Analysis of Subcontractor CTW Data at SRS 1991 to 2007

White Paper

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INTRODUCTION

For co-exposure (CX) modeling, if a significant portion of the most highly exposed workers are a part of the CX dataset, a bounding model could be constructed. SC&A continues to assert that subcontractor construction trade workers (subCTWs) at the Savannah River Site (SRS) were some of the most highly exposed workers and were monitored via job-specific sampling (NIOSH 2017, PDF pp. 262, 267–268; NIOSH 2023, PDF pp. 111–113, 122). The 1997 Notice of Violation (NOV) [Brush 1998] concerns a portion of job-specific samples that were not collected. Therefore, SC&A concludes that samples from the most highly exposed workers were not adequately collected.

During the March 2023 meeting of the SRS Work Group, Dr. James Lockey suggested an exercise to determine the validity of the assertion that subCTWs were some of the most highly exposed workers at SRS [NIOSH 2023]. During the course of the meeting, Dr. Lockey refined his vision of the exercise to be conducted, and those portions of the transcript are included in this White Paper as Attachment A. Essentially, the request was to compare bioassay data from subCTWs to bioassay data from all workers to determine whether the subCTW exposures tend to fall into the upper end of the results for all workers. This White Paper addresses that request, with two clarifications:

1. Evaluation of External Dosimetry Data in Addition to Bioassay Data: In all of the quotes in Attachment A, Dr. Lockey mentions bioassay data. The electronic data available for 1991 to 2007 also include external dosimetry data, so those data were analyzed as well.

2. Comparison of subCTWs to All Other Workers: Dr. Lockey describes comparing subCTWs to the “overall cohort” and the “whole population.” Instead of comparing part-to-whole (subCTWs to all workers), this analysis will focus on comparing subCTWs to all other workers. This approach ensures that the two groups being compared are mutually exclusive and exhaustive, which is how CX modeling is typically done. The following discussion will therefore compare "subCTW” to “Other Worker” results.

DATA SOURCES

Table 1 presents the datasets used in this analysis. All datasets are text files from Data Warehouse, provided by SRS in April 2023 [SRS 2022]. Throughout the data tables that follow, relevant field names and values from the data file are presented in all capital letters and are defined in footnotes where appropriate. Definitions were generally derived from the data dictionary [SRS 2022] and subsequent clarification provided by SRS [Brown 2023].

Table 1: Summary of Datasets Used in Analysis.

File ID	Contents	Years	Rows	Notes
IND	Personnel data – including name, social security (SSN) and employee ID numbers, employer name, job title	Not Applicable	165,022	176 rows had a non-numeric value in the SSN field[a]
EDL	External legacy data – dosimetry results	1973–2003	2,071,482	One row (for a temporary TLD[b]) had no match in IND file
EDC	Current external data – dosimetry results	2004–2023	744,409	Partial year 2023, 16 results (for 11 workers) had no match in IND file (only 1 of which was in the period of interest)
TL	Tritium legacy data – bioassay results	1989–2003	857,050	None
NTL	Non-tritium legacy data[1] – bioassay results	1990–2004	434,061	Partial years 1990 and 2004
IVC	Current tritium and non-tritium data – bioassay results	2003–2023	332,390	Partial years 2003 and 2023

a. 130 of the 176 records with non-numeric SSN have last name of DEACTIVATE.
b. TLD = thermoluminescent dosimeter.

DEFINITION OF SUBCTW

To evaluate the data for this White Paper, each row of the dosimetry files (EDL, EDC, TL, NTL, and IVC) was designated as either "subCTW" or "Other" based on information from the IND

[1] According to the data dictionary, "If the analyte is not detected, the negative of the DETECT value is shown in the 'RESULT' column. If the analyte is detected, the activity value is shown in the 'RESULT' column" [SRS 2022]. In other words, if the "RESULT" column is positive, the result is used as-is. If the "RESULT" column is negative, it is used as a censored value, unless the "SAMPLE ACTIVITY" is populated. If the "SAMPLE ACTIVITY" column is populated, the sample activity is used. The sample activity column started being populated in 1994.

(personnel data) file, using the definition in Attachment B. Typically, rows in the dosimetry files were matched to the IND file using the SSN field. However, rows in the EDC file were matched to the IND file using the CMP_ALT_ID field (a unique employee number) because SSNs were not used in the EDC file. Figures 1 through 22 present the data using this definition.

In *SC&A Evaluation of Feasibility and Utility of Subcontractor Exposure Potential Comparison* [SC&A 2023], SC&A uses a different definition of "subcontractor" versus "prime contractor" [SC&A 2024]. A summary of the SC&A definition and analogous plots using their definition are provided in Attachment C (Figures C-1 through C-22).

DATA ANALYSIS

There are many possible ways to compare subCTW data to other workers' data. Formal statistical testing could be done, but visual inspection (i.e., plots) often eliminates the need for more formal methods. However, there are characteristics of these dosimetry files that complicate plotting (and testing), such as censored results (e.g., values reported as equal to or less than a detection limit, reporting limit, or other censoring value), results of zero, many results concentrated near zero, etc. These characteristics influence the type of plot that would be most effective for analyzing the results.

Typically for CX, probability plots are considered, but those analyses assume either normality or lognormality. Therefore, to avoid making distributional assumptions and to visualize all dosimetry data, scatterplots were created for each analysis. In the scatterplots, data are presented by year; the red points (presented on the left for each year) correspond to data from subCTWs, while black points (presented on the right for each year) are from all other workers. If the red points tend to be higher than the black points for a year, the results for subCTWs tend to be higher than other workers. Note that if a plot has a horizontal dashed line at some y-value, the next plot is zoomed in to that value on the y-axis, so more detail is visible. The numbers at the top of each plot are the number of results for that group for that year.

To conduct this analysis, some preparation or "cleaning" of the files was necessary. Only data from 1991 to 2007 were analyzed, because those years are the remainder of the SEC petition period. Records for all other years were therefore excluded. The sections below identify the specific steps taken to clean the dataset. Some data preparation decisions in the following sections were made for simplification and would be handled more rigorously for actual CX models, but the decisions do not affect the conclusions of the plots.

Supporting files for the analysis described in the following sections are provided in ORAUT 2024.

External Dose

Tables 2 and 3 describe the cleaning of the external dose files, providing the legacy results (EDL) and current results (EDC), respectively.

Table 2: Summary of Steps Taken to Clean the EDL file.

#	Description	Number of Rows Remaining
1	Begin with total rows in EDL file (1971–2003)	2,071,481
2	Keep 1991–2003	1,123,595
3	Remove[a] RCD_TYP_CD of HPRH, PTD, RMVE, RMVQ, RMVR, or RMVS[b]	1,123,054
4	Remove rows where DDE_WB_QYis NA[c]	1,061,076

a. Removal of records with these codes was directed by Brown 2023 (PDF p. 4).
b. RCD_TYP_CD = record type code. HPRH = Health Protection Annual Radiation Exposure History database (HPAREH); PTD = Plant to Date; RMVE = removal of external doses; RMVQ = removal of quarterly doses; RMVR = removal of routine doses; RMVS = removal of supplemental doses [SRS 2022].
c. DDE_WB_QY = deep dose equivalent whole body quantity.

Table 3: Summary of Steps Taken to Clean the EDC file.

#	Description	Number of Rows Remaining
1	Begin with Total Rows in EDC file	744,393
2	Keep 2004–2007	156,438
3	Keep GEN_BODY_LOC of WB[a] (i.e., remove extremity doses)	116,189

a. GEN_BODY_LOC = General body location; WB = whole body.

The two clean files yield 1,177,265 usable rows of external dose data in the period of interest. Figures 1 and 2 show the deep dose cycle data. Note that cycle data in 1991 and 1992 were rounded to the nearest 5 millirem (mrem), and the limit of detection from 1991 to 2003 was 5 mrem. For that reason, the zoomed plot presents the data for those years in discrete bands at the rounded values (Figure 2).

Figures 3 and 4 are plots of the workers' annual doses, summing all cycle doses for a worker in a year, resulting in 198,631 annual doses.

Based on Figures 1 through 4, the subCTW dose data look similar to the "Other" worker group dose data for each year. The subCTW data do not tend to be higher than the other workers.

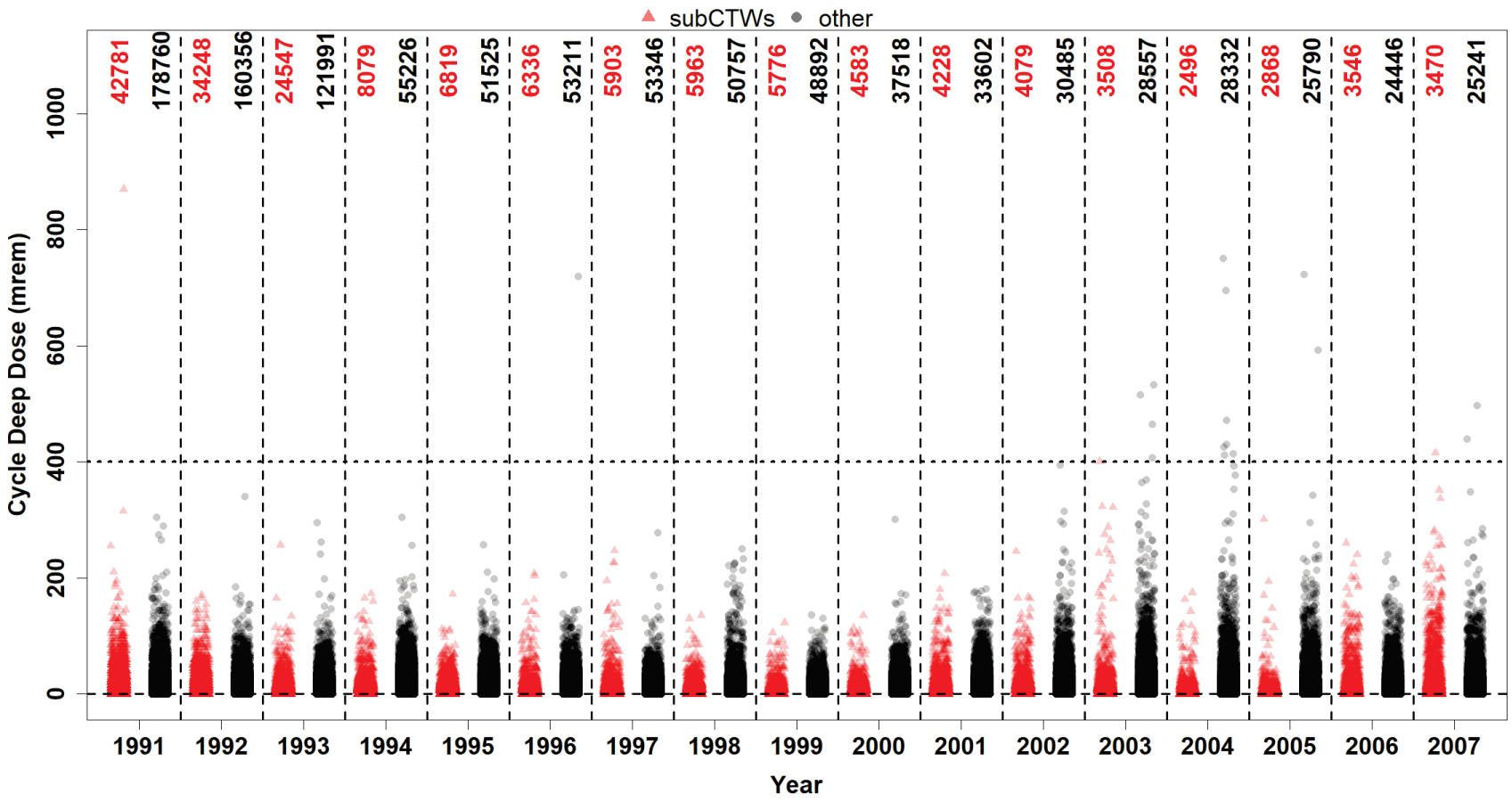

Figure 1: Scatterplot of subCTW (red, left) and Other Worker (black, right) Deep Dose Cycle Data.

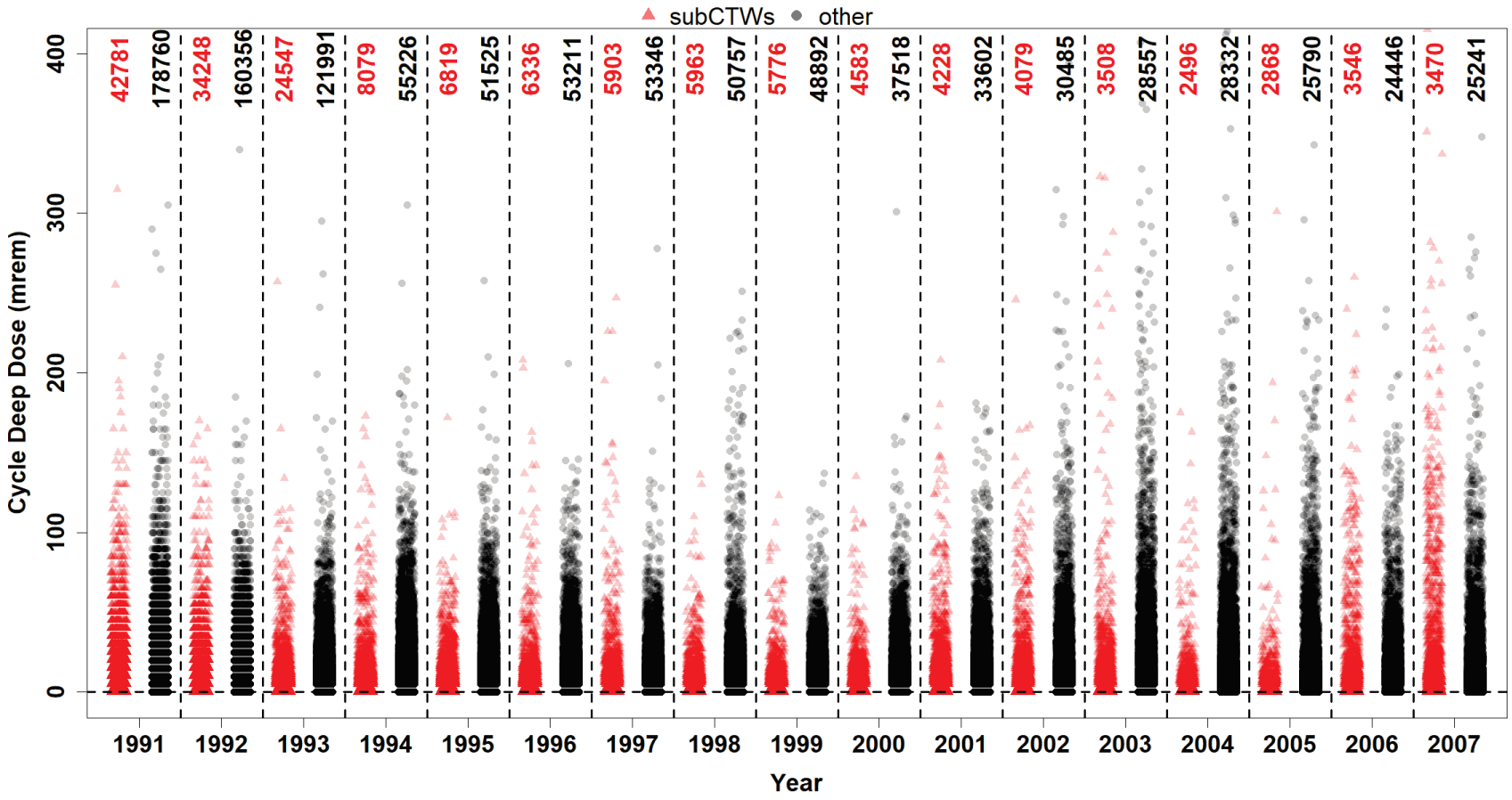

Figure 2: Scatterplot of subCTW (red, left) and Other Worker (black, right) Deep Dose Cycle Data with a Zoomed Y-Axis.

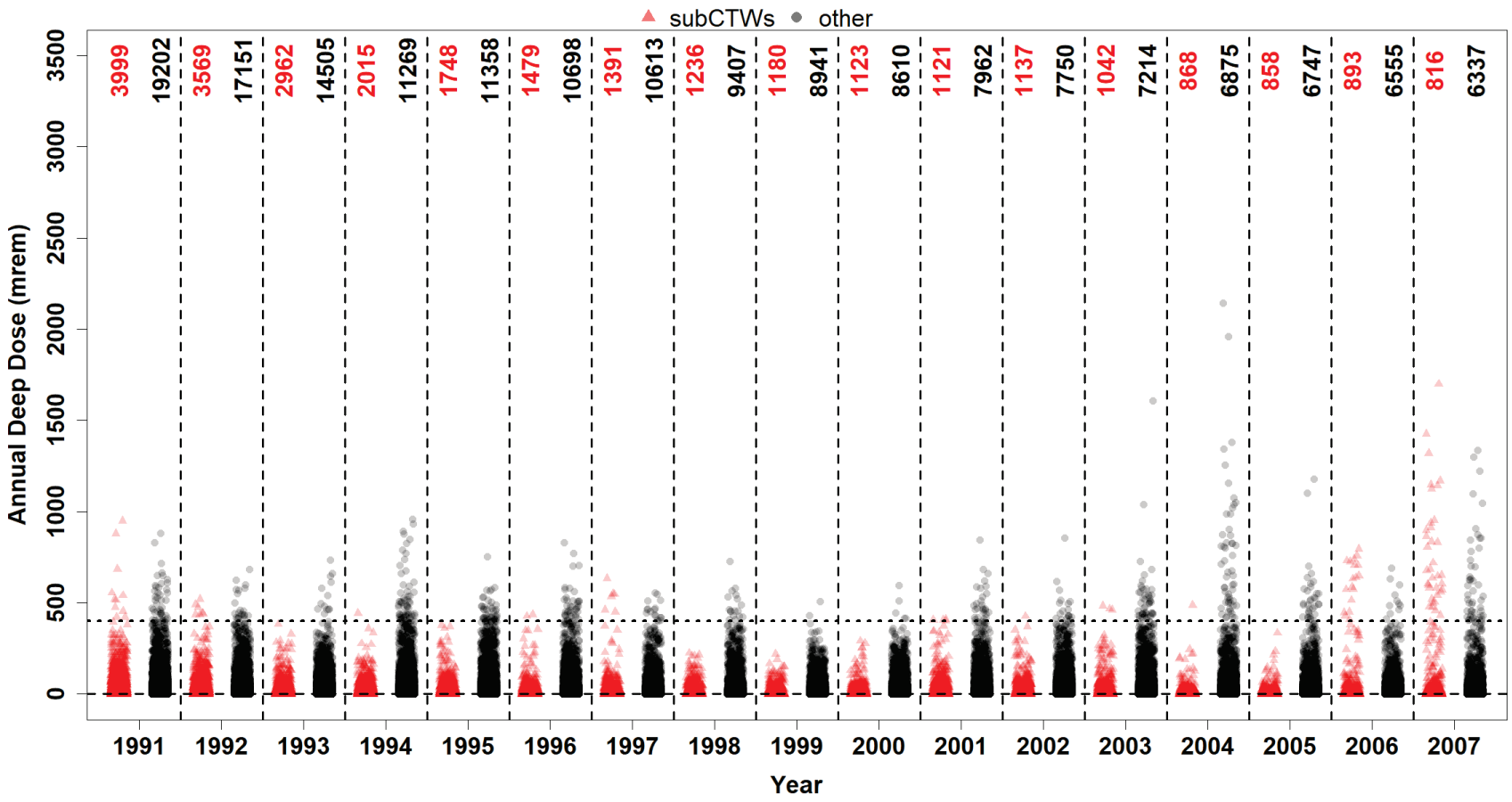

Figure 3: Scatterplot of subCTW (red, left) and Other Worker (black, right) Annual Deep Doses.

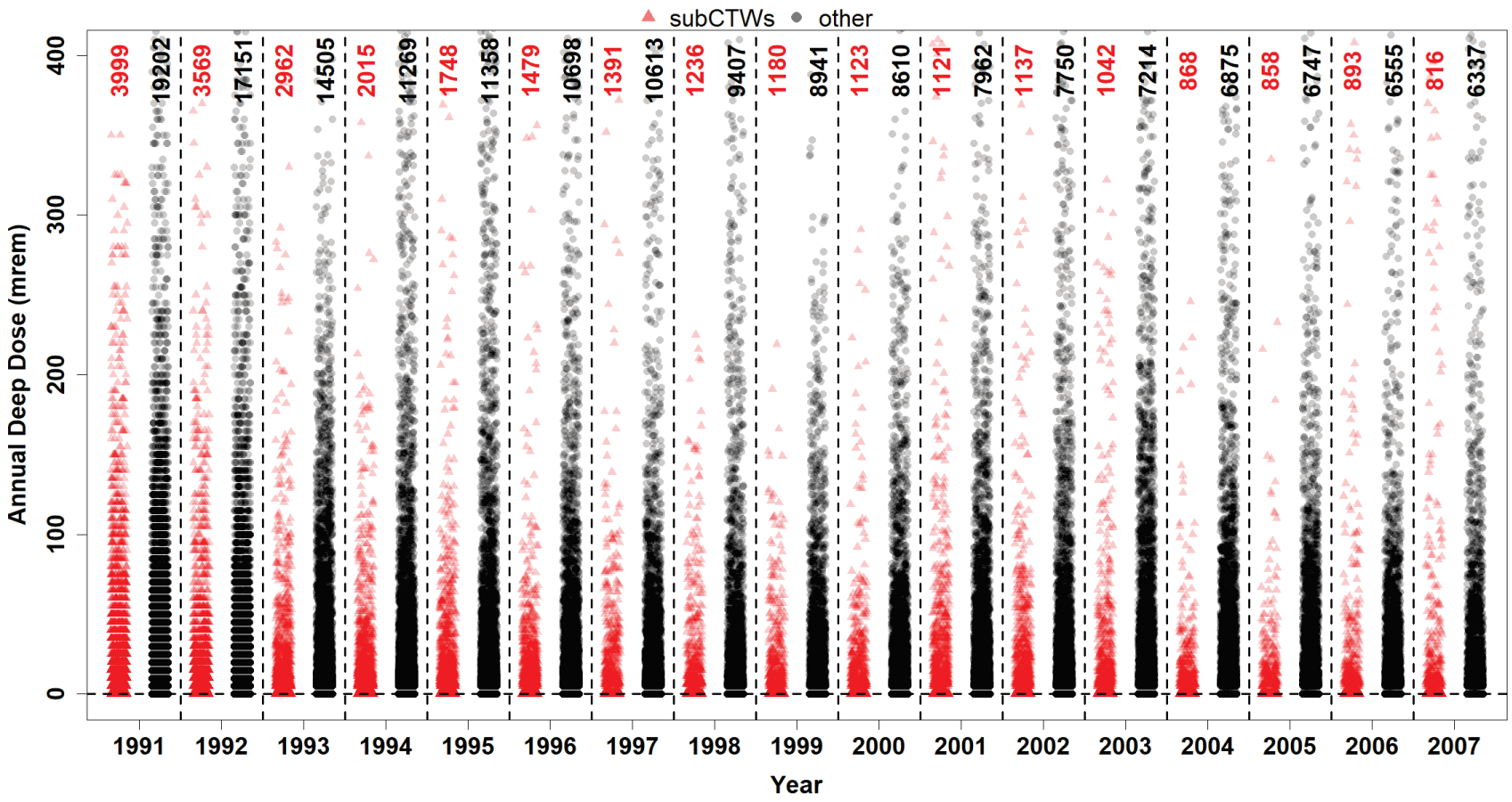

Figure 4: Scatterplot of subCTW (red, left) and Other Worker (black, right) Annual Deep Doses with a Zoomed Y-Axis.

Tritium

Tables 4 (Tritium Legacy, TL) and 5 (Current tritium and non-tritium, IVC) describe the cleaning of the tritium data files.

Table 4: Summary of Steps Taken to Clean the TL file.

#	Description	Number of Rows Remaining
1	Begin with total rows in TL file	857,050
2	Remove if LLD_IND is X[a]	857,025
3	Keep 1991–2003	559,947

a. LLD_IND = lower limit of detection indicator. The data dictionary [SRS 2022] only mentions "<" results, so values of "X" were removed.

Table 5: Summary of Steps Taken to Clean the IVC file for Tritium.

#	Description	Number of Rows Remaining
1	Begin with total rows in IVC file	332,390
2	Keep if RSLT_ISOT_CD is H3[a]	69,462
3	Keep 2003–2007	22,259
4	Remove if RESULT STATUS is IA[b]	22,242

a. RSLT_ISOT_CD = Result Isotope Code; H3 = Tritium.
b. IA = inconclusive analysis.

The two clean files yield 582,189 usable rows of tritium bioassay data in the period of interest. The tritium bioassay plot (Figure 5) and zoomed plot (Figure 6) show the rounding differences between the two data storage systems used during that time. From 1991 to 2003, tritium results were rounded to one decimal place, whereas results from 2004 to 2007 include more digits. Consequently, the tritium results for 1991 to 2003 appear in fairly discrete increments, while the results after 2003 appear more continuous.

Figures 7 and 8 display tritium doses, calculated from the tritium bioassay data according to the methodology in *Technical Information Bulletin: Tritium Calculated and Missed Dose Estimates* ORAUT-OTIB-0011, rev. 00 [ORAUT 2004] and *OTIB-0011 Dose calculations in R* [ORAUT 2016]. There are 43,342 annual tritium doses calculated from the 582,189 usable tritium bioassay results.

Based on Figures 5 through 8, the tritium bioassay and dose data look similar for the subCTW group and the "Other" worker group for each year. The data for the subCTW do not tend to be higher than the data for other workers.

