Savannah River Site Plutonium Construction Trade Worker Stratification Refinement

White Paper

National Institute for Occupational Safety and Health

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INTRODUCTION

In August 2017, a joint meeting of the Advisory Board on Radiation and Worker Health Savannah River Site (SRS) and Special Exposure Cohort (SEC) Issues Work Groups was convened to review and discuss the SRS internal dose coworker study, *Internal Coworker Dosimetry Data for the Savannah River Site*, ORAUT-OTIB-0081, Rev. 03 (ORAUT 2016). During this meeting an observation was made that:

> [ORAUT 2016] *appears to contradict itself on whether prime CTWs represent a similar monitoring protocol as subcontractor CTWs. Prime construction workers are described as being exposed "temporarily but frequently for short periods" but also on an annual bioassay schedule specified by the bioassay control procedures. Subcontractor workers were monitored on a case-by-case basis depending on the localized requirements of the job.*

The National Institute of Occupational Safety and Health (NIOSH) Division of Compensation Analysis and Support (DCAS) responded that:

> *The proper question is not whether the monitoring protocols were the same but whether the exposure conditions were similar. If prime CTWs had similar exposure conditions to subcontractor CTWs, then bioassay data from prime CTWs, and thus intakes based on that data, may be used to assign intakes to unmonitored subcontractor CTWs. It is NIOSH's position that the exposure conditions and potential for intakes were similar among all CTWs.*

Additional job plan examples and discussions in defense of this position were documented in *Internal Coworker Dosimetry Data for the Savannah River Site*, ORAUT-OTIB-0081, Rev. 04 (ORAUT 2019). Subsequent working group discussions raised the issue regarding whether there is a difference in bioassay results between prime and subcontractor Construction Trade Workers (CTWs).

NIOSH has taken the position that all CTWs should be combined into a single stratum for the assignment of intakes and doses in the internal dose coworker study, as there is no systemic difference in exposure potential between prime and subcontractor CTWs. On December 14, 2017 (initial tasking) and July 18, 2018 (expanded scope), DCAS requested Oak Ridge Associated Universities Team (ORAUT) support to develop intake models for prime (E. I. du Pont de Nemours and Company [DuPont]) CTWs and subcontractor CTWs using the uncensored plutonium bioassay data from 1974, 1977, 1980, 1983, and 1986. The intent of this effort was to stratify the CTW worker population contained in the coworker study (NIOSH-DCAS Claims Tracking System [NOCTS] data) by prime and subcontractor CTWs. This exercise involved plutonium urine bioassay data only. This white paper presents the results of a review of representative years of CTW bioassay data and the resultant calculated intakes.

SOURCE DATA

The source data for this exercise were obtained from NOCTS files and SRS Bioassay Logbooks. The initial dataset was drawn from the NOCTS source files referenced in ORAUT-OTIB-0081, Rev. 04 (ORAUT 2019). The original plutonium coworker dataset contained bioassay data from both CTWs and non-CTWs (Operations). This white paper focuses only on the CTW population from ORAUT-OTIB-0081, Rev. 04 for the 5 years selected for analysis. This original CTW dataset was stratified into prime versus subcontractor workers using SRS payroll identification (PRID) numbers. The PRID format protocol for subcontract CTWs is as follows:

- n-xxxxx where the prefix "n" is either 4, 5, 6, or a two digit number such as 17. The number to the right of the dash must be 5 digits. Examples are 4-23456, 6-12345, 17-54321
- xxxxx where xxxxx is a 5-digit number with no dashes. An example is 23456. An example of a PRID to skip is 2-3456

Each result with a PRID meeting the above criteria was considered a subcontractor CTW. All other results were considered prime CTW related results.

This original NOCTS-sourced coworker dataset provided an acceptable quantity of information to perform an analysis, however the data was highly censored for most years, particularly for the subcontractor CTW population. To increase the number of uncensored results and provide a more reasonable assessment, a second data source was created consisting of additional coding of SRS provided logbooks (DuPont 1971–1979, 1973–1974, 1973–1979, 1974–1979, 1974, 1975, 1975–1976, 1977–1978, 1978–1979, 1979–1980a, 1979–1980b, 1980a, 1980b, 1980c, 1981a, 1981b, 1980–1981a, 1980–1981b, 1980–1989, 1981–1986, 1983, 1983–1984, 1983–1985, 1984–1986, 1985–1986, 1986, 1986–1987a, 1986–1987b, 1986–1988, 1986–1989, 1986–1990). The logbook dataset served a dual purpose of increasing the number of uncensored results from the NOCTS-sourced data and increasing the number of subcontractor CTWs available for analysis in 1974, 1983, and 1986. Original NOCTS-sourced data for 1977 and 1980 contained a sufficient amount of uncensored prime and subcontractor CTWs for this analysis; therefore, additional coding of subcontractor CTWs was not performed for these years.

The reporting format found in the logbooks was not always consistent about the type of information recorded by laboratory staff. Most of the data contained either a censored (<) or uncensored result (reported as dpm/1.5L). In some instances, dpm/disc values were reported along with the corresponding conversion to dpm/1.5L; at other times, only the dpm/disc data were recorded by laboratory staff. When the raw dpm/disc values were noted in the logbooks, they were coded for all years and regression analysis was performed to estimate actual uncensored results, in lieu of actual SRS laboratory calculations that were unavailable. Tables 1 and 2 summarize the total number of prime CTW and subcontractor CTW workers, respectively, and the number of those workers with uncensored time-weighted one person-one statistic (TWOPOS) results for use in the statistical analysis.

STATISTICAL ANALYSIS

Data Analysis

The bioassay data assembled from the data sources listed above were analyzed and adjustments were made to allow statistical analysis. The measures taken were:

- Illegible date corrections
  - Exclude records with an illegible year.
  - If only the day of the month is illegible, assume the 15th.
  - If only the month is illegible, assume July.
  - If the month and day are illegible, assume July 1st.
- Incident/Exclusions:
  - [Redacted], Claim ID [Redacted], exclude all results after [Redacted], significant body content and residual excretion.
  - Infer a <0.1 result on [Redacted] for [Redacted], Claim ID [Redacted].
  - Infer a <0.1 result on [Redacted] for [Redacted], PRID [Redacted].
  - [Redacted], PRID [Redacted], was chelated on [Redacted]
- Use the following data source hierarchy:
  - If the NOCTS-sourced reported result is uncensored and nonzero, use that value, else...
  - If the Site Research Database (SRDB)-sourced reported result is uncensored and nonzero, use that value, else...
  - Use dpm/1.5L values if present.
    1. Replace any zero (or blank) dpm/1.5L values with the corresponding corrected dpm/disc value. To determine the correction, regress dpm/1.5L values on corresponding dpm/disc values and use the regression coefficients to calculate blank or zero dpm/1.5L values from their corresponding dpm/disc results.
    2. Average all the dpm/1.5L values for the sample.
  - If no uncensored data are present, use the censored reported value.
  - If none of these values are present or if the only value present is lost in process (LIP), do not use the row.
- For data reported as ^{239}Pu values, correct to plutonium gross alpha by multiplying by 1.69 (10-year 12% plutonium mix ratio). If the result is reported per liter, adjust to per day (1.5L/d).
- Do not use ^{238}Pu results.

A portion of the data contained in the logbooks noted only the raw dpm/disc value and did not report a dpm/1.5L value. The specific formula used to convert results from dpm/disc to dpm/1.5L was not readily available for each period of interest; therefore, a regression analysis technique was employed to calculate a dpm/1.5L value for use in the modeling. The regression was performed on an annual basis. All logbook samples with both a dpm/disc and a corresponding dpm/1.5L conversion were plotted and the relationship from the fitted regression was used to develop annual coefficients. The regression coefficients were then used to calculate dpm/1.5L values for samples with only a reported dpm/disc value, per the instructions. The regression coefficients discussed above are presented in Attachment A.

Statistical Analysis

Statistical analysis of the plutonium bioassay data was performed in accordance with *Analysis of Stratified Coworker Datasets*, ORAUT-RPRT-0053, Rev. 02 (ORAUT 2014) using the TWOPOS method from that document. Summary statistics for the DuPont CTW and subcontractor CTW strata for 1974, 1977, 1980, 1983, and 1986 using regression on order statistic (ROS) fits were prepared and are listed in Tables 1 and 2, respectively. Additionally, box plots of the TWOPOS data were prepared. The summary statistics plots and box plots are provided in Attachments B and C, respectively.

Table 1. Summary statistics for prime CTWs

Year	Number of TWOPOS Results	Number of Uncensored TWOPOS Results	GM (dpm/1.5L)	GSD
1974	98	38	0.004689	7.26
1977	114	35	0.003447	4.866
1980	72	32	0.005597	6.129
1983	65	23	0.007492	5.341
1986	45	20	0.01141	3.522

Table 2. Summary statistics for subcontractor CTWs

Year	Number of TWOPOS Results	Number of Uncensored TWOPOS Results	GM (dpm/1.5L)	GSD
1974	216	42	0.001439	7.45
1977	69	20	0.001745	6.838
1980	83	40	0.009319	5.736
1983	641	226	0.005914	5.364
1986	1130	472	0.00917	4.79

INTAKE MODELING

The results of the plutonium urinary excretion statistical analysis were used to calculate intakes that would result in the corresponding urinary excretions. For each year analyzed, it was assumed to be representative of the 3-year period centered on each year. Thus, the statistical analysis for 1974 is representative of the entire period from January 1, 1973, through December 31, 1975. By this method, contiguous intake periods from January 1, 1973, through December 31, 1987, were developed.

Each result that was used in the intake calculations was assumed to have a normal distribution. A uniform absolute error of 1 was applied to all results, thereby assigning the same weight to each result. The Integrated Modules for Bioassay Analysis (IMBA) program requires in vitro bioassay results to be in units of activity per day; therefore, all urinalysis results were normalized as needed to 24-hr samples using 1,500 mL (the volume of urine assumed by SRS to be excreted in a 24-hr period).

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

IMBA was used to fit the bioassay results to a series of inhalation intakes. Data were fit as a series of chronic intakes. The intake assumptions were based on observed patterns in the bioassay data. Periods with constant chronic intake rates were chosen by the selection of periods in which the bioassay results were similar. A new chronic intake period was started if the data indicated a significant sustained change in the bioassay results. By this method, the years from 1973 through 1987 were divided into two chronic intake periods.

Each chronic intake was fit independently using only the bioassay results from the single intake period for types M and S solubility. Excluded results are shown in red or dark gray in the figures in Attachment D; included results are shown in blue or light gray. The results of the statistical analysis that was used to calculate the intakes are provided in Tables 3 and 4.

Table 3. Intake modeling results, dpm/d, type M

Years	DuPont GM	DuPont 84th	DuPont GSD	DuPont 95th	Sub[a] GM	Sub 84th	Sub GSD	Sub 95th
1973–1978	0.7732	4.565	5.90	14.349	0.325	2.277	7.01	8.00
1979–1987	1.426	6.251	4.38	16.215	1.293	6.660	5.15	19.17

a. Sub = subcontractor.

Table 4. Intake modeling results, dpm/d, type S

Years	DuPont GM	DuPont 84th	DuPont GSD	DuPont 95th	Sub[a] GM	Sub 84th	Sub GSD	Sub 95th
1973–1978	15.71	88.27	5.62	268.7	6.97	48.5	6.95	169.4
1979–1987	26.38	110.7	4.20	279.2	22.65	114.6	5.06	326.1

a. Sub = subcontractor.

CONCLUSION

As can be seen by examination of the tables above, the geometric mean (GM) of the results for the DuPont CTWs are higher than that for the subcontractor CTWs for all years evaluated. For the 1973 through 1978 period, the 95th percentile intake results for the DuPont CTWs are higher as well. For the 1979 through 1987 period, the subcontractor CTWs do have a higher 95th percentile due to the higher geometric standard deviation (GSD) of the data.

Based on the premise that exposure conditions for DuPont and subcontractor CTWs were similar and the review of the bioassay results, TWOPOS data, and intake modeling for prime and subcontractor CTWs presented in this white paper, NIOSH believes it is reasonable to combine all CTWs into a single stratum for assignment of intakes in the SRS internal dose coworker study.

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ATTACHMENT A: REGRESSION COEFFICIENT PLOTS

The regression coefficient plots in this attachment were used to convert dpm/disc results to dpm/1.5L values when only the dpm/disc value was reported. The plots are the annual regressions of the dpm/1.5L values on their corresponding dpm/disc values for results where both values were present. Ideally, these pairs of values would fall on a straight line, and the regression parameters would reveal the conversion from dpm/disc to dpm/1.5L. For results where the dpm/disc value was available but not the corresponding dpm/1.5L value, the annual regression parameters were used to calculate the dpm/1.5L value.

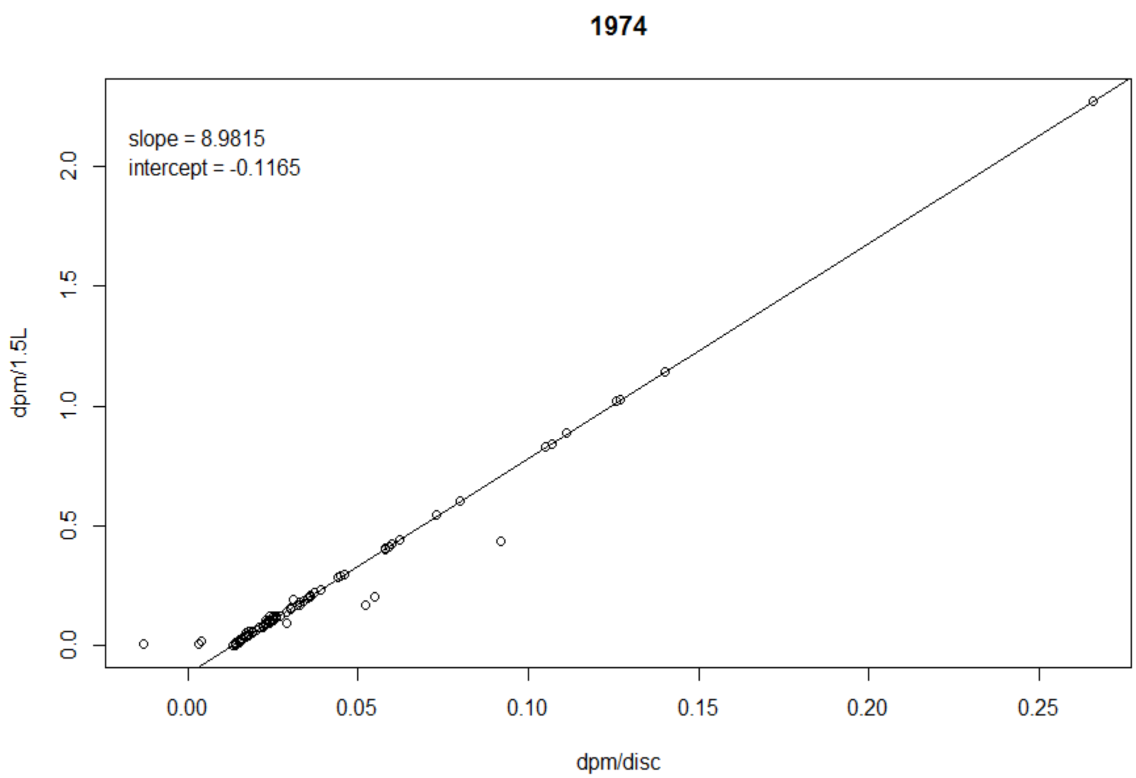

Figure A1. 1974 Regression coefficient fit plot.

