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PUBLICATION RECORD

EFFECTIVE DATE	REVISION NUMBER	DESCRIPTION
09/10/2012	00	New report initiated to evaluate Savannah River Site mixed fission and activation product coworker models. Incorporates formal internal and NIOSH review comments. 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

AMW	all monitored worker
CTW	construction trade worker
DOE	U.S. Department of Energy
dpm	disintegrations per minute
GM	geometric mean
GSD	geometric standard deviation
ID	identification
L	liter
MCPT	Monte Carlo permutation test
MFP	mixed fission product (period or dataset)
MFPG	mixed fission product-gamma (period or dataset)
MPM	maximum possible mean
nCi	nanocuries
NIOSH	National Institute for Occupational Safety and Health
NOCTS	NIOSH Claims Tracking System
OPOS	one person – one sample
ORAU	Oak Ridge Associated Universities
ROS	regression on order statistics
SRDB Ref ID	Site Research Database Reference Identification (number)
SRS	Savannah River Site
TLD	thermoluminescent dosimeter
unk	unknown
WBC	whole-body count

1.0 INTRODUCTION

At the Savannah River Site (SRS), some workers might have been exposed to mixed fission and activation products without being monitored for that potential exposure. The Oak Ridge Associated Universities (ORAU) Team Dose Reconstruction Project for the National Institute for Occupational Safety and Health (NIOSH) uses coworker models to estimate doses for workers who were not monitored for exposure to radioactive materials but might have been exposed to radioactive materials (ORAUT 2007, p. 13). These doses are referred to as *unmonitored dose*. Coworker models are typically constructed using data from all monitored workers by fitting a lognormal probability distribution to the data (ORAUT 2005, 2006) to estimate the geometric mean (GM) and geometric standard deviation (GSD) of the doses. Coworker models for external dose are usually constructed from external doses that were assigned to individuals with film badges and thermoluminescent dosimeters (TLDs). Coworker models for internal dose are calculated using bioassay data that are later evaluated in terms of chronic intake rates and, ultimately, internal doses.

Rather than using all monitored workers to construct a coworker model, an analysis can stratify monitored workers into subgroups (i.e., strata) and construct separate coworker models for each stratum. Stratification offers potential advantages, such as more precise estimates of the dose to unmonitored workers in a stratum, but it also has a number of potential drawbacks and limitations (ORAUT 2010). The purpose of this report is to evaluate two proposed strata in relation to bioassay data, potential intakes, and internal doses of mixed fission and activation products. The two strata consist of (1) the construction trade worker (CTW) stratum that includes workers classified as CTWs in accordance with ORAUT-OTIB-0052 (ORAUT 2011a) and (2) the nonCTW stratum that includes workers not classified as CTWs (non-construction trade workers). A statistically and practically significant difference between the CTW and nonCTW strata could warrant coworker models based on the individual strata rather than the entire population of monitored workers, which is designated as the all monitored worker (AMW) stratum in this document.

2.0 BIOASSAY DATA VERSUS DOSE

Monitoring for workers who have the potential for exposure to external radiation typically consists of a dosimeter (e.g., TLD or film badge) they wear on the upper torso of the body. The dosimeter indicates the cumulative dose to the whole body that is received between readings of the dosimeter, which creates monitoring intervals that can be anywhere from days to months in duration. A key property of the reported doses for each interval is that, for a given individual, the doses are statistically independent of each other. For example, the received dose in a given month, by itself, provides no information about the dose in the next month and, similarly, the received dose in a given year, by itself, provides no information about the dose in the next year.

Internal dose monitoring programs are in many ways similar to the above-described external dose programs, but internal dose programs tend to be based on bioassay rather than dosimeters. This is an important difference because, if an individual has an intake of radioactive material such that radioactive material is detected in a given sample, subsequent bioassay samples can also have detectable radioactivity even if there have been no additional intakes. This means bioassay results can correlate with each other and are no longer statistically independent. Such a correlation can exist for a brief period (after a small intake of tritium, for example), or for the length of a career (after a large intake of plutonium, for example). For most mixed fission and activation product radionuclides, such a correlation may hold for a period of a few months to a year or two.