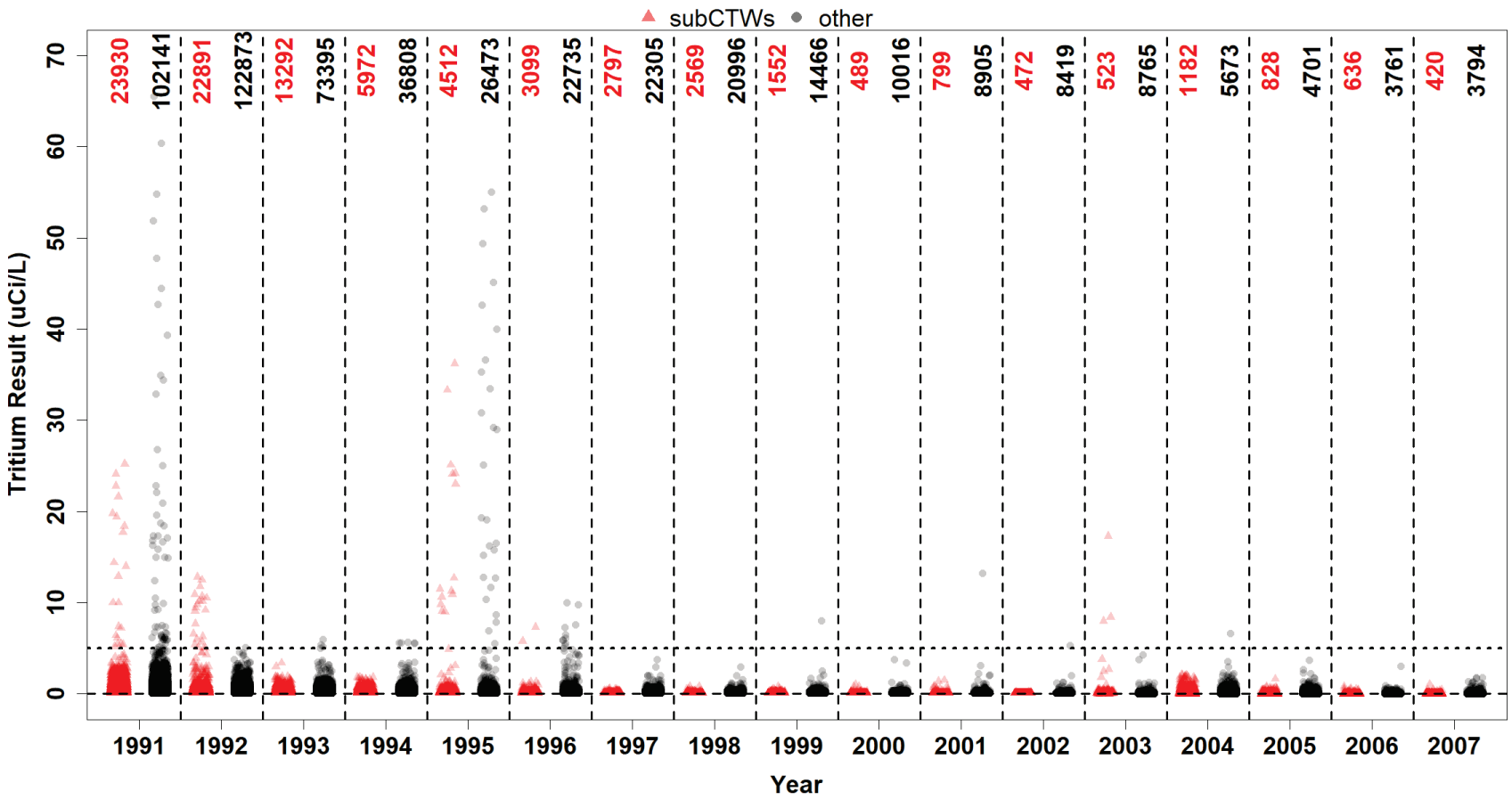

Figure 5: Scatterplot of subCTW (red, left) and Other Worker (black, right) Tritium Bioassay Data.

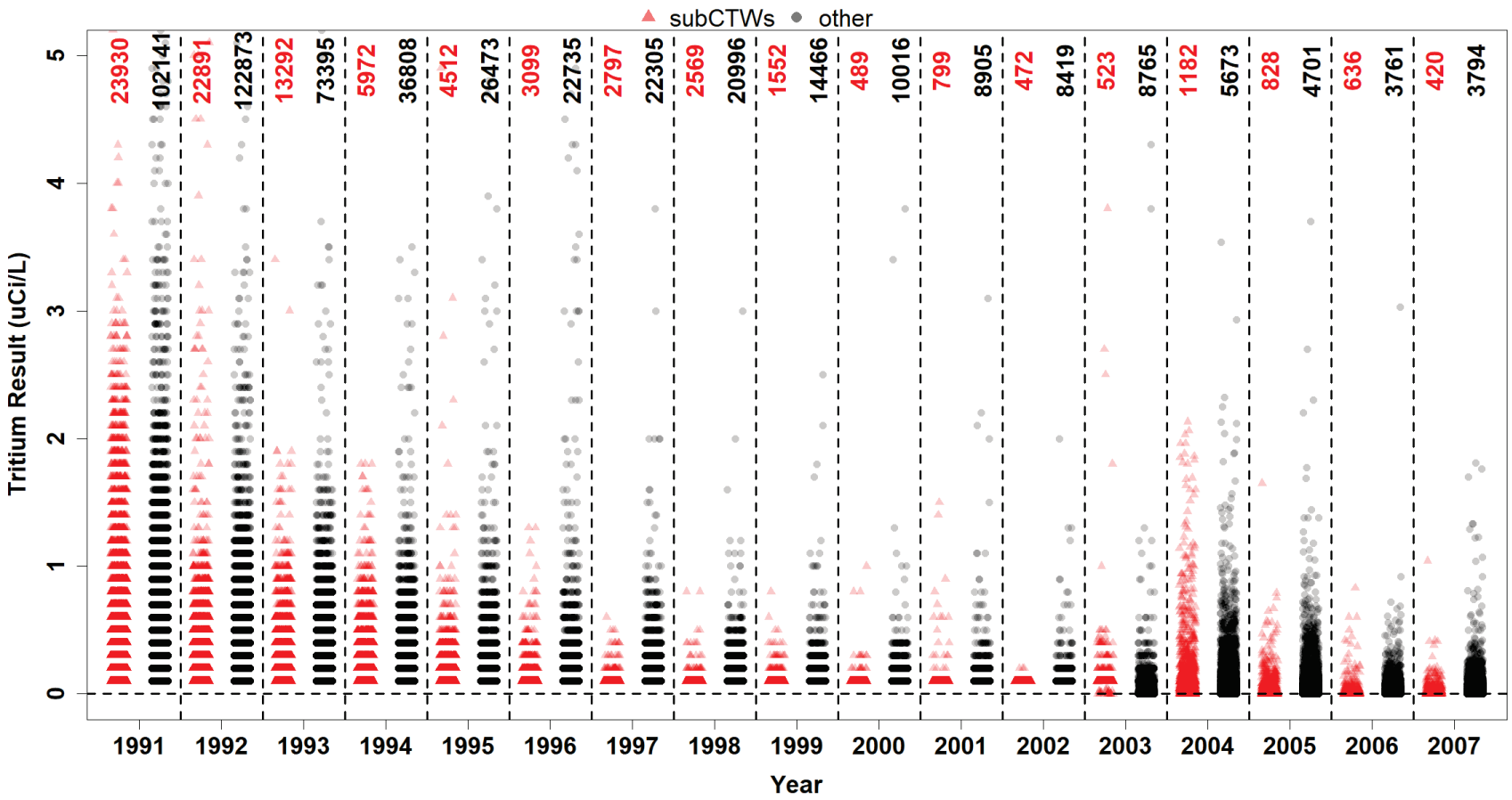

Figure 6: Scatterplot of subCTW (red, left) and Other Worker (black, right) Tritium Bioassay Data with a Zoomed Y-Axis.

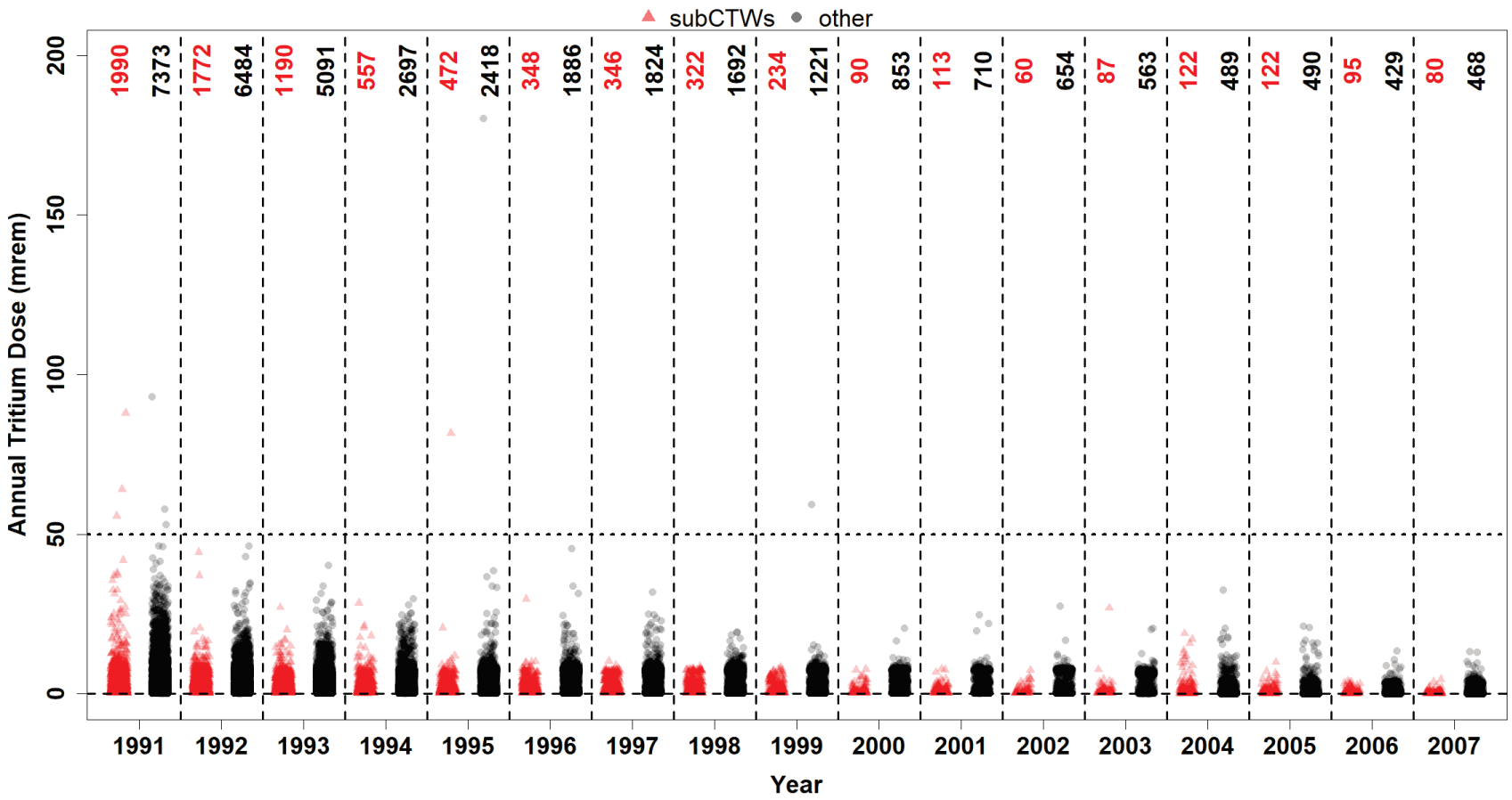

Figure 7: Scatterplot of subCTW (red, left) and Other Worker (black, right) Annual Tritium Doses.

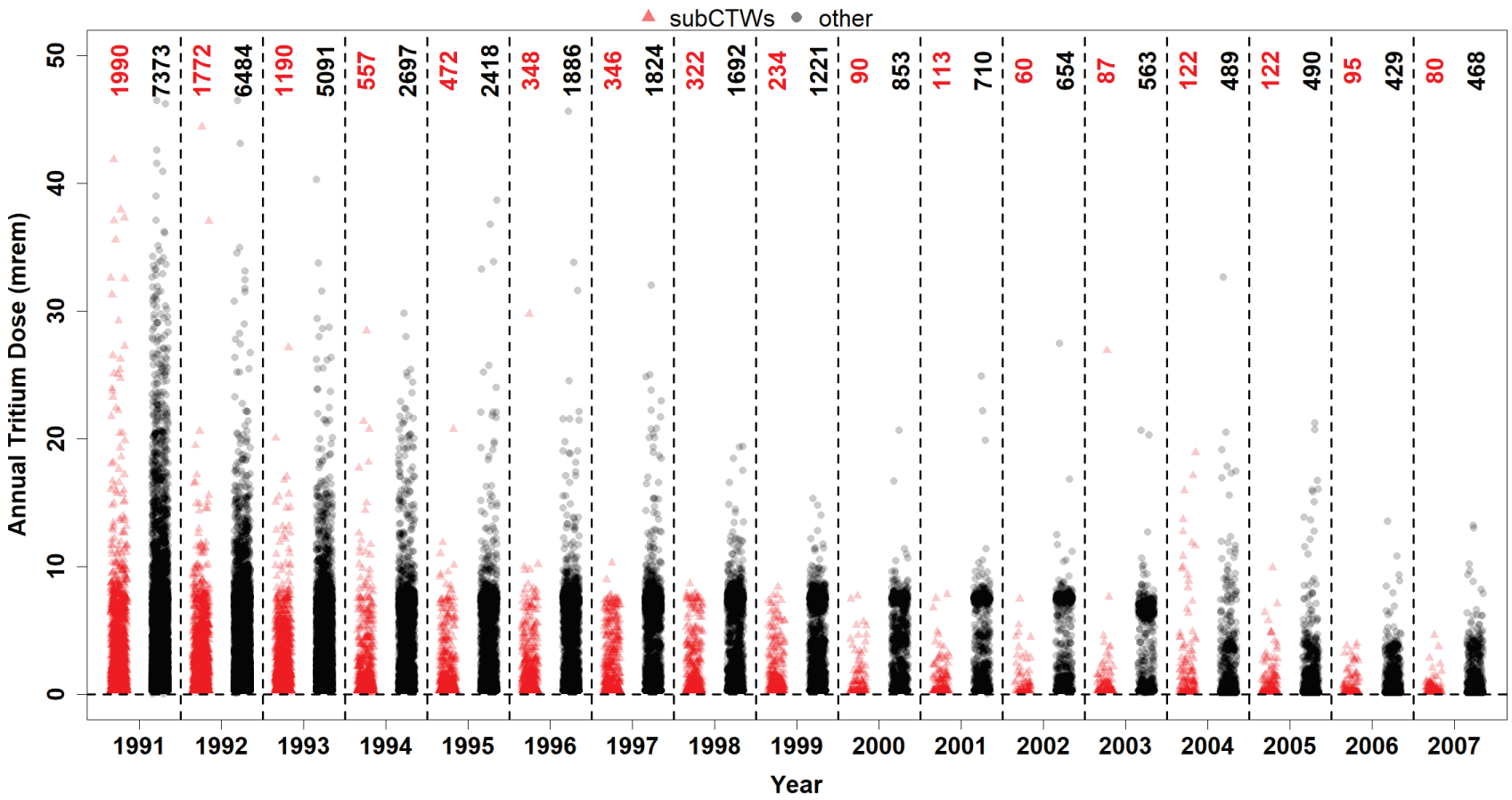

Figure 8: Scatterplot of subCTW (red, left) and Other Worker (black, right) Annual Tritium Doses with a Zoomed Y-Axis.

In the annual tritium dose plots, there are clumps of points near 10 mrem, most noticeably in the early 2000s. In the OTIB-0011 calculation, a worker who was monitored weekly with mostly censored results has an annual tritium dose between about 8 and 10 mrem. A worker who only has a single censored result in the year has an annual tritium dose of about 0.3 mrem, which is why there is another clump of results near zero in the early 2000s.

Plutonium-238

Tables 6 (NTL) and 7 (IVC) describe the cleaning of the data files for plutonium-238 (Pu-238).

Table 6: Summary of Steps Taken to Clean the NTL File for Plutonium-238.

#	Description	Number of Rows Remaining
1	Begin with Total Rows in NTL file	434,061
2	Keep if SAMP RESULT ISOTOPE is Pu-238	107,621
3	Keep 1991–2004	106,855
4	Remove records with inconsistent values of RESULT UNIT[a] (i.e., keep only results in that are dpm/L)	97,532
5	Remove if SAMP RESULT STAT is DL[b]	96,336

a. Removed: 1,234 rows of dpm/S (disintegrations per minute/sample); 8,080 rows of IA (inconclusive analysis); 7 rows of nCi/L (nanocurie per liter), 1 row of pCi/L (picocurie/L), 1 row of Split.
b. SAMP RESULT STAT = Sample result status. DL = deleted. According to SRS, these are bioassay results that were deleted [Brown 2023, PDF p. 4].

Table 7: Summary of Steps Taken to Clean the IVC File for Plutonium-238.

#	Description	Number of Rows Remaining
1	Begin with Total Rows in IVC file	332,390
2	Keep if RSLT_ISOT_CD[a] is PU-238	37,305
3	Keep 2003–2007	10,084
4	Remove if RESULT STATUS is IA[b]	10,063
5	Remove if RSLT_UN is dpm/sample[c]	10,028

a. RSLT_ISOT_CD = result isotope code.
b. IA = inconclusive analysis.
c. RSLT_UN = result unit.

The two clean files yield 106,364 usable Pu-238 results in the period of interest. Figures 9 and 10 are the full-scale and zoomed scatterplots of the Pu-238 bioassay data. Based on these figures, the Pu-238 bioassay data look similar for the subCTW group and the "Other" worker group for each year. The data for the subCTW do not tend to be higher than the data for other workers.

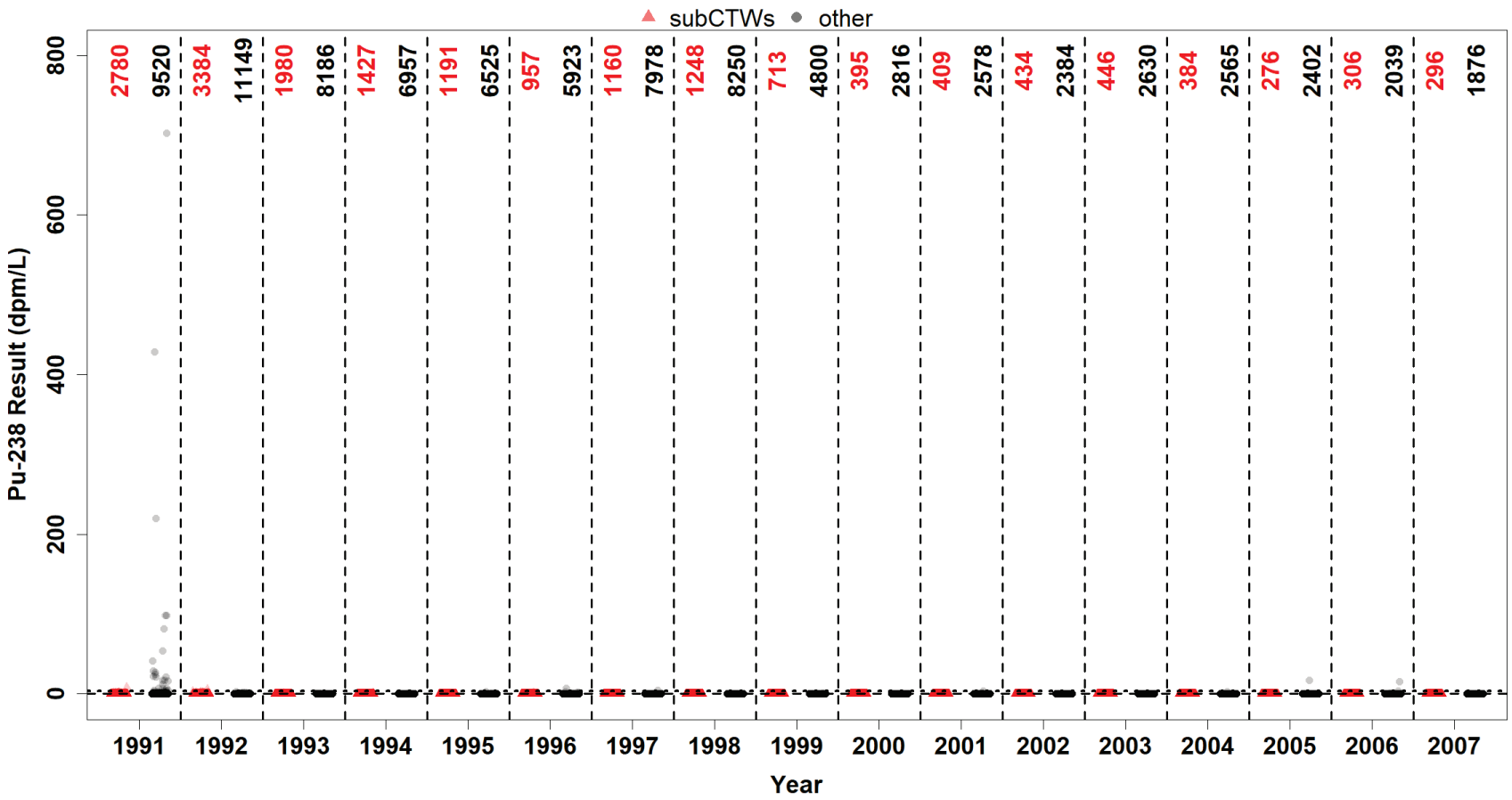

Figure 9: Scatterplot of subCTW (red, left) and Other Worker (black, right) Pu-238 Bioassay Data.

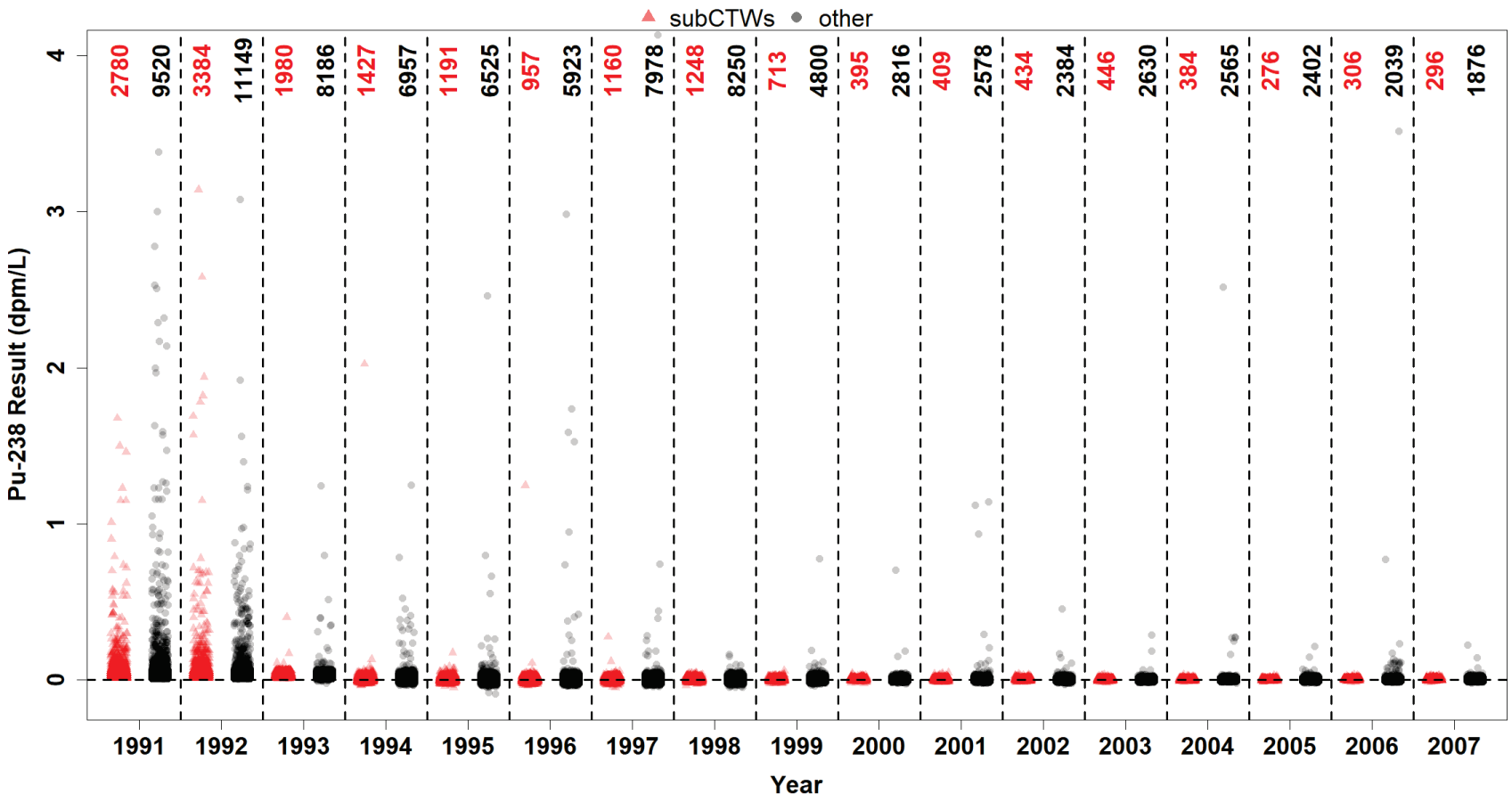

Figure 10: Scatterplot of subCTW (red, left) and Other Worker (black, right) Pu-238 Bioassay Data with a Zoomed Y-Axis.

Plutonium-239

Tables 8 (NTL) and 9 (IVC) describe the cleaning of the data files for plutonium-239 (Pu-239).

Table 8: Summary of Steps Taken to Clean the NTL File for Plutonium-239.