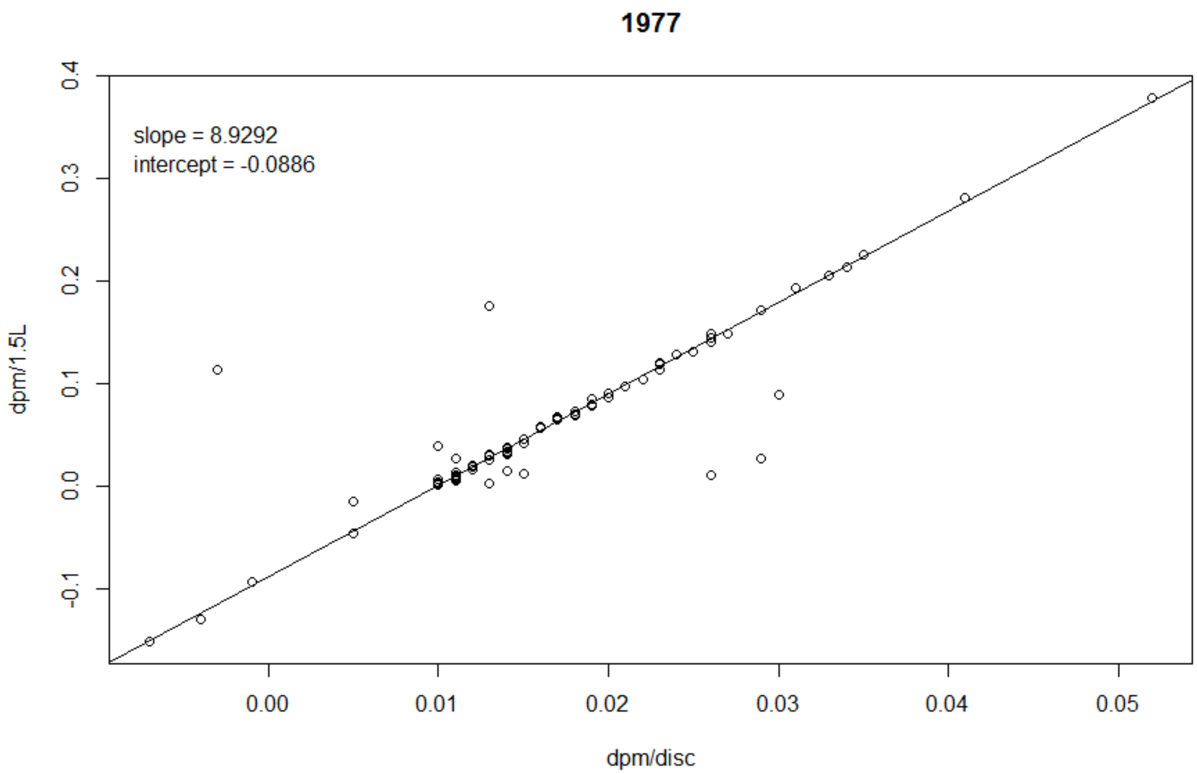

Figure A2. 1977 Regression coefficient fit plot.

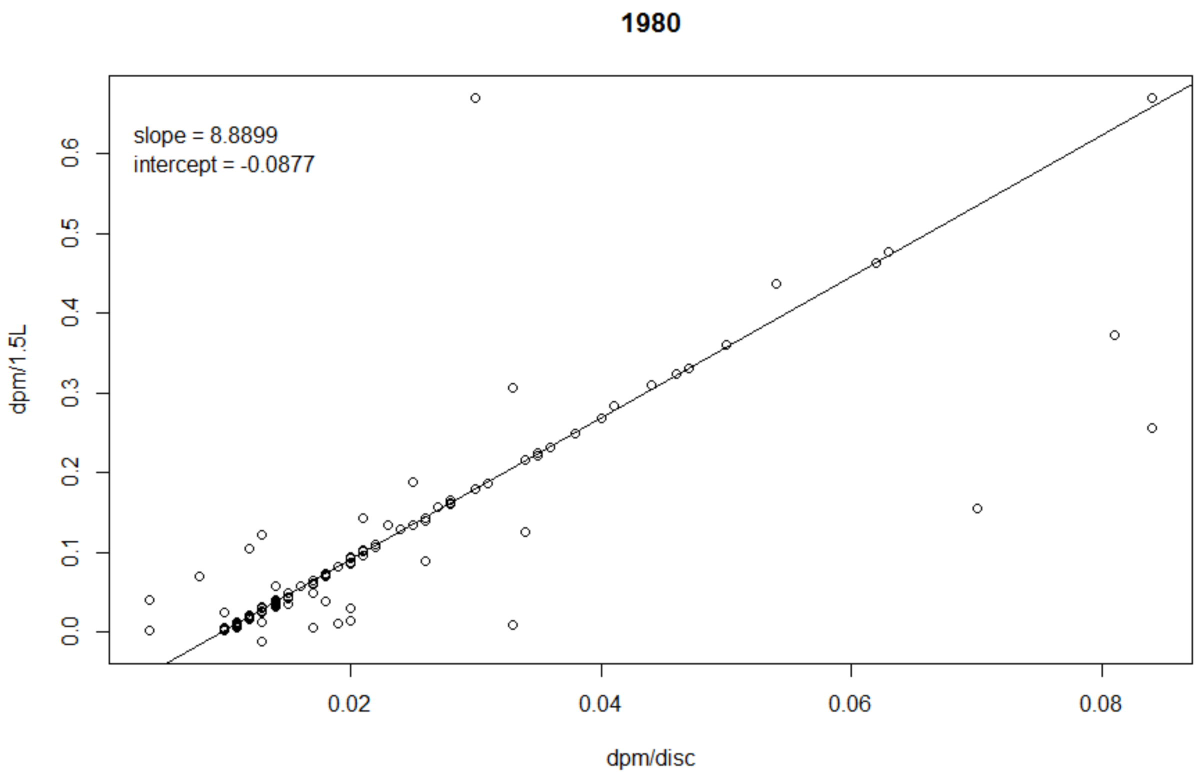

Figure A3. 1980 Regression coefficient fit plot.

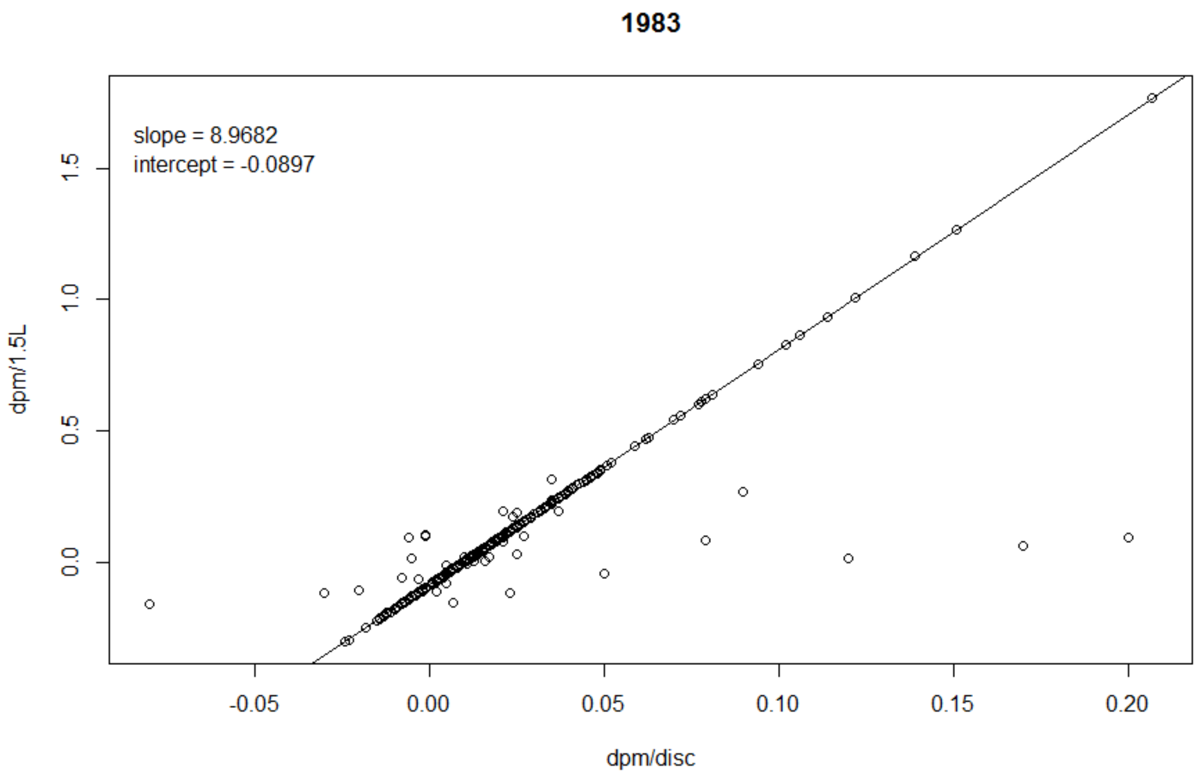

Figure A4. 1983 Regression coefficient fit plot.

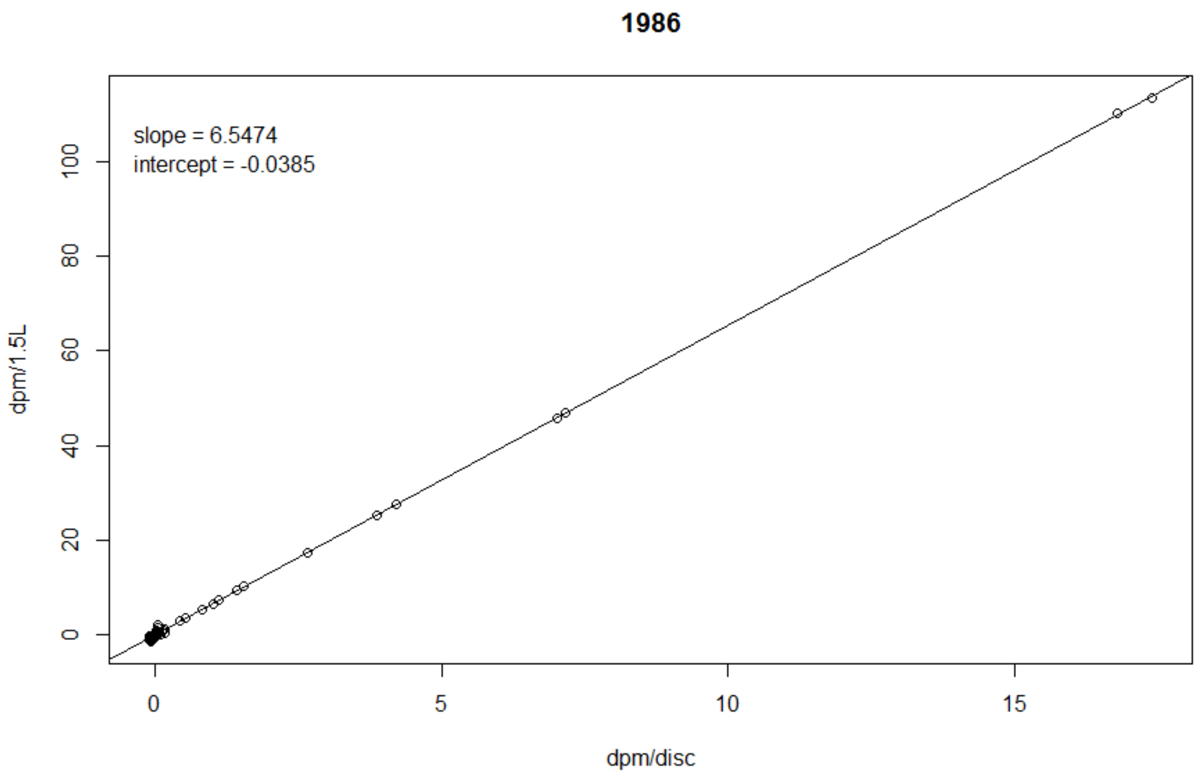

Figure A5. 1986 Regression coefficient fit plot.