Operational bioassay programs can generate multiple results for an individual in a given period (e.g., a year), which creates a related problem if an individual is involved in an incident and has more (potentially many more) bioassay results than other workers. If these are not accounted for, the problems of correlated data and unequal numbers of samples per person can skew evaluation of the data by unequally weighting data for that individual. The solution to this problem is to generate a single statistic that characterizes multiple bioassay results for each person in a given period. This is referred to as a *one person – one sample* (OPOS) statistic. The OPOS statistic is calculated using the maximum possible mean (MPM) methodology (ORAUT 2012).

3.0 METHODOLOGY

The CTW and nonCTW strata were compared using the methodology from ORAUT-RPRT-0053 (ORAUT 2012). The basic steps of this methodology, discussed in more detail below, are:

- Evaluate the complete set of bioassay data and determine the job classification (CTW or nonCTW) for each individual for each bioassay sample.
- For each individual and each period, determine the OPOS statistic for the AMW, CTW, and nonCTW strata (See Section 3.3 for more detail).
- Determine the GM and GSD urinary excretion rates for the AMW, CTW, and nonCTW for each period using the regression on order statistics (ROS), effective fit, and binomial methods (ORAUT 2012) as appropriate.
- Compare the CTW and nonCTW strata using the Monte Carlo permutation test (MCPT) and Peto-Prentice tests (ORAUT 2012) to determine if there is a statistically significant difference.
- If there is a statistically significant difference, compare the CTW and nonCTW strata to determine if there is a practical difference.

At SRS, all personnel who have worked in regulated areas (“Regulated Zones” and “Radiation Danger Zones”), including construction workers, have been periodically checked for assimilation of radioactive material by urinalysis bioassay (DuPont 1961–1969). The only exception to this might have been when special exclusion zones were established; when this occurred, the outer boundaries of the radiological areas were monitored (ORAUT 2008). Notification of sample request was given to employees through their supervisors. Special bioassay samples were requested of workers, including construction workers, by Health Physics through the worker’s supervisor, when a potential assimilation of radioactive material was suspected through air or surface contamination monitoring (DuPont 1961–1969).

CTWs are potentially subject to different bioassay practices than other workers. CTWs, many of whom are contractors, commonly submit bioassay samples after suspected uptakes and at the completion of jobs. This is in contrast to other workers, especially those who are employed directly by the prime contractor, who are more likely to be on a routine bioassay program in addition to submitting bioassay samples after suspected uptakes. A postjob bioassay is more likely to occur soon after an uptake, either suspected or unidentified, than is a routine bioassay. They are therefore more likely to have a larger result. This potential difference in how the strata are monitored for intakes may lead to higher results for CTWs in comparison with the other strata.

3.1 MIXED FISSION AND ACTIVATION PRODUCT BIOASSAY DATA

In the absence of site logbooks and databases, mixed fission and activation product bioassay data were obtained from the NIOSH Claims Tracking System (NOCTS) database for 1955 through 1989 as the best available compilation of data in a usable form (ORAUT 2009). The NOCTS database was queried on May 7, 2008, to generate a list of all claimants who worked at SRS before 1991. This list amounted to 1,421 individuals. Data for six additional individuals that became available during the data entry process were added for a total of 1,427 individuals. The NOCTS Identification (ID) numbers of the specific individuals identified are listed in ORAUT (2011b).

3.1.1 Urinalysis Data

The *in vitro* bioassay data for these individuals were entered into spreadsheets (some already existed in this form after the completion of dose reconstructions for those individuals) and subjected to a 100% verification review by a second person. Mixed fission and activation product urinalysis bioassay was performed by two methods. From 1955 through 1965, gross beta analysis was performed for the majority of the urinalysis bioassay samples. Starting in 1966 and continuing through 1988, gross gamma analysis was performed for the majority of the urinalysis bioassay samples. These two periods are called MFP for “mixed fission product” and MFPG for “mixed fission product-gamma,” respectively.

Records with results or units of “LIP” (Lost In Process), “IA” (Insufficient Amount), or “Sample lost” were excluded from the evaluation because those records represent instances in which samples were collected but not analyzed. Records with units of per-unit-volume were adjusted to “per-1.5L” based on an assumed 1.5 L/d of urinary excretion. Volumes greater than 1 L were assumed to represent a full day’s voiding and were not adjusted. Volumes less than or equal to 1 L were normalized to 1.5 L. Activity units were assumed to be in dpm for MFP data and in nCi for MFPG data.