#	Description	Number of Rows Remaining
1	Begin with Total Rows in NTL file	434,061
2	Keep if SAMP RESULT ISOTOPE is Pu-239	107,592
3	Keep 1991–2004	106,824
4	Remove records with inconsistent values of RESULT UNIT[a] (i.e., use only results in dpm/L)	97,464
5	Remove if SAMP RESULT STAT is DL[b]	96,290

a. Remove: 1,238 rows of dpm/S; 8,082 rows of IA; 16 rows of nCi/L; 1 row of pCi/L; 1 row of Split; 22 rows with blank units.
b. SAMP RESULT STAT = Sample result status. According to SRS, these are bioassay results that were deleted [Brown 2023, PDF p. 4].

Table 9: Summary of Steps Taken to Clean the IVC File for Plutonium-239.

#	Description	Number of Rows Remaining
1	Begin with Total Rows in IVC file	332,390
2	Keep if RSLT_ISOT_CD is PU-239, PU-239 MS, PU-240 MS[a]	37,864
3	Keep 2003–2007	10,516
4	Remove if RESULT STATUS is IA[b]	10,447
5	Remove if RSLT_UN is dpm/sample[c]	10,412
6	Sum Pu-239 and Pu-240 for Mass Spectrometry	10,224

a. RSLT_ISOT_CD = result isotope code; MS = mass spectrometry.
b. IA = inconclusive analysis.
c. RSLT_UN = result unit.

The two clean files yield 106,514 usable Pu-239 results in the period of interest. Figures 11 and 12 are the full-scale and zoomed scatterplots of the Pu-239 bioassay data. Based on these figures, the Pu-239 bioassay data look similar for the subCTW group and the "Other" worker group for each year. The data for the subCTW do not tend to be higher than the data for other workers.

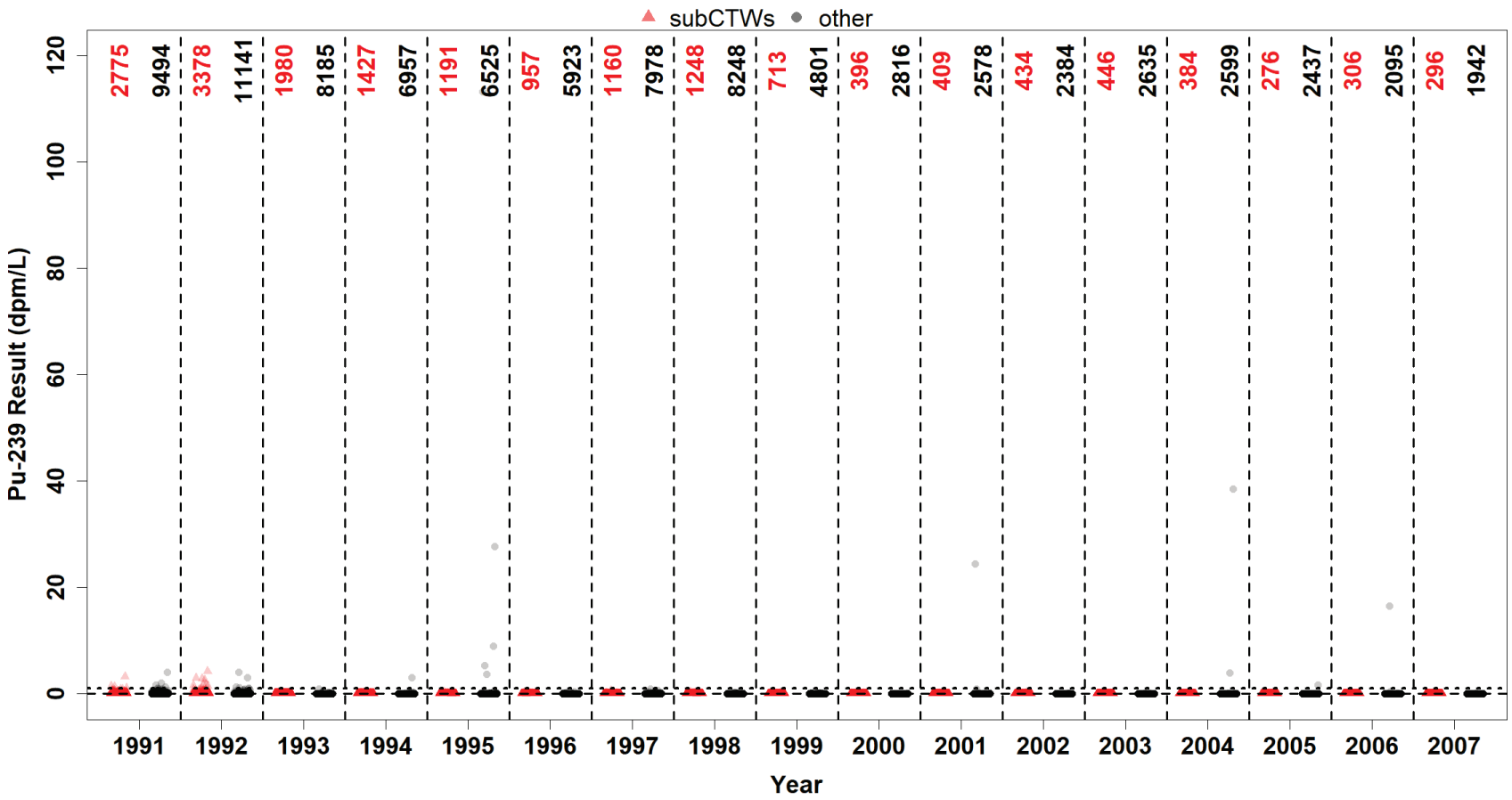

Figure 11: Scatterplot of subCTW (red, left) and Other Worker (black, right) Pu-239 Bioassay Data.

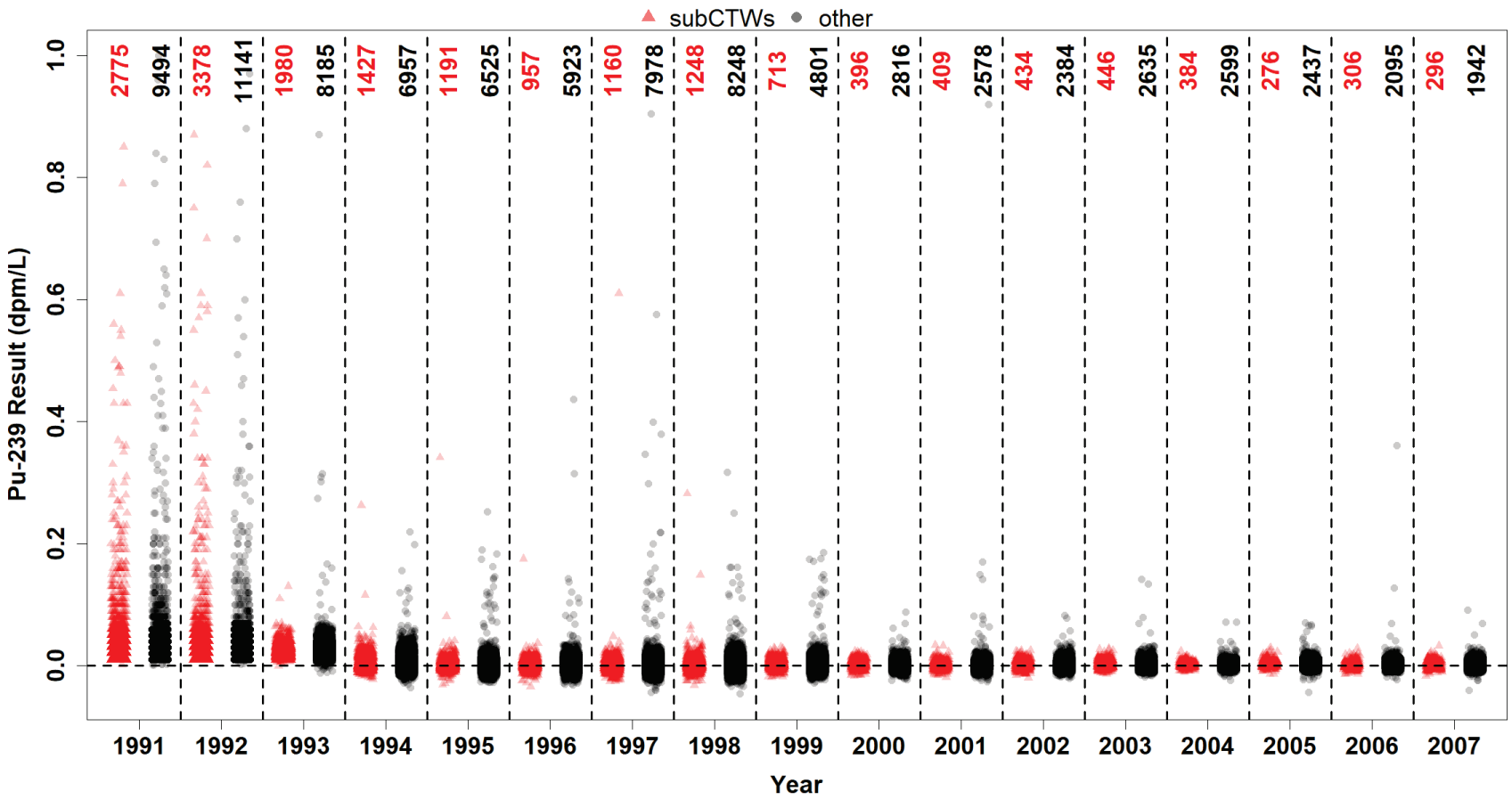

Figure 12: Scatterplot of subCTW (red, left) and Other Worker (black, right) Pu-239 Bioassay Data with a Zoomed Y-Axis.

Americium

Tables 10 (NTL) and 11 (IVC) describe the cleaning of the data files for americium (Am).

Table 10: Summary of Steps Taken to Clean the NTL File for Americium.

#	Description	Number of Rows Remaining
1	Begin with Total Rows in NTL file	434,061
2	Keep if SAMP RESULT ISOTOPE is Am-241 or AmCmCf[a]	17,727
3	Keep 1991–2004	17,687
4	Remove records with inconsistent values of RESULT UNIT[b] (i.e., use only results in dpm/L)	16,767
5	Remove if SAMP RESULT STAT is DL[c]	16,508

a. AmCmCf = americium, curium, californium.
b. Remove: 180 rows of dpm/S (dpm/sample), 724 rows of IA, 16 rows of ugm/L (database abbreviates micrograms per liter in this way).
c. SAMP RESULT STAT = Sample result status. According to SRS, these are bioassay results that were deleted [Brown 2023, PDF p. 4].

Table 11: Summary of Steps Taken to Clean the IVC File for Americium.

#	Description	Number of Rows Remaining
1	Begin with Total Rows in IVC file	332,390
2	Keep if RSLT_ISOT_CD is AM-241[a]	35,376
3	Keep 2003–2007	9,094
4	Remove if RESULT STATUS is IA[b]	9,082
5	Remove if RSLT_UN is dpm/sample[c]	9,068

a. RSLT_ISOT_CD = result isotope code.
b. IA = inconclusive analysis.
c. RSLT_UN = result unit.

The two clean files yield 25,576 usable americium results in the period of interest. Figures 13 and 14 are the full-scale and zoomed scatterplots of the americium bioassay data. Based on these figures, the americium bioassay data look similar for the subCTW group and the "Other" worker group for each year. The data for the subCTW do not tend to be higher than the data for other workers.

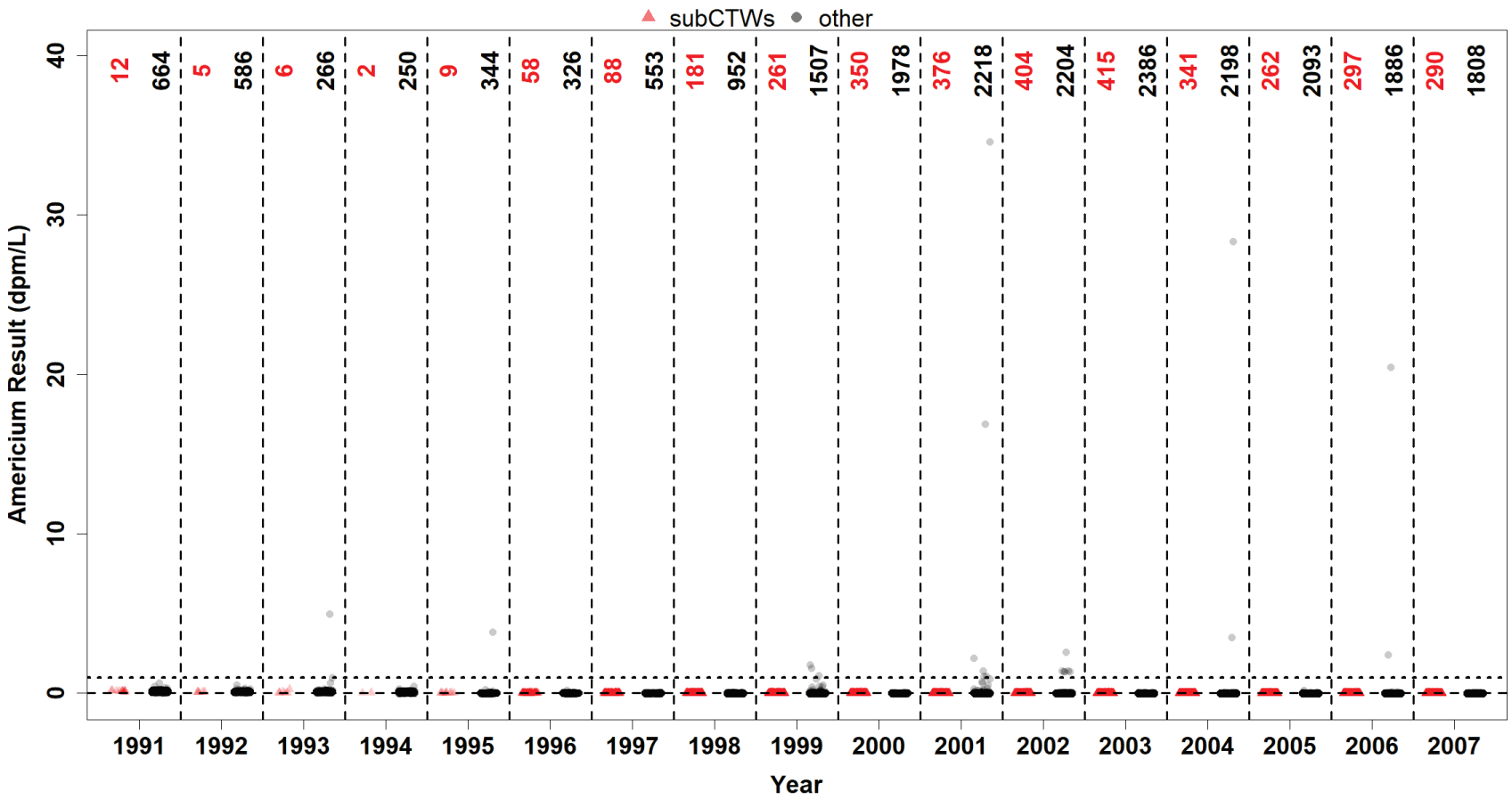

Figure 13: Scatterplot of subCTW (red, left) and Other Worker (black, right) Americium Bioassay Data.

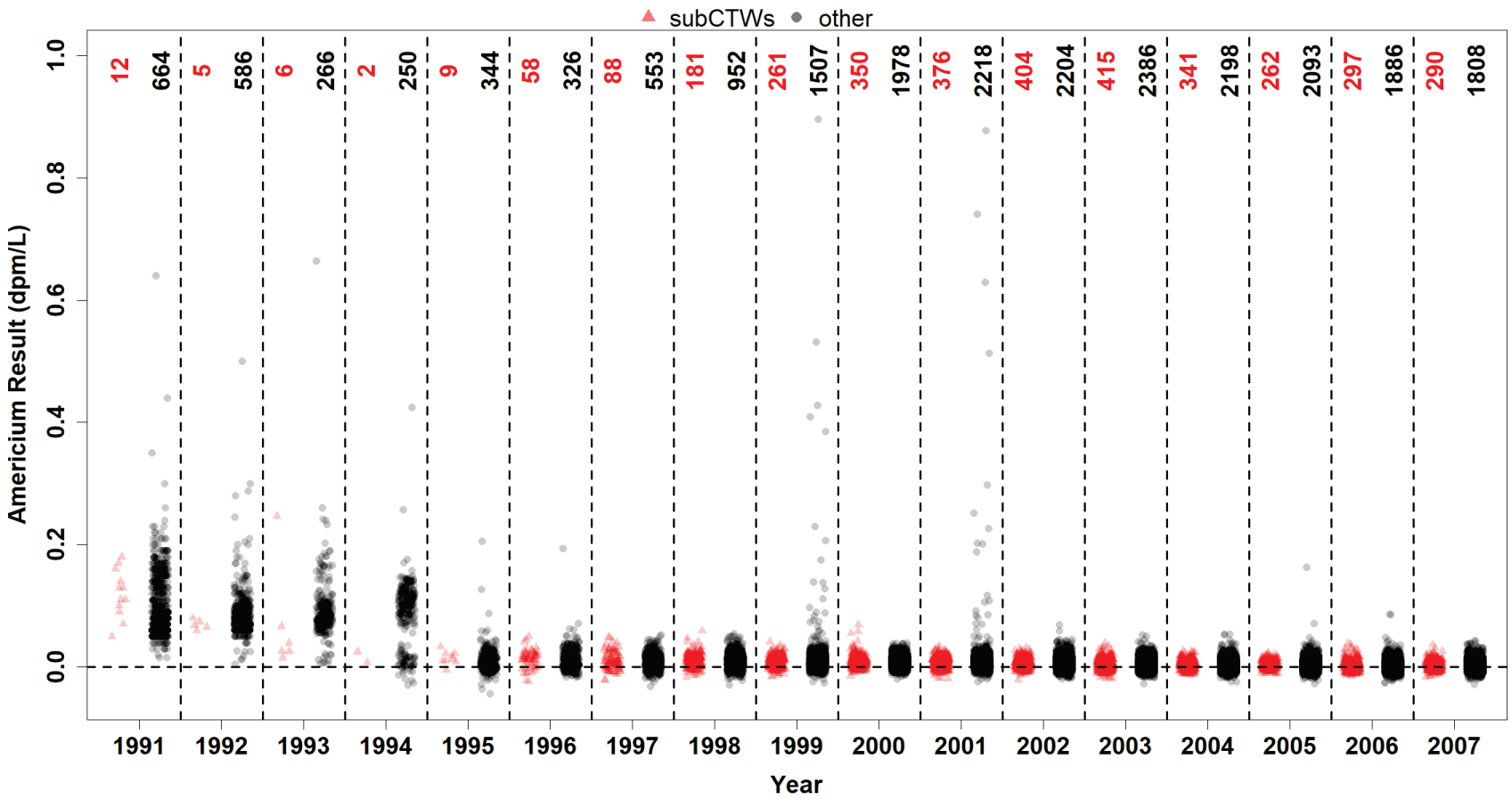

Figure 14: Scatterplot of subCTW (red, left) and Other Worker (black, right) Americium Bioassay Data with a Zoomed Y-Axis.

SRS (as Westinghouse Savannah River Company or WSRC) transitioned from using gross alpha counting for americium to alpha spectrometry in 1994 [WSRC 2012, PDF p. 156]. Most of the results before 1994 were labeled Am/Cm/Cf (gross alpha), so the results from 1991 to 1993 tend to be more variable and greater than zero. Most of the results after 1994 are labeled Am-241 (isotopic), so the results after 1994 are less variable, and negative results are reported. There are both gross alpha and isotopic results as they transitioned.

Curium

Tables 12 (NTL) and 13 (IVC) describe the cleaning of the data files for curium (Cm-244).

Table 12: Summary of Steps Taken to Clean the NTL File for Curium.

#	Description	Number of Rows Remaining
1	Begin with Total Rows in NTL file	434,061
2	Keep if SAMP RESULT ISOTOPE is Cm-244[a]	15,543
3	Keep 1991–2004	15,543
4	Remove records with inconsistent values of RESULT UNIT[b] (i.e., use only results in dpm/L)	14,983
5	Remove if SAMP RESULT STAT is DL[c]	14,801

a. There were only 36 Cm-242 results, so those were not considered.
b. Remove: 174 rows of dpm/S, 385 rows of IA; 1 row with blank units.
c. SAMP RESULT STAT = Sample result status. According to SRS, these are bioassay results that were deleted [Brown 2023, PDF p. 4].

Table 13: Summary of Steps Taken to Clean the IVC File for Curium.

#	Description	Number of Rows Remaining
1	Begin with Total Rows in IVC file	332,390
2	Keep if RSLT_ISOT_CD is CM-244[a]	35,362
3	Keep 2003–2007	9,095
4	Remove if RESULT STATUS is IA[b]	9,081
5	Remove if RSLT_UN is dpm/sample[c]	9,067

a. RSLT_ISOT_CD = result isotope code.
b. IA = inconclusive analysis.
c. RSLT_UN = result unit.

The two clean files yield 23,868 usable curium results in the period of interest. Figure 15 is the full-scale scatterplot of the curium bioassay data. Based on Figure 15, the curium bioassay data look similar for the subCTW group and the "Other" worker group for each year. The data for the subCTW do not tend to be higher than the data for other workers.

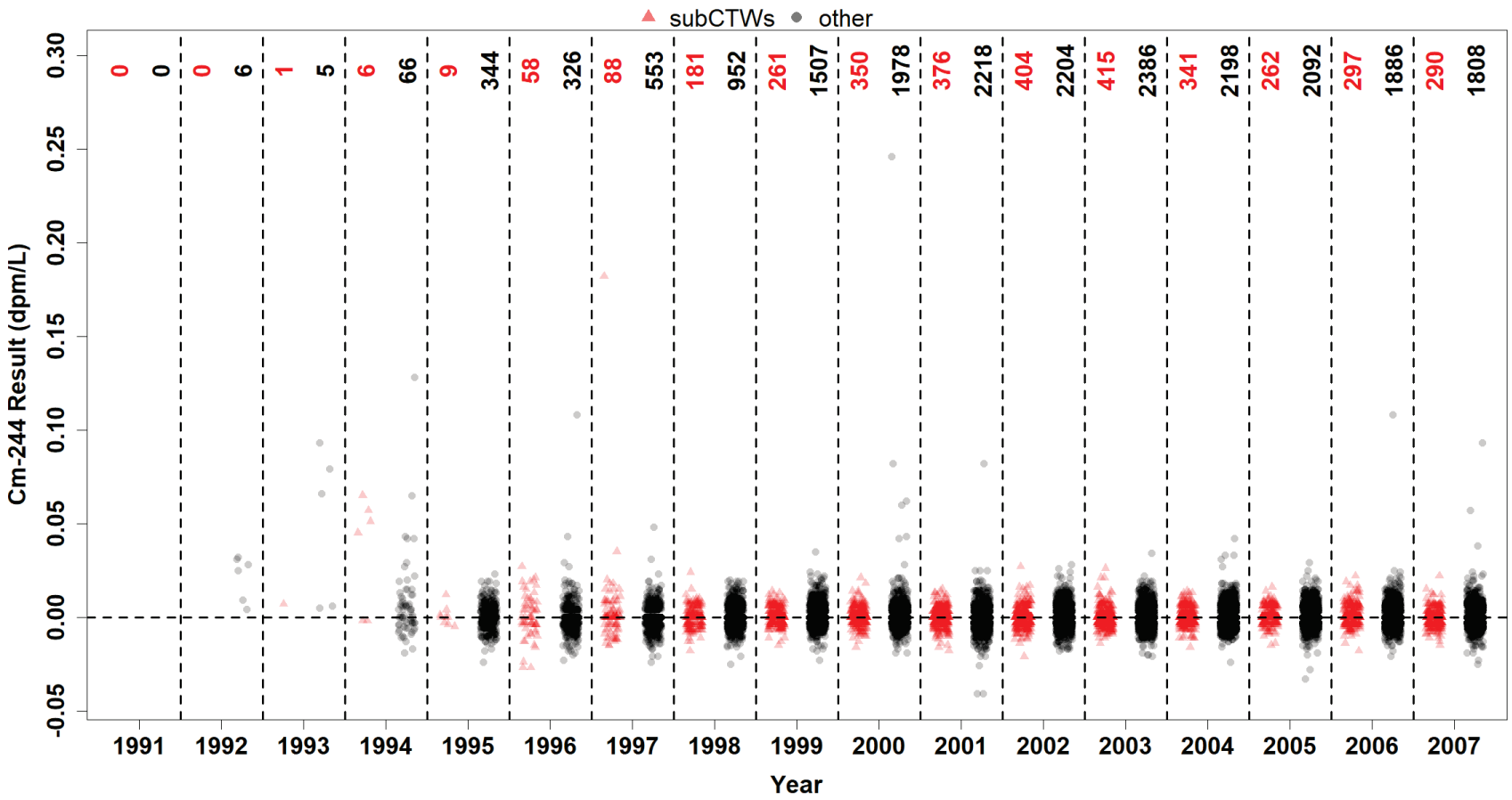

Figure 15: Scatterplot of subCTW (red, left) and Other Worker (black, right) Curium Bioassay Data.

As mentioned in the americium section, SRS transitioned from using gross alpha counting to alpha spectrometry in 1994 [WSRC 2012, PDF p. 156]. The results that were labeled Am/Cm/Cf (gross alpha) are included only in the americium section. Only isotopic curium is displayed here, so most results begin to appear in 1994.

Californium

Tables 14 (NTL) and 15 (IVC) describe the cleaning of the data files for californium (Cf-252).

Table 14: Summary of Steps Taken to Clean the NTL File for Californium.

