DOE Review Release 08/27/2020

Internal Dosimetry Co-Exposure Data for Los Alamos National Laboratory

ORAUT-OTIB-0062 Rev. 01
Effective Date: 09/01/2020
Supersedes: Revision 00

Subject Expert(s): Matthew G. Arno

Document Owner Approval:	Signature on File Matthew G. Arno, Document Owner	Approval Date:	03/09/2020
Concurrence:	Signature on File John M. Byrne, Objective 1 Manager	Concurrence Date:	03/10/2020
Concurrence:	Signature on File Scott R. Siebert, Objective 3 Manager	Concurrence Date:	03/07/2020
Concurrence:	Vickie S. Short Signature on File for Kate Kimpan, Project Director	Concurrence Date:	03/09/2020
Approval:	Signature on File Timothy D. Taulbee, Associate Director for Science	Approval Date:	08/05/2020

FOR DOCUMENTS MARKED AS A TOTAL REWRITE, REVISION, OR PAGE CHANGE, REPLACE THE PRIOR REVISION AND DISCARD / DESTROY ALL COPIES OF THE PRIOR REVISION.

☐ New ☒ Total Rewrite ☐ Revision ☐ Page Change

PUBLICATION RECORD

EFFECTIVE DATE	REVISION NUMBER	DESCRIPTION
10/15/2009	00	New technical information bulletin for internal dosimetry coworker data for Los Alamos National Laboratory. Incorporates formal internal and NIOSH review comments. Analysis of plutonium-239 and cesium-137 lung counts updated and new guidance added for type Super S plutonium-239. Training required: As determined by the Objective Manager. Initiated by Matthew Arno.
09/01/2020	01	Revision initiated to include the intake rates for type SS plutonium. Incorporates formal internal and NIOSH review comments. Constitutes a total rewrite of the document. Training required: As determined by the Objective Manager. Initiated by Matthew G. Arno.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ACRONYMS AND ABBREVIATIONS

AWE	atomic weapons employer
d	day
DOE	U.S. Department of Energy
DTPA	diethylene triamine pentaacetic acid
F	fast (absorption type)
GM	geometric mean
GSD	geometric standard deviation
hr	hour
ICRP	International Commission on Radiological Protection
IDOT	Internal Dosimetry Tool
IMBA	Integrated Modules for Bioassay Analysis
L	liter
LANL	Los Alamos National Laboratory
m	meter
M	moderate (absorption type)
MDA	minimum detectable activity
mL	milliliter
mrem	millirem
nCi	nanocurie
NIOSH	National Institute for Occupational Safety and Health
ORAU	Oak Ridge Associated Universities
pCi	picocurie
RAS	radiometric alpha spectrometry
S	slow (absorption type)
SEC	Special Exposure Cohort
SRDB Ref ID	Site Research Database Reference Identification (number)
SS	super slow (absorption type)
TIB	technical information bulletin
TIMS	thermal ionization mass spectrometry
USC	*United States Code*
µCi	microcurie
µg	microgram
µm	micrometer

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), such as changing scientific understanding of operations, processes, or procedures involving radioactive materials. TIBs may be used to assist NIOSH staff in the completion of individual dose reconstructions.

In this document the word "facility" is used to refer to an area, building, or group of buildings that served a specific purpose at a U.S. Department of Energy (DOE) or Atomic Weapons Employer (AWE) facility. It does not mean, nor should it be equated to, an "AWE facility" or a "DOE facility." The terms AWE and DOE facility are defined in 42 *United States Code* (USC) 7384l(5) and (12) of the Energy Employees Occupational Illness Compensation Program Act of 2000, respectively.

ORAUT-OTIB-0019, *Analysis of Coworker Bioassay Data for Internal Dose Assignment*, describes the general process used to analyze bioassay data for the assignment of doses to individuals based on co-exposure results [ORAUT 2005]. ORAUT-PLAN-0014, *Coworker Data Exposure Profile Development*, describes the approach and processes to develop reasonable exposure profiles based on available dosimetric information for workers at DOE sites [ORAUT 2004a].

Bioassay results were obtained directly from the Los Alamos National Laboratory (LANL) In-Vivo Measurements Laboratory and from the LANL Bioassay Repository for in vitro bioassay results. The combined databases used here contain more than half a million bioassay records from LANL and include measurements for ^{238}Pu, plutonium, tritium, polonium, and cesium for 1945 to 2008.

The database results were labeled with units that varied among the radionuclides, analysis techniques, and measurement periods. These units usually were disintegrations per minute, counts per minute, or picocuries per 24 hours or per liter. The specific units for each radionuclide are provided in the appropriate sections of this document.

A statistical analysis of the data was performed according to ORAUT-OTIB-0019 and ORAUT-PROC-0095, *Generating Summary Statistics for Coworker Bioassay Data* [ORAUT 2005, 2006]. The results were entered in the Integrated Modules for Bioassay Analysis (IMBA) to obtain intake rates for the assignment of dose distributions.

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, co-exposure data from other monitored workers can be used to assign an internal dose to address potential intakes of radioactive material. The purpose of this TIB is to provide monitored co-exposure information for calculating and assigning occupational internal doses to employees at LANL for whom no or insufficient monitoring records exist.

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 data for ^{238}Pu, plutonium, polonium, uranium, and tritium from 1945 to 2004 were extracted from a database named "LANL CO-Worker Data – Rev 1.mdb" ["co-exposure database"; ORAUT 2009a]. There are more than 400,000 records in the urinalysis database. Six measurements for ^{239}Pu in 1944 were not used because the low number of measurements does not permit reliable statistical analysis. The same data for 2005 through 2008 was extracted from a database named "LANL_invitro_dataset_feb2009.mdb" ["in vitro database"; ORAUT 2009b], which contains more than 55,000 additional urinalysis results. The units used were dependent on both the analyte and the era. The specific units used are discussed in more detail below in the discussion of each radionuclide.

In vivo data from 1965 to 2004 were extracted from a database named 2007_10_08-"LANL_IN_VIVO_DATA-Access2003.mdb" ["in vivo database"; ORAUT 2007]. There are approximately 100,000 records in this database. Most of the records are for chest or whole-body counts, although a few counts of specific organs or body regions (hand, skull, etc.) are included. Only the chest and whole-body counts were used. Bioassay data were available for in vivo measurements of ^{238}Pu, ^{239}Pu, ^{241}Am, and ^{137}Cs. Beyond these four nuclides, very limited data were available, primarily for the late 1980s when the use of high-resolution germanium detectors became more widespread, which allowed identification of a wide selection of other radionuclides. However, insufficient data were available to perform any analysis for these other radionuclides. Even for the four primary radionuclides, sufficient non-zero data for analysis were available only for ^{239}Pu and ^{137}Cs.

3.2 ANALYSIS

Bioassay data were analyzed by quarter, year, or multiyear span dependent 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 using the method in ORAUT-OTIB-0019 [ORAUT 2005]. A large fraction of the data for every radionuclide was entered as zero bioassay results. These zeros were retained in the analysis to rank the results. The acute intake of polonium in 1955 was addressed differently as discussed below in the sections regarding polonium.

3.3 TRITIUM

Tritium urine bioassay data were extracted from the co-exposure database [ORAUT 2009a]. The co_worker_data table in this database was queried to identify all records with a nuclide type of "H-3" and collection dates ranging from the earliest recorded through the end of 2004. The coll_date, z_number, and activity fields were extracted and exported to a spreadsheet. All activity results were in microcuries per liter. No other codes or fields with useful information were identified.

For the period from the start of data (June 23, 1950) through approximately 1991, no records had fields that contained information that would permit the sorting or exclusion of any data points. Later data (post-1991) identified samples as routine or special, but all pre-1989 data were identified as historical spot samples. All data were used. A total of 72,153 distinct records were identified.

Visual examination of the data indicates that almost all of the high bioassay values are clearly the result of acute intakes. Involved employees were regularly monitored while the tritium was excreted, which resulted in well-defined decaying exponential excretion curves. No attempt was made to exclude the bioassay data resulting from these acute intakes.

The minimum detectable activity (MDA) for the entire period was 1 µCi/L until late 1987, when the MDA decreased to 0.1 µCi/L. Before 1991, MDAs were reported in the database separately from the analytical result. Analytical results <MDA were recorded as zero, except for December 1968 through

January 1971, when the actual result was recorded. Starting in 1991, the actual result, regardless of whether it was above or below the MDA, was reported and the MDA was not reported separately. Activities recorded in site records as less than the MDA were input as one-half of the MDA for this analysis.

For 2005 through 2008, tritium urine bioassay data were extracted from the LANL IN VITRO DATA FEB 2009 table in the in vitro database ["in vitro database"; ORAUT 2009b]. All records with a nuclide type of "H-3" and collection dates ranging from 2005 through 2008 inclusive were identified. The ZNO, COLLECTED_DATE, and ACTIVITY fields were extracted and exported to a spreadsheet. All activity results were in microcuries per liter. No other codes or fields with useful information were identified. A total of 5,186 distinct records were identified. The actual result, regardless of whether it was above or below the MDA, was reported along with the MDA.

3.4 PLUTONIUM-238

The co_worker_data table in the co-exposure database [ORAUT 2009a] was queried to identify all records with a nuclide type of "PU-238" and collection dates that ranged from the beginning of 1968 through the end of 2004. Predominantly pure ^{238}Pu was not encountered at LANL before 1968 [ORAUT 2013]. The coll_date, z_number, and activity fields were extracted and exported to a spreadsheet. All activity results were in units of picocuries per 24 hours. For the period from the start of data (1968) through the end of 1990, all the data had the same information available in the database with no fields that contained information that would permit the sorting or exclusion of any data points. Later data (post-1991) identified samples as routine or special, but all pre-1991 data were identified as simply historical samples. All data were used.

It appears that values less than the MDA were reported beginning in 1971 with negative results reported as zero. Negative results were reported beginning in 1973 except for two results in 1971. All activity values, including zero, less than zero, and less-than MDA, were used without modification for all years.

The statistical analysis was performed on an annual basis using a total of 77,739 distinct records. Table A-1 in Attachment A lists the statistical analysis results for ^{238}Pu.

Examination of the reported activities revealed that a relatively small number of individuals accounted for the majority of the highest bioassay results. These results tended to skew the curve fit. The bioassay results for these individuals were filtered out for the indicated years to eliminate this skew. Table 3-1 lists the individuals whose results were filtered out and for which years. Additional detail, with personally identifiable information removed, for filtering out these individuals is provided below.

Table 3-1. High bioassay readings for ^{238}Pu.

Individual	Years filtered out
1	1972 through 1988
2	1972 through 1988
3	1972 through 1988
4	1977 through 1988
5	1981 through 1988

Individuals 1 through 3
These individuals were involved in the Wing-9 incident in 1971, which has been the subject of multiple studies [Hickman et al. 1995; James et al 2003]. Their bioassay data is well studied and associated with a known incident. Their data was removed for 1972 through 1988.

Individual 4
This individual had an acute intake on February 10, 1977, and was bioassayed 96 times during 1977 and treated with diethylene triamine pentaacetic acid (DTPA) [Various 1976–1980]. The bioassay measurements exhibit a clear exponential decay, and the initial data were extreme outliers and skewed the fit. All data for this individual for 1977 through 1988 were removed. The same pattern was seen in this individual's ^{239}Pu bioassay measurements.

Individual 5
This individual had an acute intake in mid-April 1981 [Inkret and Miller 1995]. He was sampled numerous times, and the bioassay data exhibits an exponential decay trend. All data for this individual for 1981 through 1988 were removed. This individual also had high ^{239}Pu bioassay measurements starting at the same time.

For 2005 through 2008, the LANL IN VITRO DATA FEB 2009 table in the in vitro database [ORAUT 2009a] was queried to identify all records with a nuclide type of "PU-238" and collection dates that ranged from the beginning of 2005 through the end of 2008. The ZNO, COLLECTED_DATE, SAMPLE_ID, ACTIVITY_PS and ACTIVITY fields were extracted and exported to a spreadsheet. For a given SAMPLE_ID, the ACTIVITY_PS field was used as the sample activity unless it was blank, in which case the value in the ACTIVITY field was used as the result. All samples were 24-hour or simulated 24-hour samples and were in units of picocuries per sample or picocuries per 24 hours. Therefore, all results were treated as picocuries per day. All data were used.

3.5 PLUTONIUM-239

3.5.1 Plutonium-239 In Vitro Data

The co_worker_data table in the co-exposure database [ORAUT 2009a] was queried to identify all urinalysis records with a nuclide type of "PU-239" and collection dates that ranged from the beginning of 1945 through the end of 2004. The coll_date, z_number, and activity fields were extracted and exported to a spreadsheet. All activity results were in units of picocuries per 24 hours. For the period from the start of data (1944) through approximately 1991, all the data had the same information available in the database with no fields that contained information that would permit the sorting or exclusion of any data points. Later data (post-1991) identified samples as routine or special, but all pre-1989 data were identified as simply historical samples. All data were used.

Values less than the MDA and negative results were reported as such from 1945 through 1957 and from 1971 onward. For 1958 through 1970, values less than zero were reported as zero. All activity values, including zero, less than zero, and above-MDA, were used without modification for all years. Before 1967, plutonium urinalysis measured gross plutonium alpha activity rather than $^{239/240}$Pu activity. However, the pre-1967 data has been treated as measuring the $^{239/240}$Pu count rate, which overestimates the actual $^{239/240}$Pu activity by 10% to 12% for weapons-grade plutonium depending on the fuel age. The statistical analysis was performed on an annual basis using 85,752 distinct records. Table A-2 in Attachment A lists the statistical analysis results for in vitro ^{239}Pu.

Examination of the reported activities revealed that, for a few years, a few individuals were responsible for the vast majority of the highest bioassay results. These results tended to skew the curve fit. The bioassay results for these individuals were filtered out for the specific year to eliminate this skew. Table 3-2 lists the individuals whose results were filtered out and for which years. The justification for filtering out these individuals is the same as given for ^{238}Pu above.

For 2005 through 2008, the LANL IN VITRO DATA FEB 2009 table in the in vitro database [ORAUT 2009a] was queried to identify all records with a nuclide type of "PU-239," "PU-240," or "PU-239+PU-240" and collection dates that ranged from the beginning of 2005 through the end of 2008. The ZNO,

Table 3-2. High bioassay readings for ^{239}Pu.

Individual	Years filtered out
4	1977 through 1988
5	1981 through 1988

COLLECTED_DATE, SAMPLE_ID, ANALYSIS_TYPE, ACTIVITY_PS and ACTIVITY fields were extracted and exported to a spreadsheet. All samples were 24-hour or simulated 24-hour samples and were in units of picocuries per sample or picocuries per 24 hours. Therefore, all results were treated as picocuries per day.

Plutonium-239/240 results were obtained by both radiometric alpha spectrometry (RAS) and thermal ionization mass spectrometry (TIMS). The TIMS results report separate concentrations for ^{239}Pu and ^{240}Pu. RAS results do not distinguish between ^{239}Pu and ^{240}Pu because the alpha particle energies for these two radionuclides are very similar and report the combined activity as PU-239. The TIMS results have a lower limit of detection and are generally more reliable. For this study, the combined $^{239/240}$Pu activity is the desired quantity. A single SAMPLE_ID in the database might have as many as eight records associated with it. To determine the single quantity to use for this study, the following priority order was used:

For a given SAMPLE_ID, use the record(s) highest in the following priority list:

1. NUCLIDE field = “PU-239+PU-240,” ANALYSIS_TYPE = “TIMS,” recorded value in the ACTIVITY_PS field.

2. NUCLIDE field = “PU-239+PU-240,” ANALYSIS_TYPE = “TIMS,” ACTIVITY_PS field blank, with a recorded value in the ACTIVITY field.

3. Sum the ACTIVITY_PS fields of:

    a. NUCLIDE field = “PU-239+PU-240,” ANALYSIS_TYPE = “TIMS,” recorded value in the ACTIVITY_PS field, and

    b. NUCLIDE field = “PU-239+PU-240,” ANALYSIS_TYPE = “TIMS,” recorded value in the ACTIVITY_PS field.

4. Sum the ACTIVITY fields of:

    a. NUCLIDE field = “PU-239+PU-240,” ANALYSIS_TYPE = “TIMS,” ACTIVITY_PS field blank, recorded value in the ACTIVITY field, and

    b. NUCLIDE field = “PU-239+PU-240,” ANALYSIS_TYPE = “TIMS,” ACTIVITY_PS field blank, recorded value in the ACTIVITY field.

5. NUCLIDE field = “PU-239,” ANALYSIS_TYPE = “RAS,” recorded value in the ACTIVITY_PS field.

6. NUCLIDE field = “PU-239,” ANALYSIS_TYPE = “RAS,” ACTIVITY_PS field blank, recorded value in the ACTIVITY field.

A single value for each SAMPLE_ID was used. All SAMPLE_IDs with reported ^{239}Pu and/or ^{240}Pu results were used. In 2007, one individual had the 67 largest results. All of this person’s bioassay data in 2007 was excluded from the analysis.

3.5.2 Plutonium-239 In Vivo Data

The TBL_NIOSH_REPORT_2007_V2 table in the in vivo database [ORAUT 2007] was queried to identify all lung count records with a nuclide type of "Pu-239," organ type of "Chest," count reason other than "new hire," "rehire," or "baseline," and collection dates ranging from the beginning of 1969 through the end of 2004. The count_date, zno, and abundance_nCi fields were extracted and exported to a spreadsheet. The zno field was used as the employee identifier, and the abundance_nCi field was used as the value of the chest count.

Records with no abundance value were entered with an abundance of zero based on the assumption that the result was less than the MDA and the fact that the recorded MDAs were much higher than the typical recorded positive values. Only 1969 through 1979 were analyzed because there were few positive results after 1979. Table A-3 in Attachment A lists the statistical analysis results for in vivo ^{239}Pu.

3.6 POLONIUM-210

The co_worker_data table in the co-exposure database [ORAUT 2009a] database was queried to identify all records with a nuclide type of "Po" and collection dates that ranged from the beginning of 1947 through the end of 2004. The coll_date, z_number, and activity fields were extracted and exported to a spreadsheet. The activity results were reported in units of picocuries per liter or counts per minute per liter. Results in counts per minute were converted to disintegrations per minute using a detector efficiency of 50% (based on the assumption that a 2-π detector was used in the absence of any other information) and a recovery fraction of 10%. The results in disintegrations per minute were then converted to picocuries for consistency with the other data. Results in picocuries per liter were adjusted assuming a recovery fraction of 10% rather than 100% [ORAUT 2017]. All the data had the same information available in the database with no fields that contained information that would permit the sorting or exclusion of any data points. Therefore, all data were used.

Examination of the data indicated several anomalies. Several individuals had acute intakes in January 1953. Because more than one individual was involved (even though a limited number), these data were left in the dataset for the entire year. In August 1954, one employee had an acute intake that resulted in all of the highest 20% of bioassay results for the year. All bioassay results for this employee for the third and fourth quarters of 1954 were excluded from the analysis.

Another acute intake involving a large number of individuals occurred in late July or early August 1955. To separate the urinalysis results due to this acute intake, urinalysis results for seven employees were excluded from the fits for the last two quarters of 1955. Although these seven individuals were not the only ones involved in the incident, these seven had the majority of the highest readings. The bioassay data for these seven individuals as a result of this incident have been analyzed separately as an acute intake. Dose reconstruction for individuals who were involved in this incident and who do not have relevant bioassay data should also be assigned this intake. This applies only to individuals for whom there is evidence or reason to believe that they were involved in this incident. An incident date of August 1, 1955, was chosen as the best fit to the available data.

All activity values, including zero, less than zero, and less-than MDA, were used without modification for all years. The normal statistical analysis was performed on a quarterly basis. For the seven identified individuals involved in the incident, the bioassay data for each individual was fit separately to determine the intake of material that occurred in the incident. Table A-4 in Attachment A lists the statistical analysis results for ^{210}Po. A total of 5,121 distinct records were used for the quarterly and incident analyses.

3.7 URANIUM

The co_worker_data table in the co-exposure database [ORAUT 2009a] was queried to identify all records with a nuclide type of "U-234," "U-235," or "U-238" and collection dates ranging from 1950 through the end of 2004. The coll_date, z_number, activity, and MDA fields were extracted and exported to a spreadsheet. All activity results were in units of picocuries per 24 hours. For the period from the start of data (1950) through approximately 1991, all the data had the same information available in the database with no fields that contained information that would permit the sorting or exclusion of any data points. Later data (post-1991) identified samples as routine or special, but all pre-1989 data were identified as historical spot samples. All data were used.

Before July 1991, the bioassay records identified the results as being specific for either ^{238}U or ^{235}U. However, both techniques truly measured the same quantity but reported the results in different units. A single measurement technique was used during any given time frame [see Table 5-13 in ORAUT 2013] for analysis of uranium in urine before 1991. The analytical results were interpreted based on the materials to which an individual was presumed to have been exposed. Therefore, the two datasets were merged to create an overall uranium dataset. The ^{238}U data were converted to activity units assuming an activity of 0.4673 pCi/µg based on the specific activity of D-38 uranium [ORAUT 2013] and merged with the ^{235}U data. All activity values, including zero, less than zero, and less-than MDA, were used without modification for all years.

Beginning in July 1991, alpha spectrometry was used to analyze the urine samples for uranium, at which time results for ^{234}U, ^{235}U, and ^{238}U were reported. Because all uranium activity was assumed to be ^{234}U for the purposes of calculating dose, the activities of all three isotopes were summed and used as the total uranium activity.

The statistical analysis was performed on an annual basis using 126,523 records. Table A-5 in Attachment A lists the statistical analysis results for uranium.

For 2005 through 2008, the LANL IN VITRO DATA FEB 2009 table in the in vitro database [ORAUT 2009a] was queried to identify all records with a nuclide type of "U-234," "U-235," or "U-238" and collection dates that ranged from the beginning of 2005 through the end of 2008. The ZNO, COLLECTED_DATE, SAMPLE_ID, ACTIVITY_PS and ACTIVITY fields were extracted and exported to a spreadsheet. For a given SAMPLE_ID, the ACTIVITY_PS field was used as the sample activity unless it was blank, in which case the value in the ACTIVITY field was used as the result. All samples were 24-hour or simulated 24-hour samples and were in units of picocuries per sample or picocuries per 24 hours. Therefore, all results were treated as picocuries per day. The ^{234}U, ^{235}U, and ^{238}U activities for a given SAMPLE_ID were summed and used as the total uranium activity. All data were used.

3.8 CESIUM-137

The TBL_NIOSH_REPORT_2007_V2 table in the in vivo database [ORAUT 2007] was queried to identify all records with a nuclide type of "Cs-137," organ type of "Whole Body," collection dates that ranged from the beginning of 1970 through the end of 2004, and count reason other than "new hire." The count_date, zno, and abundance_nCi fields were extracted and exported to a spreadsheet. The zno field was used as the employee identifier and the abundance_nCi field was used as the value of the whole-body count.

Records with no abundance value were entered with an abundance equal to the MDA based on the assumption that the result was less than the MDA and because the MDA was typically less than the positive values recorded.

Due to the small number of distinct records (301), the statistical analysis was performed in 5- or 4-year blocks: 1970 to 1974, 1975 to 1979, 1980 to 1984, 1985 to 1989, and 1990 to 1993. Table A-6 in Attachment A lists the statistical analysis results for ^{137}Cs. Insufficient data were available for after 1993 to permit analysis.

4.0 INTAKE MODELING

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

4.1 ASSUMPTIONS

Each result used in the intake calculations was assumed to have a normal distribution. A uniform absolute error of 1 was applied to all results, thus assigning the same weight to each result. IMBA requires results to be in units of activity per day; therefore, all urinalysis results were normalized as needed to 24-hour samples using 1,400 mL (the volume of urine excreted by Reference Man in a 24-hour period).

Because of the nature of work at LANL, intakes could have been either chronic or acute. However, a series of acute intakes can be approximated as a chronic intake. Therefore, intakes were assumed to be chronic and were assumed to occur through inhalation with a default breathing rate of 1.2 m^3/hr and a 5-µm activity median aerodynamic diameter particle size distribution.

For intake modeling purposes, 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 considered in this analysis 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 and the Internal Dosimetry Tool (IDOT) software were used to fit the bioassay results to a series of inhalation intakes. Data from 1945 through 2008 were fit as a series of chronic intakes.

The intake assumptions were based on patterns observed 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 from 1945 through 2008 were divided independently into multiple chronic intake periods for each radionuclide.

4.3 MATERIAL TYPES

ORAUT-TKBS-0010-5, *Los Alamos National Laboratory – Occupational Internal Dose*, discusses LANL internal dosimetry data for the dose reconstructor and includes guidance for the appropriate use of that information. Workers at LANL had the potential to receive intakes of ^{238}Pu, ^{239}Pu, uranium, polonium, tritium, and cesium. Site-specific internal dosimetry information for other radionuclides is rare or not available [ORAUT 2013].

4.3.1 Tritium

The dataset discussed in the previous section for tritium was condensed into a file for the period from January 1, 1950, to December 31, 2008, with the following columns:

Z Number	ID Number	Name	Days Post 1/1/1950	Conc uCi/L	MDA uCi/L

Duplicate records (i.e., lines that had all six fields the same as another line) were deleted to leave unique records. The doses were calculated for each individual and each calendar year from 1950 to 2008.

Workers who had only a single urine result of <MDA µCi/L for a given period were not included in the calculations of the dose distribution for that period because they were not considered part of the routine monitoring program. All remaining concentrations of <MDA µCi/L were replaced with one-half of the appropriate MDA. Any person with a single measurement in a period was assigned a second measurement 40 days later of one-half of the MDA of the first measurement.

The protocol given in ORAUT-OTIB-0011, *Technical Information Bulletin: Tritium Calculated and Missed Dose Estimates*, was used to calculate the dose for each individual with the following rules concerning the elapsed time between consecutive samples [ORAUT 2004b]:

- Type 1 calculations were performed for samples separated by 40 or fewer days.
- Type 3 calculations were performed if there were no other samples within 90 days of a sample.
- Type 2 calculations were performed in all other situations.

The doses for a period were plotted on a lognormal probability plot and the typical parameters [geometric mean (GM), geometric standard deviation (GSD), and R^2] were determined from a linear regression. The plotting positions were calculated with $i/n - 1/(2n)$ convention specified in ORAUT-PROC-0095 [ORAUT 2006].

4.3.2 Plutonium-238

Plutonium-238 urinalysis results were analyzed with IMBA using type M and S materials to derive intake rates for 1968 to 2008. Note that absorption type SS is not applicable to ^{238}Pu [ORAUT 2020].

Plutonium-238 Type M
The solid lines in Figures B-1 to B-8 and B-9 to B-15 show the individual fits to the 50th- and 84th-percentile excretion rates, respectively, for type M materials. Figures B-16 and B-17 show the 50th- and 84th-percentile predicted excretion rates, respectively, from all type M intakes. Table B-1 lists the 50th- and 84th-percentile intake rates along with the associated GSDs determined from ^{238}Pu urinalysis.

Plutonium-238 Type S
The solid lines in Figures B-18 to B-24 and B-25 to B-31 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 B-32 and B-33 show the 50th- and 84th-percentile predicted excretion rates, respectively, from all type S intakes. Table B-2 lists the 50th- and 84th-percentile intake rates along with the associated GSDs determined from ^{238}Pu urinalysis.

4.3.3 Plutonium-239

Plutonium-239 urinalysis results were analyzed with IMBA and IDOT using type M, S, and SS materials to derive intake rates for 1944 to 2008.

Plutonium-239 Type M Urinalysis
The solid lines in Figures B-34 to B-42 and B-43 to B-51 show the individual fits to the 50th- and 84th-percentile excretion rates, respectively, for type M materials. The same intake periods were applied for both percentiles because the values followed a similar pattern. Figures B-52 and B-53 show the 50th- and 84th-percentile predicted excretion rates, respectively, from all type M intakes. Table B-3 lists the 50th- and 84th-percentile intake rates along with the associated GSDs determined from ^{239}Pu urinalysis.

Plutonium-239 Type S Urinalysis
The solid lines in Figures B-54 to B-62 and B-63 to B-71 show the individual fits to the 50th- and 84th-percentile excretion rates, respectively, for type S materials. Figures B-72 and B-73 show the 50th- and 84th-percentile predicted excretion rates, respectively, from all type S intakes. Table B-4 lists the 50th- and 84th-percentile intake rates along with the associated GSDs determined from ^{239}Pu urinalysis.

Plutonium-239 Type S Lung Counts
The solid lines in Figures B-74 to B-78 and B-79 to B-83 show the individual fits to the 50th- and 84th-percentile lung burdens, respectively, for type S materials. The same intake periods were applied for both percentiles as the values followed a similar pattern. Table B-5 lists the 50th- and 84th-percentile intake rates along with the associated GSDs determined from ^{239}Pu lung burdens.

Plutonium-239 Type SS Urinalysis
The solid lines in Figures B-84 to B-92 and B-93 to B-101 show the individual fits to the 50th- and 84th-percentile excretion rates, respectively, for type SS materials. Figures B-102 and B-103 show the 50th- and 84th-percentile predicted excretion rates, respectively, from all type SS intakes. Table B-6 lists the 50th- and 84th-percentile intake rates along with the associated GSDs determined from ^{239}Pu urinalysis.

Plutonium-239 Type SS Lung Counts
The solid lines in Figures B-104 to B-108 and B-109 to B-113 show the individual fits to the 50th- and 84th-percentile lung burdens, respectively, for type SS materials. The same intake periods were applied for both percentiles as the values followed a similar pattern. Table B-7 lists the 50th- and 84th-percentile intake rates along with the associated GSDs determined from ^{239}Pu lung burdens.

4.3.4 Polonium

Polonium urinalysis results were analyzed with IMBA using type F and M materials to derive intake rates for 1947 to 1956.

Polonium Type F
The solid lines in Figures B-114 and B-115 show the fit to the 50th- and 84th-percentile excretion rates, respectively, for type F materials. Table B-8 lists the 50th- and 84th-percentile intake rates along with the associated GSDs determined from the polonium urinalysis.

Polonium Type M
The solid lines in Figures B-116 and B-117 show the fit to the 50th- and 84th-percentile excretion rates, respectively, for type M materials. Table B-9 lists the 50th- and 84th-percentile intake rates along with the associated GSDs determined from the polonium urinalysis.

August 1, 1955, Incident
The bioassay data for the seven individuals positively identified as having been involved in this incident were analyzed separately using standard dose reconstruction bioassay fitting methods assuming both type F and type M material types. Figures B-118 through B-124 and B-125 through B-131 show the fits for each individual for type F and M material types respectively. Table B-10 lists the calculated intakes from these fits.

1944 to 1946
Polonium bioassay data to evaluate co-exposure intakes is not available for this period. To approximate intakes during this period, which falls within a Special Exposure Cohort (SEC) definition, the intake rate for each absorption type for 1947 to 1949 was applied.

4.3.5 Uranium

Because the uranium isotopes present at LANL 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 Los Alamos National Laboratory for relatively short periods, each chronic intake was fit independently using only the bioassay results from the single intake period for type S materials. This method results in an overestimate of intakes for exposures that extended through multiple assumed intake periods. Only the results in the intake period were selected for use in the fitting of each period. Excluded results are shown in light gray in the figures. For type M and F materials, this approach was not used.

Uranium Type F
The solid lines in Figures B-132 and B-133 show the fit to the 50th- and 84th-percentile excretion rates, respectively, for type F materials. Table B-11 lists the 50th- and 84th-percentile intake rates along with the associated GSDs determined from the uranium urinalysis.

Uranium Type M
The solid lines in Figures B-134 and B-135 show the fit to the 50th- and 84th-percentile excretion rates, respectively, for type M materials. Table B-12 lists the 50th- and 84th-percentile intake rates along with the associated GSDs determined from the uranium urinalysis.

Uranium Type S
The solid lines in Figures B-136 to B-142 and B-143 to B-149 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 B-150 and B-151 show the 50th- and 84th-percentile predicted excretion rates, respectively, from all type S intakes. Table B-13 lists the 50th- and 84th-percentile intake rates along with the associated GSDs determined from the uranium urinalysis.

1947 to 1949
Uranium bioassay data to evaluate co-exposure intakes is not available for this period. To approximate intakes during this period, which falls within a SEC definition, the intake rate for each absorption type for 1950 to 1955 was applied.

4.3.6 Cesium-137

Cesium whole-body count results were analyzed with IMBA using type F materials to derive intake rates for 1970 through 1993. The solid lines in Figures B-152 and B-153 show the fit to the 50th- and 84th-percentile excretion rates, respectively, for type F materials. Table B-14 lists the 50th- and

84th-percentile intake rates along with the associated GSDs determined from the cesium whole-body counts.

5.0 ASSIGNING INTAKES AND DOSES

This section describes the derived intake rates and provides guidance for assigning doses.

5.1 INTAKE RATE SUMMARY

For the calculation of doses to individuals from bioassay data, a 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 co-exposure data. Therefore, a GSD of at least 3 was assigned for each of the intake periods. The GSDs for different intake periods have been conservatively adjusted for consistency between intake periods for calculational efficiency.

The following subsections list the intake rates that should be used for each radionuclide and the period of applicability of each intake rate except that for tritium. For tritium, the actual dose that should be used is provided.

5.2 TRITIUM

Table 5-1 lists the tritium doses and GSDs to be used for each year of potential tritium exposure.

Table 5-1. Tritium annual doses (mrem) and GSDs.

Year	Dose	GSD
1950	33	7.2
1951	36	5.9
1952	25	4.2
1953	26	6.7
1954	16	6.2
1955	43	6.5
1956	33	6.9
1957	35	6.9
1958	26	5.7
1959	22	5.5
1960	27	5.2
1961	20	4.7
1962	17	4.7
1963	18	3.7
1964	17	3.5
1965	18	3.5
1966	19	4.2
1967	23	6.0
1968	16	4.6
1969	21	5.0
1970	25	7.0
1971	16	4.9
1972	14	5.4
1973	16	5.3
1974	25	6.7
1975	19	6.2
1976	13	4.1
1977	20	5.5
1978	20	5.2
1979	12	4.9
1980	15	4.1
1981	17	4.1
1982	21	4.5
1983	18	4.8
1984	16	3.4
1985	18	3.3
1986	21	3.8
1987	17	4.3
1988	7	4.4
1989	7	3.5
1990	6	3.2
1991	2	3.0
1992	5	3.5
1993	6	3.4
1994	3	3.0
1995	5	3.0
1996	5	3.0
1997	4	3.0
1998	7	3.0
1999	4	3.0
2000	9	4.1
2001	6	3.0
2002	6	3.5
2003	5	3.3
2004	3	3.0
2005	3	3.0
2006	4	3.0
2007	4	3.0
2008	6	3.3

5.3 PLUTONIUM-238

Intakes of ^{238}Pu should be assigned if the worker is known or believed to have been exposed to heat source plutonium. For heat source plutonium, absorption type SS is not applicable. If the worker was exposed only to weapons-grade plutonium (^{239}Pu), the intake of ^{238}Pu should be based on the isotope mixture for weapons-grade ^{239}Pu and the ^{239}Pu intakes given in Section 5.4 and not on the intakes in this section. Table 5-2 lists the ^{238}Pu intakes and associated GSDs to be used for each year of potential ^{238}Pu exposure for both type M and type S material. Absorption type SS is not applicable to ^{238}Pu [ORAUT 2020].

Table 5-2. Plutonium-238 type M and S intake rates (pCi/d).

Start	End	Type M 50th percentile	Type M GSD	Type S 50th percentile	Type S GSD
01/01/1968	12/31/1971	1.8	5.63	43	5.74
01/01/1972	12/31/1972	14.	3.13	765	3.13
01/01/1973	12/31/1974	2.0	4.31	72	4.17
01/01/1975	12/31/1977	0.67	3.59	5.2	8.47
01/01/1978	12/31/1981	0.32	7.56	5.2	8.47
01/01/1982	12/31/1988	0.084	8.73	1.8	8.47
01/01/1989	12/31/1993	0.44	4.31	9.7	4.17
01/01/1994	12/31/2008	0.048	6.82	0.72	6.58

5.4 PLUTONIUM-239

Intakes of ^{239}Pu should be assigned if the worker is known or believed to have been exposed to weapons-grade plutonium. For weapons-grade plutonium, absorption type SS must be considered. If the worker was exposed only to heat source plutonium (^{238}Pu), the plutonium intake should be based on the ^{238}Pu intakes in Section 5.3 and not on the intakes in this section. Tables 5-3 through 5-5 list the ^{239}Pu intakes and associated GSDs to be used for each year of potential ^{239}Pu exposure for material types M, S, and SS respectively. Intakes of the associated isotopes as given in Table 5-9 of the LANL internal technical basis document [ORAUT 2013] must also be assigned.

Table 5-3. Plutonium-239 type M intake rates (pCi/d).

Start	End	50th percentile	GSD
01/01/1944	12/31/1945	248	5.05
01/01/1946	12/31/1946	95	6.24
01/01/1947	12/31/1953	10	5.16
01/01/1954	12/31/1954	3.1	17.2
01/01/1955	12/31/1956	3.1	12.4
01/01/1957	12/31/1966	0.38	12.4
01/01/1967	12/31/1972	3.3	4.81
01/01/1973	12/31/1975	1.5	6.21
01/01/1976	12/31/1993	0.16	6.83
01/01/1994	12/31/2008	0.013	12.2

Table 5-4. Plutonium-239 type S intake rates (pCi/d).

Start	End	50th percentile	GSD
01/01/1944	12/31/1945	8,651	5.05
01/01/1946	12/31/1946	5,125	6.24
01/01/1947	12/31/1953	200	4.87
01/01/1954	12/31/1954	88	11.12
01/01/1955	12/31/1956	88	15.3
01/01/1957	12/31/1966	6.3	11.91
01/01/1967	12/31/1968	73	4.62
01/01/1969	12/31/1971	27.66	4.50
01/01/1972	12/31/1974	29.43	4.50
01/01/1975	12/31/1975	41	6.34
01/01/1976	12/31/1993	2.3	6.34
01/01/1994	12/31/2008	0.14	12.8

Table 5-5. Plutonium-239 type SS intake rates (pCi/d).

Start	End	50th percentile	GSD
01/01/1944	12/31/1945	51,900	5.05
01/01/1946	12/31/1946	11,200	6.21
01/01/1947	12/31/1953	1,460	5.13
01/01/1954	12/31/1954	437	17.14
01/01/1955	12/31/1956	437	12.06
01/01/1957	12/31/1966	52	12.21
01/01/1967	12/31/1968	452	4.82
01/01/1969	12/31/1971	24.4	4.30
01/01/1972	12/31/1974	25.9	4.52
01/01/1975	12/31/1975	214	6.21
01/01/1976	12/31/1977	21.1	6.82
01/01/1978	12/31/1979	17.1	5.19
01/01/1980	12/31/1993	21.1	6.82
01/01/1994	12/31/2008	1.69	11.83

5.5 POLONIUM

Table 5-6 lists the polonium intakes and associated GSDs to be used for each year of potential polonium exposure.

Table 5-6. Polonium type F and M intake rates (pCi/d).

Start	End	Type F 50th percentile	Type F GSD	Type M 50th percentile	Type M GSD
01/01/1944	12/31/1946	592.8[a]	6.96	2013[a]	7.01
01/01/1947	03/31/1949	592.8	6.96	2013	7.01
04/01/1949	12/31/1956	592.8	3.00	2013	3.00

a. Intakes for 1944 through 1946 are based on the 1947 to March 31, 1949, intakes.

Dose reconstruction for individuals who were involved in the polonium incident that occurred at or near the beginning of August 1955 and who do not have relevant bioassay data, should be assigned the intakes in Table 5-7. The most favorable to claimant material type should be used. This intake should be applied only to individuals for whom there is evidence or reason to believe that they were involved in this incident.

Table 5-7. August 1, 1955, incident type F and M polonium intakes (pCi).

Date	Type F 50th percentile	Type F GSD	Type M 50th percentile	Type M GSD
08/01/1955	2.8E6	3.00	1.2E7	3.00

5.6 URANIUM

Table 5-8 lists the uranium intakes and associated GSDs to be used for each year of potential uranium exposure.

Table 5-8. Uranium types F, M, and S intake rates (pCi/d).

Start	End	Type F 50th percentile	Type F GSD	Type M 50th percentile	Type M GSD	Type S 50th percentile	Type S GSD
01/01/1947	12/31/1949	21.3[a]	3.36	88.7[a]	3.36	1,520[a]	3.24
01/01/1950	12/31/1955	21.3	3.36	88.7	3.36	1,520	3.24
01/01/1956	12/31/1957	5.36	3.36	16.0	3.36	656	3.24
01/01/1958	12/31/1965	1.98	4.81	7.95	4.90	141	4.71
01/01/1966	12/31/1973	0.909	6.84	3.53	7.03	59.3	6.59
01/01/1974	12/31/1982	0.227	11.31	1.03	10.6	19.7	9.27
01/01/1983	12/31/1989	1.53	4.81	6.29	4.90	105	4.44
01/01/1990	12/31/2000	0.201	4.03	0.756	4.06	11.0	4.57
01/01/2001	12/31/2001	1.019	3.00	4.70	3.00	92.0	3.00
01/01/2002	12/31/2008	0.201	4.03	0.756	4.06	11.0	4.57

a. Intakes for 1947 through 1949 are based on the 1950 through 1955 intakes.

5.7 CESIUM-137

Table 5-9 lists the cesium intakes and associated GSDs to be used for each year of potential cesium exposure.

Table 5-9. Type F ^{137}Cs intake rates (pCi/d).

Start	End	Type F 50th percentile	Type F GSD
01/01/1970	12/31/1974	185.5	3.00
01/01/1975	12/31/1979	130.7	3.28
01/01/1980	12/31/1984	69.47	3.00
01/01/1985	12/31/1989	47.36	3.00
01/01/1990	12/31/1993	30.16	3.00

6.0 ATTRIBUTIONS AND ANNOTATIONS

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

REFERENCES

Hickman AW, Griffith WC, Roessler GS, and Guilmette RA [1995]. Application of a canine ^{238}Pu biokinetics/dosimetry model to human bioassay data. Health Phys *68*(3):359–370. [SRDB Ref ID: 167452]

ICRP [1995]. Dose coefficients for intakes of radionuclides by workers. ICRP Publication 68. Ann ICRP *34*(4). [SRDB Ref ID: 22731]

Inkret B, Miller G [1995]. On the front lines: plutonium workers past and present share their experiences. Los Alamos Science No. 23. Los Alamos National Laboratory, Los Alamos, NM: University of California. [SRDB Ref ID: 43568]

James AC, Filipy RE, Russell JJ, and McInroy JF [2003]. USTUR case 0259 whole body donation: a comprehensive test of the current ICRP models for the behavior of inhaled $^{238}PuO_2$ ceramic particles. Health Phys *84*(1). [SRDB Ref ID: 77731]

ORAUT [2004a]. Coworker data exposure profile development. ORAUT-PLAN-0014 Rev. 00. Oak Ridge, TN: Oak Ridge Associated Universities Team. November 24. [SRDB Ref ID: 166559]

ORAUT [2004b]. Technical information bulletin: tritium calculated and missed dose estimates. ORAUT-OTIB-0011 Rev. 00. Oak Ridge, TN: Oak Ridge Associated Universities Team. June 29. [SRDB Ref ID: 19430]

ORAUT [2005]. Analysis of coworker bioassay data for internal dose assignment. ORAUT-OTIB-0019 Rev. 01. Oak Ridge, TN: Oak Ridge Associated Universities Team. October 7. [SRDB Ref ID: 19438]

ORAUT [2006]. Generating summary statistics for coworker bioassay data. ORAUT-PROC-0095 Rev. 00. Oak Ridge, TN: Oak Ridge Associated Universities Team. June 5. [SRDB Ref ID: 73397]

ORAUT [2007]. LANL in vivo data. Database. Oak Ridge, TN: Oak Ridge Associated Universities Team. October 8. [SRDB Ref ID: 175106]

ORAUT [2009a]. LANL co-worker data Rev. 1. Database. Oak Ridge, TN: Oak Ridge Associated Universities Team. February. [SRDB Ref ID: 175107]

ORAUT [2009b]. LANL in vitro dataset February 2009. Database. Oak Ridge, TN: Oak Ridge Associated Universities Team. February. [SRDB Ref ID: 175108]

ORAUT [2013]. Los Alamos National Laboratory – occupational internal dose. ORAUT-TKBS-0010-5 Rev. 02. Oak Ridge, TN: Oak Ridge Associated Universities Team. April 18. [SRDB Ref ID: 124166]

ORAUT [2017]. Mound Site – occupational internal dose. ORAUT-TKBS-0016-5 Rev. 03. Oak Ridge, TN: Oak Ridge Associated Universities Team. March 3. [SRDB Ref ID: 165903]

ORAUT [2020]. Estimating doses for plutonium strongly retained in the lung. ORAUT-OTIB-0049 Rev. 02. Oak Ridge, TN: Oak Ridge Associated Universities Team. September 1. [SRDB Ref ID: 178329]

Various authors [1976–1980]. Chelation DTPA data for DOE Employees - REAC_TS_DTPA_210.0001_Charlie Arnold. [SRDB Ref ID: 71439]

ATTACHMENT A
CO-EXPOSURE DATA TABLES

LIST OF TABLES

ATTACHMENT A
CO-EXPOSURE DATA TABLES

Table A-1. Statistical summary of ^{238}Pu urinary excretion rates (pCi/d), 1968 to 2008.