3.1.2 WBC Data

In addition, ^{137}Cs WBC data are available for 1961 through 1989. The *in vivo* bioassay data for these individuals, 923 of which had whole-body count (WBC) data, were entered into spreadsheets (some of which already existed in this form after the completion of dose reconstructions for individuals). The spreadsheets were subjected to a quality assurance verification in accordance with MIL-STD-105E, *Sampling Procedures and Tables for Inspection by Attributes* (DOD 1989), which it passed with less than a 1% error rate. For this verification, 315 records (of 33,088) were checked with only 1 error found. Per MIL-STD-105E, for a lot between 10,001 and 35,000 items, less than 8 errors results in lot acceptance based on the statistical variability of sampling. Records with Illegible, incomplete, or blank results were excluded. Multiple same-day WBCs were averaged unless one record was marked as “MDA activity used,” in which case the result for that record was excluded from the average.

The various bioassay data types and their periods of use are given in Table 3-1.

Table 3-1. Bioassay data types and date ranges used.

Bioassay type	Date range
Urine – MFP	1955–1965
Urine – MFPG	1966–1988
Cs-137 WBC	1971–1989

3.2 JOB CLASSIFICATION DETERMINATION

NIOSH directed the ORAU Team to use *1954 Craft Payroll Codes* (Author unknown undated) as the source of crafts and occupations and the payroll ID field to determine which workers should be assigned to the CTW stratum. NIOSH and the ORAU Team reviewed the crafts in that document and determined that the following are CTW crafts at SRS that could have involved radiological exposure. The payroll ID prefix is listed first with each of the CTW crafts:

- 02 – Instruments (considered electricians in this analysis)
- 05 – Laborer

- 06 – Carpenter
- 12 – Iron Worker
- 14 – Heavy Equipment Operator
- 15 – Steelworker
- 18 – Millwright
- 20 – Boilermaker
- 21 – Sheetmetal Worker
- 25 – Electrician
- 26 – Pipefitter
- 31 – Insulator
- 33 – Painter

In addition, NIOSH and the ORAU Team considered any worker in Payroll Roll #2 (which is different from payroll prefix 02 in the list above) with one of the craft (occupational title) listings above to be a CTW for this analysis. An additional craft code, 17, was not given in *1954 Craft Payroll Codes* but was determined to be associated with "Painter" from examination of SRS work history data. The worker history cards were reviewed to determine the Payroll ID# and/or occupational title for each individual for each bioassay results. The last entry on the worker history card before the date of the bioassay was used to determine the Payroll ID# and/or occupational title.

The following steps were used to create a spreadsheet and identify CTW, nonCTW, and unk data. For each bioassay record, the ORAU Team used the sample date, name, and payroll ID number (PR ID) to retrieve the assigned job or occupational title from the worker's SRS work history card (O:\DOE Site Images\Savannah River\Work History Information\EDAR & WkHx Images) for the sampled date because a worker could have multiple occupational titles over time. In some instances, the value of the PR ID field was different on the card than in the bioassay file and was changed in the spreadsheet for this evaluation. Occupational titles were recorded as stated on the card. When either the personal information could not be found in the SRS worker history cards or when an occupational title was not recorded on the matched card, an entry of "unknown" was recorded in the Occupational Title field. Once occupational titles had been queried for all bioassay records, various instances of the same high-level occupational title were made consistent and recorded in the Changed Occupational Title field. For example, Research Chemist and Junior Chemist were considered to be Chemist. The values of two fields, "Changed Payroll ID#" and "Changed Occupational Title," were used to denote the value of the CTW field in that particular row. The name of these fields includes "Changed" to distinguish them from the original Payroll ID# and occupation title fields. The "changed Payroll ID #" field reformats the originally recorded Payroll ID#s into a consistent format (hyphens, leading zeros, etc.) while retaining the originally recorded number. No distinction was made between DuPont workers and non-DuPont workers.

1. If the Changed Payroll ID# was of the form "XX-ppppp" where "XX" is 02, 05, 06, 12, 14, 15, 17, 18, 20, 21, 25, 26, 31, or 33 and "ppppp" is a 5- or more digit number, the record was treated as that of a CTW.