#	Description	Number of Rows Remaining
1	Begin with Total Rows in NTL file	434,061
2	Keep if SAMP RESULT ISOTOPE is Cf-252	15,518
3	Keep 1991–2004	15,518
4	Remove records with inconsistent values of RESULT UNIT[a] (i.e., use only results in dpm/L)	14,958
5	Remove if SAMP RESULT STAT is DL[b]	14,772

a. 172 rows of dpm/S, 387 rows of IA, 1 row with blank units.
b. SAMP RESULT STAT = Sample result status. According to SRS, these are bioassay results that were deleted [Brown 2023, PDF p. 4].

Table 15: Summary of Steps Taken to Clean the IVC File for Californium.

#	Description	Number of Rows Remaining
1	Begin with Total Rows in IVC file	332,390
2	Keep if RSLT_ISOT_CD is CF-252[a]	35,360
3	Keep 2003–2007	9,095
4	Remove if RESULT STATUS is IA[b]	9,081
5	Remove if RSLT_UN is dpm/sample[c]	9,067

a. RSLT_ISOT_CD = result isotope code.
b. IA = inconclusive analysis.
c. RSLT_UN = result unit.

The two clean files yield 23,839 usable californium results in the period of interest. Figure 16 is the full-scale scatterplot of the californium bioassay data. Based on Figure 16, the californium bioassay data look similar for the subCTW group and the "Other" worker group for each year. The data for the subCTW do not tend to be higher than the data for other workers.

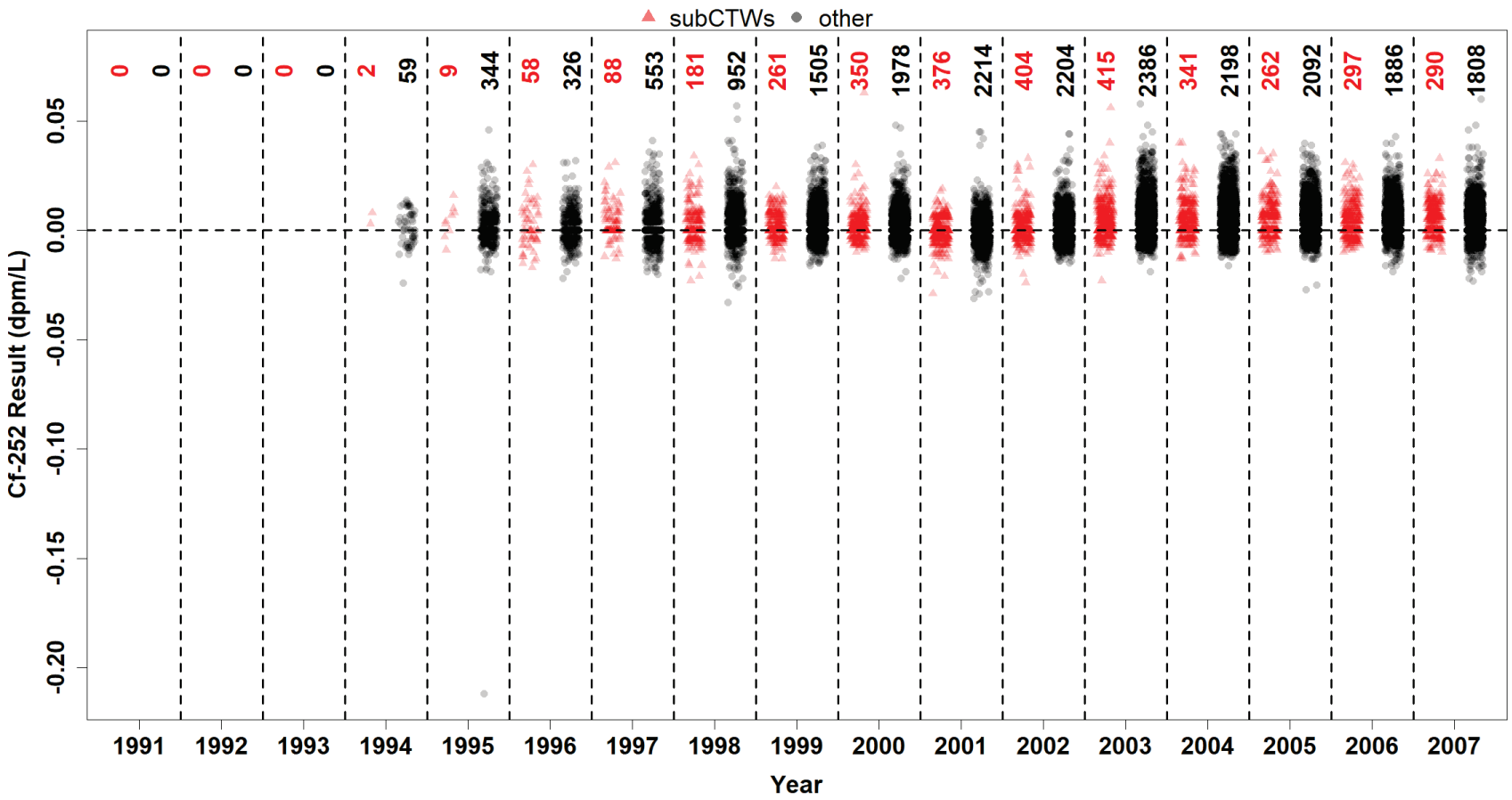

Figure 16: Scatterplot of subCTW (red, left) and Other Worker (black, right) Californium Bioassay Data.

As mentioned in the americium section, SRS transitioned from using gross alpha counting to alpha spectrometry in 1994 [WSRC 2012, PDF p. 156]. The results that were labeled Am/Cm/Cf (gross alpha) are only included in the americium section. Only isotopic californium is displayed here, so results begin to appear in 1994.[2]

Uranium

Tables 16 (NTL) and 17 (IVC) describe the cleaning of the data files for uranium.

Table 16: Summary of Steps Taken to Clean the NTL File for Uranium.

#	Description	Number of Rows Remaining
1	Begin with Total Rows in NTL file	434,061
2	Keep if SAMP RESULT ISOTOPE is EU, NT/DU, U-234, U-235, or U-238[a]	108,182
3	Keep 1991–2004	107,878
4	Remove rows where RESULT UNIT is not ugm/L or dpm/L[b] and convert results to dpm/L where RESULT UNIT is ugm/L[c]	101,690
5	Sum U-234, U-235, and U-238 by sample number (or unique SSN/date)	46,898
6	Remove if SAMP RESULT STAT is DL[d]	46,610

a. EU = enriched uranium, NT = natural, DU = depleted uranium.
There were only 2 U-236 results, so those were not considered.
b. Remove 21 rows of dpm/S; 6,155 rows of IA; 1 row of nCi/1.5L; 10 rows of nCi/L; 1 row of ugm/1.5L.
c. Assuming depleted uranium for the µg/L (micrograms per liter) results, use conversion factor of 0.826 dpm/µg.
d. SAMP RESULT STAT = Sample result status. According to SRS, these are bioassay results that were deleted [Brown 2023, PDF p. 4].

[2] The very low Cf-252 result (-0.212 dpm/L) in 1995 was part of a special sample that contained high americium and plutonium results.

Table 17: Summary of Steps Taken to Clean the IVC File for Uranium.

#	Description	Number of Rows Remaining
1	Begin with Total Rows in IVC file	332,390
2	Keep if RSLT_ISOT_CD is U-234, U-235, or U-238[a]	45,105
3	Keep 2003–2007	15,435
4	Remove if RESULT STATUS is IA[b]	15,423
5	Remove if RSLT_UN is dpm/sample[c]	15,409
6	Sum U-234, U-235, and U-238 by SAMPLE_ID	5,137

a. RSLT_ISOT_CD = result isotope code.
b. IA = inconclusive analysis.
c. RSLT_UN = result unit.

The two clean files yield 51,747 usable uranium results in the period of interest. Figures 17 and 18 are the full-scale and zoomed scatterplots of the uranium bioassay data. Based on these figures, the uranium bioassay data look similar for the subCTW group and the "Other" worker group for each year. The data for the subCTW do not tend to be higher than the data for other workers.

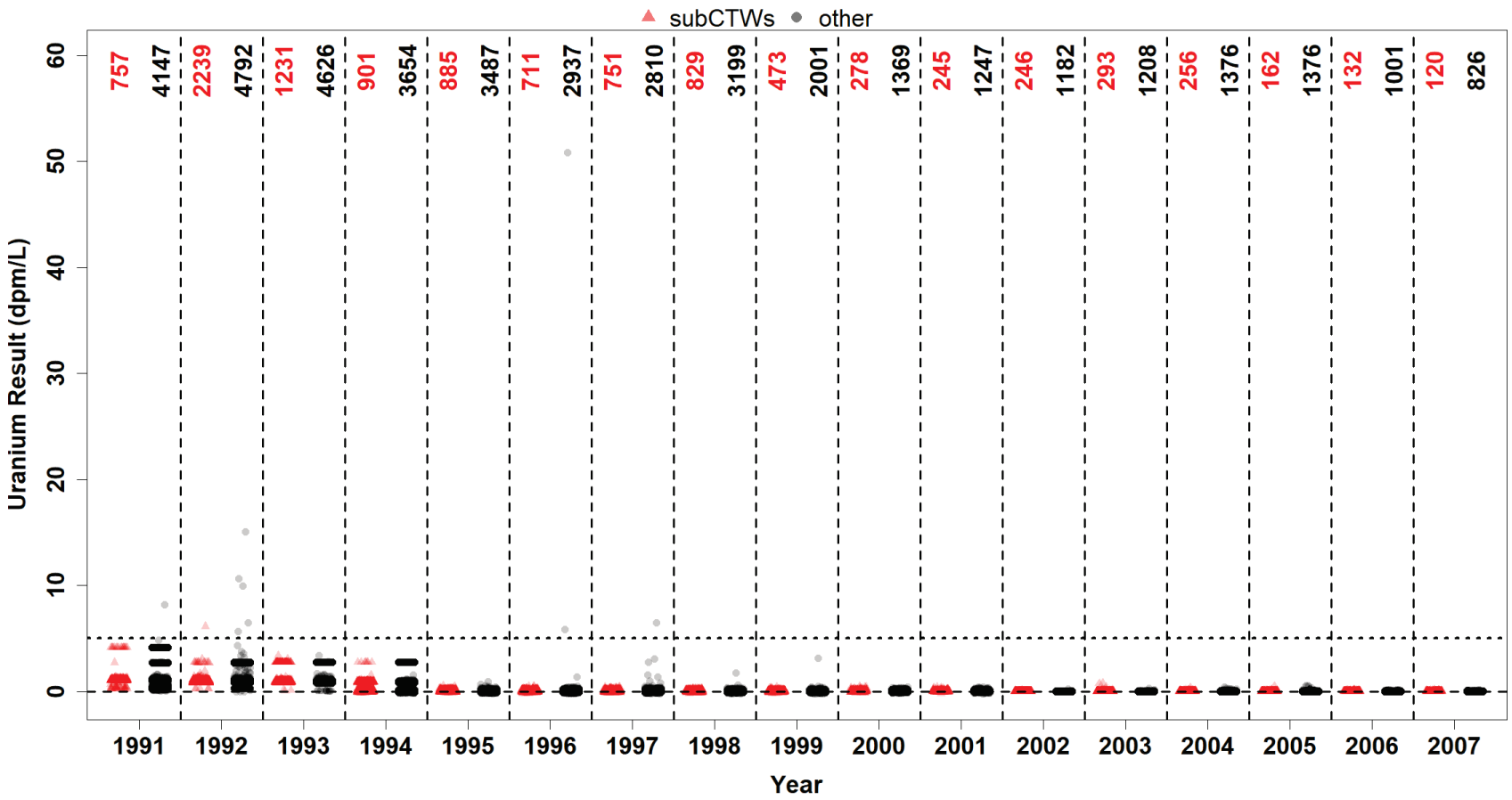

Figure 17: Scatterplot of subCTW (red, left) and Other Worker (black, right) Uranium Bioassay Data.

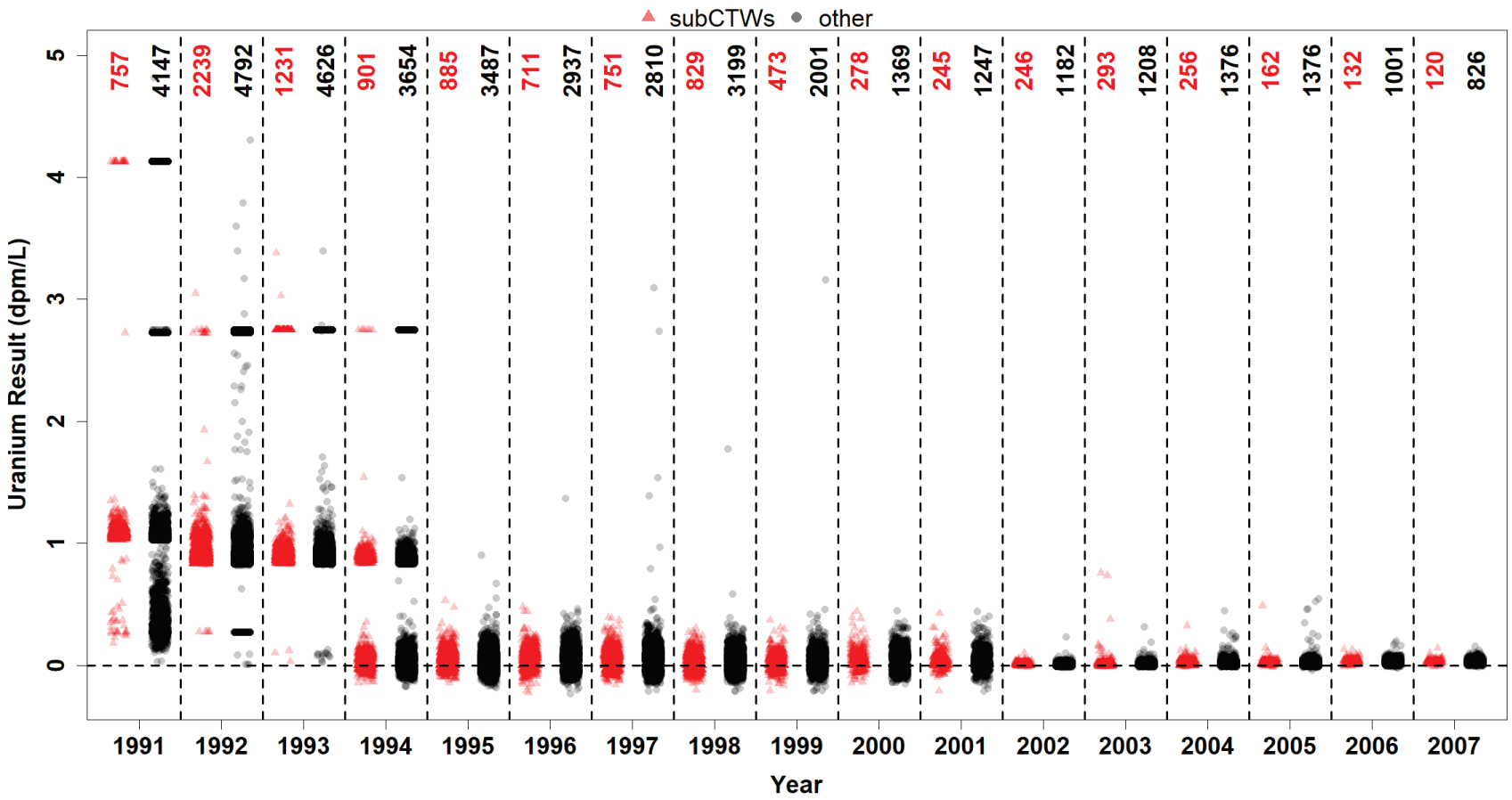

Figure 18: Scatterplot of subCTW (red, left) and Other Worker (black, right) Uranium Bioassay Data with a Zoomed Y-Axis.

For part of 1994 and years prior, the vast majority of uranium results are labeled as EU (enriched uranium) or DU (depleted uranium). The bands at 0.27, 2.7, and 4.13 dpm/L (Figure 18) are all DU results with censoring levels of 0.33, 3.3, and 5 µg/L. The 1990 SRS *Internal Dosimetry Technical Basis Manual* cites a reporting level of 3.3 µg/L and a minimum detectable activity of 0.3 µg/L for DU [WSRC 1990, PDF p. 384]. There are uranium logbooks, containing results from the early 1990s, that also have results reported as less than 5 µg/L [SRS 1989–1991]. The clumps of points starting just above 1 for 1991 and starting just below one for 1992 to 1994, are all EU results, mostly censored. These various censoring levels for EU in the early 1990s are confirmed by uranium logbooks [SRS 1992]. The clumps of points less than 1 in 1991 are also mostly censored EU results and are confirmed by uranium logbooks [SRS 1991].

SRS began using alpha spectroscopy in 1994 [WSRC 2012, PDF p. 156], so all uranium results after 1994 (and some in 1994) are isotopic and are labeled U-234, U-235, and U-238. This phenomenon is evident in the behavior in Figure 18 of the uranium results from part of 1994 forward. Additionally, SRS "completed a decade long consolidation of its chemical separation procedures" in 2001 [WSRC 2001, PDF p. 169], which could explain the decrease in variability of the isotopic uranium results after 2001.

Neptunium

Tables 18 (NTL) and 19 (IVC) describe the cleaning of the data files for neptunium (Np-237).

Table 18: Summary of Steps Taken to Clean the NTL File for Neptunium.

#	Description	Number of Rows Remaining
1	Begin with Total Rows in NTL file	434,061
2	Keep if SAMP RESULT ISOTOPE is Np-237	9,703
3	Keep 1991–2004	9,703
4	Remove records with inconsistent values of RESULT UNIT[a] (i.e., use only results in dpm/L)	8,916
5	Remove if SAMP RESULT STAT is DL[b]	8,646

a. 30 rows of dpm/S; 757 rows of IA.
b. SAMP RESULT STAT = Sample result status. According to SRS, these are bioassay results that were deleted [Brown 2023, PDF p. 4].

Table 19: Summary of Steps Taken to Clean the IVC File for Neptunium.

#	Description	Number of Rows Remaining
1	Begin with Total Rows in IVC file	332,390
2	Keep if RSLT_ISOT_CD is NP-237[a]	14,056
3	Keep 2003–2007	4,524
4	Remove if RESULT STATUS is IA[b]	4,504
5	Remove if RSLT_UN is dpm/sample[c]	4,501

a. RSLT_ISOT_CD = result isotope code.
b. IA = inconclusive analysis.
c. RSLT_UN = result unit.

The two cleaned files yield 13,147 usable neptunium results in the period of interest. Figures 19 and 20 are the full-scale and zoomed scatterplots of the neptunium bioassay data. Based on Figures 19 and 20, the neptunium bioassay data look similar for the subCTW group and the "Other" worker group for each year. The data for the subCTW do not tend to be higher than the data for other workers.

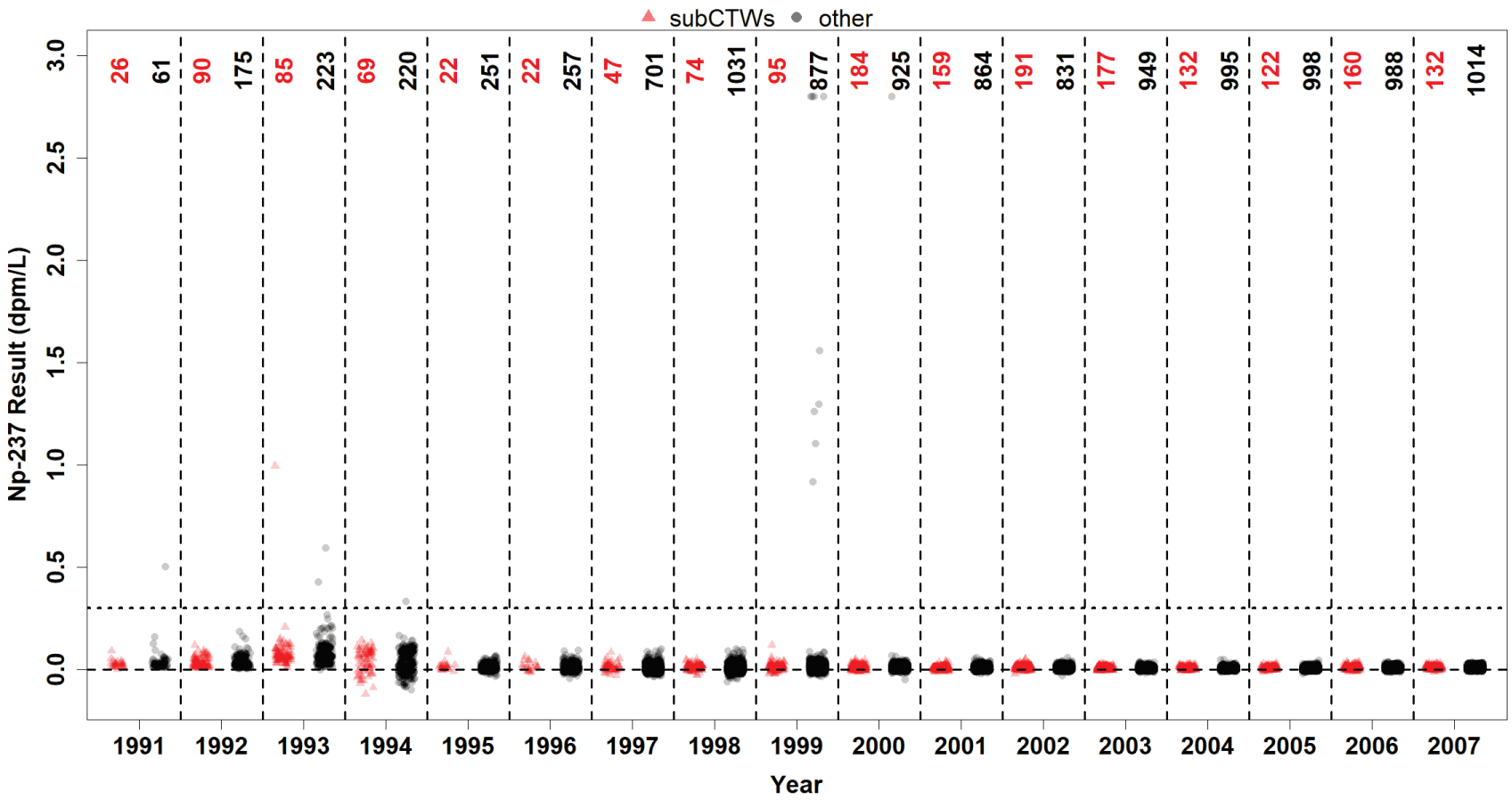

Figure 19: Scatterplot of subCTW (red, left) and Other Worker (black, right) Neptunium Bioassay Data.

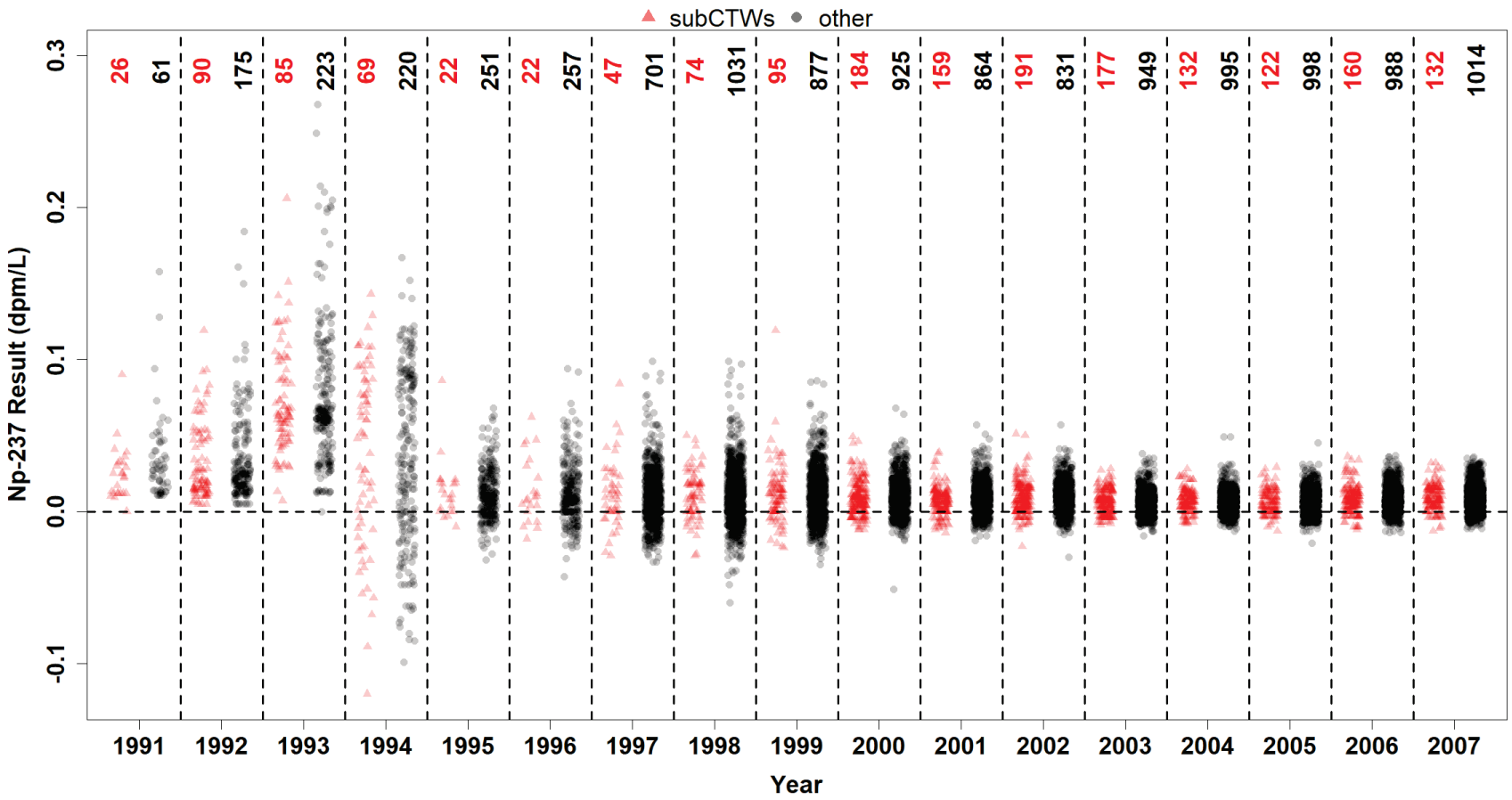

Figure 20: Scatterplot of subCTW (red, left) and Other Worker (black, right) Neptunium Bioassay Data with a Zoomed Y-Axis.