ATTACHMENT B: ROS FIT PLOTS

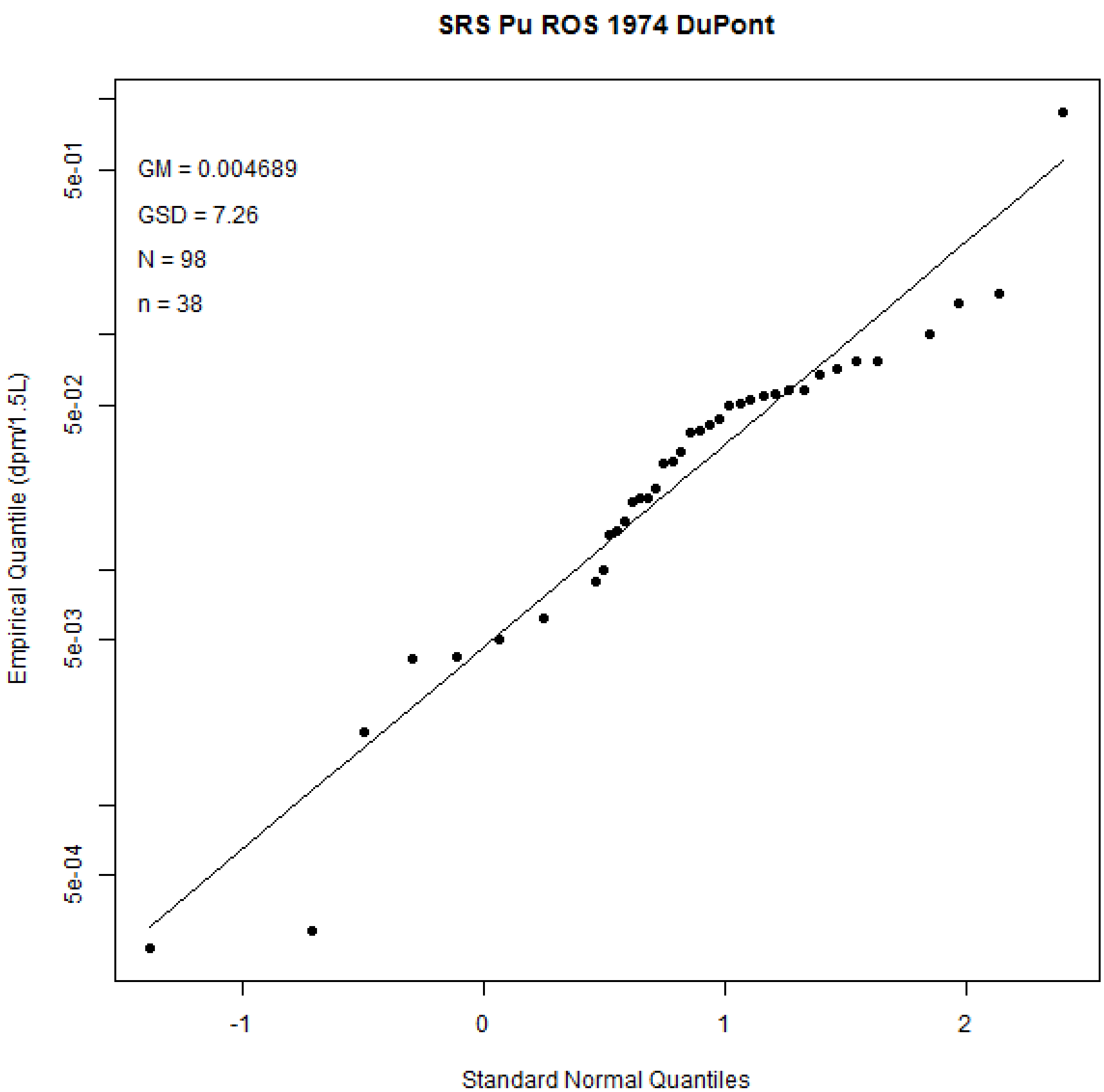

Figure B1. ROS fit to 1974 DuPont CTW TWOPOS data.

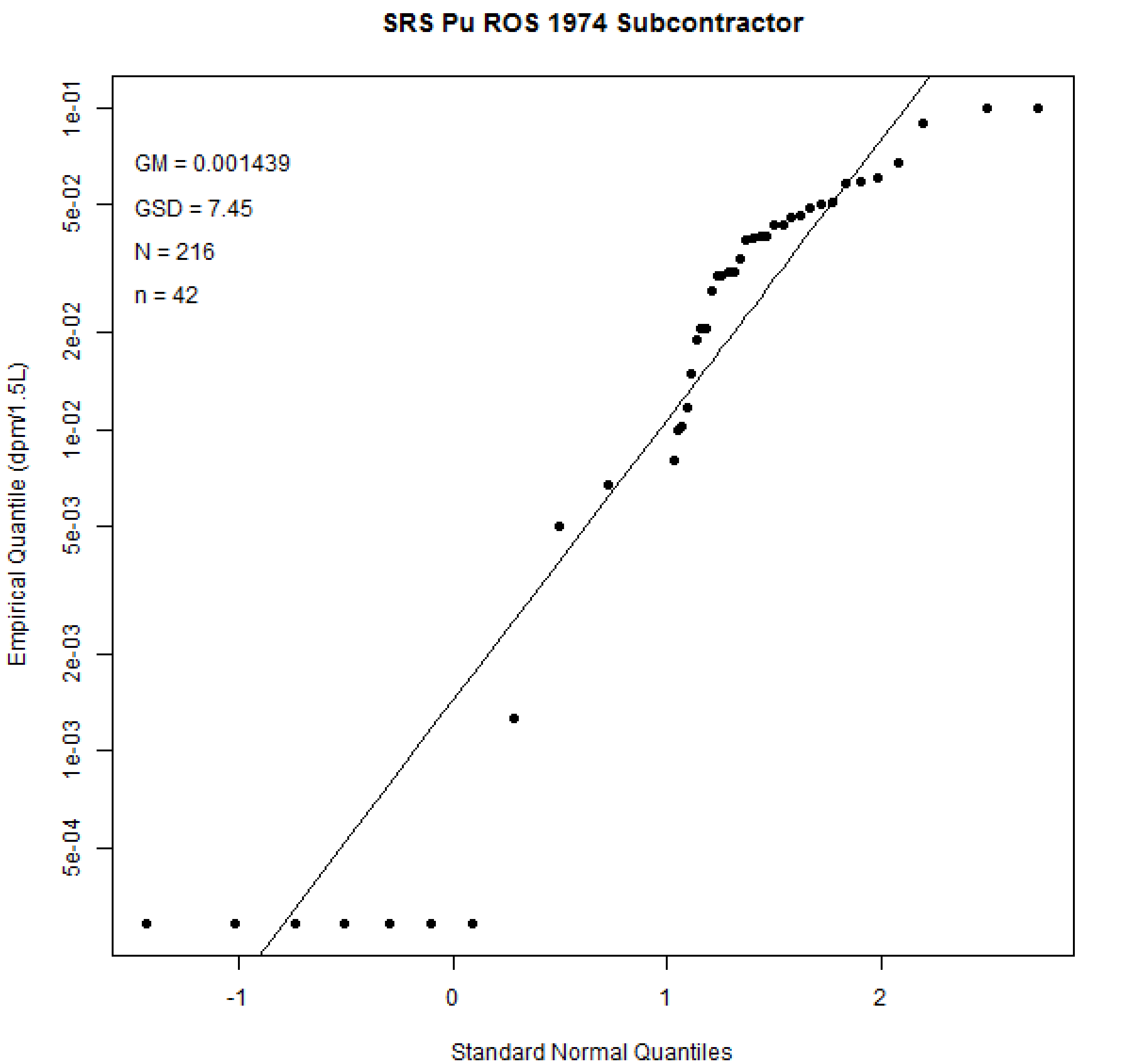

Figure B2. ROS fit to 1974 subcontractor CTW TWOPOS data.

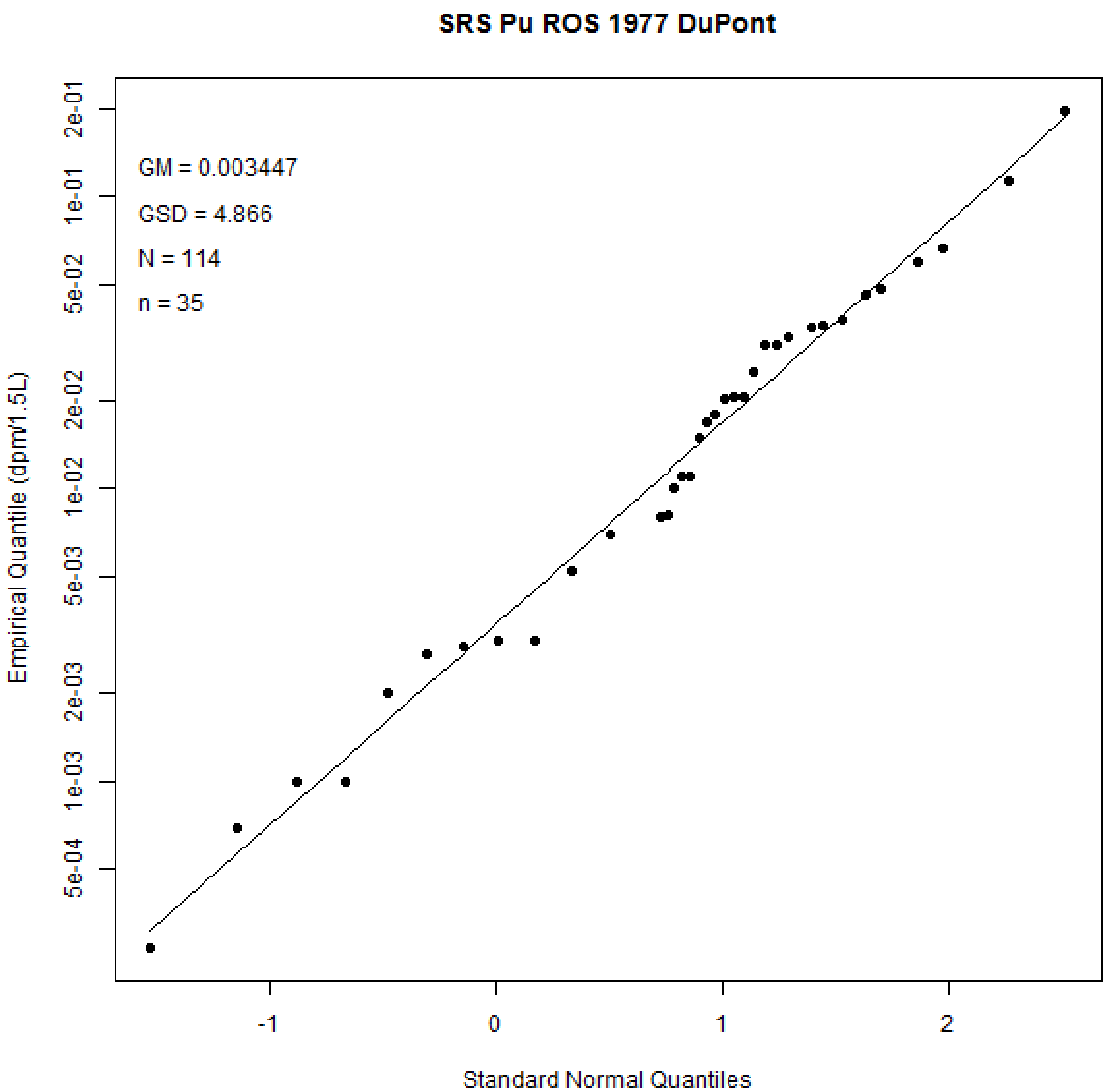

Figure B3. ROS fit to 1977 DuPont CTW TWOPOS data.

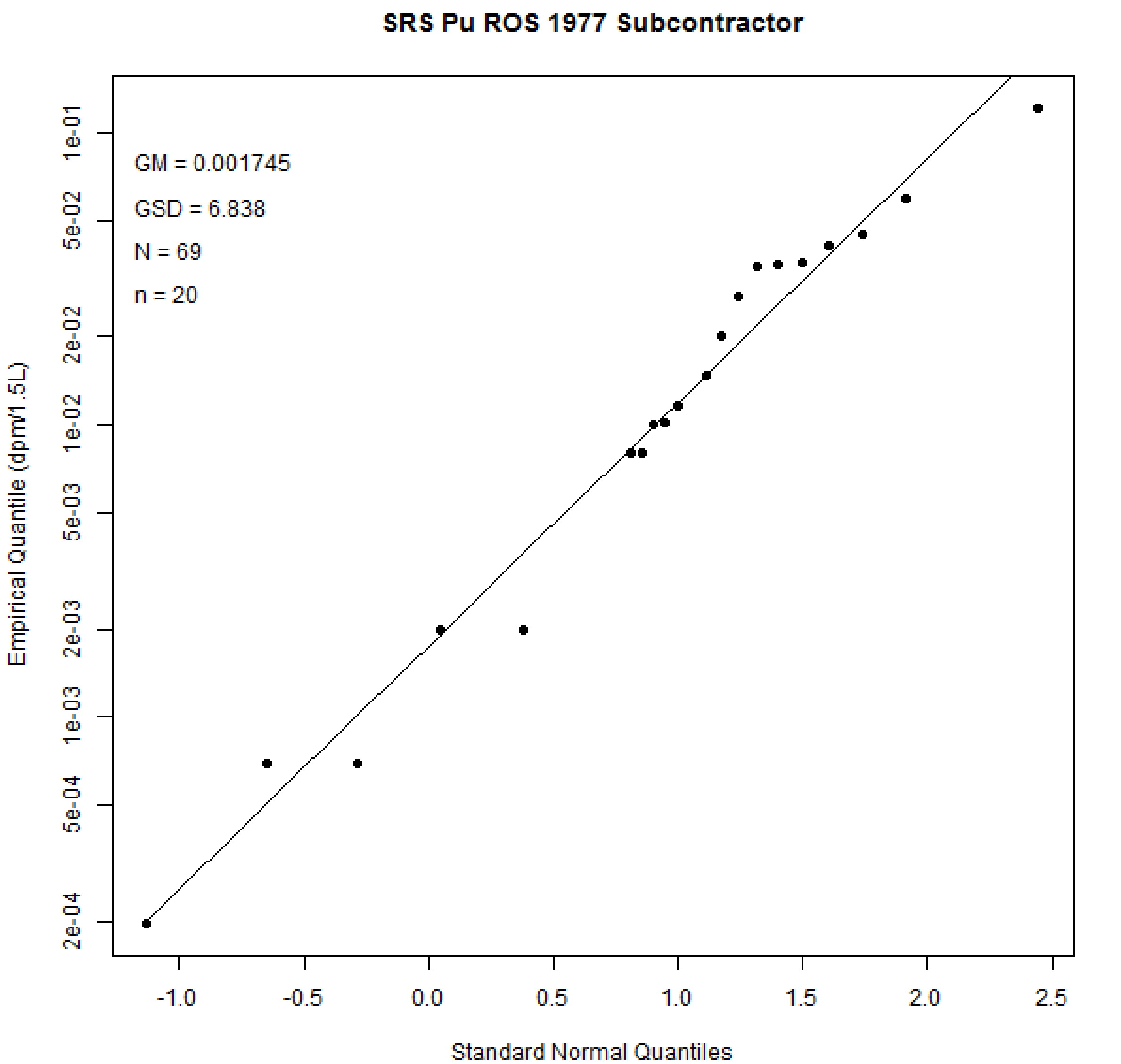

Figure B4. ROS fit to 1977 subcontractor CTW TWOPOS data.