2. If the Changed Payroll ID# was of the form "T-nnnn" where "nnnn" is a number, the record was treated as that of a nonCTW. (Payroll IDs starting with "T-" indicate payroll 1, which did not apply to CTWs.)

3. If the Changed Payroll ID# was of the form "mmmmm" where "mmmmm" is a 2-, 3-, 4-, or 5-digit number only, the value of Changed Occupational Title was checked.

   a. If the Changed Occupational Title was “Boilermaker,” “Carpenter,” “CTW,” “Electrician,” “Glass Blower,” “Heavy Equipment Operator,” “Helper,” “Laborer,” “Maintenance,” “Mechanic,” “Millwright,” “Painter,” or “Rigger,” the record was treated as that of a CTW.

   b. If the Changed Occupational Title was “Roll 2”, “unknown,” or null, the value of CTW was set to “unk.”

   c. For all remaining rows, the record was treated as that of a nonCTW.

4. All remaining records were treated as unk.

Sufficient data was available for all bioassay data to classify the record as CTW or nonCTW. Therefore, there were no unknowns.

3.3 ONE PERSON – ONE SAMPLE STATISTIC

An average bioassay result using the MPM method was determined for each individual for each evaluated period and each job category. This resulted in a table of OPOS results for the AMW stratum that used all available bioassay data and two other tables for the CTW and nonCTW strata that used only bioassay data that was identified as belonging to each of those strata. Because it was possible for a worker to change jobs during the course of a single evaluated period, it is possible that a worker had some samples identified as nonCTW and others as CTW in the same period. Therefore, one person might have as many as three different OPOS results, one each for the AMW, CTW, and nonCTW stratum. Table 3-2 lists the number of total bioassay results and number of OPOS results for AMW and each stratum.

Table 3-2. Number of total bioassay and OPOS results per time period per stratum.

	AMW		CTW		nonCTW	
Period	Total results	OPOS results	Total results	OPOS results	Total results	OPOS results
1955	296	209	54	44	242	165
1956	477	285	96	64	381	221
1957	280	177	85	51	195	126
1958	237	136	80	50	157	86
1959	311	191	60	42	251	149
1960	382	276	115	74	267	202
1962	600	391	191	122	409	269
1963	501	328	152	102	349	226
1964	468	319	150	101	318	220
1965	491	314	155	97	336	217
1974	101	70	14	13	87	58
1975	132	87	27	22	105	65
1976	72	60	22	18	50	42
1977	99	81	20	19	79	62
1978	133	94	28	20	105	74
1979	116	94	21	19	95	75
1980	139	109	24	20	115	89
1981	147	120	25	23	122	97
1982	146	119	29	26	117	93
1983	140	113	29	28	111	85
1984	149	115	34	27	115	89
1985	97	78	18	13	79	65
1986	165	117	23	19	142	98
1987	126	110	28	24	98	86
1988	123	110	20	16	103	94

Most workers had only one or two bioassay results in a given period. However, some workers had more results due either to having a higher potential for routine exposure or as a result of an incident. Table 3-3 details the numbers of occurrences of multiple bioassay results averaged using the MPM method for each stratum.

Table 3-3. Number of bioassay results per individual per period.

Number of bioassay results per individual	Occurrences per stratum		
	AMW	**CTW**	**nonCTW**
Urinalysis data			
1	6,330	2,620	4,585
2	2,015	320	785
3	280	79	183
>3	115	57	122
WBC data			
1	1,473	316	1,159
2	266	40	226
3	50	3	49
>3	23	5	16

Table 3-4 lists the ratio of CTWs to nonCTWs that received bioassay monitoring for mixed fission and activation products for each year in the 1974 through 1981 time period. The number of manufacturing and technical workers (assumed to represent the nonCTWs) and the number of construction workers is based on the SRS monthly report abstracts prepared by Taulbee (2011) using the number of manufacturing, technical, and construction workers summarized for July of each year. In the early years, the CTWs had a higher bioassay rate than nonCTWs. Starting in 1978, the population and bioassay ratio annual variations level out and are consistent between the two groups. This is consistent with the implementation of the same radiological monitoring procedures for the two groups.

Table 3-4. Population and MFP monitoring ratios.