As mentioned previously, SRS began reporting negative results in 1994. SRS also transitioned to an ion exchange sequential analysis for neptunium in 1994 [WSRC 2012, PDF p. 170]. The transition to the sequential analysis explains the decrease in the variability of the results from 1994 to 1995.

Strontium

Tables 20 (NTL) and 21 (IVC) describe the cleaning of the data files for strontium (Sr-90).

Table 20: Summary of Steps Taken to Clean the NTL File for Strontium.

#	Description	Number of Rows Remaining
1	Begin with Total Rows in NTL file	434,061
2	Keep if SAMP RESULT ISOTOPE is Sr-90	52,108
3	Keep 1991–2004	52,025
4	Remove if RESULT UNIT is not nCi/L, pCi/L, or dpm/L[a] (Convert any results in nCi/L or pCi/L to dpm/L)	49,032
5	Remove if SAMP RESULT STAT is DL[b]	48,696

a. 5 rows of dpm/1.5L; 2,977 rows of IA; 5 rows of nCi/1.5L; 4 rows of nCi/S; 2 rows ugm/L.
b. SAMP RESULT STAT = Sample result status. According to SRS, these are bioassay results that were deleted [Brown 2023, PDF p. 4].

Table 21: Summary of Steps Taken to Clean the IVC File for Strontium.

#	Description	Number of Rows Remaining
1	Begin with Total Rows in IVC file	332,390
2	Keep if RSLT_ISOT_CD is SR 90[a]	22,473
3	Keep 2003–2007	5,032

a. RSLT_ISOT_CD = result isotope code.

The two clean files yield 53,728 usable strontium results in the period of interest. Figures 21 (full scale) and 22 (zoomed y-axis) are the scatterplots of the strontium bioassay data. Based on these figures, the Sr-90 bioassay data look similar for the subCTW group and the "Other" worker group for each year. The data for the subCTW do not tend to be higher than the data for other workers.

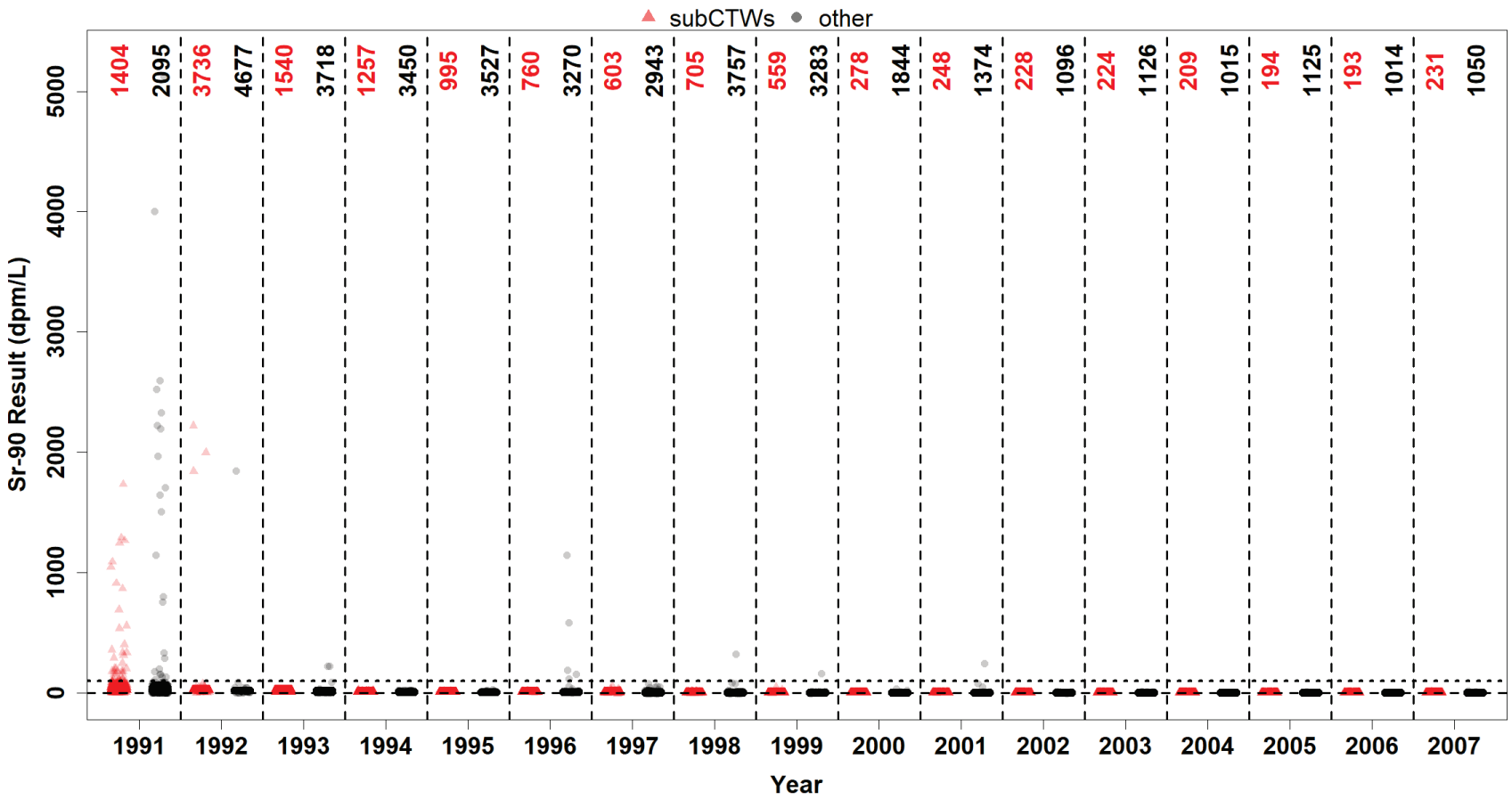

Figure 21: Scatterplot of subCTW (red, left) and Other Worker (black, right) Strontium Bioassay Data.

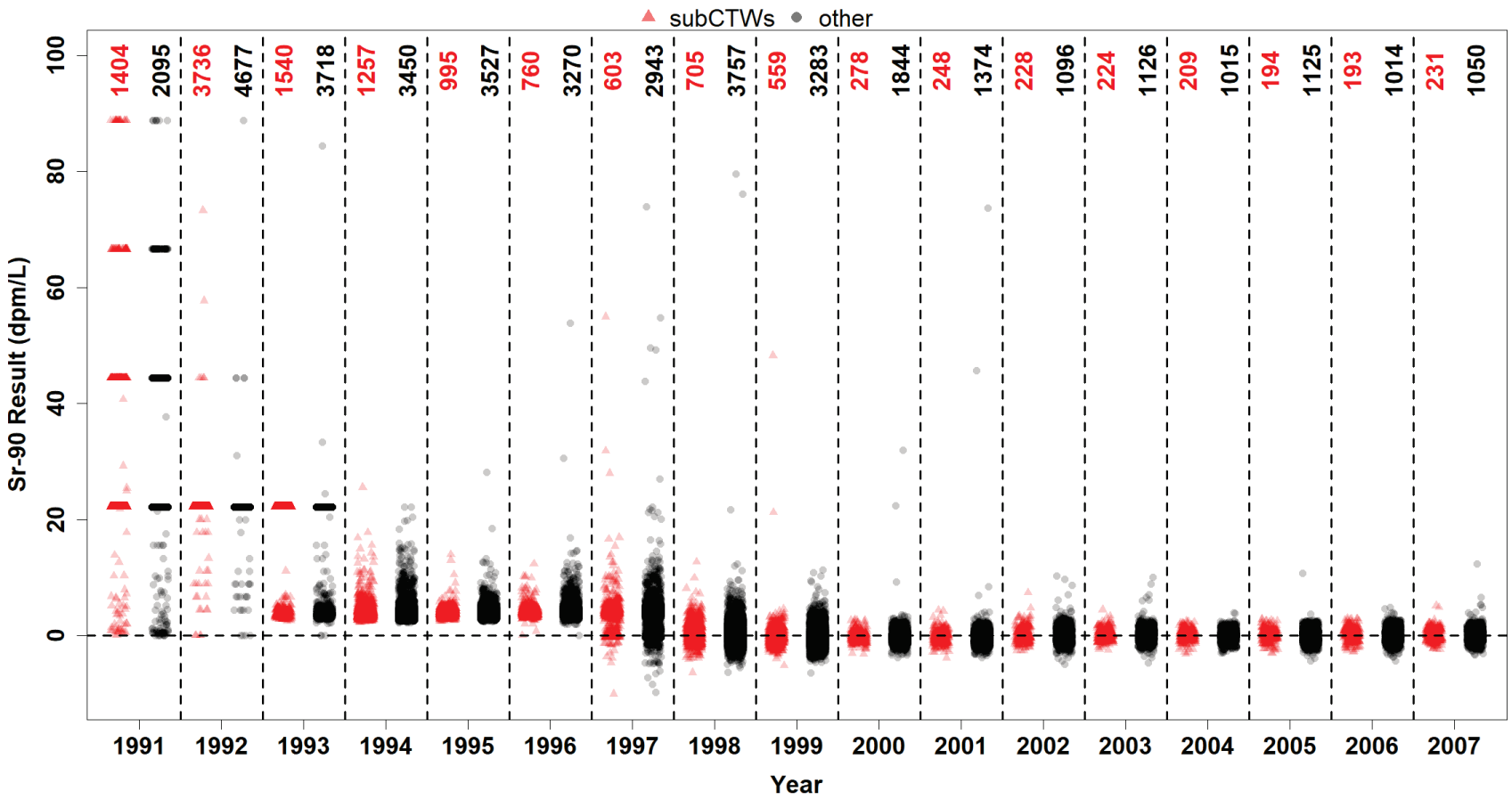

Figure 22: Scatterplot of subCTW (red, left) and Other Worker (black, right) Strontium Bioassay Data with a Zoomed Y-Axis.

Most strontium results in 1991 and 1992 were recorded in nCi/L. Results of 0.01, 0.02, 0.03, and 0.04 nCi/L were converted to 22.2 dpm/L, 44.4 dpm/L, 66.6 dpm/L, and 88.8 dpm/L, respectively. Those dpm/L values are the bands in Figure 22. SRS began reporting strontium results in pCi/L in 1993. Negative results were included at around 1997. At around this time, recovery began to be determined from spiked batch urine samples and was applied to every sample in the batch [WSRC 2012, PDF p. 171].

Short-term Versus Longer-term Workers

The SC&A definition of subcontractor (see Attachment C) probably tends to include more short-term workers, whereas the definition used in this White Paper may tend to include both short-term and longer-term workers (see Attachment B). Each plot in the White Paper (Figures 1 through 22) can be compared to its corresponding plot in Attachment C (Figures C-1 through C-22) to see that the term of the worker has little effect on the comparison/conclusion. For example, comparing Figure 12 to Figure C-12 for Pu-239, the plots look very similar.

CONCLUSION

In Figures 1 through 22, the external dose and bioassay data look similar for the subCTW group and the "Other" worker group for each year for each type of data. The subCTW data do not tend to be higher than the other workers, so there is no evidence in the data that subCTWs were the most highly exposed workers at SRS.

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ATTACHMENT A

The following quotes are three portions of the March 2023 SRS work group transcript [NIOSH 2023] where Dr. James Lockey suggests an analysis to determine the validity of the assertion that subCTWs were some of the most highly exposed workers at SRS.

From NIOSH 2023, PDF p. 123:

> *Maybe I would go back and look at subcontractors, short-term subcontractors by duration of work and year where there is bioassay data available and compare that to the overall cohort and see how it differs. If it sort of falls in the same range, or it's in the confidence intervals, then I'm reassured. If it represents the most highest exposed, then that becomes a little more problematic for me. But look at the subcontractors where you have data short-term and do it by time, short term and by year and compare it to the overall database and see -- and see where they fall.*

From NIOSH 2023, PDF pp. 125–126

> *Look at those subcontractors that were – where we have bioassays data, how long – time frame, how long – are they short term, long term, and their work, and look at their bioassay data and compare that to the whole population and see where it falls. If it falls in the middle, that's reassuring to me that, you know, more likely than not they represent the population. If they fall into the top 5 percent, then that's a problem for me, okay, because that indicates that more likely that, as you say, these were the highest exposures, we probably are missing people and there may be exposures even higher who never got bioassay data.*
>
> *So, your end point here is the bioassay data. I don't care if they're electricians or pipefitters or whatever. I just want to know what their bioassay data was as a short-term subcontractor. And I think we do have some of that data.*

From NIOSH 2023, PDF p. 131, **emphasis** added

> *Let me -- suppose you look at the bioassay data of these short-term workers where data does exist. And the -- and the point estimate and distribution is way out of hand of what the overall cohort is. That tells me something. If it falls right in the middle, that also tells me something.* ***The question is --*** *that Joe keeps raising, which I completely understand --* ***that short-term workers could have been brought in to do the most hazardous jobs, the most abysmal -- under the most abysmal working situations, and they were never -- never monitored****. I can't be sure that the ones that were monitored reflect that worst-case situation, but at least I can look at the data, the bioassay data, and see where it falls, how representative it is of the cohort as a whole.*

ATTACHMENT B

For this analysis, a subCTW is any record in the IND file where any of the following is true. Otherwise, the record is marked "other." See the data dictionary provided by SRS for details on the column contents [SRS 2022].

1. COMPANY_NM is "BECHTEL SAVANNAH RIVER INC"
2. ORG_TL is any of the following
    a. "VERIZON-FNS"
    b. "R. B. WRIGHT CO."
    c. "THOMSON ROOFING & METAL CO"
    d. "HEBBARD ELECTRIC"
    e. "THOMSON ROOFING & METAL, CO."
    f. "QUEEN CITY RAILROAD CONSTRUCTI"
    g. "IVEY'S CONSTRUCTION INC"
    h. "R.L. CAMPBELL ROOFING CO."
    i. "WSB CONSTRUCTION"
    j. "C.A. MURREN"
    k. "TYLER CONSTRUCTION"
    l. "JOHNSON'S ROOFING SERVICE, INC"
    m. "WSB MAINTENANCE/OPERATIONS"
    n. "ALPHA CONSTRUCTION CO."
    o. "AT&T"
    p. "DIVERSCO"
    q. "GUY C SMITH CONSTR CO"
    r. "TWO STATE CONSTRUCTION CO. INC"
    s. "WSB PROJECT MANAGER"
3. ORG_TL
    a. Ends with "CONSTRUCTION"
    b. Starts with "LABOR"
    c. Starts with "SHEETMETAL"
    d. Contains "BOILERM"
    e. Contains "CARPENTE"
    f. Contains "CEMEN"
    g. Contains "ELECTRICIAN"
    h. Contains "HEAVY EQUIP"
    i. Contains "IRONWORKER"
    j. Contains "LABORER"
    k. Contains "MILLWRIGHT"
    l. Contains "MASON"
    m. Contains "PAINTER"
    n. Contains "PIPEFITT"

4. EMP_UNION_CRAFT_CD is not null

ATTACHMENT C

The following section provides analogous plots of all data presented in this White Paper but using the SC&A definition of "subcontractor" instead of "subCTW," as clarified in SC&A 2023b. According to the SC&A definition, the worker is a "subcontractor" if the IND file has COMPANY_NM equal to "SUB." If a worker is not designated "SUB," that worker is assumed to be employed by the prime contractor. Therefore, in the figures that follow, workers are designated as either "Subcontractors" or "Primes."

Figures C-1 through C-22 provide all results using that definition. As in the main body of this White Paper, the results are presented using scatterplots. The red points (presented on the left for each year) correspond to data from "Subcontractors," while the black points (presented on the right for each year) are from "Primes." If the red points tend to be higher than the black points for a year, the results for subcontractors tend to be higher than the other workers. Note that if a plot has a horizontal dashed line at some y-value, the next plot is zoomed in to that value on the y-axis, so more detail is visible. The numbers at the top of each plot are the number of results for that group for that year.

The conclusions from examination of these figures are the same as the conclusions presented in the White Paper.

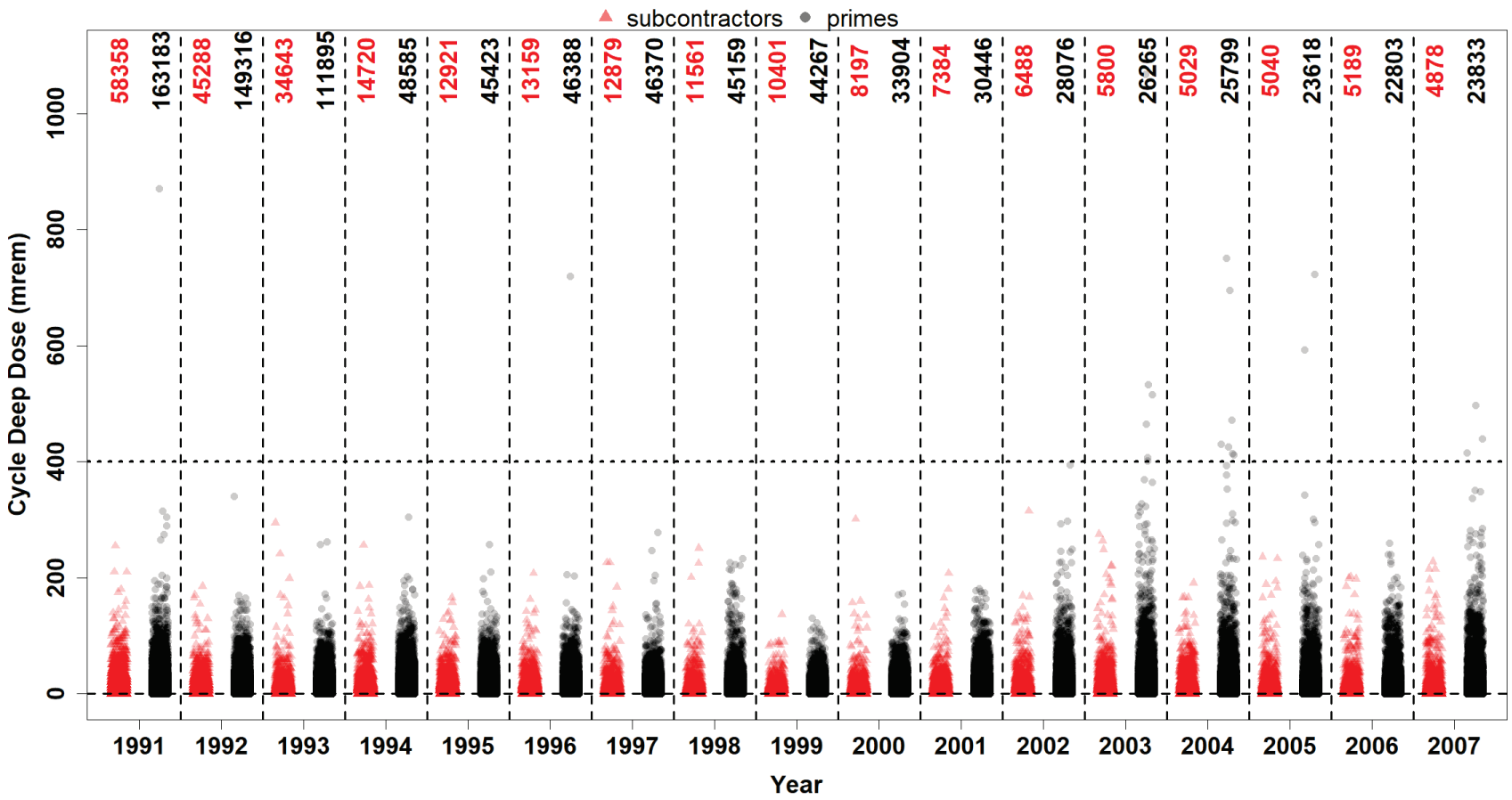

Figure C-1: Scatterplot Using SC&A Definition of Subcontractors (red, left) and Primes (black, right) Deep Dose Cycle Data.

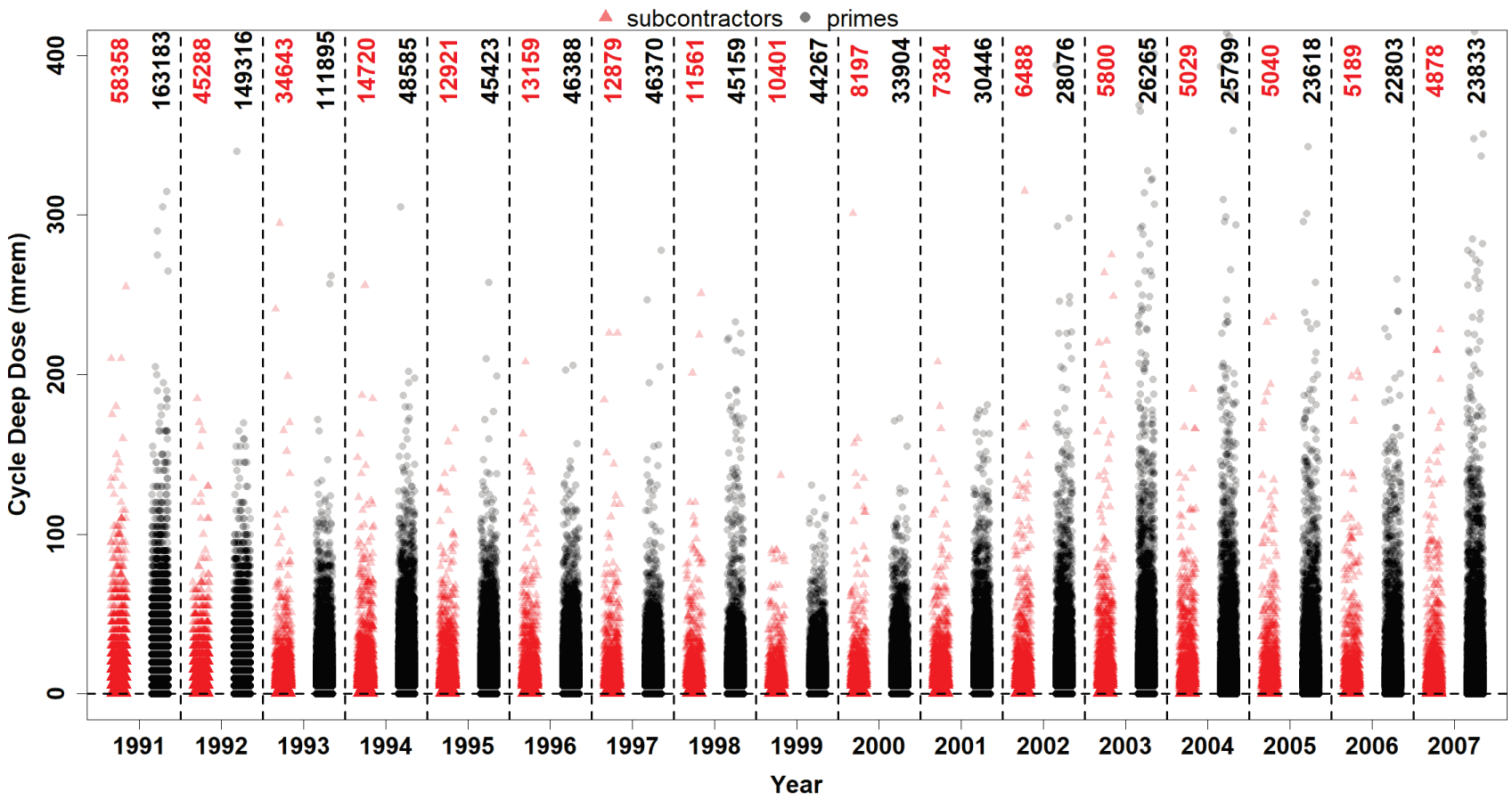

Figure C-2: Scatterplot Using SC&A Definition of Subcontractors (red, left) and Primes (black, right) Deep Dose Cycle Data with a Zoomed Y-Axis.