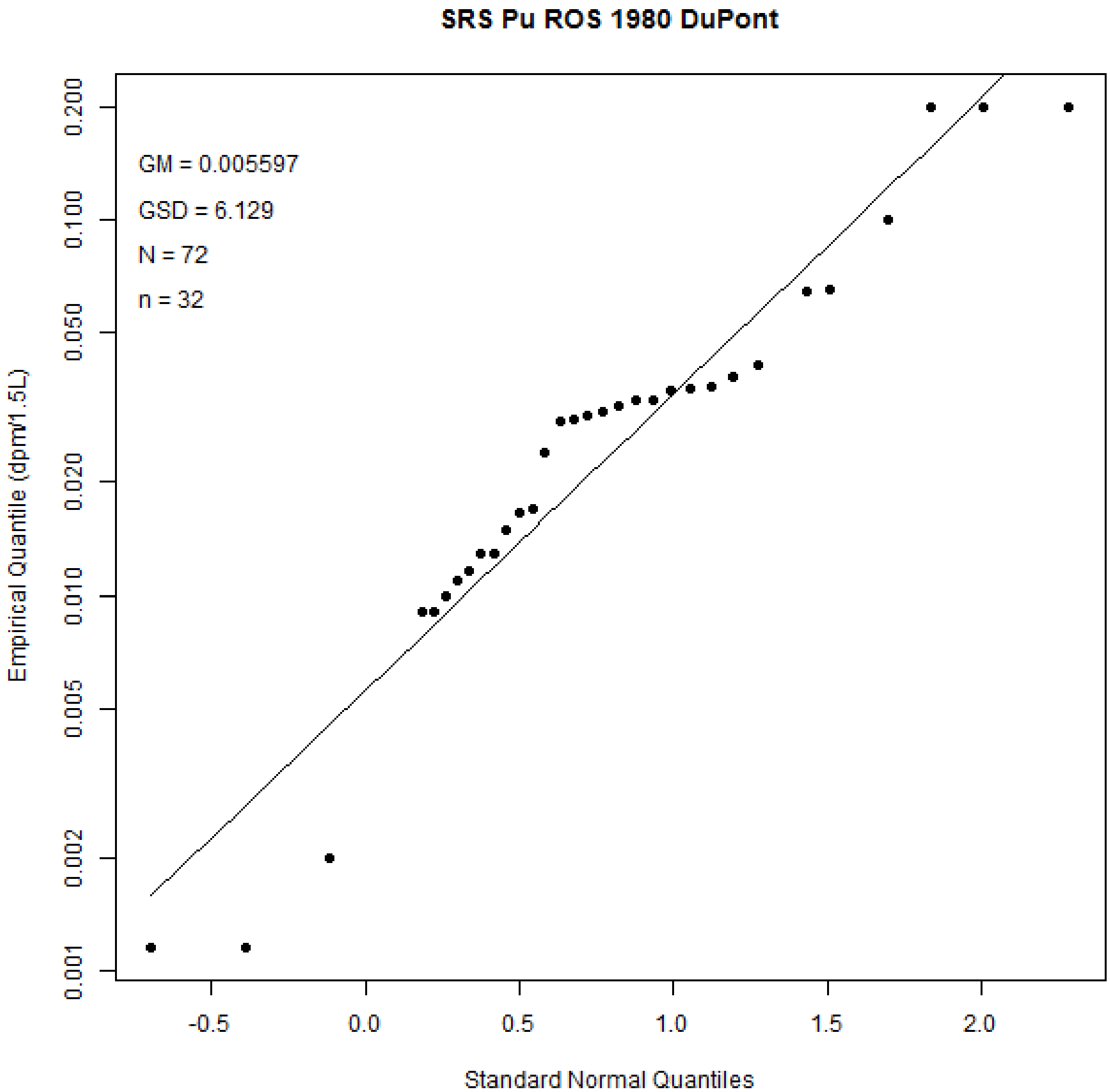

Figure B5. ROS fit to 1980 DuPont CTW TWOPOS data.

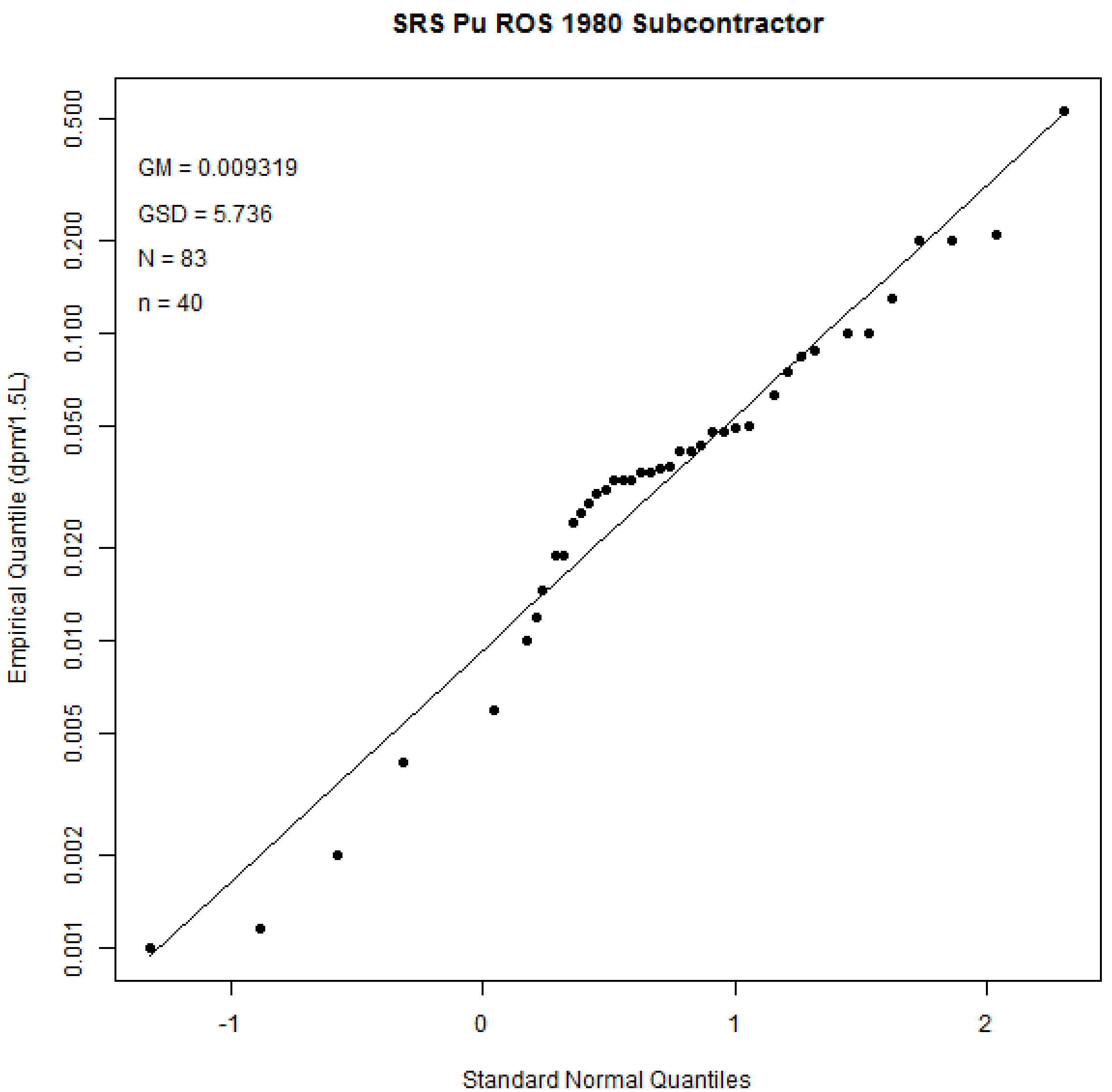

Figure B6. ROS fit to 1980 subcontractor CTW TWOPOS data.

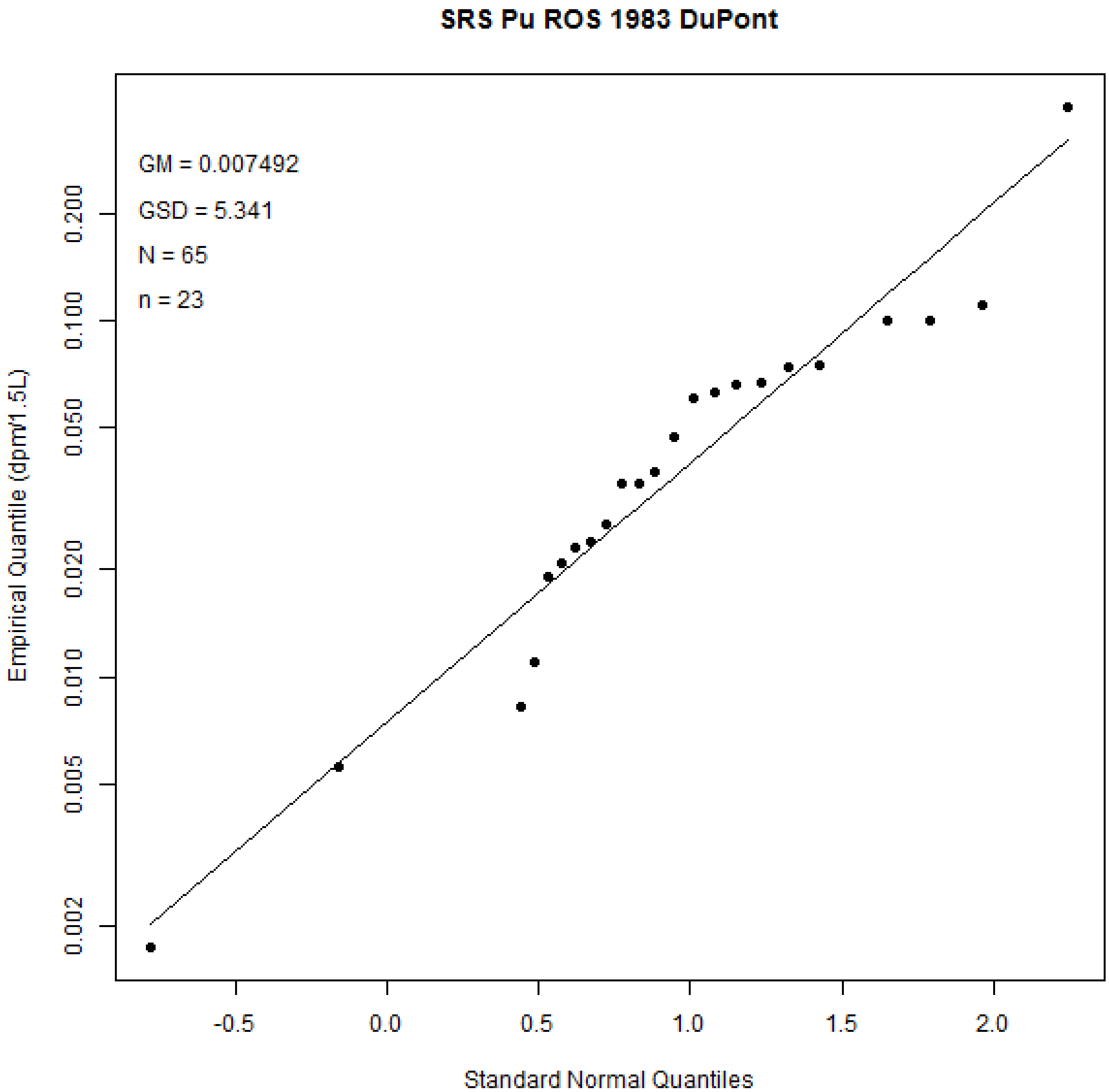

Figure B7. ROS fit to 1983 DuPont CTW TWOPOS data.

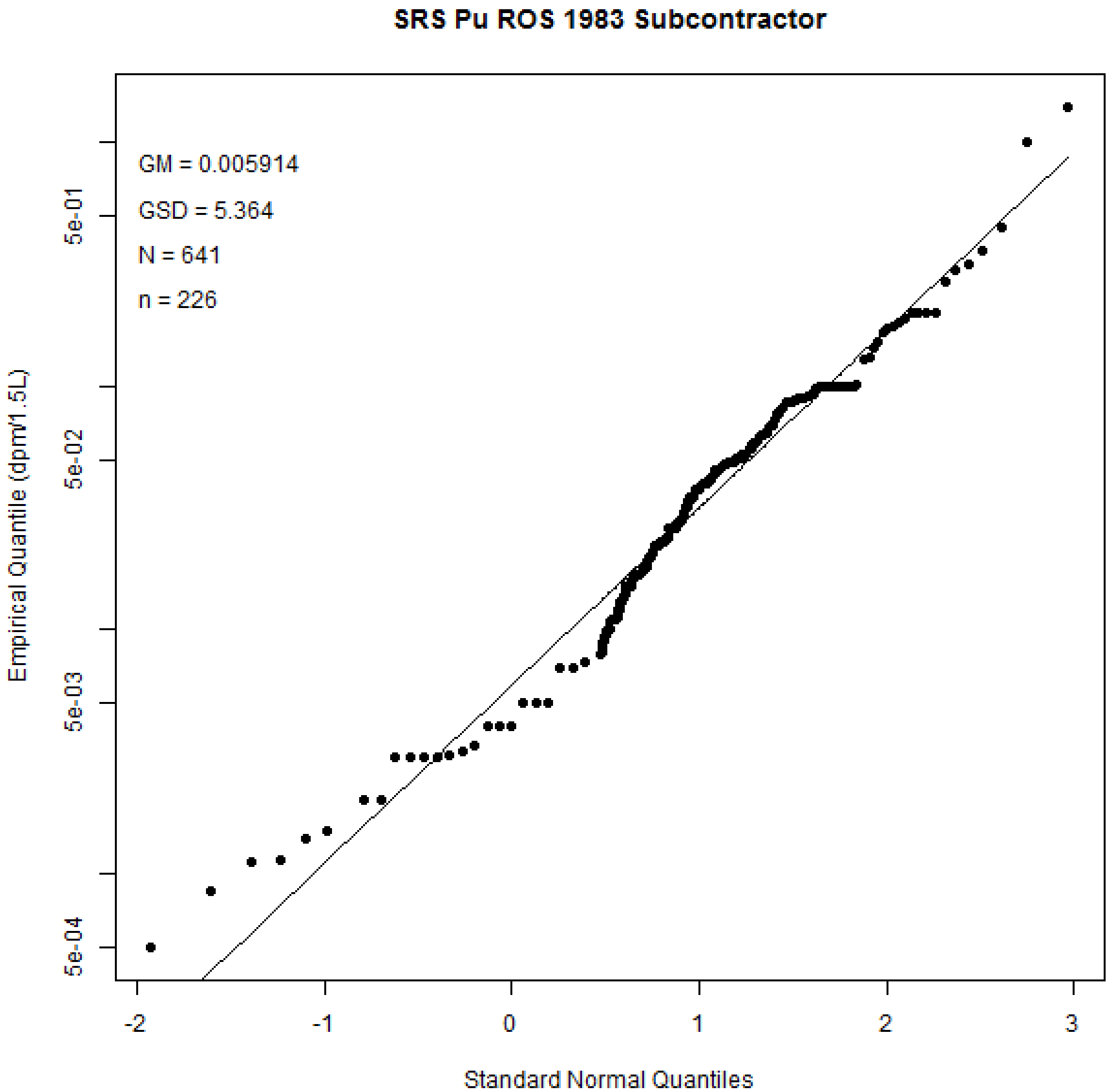

Figure B8. ROS fit to 1983 subcontractor CTW TWOPOS data.