Year	# CTWs	# nonCTWs	Population ratio	Bioassay ratio
1974	600	5,205	0.12	0.22
1975	973	5,140	0.19	0.34
1976	995	5,407	0.18	0.43
1977	1,344	5,598	0.24	0.31
1978	1,973	5,944	0.33	0.27
1979	1,958	5,709	0.34	0.25
1980	1,991	6,050	0.33	0.22
1981	2,159	6,593	0.33	0.24

3.4 STATISTICAL ANALYSIS

Statistical analysis of each dataset was performed in accordance with ORAUT-RPRT-0053 (ORAUT 2012). First, each period was evaluated using the ROS method. If this method failed or yielded an unacceptable fit, the effective fit (maximum likelihood) method was used. For instances in which there were little or no uncensored data, the binomial fit method was used.

3.5 STRATA COMPARISON

For each period, the CTW stratum was compared to the nonCTW stratum to determine whether there were statistical differences at the 0.05 level of significance. Presence of a statistically significant difference was determined using the Peto-Prentice and MCPT tests. The Peto-Prentice and MCPT tests were not performed on the MFP and MFPG datasets due to the small amount of uncensored data.

4.0 RESULTS

4.1 BIOASSAY FITTING

- For the AMW population and each of the CTW and nonCTW strata, the ROS fit was calculated for the data periods for which there were sufficient data (i.e., more than one uncensored result). If there was one or no uncensored results, the binomial fit was used. The effective fit methodology was not used. The ROS fit was used for all time periods and strata for the MFP data except the CTW strata in 1955, 1960, 1961, and 1965.
- The binomial fit was used for the CTW strata MFP data in 1955, 1960, 1961, and 1965.
- The binomial fit was used for all time periods for the AMW strata MFPG data. The CTW and nonCTW strata MFPG data were not fit.
- The ROS fit was used for all time periods and strata for the WBC data.

Attachment A contains the plots of the ROS and binomial fits for each stratum (including AMW).

4.2 STRATA COMPARISONS

For 1955 through 1988, there were insufficient uncensored data to perform a comparison between the strata with the MFP and MFPG data. Insufficient WBC data was available to perform a comparison before 1974 and for 1989. Peto-Prentice and MCPT tests were performed from 1974 through 1988 on the WBC data. The result of the MCPT is a simple yes or no: either the observed strata difference is outside the 95% confidence bivariate normal confidence ellipse, or it is not. If the observed difference is outside the ellipse, there is a statistically significant difference between the strata. Table 4-1 contains the results of these tests. Attachment B contains the plotted results of the MCPT tests.

The Peto-Prentice test is used to determine whether the distribution of the OPOS bioassay data is the same in the CTW stratum and the nonCTW stratum. The result of the Peto-Prentice test is a two-sided p-value. These p-values are compared to the Holm cutoffs (ORAUT 2012) calculated for the family of tests (all the Peto-Prentice tests for a given strata comparison) with a family-wise significance level of 0.05. If the p-value for a single test is less than its corresponding Holm cutoff value, the strata are considered different at a statistically significant level. Table 4-1 contains the results of these Peto-Prentice tests. Attachment B contains the plotted results of the Peto-Prentice tests

The MCPT and Peto-Prentice tests did not identify statistically significant differences for any year. Therefore, no evaluation of practical significance was performed.

Table 4-1. CTW:nonCTW strata comparison.

Year	Peto-Prentice *p*-value	Holm cutoff value	MCPT result
1974	0.7207	0.0100	No
1975	0.5142	0.0071	No
1976	0.2087	0.0045	No
1977	0.0161	0.0033	No
1978	0.0480	0.0036	No
1979	0.0997	0.0038	No
1980	0.4312	0.0056	No
1981	0.7245	0.0167	No
1982	0.2990	0.0050	No

Year	Peto-Prentice *p*-value	Holm cutoff value	MCPT result
1983	0.8719	0.0250	No
1984	0.7220	0.0125	No
1985	0.9893	0.0500	No
1986	0.5126	0.0062	No
1987	0.1862	0.0042	No
1988	0.5935	0.0083	No

5.0 CONCLUSIONS

Statistical analysis revealed that the CTW stratum did not differ from the nonCTW stratum in a statistically significant manner for any periods with sufficient data. Therefore, there would be no benefit in evaluating the CTW stratum separately from other site workers. The SRS internal dose coworker study should evaluate mixed fission and activation product intakes based on the AMW data.