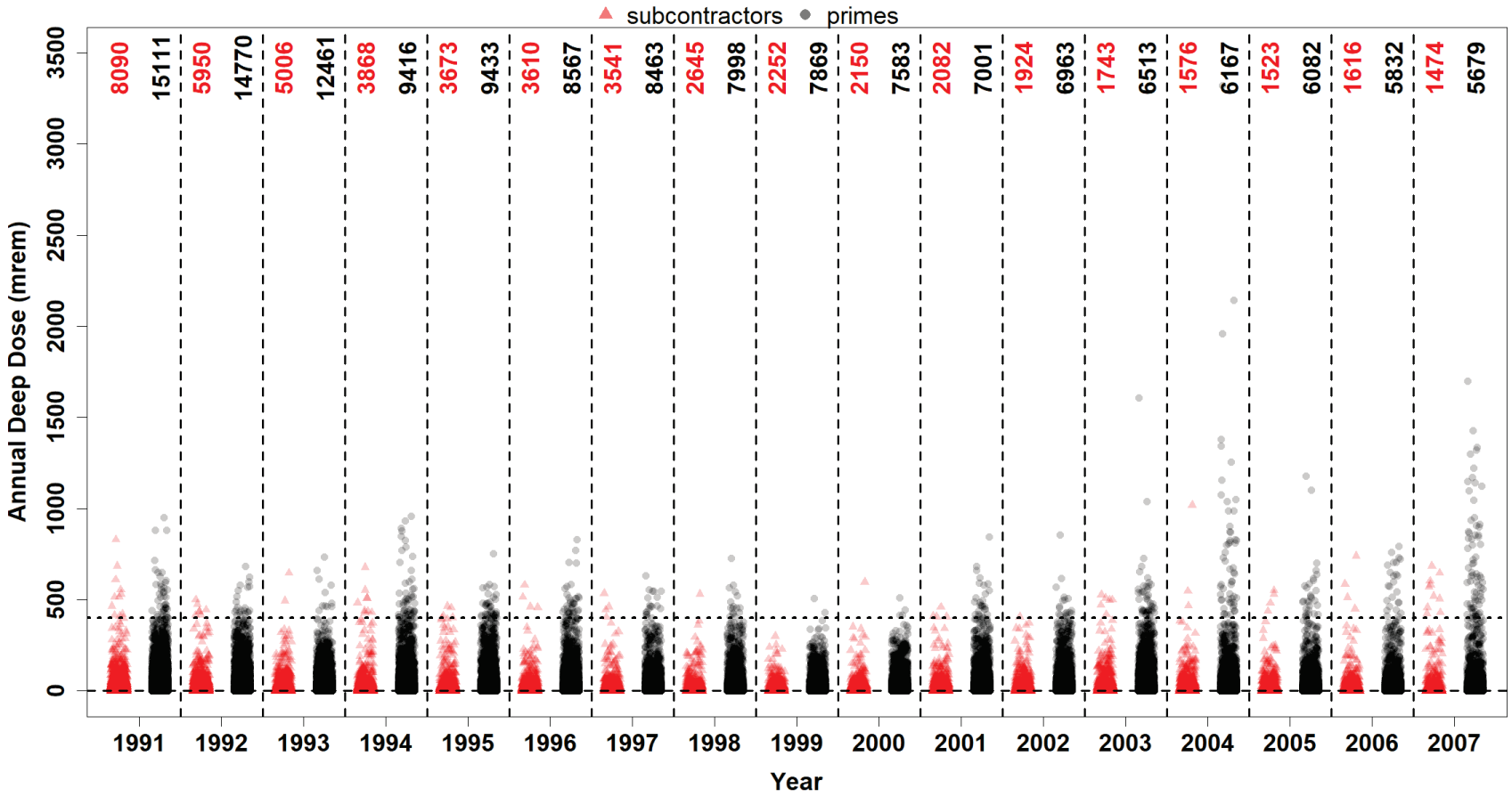

Figure C-3: Scatterplot Using SC&A Definition of Subcontractors (red, left) and Primes (black, right) Annual Deep Doses.

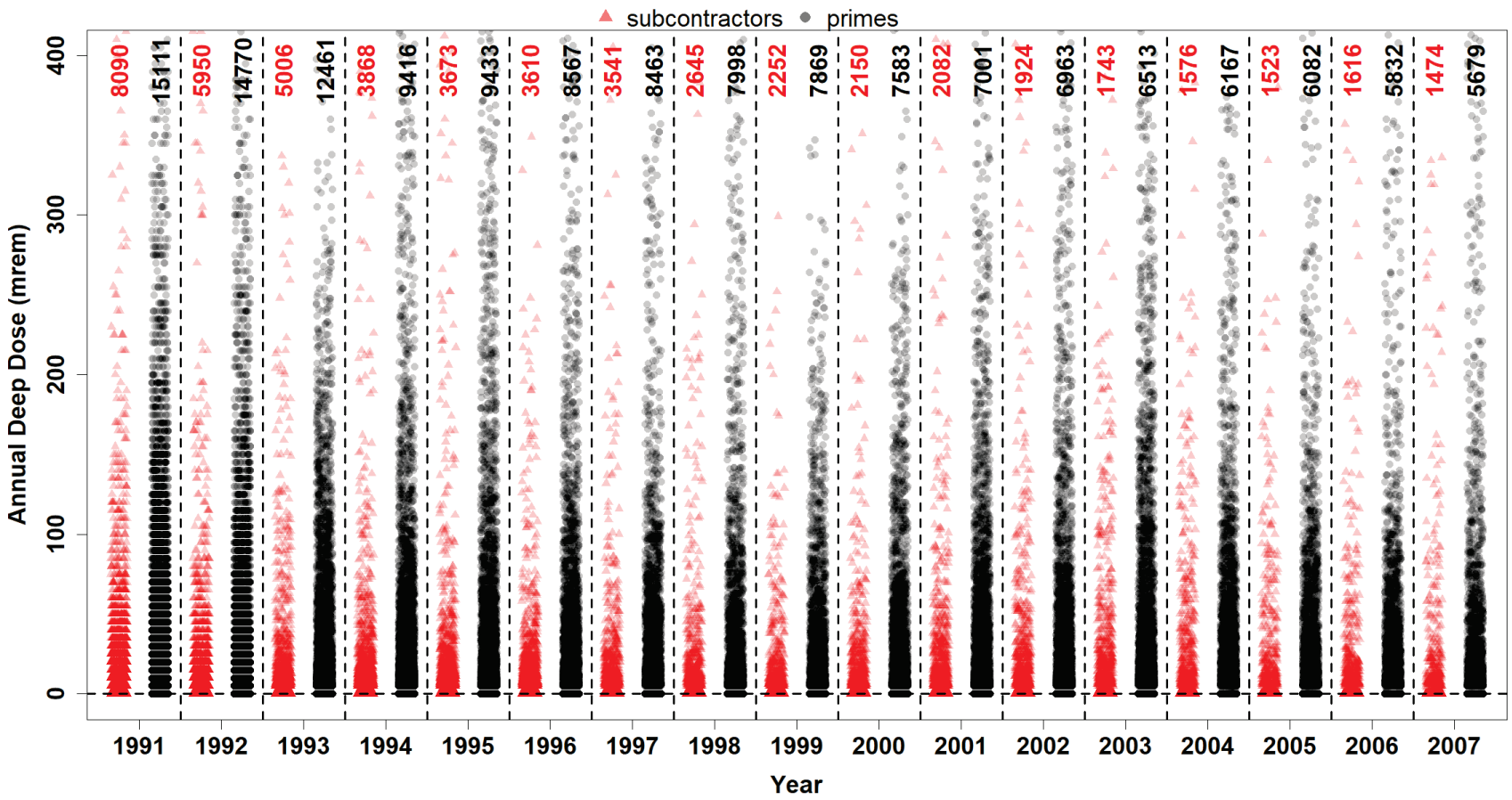

Figure C-4: Scatterplot Using SC&A Definition of Subcontractors (red, left) and Primes (black, right) Annual Deep Doses with a Zoomed Y-Axis.

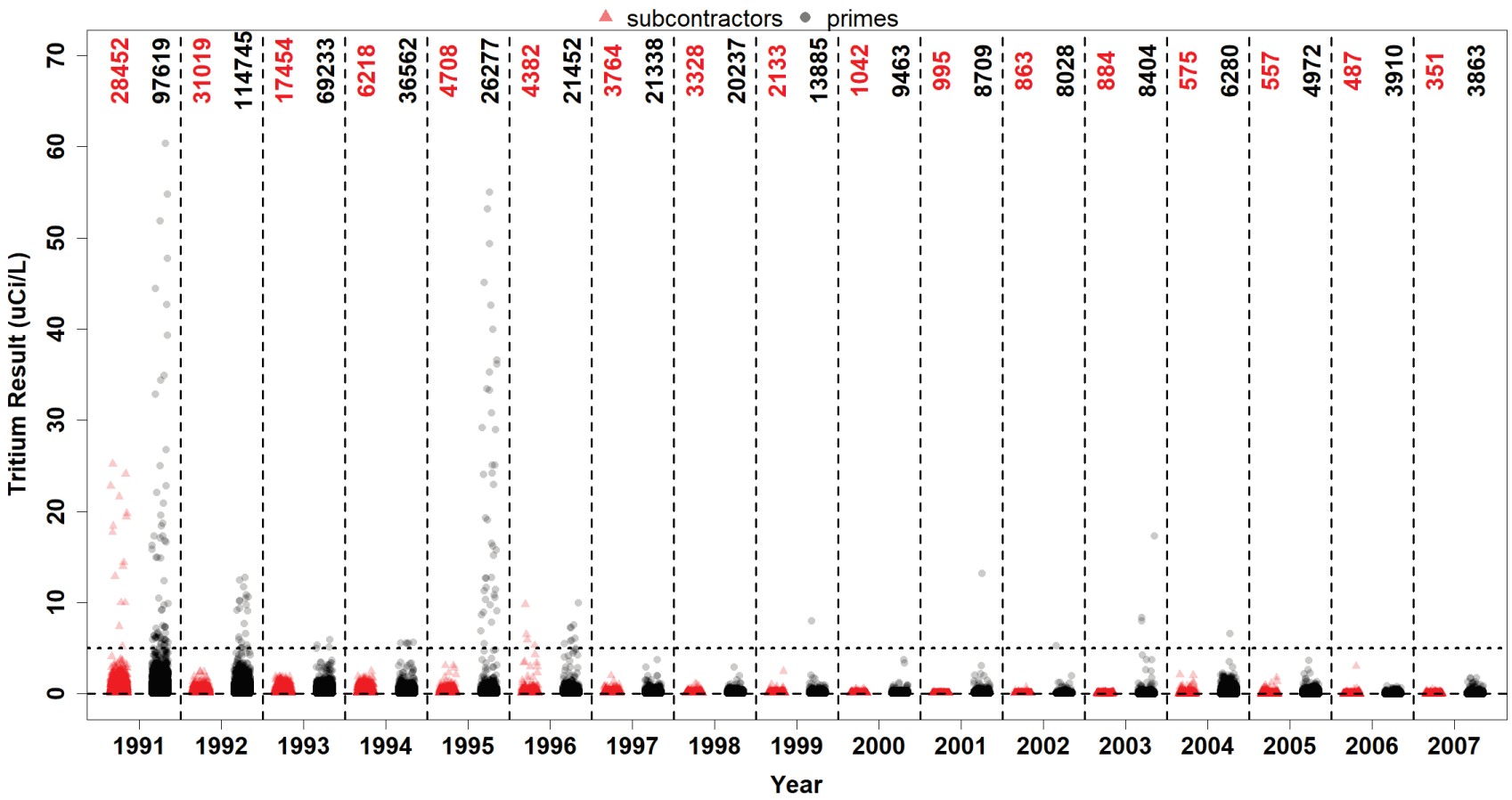

Figure C-5: Scatterplot Using SC&A Definition of Subcontractors (red, left) and Primes (black, right) Tritium Bioassay Data.

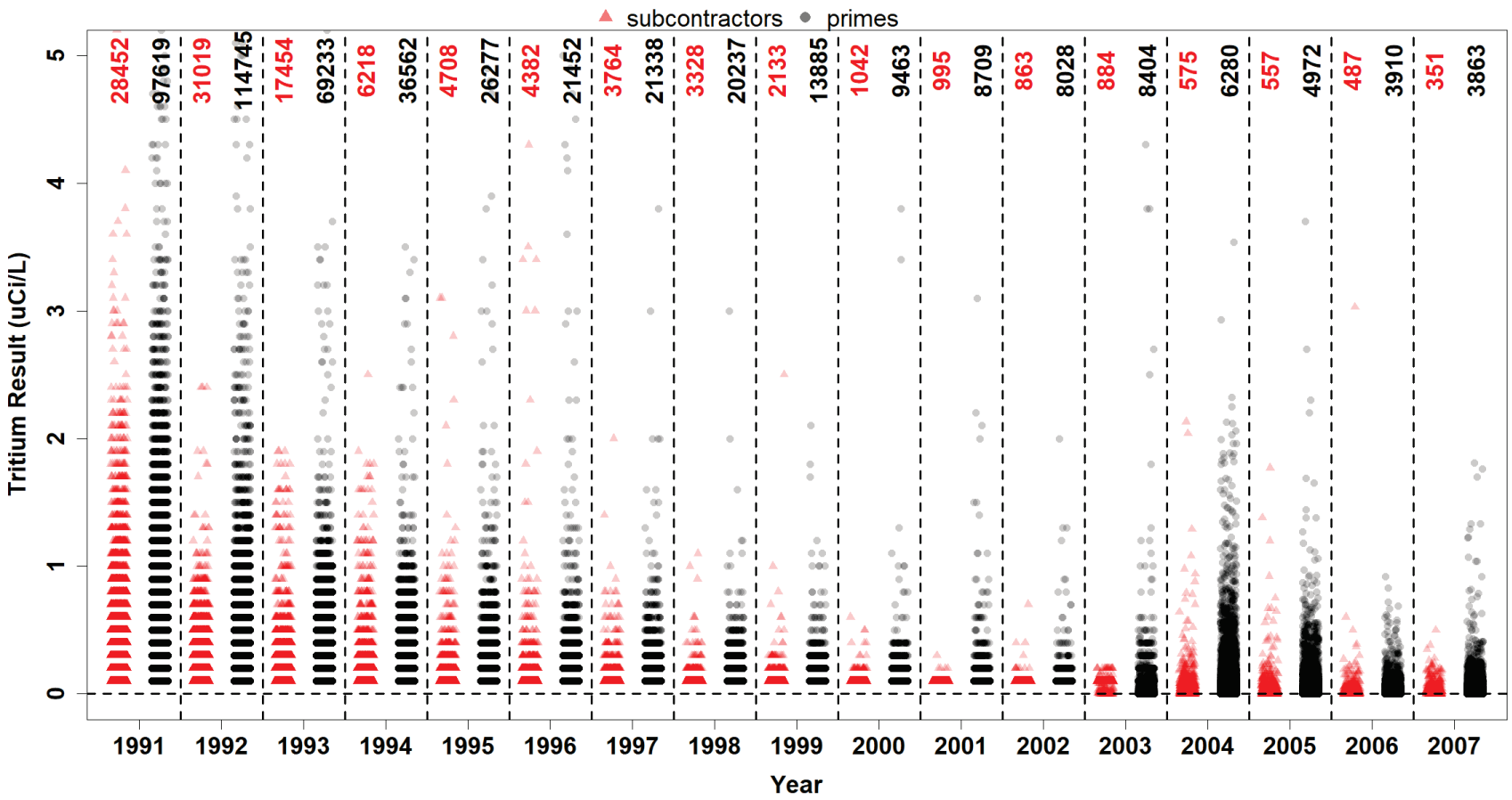

Figure C-6: Scatterplot Using SC&A Definition of Subcontractors (red, left) and Primes (black, right) Tritium Bioassay Data with a Zoomed Y-Axis.

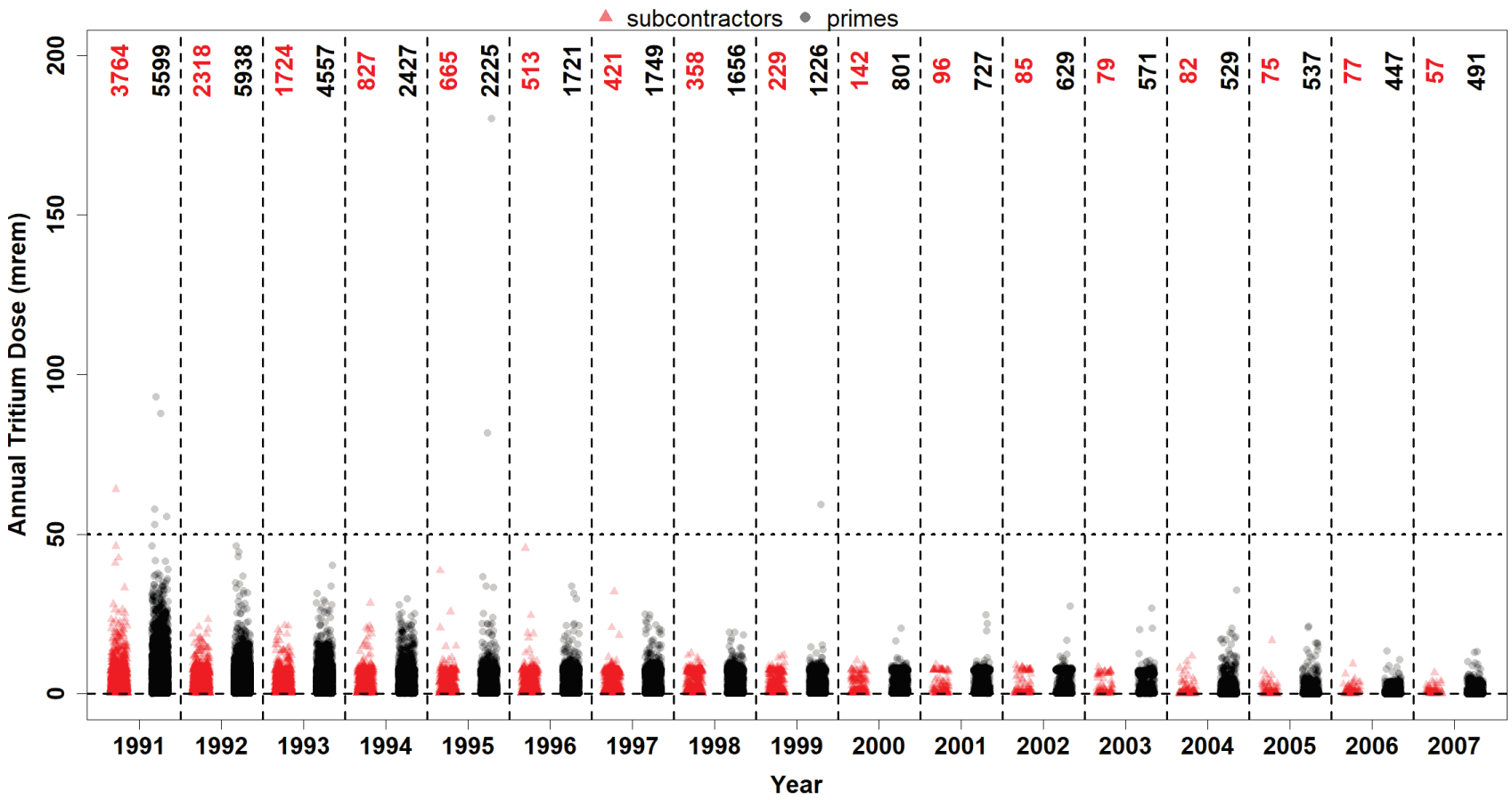

Figure C-7: Scatterplot Using SC&A Definition of Subcontractors (red, left) and Primes (black, right) Annual Tritium Doses.

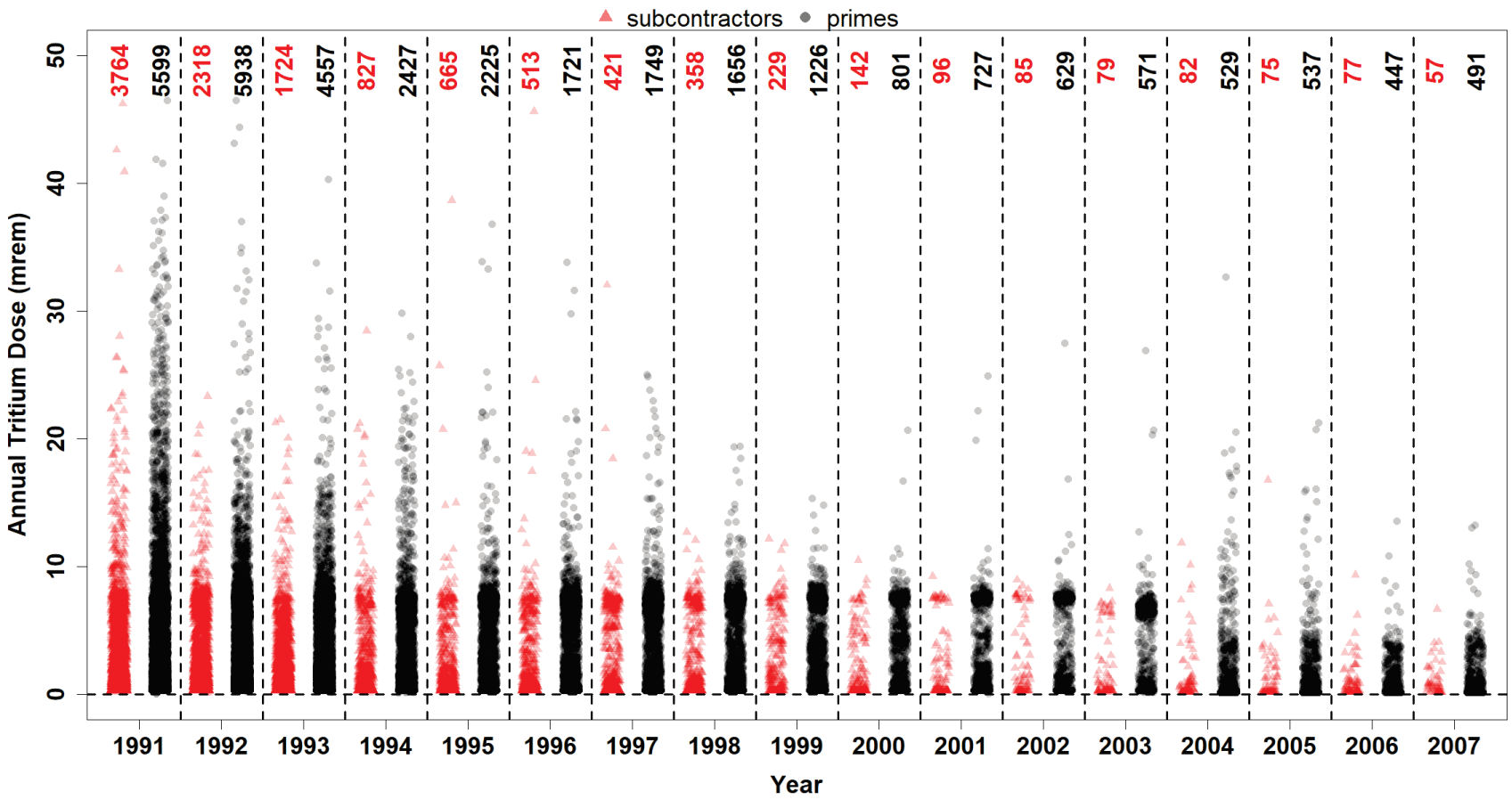

Figure C-8: Scatterplot Using SC&A Definition of Subcontractors (red, left) and Primes (black, right) Annual Tritium Doses with a Zoomed Y-Axis.

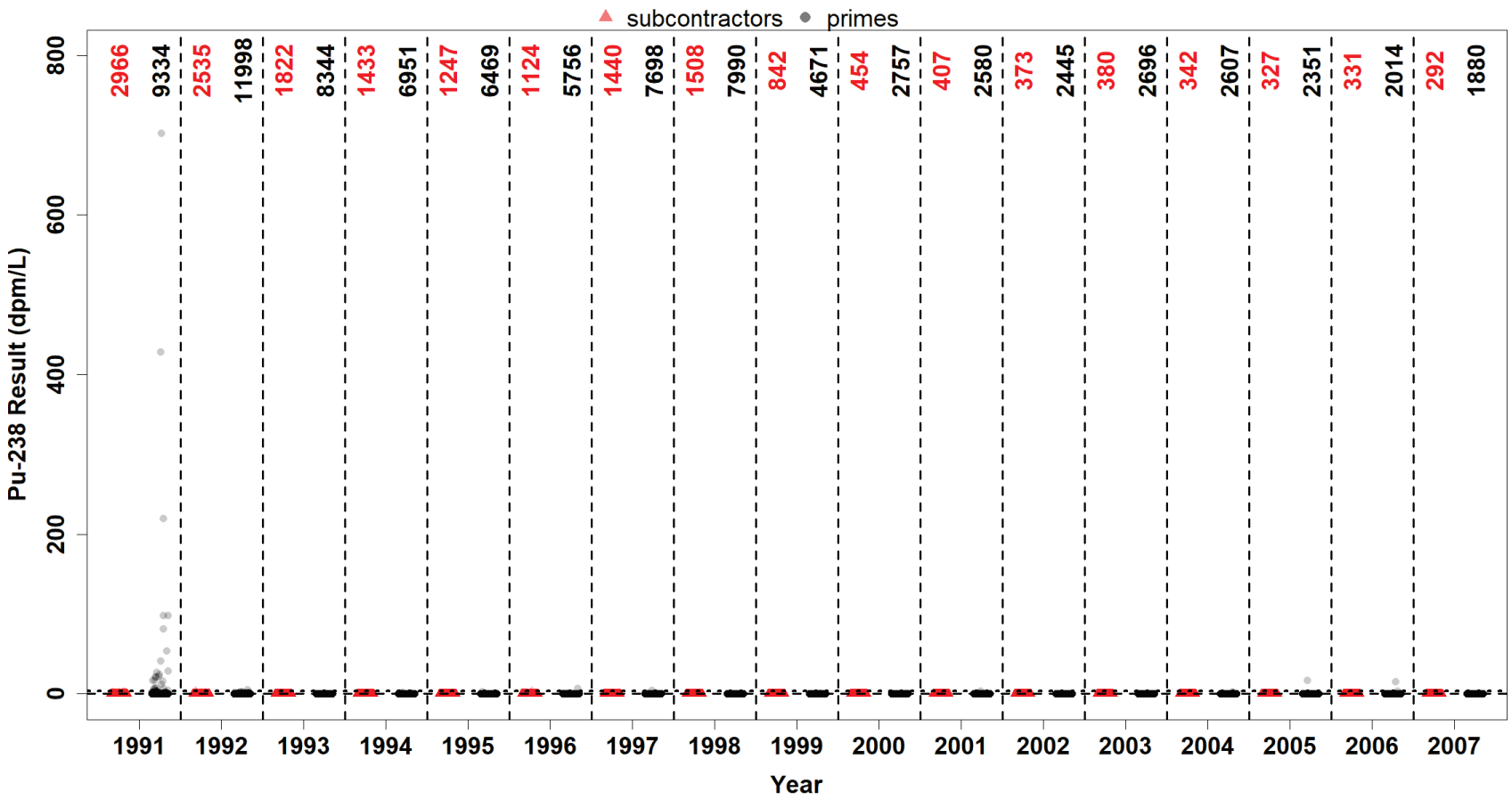

Figure C-9: Scatterplot Using SC&A Definition of Subcontractors (red, left) and Primes (black, right) Pu-238 Bioassay Data.