Effective bioassay date	GM (50th)	GM × GSD (84th)
07/01/1968	0.00823	0.0339
07/01/1969	0.00486	0.0332
07/01/1970	0.00147	0.0062
07/01/1971	0.00815	0.0466
07/01/1972	0.02683	0.0840
07/01/1973	0.00581	0.0308
07/01/1974	0.00571	0.0214
07/01/1975	0.00261	0.0154
07/01/1976	0.00224	0.0164
07/01/1977	0.00232	0.0182
07/01/1978	0.00101	0.0143
07/01/1979	0.00162	0.0118
07/01/1980	0.00126	0.0091
07/01/1981	0.00124	0.0118
07/01/1982	0.00010	0.0027
07/01/1983	0.00010	0.0019
07/01/1984	0.00011	0.0026
07/01/1985	0.00028	0.0038
07/01/1986	0.00079	0.0053
07/01/1987	0.00056	0.0047
07/01/1988	0.00072	0.0048
07/01/1989	0.0017	0.0079
07/01/1990	0.0021	0.0081
07/01/1991	0.0025	0.0091
07/01/1992	0.0022	0.0079
07/01/1993	0.0016	0.0078
07/01/1994	0.0006	0.0046
07/01/1995	0.0003	0.0049
07/01/1996	0.0006	0.0035
07/01/1997	0.0004	0.0035
07/01/1998	0.0004	0.0029
07/01/1999	0.0002	0.0013
07/01/2000	0.0002	0.0028
07/01/2001	0.0002	0.0017
07/01/2002	0.0002	0.0012
07/01/2003	0.0002	0.0011
07/01/2004	0.0003	0.0016
07/01/2005	0.0005	0.0022
07/01/2006	0.0007	0.0031
07/01/2007	0.0004	0.0042
07/01/2008	0.0005	0.0029

ATTACHMENT A
CO-EXPOSURE DATA TABLES

Table A-2. Statistical summary of ^{239}Pu urinary excretion rates (pCi/d), 1945 to 2008.

Effective bioassay date	GM (50th)	GM × GSD (84th)
07/01/1945	0.8332	4.2106
07/01/1946	0.1793	1.1191
07/01/1947	0.1065	0.4876
07/01/1948	0.0571	0.4084
07/01/1949	0.0301	0.2028
07/01/1950	0.0434	0.2118
07/01/1951	0.0574	0.2595
07/01/1952	0.0628	0.4073
07/01/1953	0.0703	0.4009
07/01/1954	0.0153	0.1779
07/01/1955	0.0119	0.0978
07/01/1956	0.0115	0.0979
07/01/1957	0.0042	0.052
07/01/1958	0.0040	0.0537
07/01/1959	0.0020	0.0322
07/01/1960	0.0022	0.0306
07/01/1961	0.0019	0.0201
07/01/1962	0.0016	0.0232
07/01/1963	0.002	0.0306
07/01/1964	0.0026	0.0265
07/01/1965	0.0023	0.0253
07/01/1966	0.0037	0.0380
07/01/1967	0.0066	0.0471
07/01/1968	0.0093	0.0584
07/01/1969	0.0145	0.0814
07/01/1970	0.0066	0.0422
07/01/1971	0.0157	0.1008
07/01/1972	0.0341	0.1136
07/01/1973	0.0083	0.0446
07/01/1974	0.0061	0.0350
07/01/1975	0.0037	0.0265
07/01/1976	0.0022	0.0201
07/01/1977	0.0023	0.0292
07/01/1978	0.0012	0.0157
07/01/1979	0.0011	0.0116
07/01/1980	0.0018	0.0154
07/01/1981	0.0014	0.0137
07/01/1982	0.0003	0.0057
07/01/1983	0.0006	0.0093
07/01/1984	0.0003	0.0053
07/01/1985	0.0017	0.0111
07/01/1986	0.0013	0.0108
07/01/1987	0.0013	0.0084
07/01/1988	0.0012	0.0071
07/01/1989	0.0017	0.0077
07/01/1990	0.0021	0.0083
07/01/1991	0.0023	0.0084
07/01/1992	0.0017	0.0076
07/01/1993	0.0015	0.0083
07/01/1994	0.0004	0.0045
07/01/1995	0.0003	0.0043
07/01/1996	0.0007	0.0040
07/01/1997	0.0002	0.0038
07/01/1998	0.0002	0.0026
07/01/1999	0.00010	0.00120
07/01/2000	0.00009	0.00136
07/01/2001	0.00004	0.00094
07/01/2002	0.00003	0.00064
07/01/2003	0.00002	0.00034
07/01/2004	0.00002	0.00041
07/01/2005	0.00004	0.00049
07/01/2006	0.00002	0.00035
07/01/2007	0.00004	0.00051
07/01/2008	0.00006	0.00068

Table A-3. Statistical summary of ^{239}Pu lung burdens (pCi), 1969 to 1979.

Measurement data date range	Effective bioassay date	GM (50th)	GM × GSD (84th)
1969–1970	07/01/1970	473	2,033
1971–1974	07/01/1973	504	2,268
1975	07/01/1975	3,712	6,922
1976–1977	01/01/1977	1,221	4,319
1978–1979	01/01/1979	248	1,290

ATTACHMENT A
CO-EXPOSURE DATA TABLES

Table A-4. Statistical summary of polonium urinary excretion rates (pCi/d), 1947 to 1956.

Effective bioassay date	GM (50th)	GM × GSD (84th)
02/15/1947	54.51	219.82
05/15/1947	76.59	343.47
08/15/1947	25.15	240.80
11/15/1947	50.89	200.17
02/15/1948	48.88	252.94
05/15/1948	52.76	294.13
08/15/1948	98.45	507.63
11/15/1948	53.79	189.88
02/15/1949	79.84	364.04
05/15/1949	49.10	148.29
08/15/1949	32.53	86.43
11/15/1949	29.78	120.96
02/15/1950	20.90	63.53
05/15/1950	41.23	90.29
08/15/1950	25.93	79.71
11/15/1950	31.89	119.93
02/15/1951	42.18	115.02
05/15/1951	33.14	111.07
08/15/1951	41.25	144.68
11/15/1951	36.96	125.69
02/15/1952	45.76	142.02
05/15/1952	32.36	157.48
08/15/1952	27.83	105.86
11/15/1952	27.15	84.03
02/15/1953	76.61	299.93
05/15/1953	33.87	127.48
08/15/1953	51.79	138.64
11/15/1953	65.50	225.54
02/15/1954	43.99	122.20
05/15/1954	46.75	120.15
08/15/1954	39.35	89.36
11/15/1954	34.75	76.77
02/15/1955	33.08	77.69
05/15/1955	16.99	52.10
08/15/1955	55.54	200.24
11/15/1955	30.19	54.61
07/01/1956	14.44	52.33

ATTACHMENT A
CO-EXPOSURE DATA TABLES

Table A-5. Statistical summary of uranium urinary excretion rates (pCi/d), 1950 to 2008.

Effective bioassay date	GM (50th)	GM × GSD (84th)
07/01/1950	6.941	24.394
07/01/1951	5.035	15.898
07/01/1952	6.764	19.354
07/01/1953	3.979	11.575
07/01/1954	5.656	20.846
07/01/1955	6.536	18.864
07/01/1956	1.447	5.702
07/01/1957	1.518	4.324
07/01/1958	0.410	2.087
07/01/1959	0.090	1.110
07/01/1960	0.083	0.660
07/01/1961	0.206	1.498
07/01/1962	0.723	4.006
07/01/1963	0.471	2.691
07/01/1964	1.009	3.153
07/01/1965	0.722	3.779
07/01/1966	0.467	2.249
07/01/1967	0.356	3.554
07/01/1968	0.065	0.919
07/01/1969	0.204	1.287
07/01/1970	0.224	1.370
07/01/1971	0.001	0.044
07/01/1972	0.150	1.046
07/01/1973	0.233	1.501
07/01/1974	0.070	0.876
07/01/1975	0.080	0.784
07/01/1976	0.040	0.529
07/01/1977	0.023	0.391
07/01/1978	0.034	0.513
07/01/1979	0.055	0.590
07/01/1980	0.002	0.054
07/01/1981	0.003	0.060
07/01/1982	0.016	0.274
07/01/1983	0.438	2.136
07/01/1984	0.410	1.788
07/01/1985	0.215	1.045
07/01/1986	0.482	1.723
07/01/1987	0.286	1.893
07/01/1988	0.348	1.543
07/01/1989	0.317	1.351
07/01/1990	0.030	0.240
10/01/1991	0.058	0.231
07/01/1992	0.024	0.168
07/01/1993	0.033	0.223
07/01/1994	0.074	0.346
07/01/1995	0.084	0.399
07/01/1996	0.088	0.366
07/01/1997	0.072	0.292
07/01/1998	0.070	0.291
07/01/1999	0.064	0.307
07/01/2000	0.066	0.383
07/01/2001	0.285	0.746
07/01/2002	0.070	0.231
07/01/2003	0.053	0.164
07/01/2004	0.059	0.197
07/01/2005	0.114	0.312
07/01/2006	0.078	0.230
07/01/2007	0.103	0.288
07/01/2008	0.074	0.216

Table A-6. Statistical summary of cesium whole-body counts (pCi), 1970 to 1993.

Measurement data date range	Effective bioassay date	GM (50th)	GM × GSD (84th)
1970–1974	07/01/1972	12,740	37,156
1975–1979	07/01/1977	9,013	29,573
1980–1984	07/01/1982	4,799	9,442
1985–1989	01/01/1987	3,277	6,896
1990–1993	01/01/1992	2,089	4,354

ATTACHMENT B
CO-EXPOSURE DATA FIGURES

LIST OF TABLES

LIST OF FIGURES

ATTACHMENT B
CO-EXPOSURE DATA FIGURES

ATTACHMENT B
CO-EXPOSURE DATA FIGURES

ATTACHMENT B
CO-EXPOSURE DATA FIGURES

ATTACHMENT B
CO-EXPOSURE DATA FIGURES

ATTACHMENT B
CO-EXPOSURE DATA FIGURES

ATTACHMENT B
CO-EXPOSURE DATA FIGURES

ATTACHMENT B
CO-EXPOSURE DATA FIGURES

ATTACHMENT B
CO-EXPOSURE DATA FIGURES

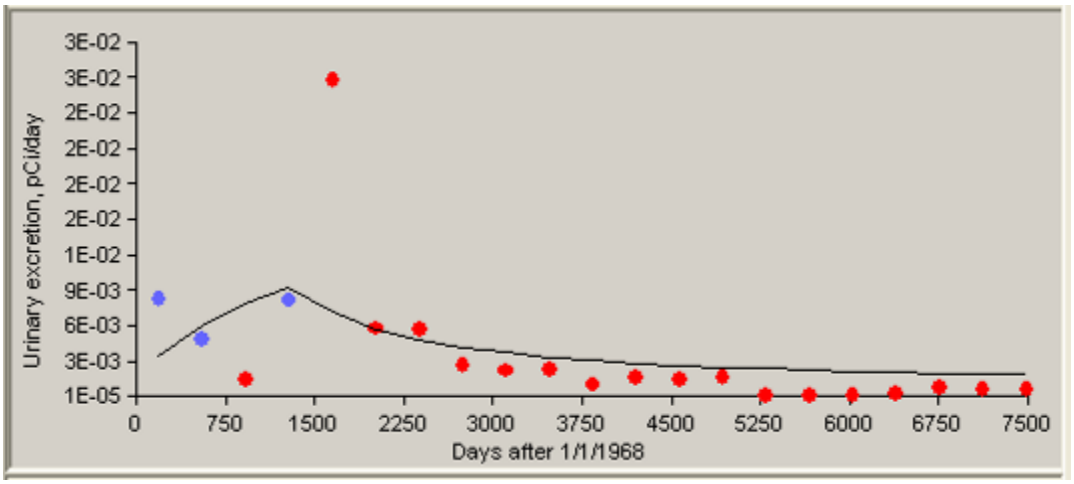

Figure B-1. Predicted ^{238}Pu bioassay results calculated using IMBA-derived ^{238}Pu intake rates (line) compared with bioassay results (dots), 1968 to 1971, 50th percentile, type M.

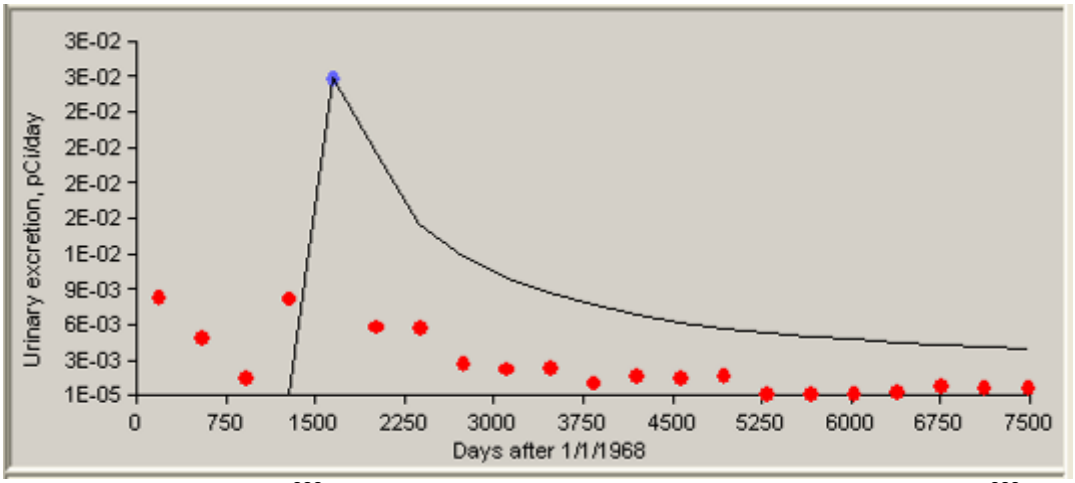

Figure B-2. Predicted ^{238}Pu bioassay results calculated using IMBA-derived ^{238}Pu intake rates (line) compared with bioassay results (dots), 1972, 50th percentile, type M.

ATTACHMENT B
CO-EXPOSURE DATA FIGURES

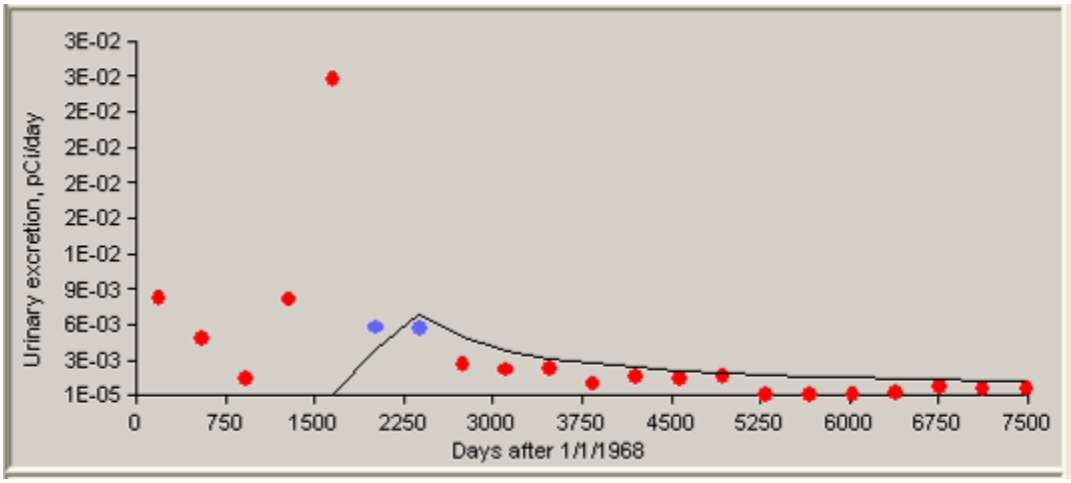

Figure B-3. Predicted ^{238}Pu bioassay results calculated using IMBA-derived ^{238}Pu intake rates (line) compared with bioassay results (dots), 1973 to 1974, 50th percentile, type M.

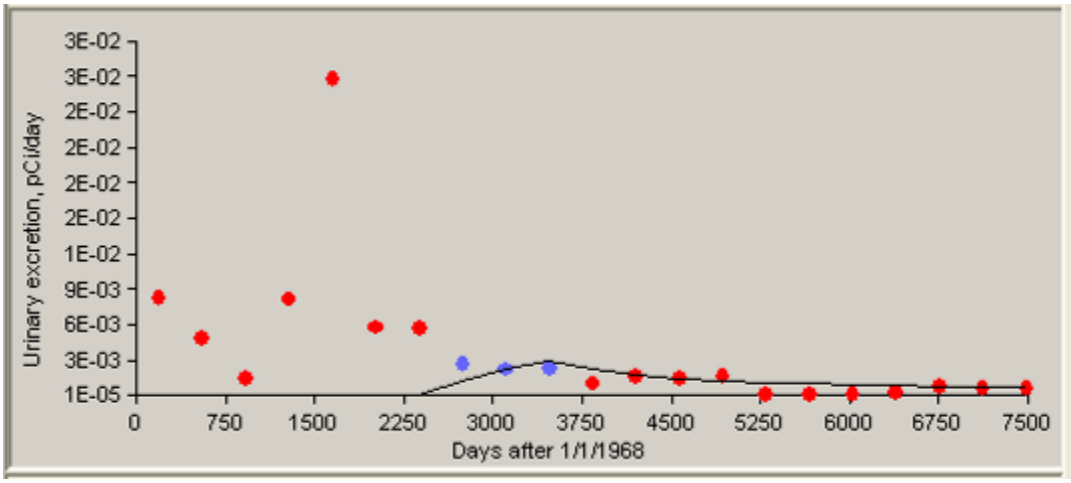

Figure B-4. Predicted ^{238}Pu bioassay results calculated using IMBA-derived ^{238}Pu intake rates (line) compared with bioassay results (dots), 1975 to 1977, 50th percentile, type M.

ATTACHMENT B
CO-EXPOSURE DATA FIGURES

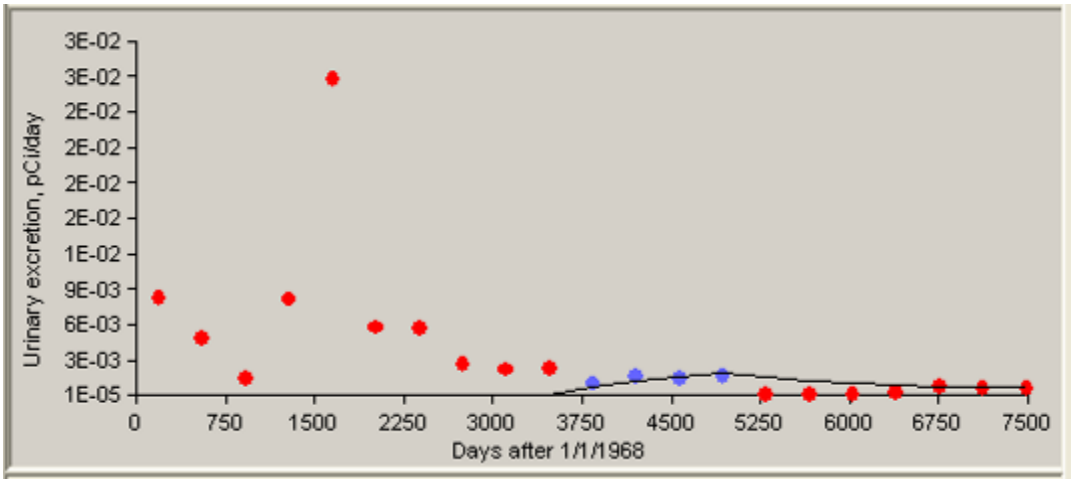

Figure B-5. Predicted ^{238}Pu bioassay results calculated using IMBA-derived ^{238}Pu intake rates (line) compared with bioassay results (dots), 1978 to 1981, 50th percentile, type M.

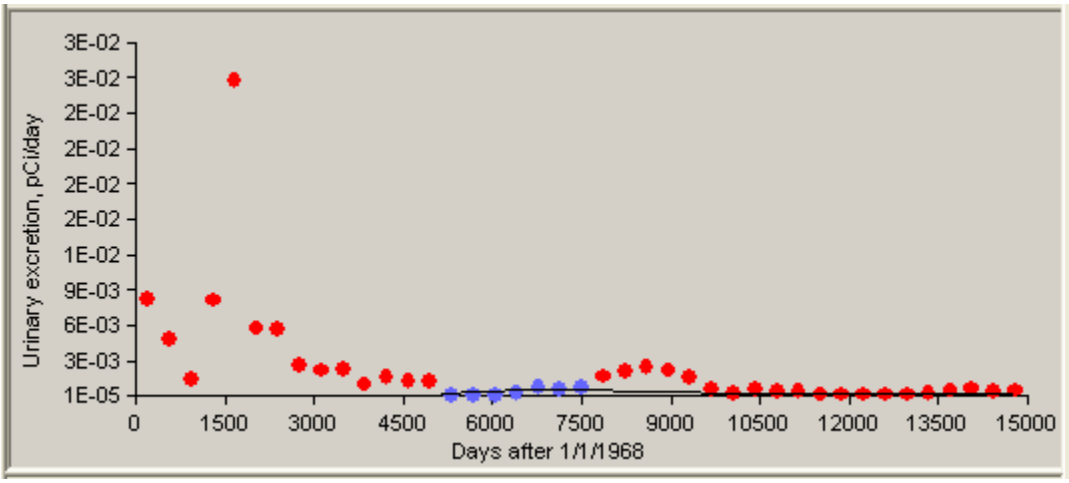

Figure B-6. Predicted ^{238}Pu bioassay results calculated using IMBA-derived ^{238}Pu intake rates (line) compared with bioassay results (dots), 1982 to 1988, 50th percentile, type M.

ATTACHMENT B
CO-EXPOSURE DATA FIGURES

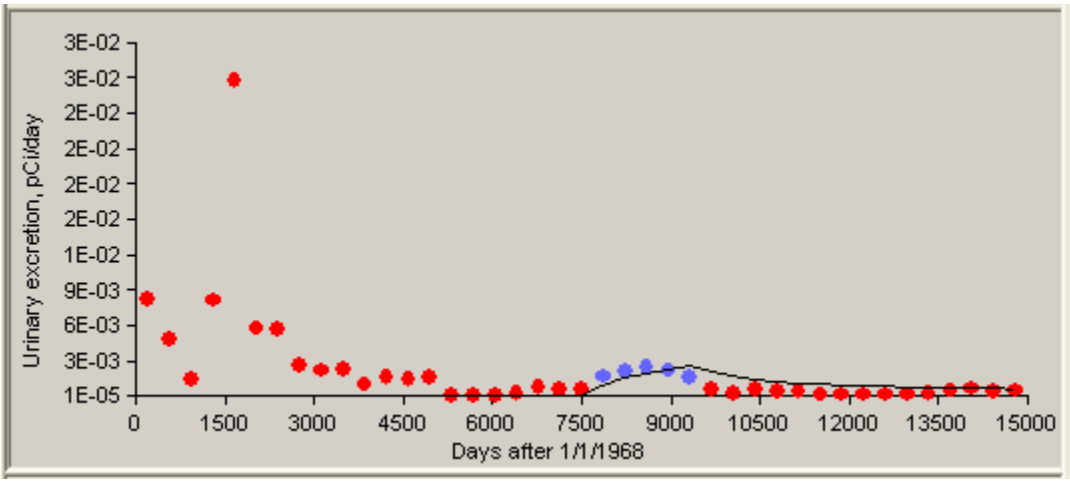

Figure B-7. Predicted ^{238}Pu bioassay results calculated using IMBA-derived ^{238}Pu intake rates (line) compared with bioassay results (dots), 1989 to 1993, 50th percentile, type M.

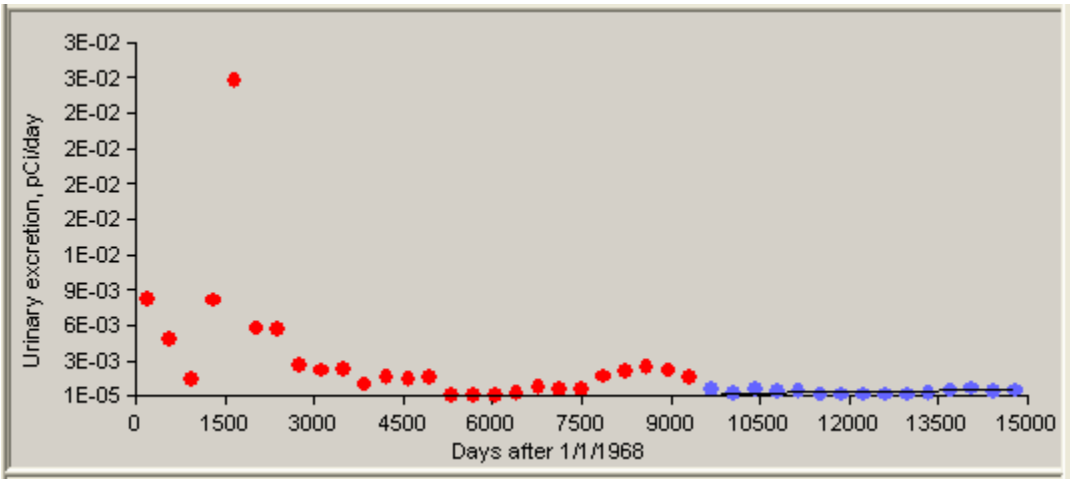

Figure B-8. Predicted ^{238}Pu bioassay results calculated using IMBA-derived ^{238}Pu intake rates (line) compared with bioassay results (dots), 1994 to 2008, 50th percentile, type M.

ATTACHMENT B
CO-EXPOSURE DATA FIGURES

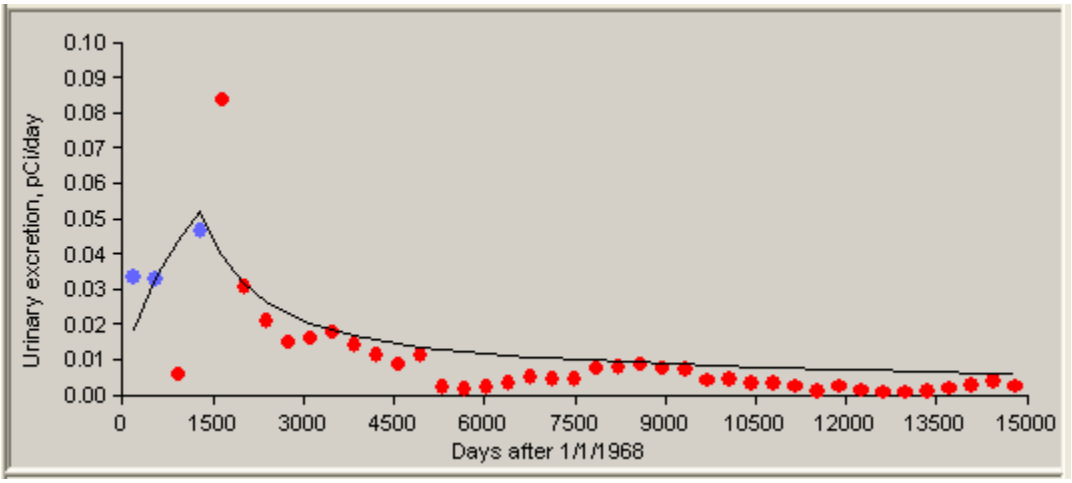

Figure B-9. Predicted ^{238}Pu bioassay results calculated using IMBA-derived ^{238}Pu intake rates (line) compared with bioassay results (dots), 1968 to 1971, 84th percentile, type M.

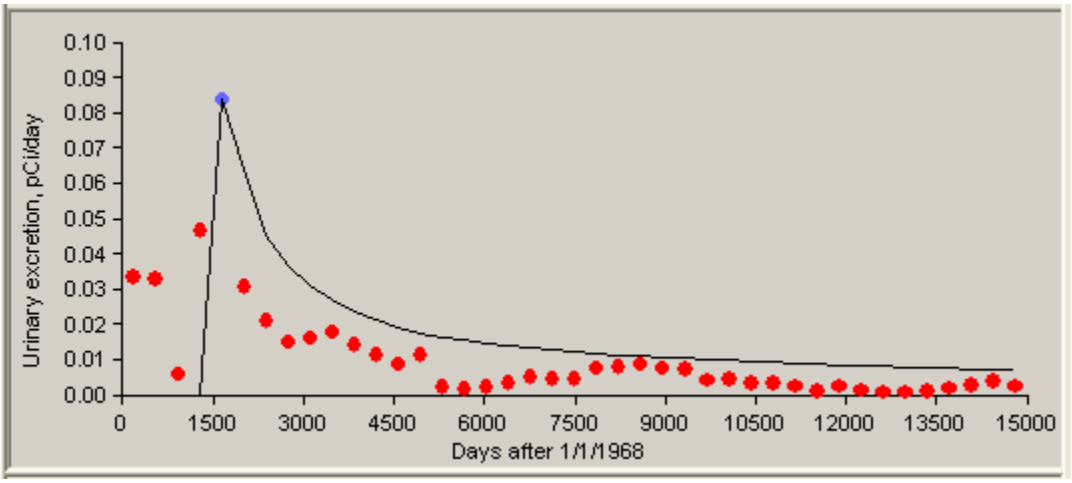

Figure B-10. Predicted ^{238}Pu bioassay results calculated using IMBA-derived ^{238}Pu intake rates (line) compared with bioassay results (dots), 1972, 84th percentile, type M.

ATTACHMENT B
CO-EXPOSURE DATA FIGURES

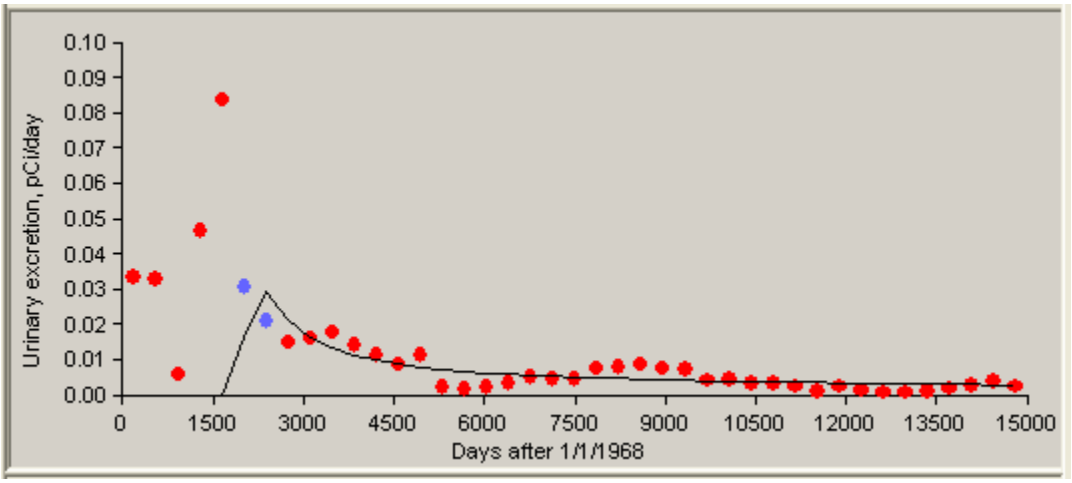

Figure B-11. Predicted ^{238}Pu bioassay results calculated using IMBA-derived ^{238}Pu intake rates (line) compared with bioassay results (dots), 1973 to 1974, 84th percentile, type M.

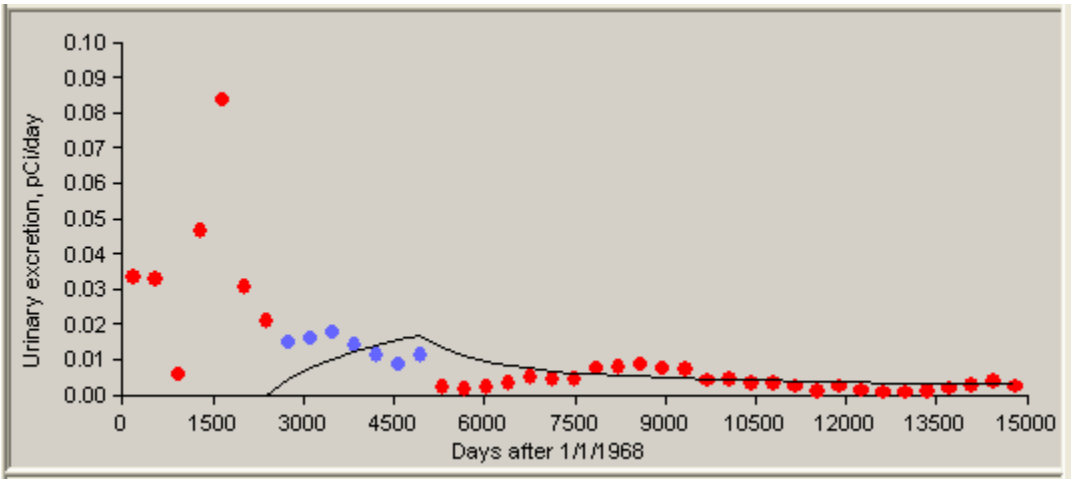

Figure B-12. Predicted ^{238}Pu bioassay results calculated using IMBA-derived ^{238}Pu intake rates (line) compared with bioassay results (dots), 1975 to 1981, 84th percentile, type M.

ATTACHMENT B
CO-EXPOSURE DATA FIGURES

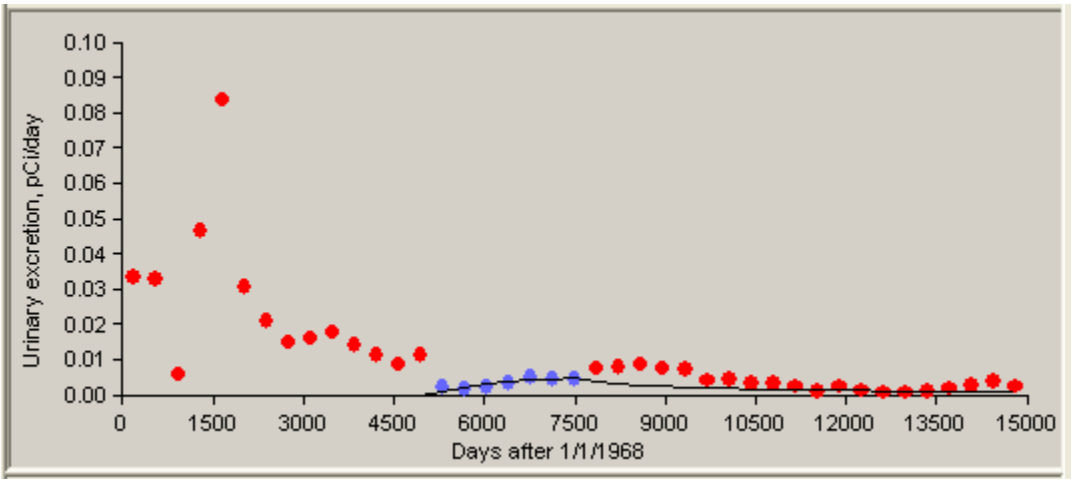

Figure B-13. Predicted ^{238}Pu bioassay results calculated using IMBA-derived ^{238}Pu intake rates (line) compared with bioassay results (dots), 1982 to 1988, 84th percentile, type M.

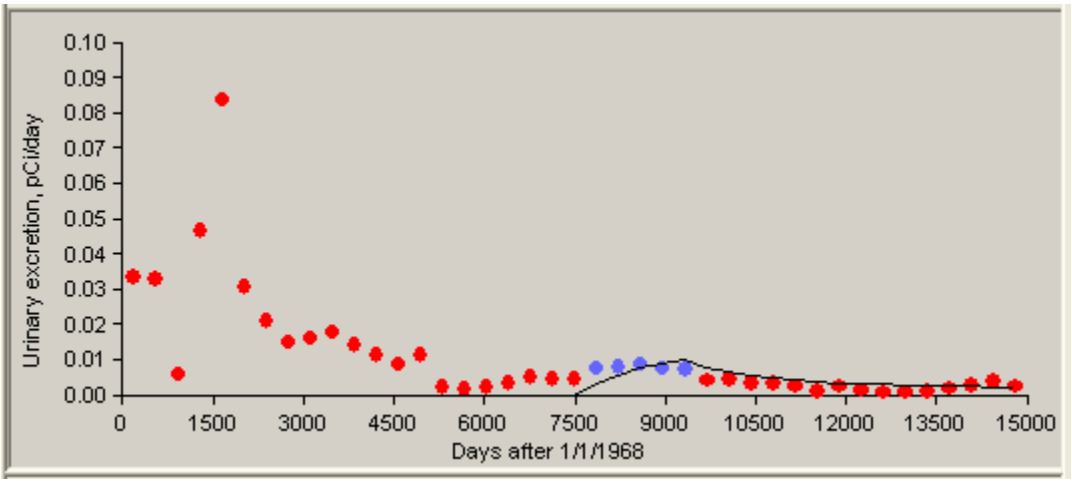

Figure B-14. Predicted ^{238}Pu bioassay results calculated using IMBA-derived ^{238}Pu intake rates (line) compared with bioassay results (dots), 1989 to 1993, 84th percentile, type M.

ATTACHMENT B
CO-EXPOSURE DATA FIGURES

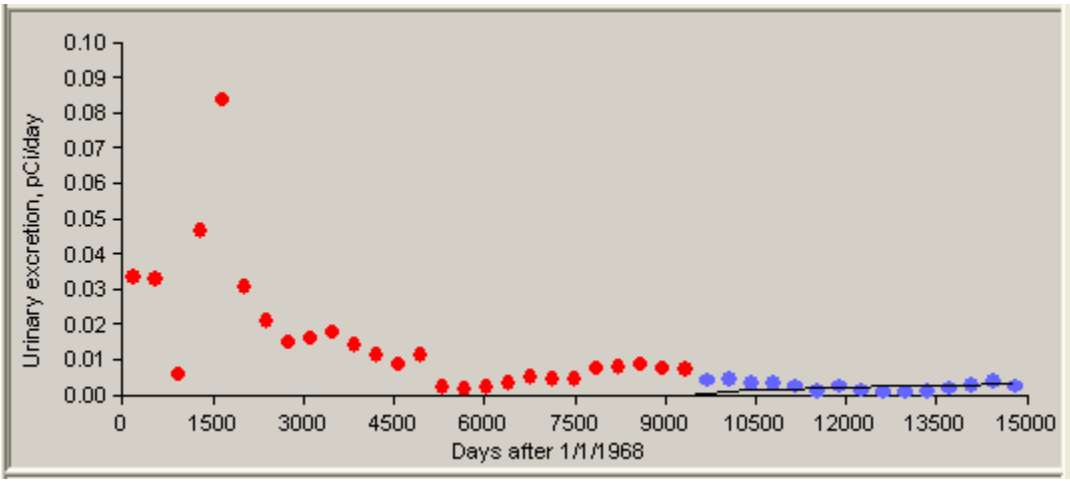

Figure B-15. Predicted ^{238}Pu bioassay results calculated using IMBA-derived ^{238}Pu intake rates (line) compared with bioassay results (dots), 1994 to 2008, 84th percentile, type M.

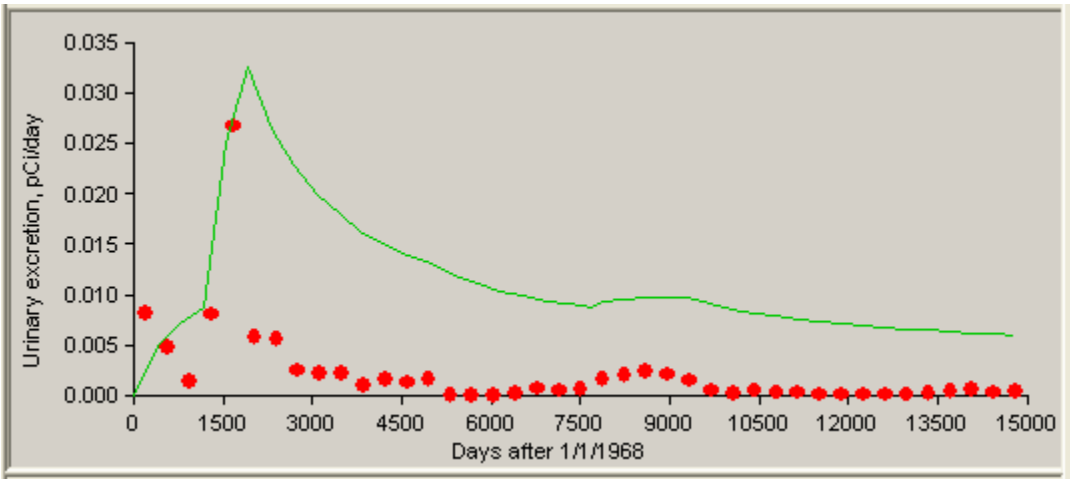

Figure B-16. Predicted ^{238}Pu bioassay results calculated using IMBA-derived ^{238}Pu intake rates (line) compared with bioassay results (dots) from all intakes, 50th percentile, type M.

ATTACHMENT B
CO-EXPOSURE DATA FIGURES

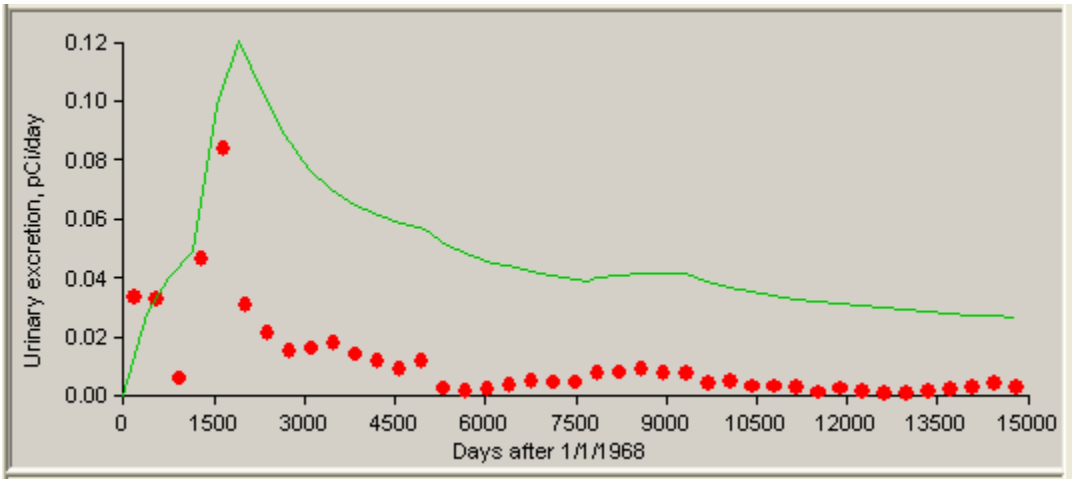

Figure B-17. Predicted ^{238}Pu bioassay results calculated using IMBA-derived ^{238}Pu intake rates (line) compared with bioassay results (dots) from all intakes, 84th percentile, type M.

Table B-1. Summary of ^{238}Pu type M intake rates (pCi/d) and dates.

Start	End	50th percentile	84th percentile	GSD
01/01/1968	12/31/1971	1.774	9.981	5.63
01/01/1972	12/31/1972	14.12	44.22	3.13
01/01/1973	12/31/1974	2.038	8.793	4.31
01/01/1975	12/31/1977	0.666	2.394	3.59
01/01/1978	12/31/1981	0.317	2.394	7.56
01/01/1982	12/31/1988	0.084	0.737	8.74
01/01/1989	12/31/1993	0.439	1.764	4.02
01/01/1994	12/31/2008	0.048	0.326	6.82

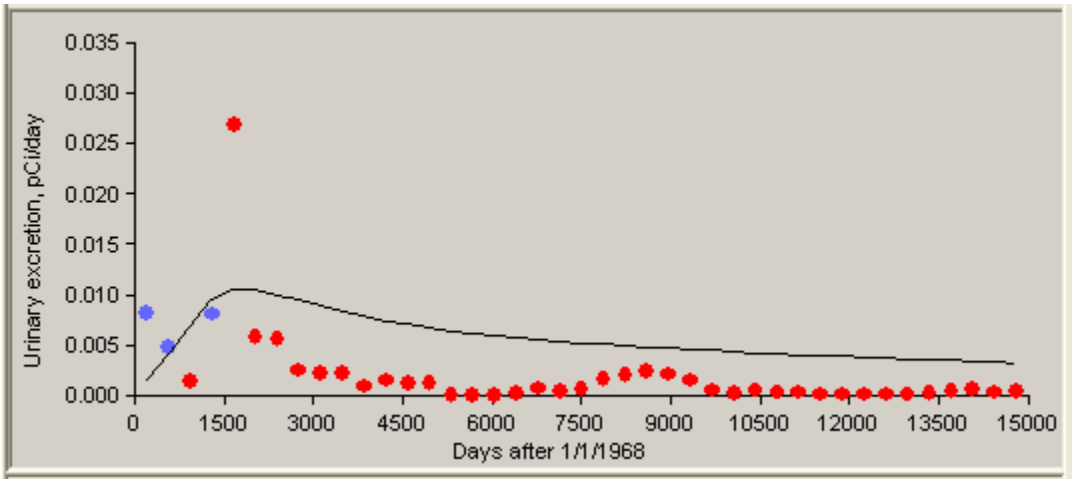

Figure B-18. Predicted ^{238}Pu bioassay results calculated using IMBA-derived ^{238}Pu intake rates (line) compared with bioassay results (dots), 1968 to 1971, 50th percentile, type S.