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ATTACHMENT A
ROS AND BINOMIAL FIT PLOTS FOR AMWS, CTWS, AND NONCTWS

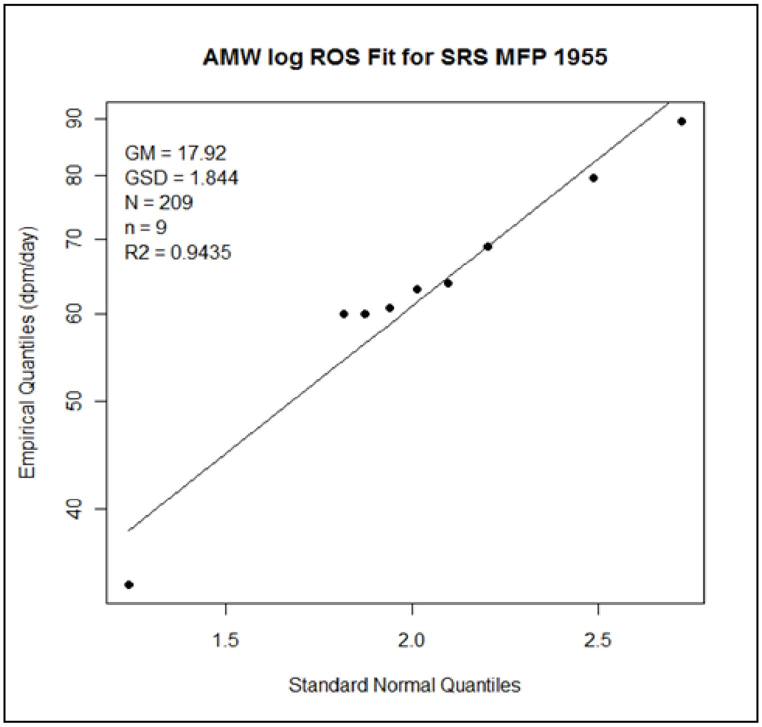

Figure A-1. MFP ROS fit for AMWs, 1955.

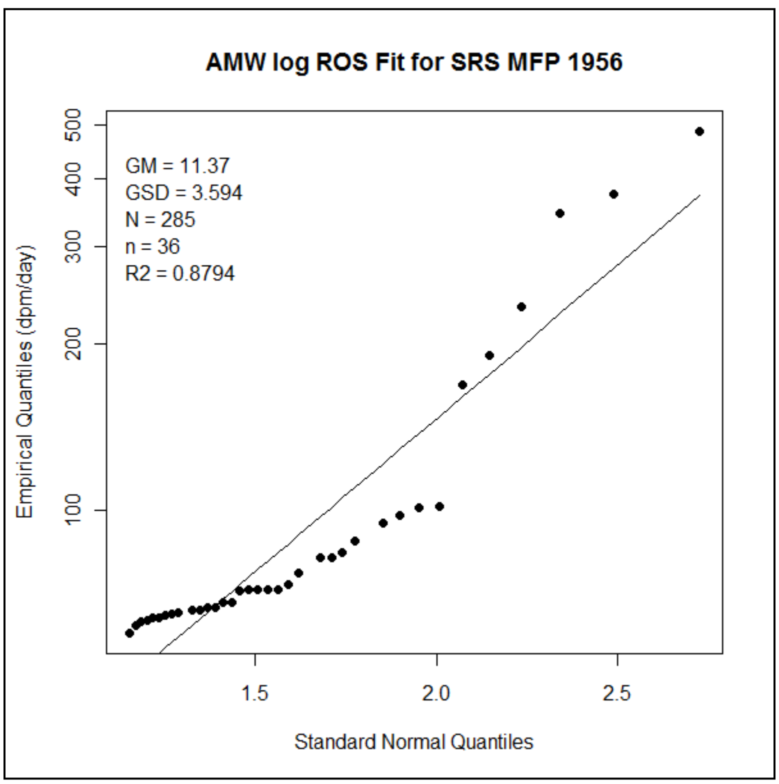

Figure A-2. MFP ROS fit for AMWs, 1956.