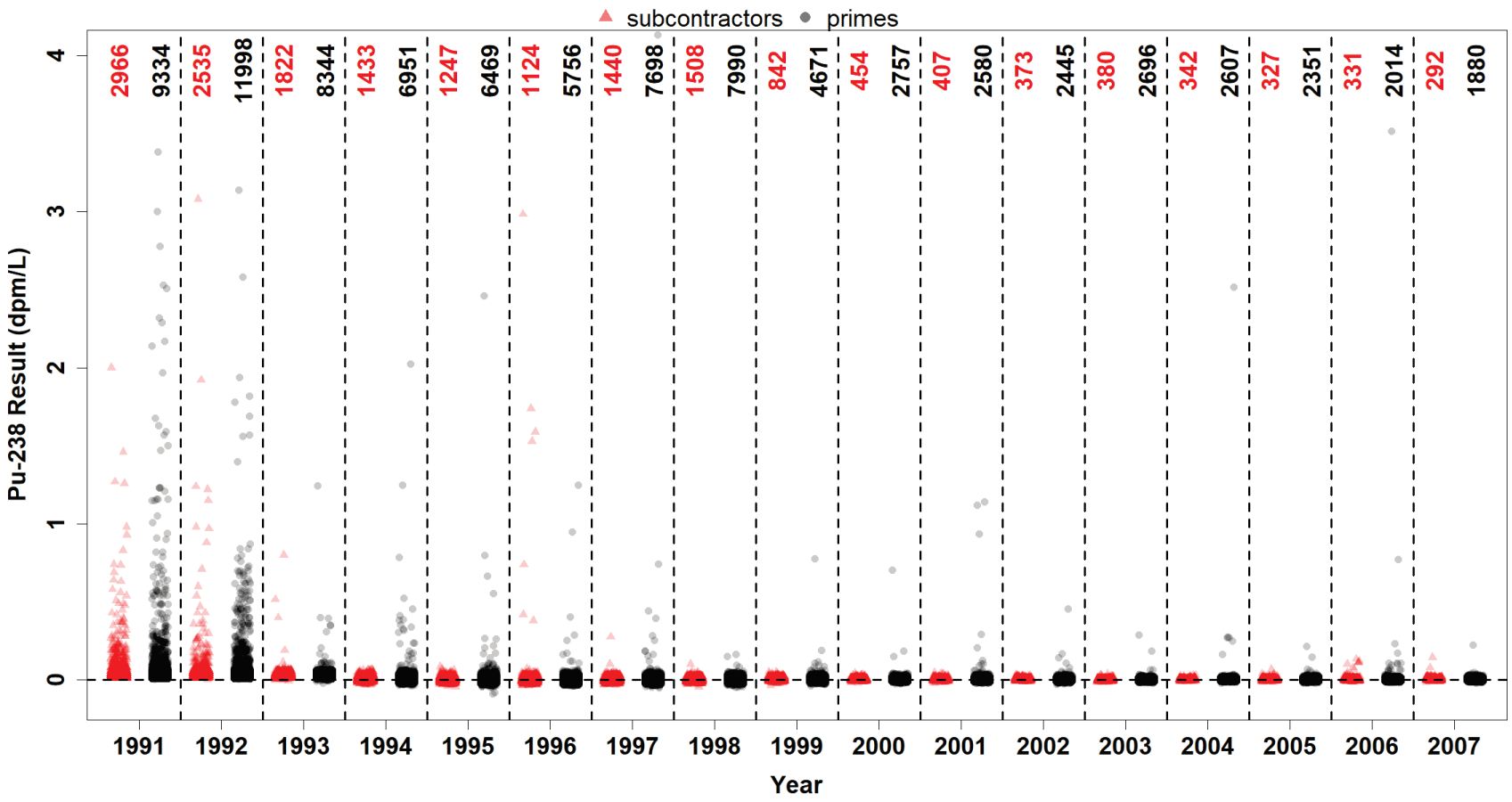

Figure C-10: Scatterplot Using SC&A Definition of Subcontractors (red, left) and Primes (black, right) Pu-238 Bioassay Data with a Zoomed Y-Axis.

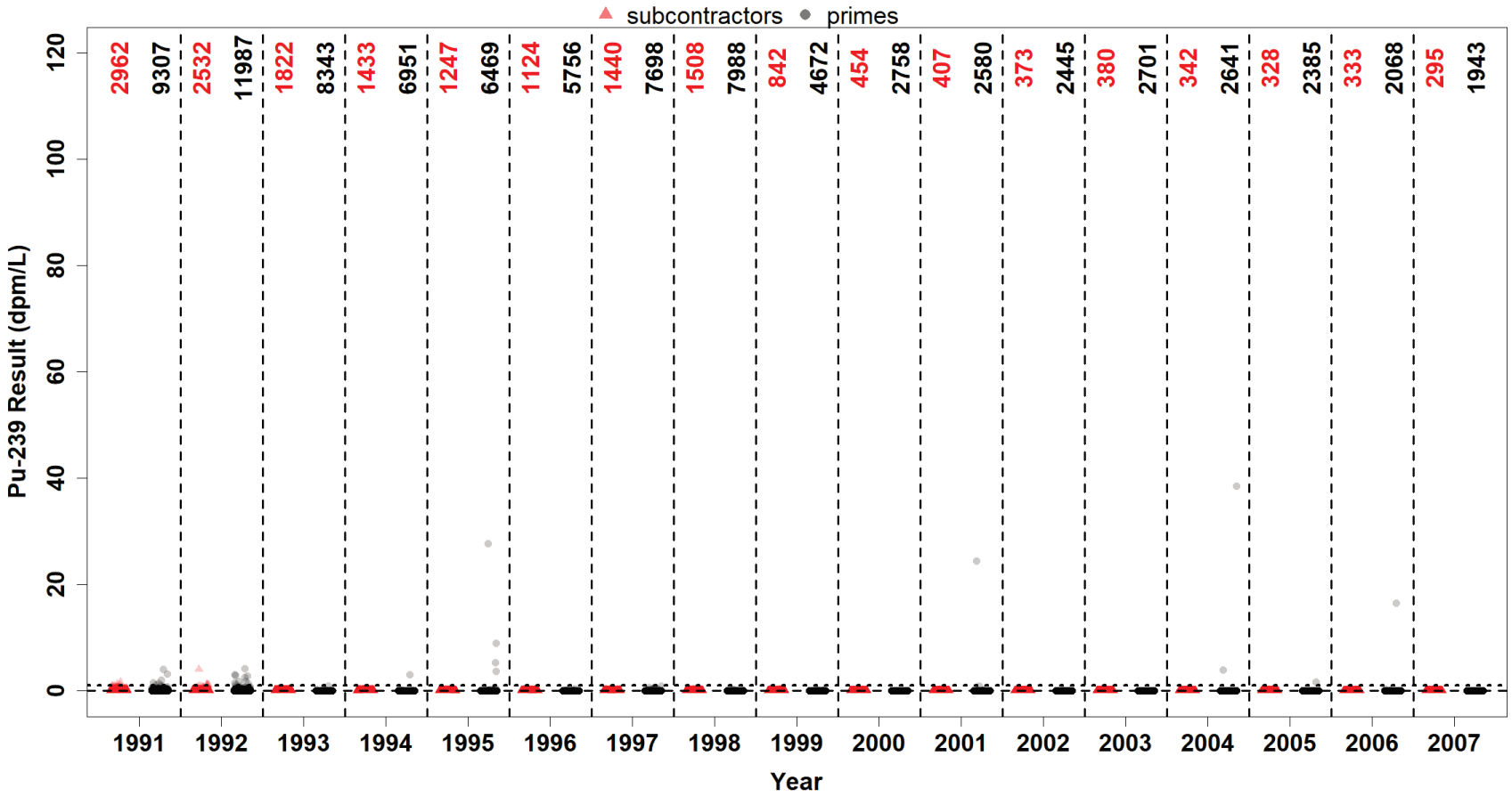

Figure C-11: Scatterplot Using SC&A Definition of Subcontractors (red, left) and Primes (black, right) Pu-239 Bioassay Data.

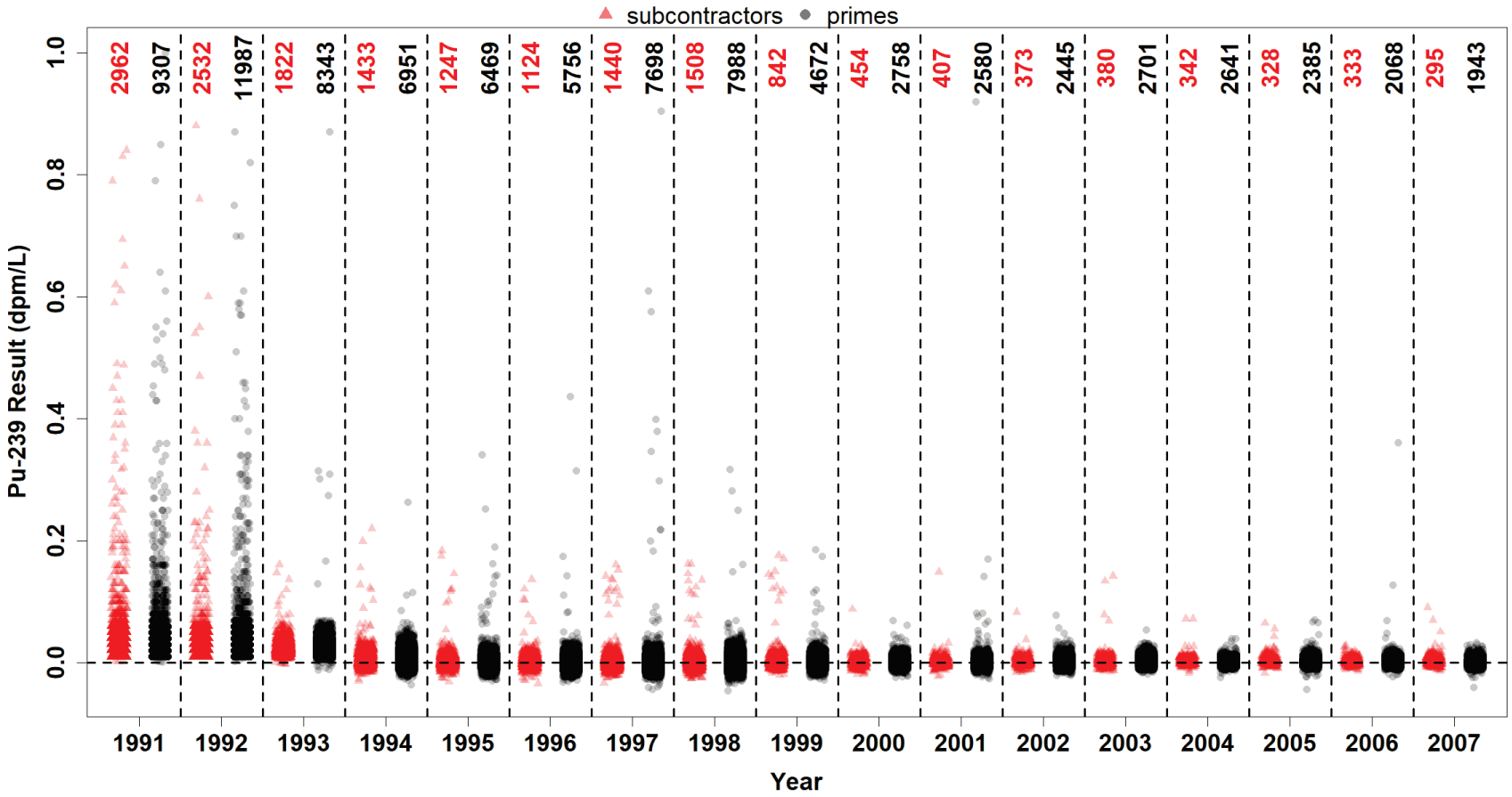

Figure C-12: Scatterplot Using SC&A Definition of Subcontractors (red, left) and Primes (black, right) Pu-239 Bioassay Data with a Zoomed Y-Axis.

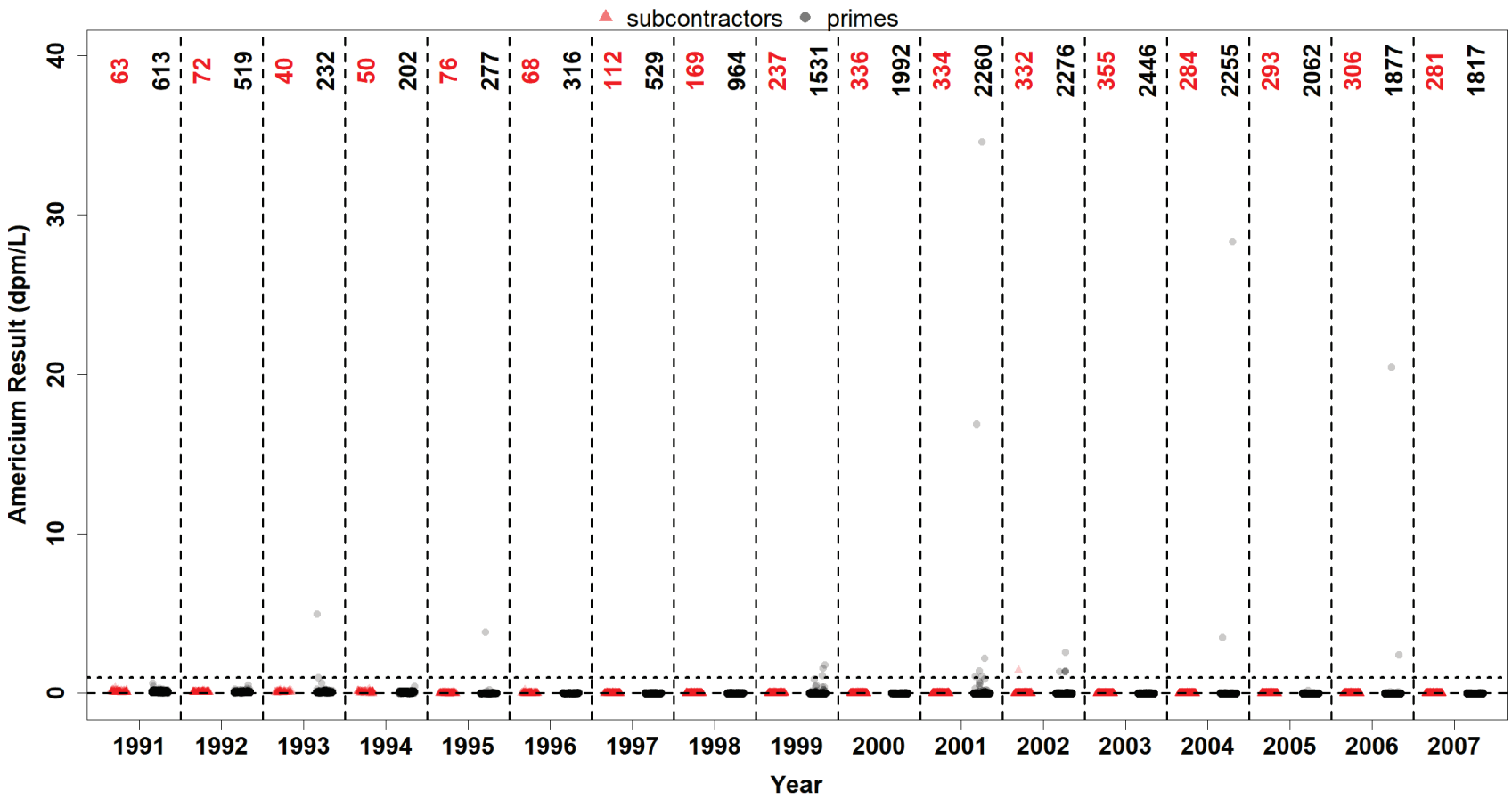

Figure C-13: Scatterplot Using SC&A Definition of Subcontractors (red, left) and Primes (black, right) Americium Bioassay Data.

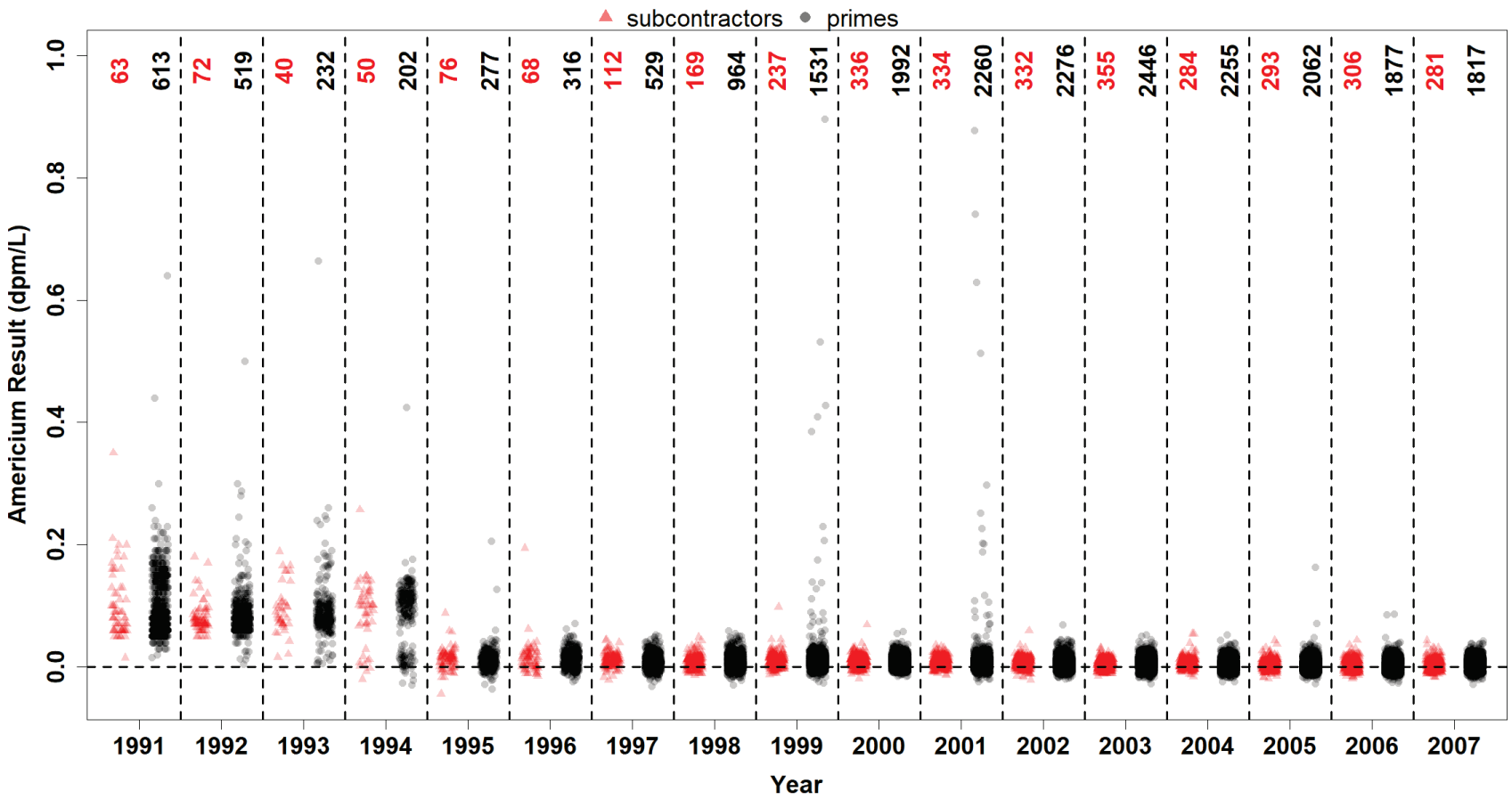

Figure C-14: Scatterplot Using SC&A Definition of Subcontractors (red, left) and Primes (black, right) Americium Bioassay Data with a Zoomed Y-Axis.

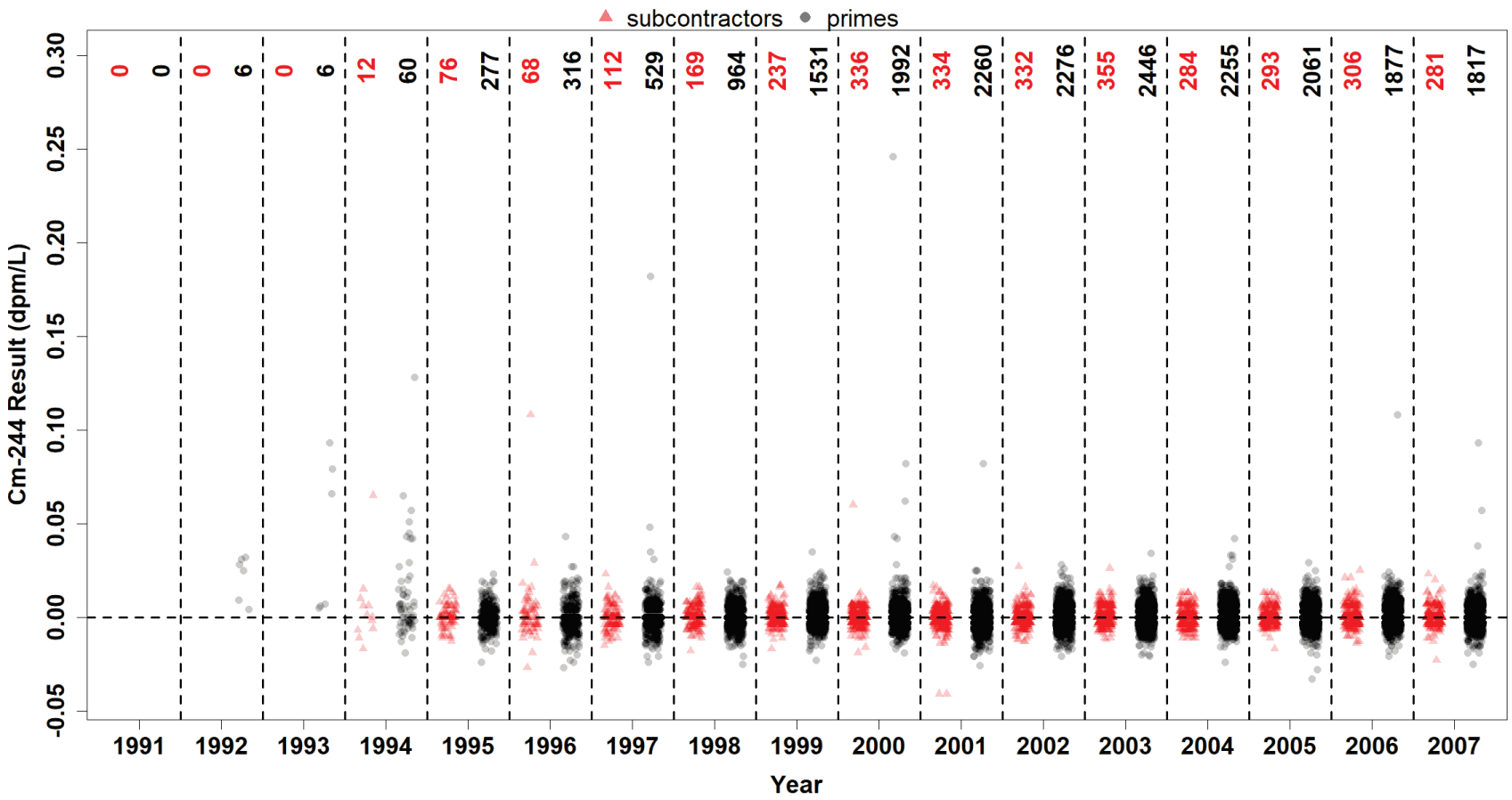

Figure C-15: Scatterplot Using SC&A Definition of Subcontractors (red, left) and Primes (black, right) Curium Bioassay Data.