ATTACHMENT B
CO-EXPOSURE DATA FIGURES

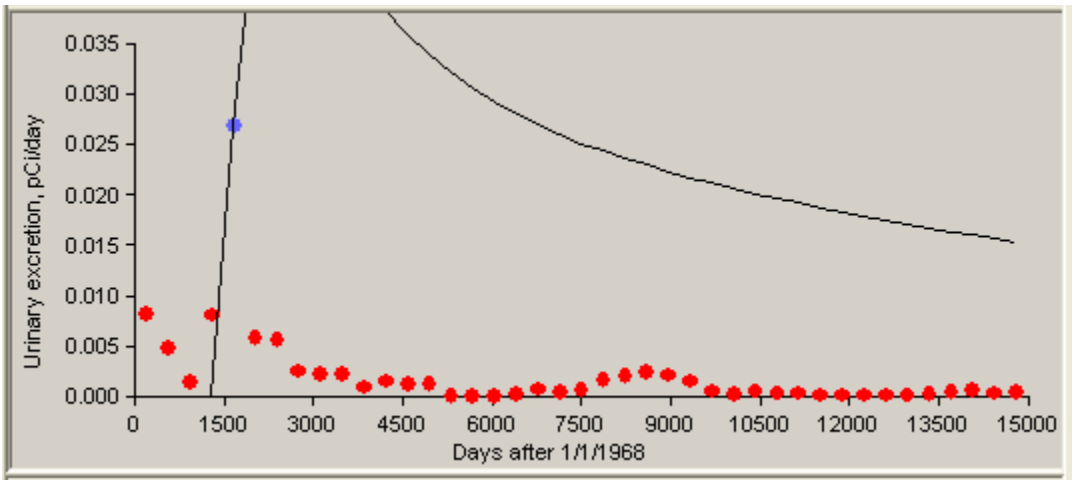

Figure B-19. Predicted ^{238}Pu bioassay results calculated using IMBA-derived ^{238}Pu intake rates (line) compared with bioassay results (dots), 1972, 50th percentile, type S.

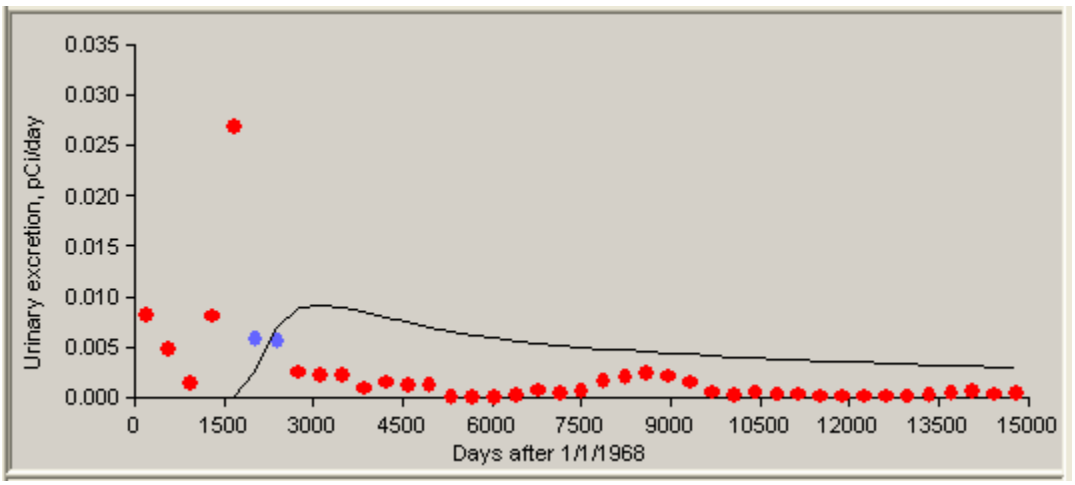

Figure B-20. Predicted ^{238}Pu bioassay results calculated using IMBA-derived ^{238}Pu intake rates (line) compared with bioassay results (dots), 1973 to 1974, 50th percentile, type S.

ATTACHMENT B
CO-EXPOSURE DATA FIGURES

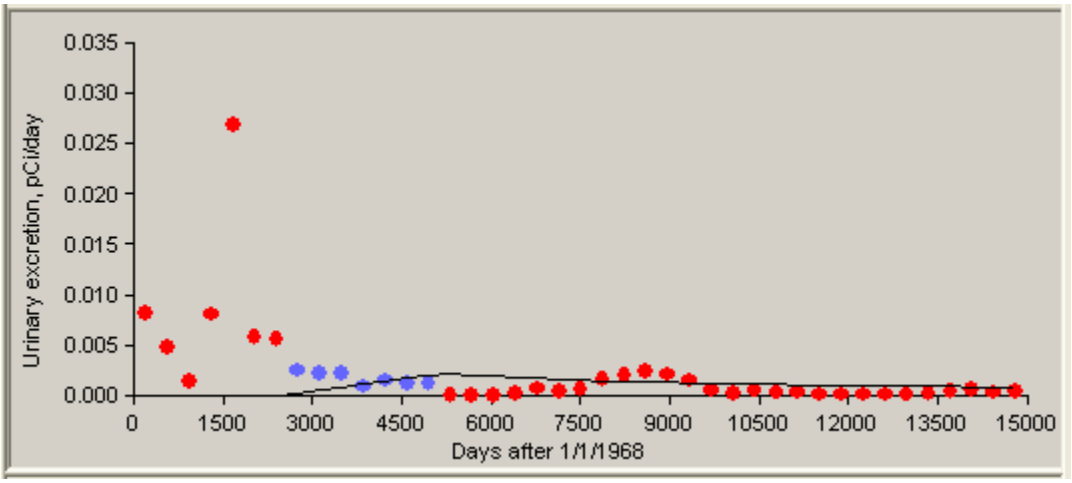

Figure B-21. Predicted ^{238}Pu bioassay results calculated using IMBA-derived ^{238}Pu intake rates (line) compared with bioassay results (dots), 1975 to 1981, 50th percentile, type S.

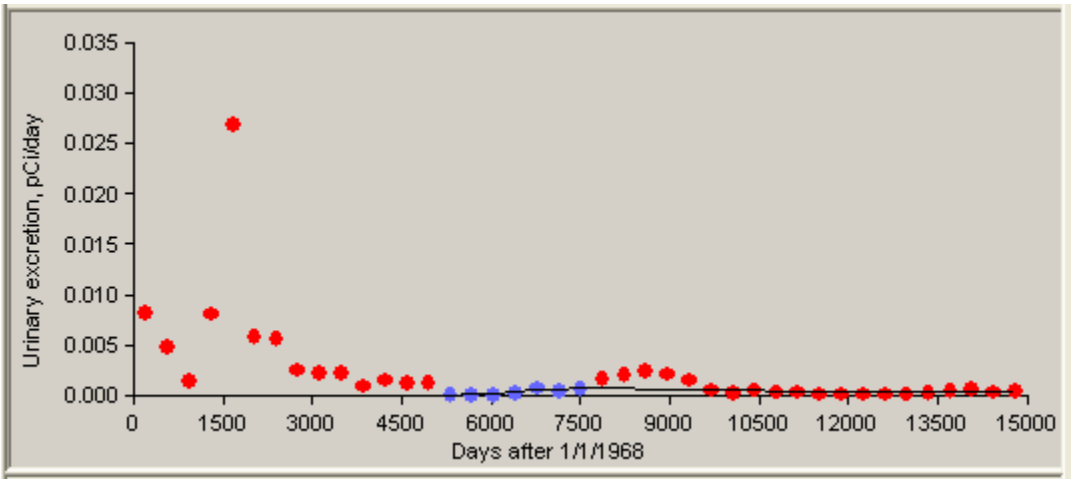

Figure B-22. Predicted ^{238}Pu bioassay results calculated using IMBA-derived ^{238}Pu intake rates (line) compared with bioassay results (dots), 1982 to 1988, 50th percentile, type S.

ATTACHMENT B
CO-EXPOSURE DATA FIGURES

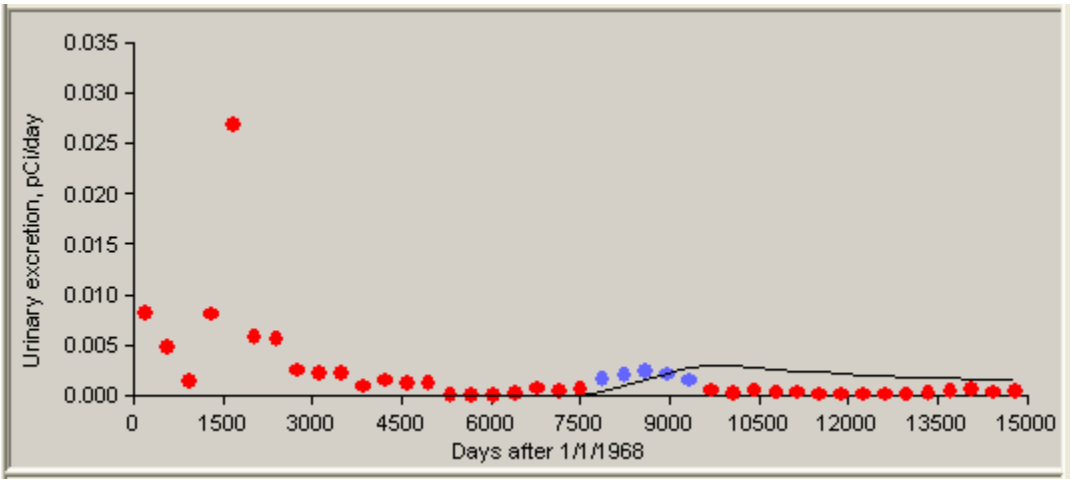

Figure B-23. Predicted ^{238}Pu bioassay results calculated using IMBA-derived ^{238}Pu intake rates (line) compared with bioassay results (dots), 1989 to 1993, 50th percentile, type S.

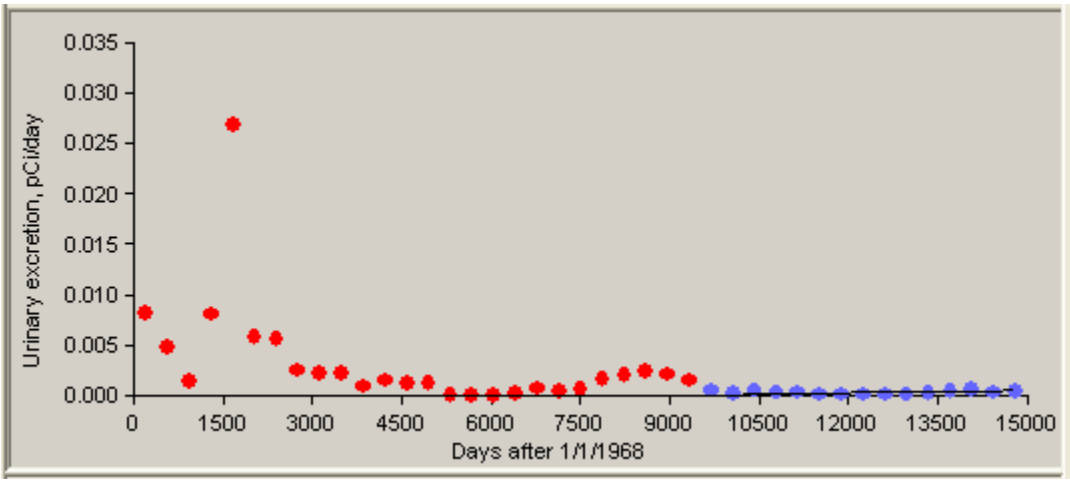

Figure B-24. Predicted ^{238}Pu bioassay results calculated using IMBA-derived ^{238}Pu intake rates (line) compared with bioassay results (dots), 1994 to 2008, 50th percentile, type S.

ATTACHMENT B
CO-EXPOSURE DATA FIGURES

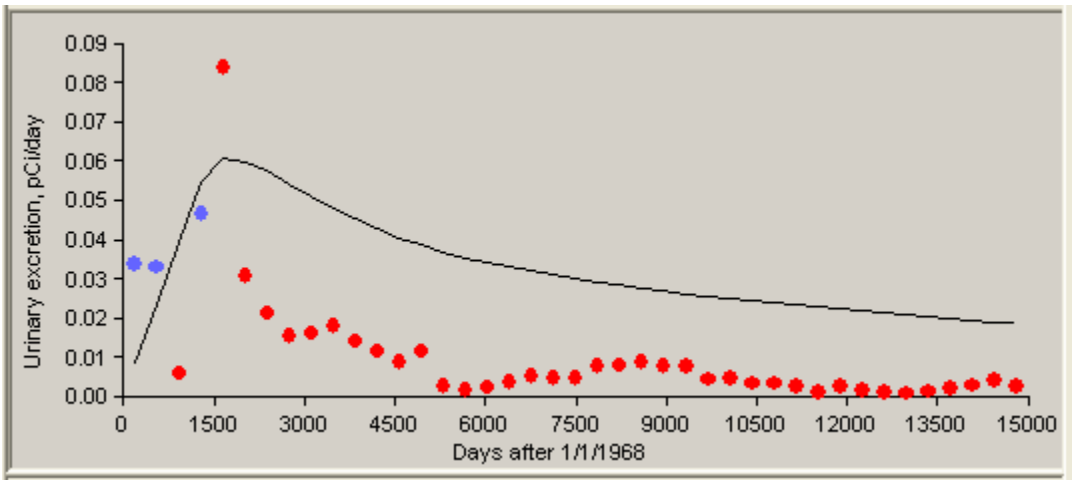

Figure B-25. Predicted ^{238}Pu bioassay results calculated using IMBA-derived ^{238}Pu intake rates (line) compared with bioassay results (dots), 1968 to 1971, 84th percentile, type S.

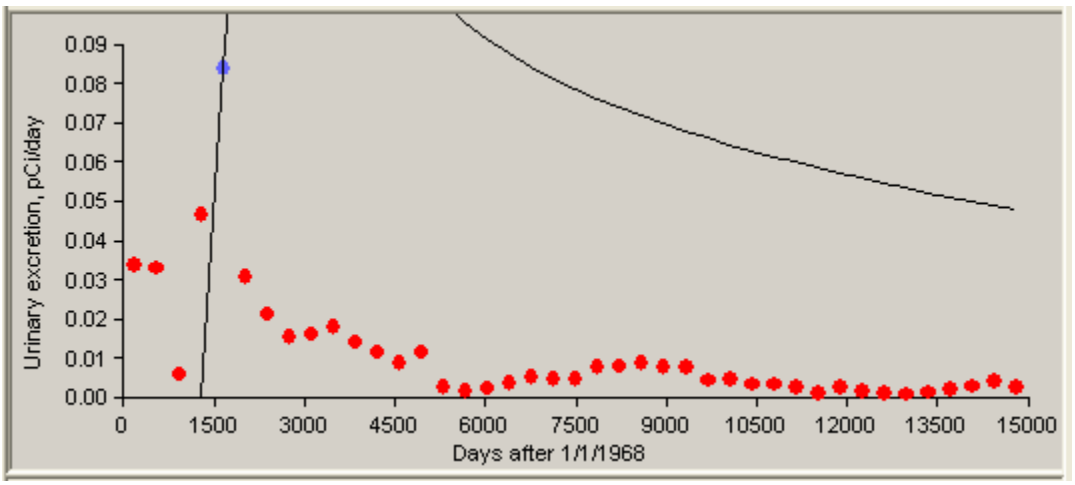

Figure B-26. Predicted ^{238}Pu bioassay results calculated using IMBA-derived ^{238}Pu intake rates (line) compared with bioassay results (dots), 1972, 84th percentile, type S.

ATTACHMENT B
CO-EXPOSURE DATA FIGURES

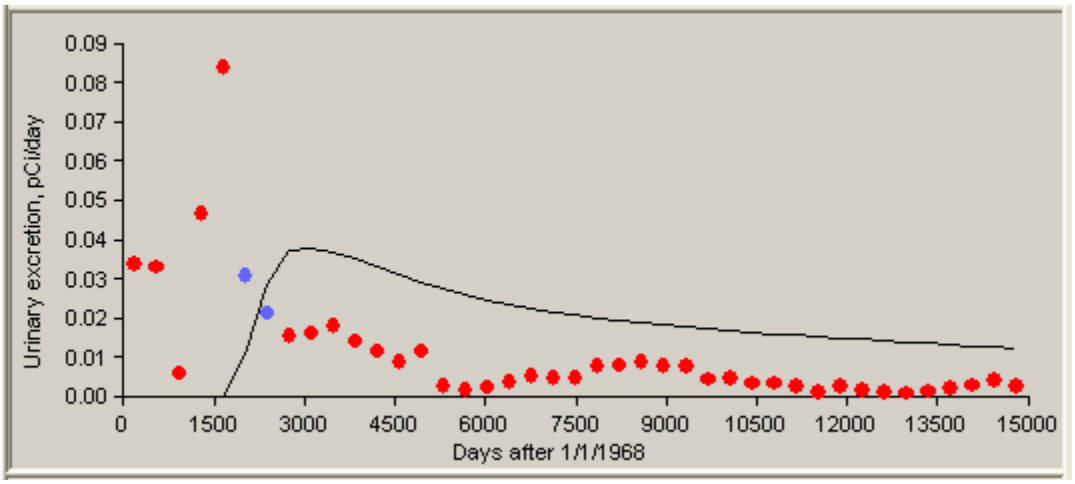

Figure B-27. Predicted ^{238}Pu bioassay results calculated using IMBA-derived ^{238}Pu intake rates (line) compared with bioassay results (dots), 1973 to 1974, 84th percentile, type S.

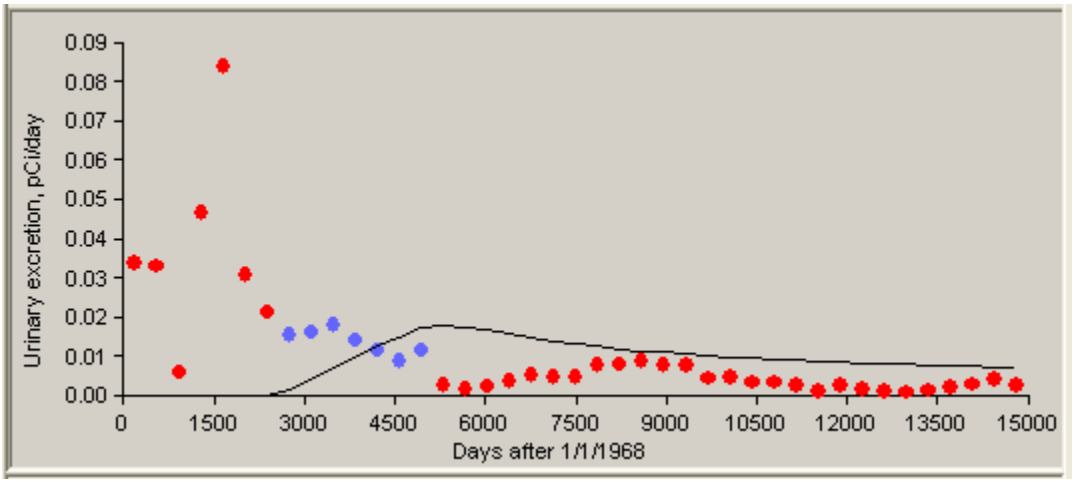

Figure B-28. Predicted ^{238}Pu bioassay results calculated using IMBA-derived ^{238}Pu intake rates (line) compared with bioassay results (dots), 1975 to 1981, 84th percentile, type S.

ATTACHMENT B
CO-EXPOSURE DATA FIGURES

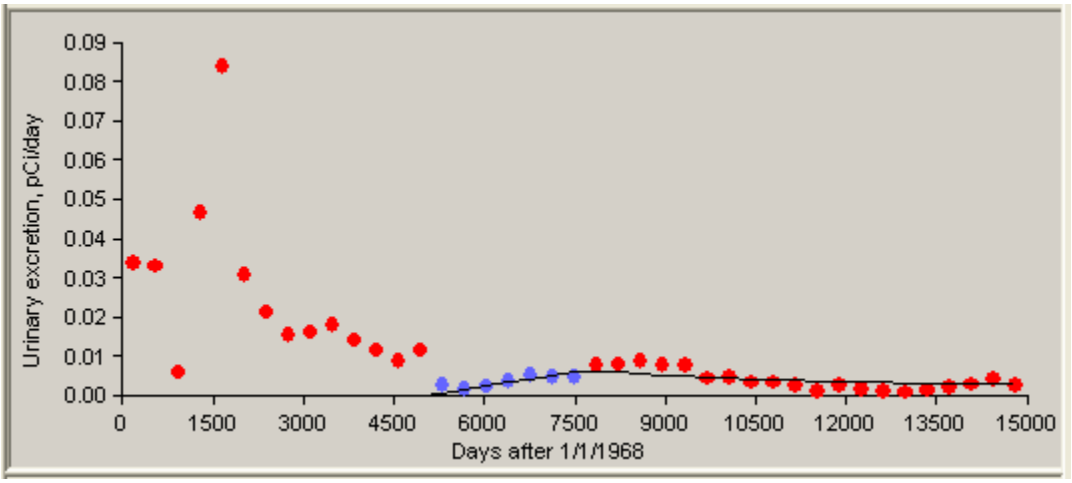

Figure B-29. Predicted ^{238}Pu bioassay results calculated using IMBA-derived ^{238}Pu intake rates (line) compared with bioassay results (dots), 1982 to 1988, 84th percentile, type S.

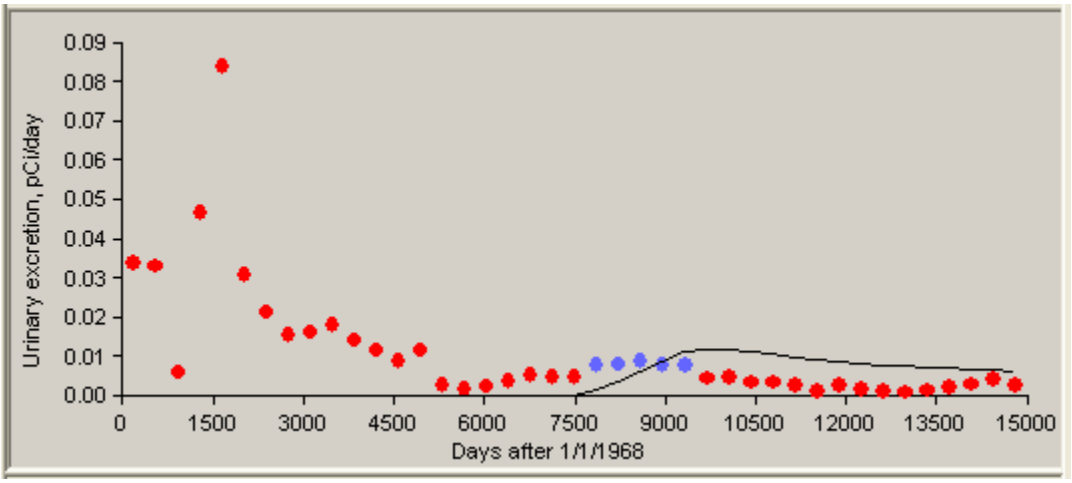

Figure B-30. Predicted ^{238}Pu bioassay results calculated using IMBA-derived ^{238}Pu intake rates (line) compared with bioassay results (dots), 1989 to 1993, 84th percentile, type S.

ATTACHMENT B
CO-EXPOSURE DATA FIGURES

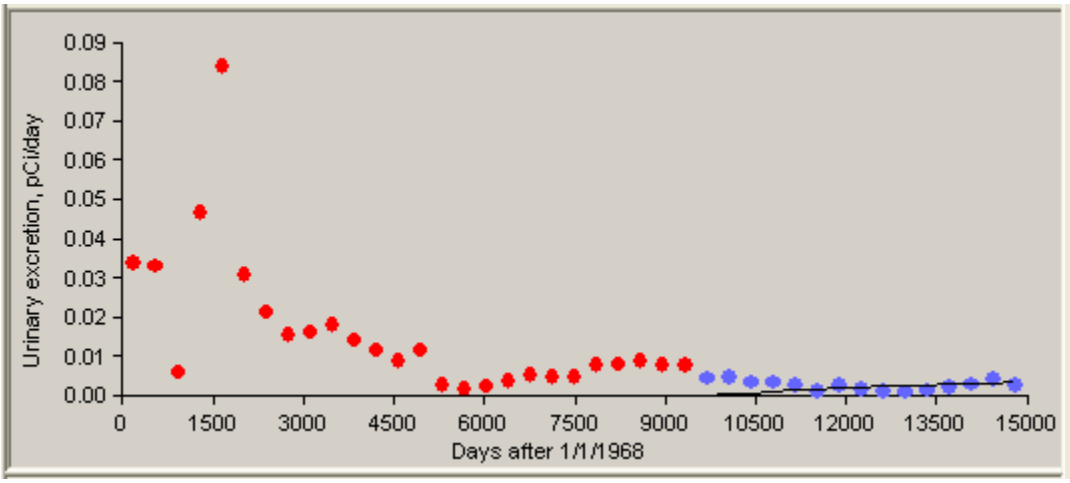

Figure B-31. Predicted ^{238}Pu bioassay results calculated using IMBA-derived ^{238}Pu intake rates (line) compared with bioassay results (dots), 1994 to 2008, 84th percentile, type S.

Figure B-32. Predicted ^{238}Pu bioassay results calculated using IMBA-derived ^{238}Pu intake rates (line) compared with bioassay results (dots) from all intakes, 50th percentile, type S.

ATTACHMENT B
CO-EXPOSURE DATA FIGURES

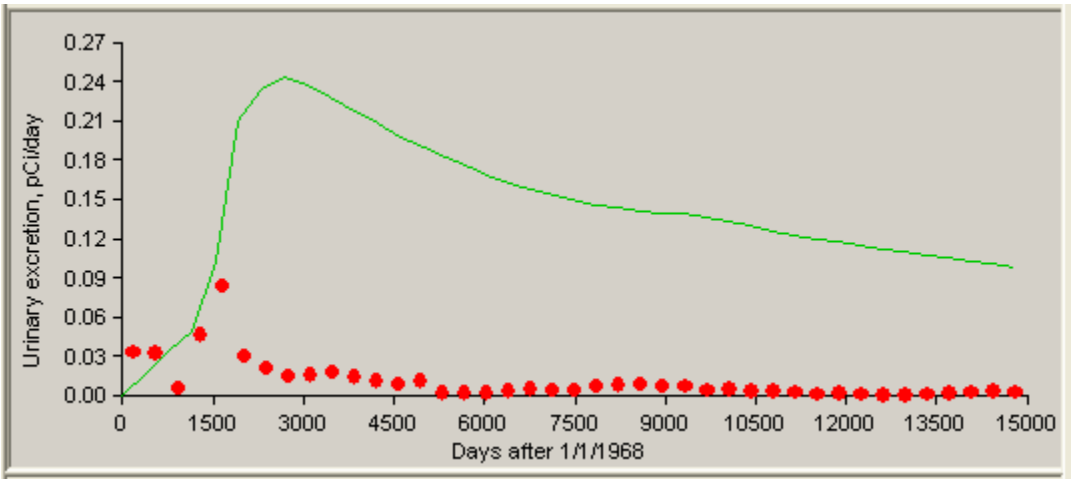

Figure B-33. Predicted ^{238}Pu bioassay results calculated using IMBA-derived ^{238}Pu intake rates (line) compared with bioassay results (dots) from all intakes, 84th percentile, type S.

Table B-2. Summary of ^{238}Pu type S intake rates (pCi/d) and dates.

Start	End	50th percentile	84th percentile	GSD
01/01/1968	12/31/1971	42.95	246.5	5.74
01/01/1972	12/31/1972	764.7	2,394	3.13
01/01/1973	12/31/1974	72.28	301.3	4.17
01/01/1975	12/31/1981	5.235	44.34	8.47
01/01/1982	12/31/1988	1.818	15.02	8.26
01/01/1989	12/31/1993	9.708	39.21	4.04
01/01/1994	12/31/2008	0.717	4.72	6.58

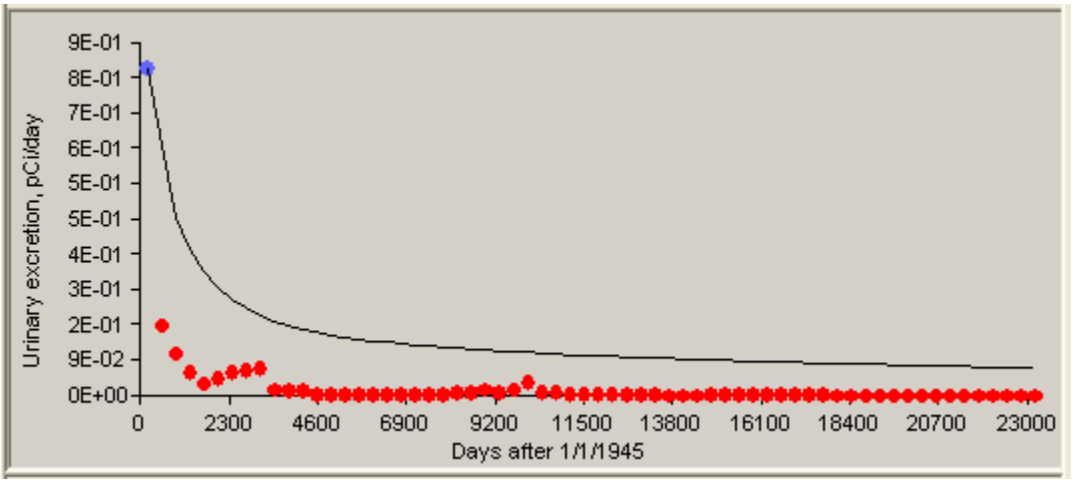

Figure B-34. Predicted ^{239}Pu bioassay results calculated using IMBA-derived ^{239}Pu intake rates (line) compared with bioassay results (dots), 1944 to 1945, 50th percentile, type M.

ATTACHMENT B
CO-EXPOSURE DATA FIGURES

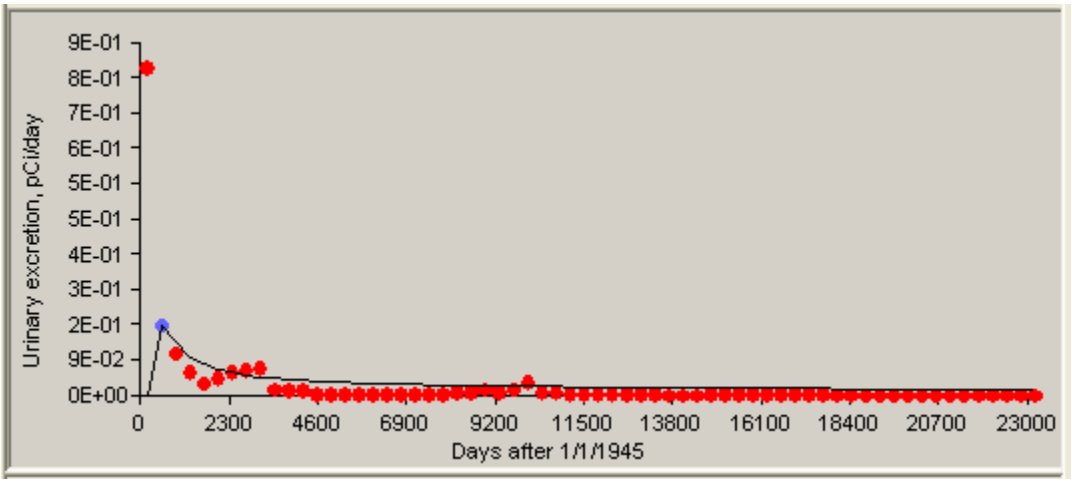

Figure B-35. Predicted ^{239}Pu bioassay results calculated using IMBA-derived ^{239}Pu intake rates (line) compared with bioassay results (dots), 1946, 50th percentile, type M.

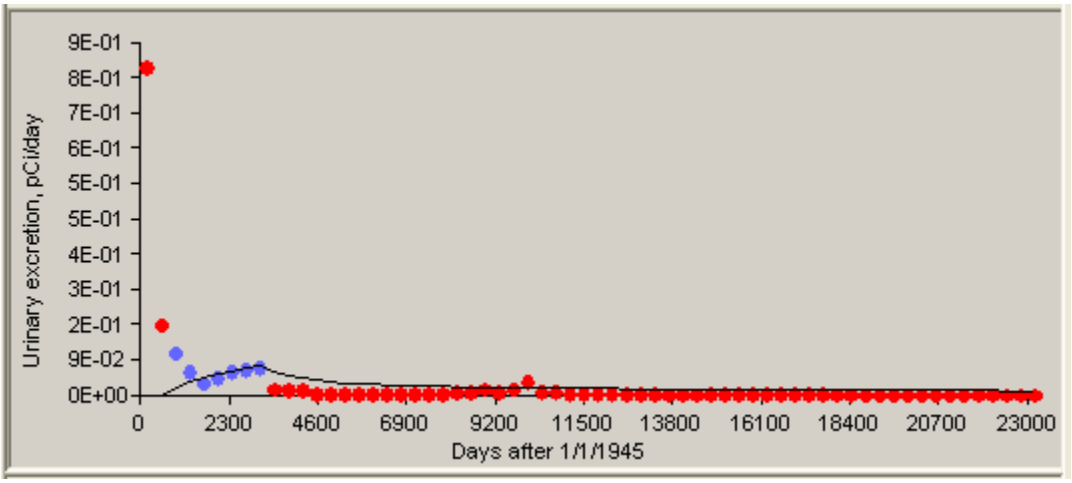

Figure B-36. Predicted ^{239}Pu bioassay results calculated using IMBA-derived ^{239}Pu intake rates (line) compared with bioassay results (dots), 1947, 50th percentile, type M.

ATTACHMENT B
CO-EXPOSURE DATA FIGURES

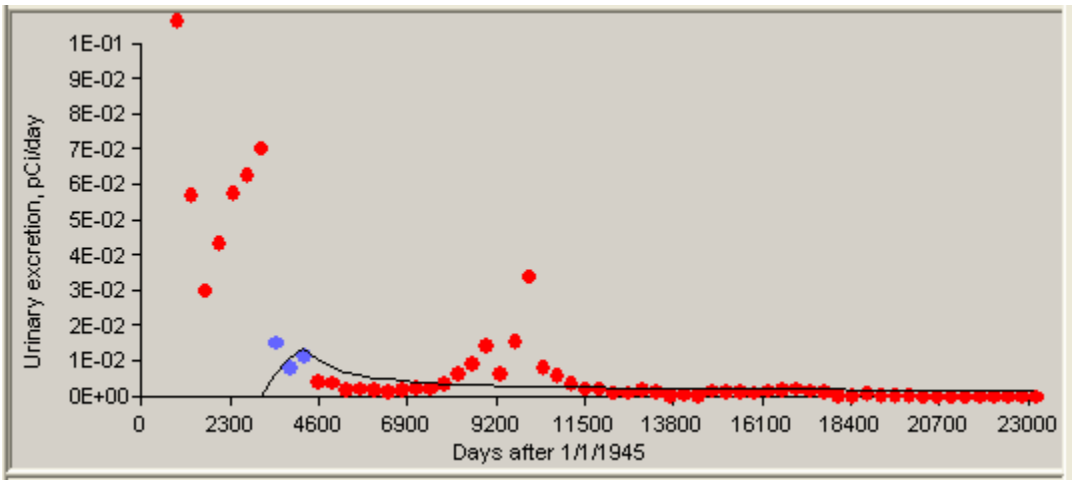

Figure B-37. Predicted ^{239}Pu bioassay results calculated using IMBA-derived ^{239}Pu intake rates (line) compared with bioassay results (dots), 1954 to 1956, 50th percentile, type M.

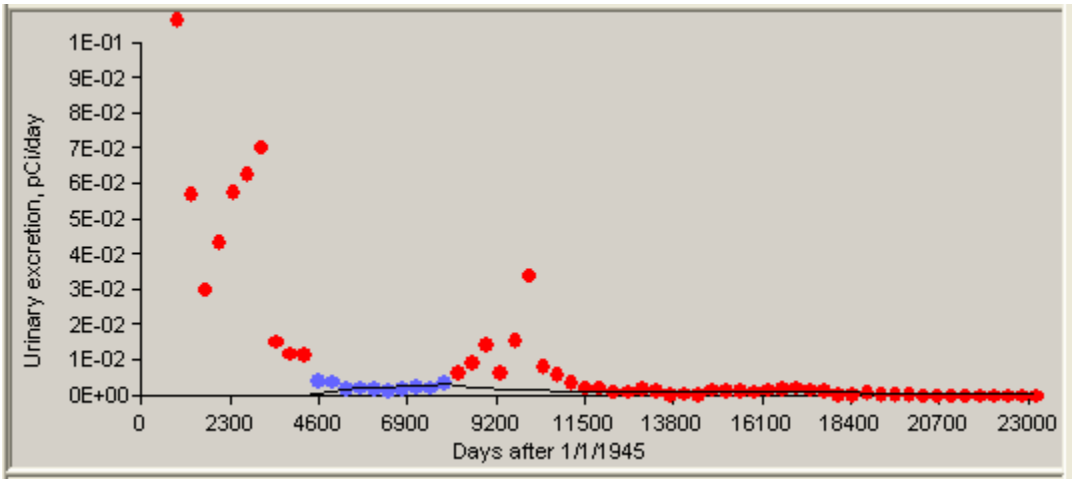

Figure B-38. Predicted ^{239}Pu bioassay results calculated using IMBA-derived ^{239}Pu intake rates (line) compared with bioassay results (dots), 1957 to 1966, 50th percentile, type M.

ATTACHMENT B
CO-EXPOSURE DATA FIGURES

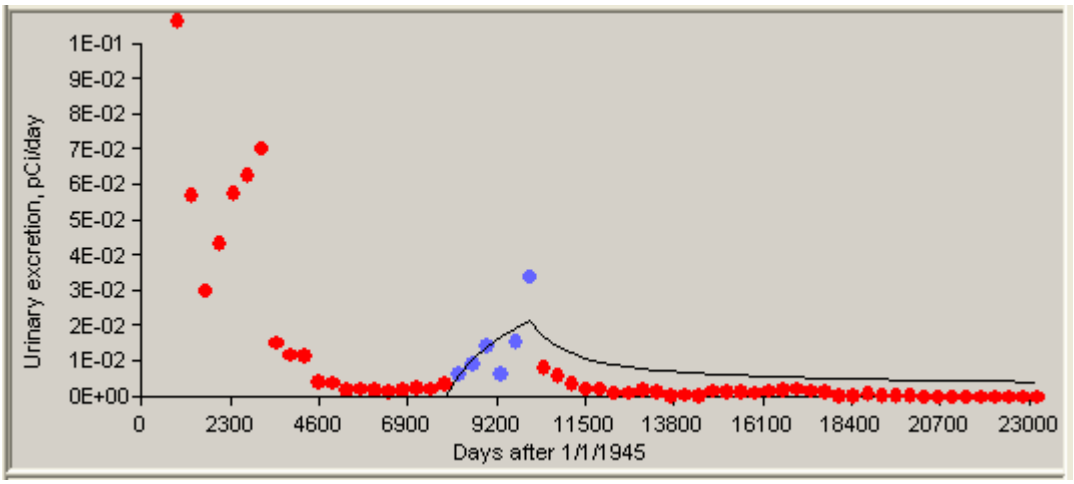

Figure B-39. Predicted ^{239}Pu bioassay results calculated using IMBA-derived ^{239}Pu intake rates (line) compared with bioassay results (dots), 1967 to 1972, 50th percentile, type M.

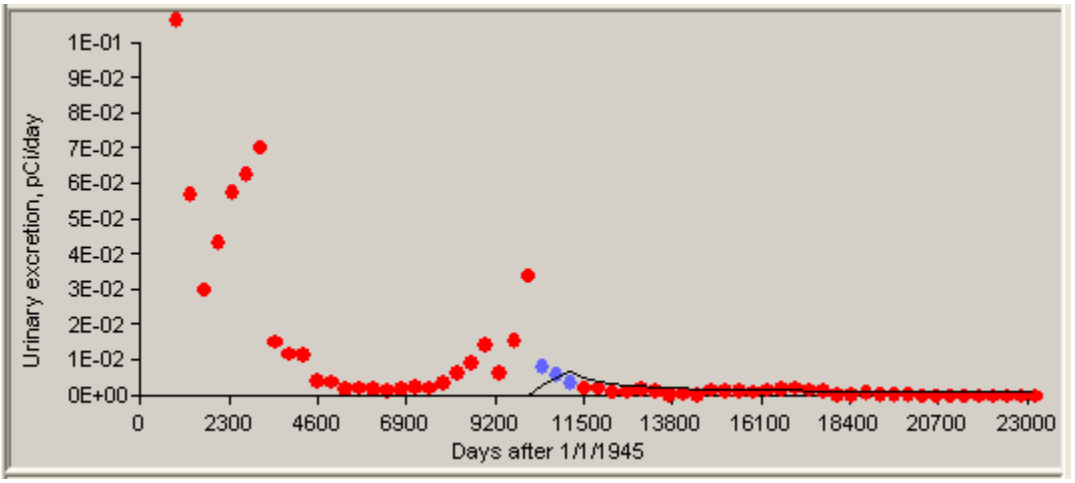

Figure B-40. Predicted ^{239}Pu bioassay results calculated using IMBA-derived ^{239}Pu intake rates (line) compared with bioassay results (dots), 1973 to 1975, 50th percentile, type M.

ATTACHMENT B
CO-EXPOSURE DATA FIGURES

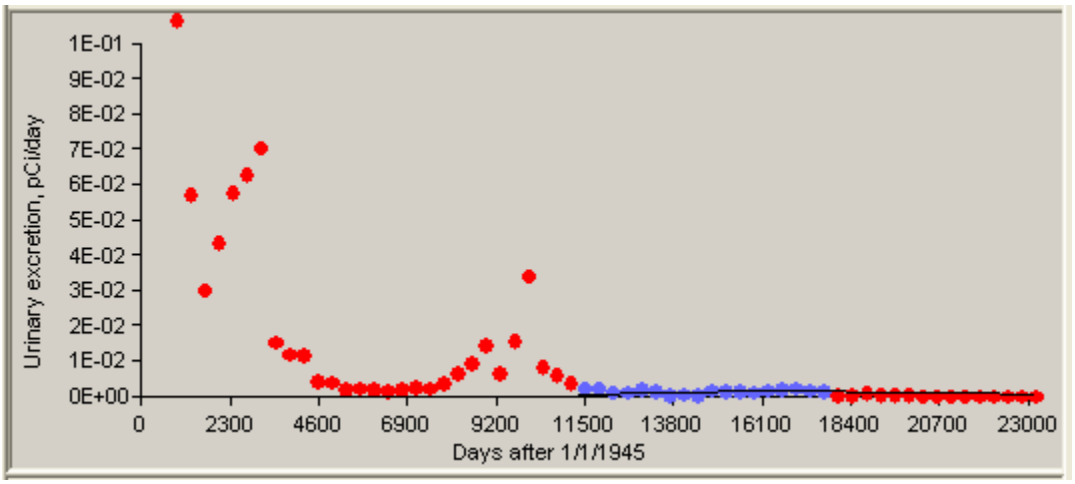

Figure B-41. Predicted ^{239}Pu bioassay results calculated using IMBA-derived ^{239}Pu intake rates (line) compared with bioassay results (dots), 1976 to 1993, 50th percentile, type M.

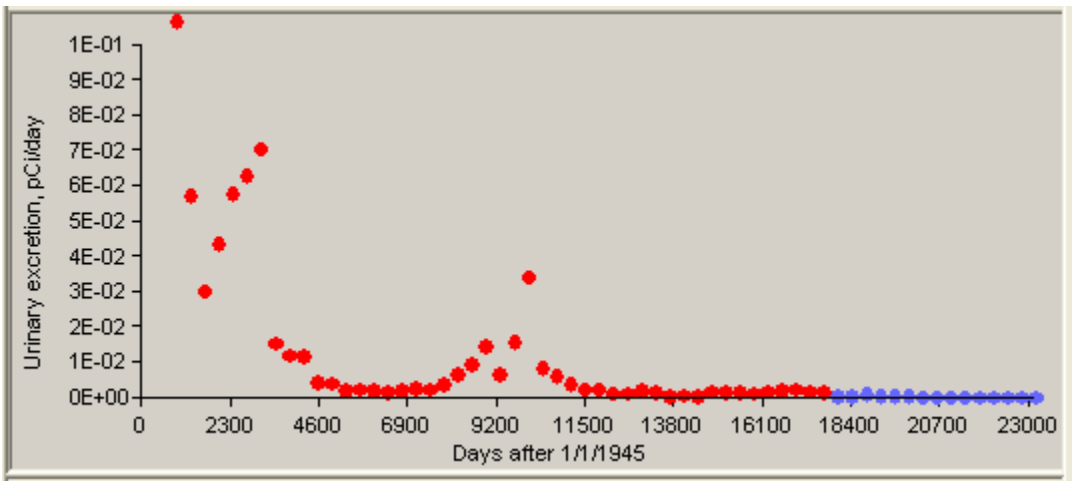

Figure B-42. Predicted ^{239}Pu bioassay results calculated using IMBA-derived ^{239}Pu intake rates (line) compared with bioassay results (dots), 1994 to 2008, 50th percentile, type M.

ATTACHMENT B
CO-EXPOSURE DATA FIGURES

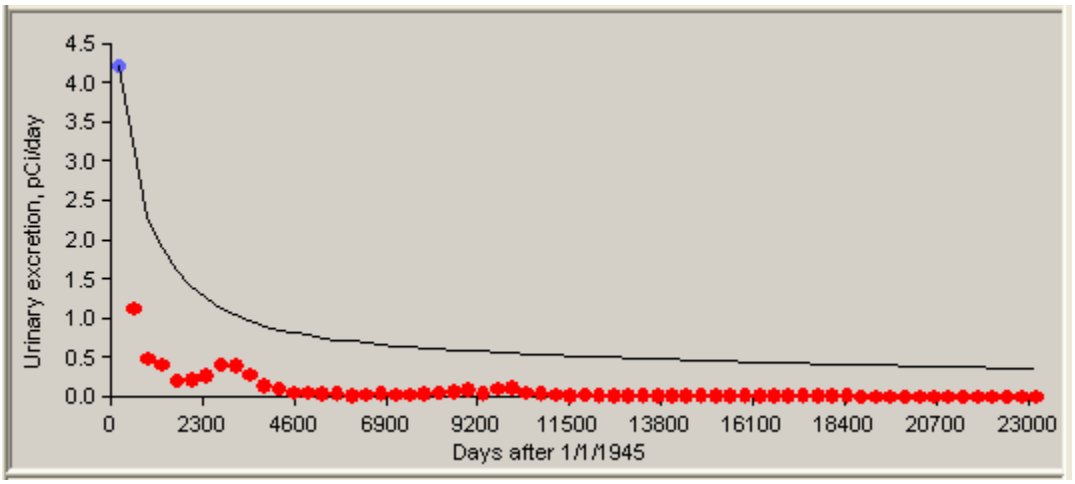

Figure B-43. Predicted ^{239}Pu bioassay results calculated using IMBA-derived ^{239}Pu intake rates (line) compared with bioassay results (dots), 1944 to 1945, 84th percentile, type M.