ATTACHMENT A
ROS AND BINOMIAL FIT PLOTS FOR AMWS, CTWS, AND NONCTWS

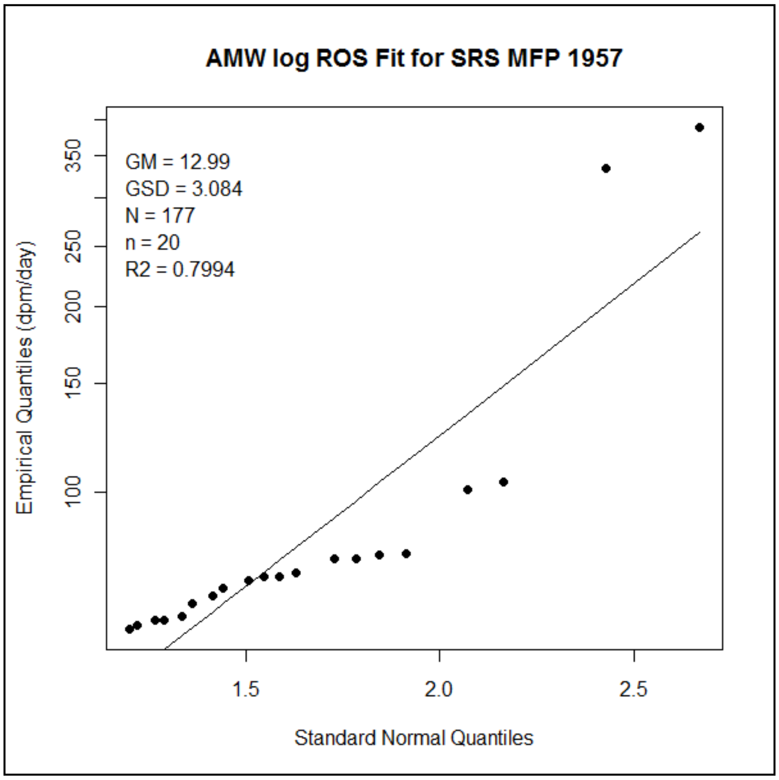

Figure A-3. MFP ROS fit for AMWs, 1957.

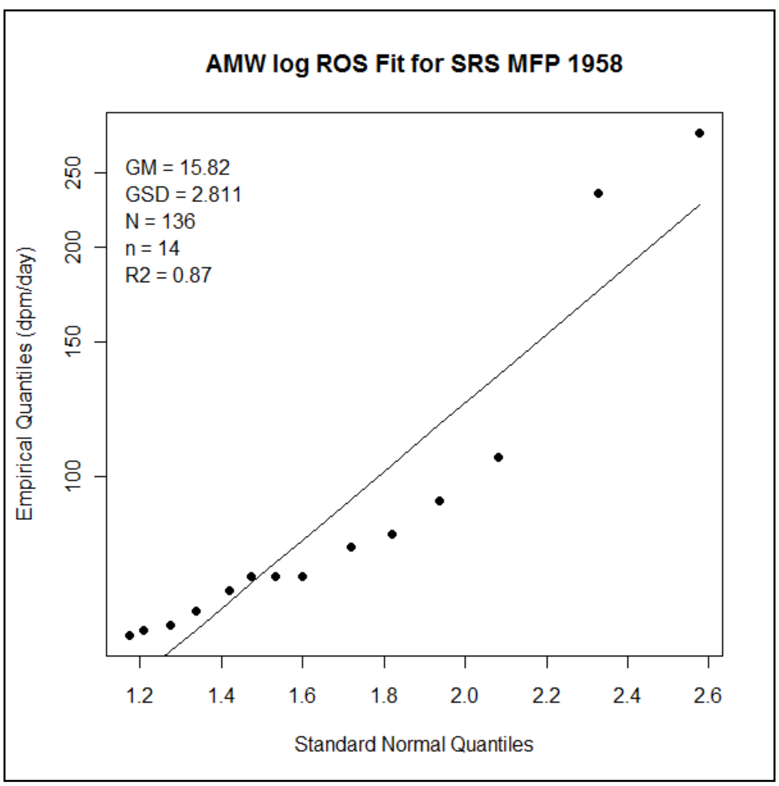

Figure A-4. MFP ROS fit for AMWs, 1958.

