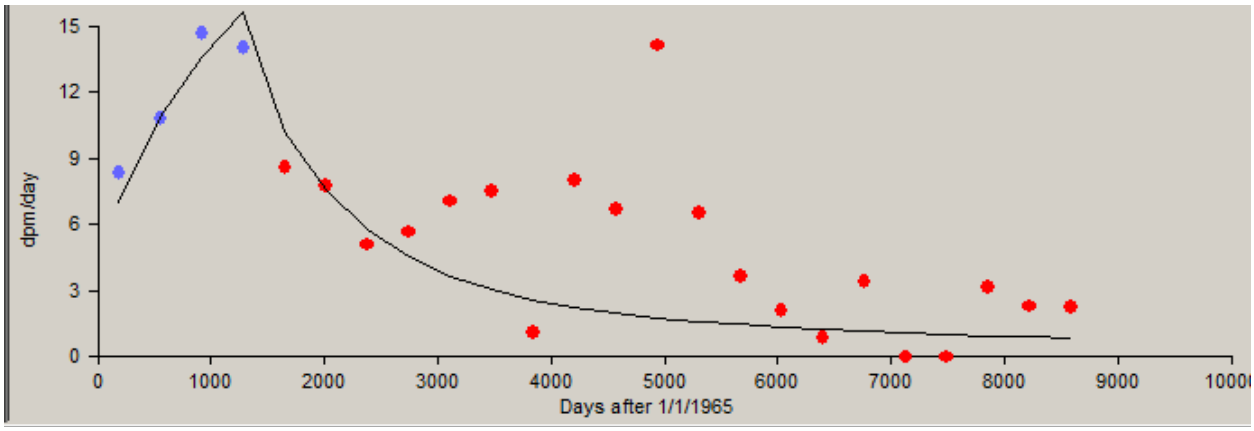

Figure A-21. Predicted uranium bioassay results calculated using IMBA-derived uranium intake rates (line) compared with bioassay results (dots), 84th percentile, 1965 to 1968, type S.

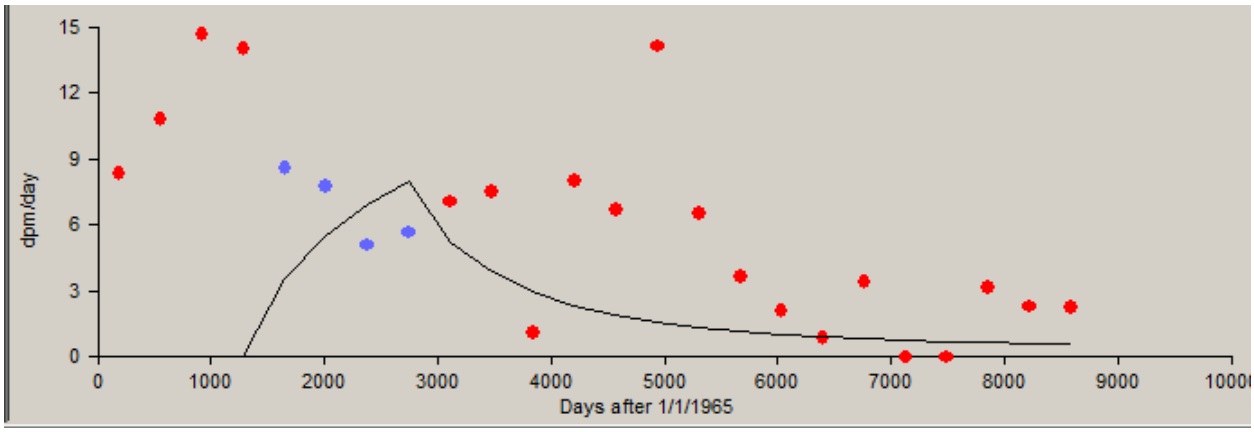

Figure A-22. Predicted uranium bioassay results calculated using IMBA-derived uranium intake rates (line) compared with bioassay results (dots), 84th percentile, 1969 to 1972, type S.