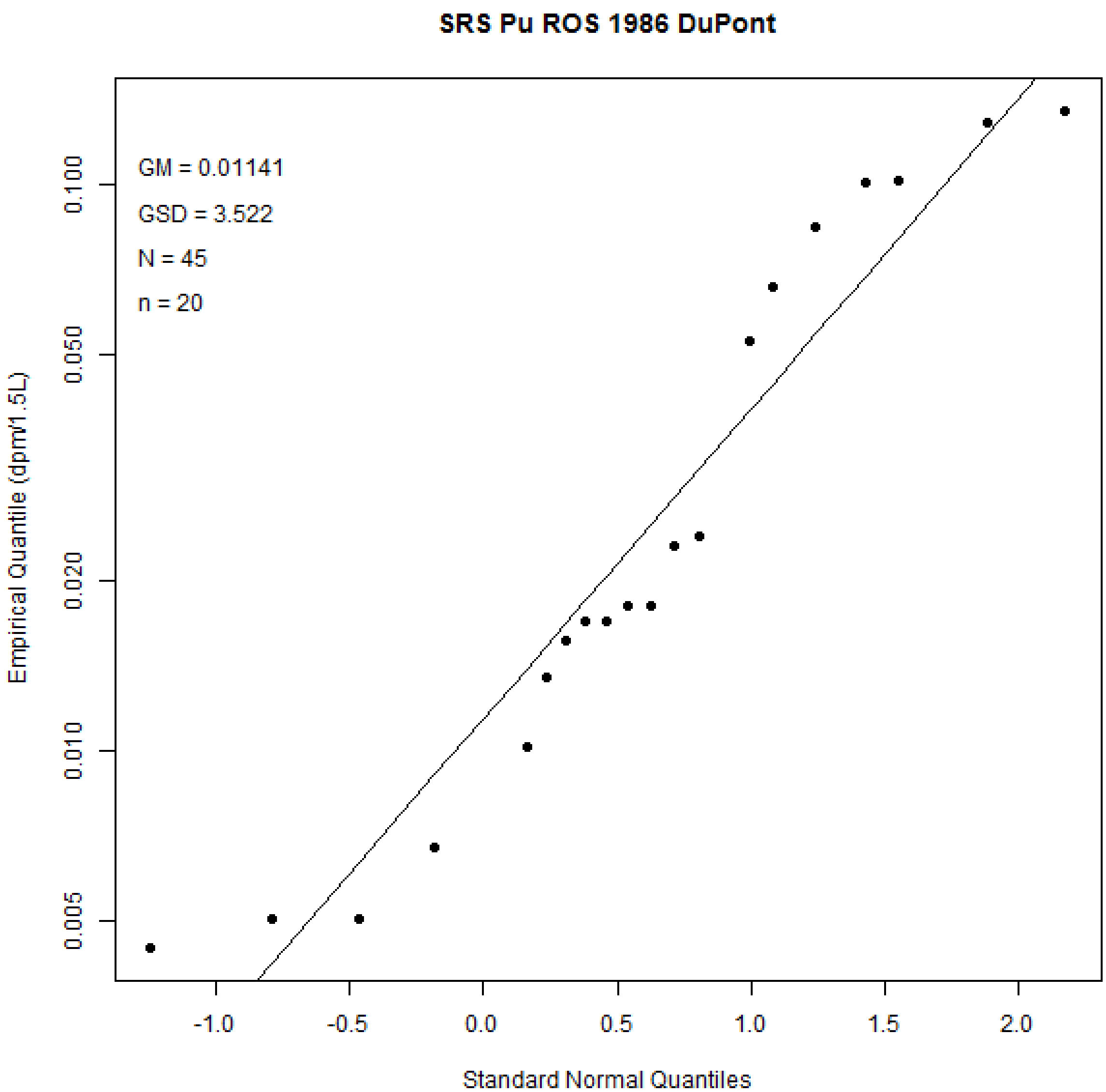

Figure B9. ROS fit to 1986 DuPont CTW TWOPOS data.

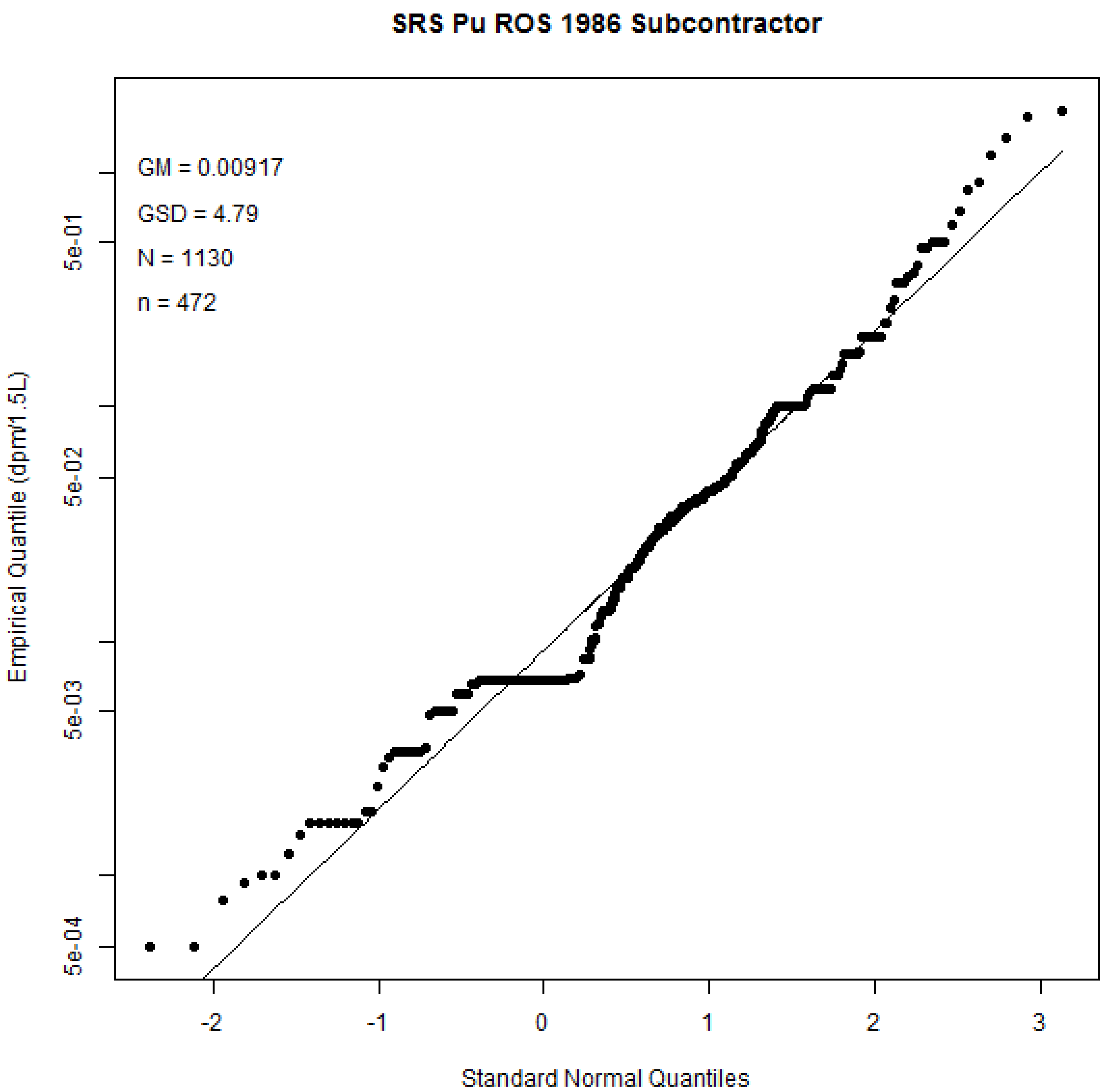

Figure B10. ROS fit to 1986 subcontractor CTW TWOPOS data.

ATTACHMENT C: BOX PLOTS

Censored and maximum possible percentile plots using TWOPOS data were developed for comparison of prime (DuPont) and subcontractor CTW workers. These are not traditional box plots, as censored TWOPOS results are included in the dataset. Censored box plots replace the censored results with the lognormal quantile associated with the plotting position of the censored result. This means there are no results of zero, so a log scale plot is possible. The maximum possible percentile plots use the censored results at face value (simply dropping the <) to make box plots. There are results of zero, so a log scale is not possible for the maximum possible percentile plot. In every plot, the bottom whisker of the box plot extends to the 5th percentile, while the upper whisker extends to the 95th percentile, and there is a horizontal line at 0.1 dpm/d for comparison with the censoring level for plutonium in urine.

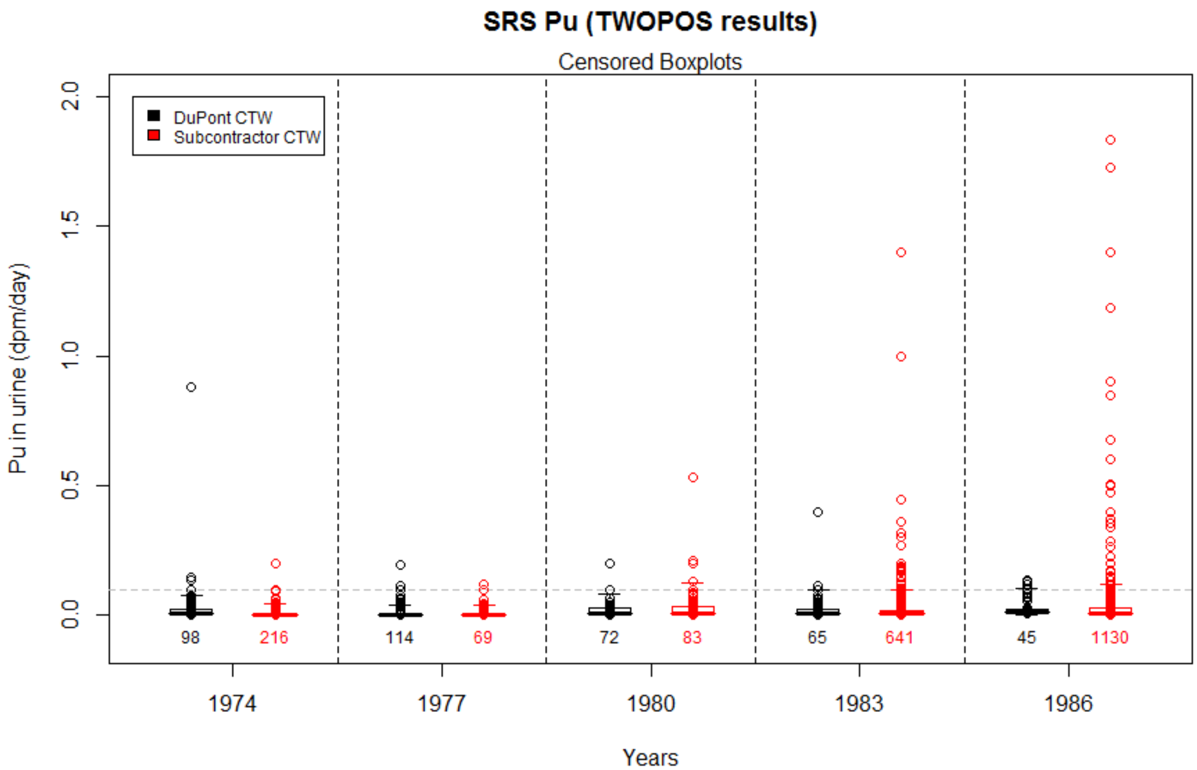

Figure C1. Censored data box plots showing full data range.