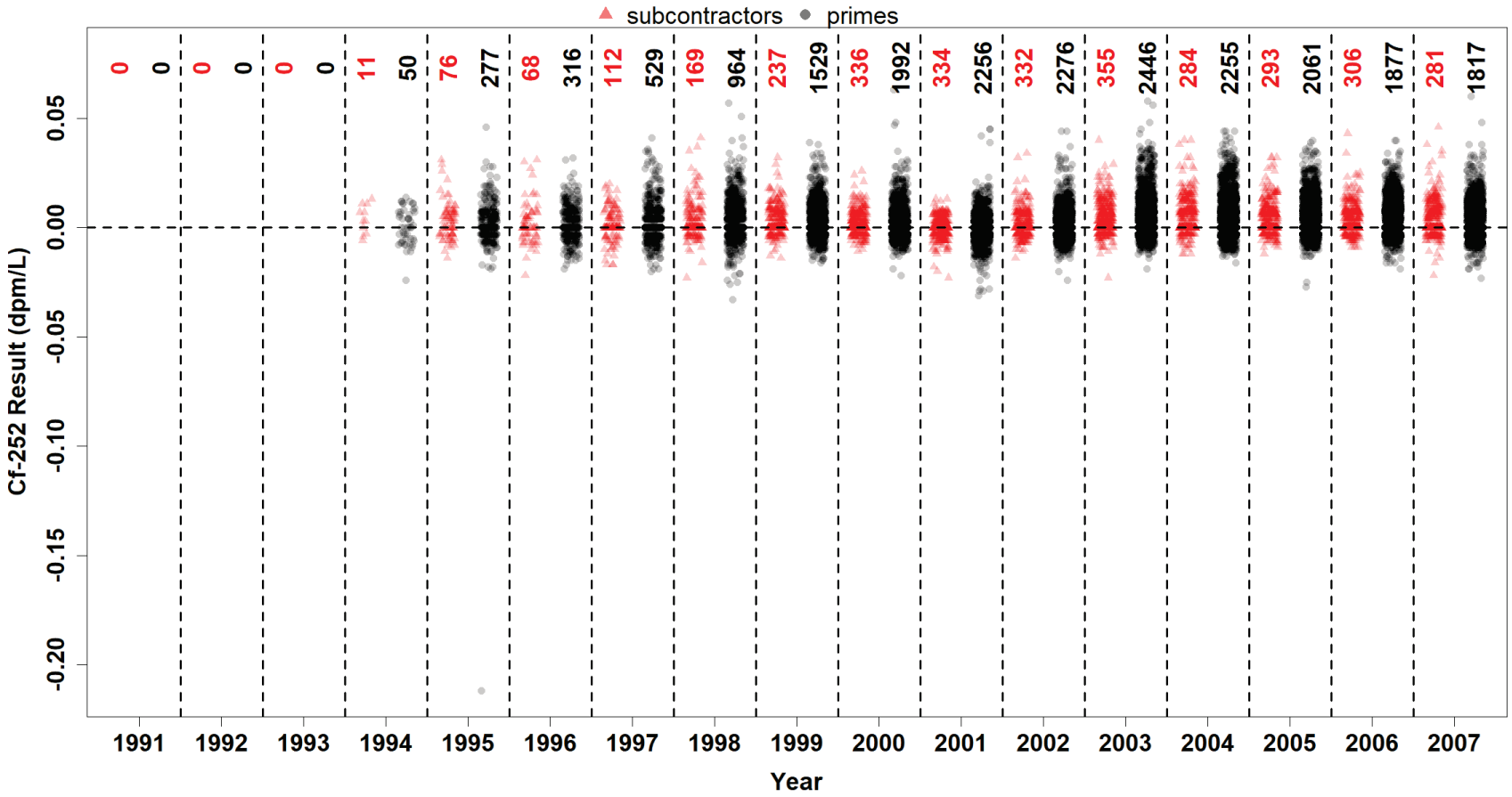

Figure C-16: Scatterplot Using SC&A Definition of Subcontractors (red, left) and Primes (black, right) Californium Bioassay Data.

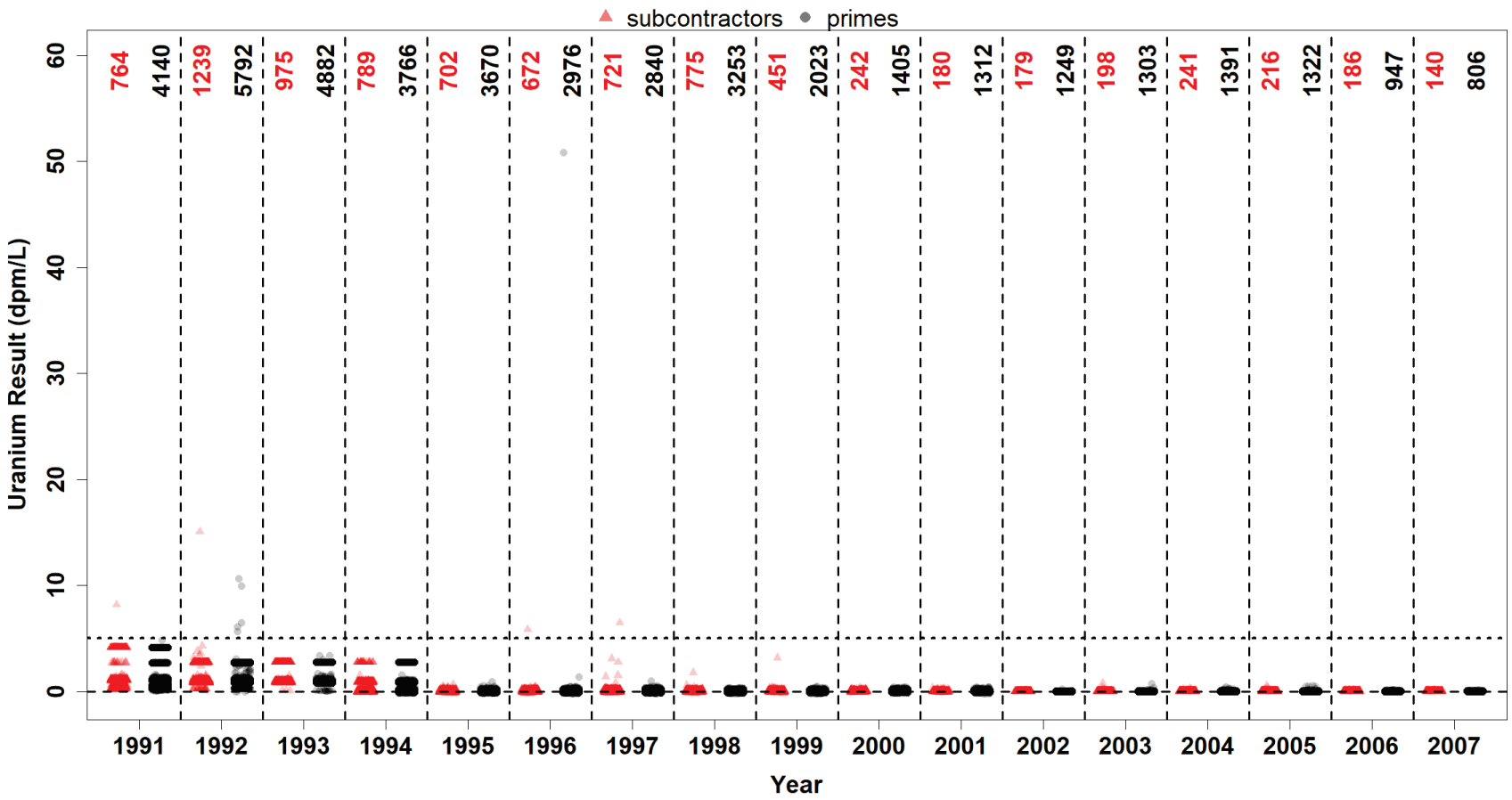

Figure C-17: Scatterplot Using SC&A Definition of Subcontractors (red, left) and Primes (black, right) Uranium Bioassay Data.

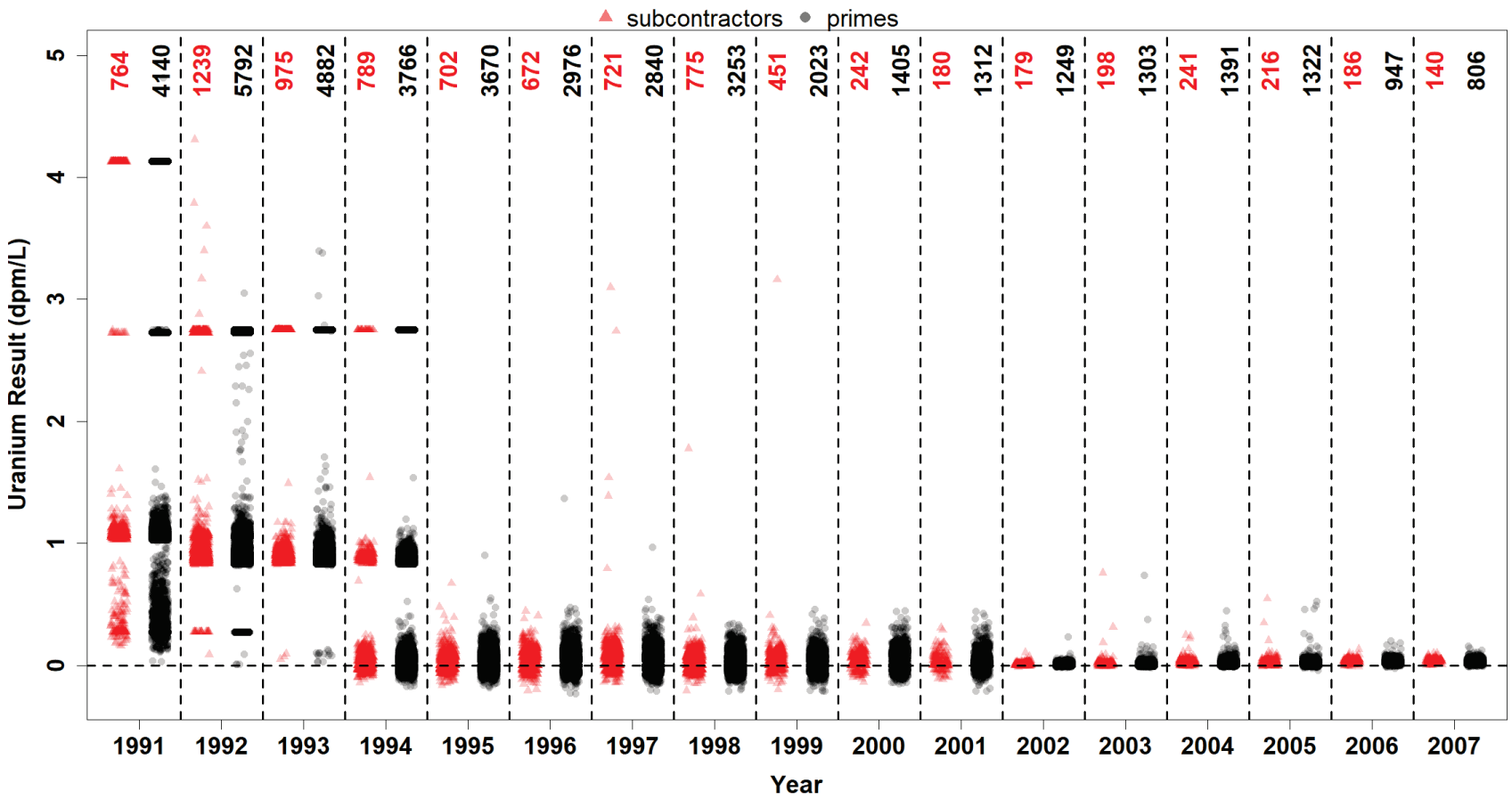

Figure C-18: Scatterplot Using SC&A Definition of Subcontractors (red, left) and Primes (black, right) Uranium Bioassay Data with a Zoomed Y-Axis.

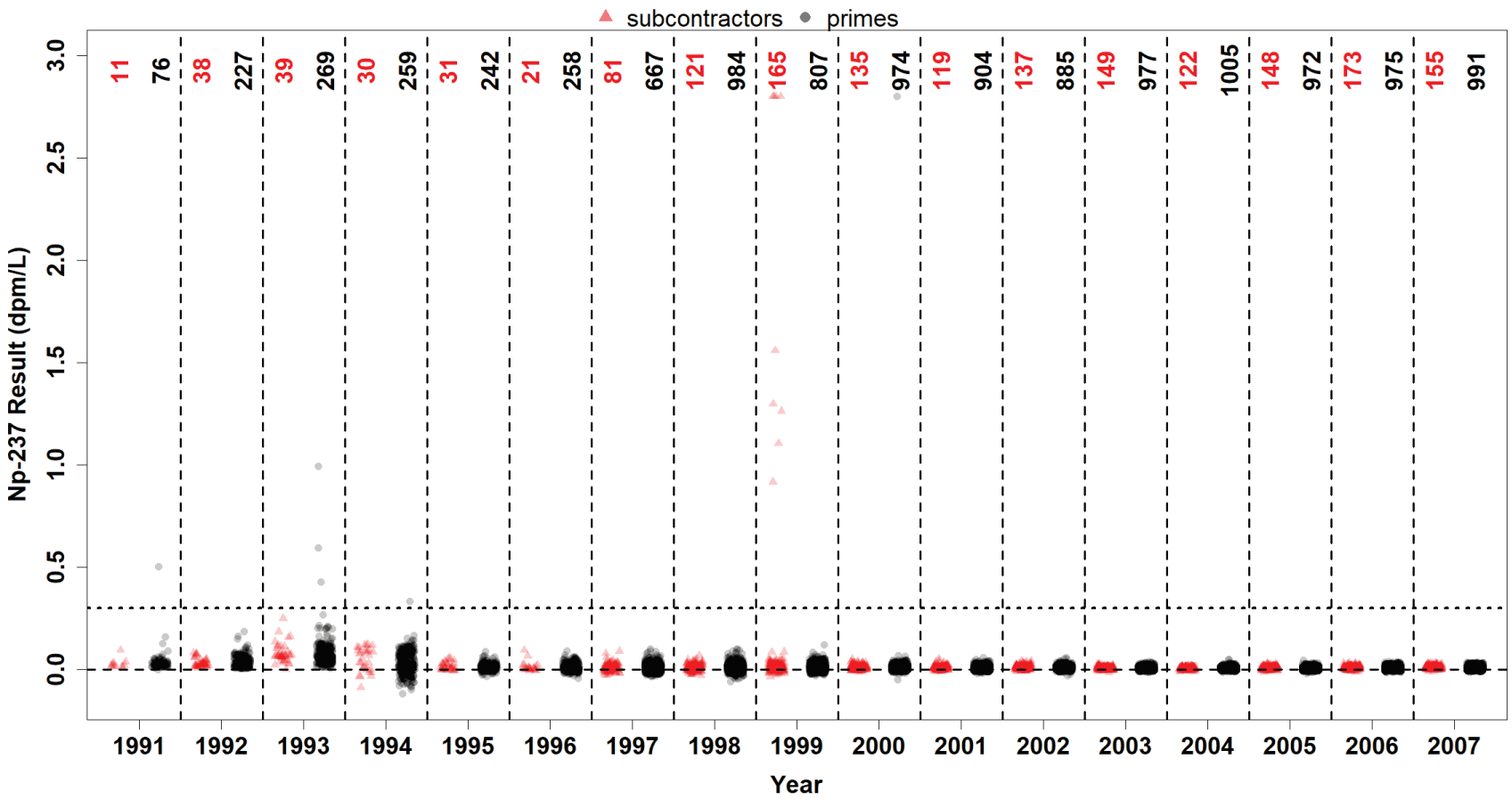

Figure C-19: Scatterplot Using SC&A Definition of Subcontractors (red, left) and Primes (black, right) Neptunium Bioassay Data.

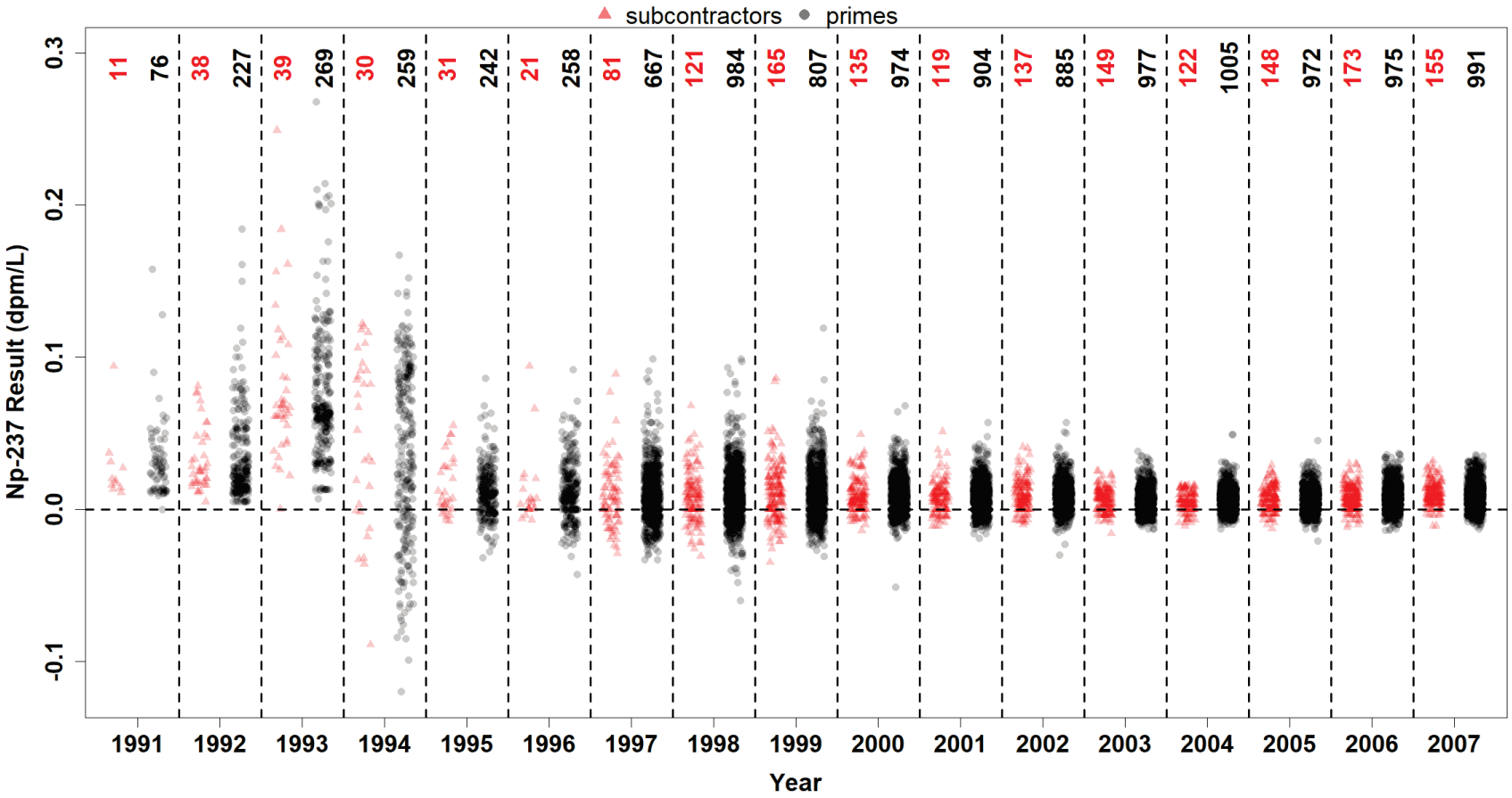

Figure C-20: Scatterplot Using SC&A Definition of Subcontractors (red, left) and Primes (black, right) Neptunium Bioassay Data with a Zoomed Y-Axis.

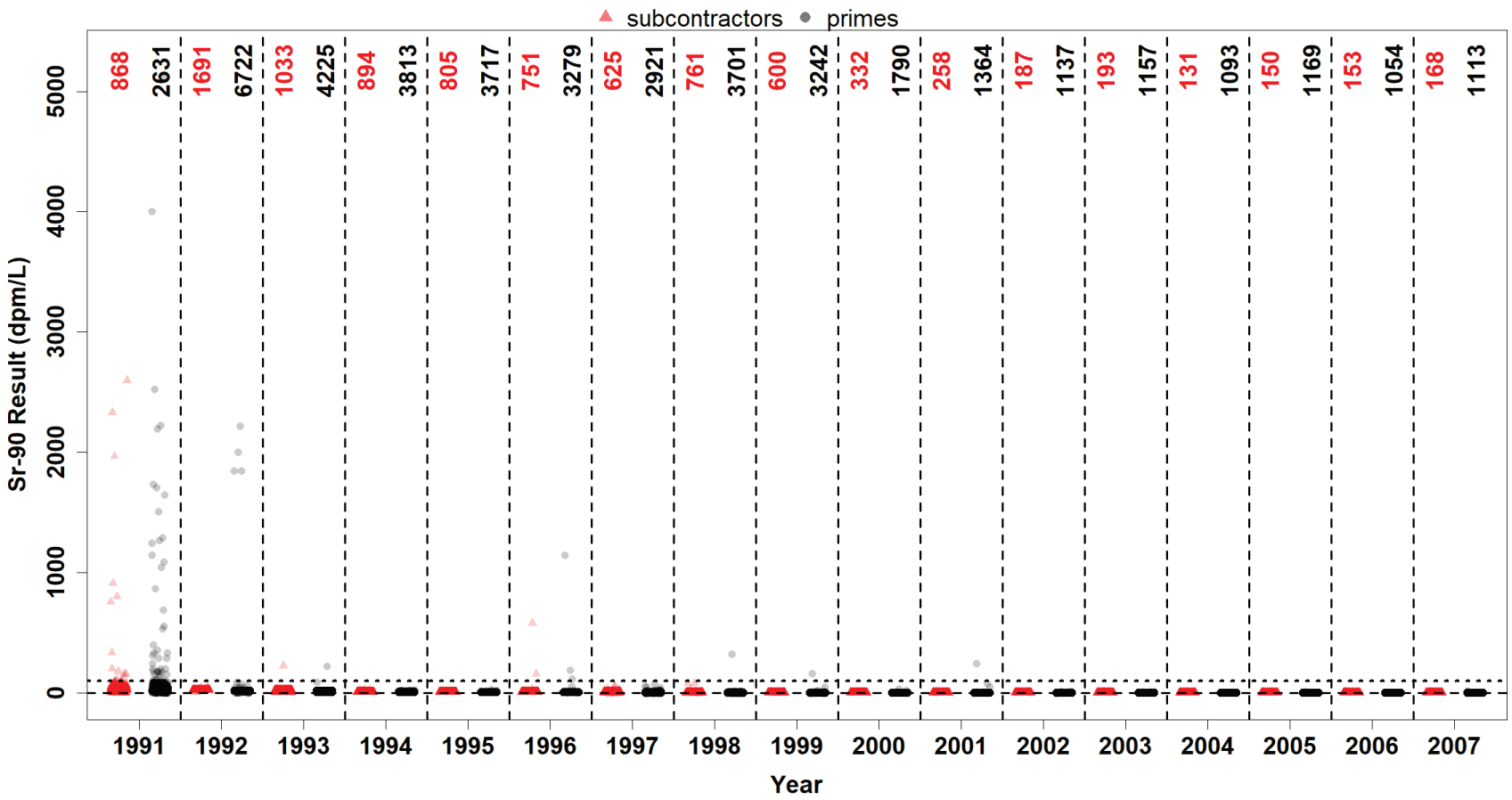

Figure C-21: Scatterplot Using SC&A Definition of Subcontractors (red, left) and Primes (black, right) Strontium Bioassay Data.

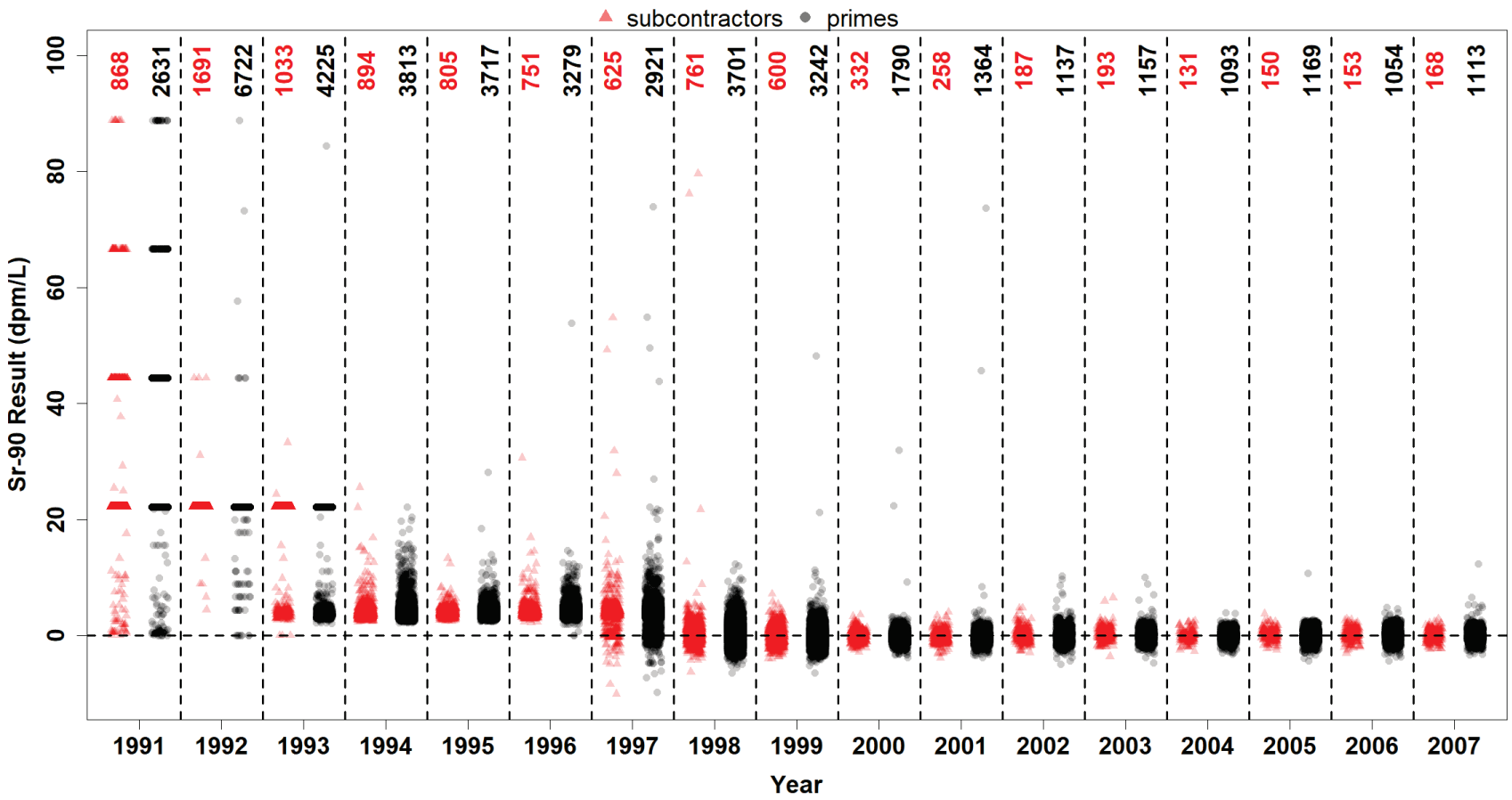

Figure C-22: Scatterplot Using SC&A Definition of Subcontractors (red, left) and Primes (black, right) Strontium Bioassay Data with a Zoomed Y-Axis.