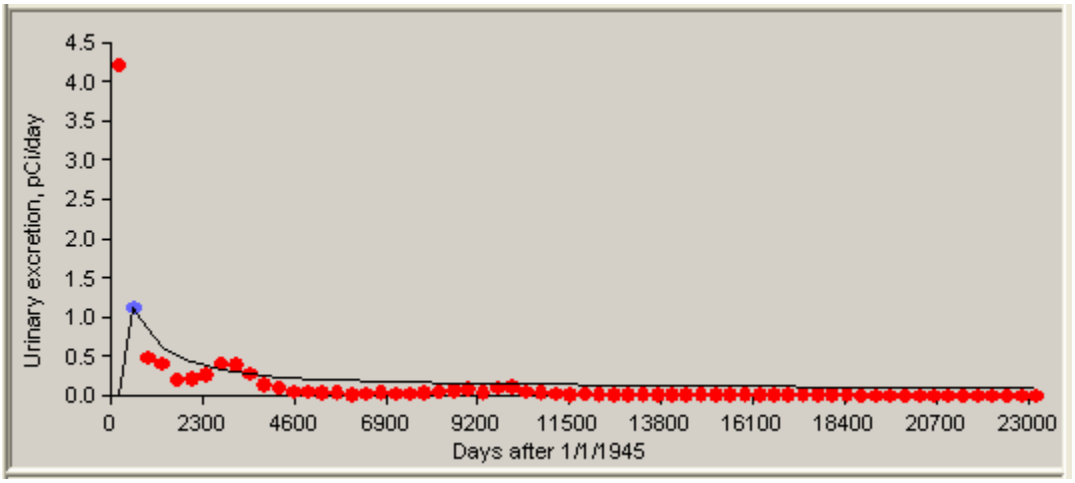

Figure B-44. Predicted ^{239}Pu bioassay results calculated using IMBA-derived ^{239}Pu intake rates (line) compared with bioassay results (dots), 1946, 84th percentile, type M.

ATTACHMENT B
CO-EXPOSURE DATA FIGURES

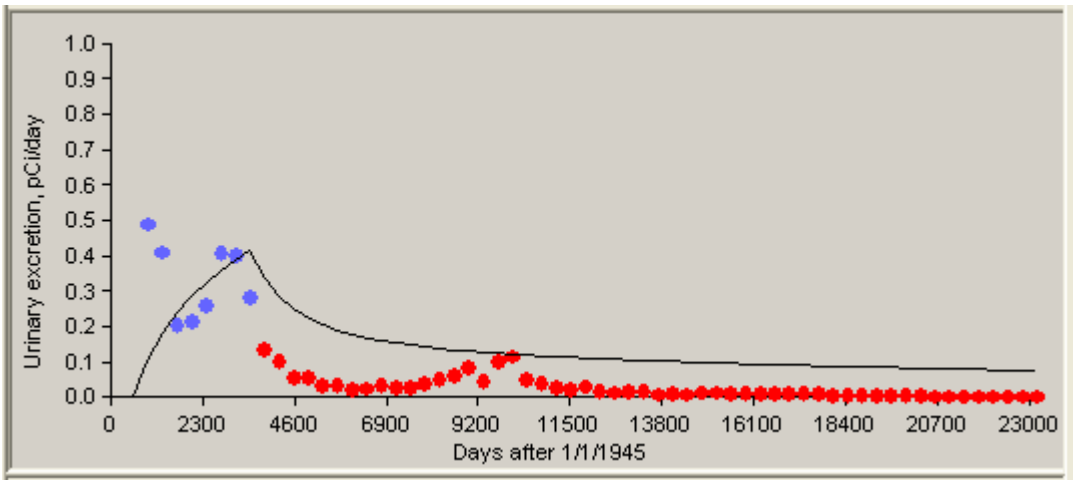

Figure B-45. Predicted ^{239}Pu bioassay results calculated using IMBA-derived ^{239}Pu intake rates (line) compared with bioassay results (dots), 1947 to 1954, 84th percentile, type M.

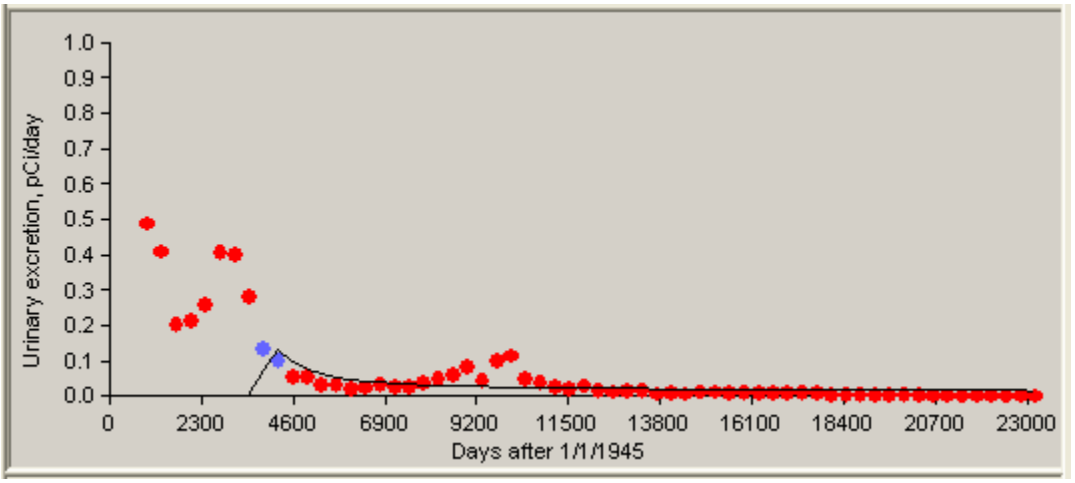

Figure B-46. Predicted ^{239}Pu bioassay results calculated using IMBA-derived ^{239}Pu intake rates (line) compared with bioassay results (dots), 1955 to 1956, 84th percentile, type M.

ATTACHMENT B
CO-EXPOSURE DATA FIGURES

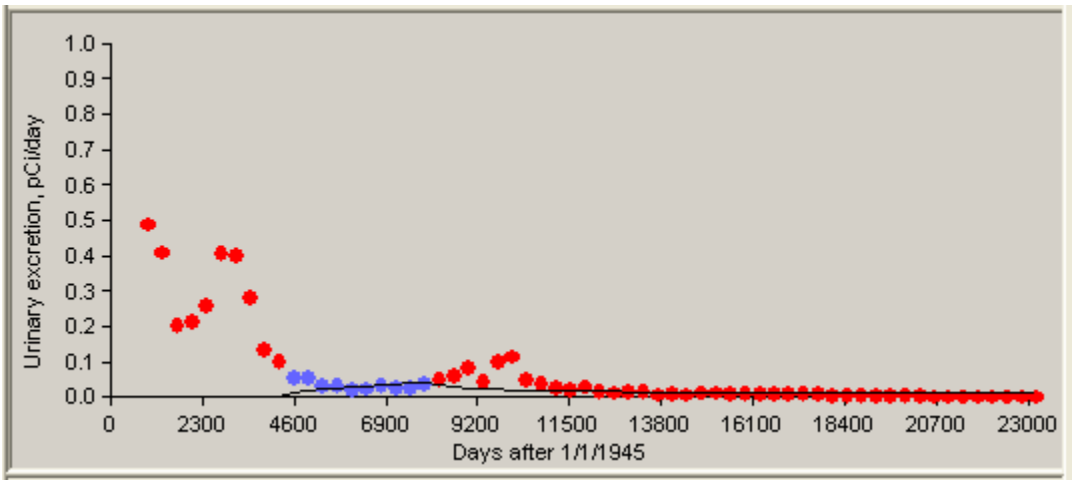

Figure B-47. Predicted ^{239}Pu bioassay results calculated using IMBA-derived ^{239}Pu intake rates (line) compared with bioassay results (dots), 1957 to 1966, 84th percentile, type M.

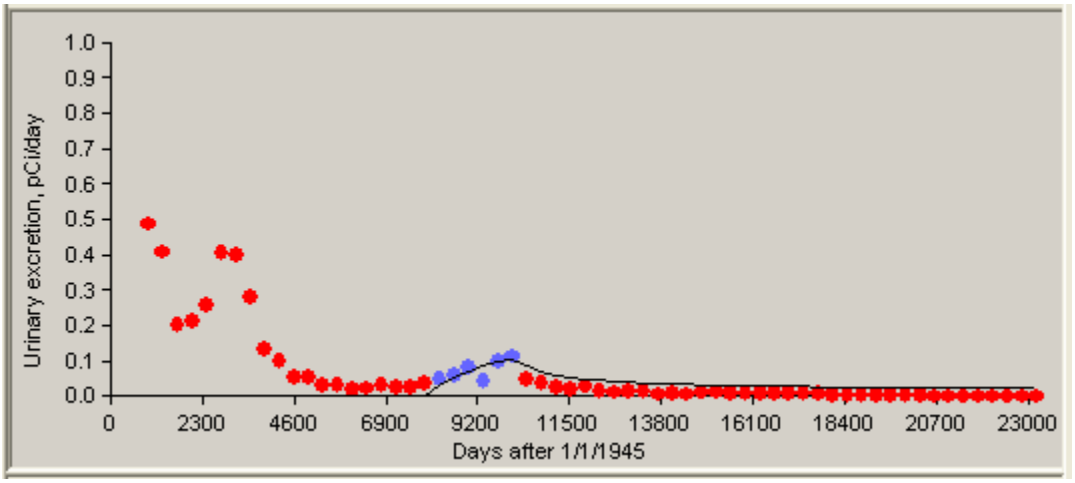

Figure B-48. Predicted ^{239}Pu bioassay results calculated using IMBA-derived ^{239}Pu intake rates (line) compared with bioassay results (dots), 1967 to 1972, 84th percentile, type M.

ATTACHMENT B
CO-EXPOSURE DATA FIGURES

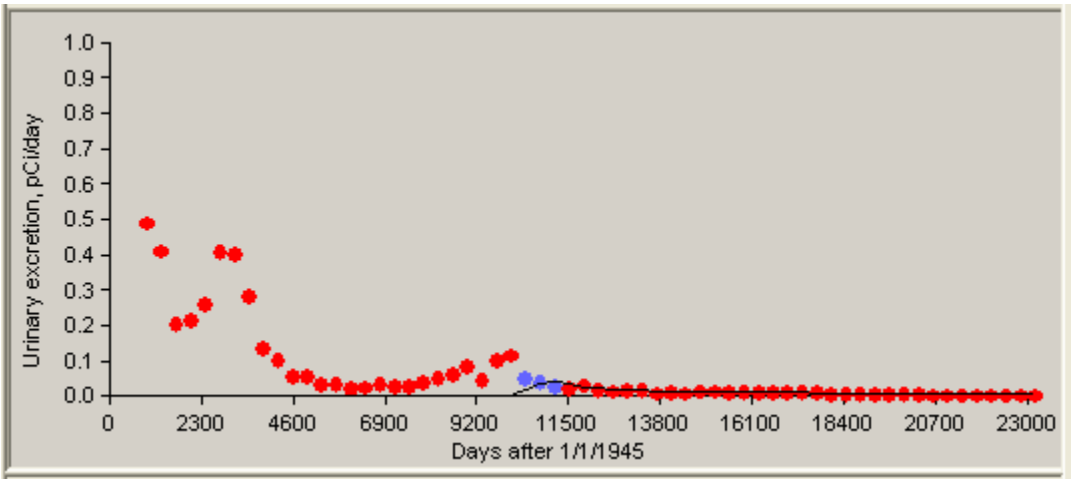

Figure B-49. Predicted ^{239}Pu bioassay results calculated using IMBA-derived ^{239}Pu intake rates (line) compared with bioassay results (dots), 1973 to 1975, 84th percentile, type M.

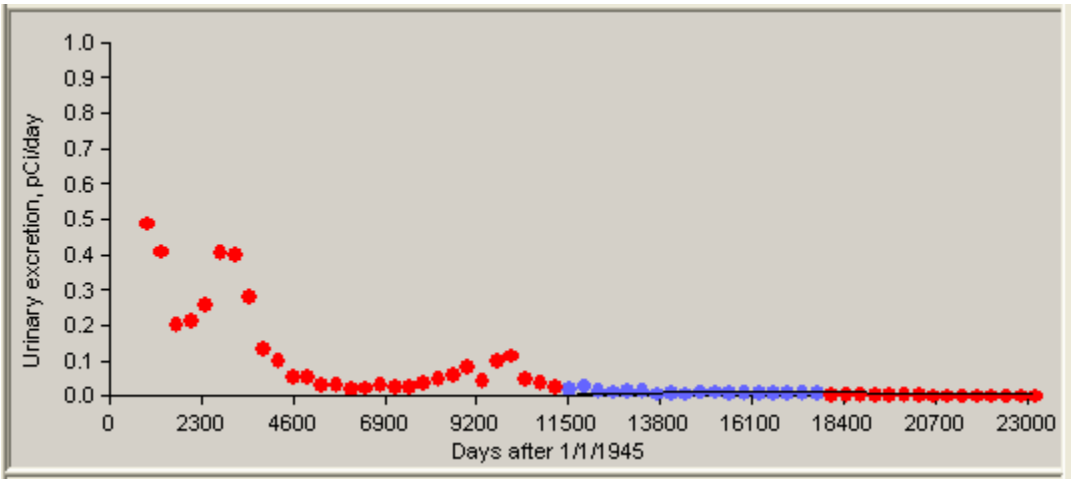

Figure B-50. Predicted ^{239}Pu bioassay results calculated using IMBA-derived ^{239}Pu intake rates (line) compared with bioassay results (dots), 1976 to 1993, 84th percentile, type M.

ATTACHMENT B
CO-EXPOSURE DATA FIGURES

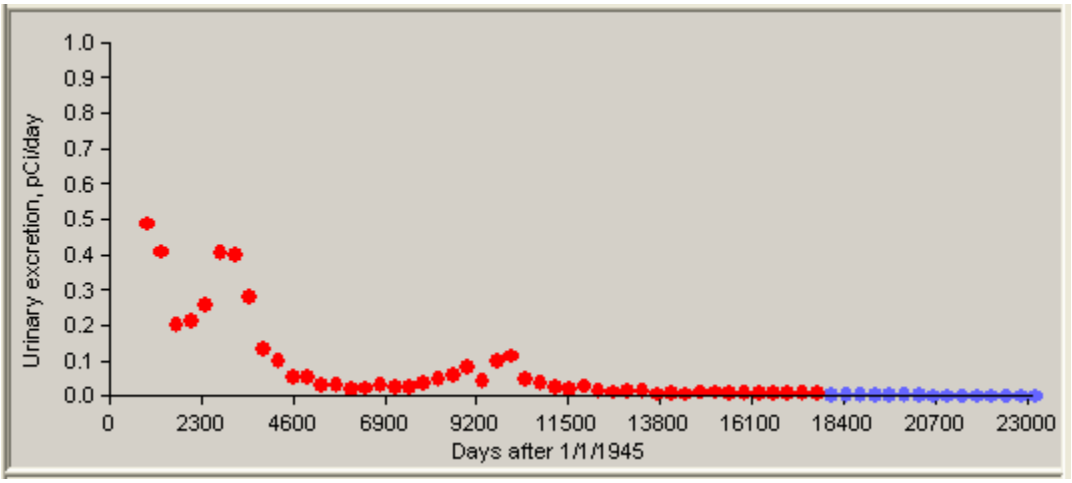

Figure B-51. Predicted ^{239}Pu bioassay results calculated using IMBA-derived ^{239}Pu intake rates (line) compared with bioassay results (dots), 1994 to 2008, 84th percentile, type M.

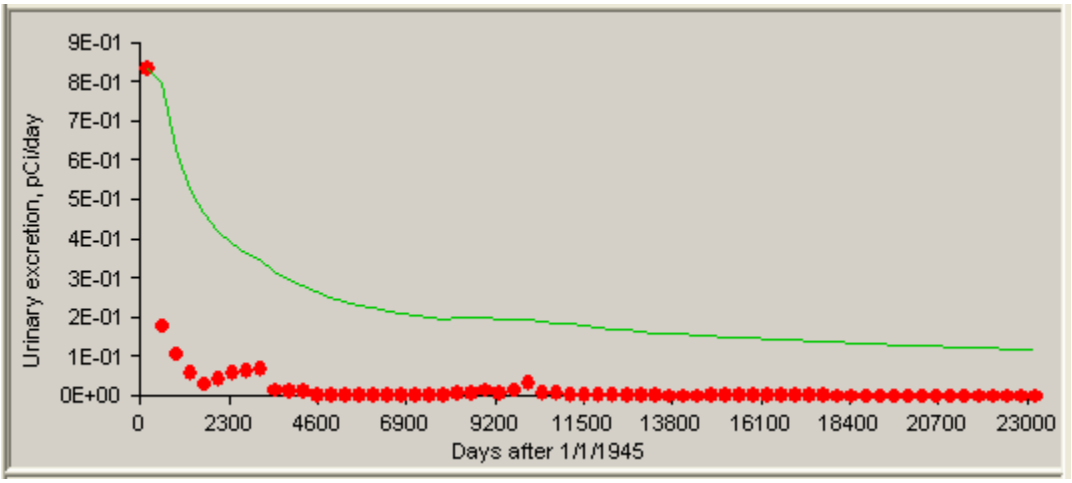

Figure B-52. Predicted ^{239}Pu bioassay results calculated using IMBA-derived ^{239}Pu intake rates (line) compared with bioassay results (dots) from all intakes, 50th percentile, type M.

ATTACHMENT B
CO-EXPOSURE DATA FIGURES

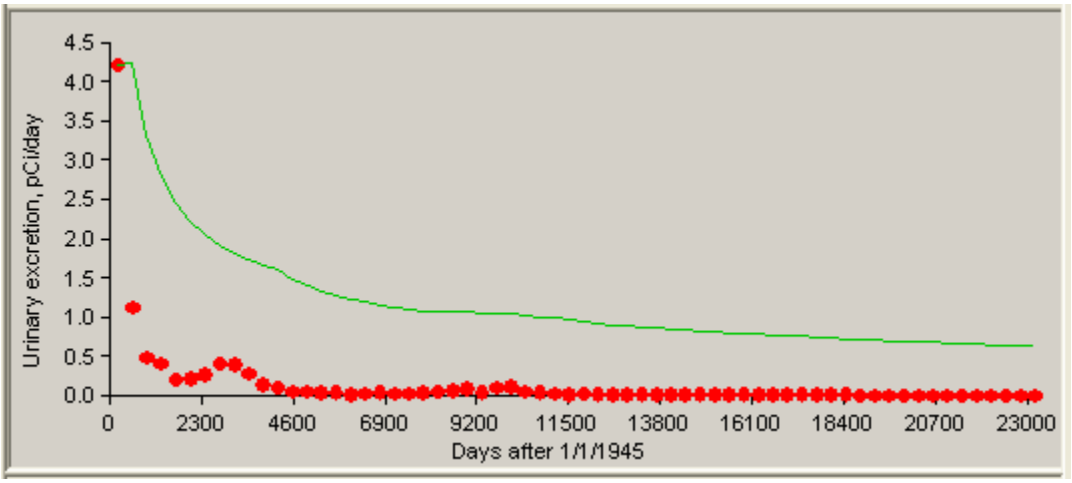

Figure B-53. Predicted ^{239}Pu bioassay results calculated using IMBA-derived ^{239}Pu intake rates (line) compared with bioassay results (dots) from all intakes, 84th percentile, type M.

Table B-3. Summary of ^{239}Pu type M intake rates (pCi/d) and dates.

Start	End	50th percentile	84th percentile	GSD
01/01/1944	12/31/1945	247.9	1,253	5.05
01/01/1946	12/31/1946	94.53	590	6.24
01/01/1947	12/31/1953	10.46	53.96	5.16
01/01/1954	12/31/1954	3.146	53.96	17.15
01/01/1955	12/31/1956	3.146	39.05	12.41
01/01/1957	12/31/1966	0.379	4.62	12.19
01/01/1967	12/31/1972	3.267	15.71	4.81
01/01/1973	12/31/1975	1.535	9.54	6.21
01/01/1976	12/31/1993	0.164	1.12	6.83
01/01/1994	12/31/2008	0.013	0.15	12.20

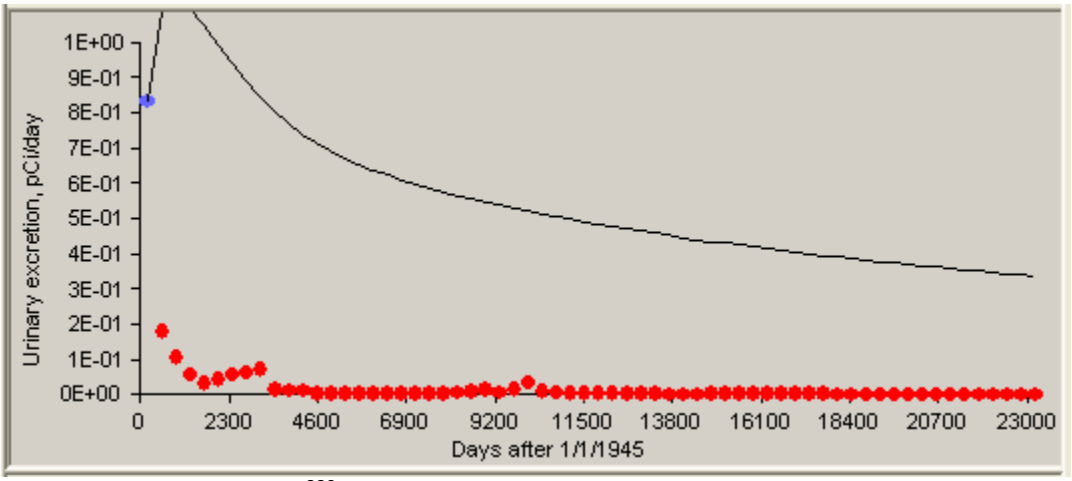

Figure B-54. Predicted ^{239}Pu urinalysis bioassay results calculated using IMBA-derived ^{239}Pu intake rates (line) compared with bioassay results (dots), 1944 to 1945, 50th percentile, type S.

ATTACHMENT B
CO-EXPOSURE DATA FIGURES

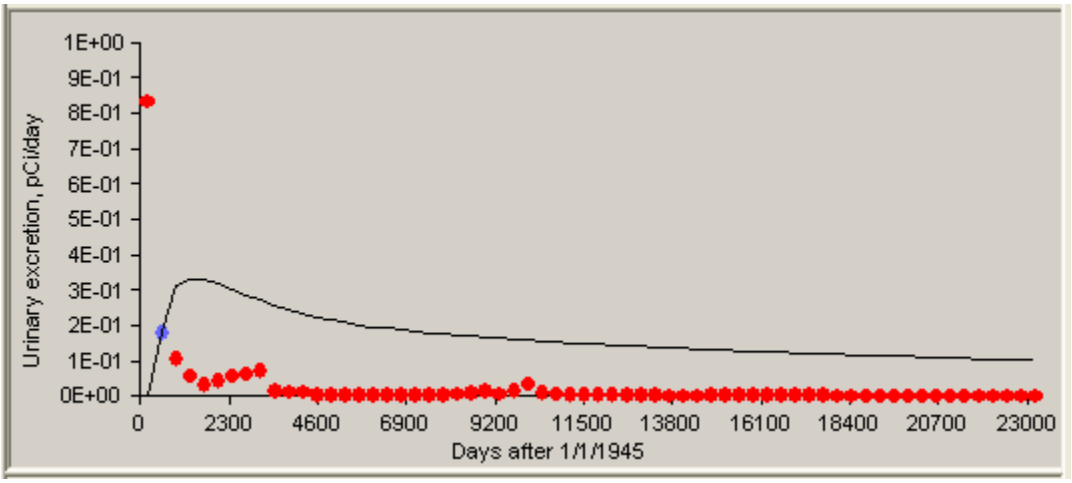

Figure B-55. Predicted ^{239}Pu urinalysis bioassay results calculated using IMBA-derived ^{239}Pu intake rates (line) compared with bioassay results (dots), 1946, 50th percentile, type S.

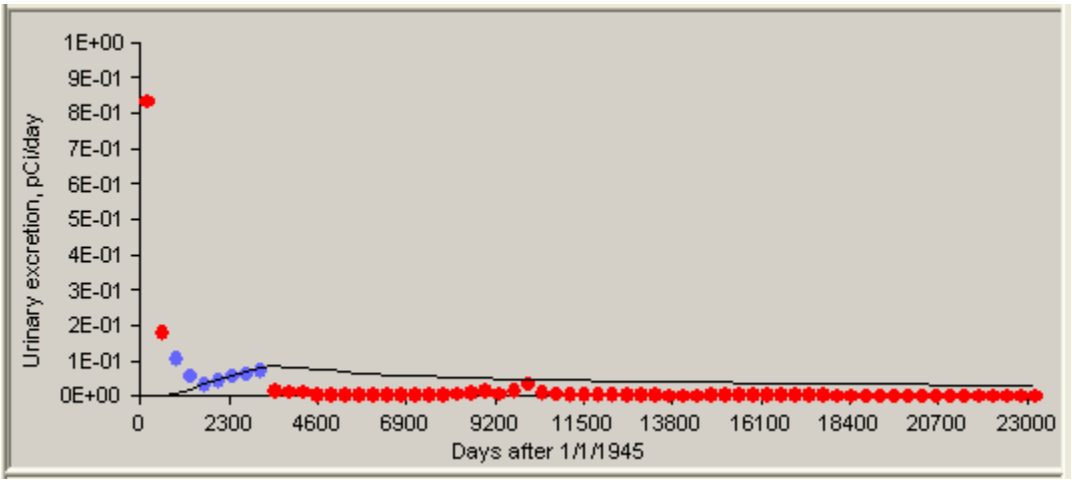

Figure B-56. Predicted ^{239}Pu urinalysis bioassay results calculated using IMBA-derived ^{239}Pu intake rates (line) compared with bioassay results (dots), 1947 to 1953, 50th percentile, type S.

ATTACHMENT B
CO-EXPOSURE DATA FIGURES

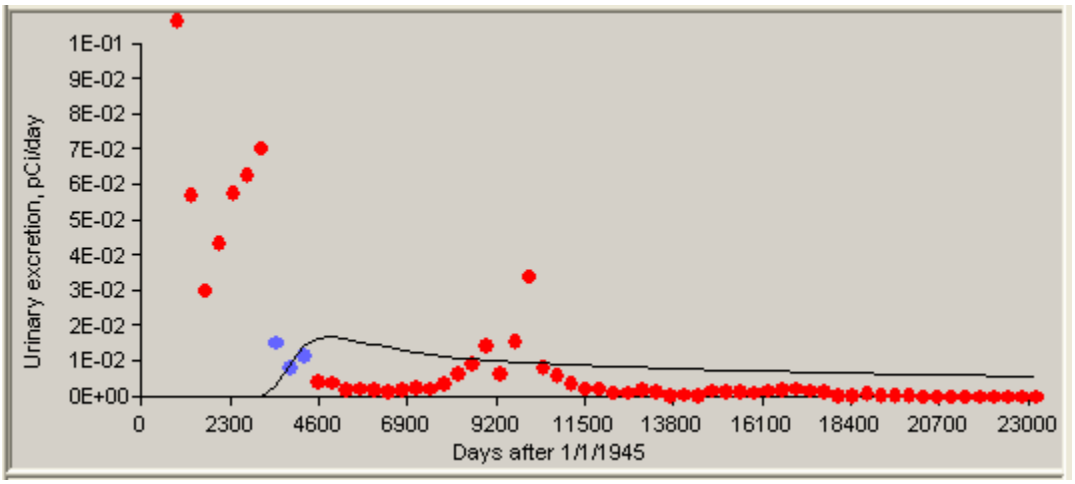

Figure B-57. Predicted ^{239}Pu urinalysis bioassay results calculated using IMBA-derived ^{239}Pu intake rates (line) compared with bioassay results (dots), 1954 to 1956, 50th percentile, type S.

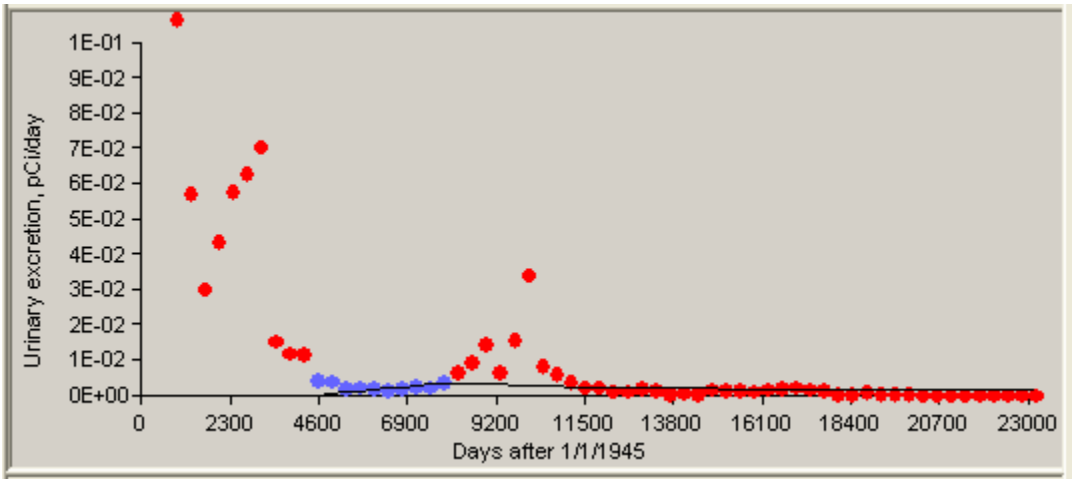

Figure B-58. Predicted ^{239}Pu urinalysis bioassay results calculated using IMBA-derived ^{239}Pu intake rates (line) compared with bioassay results (dots), 1957 to 1966, 50th percentile, type S.

ATTACHMENT B
CO-EXPOSURE DATA FIGURES

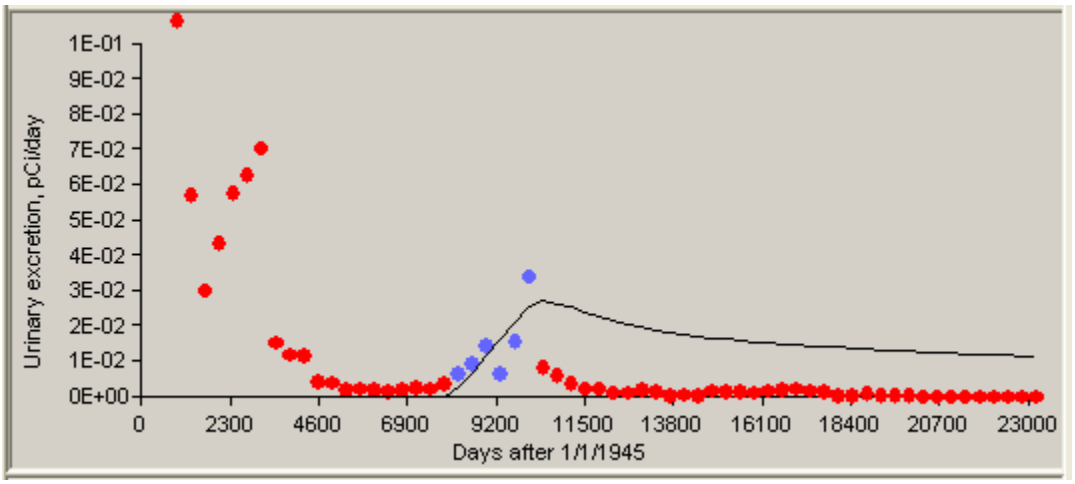

Figure B-59. Predicted ^{239}Pu urinalysis bioassay results calculated using IMBA-derived ^{239}Pu intake rates (line) compared with bioassay results (dots), 1967 to 1972, 50th percentile, type S.

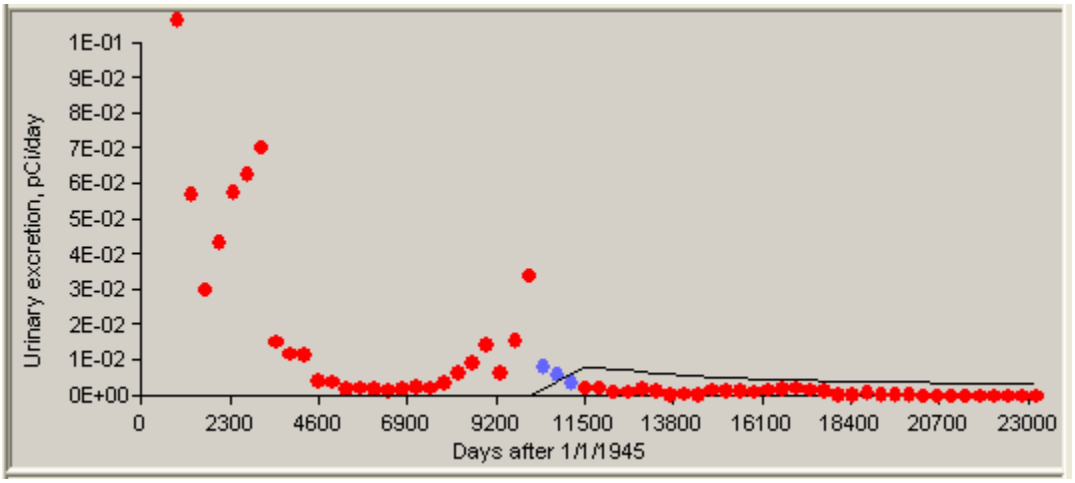

Figure B-60. Predicted ^{239}Pu urinalysis bioassay results calculated using IMBA-derived ^{239}Pu intake rates (line) compared with bioassay results (dots), 1973 to 1975, 50th percentile, type S.

ATTACHMENT B
CO-EXPOSURE DATA FIGURES

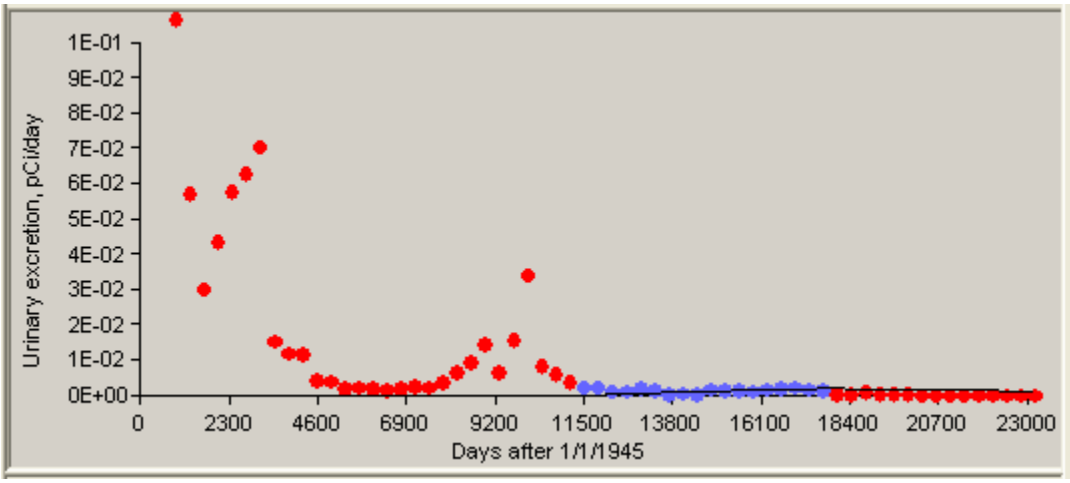

Figure B-61. Predicted ^{239}Pu urinalysis bioassay results calculated using IMBA-derived ^{239}Pu intake rates (line) compared with bioassay results (dots), 1976 to 1993, 50th percentile, type S.

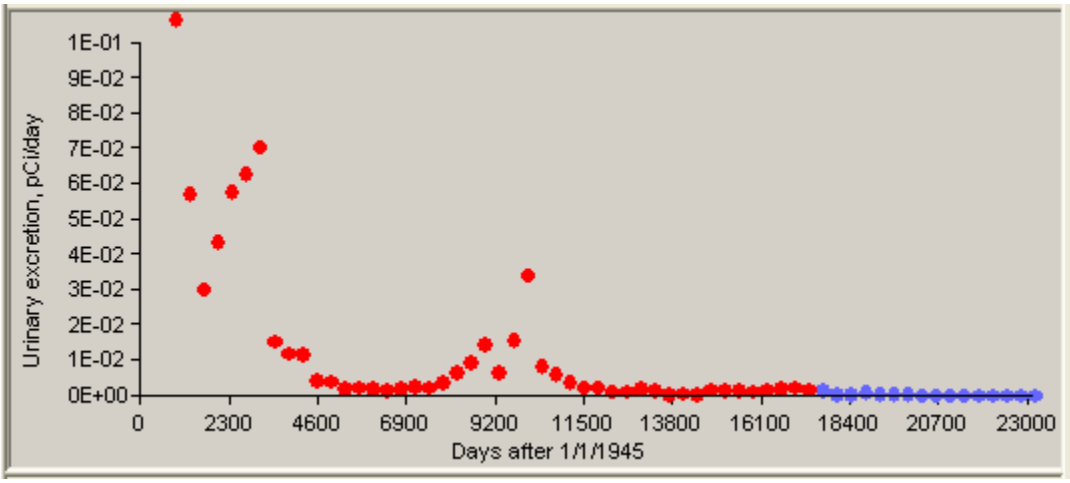

Figure B-62. Predicted ^{239}Pu urinalysis bioassay results calculated using IMBA-derived ^{239}Pu intake rates (line) compared with bioassay results (dots), 1994 to 2008, 50th percentile, type S.

ATTACHMENT B
CO-EXPOSURE DATA FIGURES

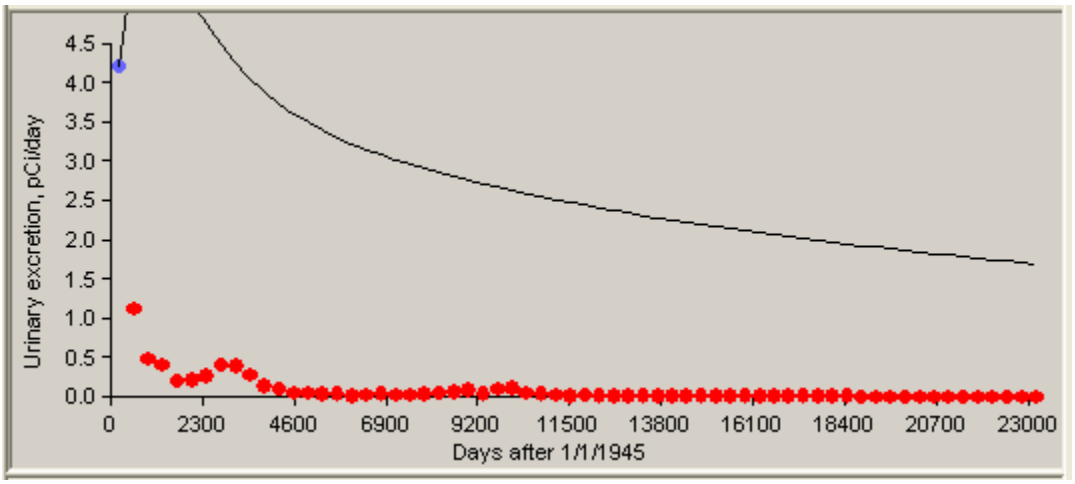

Figure B-63. Predicted ^{239}Pu urinalysis bioassay results calculated using IMBA-derived ^{239}Pu intake rates (line) compared with bioassay results (dots), 1944 to 1945, 84th percentile, type S.

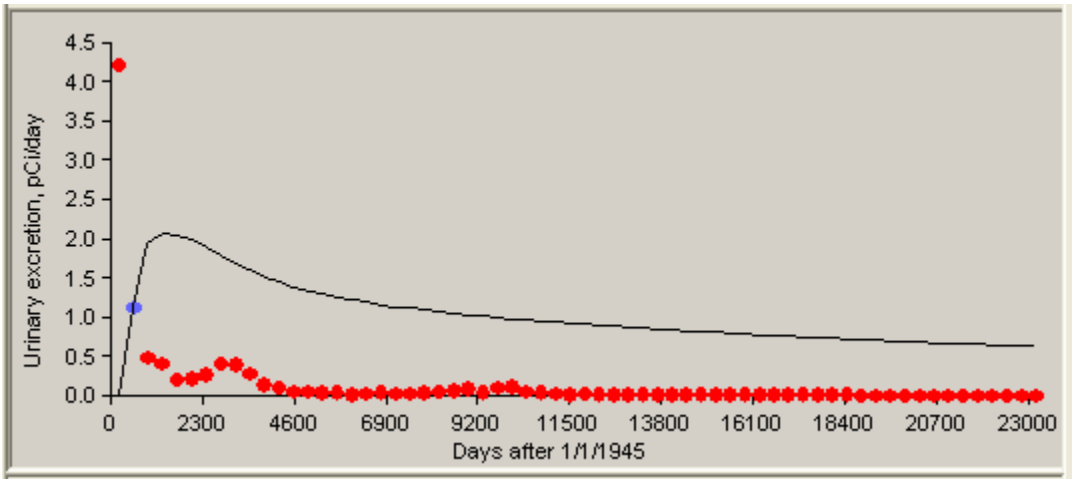

Figure B-64. Predicted ^{239}Pu urinalysis bioassay results calculated using IMBA-derived ^{239}Pu intake rates (line) compared with bioassay results (dots), 1946, 84th percentile, type S.

ATTACHMENT B
CO-EXPOSURE DATA FIGURES

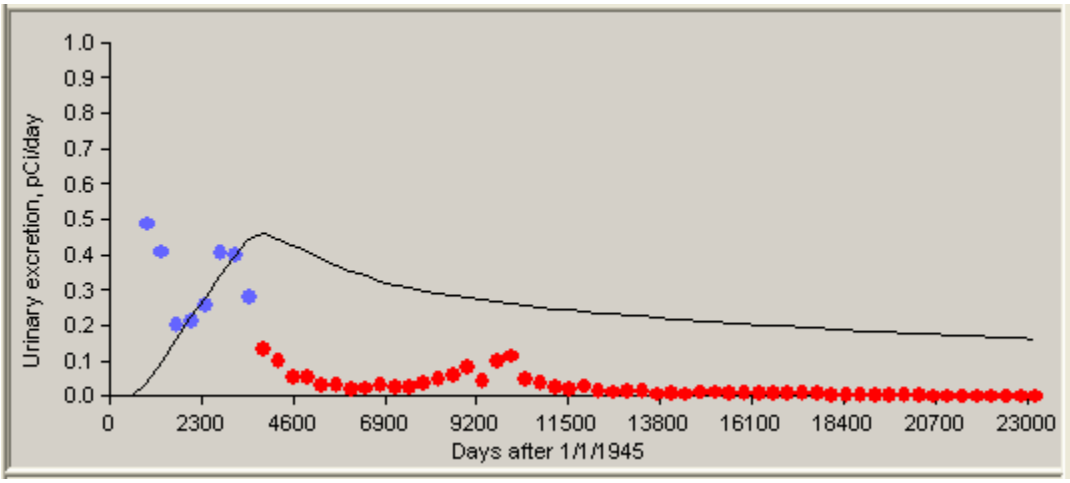

Figure B-65. Predicted ^{239}Pu urinalysis bioassay results calculated using IMBA-derived ^{239}Pu intake rates (line) compared with bioassay results (dots), 1947 to 1954, 84th percentile, type S.

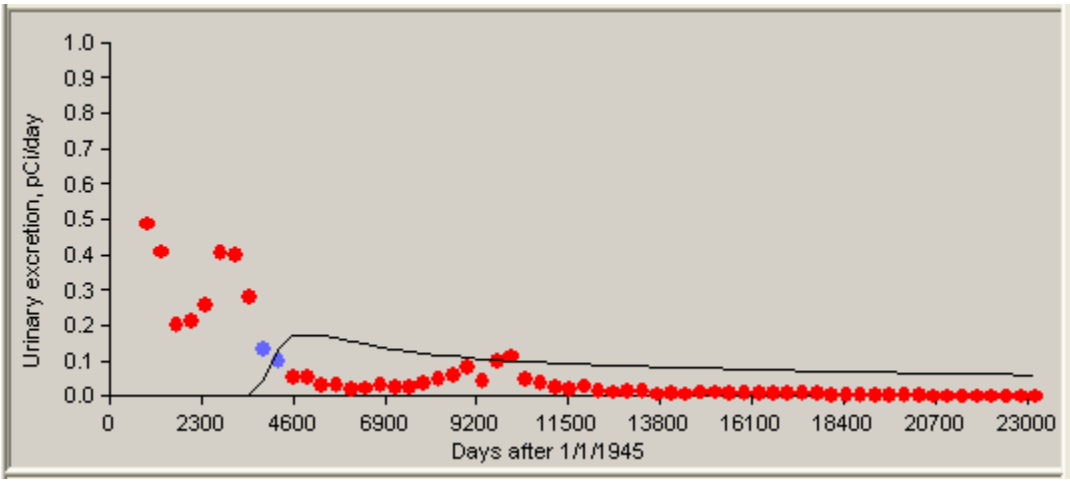

Figure B-66. Predicted ^{239}Pu urinalysis bioassay results calculated using IMBA-derived ^{239}Pu intake rates (line) compared with bioassay results (dots), 1955 to 1956, 84th percentile, type S.