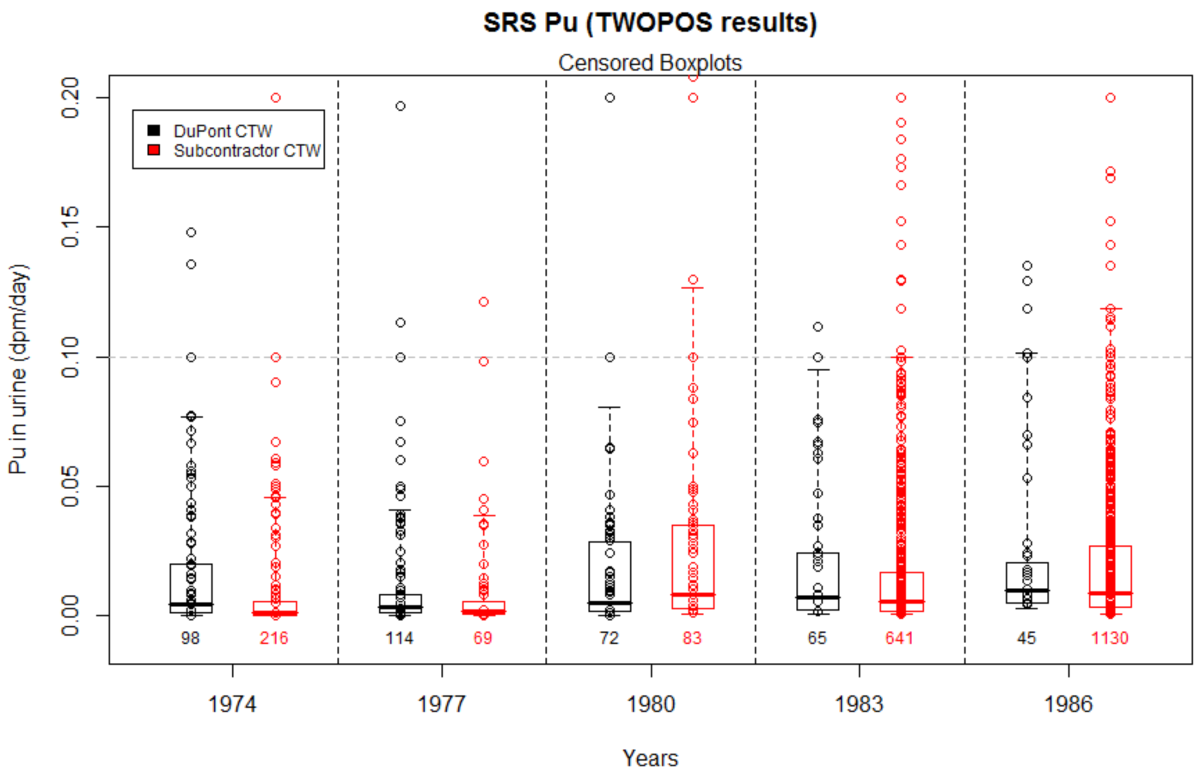

Figure C2. Censored data box plots zoomed in.

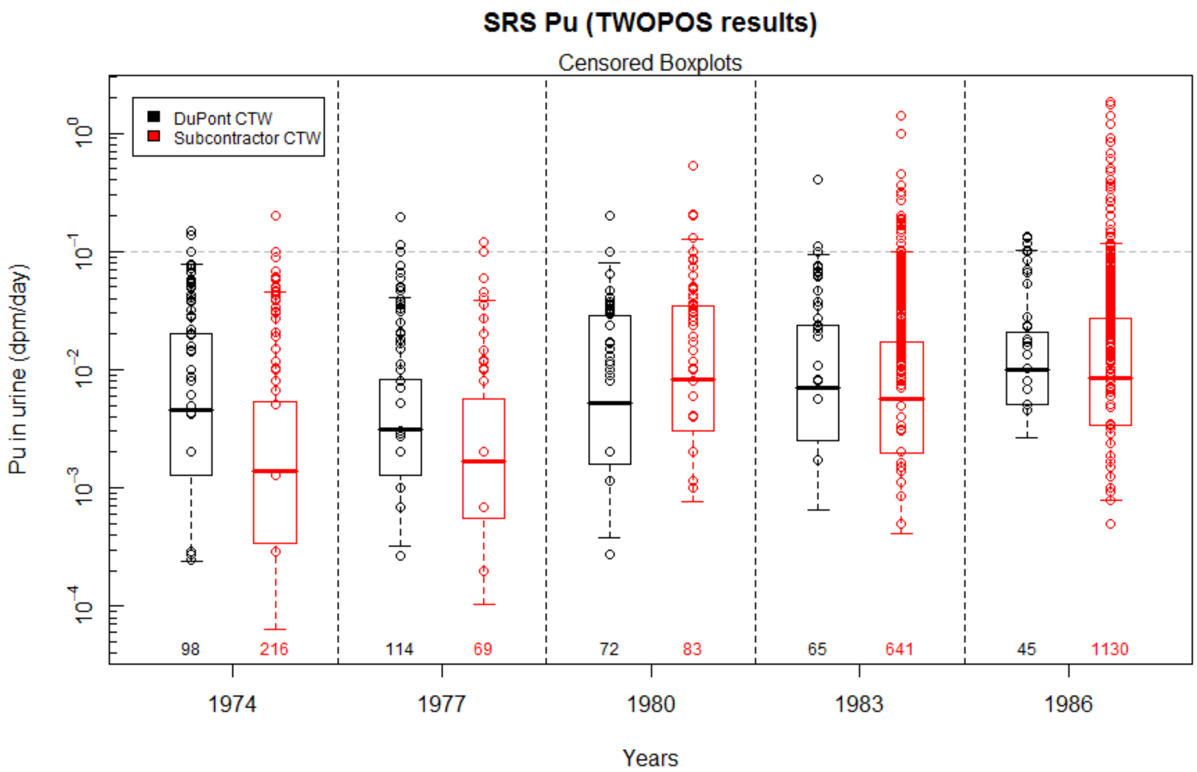

Figure C3. Censored data box plots showing full data range, log scale.

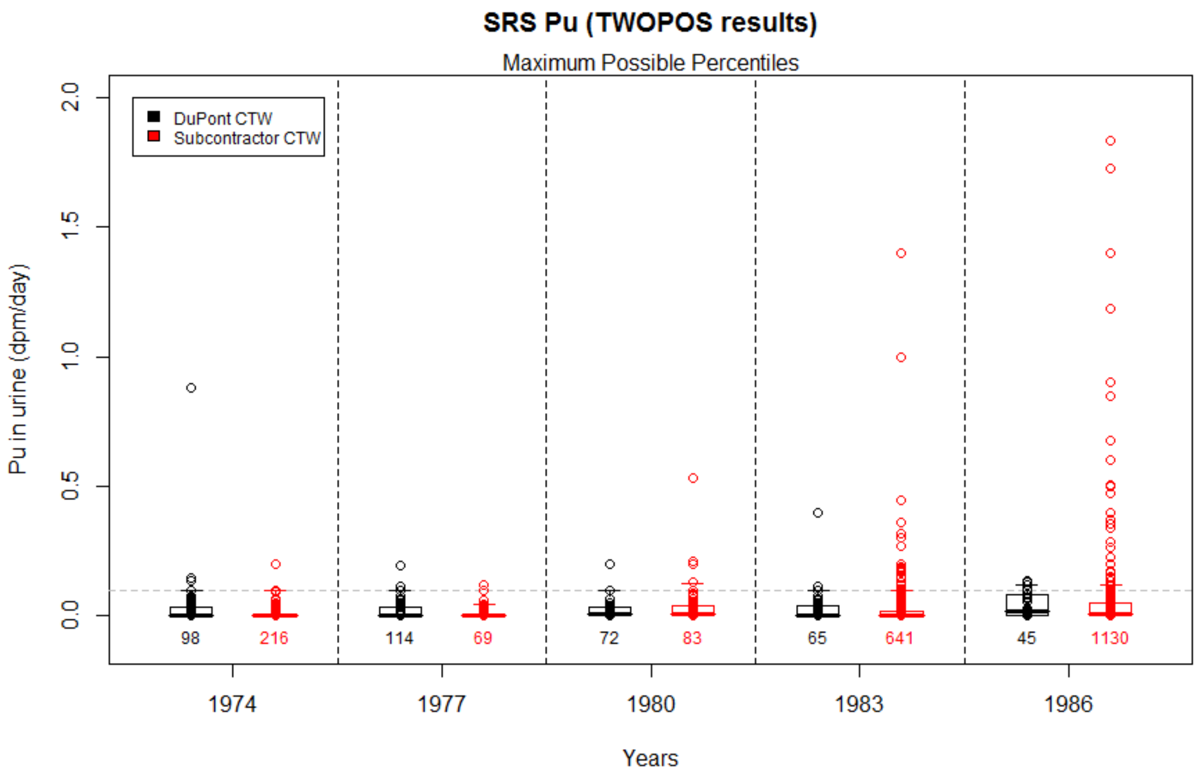

Figure C4. Maximum possible percentile data box plots showing full data range.

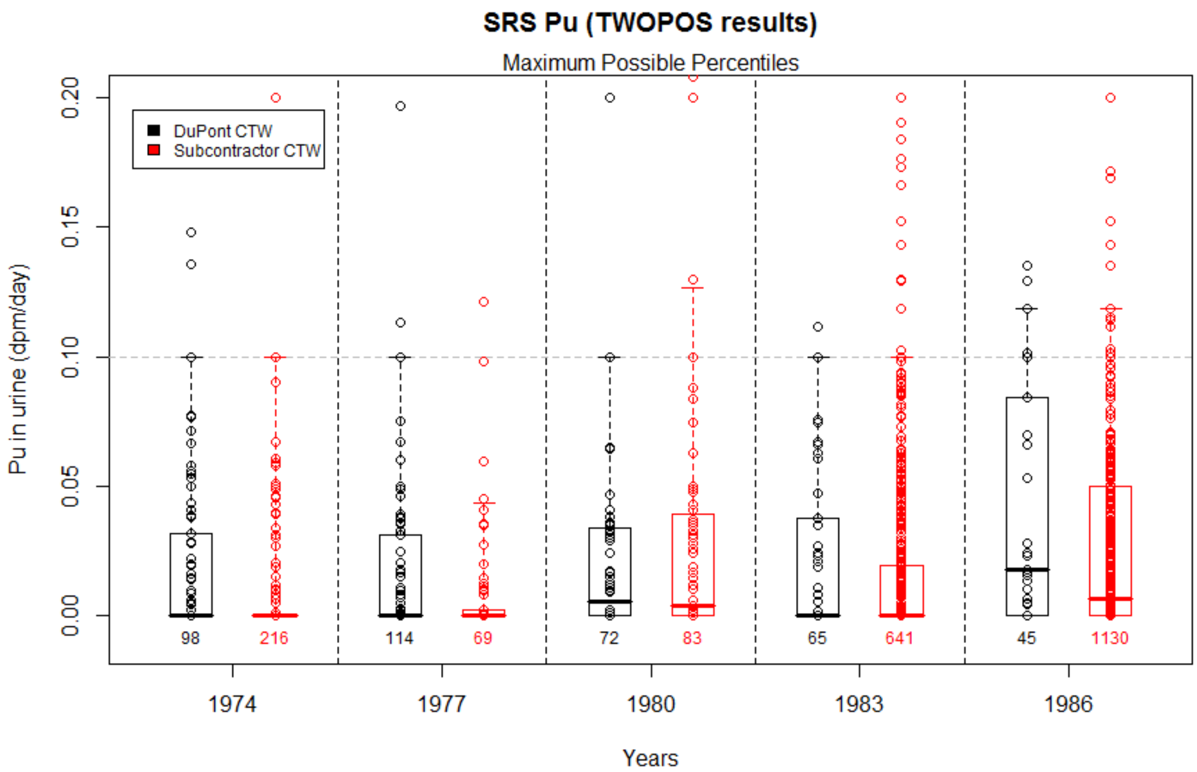

Figure C5. Maximum possible percentile data box plots zoomed in.

ATTACHMENT D: INTAKE MODELING PLOTS

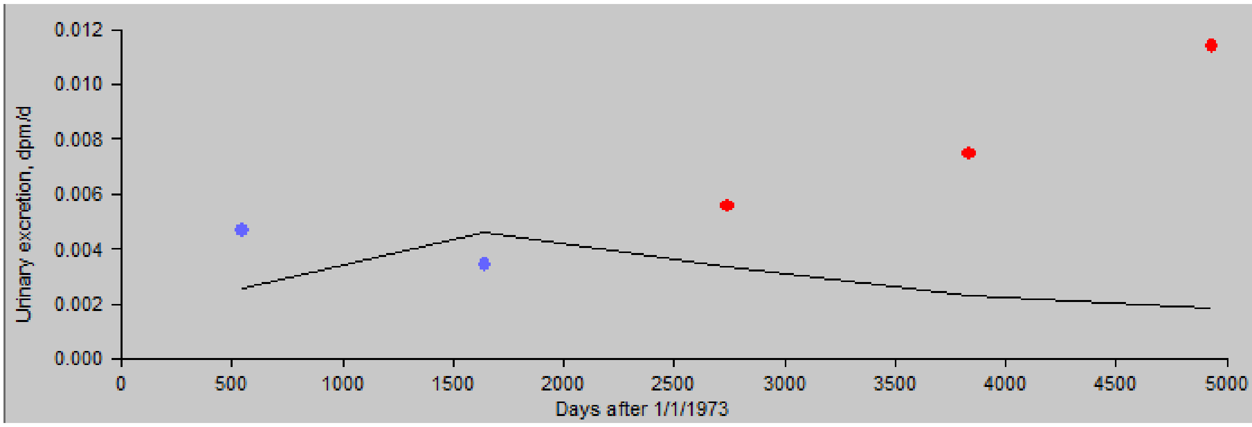

Figure D1. DuPont CTW predicted plutonium bioassay results calculated using IMBA-derived plutonium intake rates (line) compared with measured bioassay results (dots), 50th percentile, 1973 to 1978, type M.

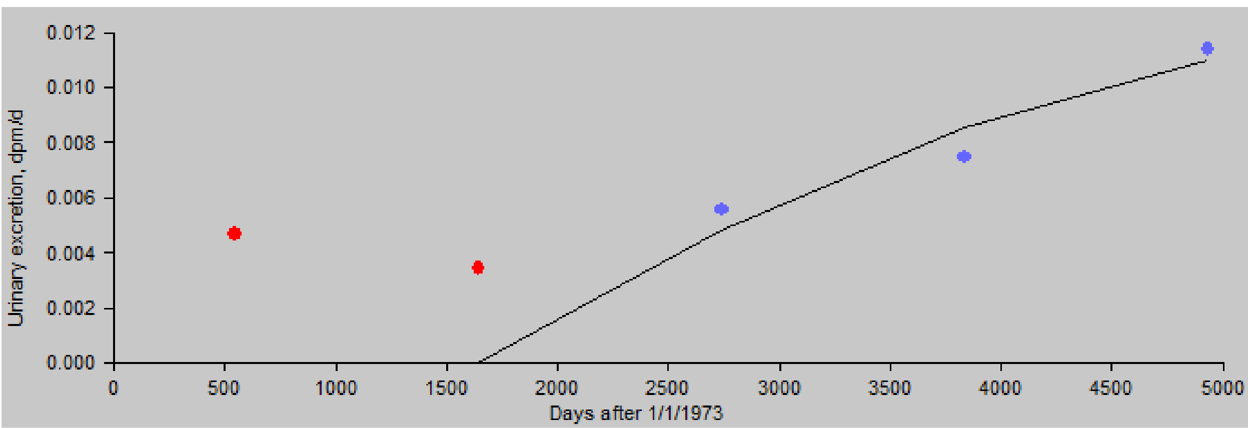

Figure D2. DuPont CTW predicted plutonium bioassay results calculated using IMBA-derived plutonium intake rates (line) compared with measured bioassay results (dots), 50th percentile, 1979 to 1987, type M.