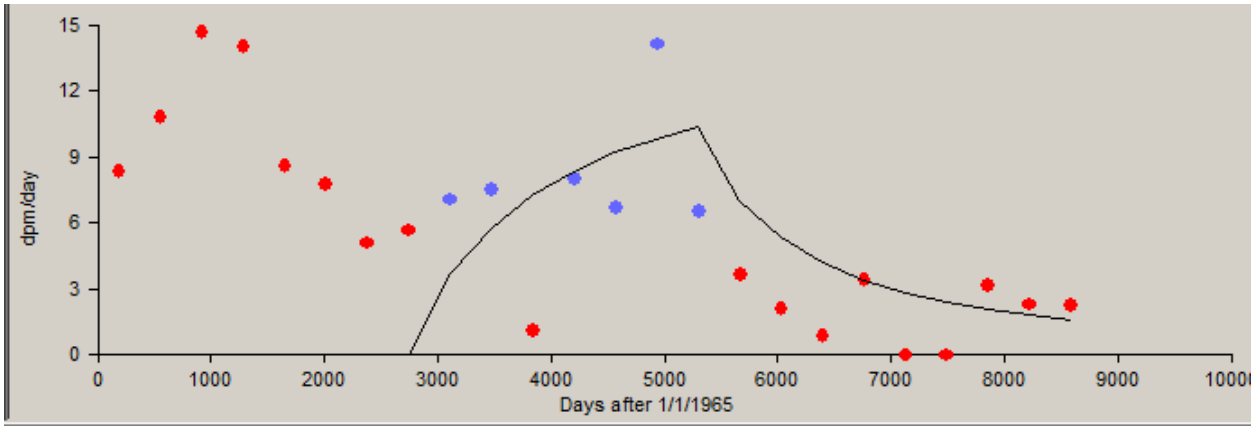

Figure A-23. Predicted uranium bioassay results calculated using IMBA-derived uranium intake rates (line) compared with bioassay results (dots), 84th percentile, 1973 to 1979, type S.

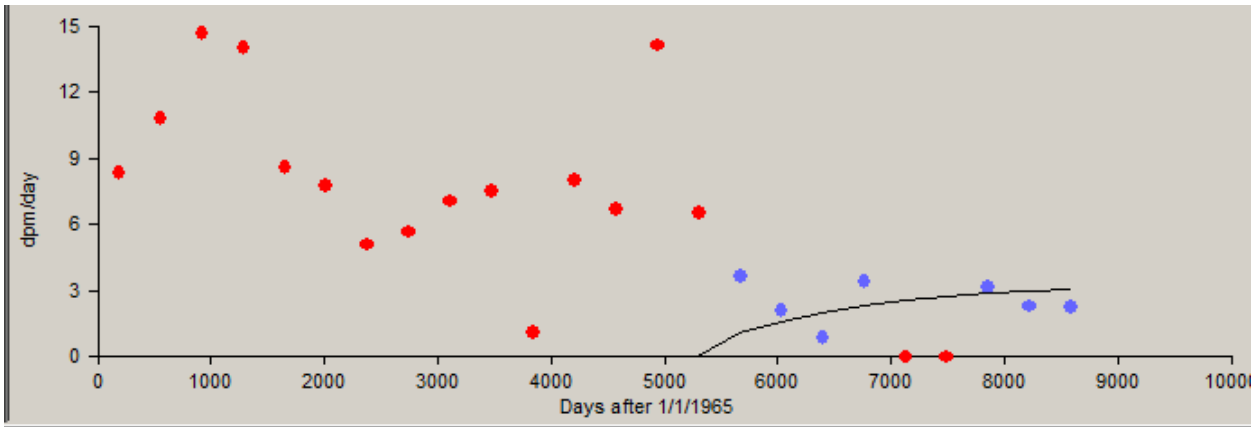

Figure A-24. Predicted uranium bioassay results calculated using IMBA-derived uranium intake rates (line) compared with bioassay results (dots), 84th percentile, 1980 to 1988, type S.