ATTACHMENT B
CO-EXPOSURE DATA FIGURES

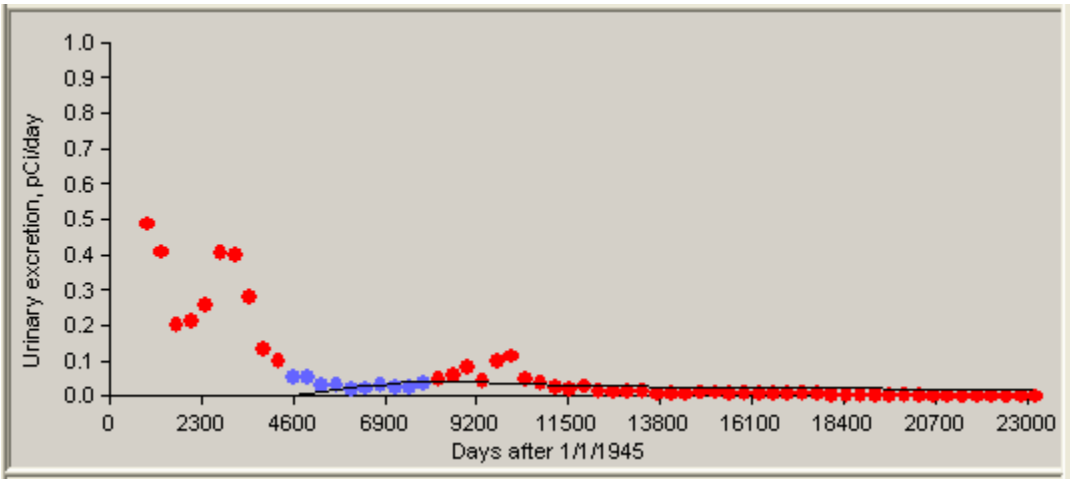

Figure B-67. Predicted ^{239}Pu urinalysis bioassay results calculated using IMBA-derived ^{239}Pu intake rates (line) compared with bioassay results (dots), 1957 to 1966, 84th percentile, type S.

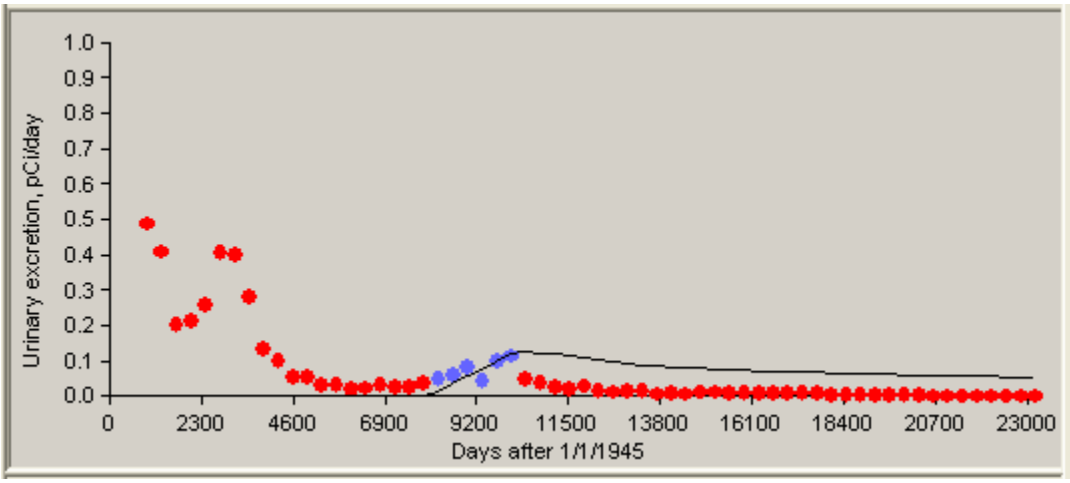

Figure B-68. Predicted ^{239}Pu urinalysis bioassay results calculated using IMBA-derived ^{239}Pu intake rates (line) compared with bioassay results (dots), 1967 to 1972, 84th percentile, type S.

ATTACHMENT B
CO-EXPOSURE DATA FIGURES

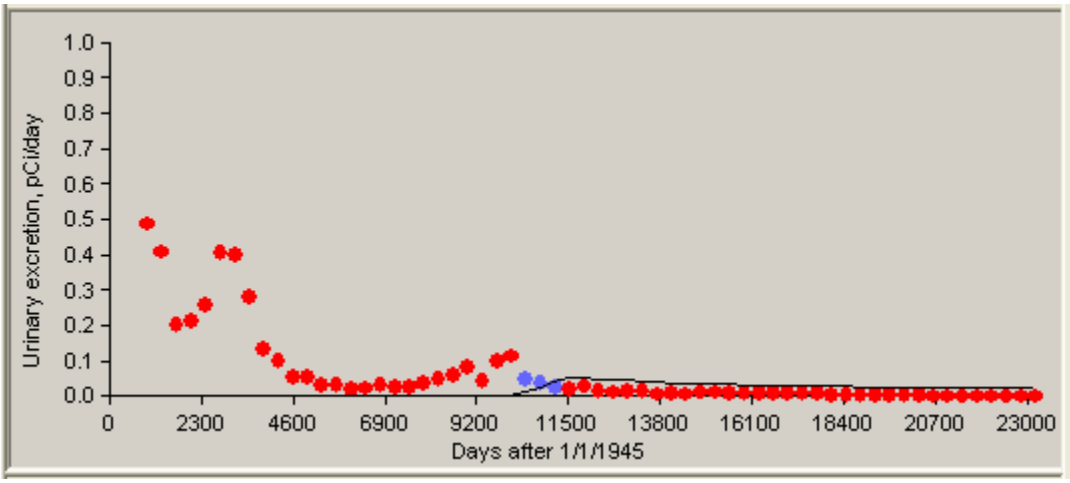

Figure B-69. Predicted ^{239}Pu urinalysis bioassay results calculated using IMBA-derived ^{239}Pu intake rates (line) compared with bioassay results (dots), 1973 to 1975, 84th percentile, type S.

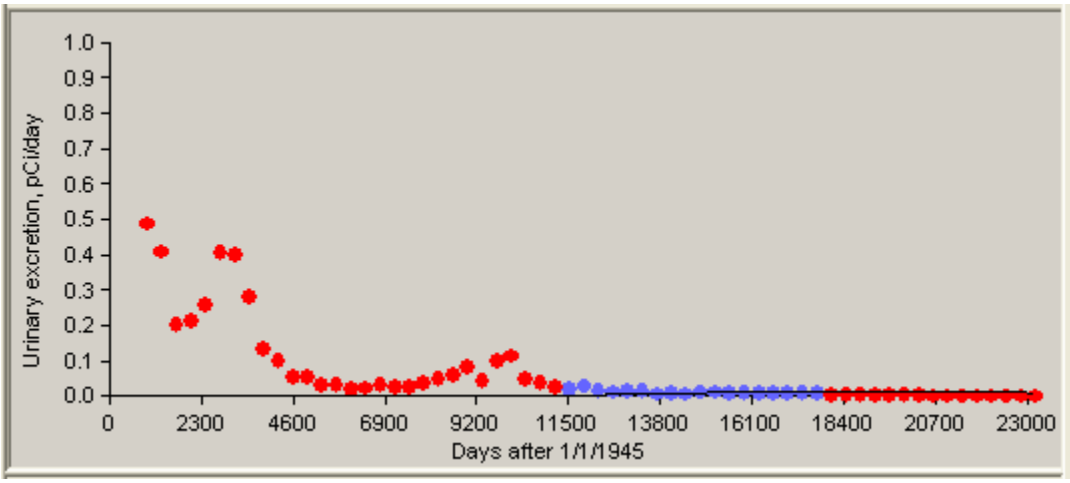

Figure B-70. Predicted ^{239}Pu urinalysis bioassay results calculated using IMBA-derived ^{239}Pu intake rates (line) compared with bioassay results (dots), 1976 to 1993, 84th percentile, type S.

ATTACHMENT B
CO-EXPOSURE DATA FIGURES

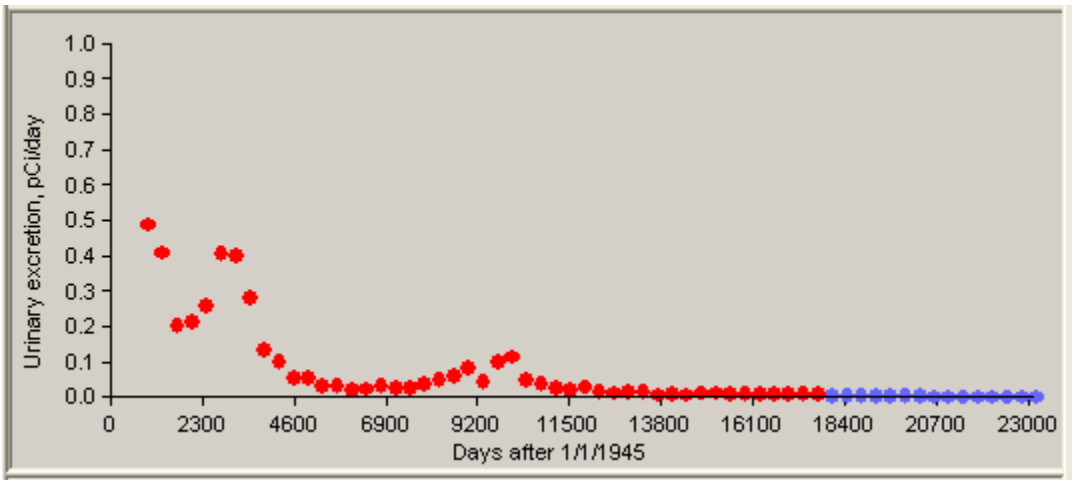

Figure B-71. Predicted ^{239}Pu urinalysis bioassay results calculated using IMBA-derived ^{239}Pu intake rates (line) compared with bioassay results (dots), 1994 to 2008, 84th percentile, type S.

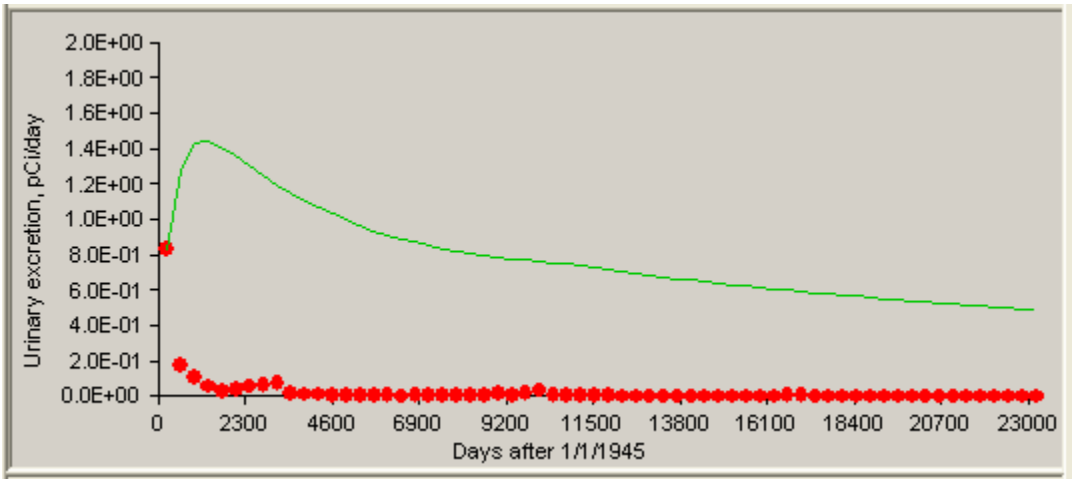

Figure B-72. Predicted ^{239}Pu urinalysis bioassay results calculated using IMBA-derived ^{239}Pu intake rates (line) compared with bioassay results (dots) from all intakes, 50th percentile, type S.

ATTACHMENT B
CO-EXPOSURE DATA FIGURES

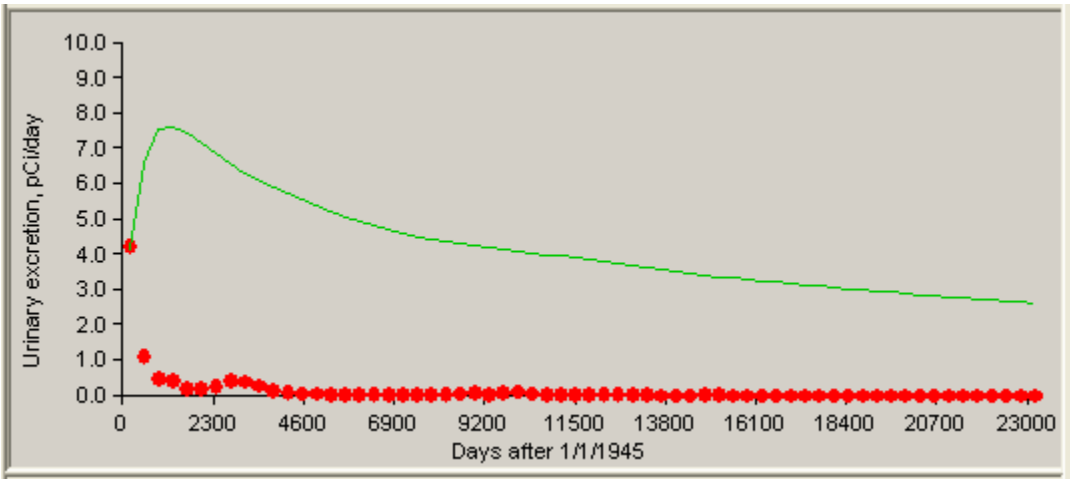

Figure B-73. Predicted ^{239}Pu urinalysis bioassay results calculated using IMBA-derived ^{239}Pu intake rates (line) compared with bioassay results (dots) from all intakes, 84th percentile, type S.

Table B-4. Summary of ^{239}Pu type S urinalysis-based intake rates (pCi/d) and dates.

Start	End	50th percentile	84th percentile	GSD
01/01/1944	12/31/1945	8,651	43,270	5.05
01/01/1946	12/31/1946	5,125	31,990	6.24
01/01/1947	12/31/1953	200.2	975	4.87
01/01/1954	12/31/1954	87.71	975	11.12
01/01/1955	12/31/1956	87.71	1,342	15.30
01/01/1957	12/31/1966	6.27	74.67	11.91
01/01/1967	12/31/1972	73.47	339.2	4.62
01/01/1973	12/31/1975	40.56	257	6.34
01/01/1976	12/31/1993	2.303	14.51	6.30
01/01/1994	12/31/2008	0.1402	1.798	12.82

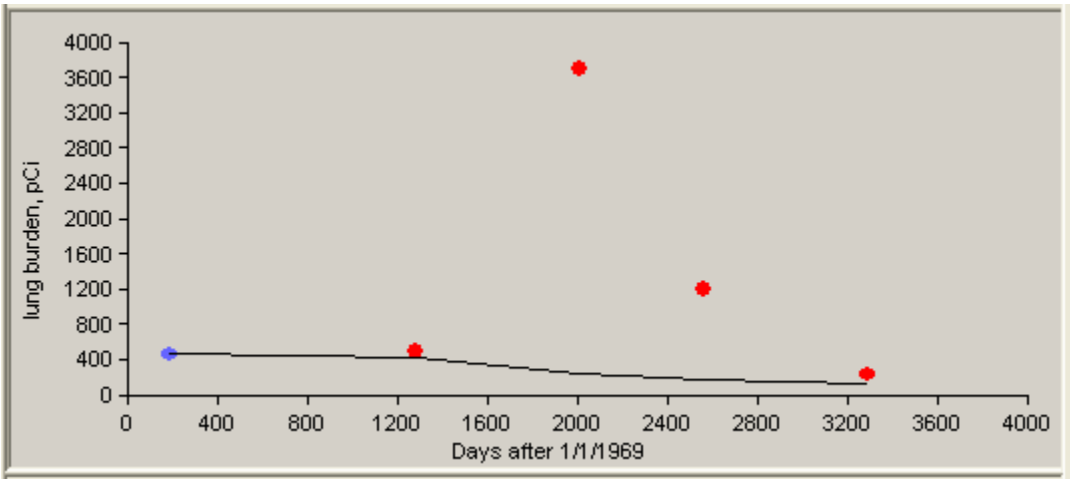

Figure B-74. Predicted ^{239}Pu lung burden bioassay results calculated using IMBA-derived ^{239}Pu intake rates (line) compared with bioassay results (dots), 1969 to 1971, 50th percentile, type S.

ATTACHMENT B
CO-EXPOSURE DATA FIGURES

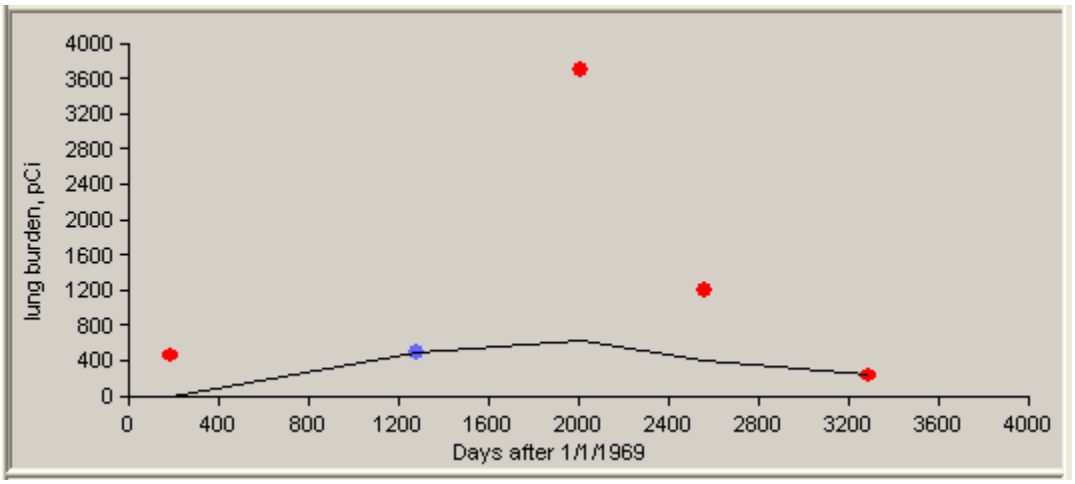

Figure B-75. Predicted ^{239}Pu lung burden bioassay results calculated using IMBA-derived ^{239}Pu intake rates (line) compared with bioassay results (dots), 1972 to 1974, 50th percentile, type S.

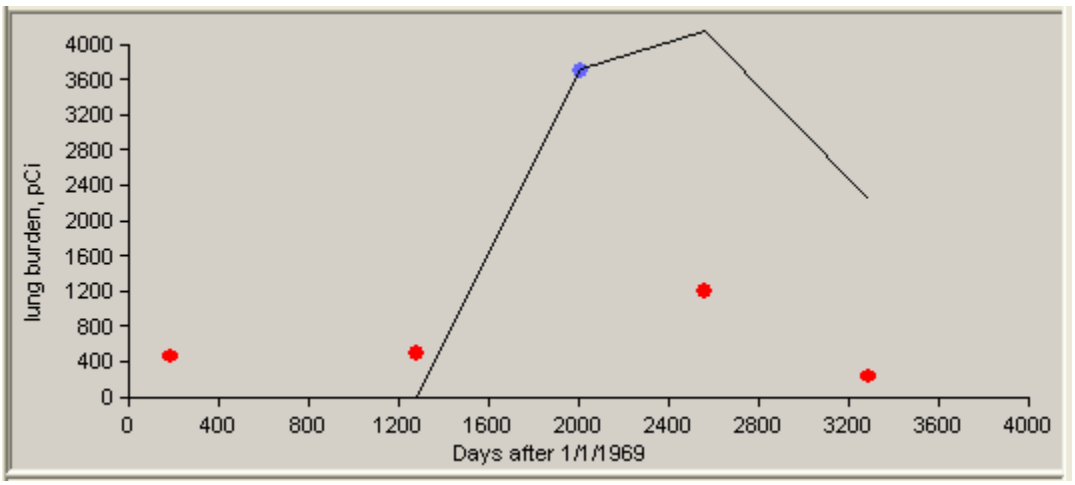

Figure B-76. Predicted ^{239}Pu lung burden bioassay results calculated using IMBA-derived ^{239}Pu intake rates (line) compared with bioassay results (dots), 1975, 50th percentile, type S.

ATTACHMENT B
CO-EXPOSURE DATA FIGURES

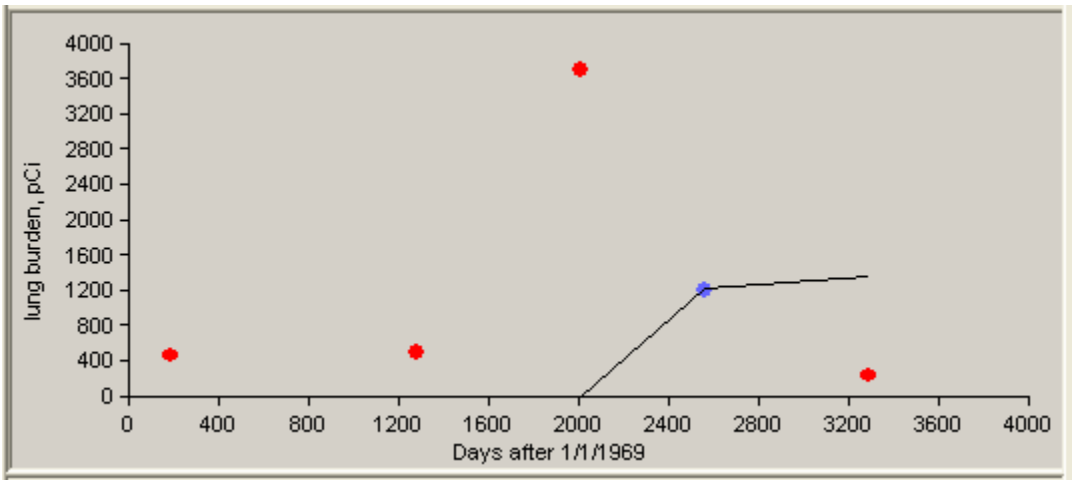

Figure B-77. Predicted ^{239}Pu lung burden bioassay results calculated using IMBA-derived ^{239}Pu intake rates (line) compared with bioassay results (dots), 1976 to 1977, 50th percentile, type S.

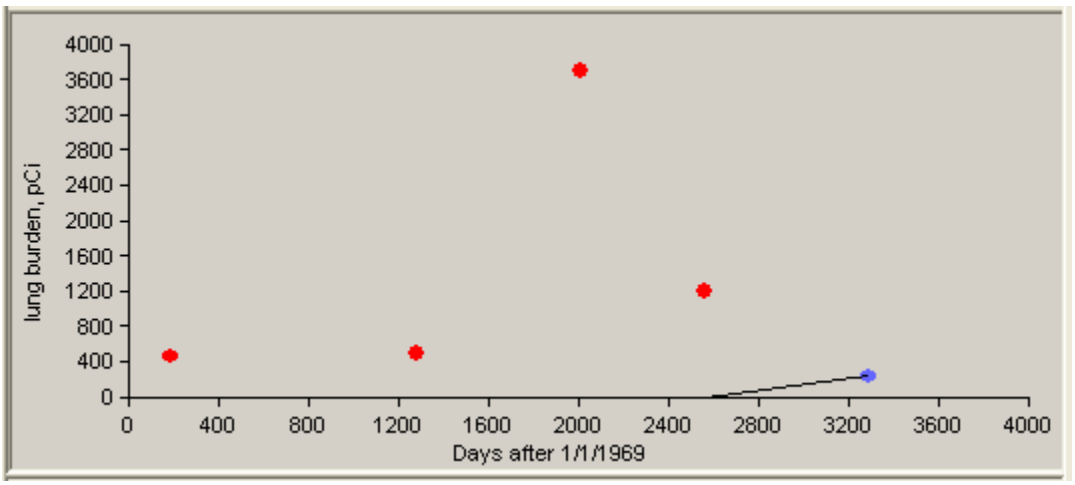

Figure B-78. Predicted ^{239}Pu lung burden bioassay results calculated using IMBA-derived ^{239}Pu intake rates (line) compared with bioassay results (dots), 1978 to 1979, 50th percentile, type S.

ATTACHMENT B
CO-EXPOSURE DATA FIGURES

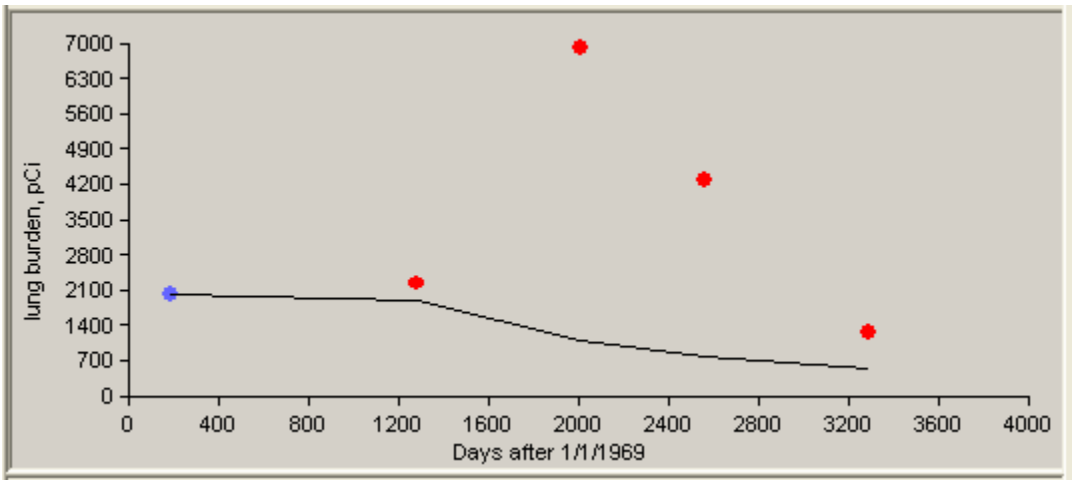

Figure B-79. Predicted ^{239}Pu lung burden bioassay results calculated using IMBA-derived ^{239}Pu intake rates (line) compared with bioassay results (dots), 1969 to 1971, 84th percentile, type S.

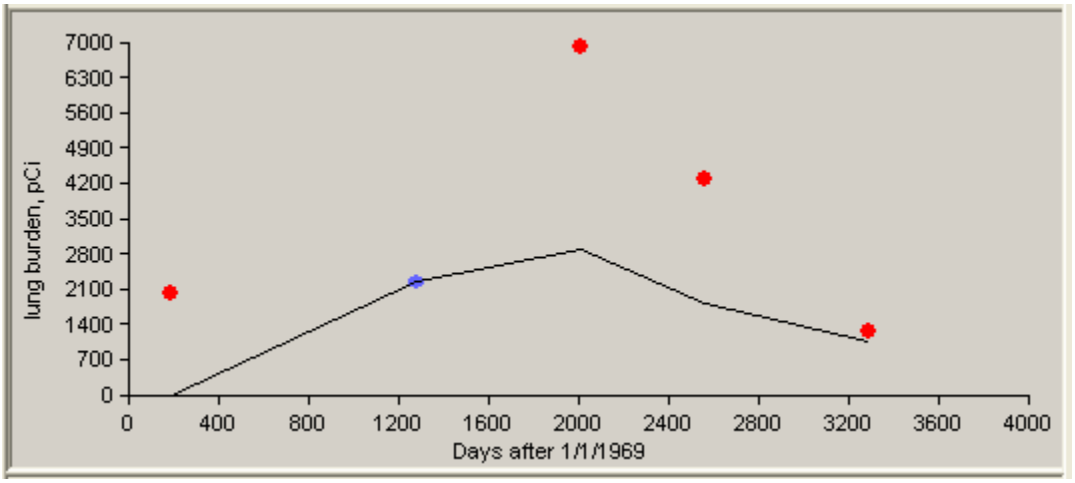

Figure B-80. Predicted ^{239}Pu lung burden bioassay results calculated using IMBA-derived ^{239}Pu intake rates (line) compared with bioassay results (dots), 1972 to 1974, 84th percentile, type S.

ATTACHMENT B
CO-EXPOSURE DATA FIGURES

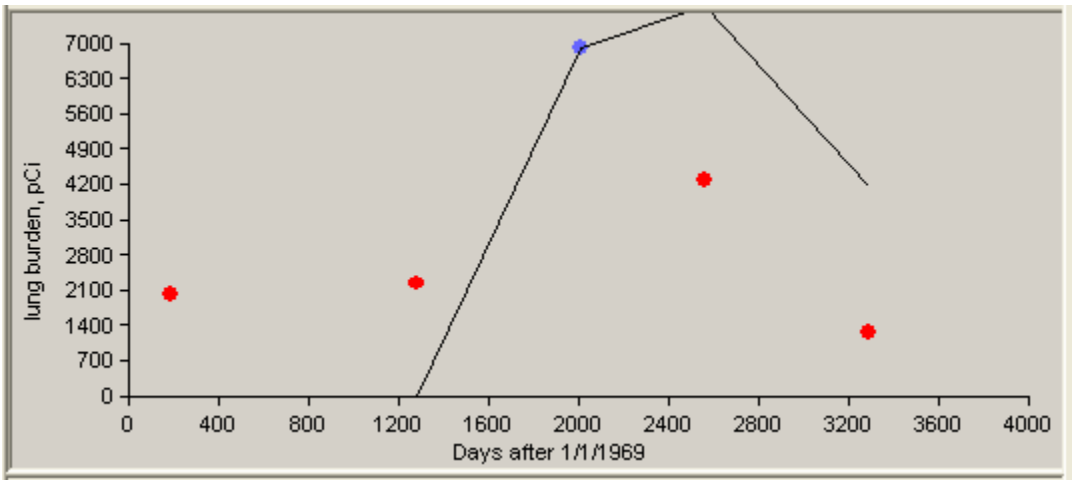

Figure B-81. Predicted ^{239}Pu lung burden bioassay results calculated using IMBA-derived ^{239}Pu intake rates (line) compared with bioassay results (dots), 1975, 84th percentile, type S.

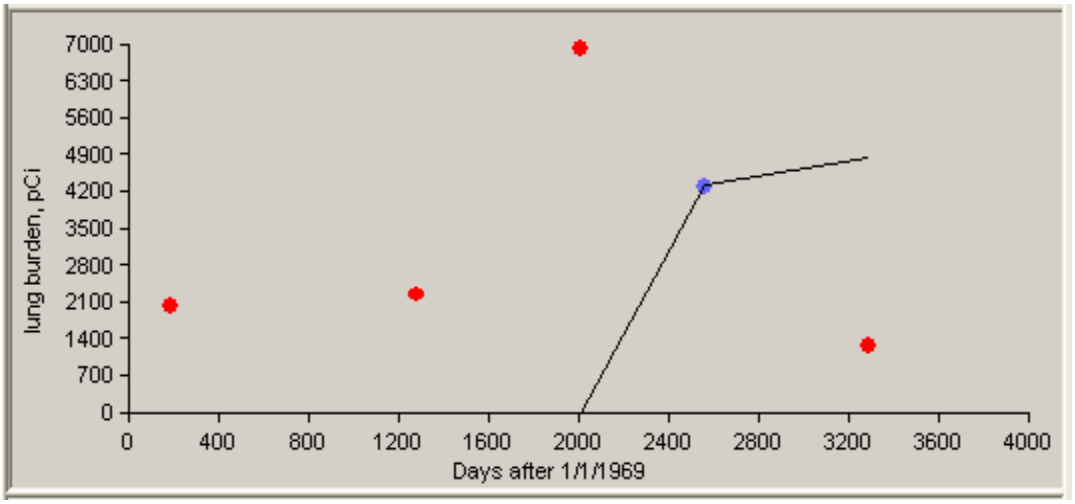

Figure B-82. Predicted ^{239}Pu lung burden bioassay results calculated using IMBA-derived ^{239}Pu intake rates (line) compared with bioassay results (dots), 1976 to 1977, 84th percentile, type S.

ATTACHMENT B
CO-EXPOSURE DATA FIGURES

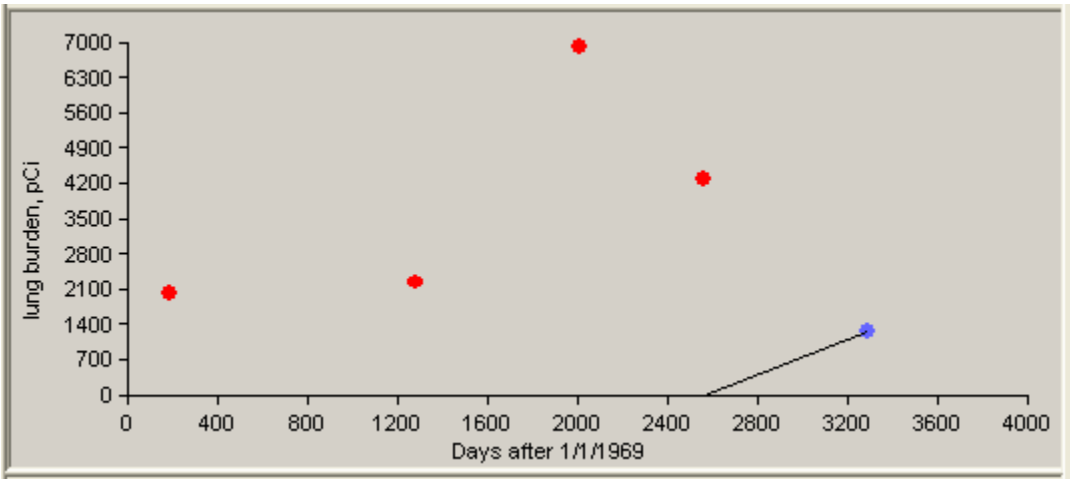

Figure B-83. Predicted ^{239}Pu lung burden bioassay results calculated using IMBA-derived ^{239}Pu intake rates (line) compared with bioassay results (dots), 1978 to 1979, 84th percentile, type S.

Table B-5. Summary of ^{239}Pu type S lung burden-based intake rates (pCi/d) and dates.

Start	End	50th percentile	84th percentile	GSD
01/01/1969	12/31/1971	27.66	118.9	4.30
01/01/1972	12/31/1974	29.43	132.5	4.50
01/01/1975	12/31/1975	505.4	942.5	1.86
01/01/1976	12/31/1977	96.07	339.8	3.54
01/01/1978	12/31/1979	19.55	101.7	5.20

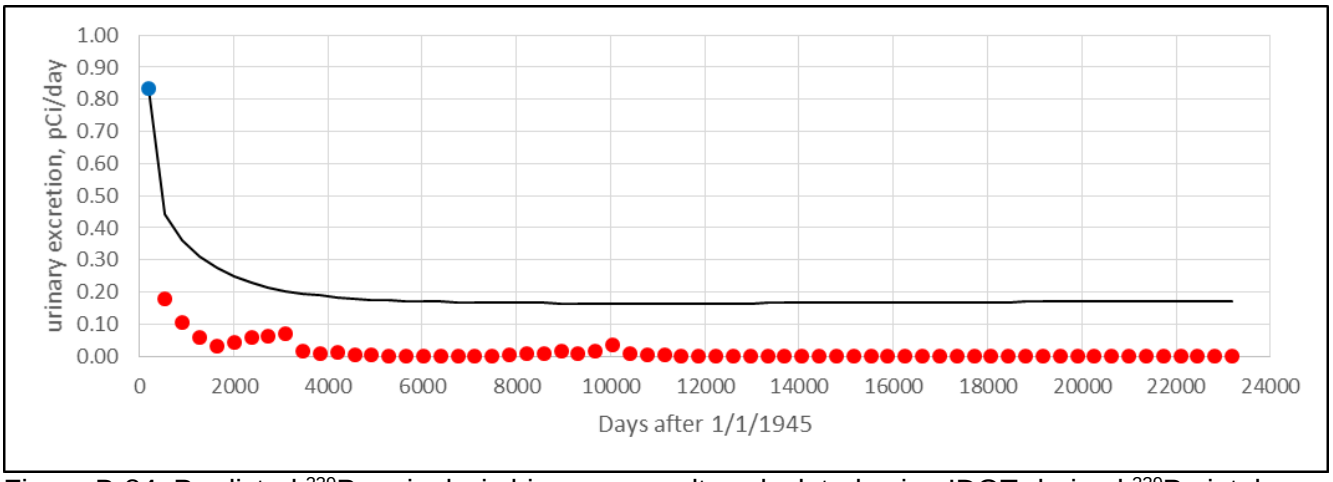

Figure B-84. Predicted ^{239}Pu urinalysis bioassay results calculated using IDOT-derived ^{239}Pu intake rates (line) compared with bioassay results (dots), 1944 to 1945, 50th percentile, type SS.

ATTACHMENT B
CO-EXPOSURE DATA FIGURES

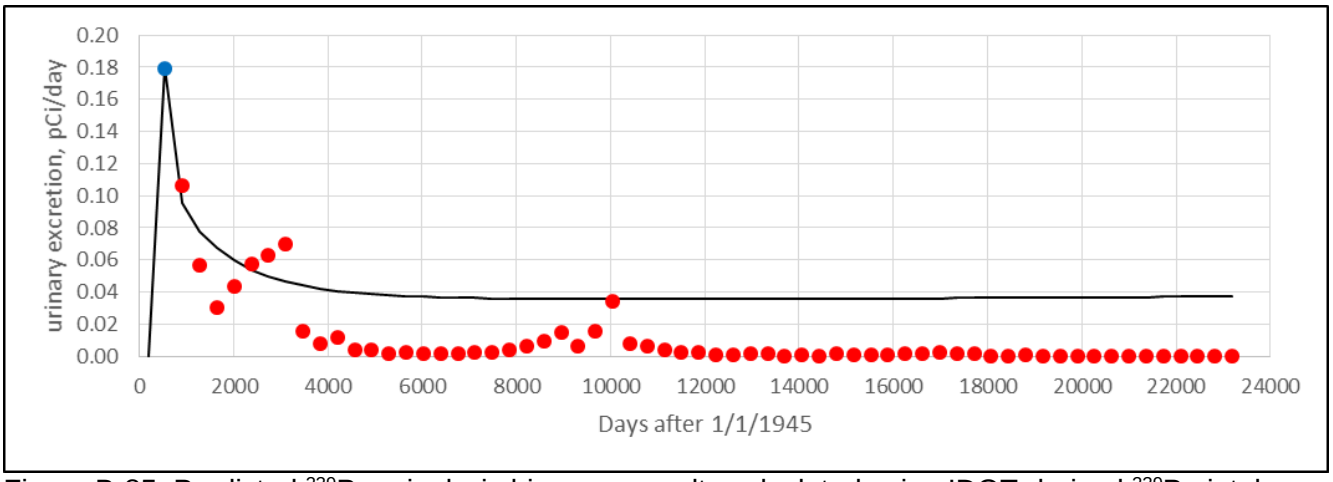

Figure B-85. Predicted ^{239}Pu urinalysis bioassay results calculated using IDOT-derived ^{239}Pu intake rates (line) compared with bioassay results (dots), 1946, 50th percentile, type SS.

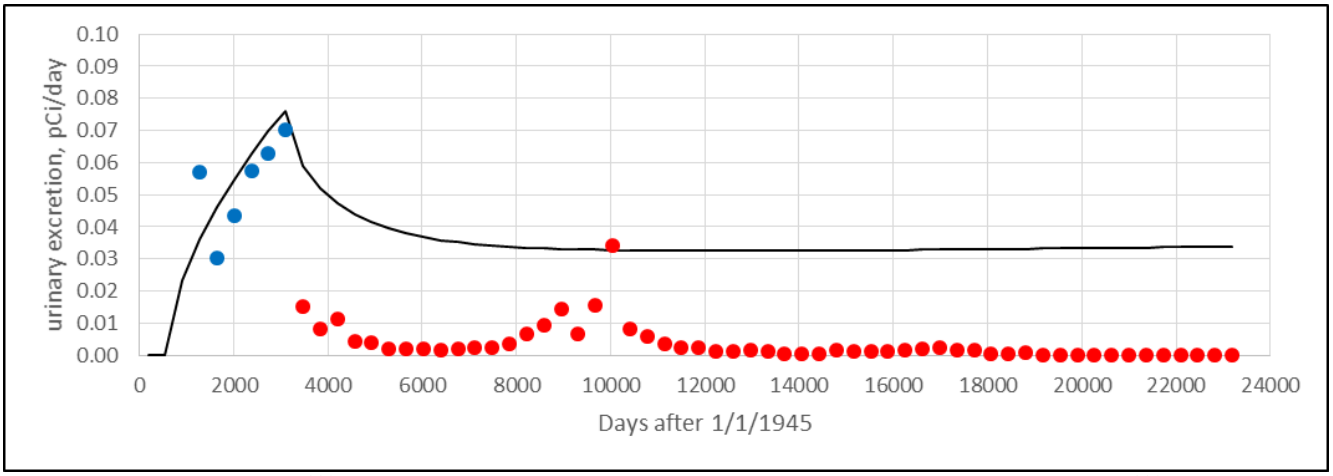

Figure B-86. Predicted ^{239}Pu urinalysis bioassay results calculated using IDOT-derived ^{239}Pu intake rates (line) compared with bioassay results (dots), 1947 to 1953, 50th percentile, type SS.

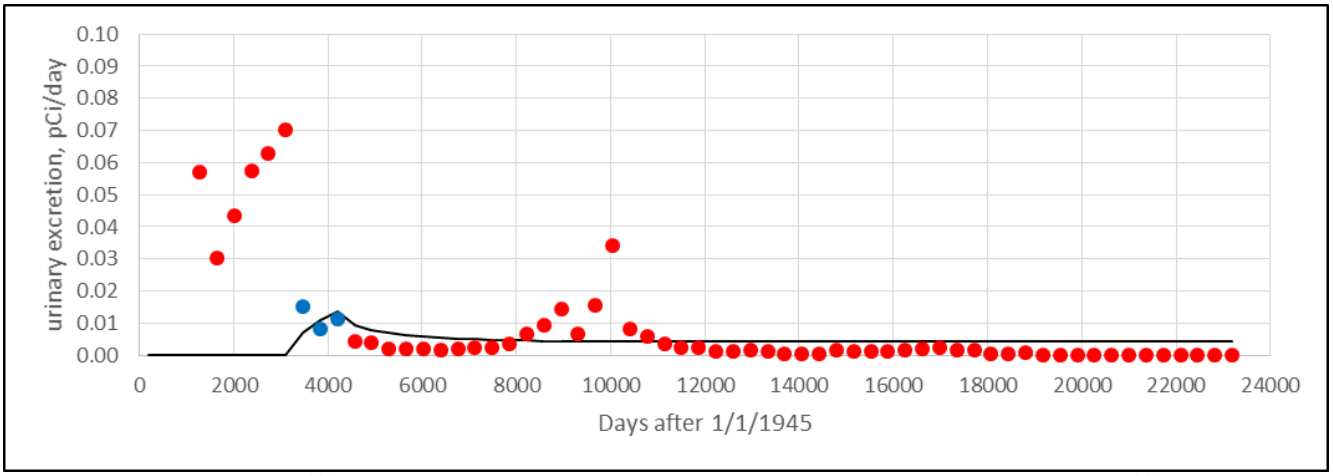

Figure B-87. Predicted ^{239}Pu urinalysis bioassay results calculated using IDOT-derived ^{239}Pu intake rates (line) compared with bioassay results (dots), 1954 to 1956, 50th percentile, type SS.

ATTACHMENT B
CO-EXPOSURE DATA FIGURES

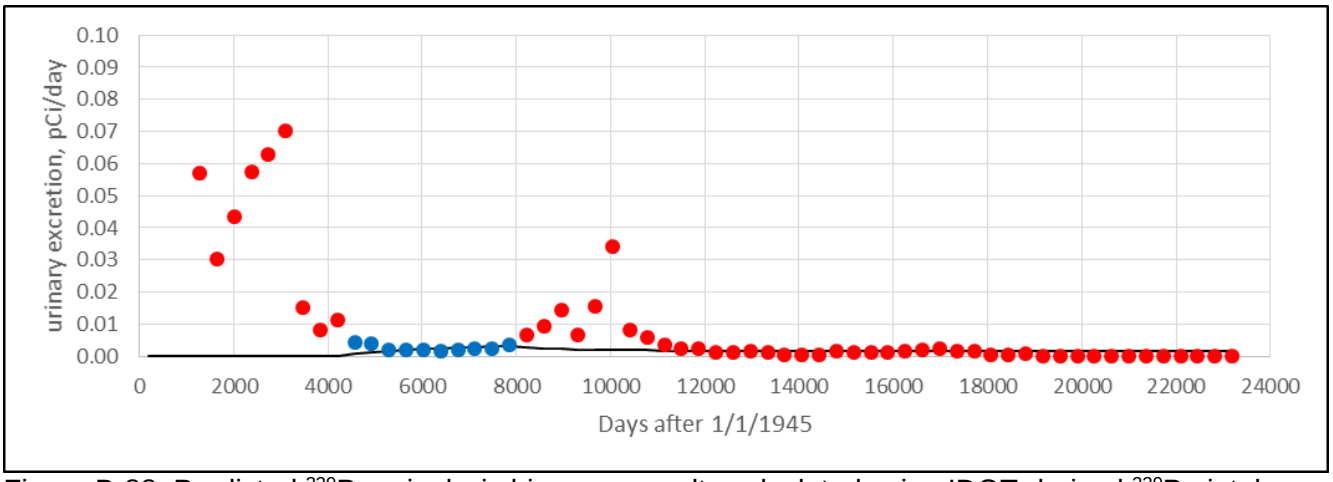

Figure B-88. Predicted ^{239}Pu urinalysis bioassay results calculated using IDOT-derived ^{239}Pu intake rates (line) compared with bioassay results (dots), 1957 to 1966, 50th percentile, type SS.