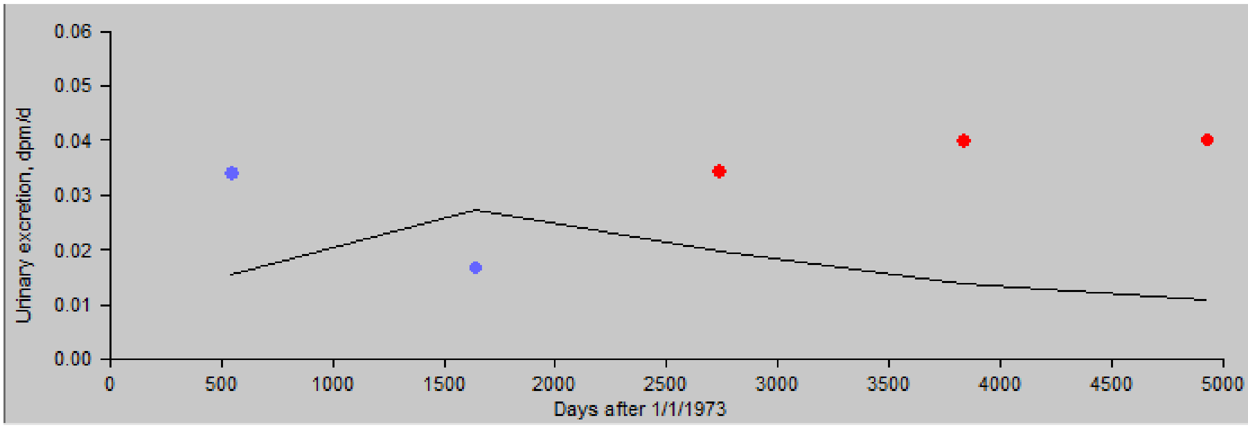

Figure D3. DuPont CTW predicted plutonium bioassay results calculated using IMBA-derived plutonium intake rates (line) compared with measured bioassay results (dots), 84th percentile, 1973 to 1978, type M.

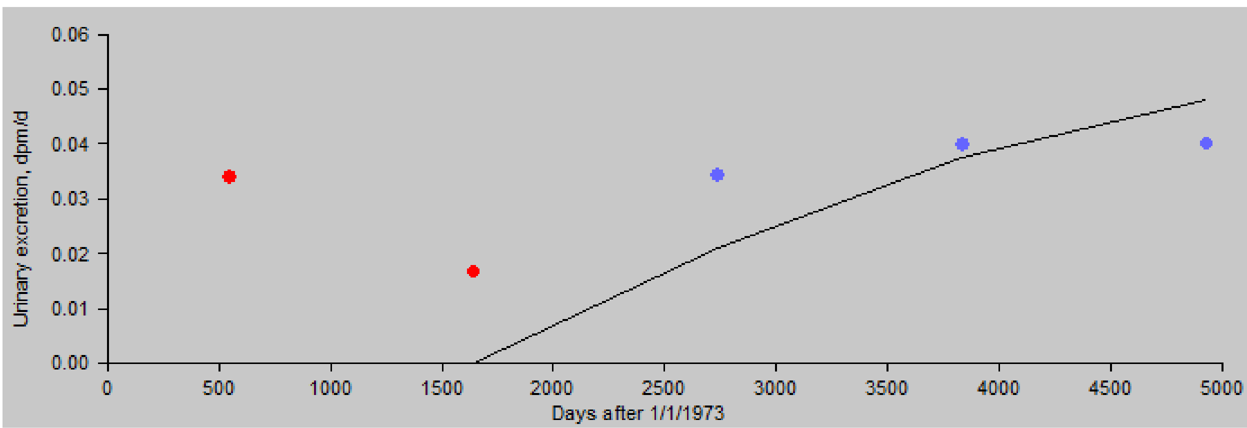

Figure D4. DuPont CTW predicted plutonium bioassay results calculated using IMBA-derived plutonium intake rates (line) compared with measured bioassay results (dots), 84th percentile, 1979 to 1987, type M.

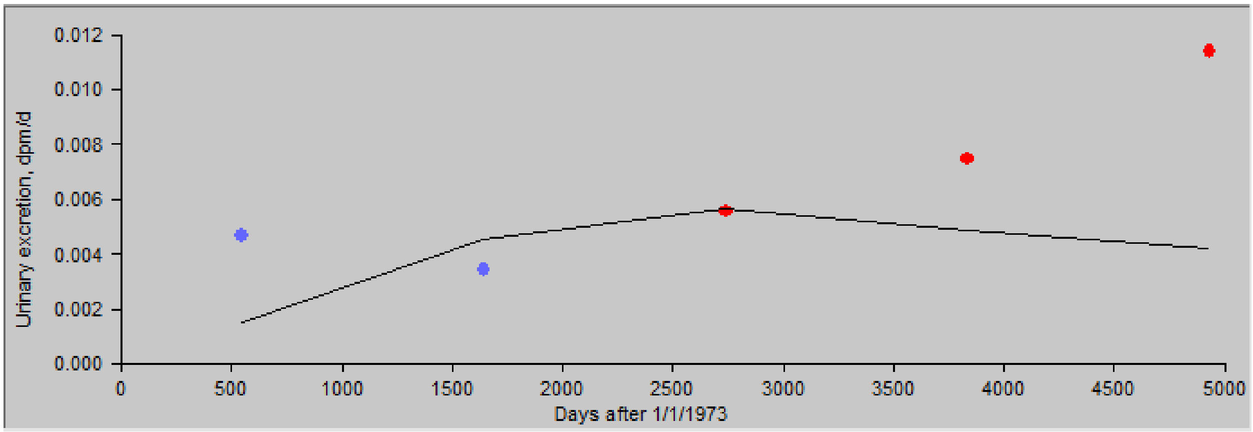

Figure D5. DuPont CTW predicted plutonium bioassay results calculated using IMBA-derived plutonium intake rates (line) compared with measured bioassay results (dots), 50th percentile, 1973 to 1978, type S.

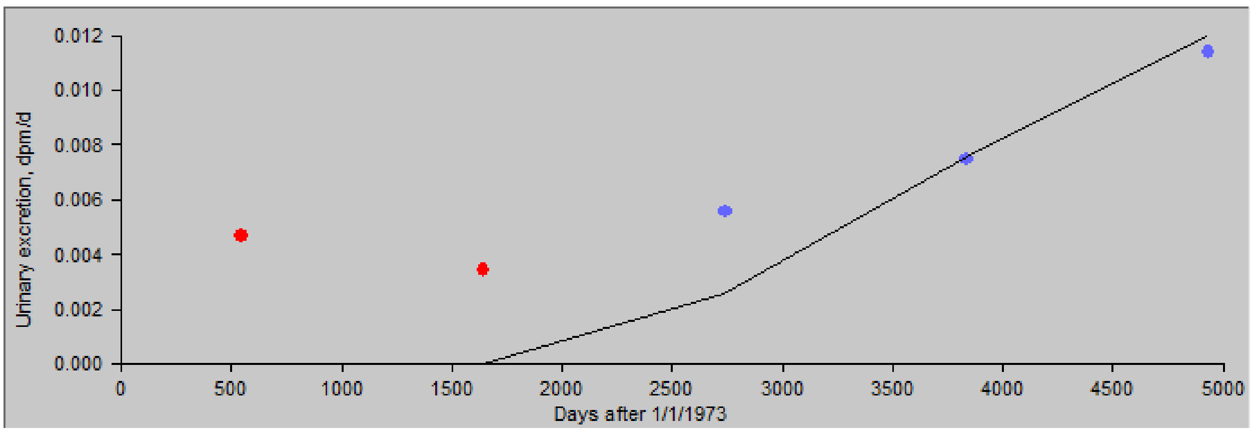

Figure D6. DuPont CTW predicted plutonium bioassay results calculated using IMBA-derived plutonium intake rates (line) compared with measured bioassay results (dots), 50th percentile, 1979 to 1987, type S.

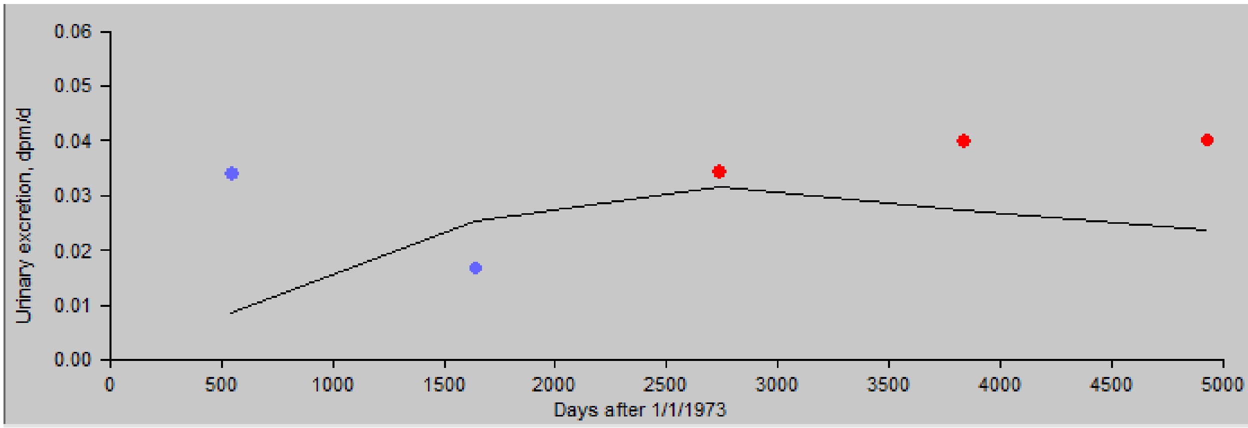

Figure D7. DuPont CTW predicted plutonium bioassay results calculated using IMBA-derived plutonium intake rates (line) compared with measured bioassay results (dots), 84th percentile, 1973 to 1978, type S.

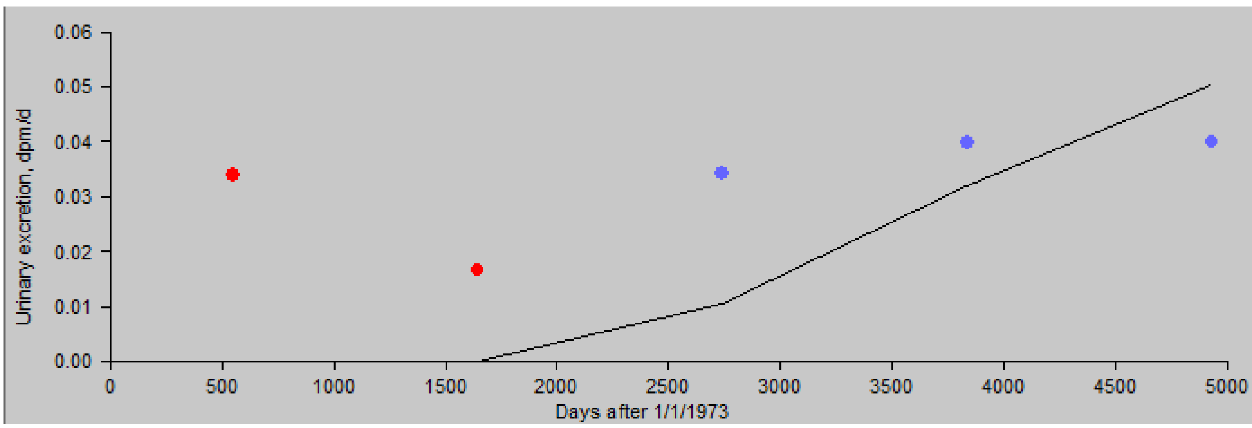

Figure D8. DuPont CTW predicted plutonium bioassay results calculated using IMBA-derived plutonium intake rates (line) compared with measured bioassay results (dots), 84th percentile, 1979 to 1987, type S.

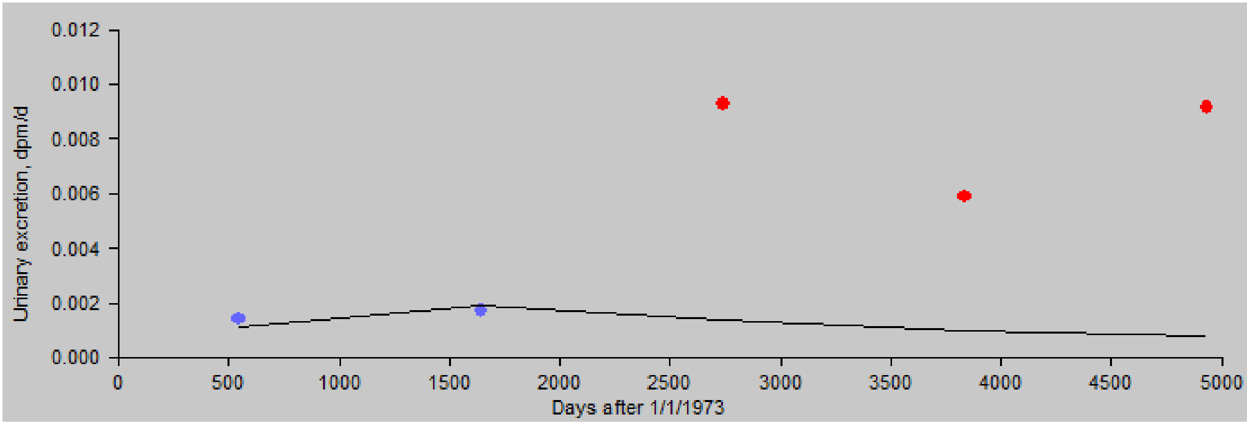

Figure D9. Subcontractor CTW predicted plutonium bioassay results calculated using IMBA-derived plutonium intake rates (line) compared with measured bioassay results (dots), 50th percentile, 1973 to 1978, type M.