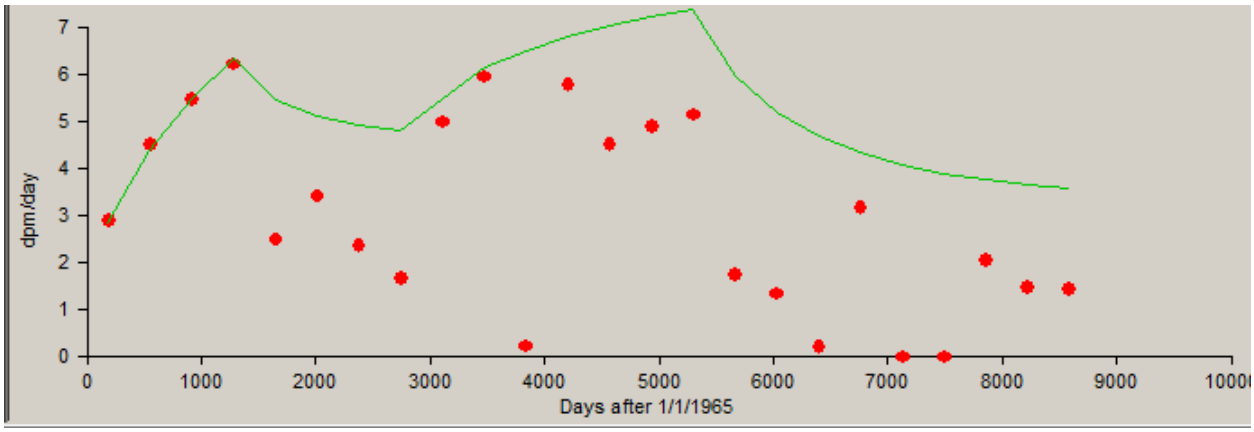

Figure A-25. Predicted uranium bioassay results calculated using IMBA-derived uranium intake rates (line) compared with bioassay results (dots), 50th percentile, all years, type S.

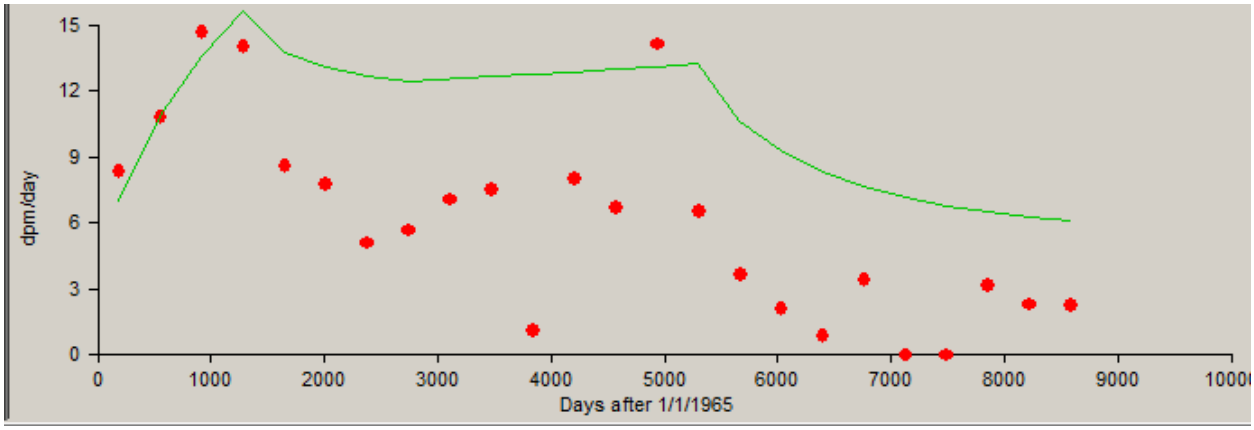

Figure A-26. Predicted uranium bioassay results calculated using IMBA-derived uranium intake rates (line) compared with bioassay results (dots), 84th percentile, all years, type S.

Table A-8. Type S uranium intake modeling results (dpm/d).