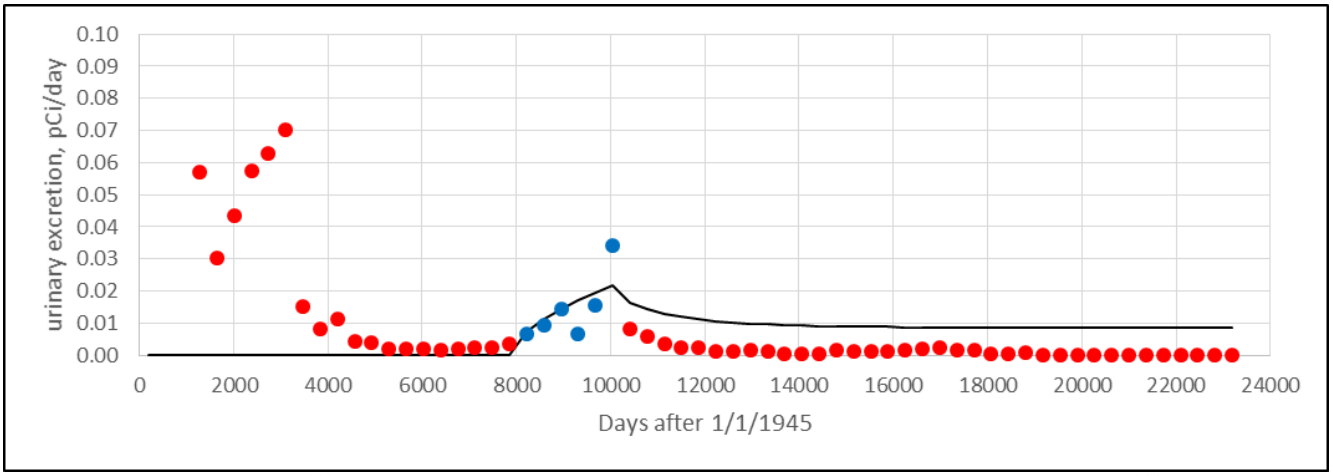

Figure B-89. Predicted ^{239}Pu urinalysis bioassay results calculated using IDOT-derived ^{239}Pu intake rates (line) compared with bioassay results (dots), 1967 to 1972, 50th percentile, type SS.

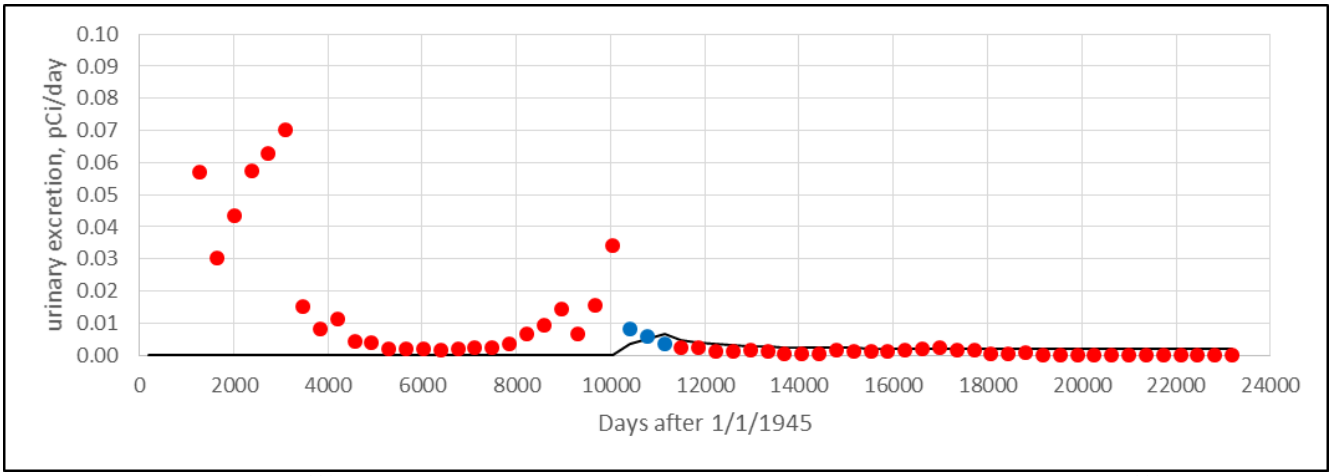

Figure B-90. Predicted ^{239}Pu urinalysis bioassay results calculated using IDOT-derived ^{239}Pu intake rates (line) compared with bioassay results (dots), 1973 to 1975, 50th percentile, type SS.

ATTACHMENT B
CO-EXPOSURE DATA FIGURES

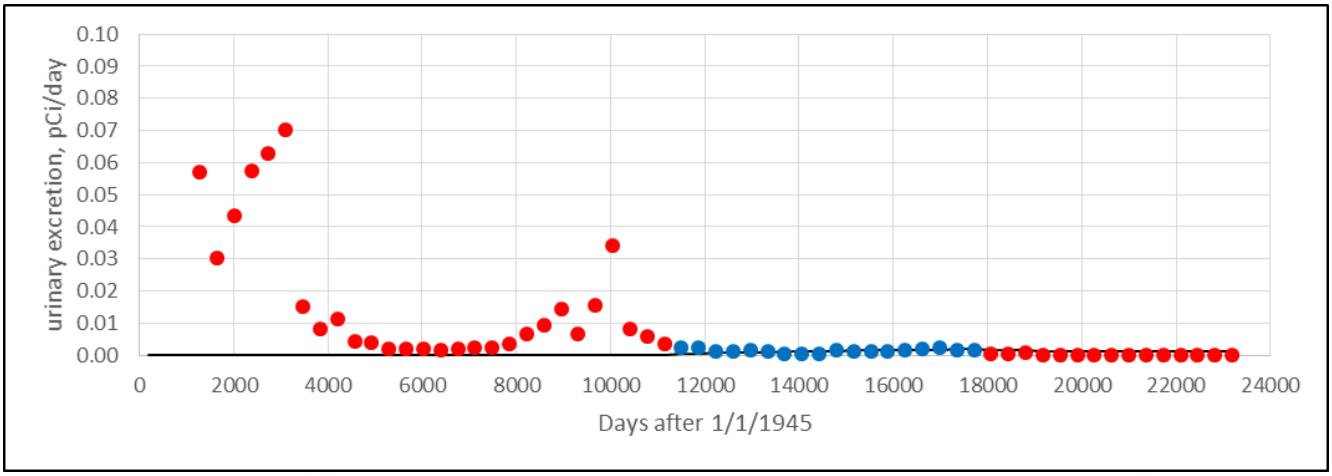

Figure B-91. Predicted ^{239}Pu urinalysis bioassay results calculated using IDOT-derived ^{239}Pu intake rates (line) compared with bioassay results (dots), 1976 to 1993, 50th percentile, type SS.

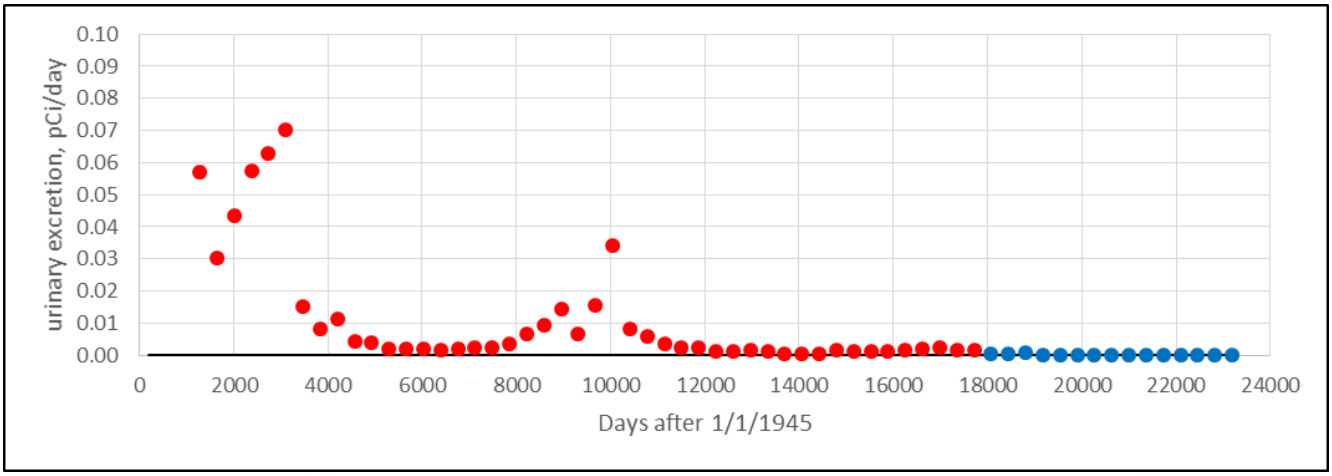

Figure B-92. Predicted ^{239}Pu urinalysis bioassay results calculated using IDOT-derived ^{239}Pu intake rates (line) compared with bioassay results (dots), 1994 to 2008, 50th percentile, type SS.

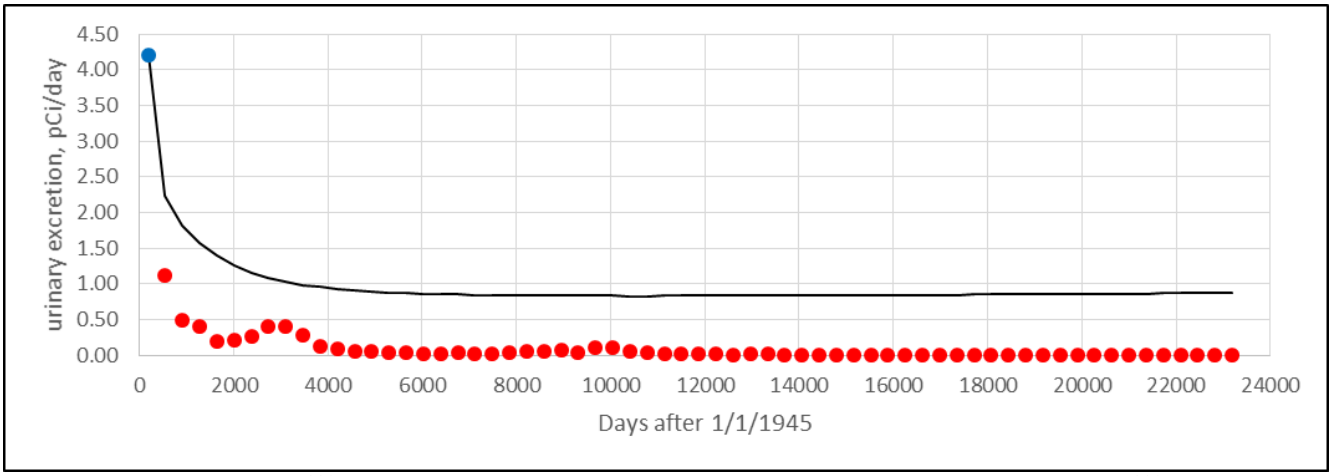

Figure B-93. Predicted ^{239}Pu urinalysis bioassay results calculated using IDOT-derived ^{239}Pu intake rates (line) compared with bioassay results (dots), 1944 to 1945, 84th percentile, type SS.

ATTACHMENT B
CO-EXPOSURE DATA FIGURES

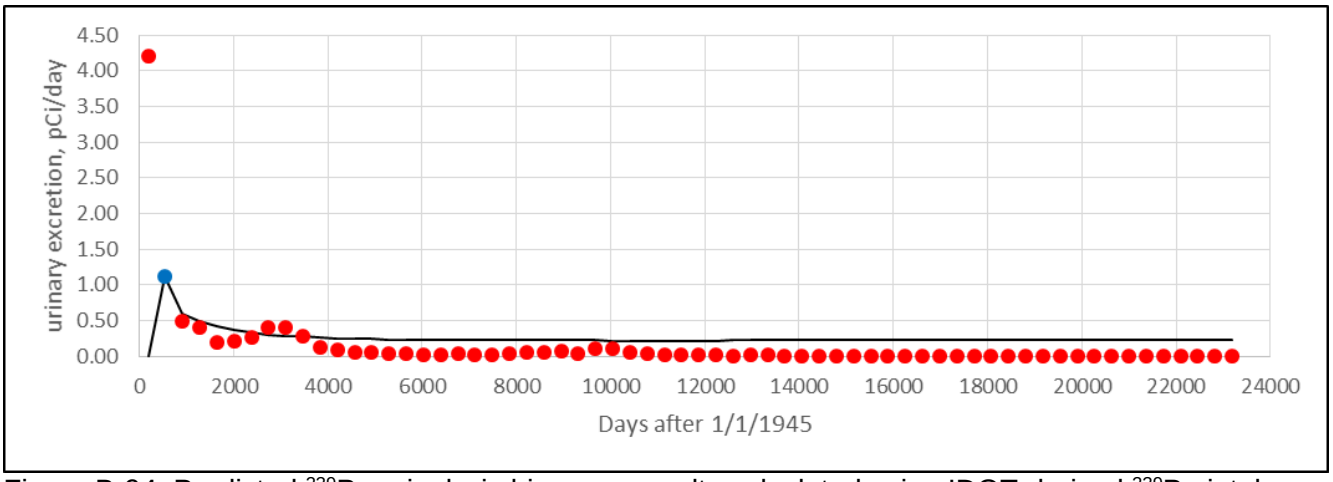

Figure B-94. Predicted ^{239}Pu urinalysis bioassay results calculated using IDOT-derived ^{239}Pu intake rates (line) compared with bioassay results (dots), 1946, 84th percentile, type SS.

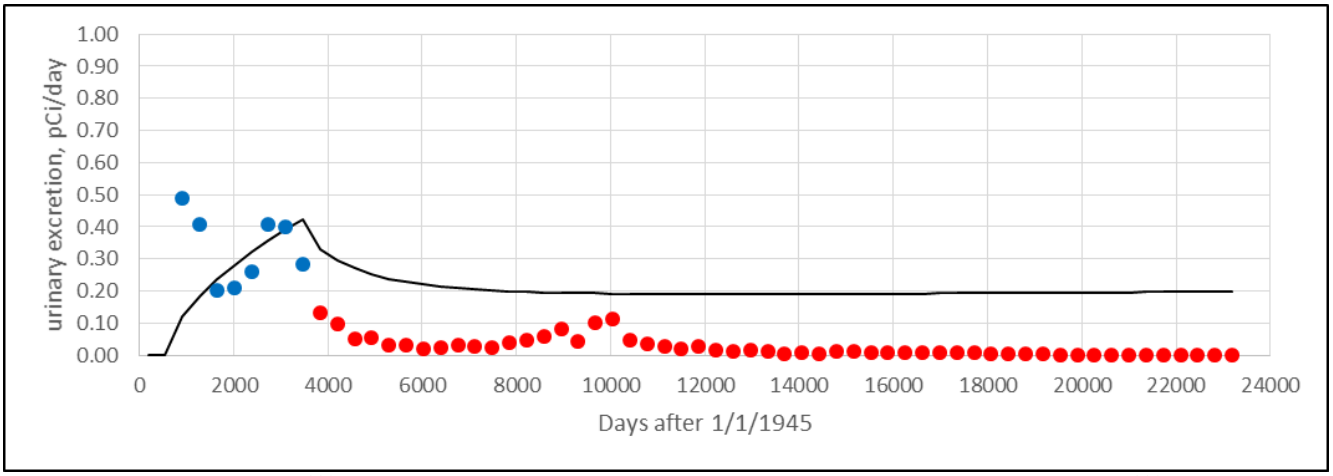

Figure B-95. Predicted ^{239}Pu urinalysis bioassay results calculated using IDOT-derived ^{239}Pu intake rates (line) compared with bioassay results (dots), 1947 to 1954, 84th percentile, type SS.

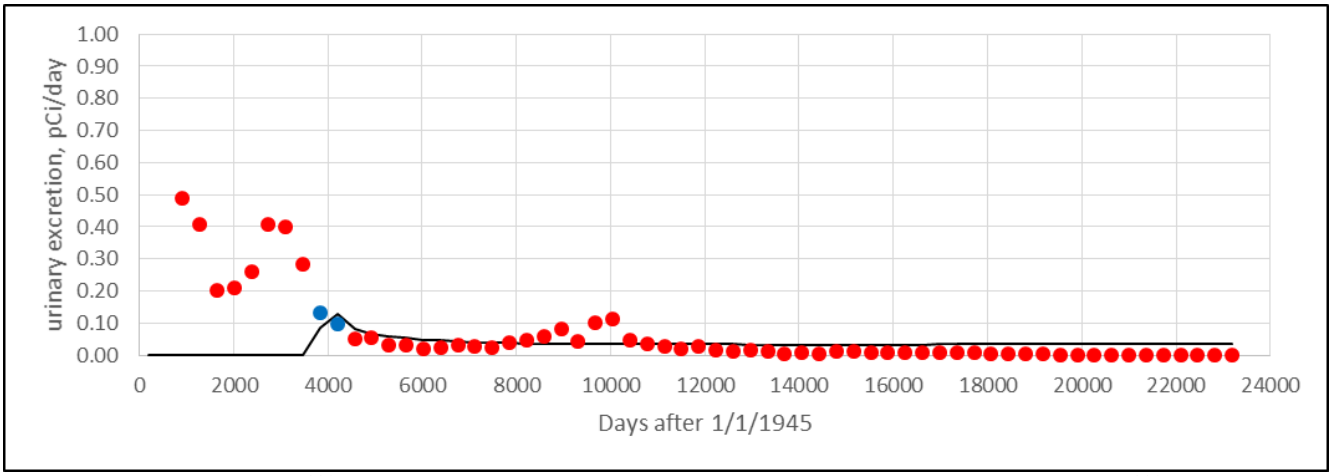

Figure B-96. Predicted ^{239}Pu urinalysis bioassay results calculated using IDOT-derived ^{239}Pu intake rates (line) compared with bioassay results (dots), 1955 to 1956, 84th percentile, type SS.

ATTACHMENT B
CO-EXPOSURE DATA FIGURES

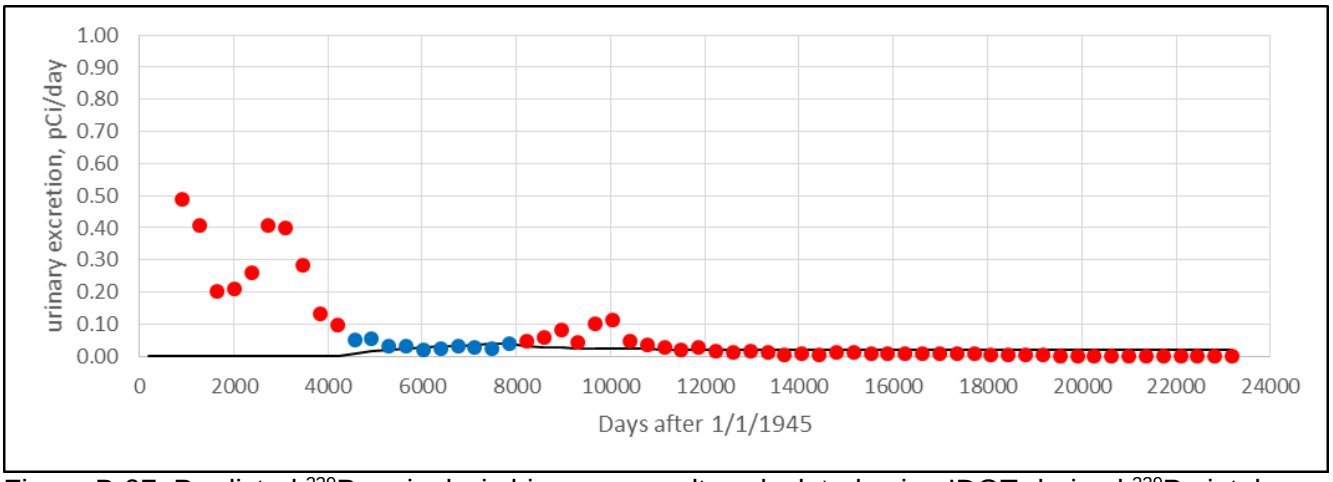

Figure B-97. Predicted ^{239}Pu urinalysis bioassay results calculated using IDOT-derived ^{239}Pu intake rates (line) compared with bioassay results (dots), 1957 to 1966, 84th percentile, type SS.

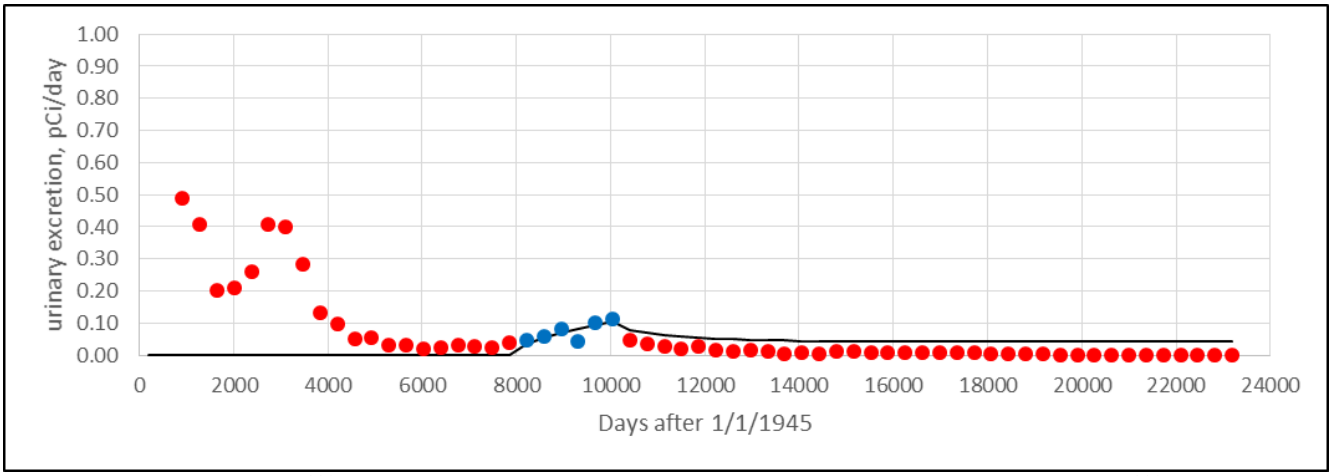

Figure B-98. Predicted ^{239}Pu urinalysis bioassay results calculated using IDOT-derived ^{239}Pu intake rates (line) compared with bioassay results (dots), 1967 to 1972, 84th percentile, type SS.

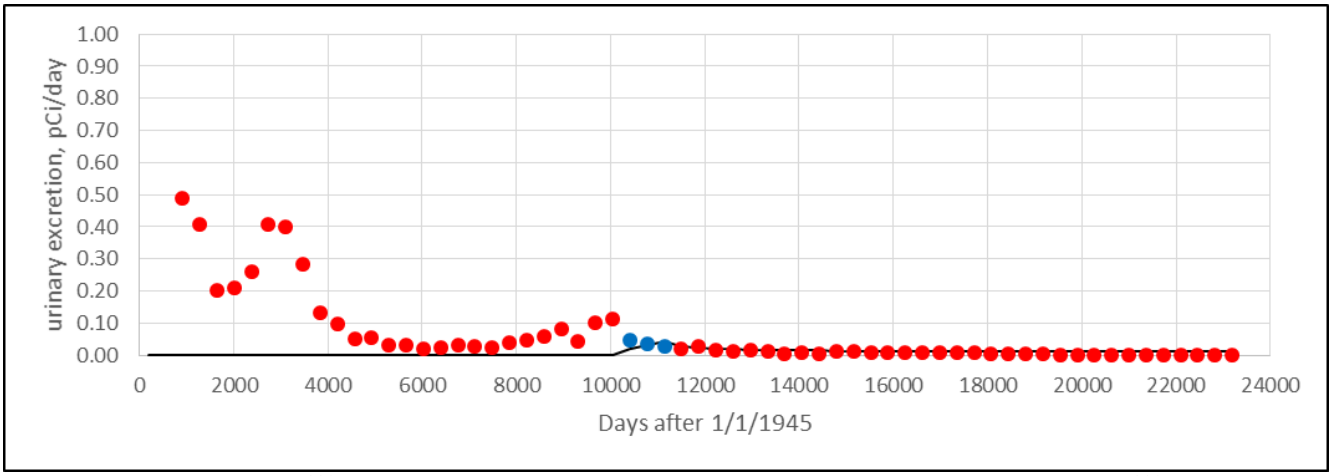

Figure B-99. Predicted ^{239}Pu urinalysis bioassay results calculated using IDOT-derived ^{239}Pu intake rates (line) compared with bioassay results (dots), 1973 to 1975, 84th percentile, type SS.

ATTACHMENT B
CO-EXPOSURE DATA FIGURES

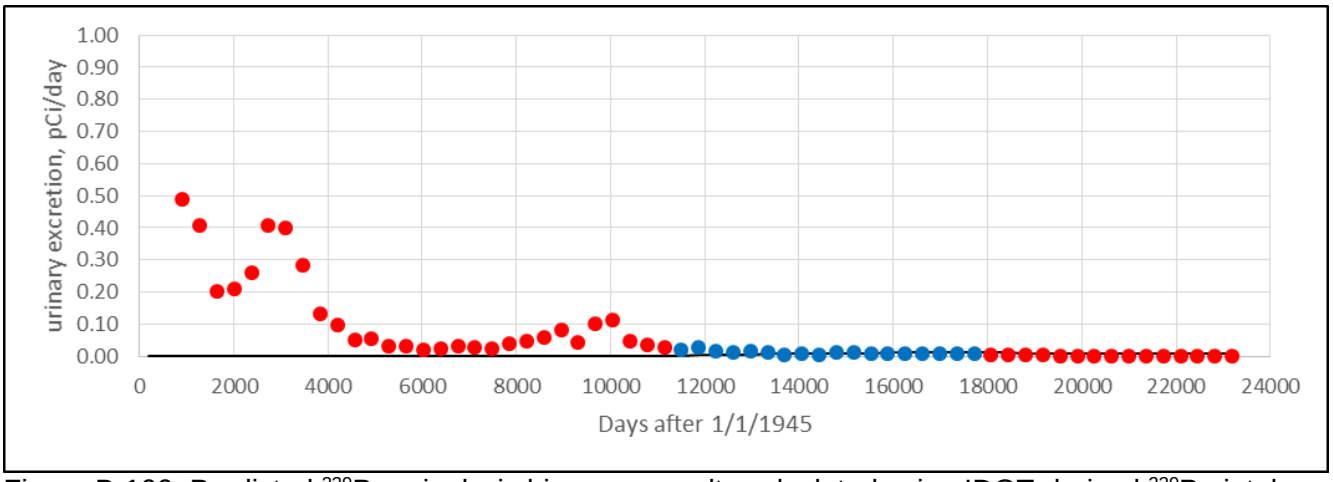

Figure B-100. Predicted ^{239}Pu urinalysis bioassay results calculated using IDOT-derived ^{239}Pu intake rates (line) compared with bioassay results (dots), 1976 to 1993, 84th percentile, type SS.

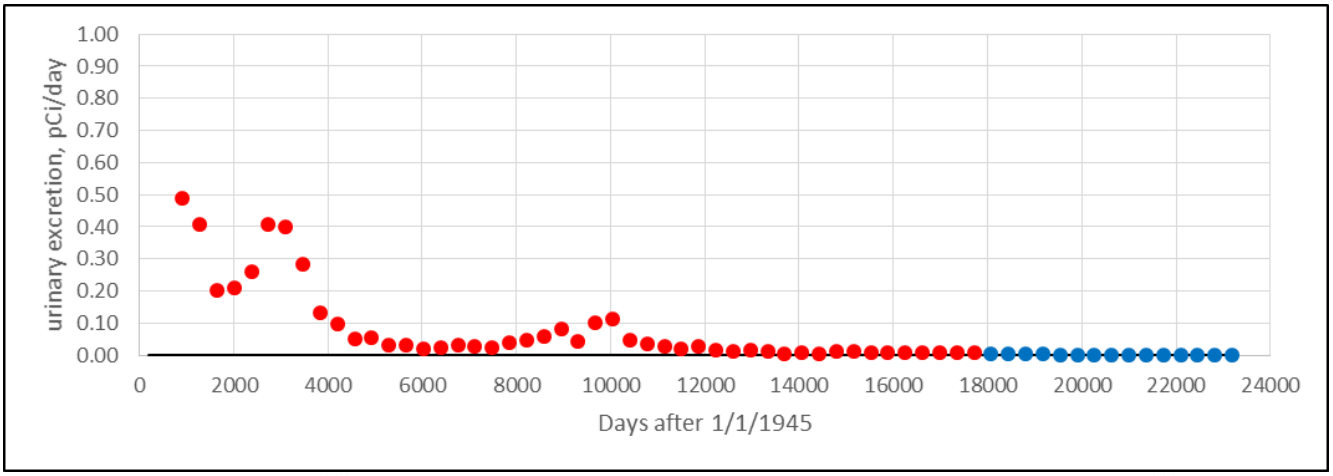

Figure B-101. Predicted ^{239}Pu urinalysis bioassay results calculated using IDOT-derived ^{239}Pu intake rates (line) compared with bioassay results (dots), 1994 to 2008, 84th percentile, type SS.

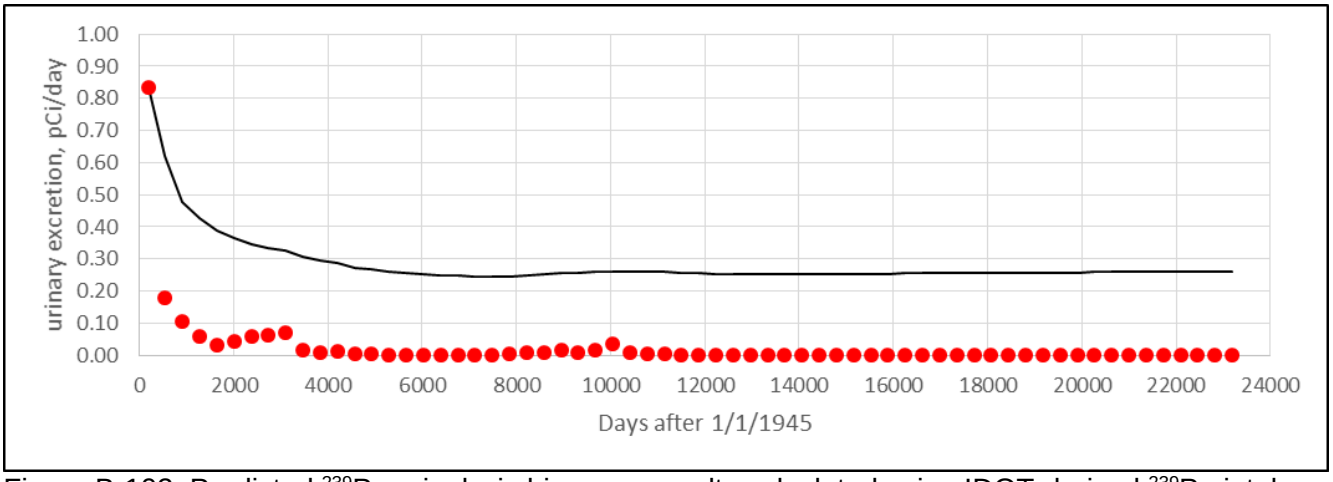

Figure B-102. Predicted ^{239}Pu urinalysis bioassay results calculated using IDOT-derived ^{239}Pu intake rates (line) compared with bioassay results (dots) from all intakes, 50th percentile, type SS.

ATTACHMENT B
CO-EXPOSURE DATA FIGURES

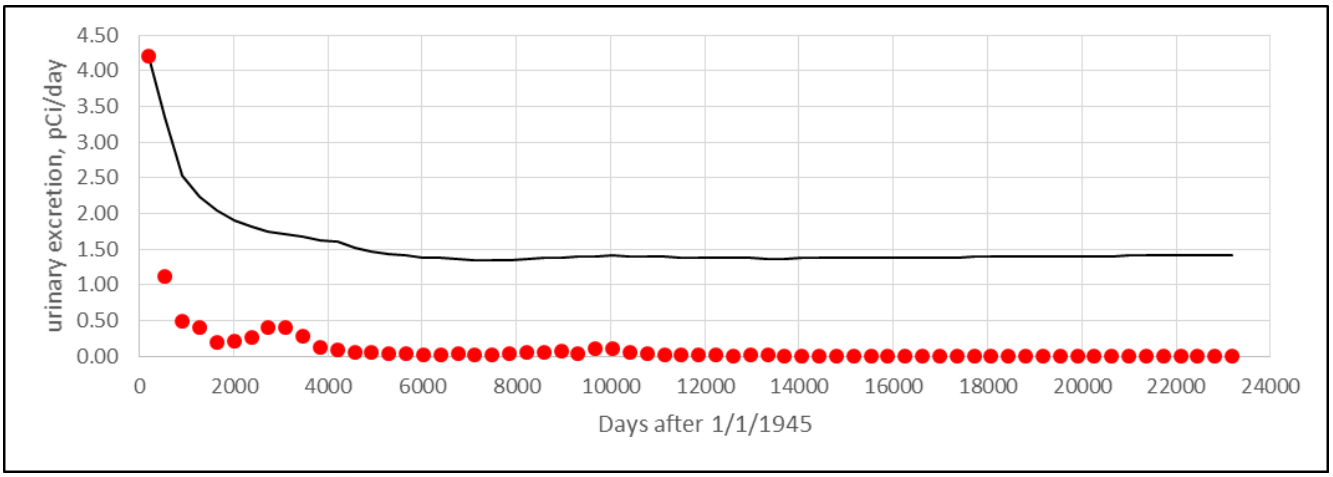

Figure B-103. Predicted ^{239}Pu urinalysis bioassay results calculated using IDOT-derived ^{239}Pu intake rates (line) compared with bioassay results (dots) from all intakes, 84th percentile, type SS.

Table B-6. Summary of ^{239}Pu type SS urinalysis-based intake rates (pCi/d) and dates.

Start	End	50th percentile	84th percentile	GSD
01/01/1944	12/31/1945	51,900	262,000	5.05
01/01/1946	12/31/1946	11,200	69,600	6.21
01/01/1947	12/31/1953	1,460	7,490	5.13
01/01/1954	12/31/1954	437	7,490	17.14
01/01/1955	12/31/1956	437	5,270	12.06
01/01/1957	12/31/1966	52	635	12.21
01/01/1967	12/31/1972	452	2,180	4.82
01/01/1973	12/31/1975	214	1,330	6.21
01/01/1976	12/31/1993	21.1	144	6.82
01/01/1994	12/31/2008	1.69	20	11.83

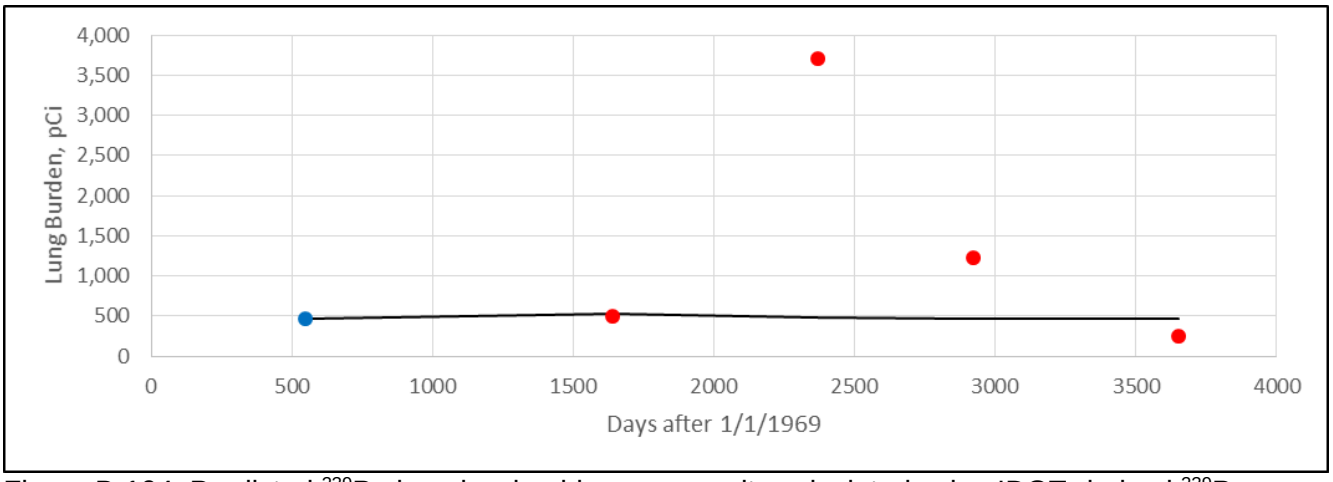

Figure B-104. Predicted ^{239}Pu lung burden bioassay results calculated using IDOT-derived ^{239}Pu intake rates (line) compared with bioassay results (dots), 1969 to 1971, 50th percentile, type SS.

ATTACHMENT B
CO-EXPOSURE DATA FIGURES

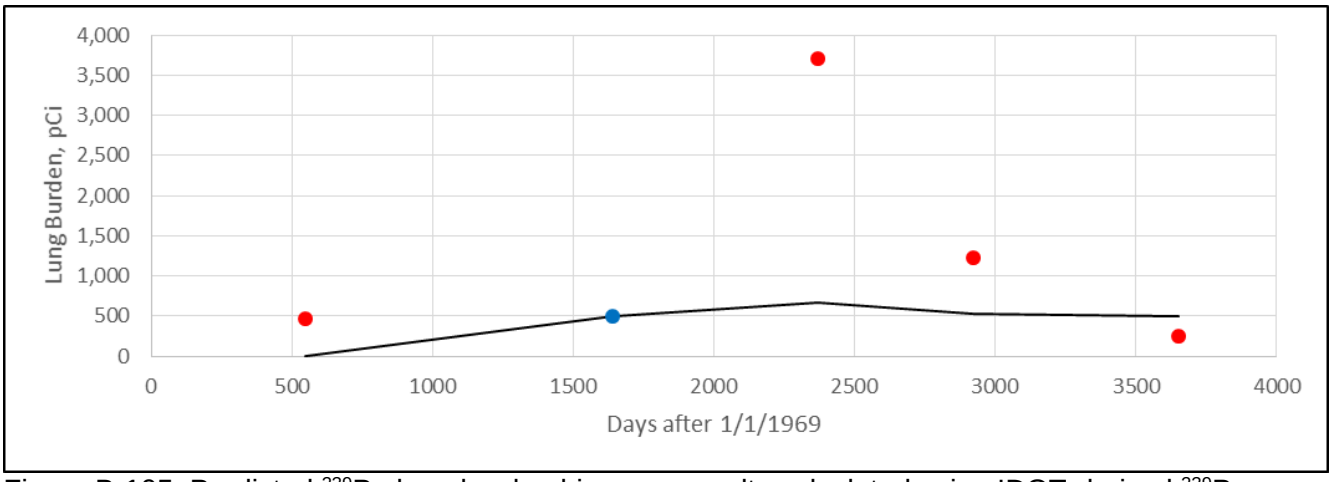

Figure B-105. Predicted ^{239}Pu lung burden bioassay results calculated using IDOT-derived ^{239}Pu intake rates (line) compared with bioassay results (dots), 1972 to 1974, 50th percentile, type SS.

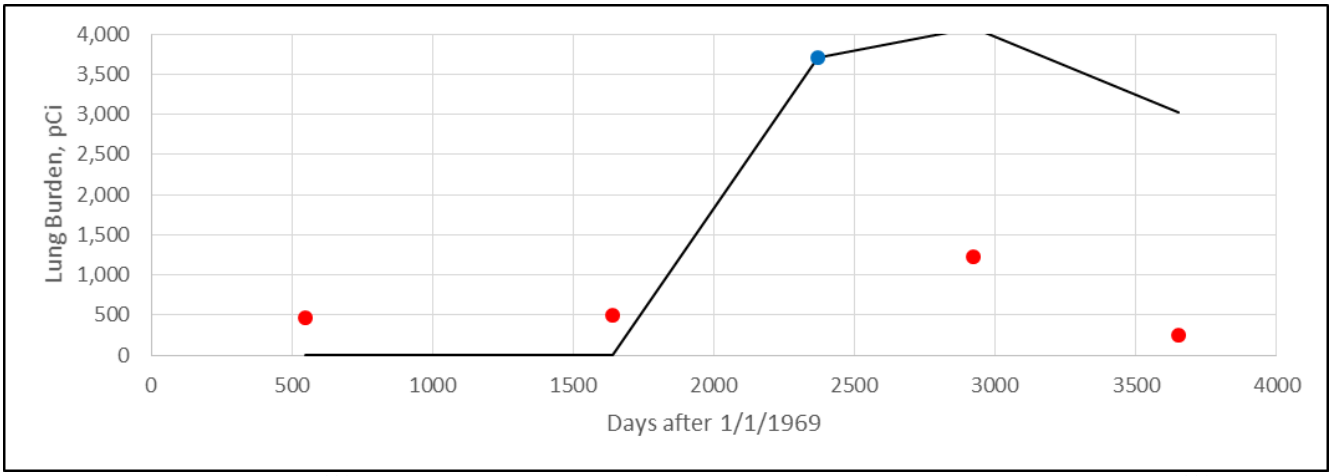

Figure B-106. Predicted ^{239}Pu lung burden bioassay results calculated using IDOT-derived ^{239}Pu intake rates (line) compared with bioassay results (dots), 1975, 50th percentile, type SS.

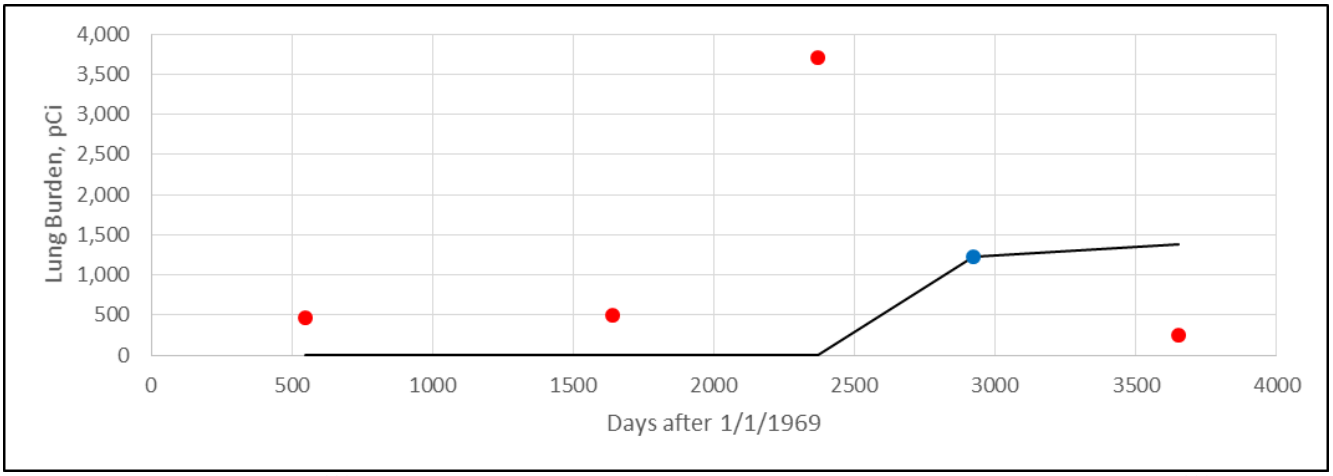

Figure B-107. Predicted ^{239}Pu lung burden bioassay results calculated using IDOT-derived ^{239}Pu intake rates (line) compared with bioassay results (dots), 1976 to 1977, 50th percentile, type SS.

ATTACHMENT B
CO-EXPOSURE DATA FIGURES

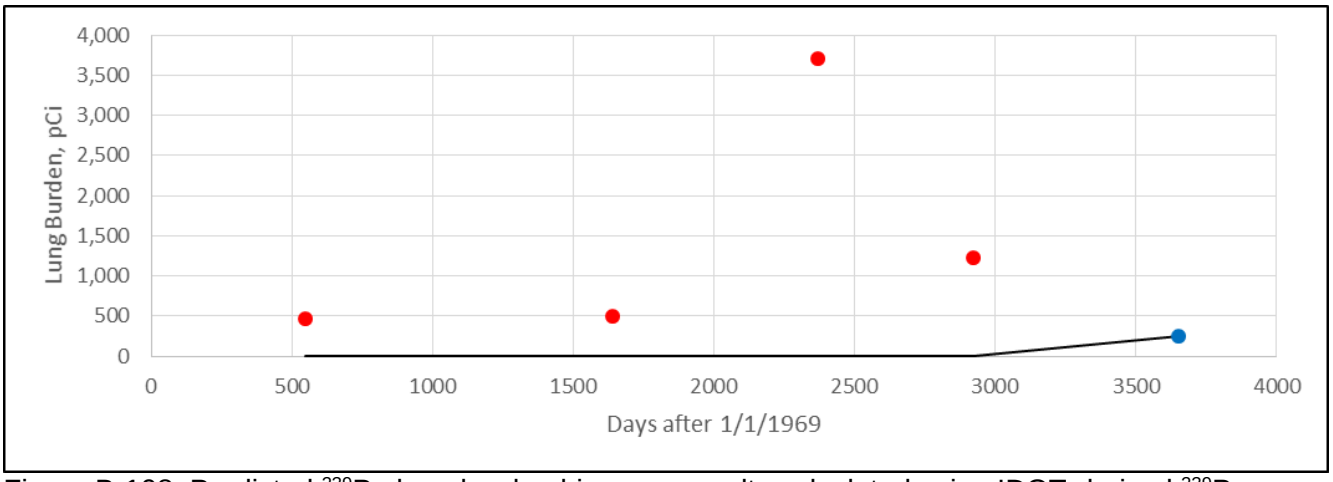

Figure B-108. Predicted ^{239}Pu lung burden bioassay results calculated using IDOT-derived ^{239}Pu intake rates (line) compared with bioassay results (dots), 1978 to 1979, 50th percentile, type SS.