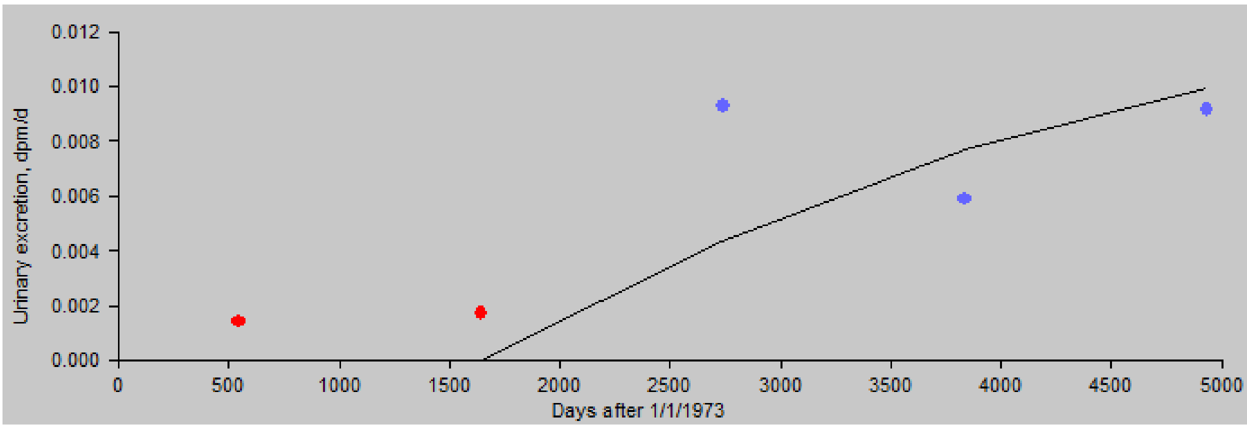

Figure D10. Subcontractor CTW predicted plutonium bioassay results calculated using IMBA-derived plutonium intake rates (line) compared with measured bioassay results (dots), 50th percentile, 1979 to 1987, type M.

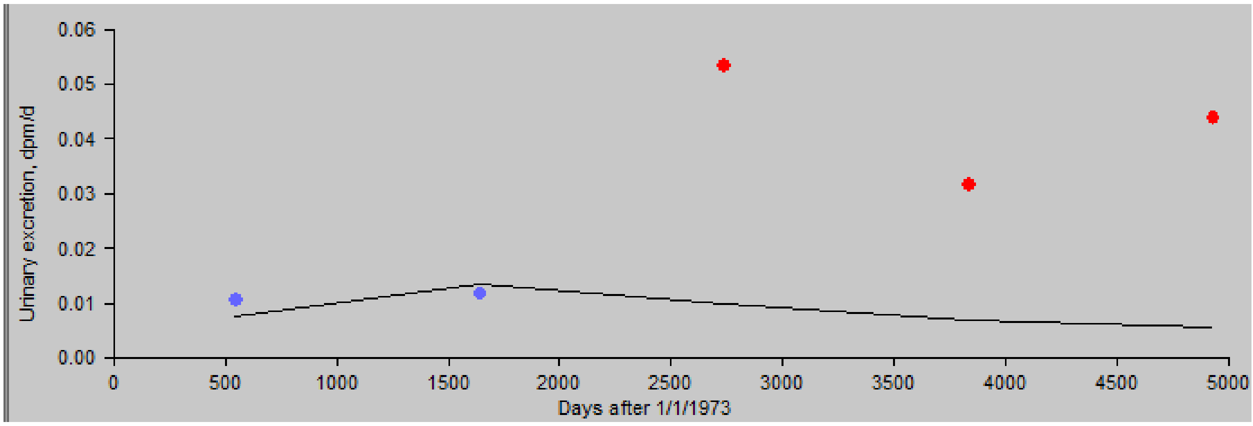

Figure D11. Subcontractor CTW predicted plutonium bioassay results calculated using IMBA-derived plutonium intake rates (line) compared with measured bioassay results (dots), 84th percentile, 1973 to 1978, type M.

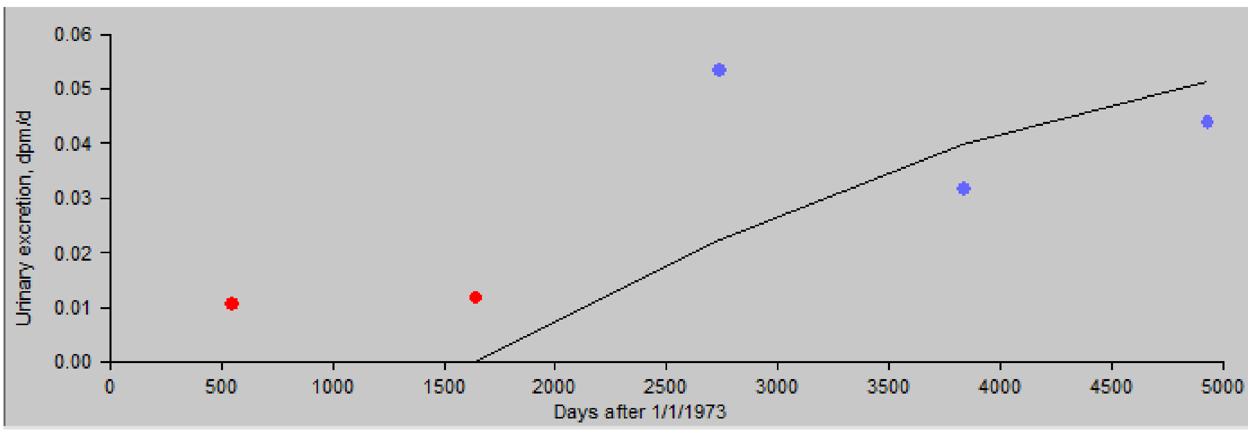

Figure D12. Subcontractor CTW predicted plutonium bioassay results calculated using IMBA-derived plutonium intake rates (line) compared with measured bioassay results (dots), 84th percentile, 1979 to 1987, type M.

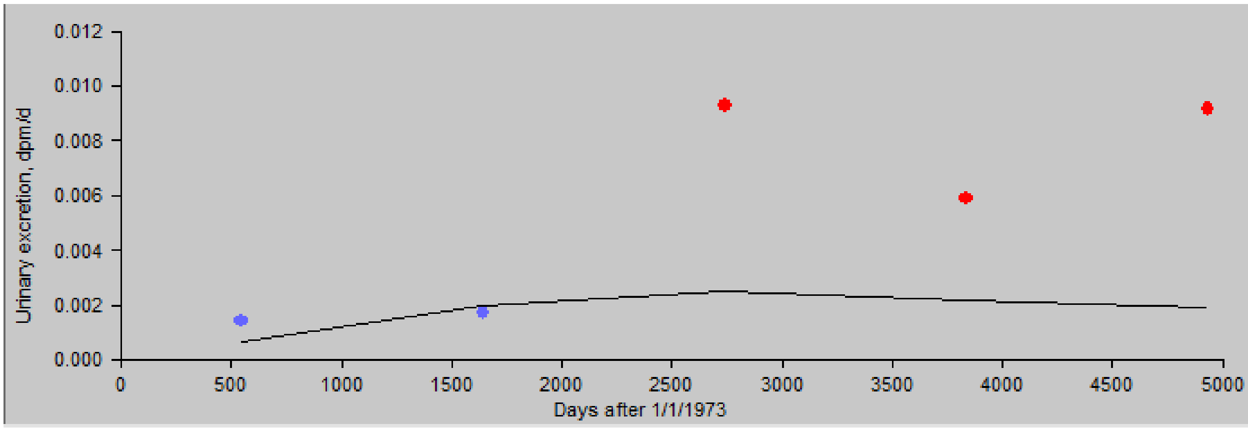

Figure D13. Subcontractor CTW predicted plutonium bioassay results calculated using IMBA-derived plutonium intake rates (line) compared with measured bioassay results (dots), 50th percentile, 1973 to 1978, type S.

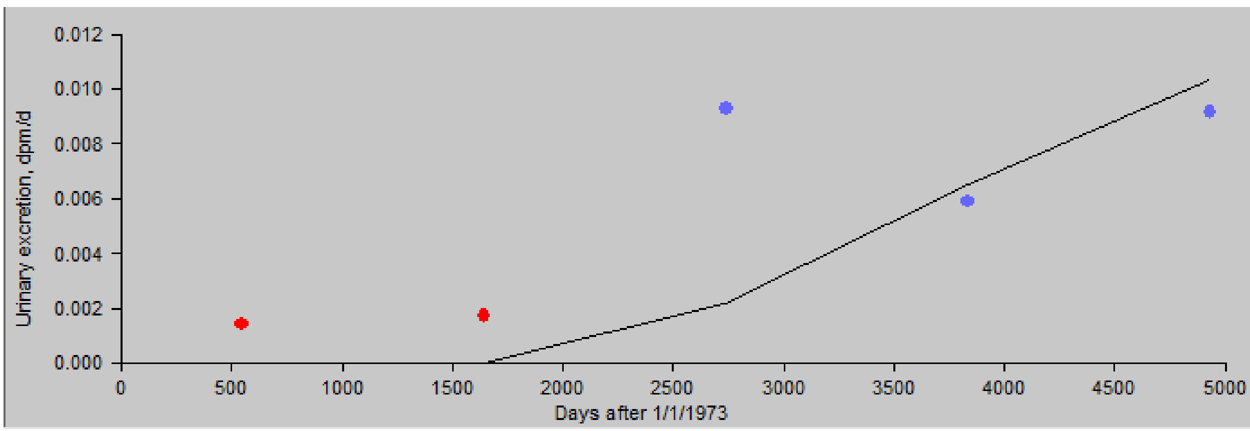

Figure D14. Subcontractor CTW predicted plutonium bioassay results calculated using IMBA-derived plutonium intake rates (line) compared with measured bioassay results (dots), 50th percentile, 1979 to 1987, type S.

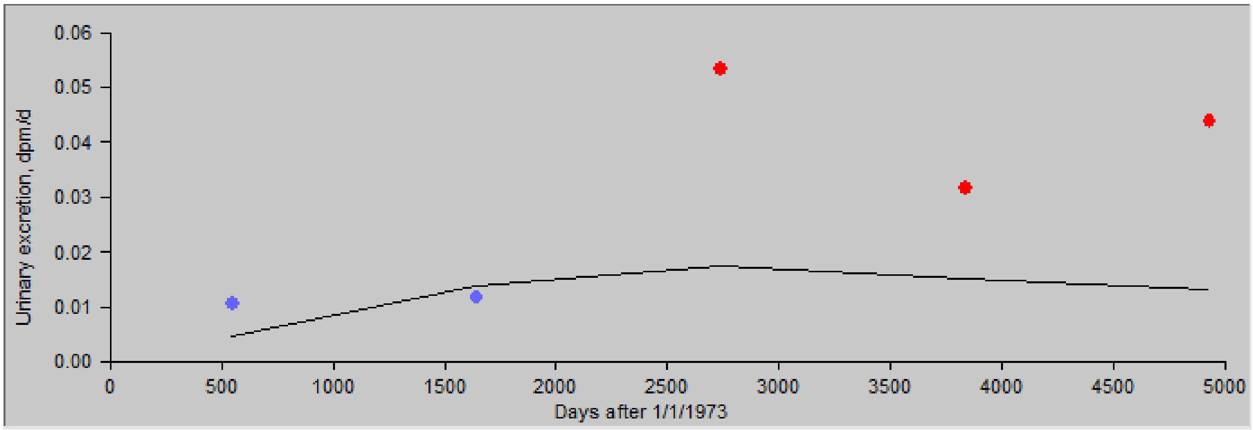

Figure D15. Subcontractor CTW predicted plutonium bioassay results calculated using IMBA-derived plutonium intake rates (line) compared with measured bioassay results (dots), 84th percentile, 1973 to 1978, type S.

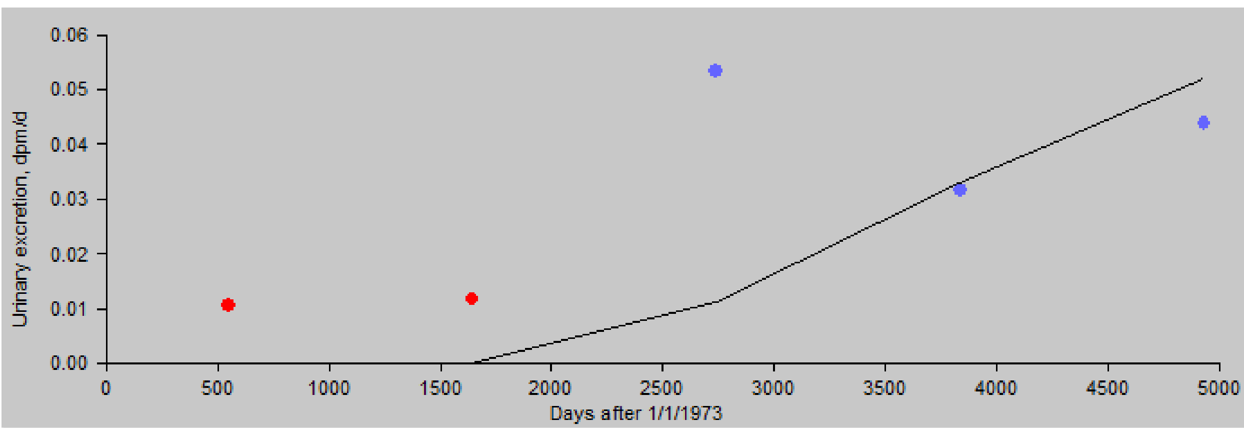

Figure D16. Subcontractor CTW predicted plutonium bioassay results calculated using IMBA-derived plutonium intake rates (line) compared with measured bioassay results (dots), 84th percentile, 1979 to 1987, type S.