Year(s)	GM	84th percentile	GSD	Adj. GSD	95th percentile
1965–1968	1,592	3,930	2.47	3.00	9,701
1969–1972	744.4	1,998	2.68	3.00	4,536
1973–1979	1,266	2,101	1.66	3.00	7,714
1980–1988	389	581	1.49	3.00	2,370

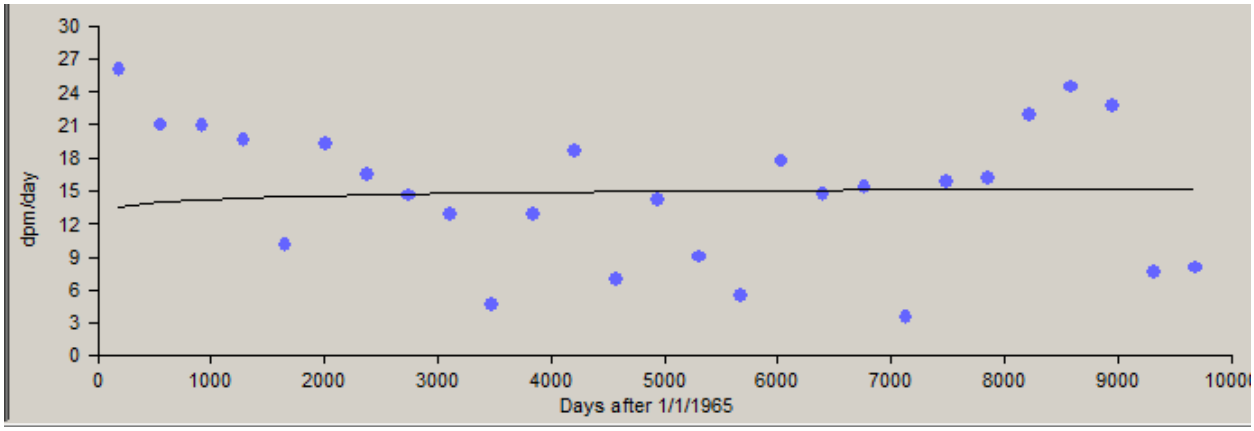

Figure A-27. Predicted strontium bioassay results calculated using IMBA-derived strontium intake rates (line) compared with bioassay results (dots), 50th percentile, all years, type F.

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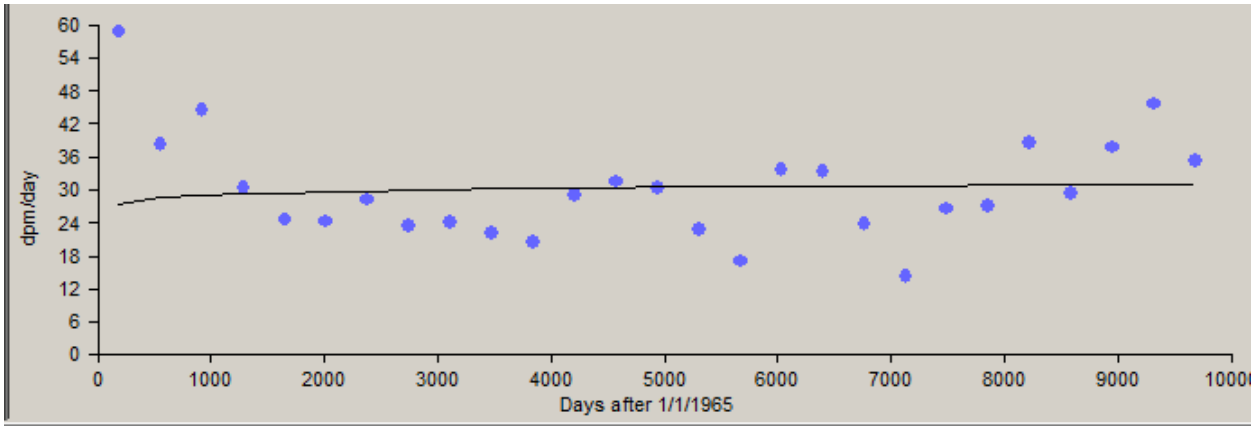

Figure A-28. Predicted strontium bioassay results calculated using IMBA-derived strontium intake rates (line) compared with bioassay results (dots), 84th percentile, all years, type F.

Table A-9. Type F strontium intake modeling results (dpm/d).

Year(s)	GM	84th percentile	GSD	Adj. GSD	95th percentile
1965–1991	61.05	124.3	2.04	3.00	372