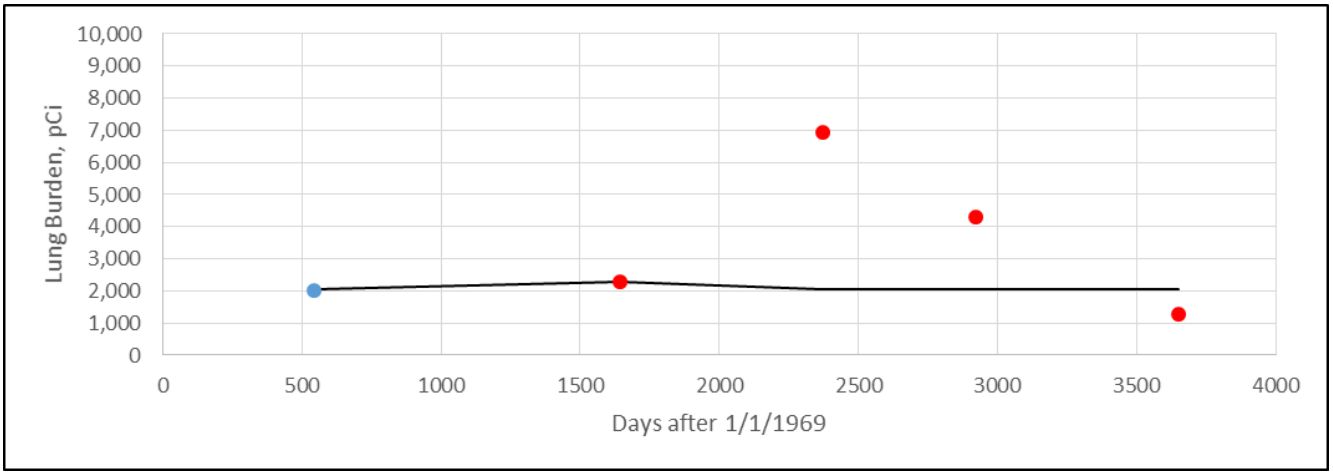

Figure B-109. Predicted ^{239}Pu lung burden bioassay results calculated using IDOT-derived ^{239}Pu intake rates (line) compared with bioassay results (dots), 1969 to 1971, 84th percentile, type SS.

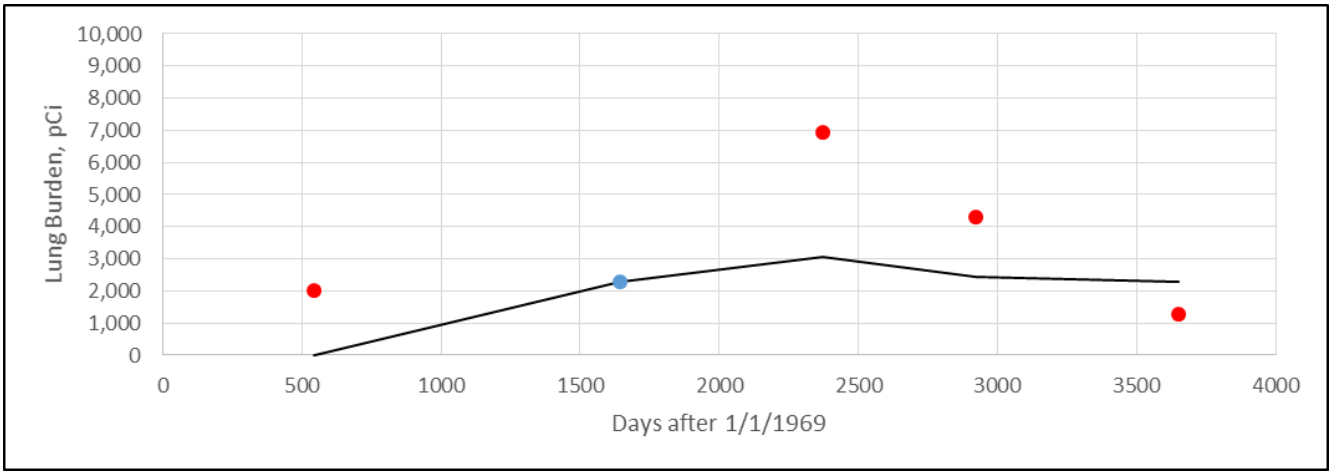

Figure B-110. Predicted ^{239}Pu lung burden bioassay results calculated using IDOT-derived ^{239}Pu intake rates (line) compared with bioassay results (dots), 1972 to 1974, 84th percentile, type SS.

ATTACHMENT B
CO-EXPOSURE DATA FIGURES

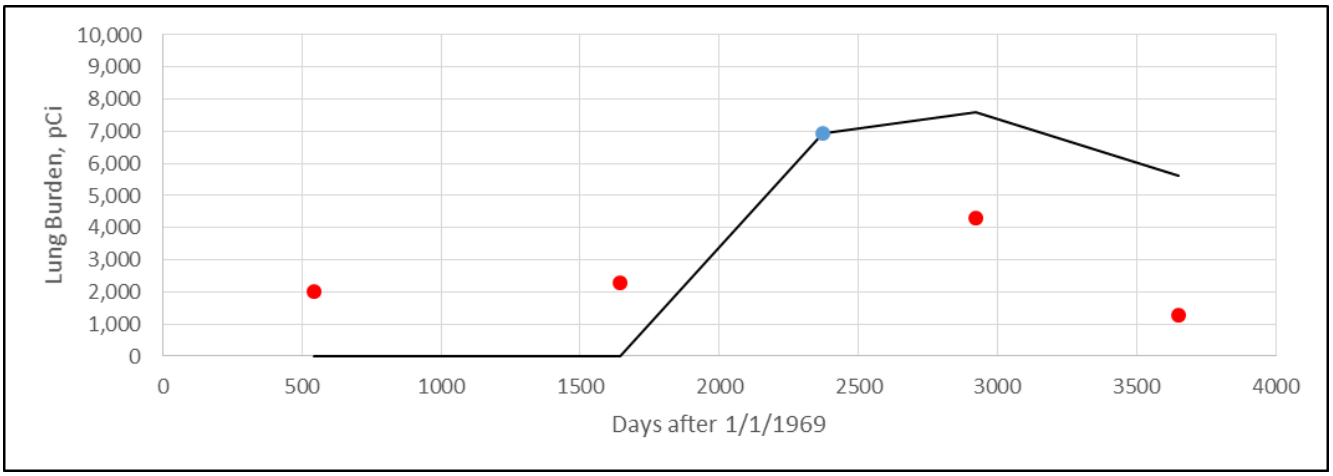

Figure B-111. Predicted ^{239}Pu lung burden bioassay results calculated using IDOT-derived ^{239}Pu intake rates (line) compared with bioassay results (dots), 1975, 84th percentile, type SS.

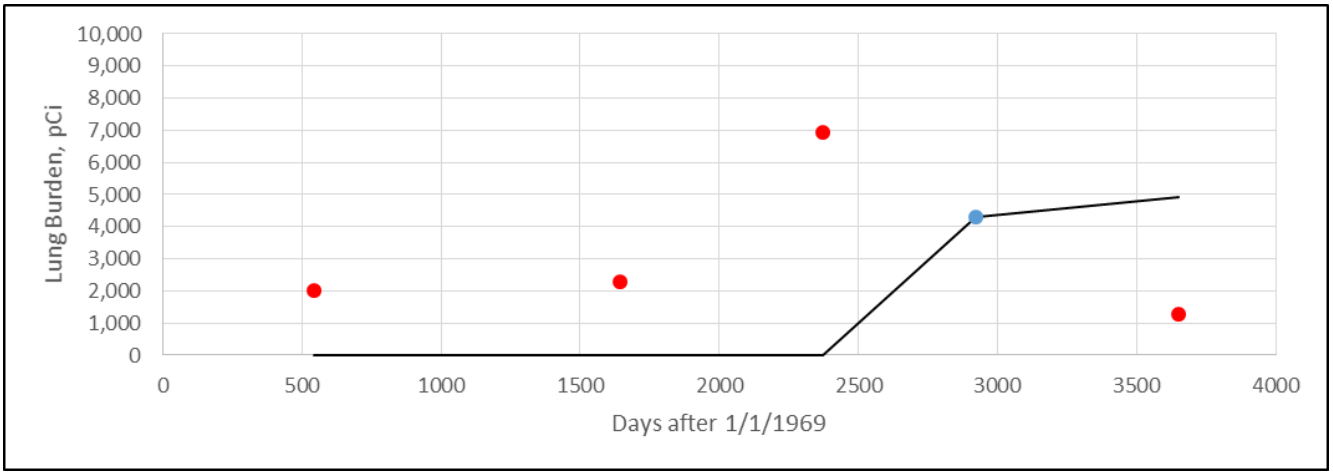

Figure B-112. Predicted ^{239}Pu lung burden bioassay results calculated using IDOT-derived ^{239}Pu intake rates (line) compared with bioassay results (dots), 1976 to 1977, 84th percentile, type SS.

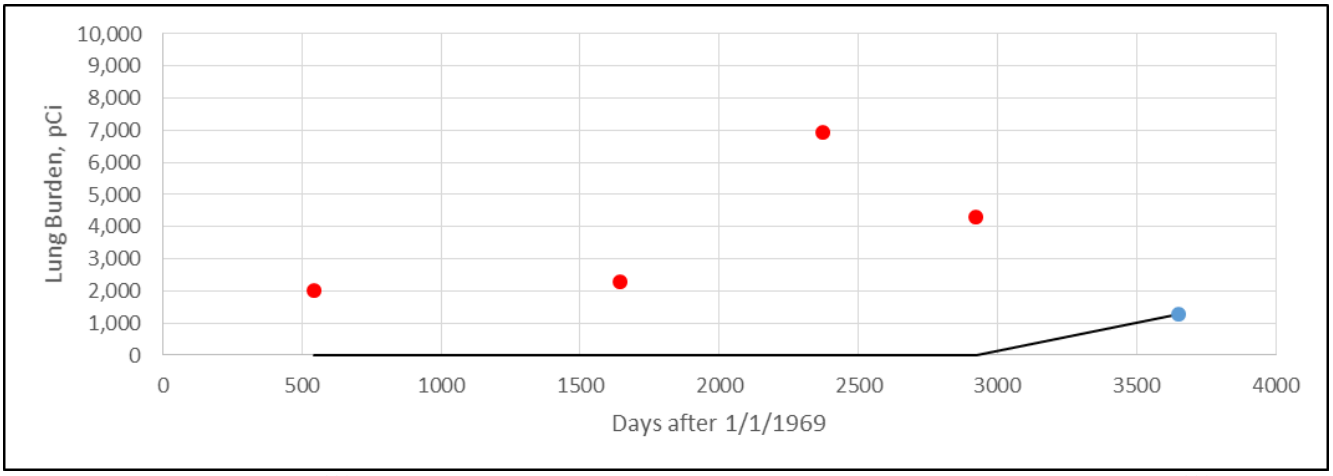

Figure B-113. Predicted ^{239}Pu lung burden bioassay results calculated using IDOT-derived ^{239}Pu intake rates (line) compared with bioassay results (dots), 1978 to 1979, 84th percentile, type SS.

ATTACHMENT B
CO-EXPOSURE DATA FIGURES

Table B-7. Summary of ^{239}Pu type SS lung burden-based intake rates (pCi/d) and dates.

Start	End	50th percentile	84th percentile	GSD
01/01/1969	12/31/1971	24.4	105	4.30
01/01/1972	12/31/1974	25.9	117	4.52
01/01/1975	12/31/1975	447	834	1.87
01/01/1976	12/31/1977	83.9	297	3.54
01/01/1978	12/31/1979	17.1	88.8	5.19

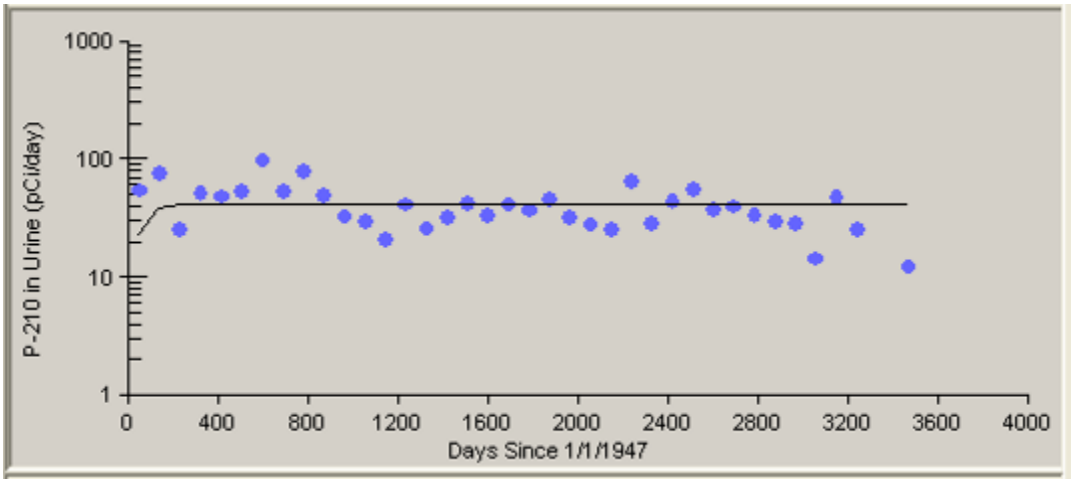

Figure B-114. Predicted polonium bioassay results calculated using IMBA-derived polonium intake rates (line) compared with bioassay results (dots) from all intakes, 50th percentile, type F.

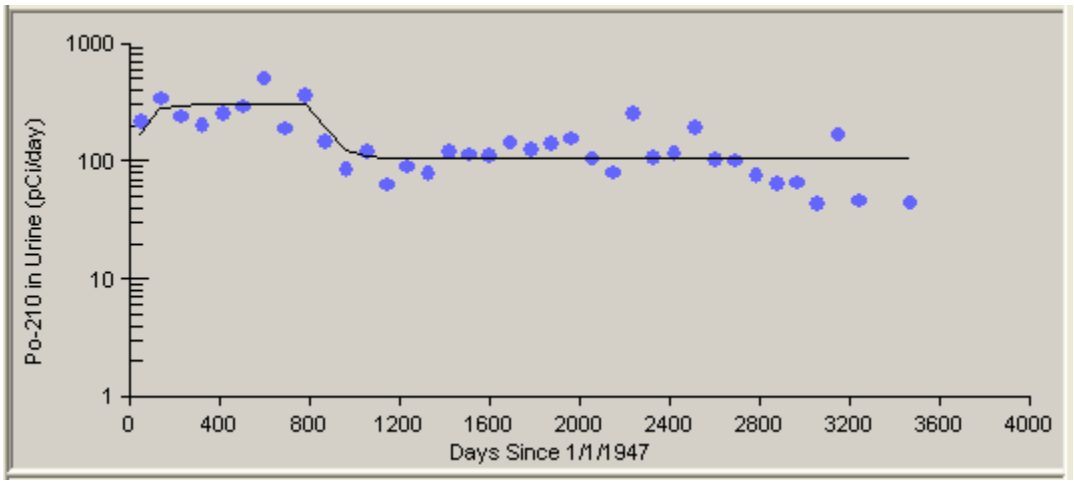

Figure B-115. Predicted polonium bioassay results calculated using IMBA-derived polonium intake rates (line) compared with bioassay results (dots) from all intakes, 84th percentile, type F.

Table B-8. Summary of polonium type F intake rates (pCi/d) and dates.

Start	End	50th percentile	84th percentile	GSD
01/01/1947	03/31/1949	592.8	4,126	6.96
04/01/1949	12/31/1956	592.8	1,587	2.68

ATTACHMENT B
CO-EXPOSURE DATA FIGURES

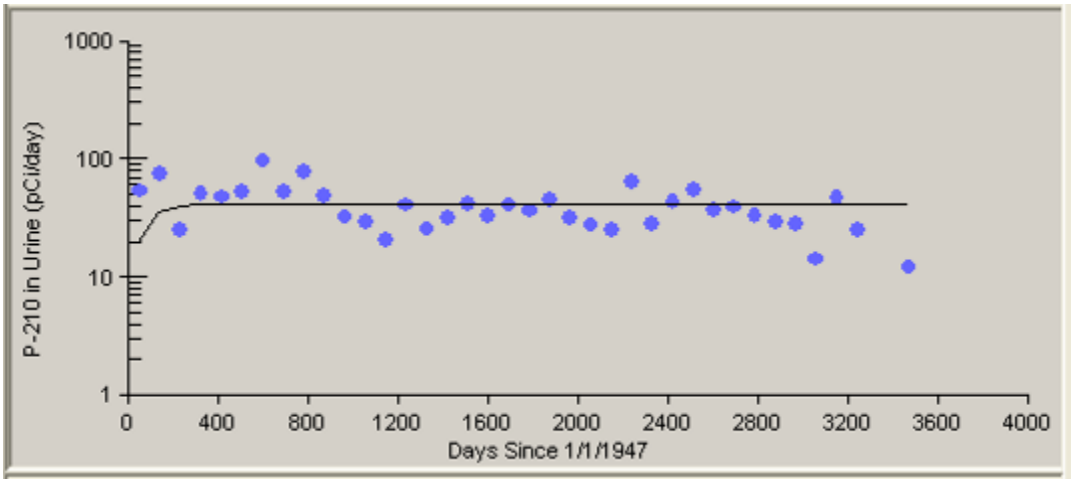

Figure B-116. Predicted polonium bioassay results calculated using IMBA-derived polonium intake rates (line) compared with bioassay results (dots) from all intakes, 50th percentile, type M.

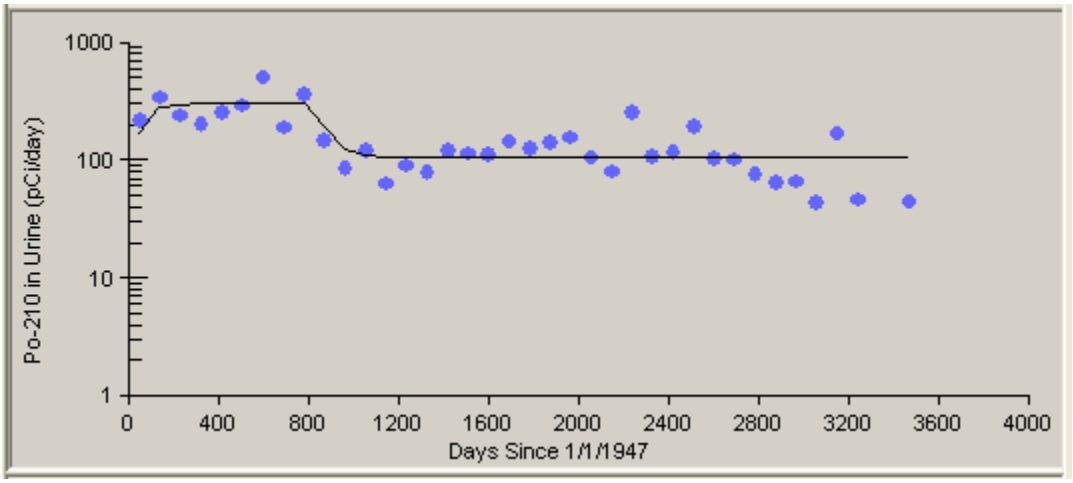

Figure B-117. Predicted polonium bioassay results calculated using IMBA-derived polonium intake rates (line) compared with bioassay results (dots) from all intakes, 84th percentile, type M.

Table B-9. Summary of polonium type M intake rates (pCi/d) and dates.

Start	End	50th percentile	84th percentile	GSD
01/01/1947	03/31/1949	2,013	14,120	7.01
04/01/1949	12/31/1956	2,013	5,346	2.65

ATTACHMENT B
CO-EXPOSURE DATA FIGURES

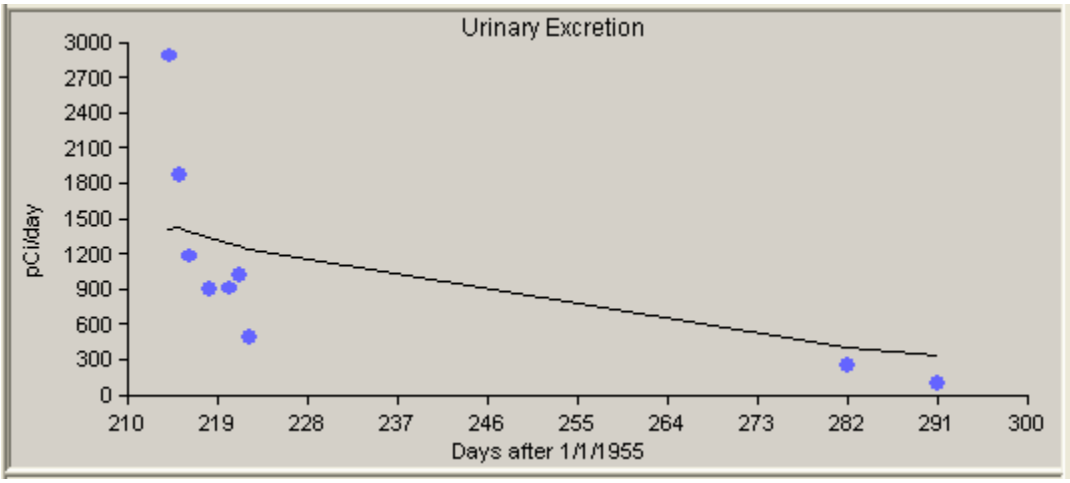

Figure B-118. Predicted polonium acute intake bioassay fit calculated using an IMBA-derived polonium intake rate (line) compared with bioassay results (dots) for individual "A," type F.

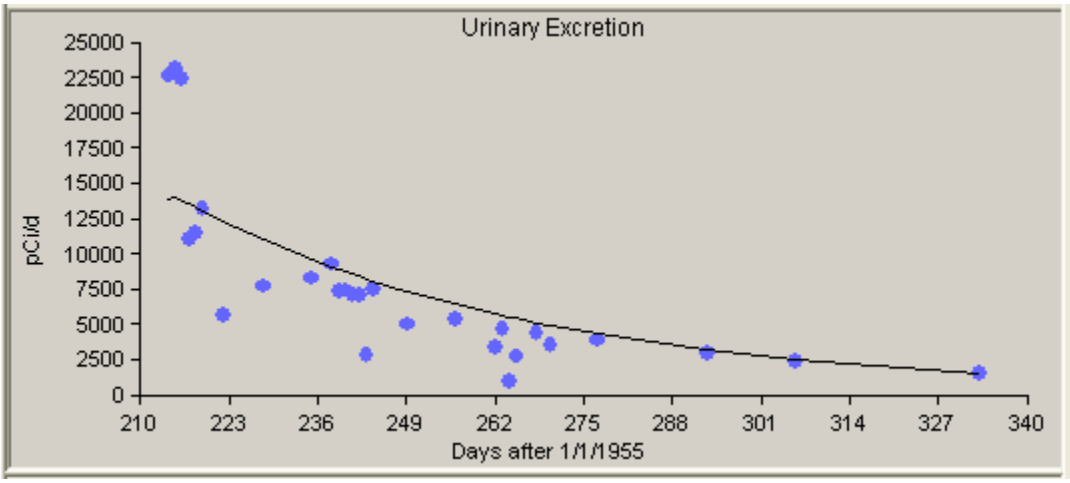

Figure B-119. Predicted polonium acute intake bioassay fit calculated using an IMBA-derived polonium intake rate (line) compared with bioassay results (dots) for individual "B," type F.

ATTACHMENT B
CO-EXPOSURE DATA FIGURES

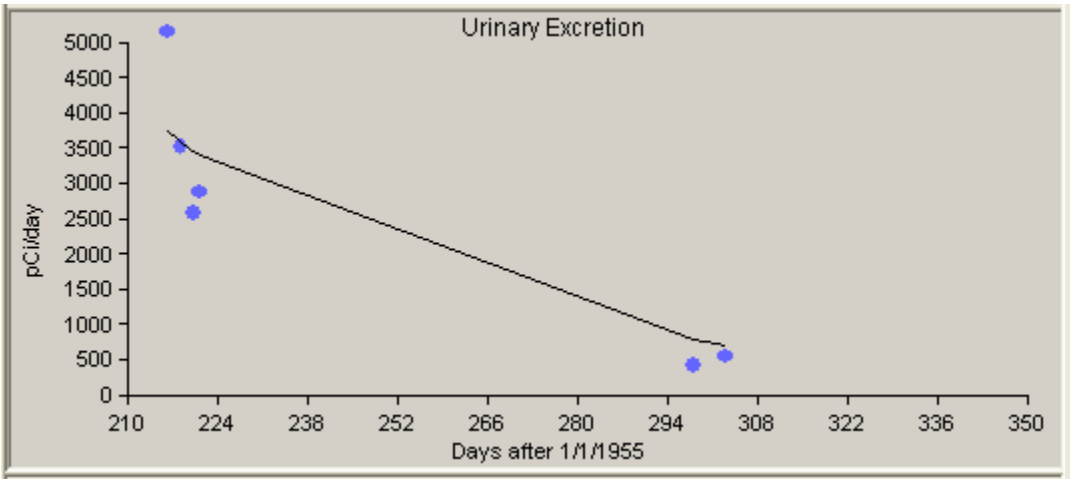

Figure B-120. Predicted polonium acute intake bioassay fit calculated using an IMBA-derived polonium intake rate (line) compared with bioassay results (dots) for individual “C,” type F.

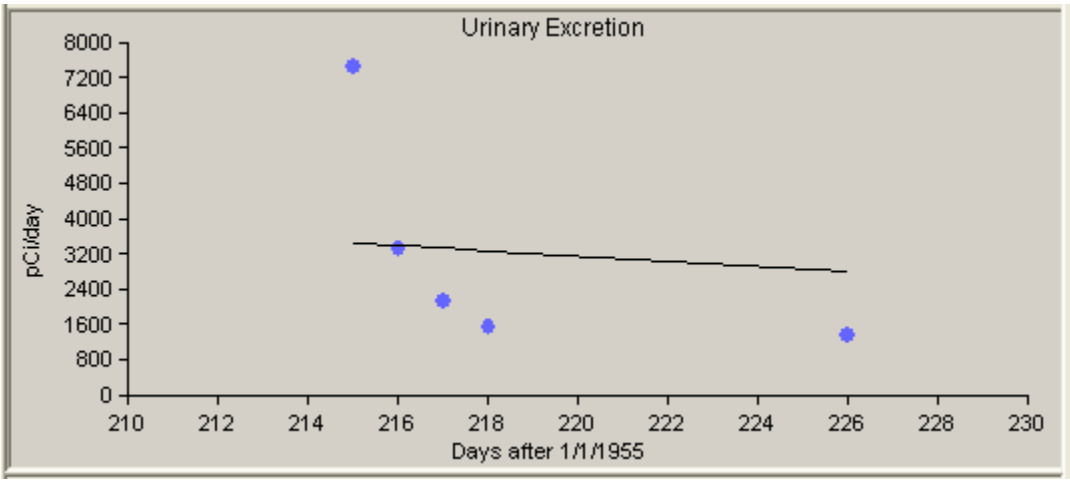

Figure B-121. Predicted polonium acute intake bioassay fit calculated using an IMBA-derived polonium intake rate (line) compared with bioassay results (dots) for individual “D,” type F.

ATTACHMENT B
CO-EXPOSURE DATA FIGURES

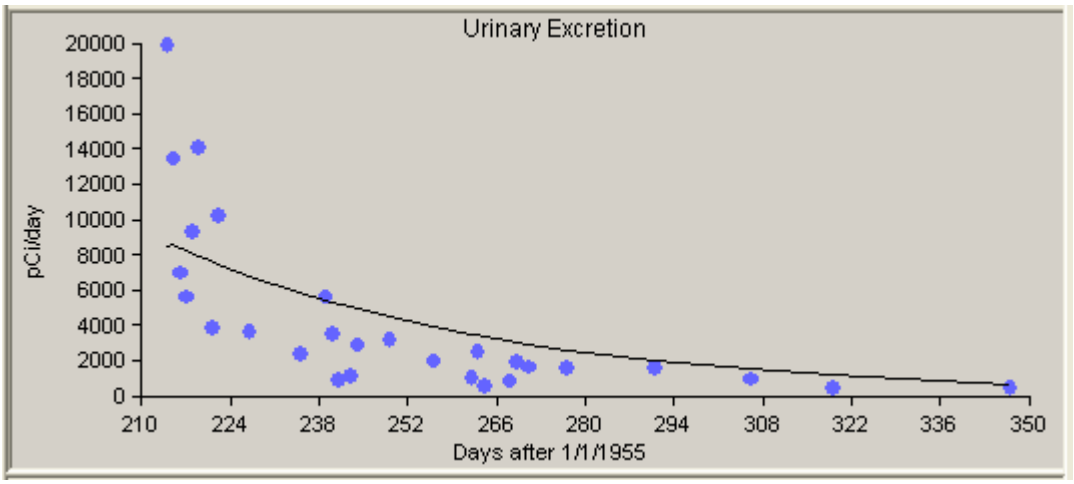

Figure B-122. Predicted polonium acute intake bioassay fit calculated using an IMBA-derived polonium intake rate (line) compared with bioassay results (dots) for individual “E,” type F.

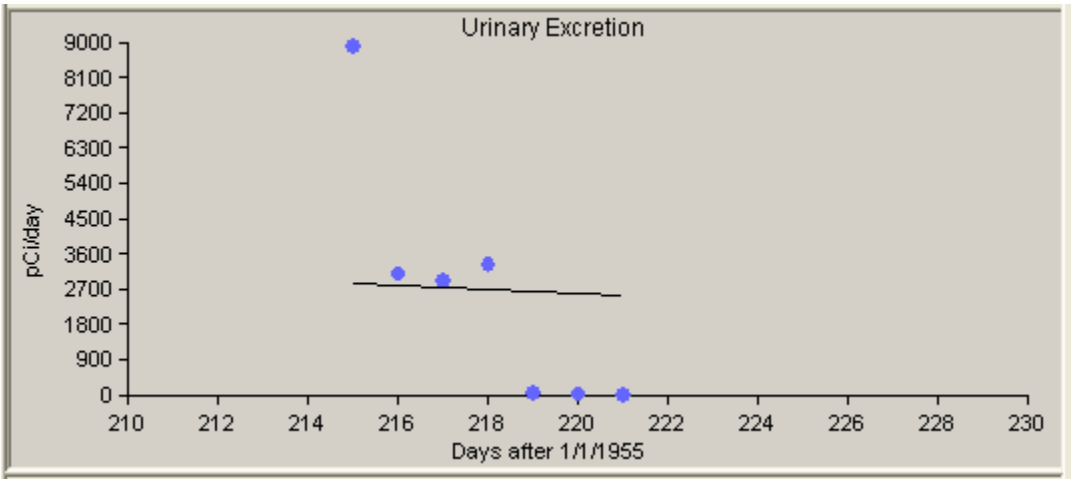

Figure B-123. Predicted polonium acute intake bioassay fit calculated using an IMBA-derived polonium intake rate (line) compared with bioassay results (dots) for individual “F,” type F.

ATTACHMENT B
CO-EXPOSURE DATA FIGURES

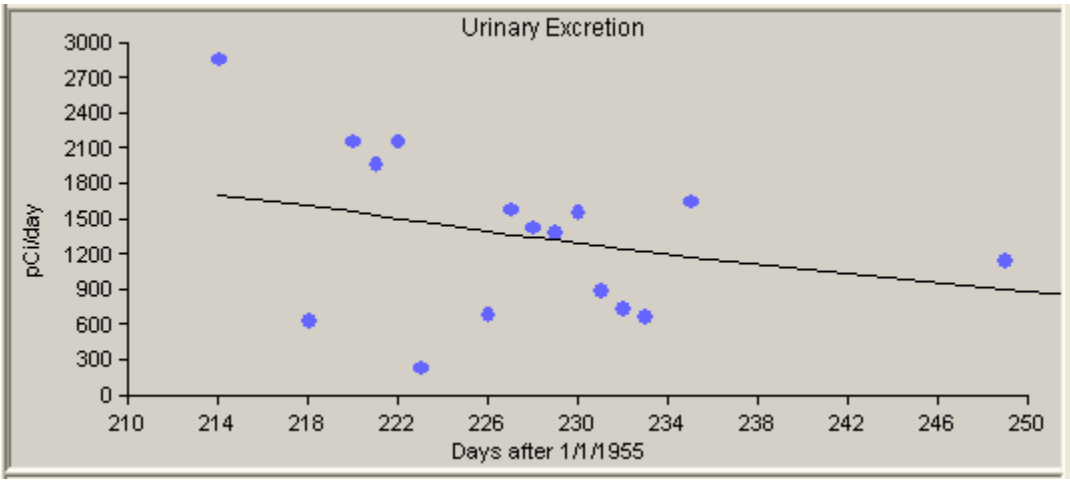

Figure B-124. Predicted polonium acute intake bioassay fit calculated using an IMBA-derived polonium intake rate (line) compared with bioassay results (dots) for individual “G,” type F.

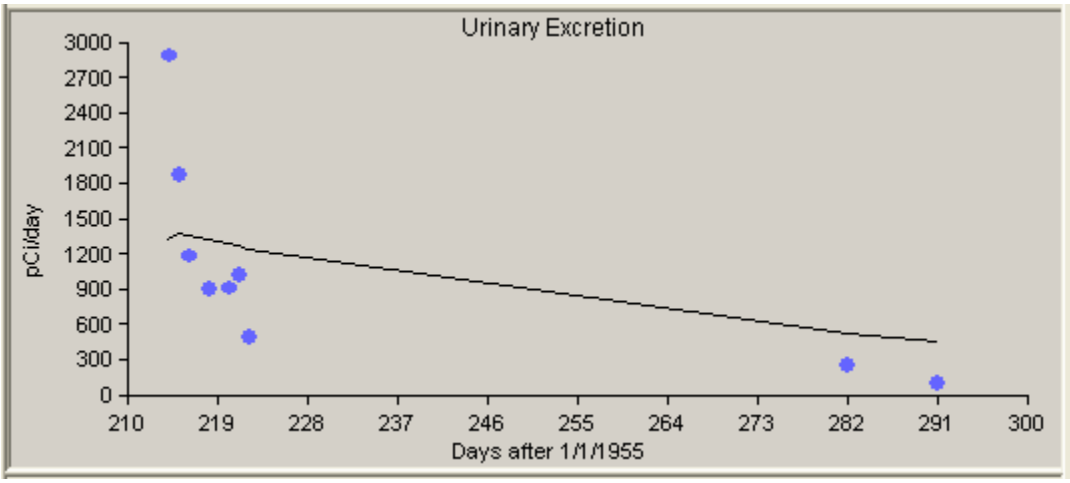

Figure B-125. Predicted polonium acute intake bioassay fit calculated using an IMBA-derived polonium intake rate (line) compared with bioassay results (dots) for individual “A,” type M.

ATTACHMENT B
CO-EXPOSURE DATA FIGURES

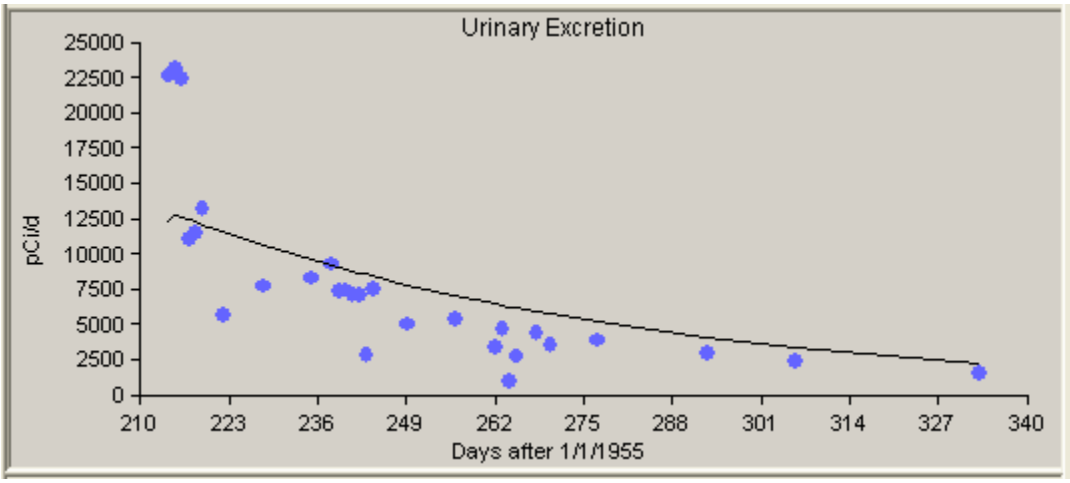

Figure B-126. Predicted polonium acute intake bioassay fit calculated using an IMBA-derived polonium intake rate (line) compared with bioassay results (dots) for individual “B,” type M.

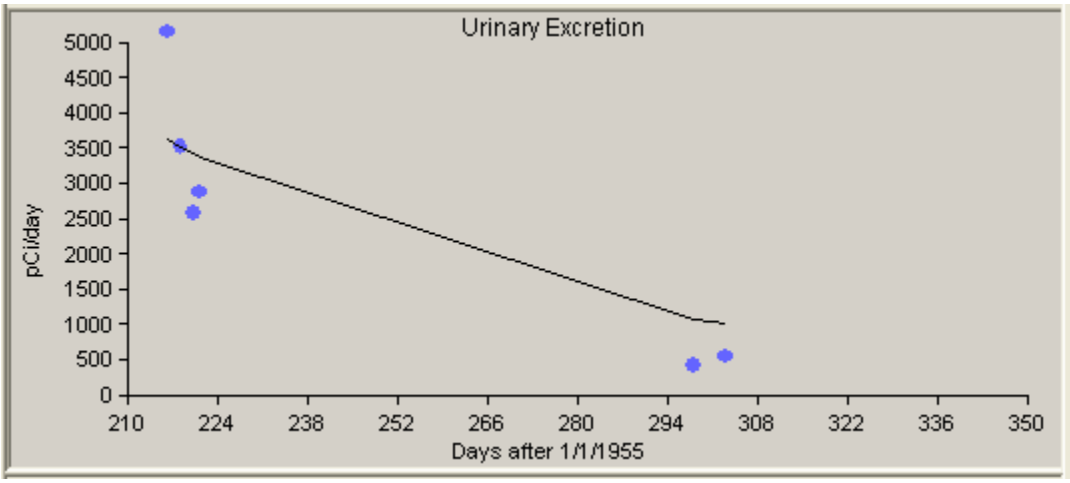

Figure B-127. Predicted polonium acute intake bioassay fit calculated using an IMBA-derived polonium intake rate (line) compared with bioassay results (dots) for individual “C,” type M.

ATTACHMENT B
CO-EXPOSURE DATA FIGURES

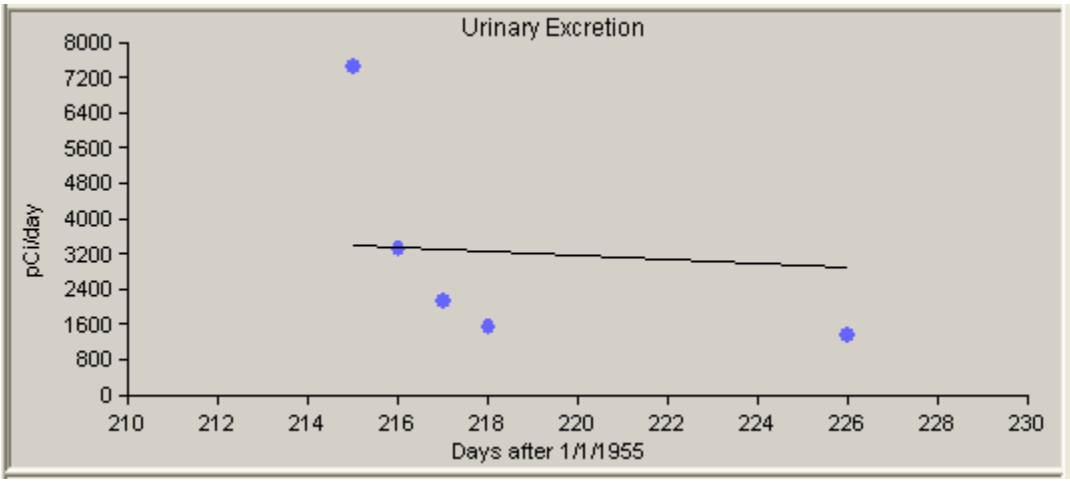

Figure B-128. Predicted polonium acute intake bioassay fit calculated using an IMBA-derived polonium intake rate (line) compared with bioassay results (dots) for individual “D,” type M.

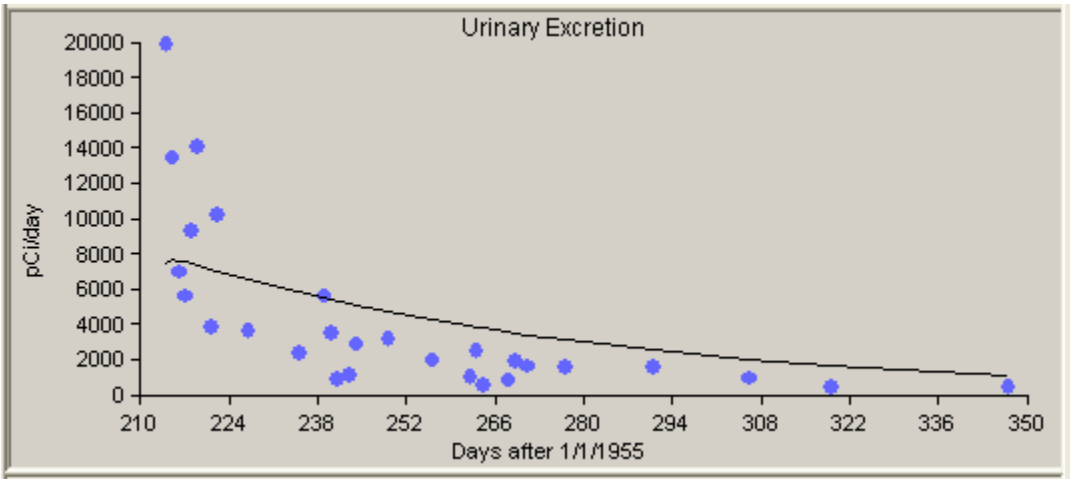

Figure B-129. Predicted polonium acute intake bioassay fit calculated using an IMBA-derived polonium intake rate (line) compared with bioassay results (dots) for individual “E,” type M.

ATTACHMENT B
CO-EXPOSURE DATA FIGURES

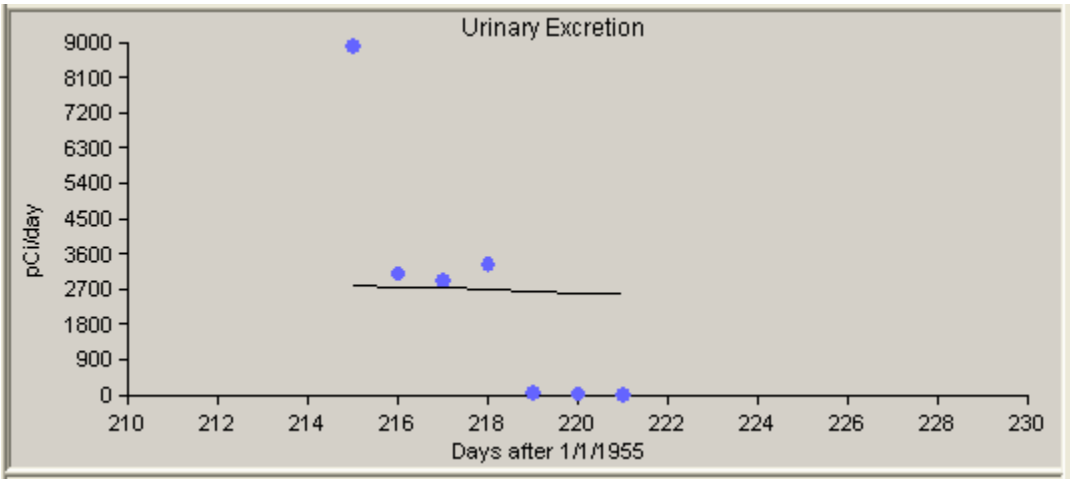

Figure B-130. Predicted polonium acute intake bioassay fit calculated using an IMBA-derived polonium intake rate (line) compared with bioassay results (dots) for individual “F,” type M.

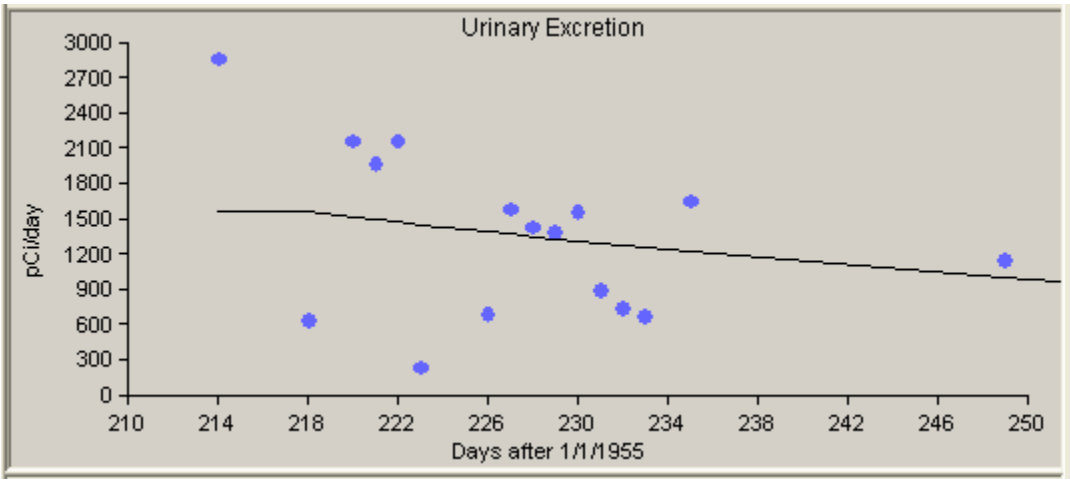

Figure B-131. Predicted polonium acute intake bioassay fit calculated using an IMBA-derived polonium intake rate (line) compared with bioassay results (dots) for individual “G,” type M.

Table B-10. Summary of polonium acute intakes (pCi) type F and M.

Individual	Type F	Type M
A	1.07E+06	4.55E+06
B	1.06E+07	4.22E+07
C	2.85E+06	1.21E+07
D	2.61E+06	1.12E+07
E	6.44E+06	2.56E+07
F	2.16E+06	9.30E+06
G	1.29E+06	5.36E+06
GM	2.84E+06	1.19E+07

ATTACHMENT B
CO-EXPOSURE DATA FIGURES

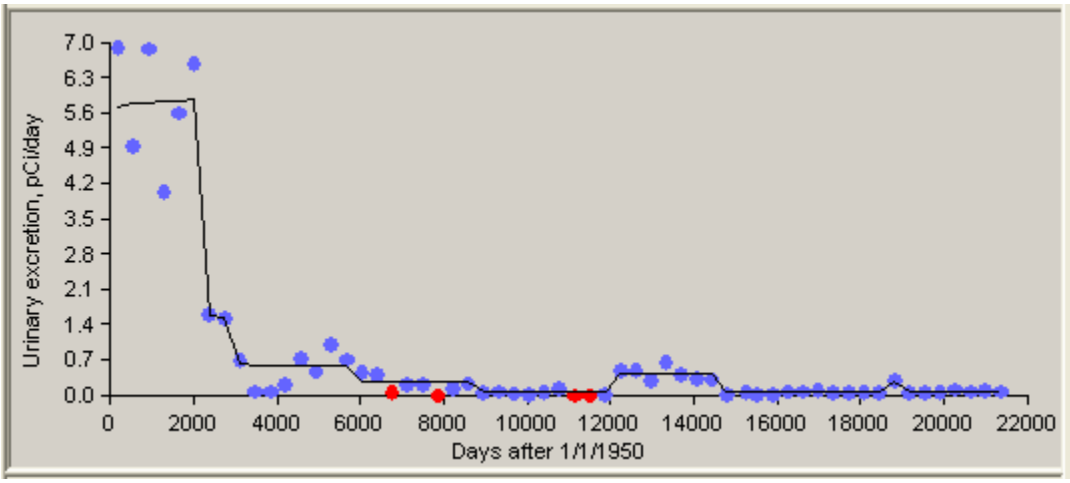

Figure B-132. Predicted uranium bioassay results calculated using IMBA-derived uranium intake rates (line) compared with bioassay results (dots) from all intakes, 50th percentile, type F.

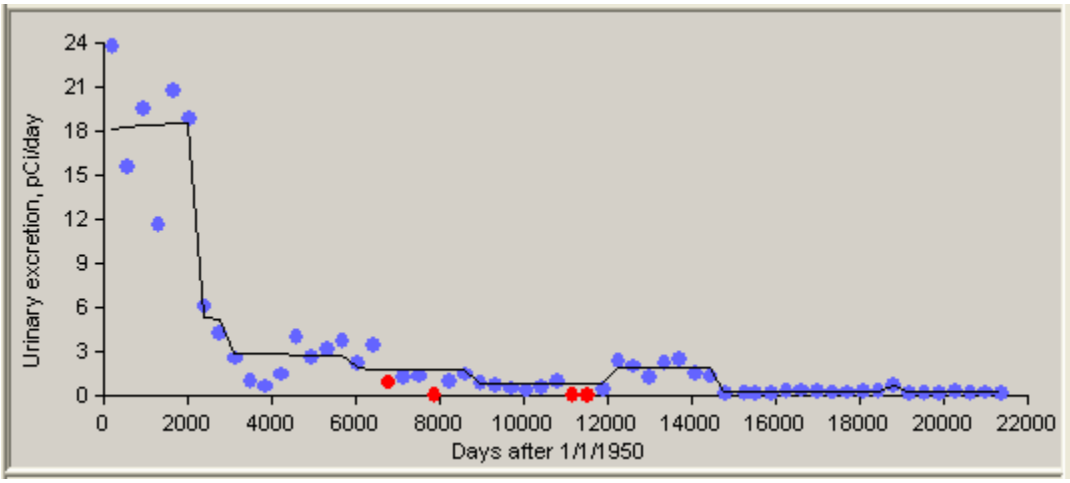

Figure B-133. Predicted uranium bioassay results calculated using IMBA-derived uranium intake rates (line) compared with bioassay results (dots) from all intakes, 84th percentile, type F.

Table B-11. Summary of uranium type F intake rates (pCi/d) and dates.

Start	End	50th percentile	84th percentile	GSD
01/01/1950	12/31/1955	21.28	67.25	3.16
01/01/1956	12/31/1957	5.358	17.99	3.36
01/01/1958	12/31/1965	1.981	9.535	4.81
01/01/1966	12/31/1973	0.9086	6.218	6.84
01/01/1974	12/31/1982	0.2270	2.567	11.31
01/01/1983	12/31/1989	1.526	6.768	4.44
01/01/1990	12/31/2008	0.201	0.8091	4.03
01/01/2001	12/31/2001	0.818	1.794	2.19

a. Note: the 2001 intake is additive to the 1990–2008 intake.

ATTACHMENT B
CO-EXPOSURE DATA FIGURES

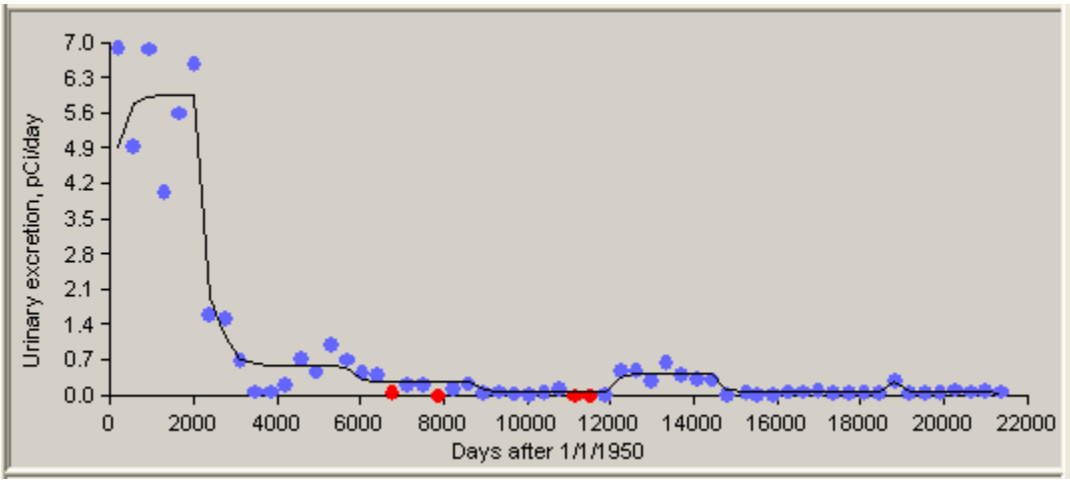

Figure B-134. Predicted uranium bioassay results calculated using IMBA-derived uranium intake rates (line) compared with bioassay results (dots) from all intakes, 50th percentile, type M.

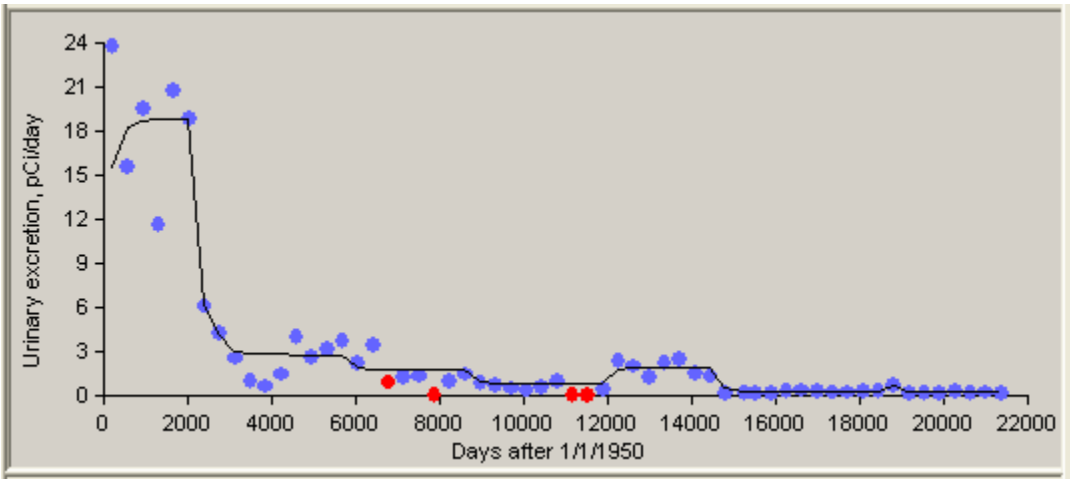

Figure B-135. Predicted uranium bioassay results calculated using IMBA-derived uranium intake rates (line) compared with bioassay results (dots) from all intakes, 84th percentile, type M.

Table B-12. Summary of uranium type M intake rates (pCi/d) and dates.

Start	End	50th percentile	84th percentile	GSD
01/01/1950	12/31/1955	88.72	279.9	3.15
01/01/1956	12/31/1957	15.96	53.6	3.36
01/01/1958	12/31/1965	7.946	38.94	4.90
01/01/1966	12/31/1973	3.528	24.8	7.03
01/01/1974	12/31/1982	1.029	10.91	10.60
01/01/1983	12/31/1989	6.285	27.74	4.41
01/01/1990	12/31/2008	0.7555	3.065	4.06
01/01/2001	12/31/2001	3.944	8.644	2.19

a. Note: the 2001 intake is additive to the 1990–2008 intake.

ATTACHMENT B
CO-EXPOSURE DATA FIGURES

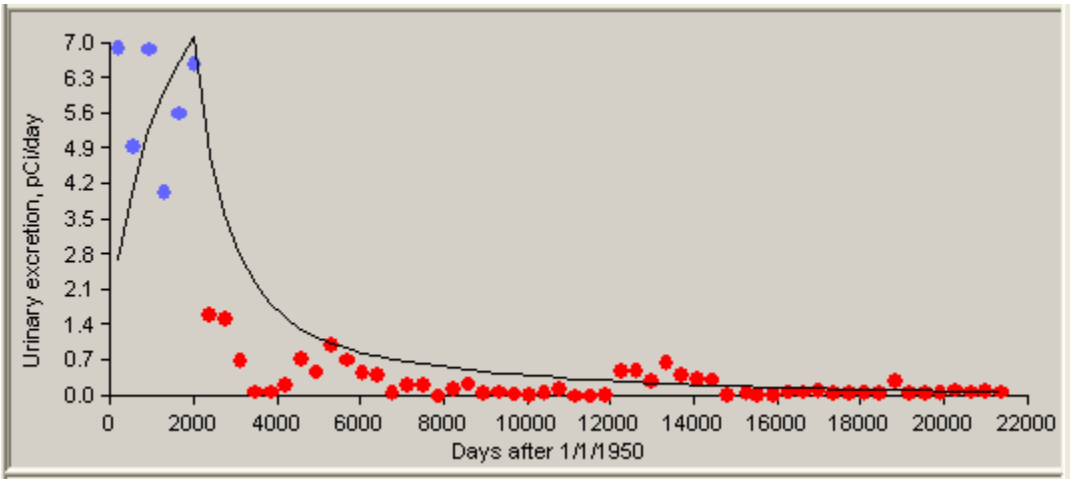

Figure B-136. Predicted uranium bioassay results calculated using IMBA-derived uranium intake rates (line) compared with bioassay results (dots), 1950 to 1955, 50th percentile, type S.

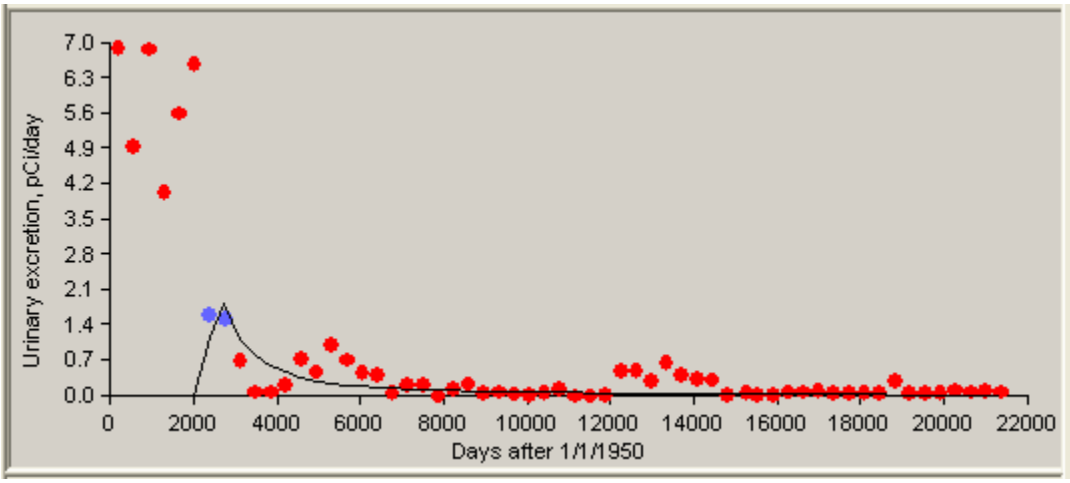

Figure B-137. Predicted uranium bioassay results calculated using IMBA-derived uranium intake rates (line) compared with bioassay results (dots), 1956 to 1957, 50th percentile, type S.

ATTACHMENT B
CO-EXPOSURE DATA FIGURES

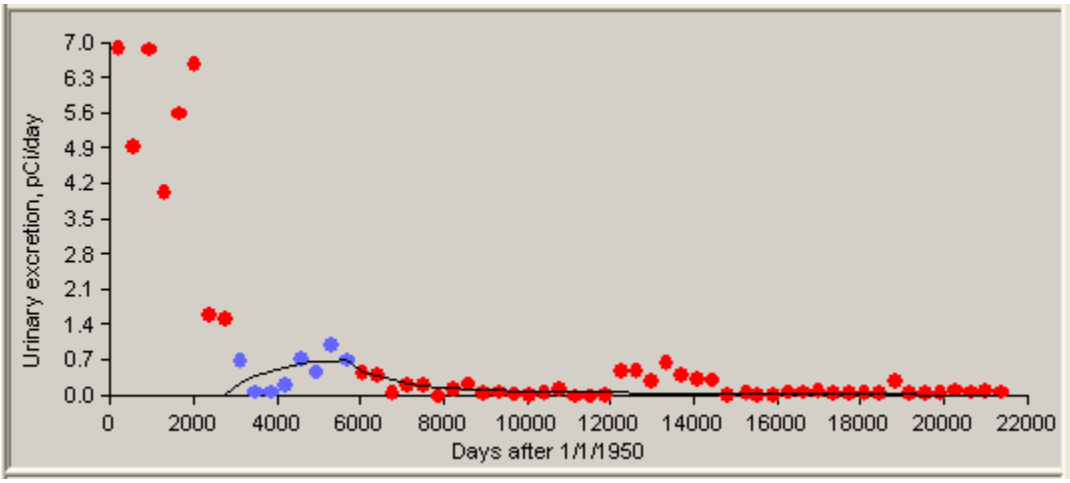

Figure B-138. Predicted uranium bioassay results calculated using IMBA-derived uranium intake rates (line) compared with bioassay results (dots), 1958 to 1965, 50th percentile, type S.

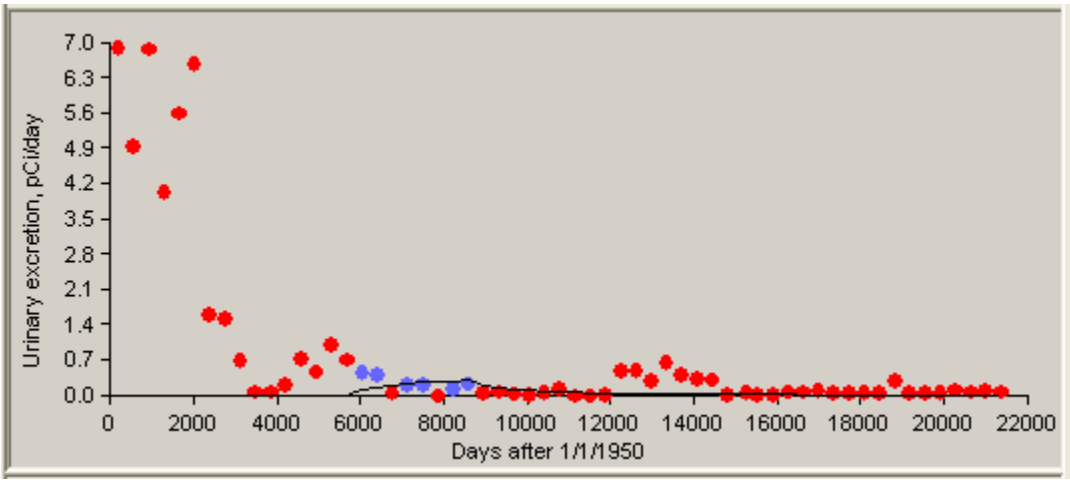

Figure B-139. Predicted uranium bioassay results calculated using IMBA-derived uranium intake rates (line) compared with bioassay results (dots), 1966 to 1973, 50th percentile, type S.

ATTACHMENT B
CO-EXPOSURE DATA FIGURES

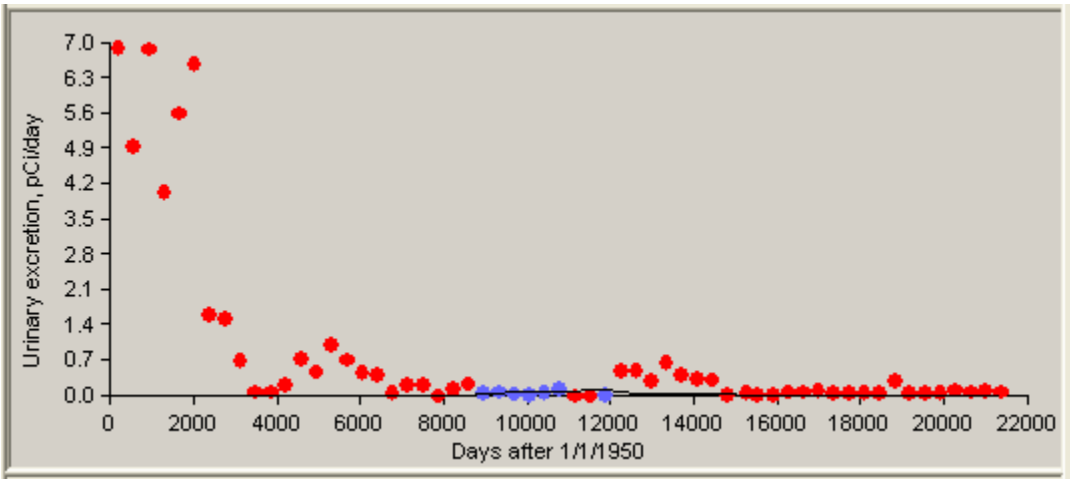

Figure B-140. Predicted uranium bioassay results calculated using IMBA-derived uranium intake rates (line) compared with bioassay results (dots), 1974 to 1982, 50th percentile, type S.

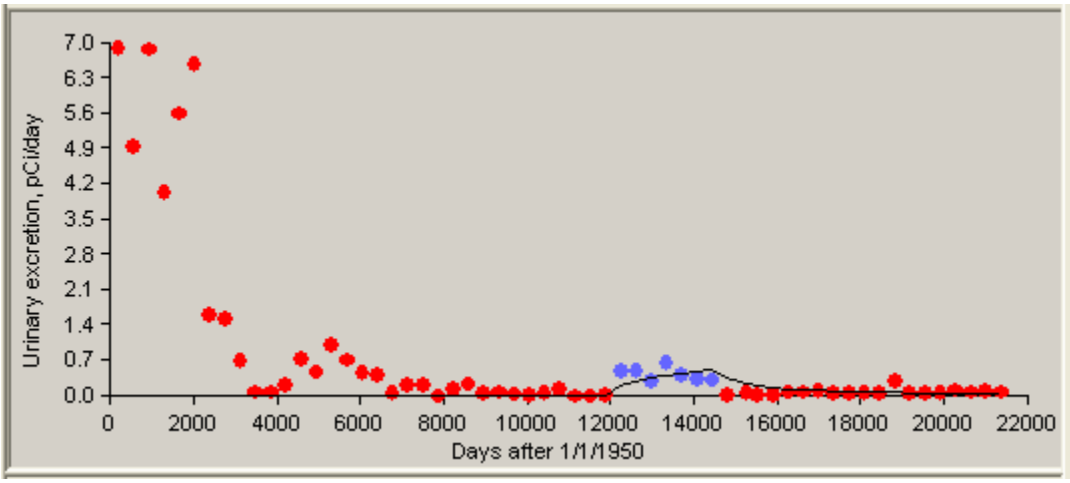

Figure B-141. Predicted uranium bioassay results calculated using IMBA-derived uranium intake rates (line) compared with bioassay results (dots), 1983 to 1989, 50th percentile, type S.

ATTACHMENT B
CO-EXPOSURE DATA FIGURES

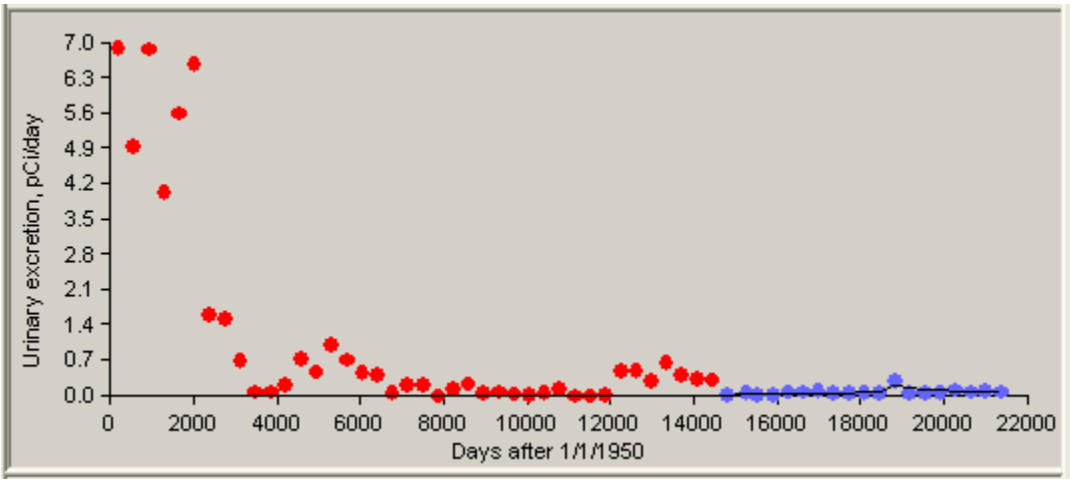

Figure B-142. Predicted uranium bioassay results calculated using IMBA-derived uranium intake rates (line) compared with bioassay results (dots), 1990 to 2008, 50th percentile, type S.

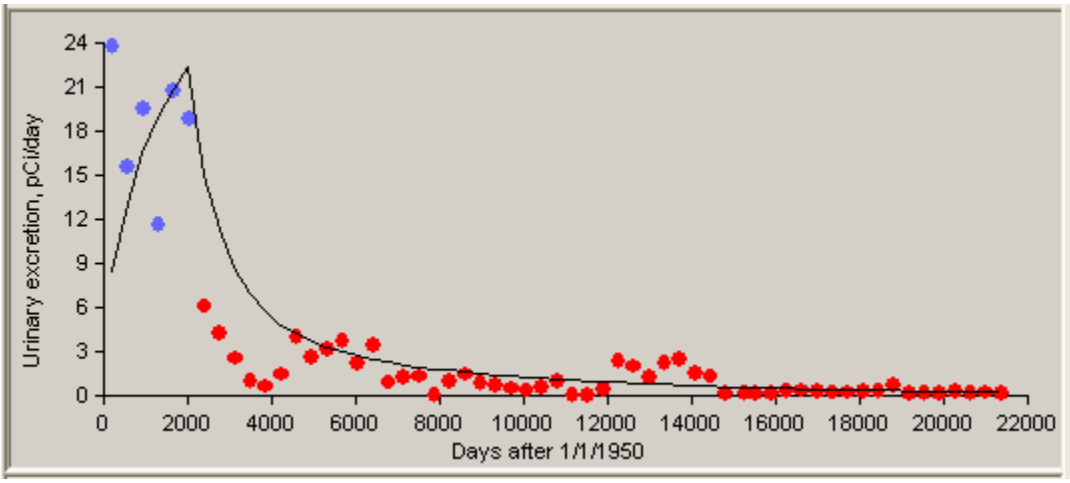

Figure B-143. Predicted uranium bioassay results calculated using IMBA-derived uranium intake rates (line) compared with bioassay results (dots), 1950 to 1955, 84th percentile, type S.

ATTACHMENT B
CO-EXPOSURE DATA FIGURES

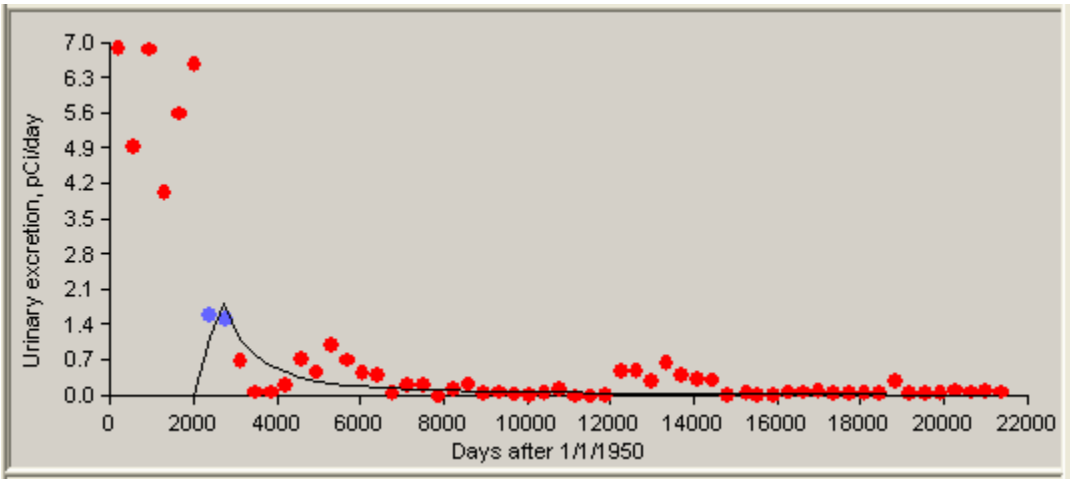

Figure B-144. Predicted uranium bioassay results calculated using IMBA-derived uranium intake rates (line) compared with bioassay results (dots), 1956 and 1957, 84th percentile, type S.

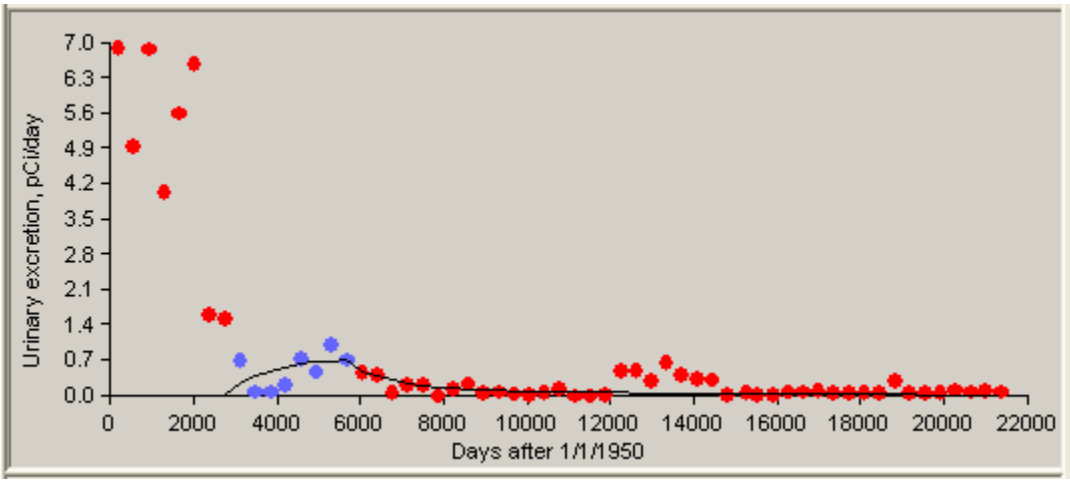

Figure B-145. Predicted uranium bioassay results calculated using IMBA-derived uranium intake rates (line) compared with bioassay results (dots), 1958 to 1965, 84th percentile, type S.

ATTACHMENT B
CO-EXPOSURE DATA FIGURES

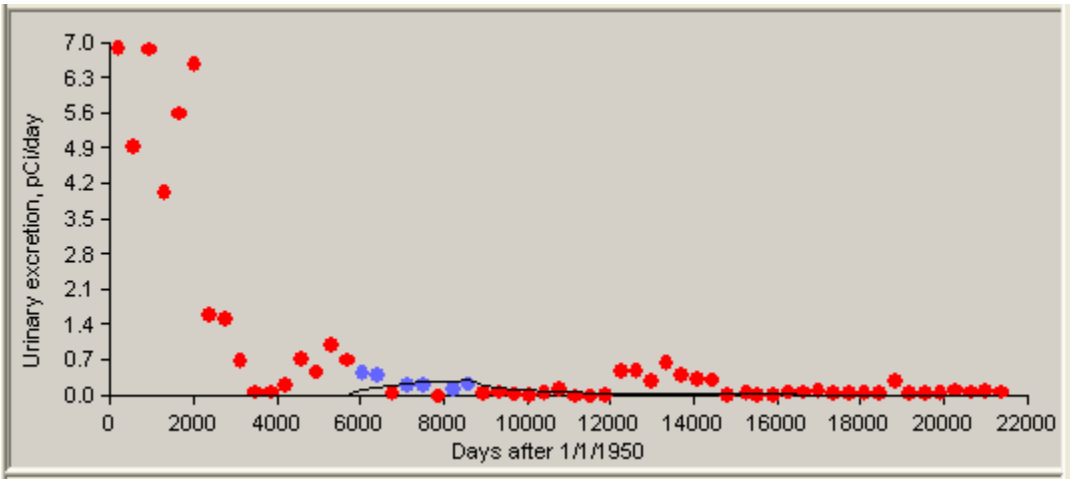

Figure B-146. Predicted uranium bioassay results calculated using IMBA-derived uranium intake rates (line) compared with bioassay results (dots), 1966 to 1973, 84th percentile, type S.

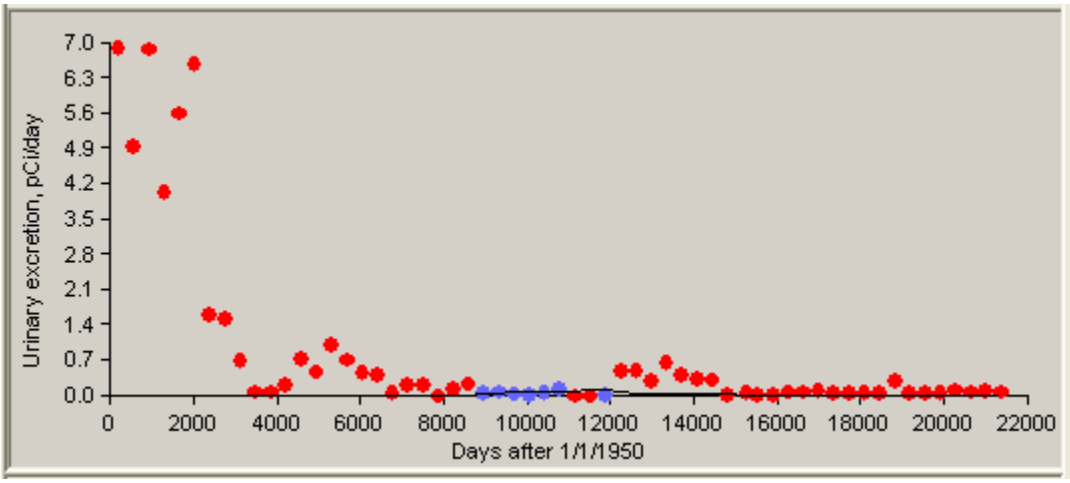

Figure B-147. Predicted uranium bioassay results calculated using IMBA-derived uranium intake rates (line) compared with bioassay results (dots), 1974 to 1982, 84th percentile, type S.

ATTACHMENT B
CO-EXPOSURE DATA FIGURES

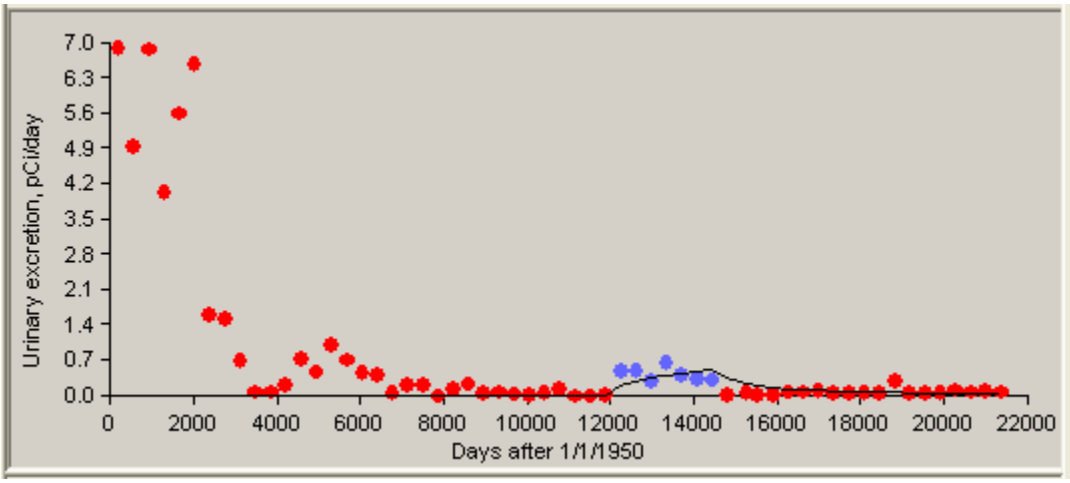

Figure B-148. Predicted uranium bioassay results calculated using IMBA-derived uranium intake rates (line) compared with bioassay results (dots), 1983 to 1989, 84th percentile, type S.

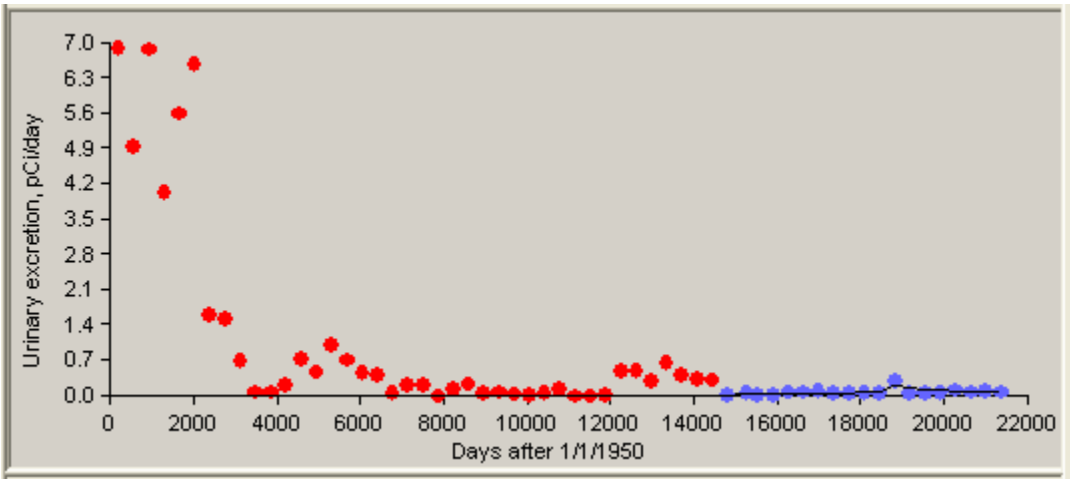

Figure B-149. Predicted uranium bioassay results calculated using IMBA-derived uranium intake rates (line) compared with bioassay results (dots), 1990 to 2008, 84th percentile, type S.

ATTACHMENT B
CO-EXPOSURE DATA FIGURES

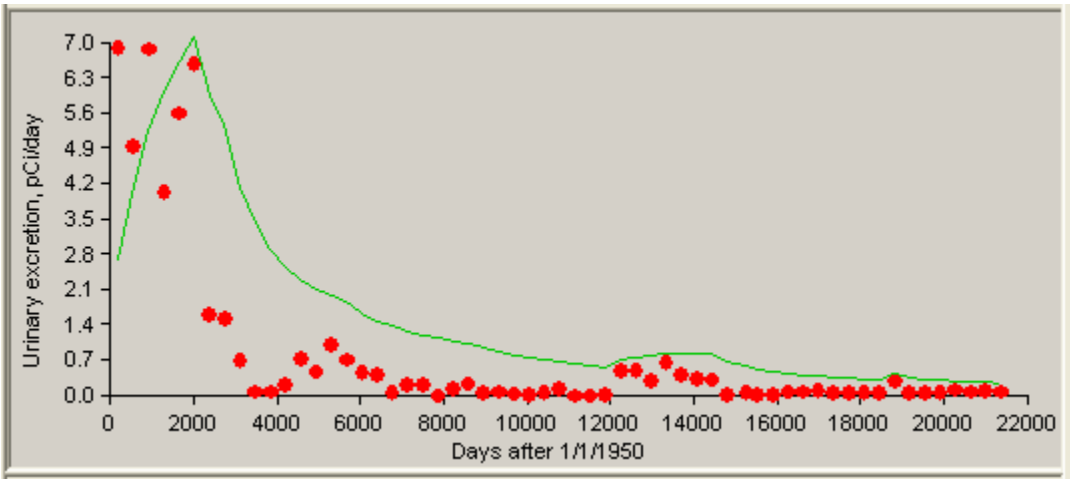

Figure B-150. Predicted uranium bioassay results calculated using IMBA-derived uranium intake rates (line) compared with bioassay results (dots), all intake periods, 50th percentile, type S.

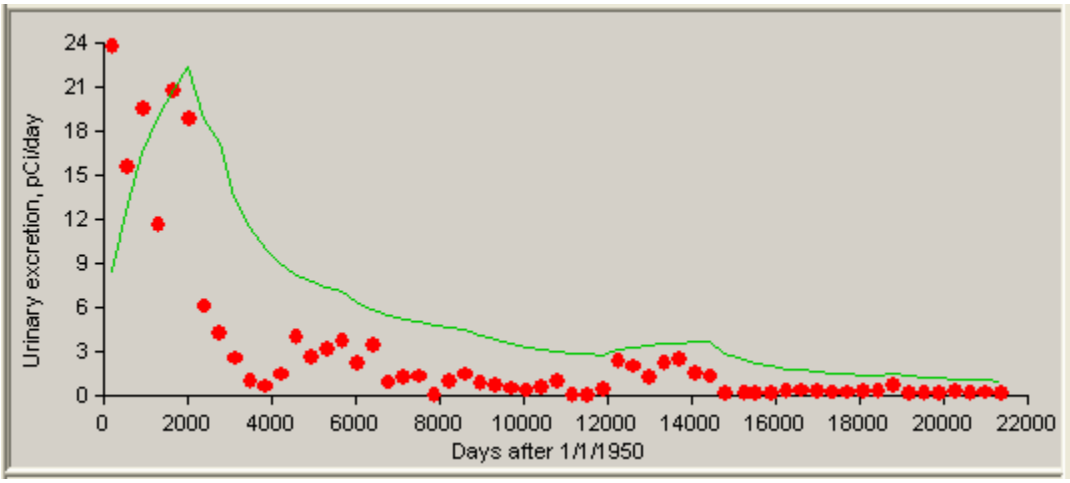

Figure B-151. Predicted uranium bioassay results calculated using IMBA-derived uranium intake rates (line) compared with bioassay results (dots), all intake periods, 84th percentile, type S.

Table B-13. Summary of uranium type S intake rates (pCi/d) and dates.

Start	End	50th percentile	84th percentile	GSD
01/01/1950	12/31/1955	1,520	4,760	3.13
01/01/1956	12/31/1957	655.5	2,125	3.24
01/01/1958	12/31/1965	141	664.5	4.71
01/01/1966	12/31/1973	59.25	390.4	6.59
01/01/1974	12/31/1982	19.66	182.3	9.27
01/01/1983	12/31/1989	104.5	463.5	4.44
01/01/1990	12/31/2008	10.97	50.12	4.57
01/01/2001	12/31/2001	80.980	109.5	1.35

a. Note: The 2001 intake is additive to the 1990–2008 intake.

ATTACHMENT B
CO-EXPOSURE DATA FIGURES

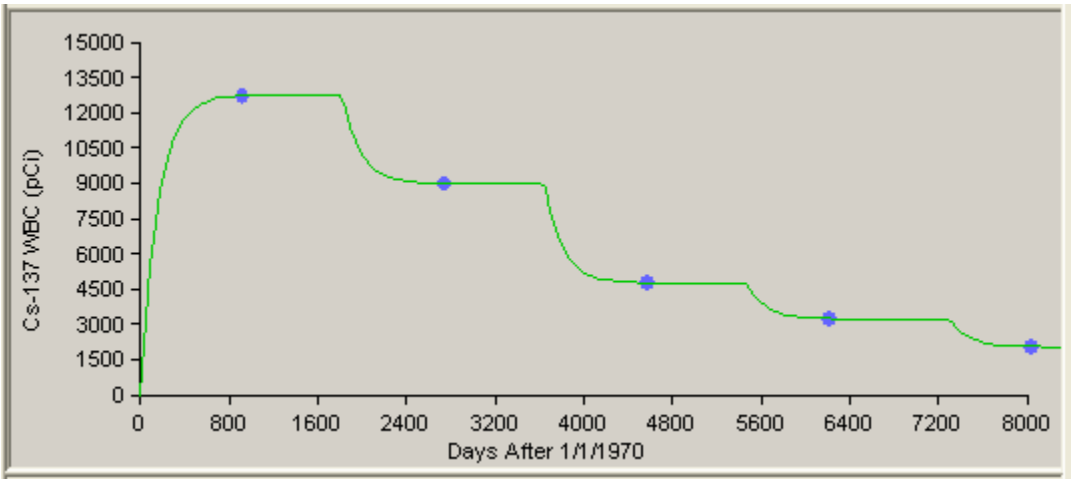

Figure B-152. Predicted cesium bioassay results calculated using IMBA-derived cesium intake rates (line) compared with bioassay results (dots) from all intakes, 50th percentile, type F.

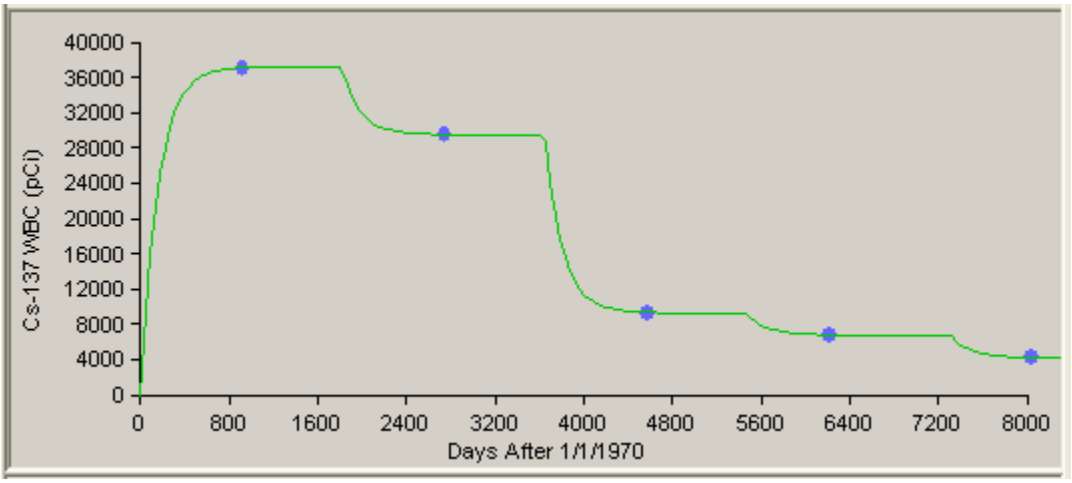

Figure B-153. Predicted cesium bioassay results calculated using IMBA-derived cesium intake rates (line) compared with bioassay results (dots) from all intakes, 84th percentile, type F.

Table B-14. Summary of type F ^{137}Cs intake rates (pCi/d) and dates.

Start	End	50th percentile	84th percentile	GSD
01/01/1970	12/31/1974	185.5	540.9	2.92
01/01/1975	12/31/1979	130.7	428.9	3.28
01/01/1980	12/31/1984	69.47	136.2	1.96
01/01/1985	12/31/1988	47.36	99.75	2.11
01/01/1990	12/31/1993	30.16	62.85	2.08