ATTACHMENT A
ROS AND BINOMIAL FIT PLOTS FOR AMWS, CTWS, AND NONCTWS

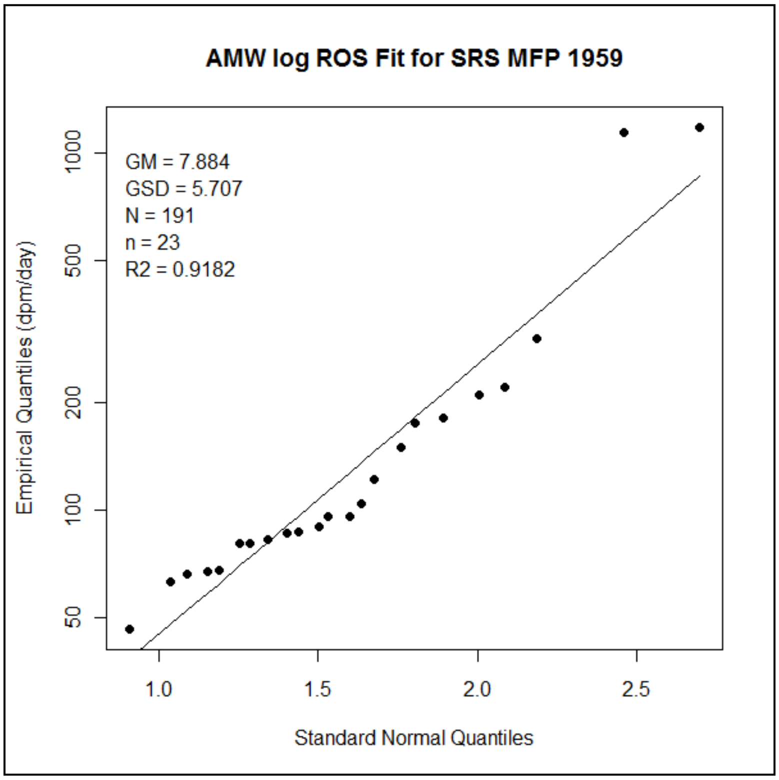

Figure A-5. MFP ROS fit for AMWs, 1959.

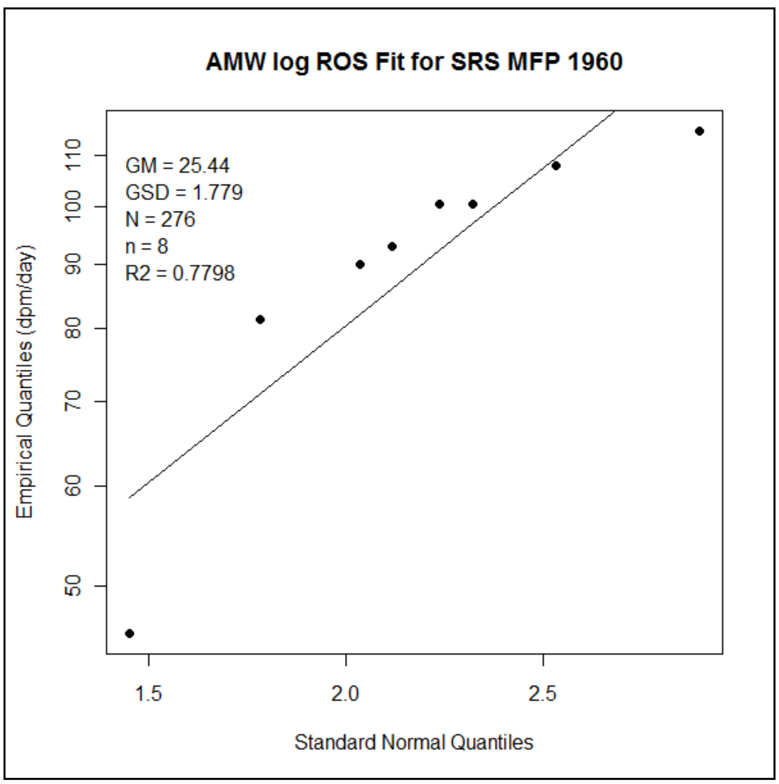

Figure A-6. MFP ROS fit for AMWs, 1960.

ATTACHMENT A
ROS AND BINOMIAL FIT PLOTS FOR AMWS, CTWS, AND NONCTWS

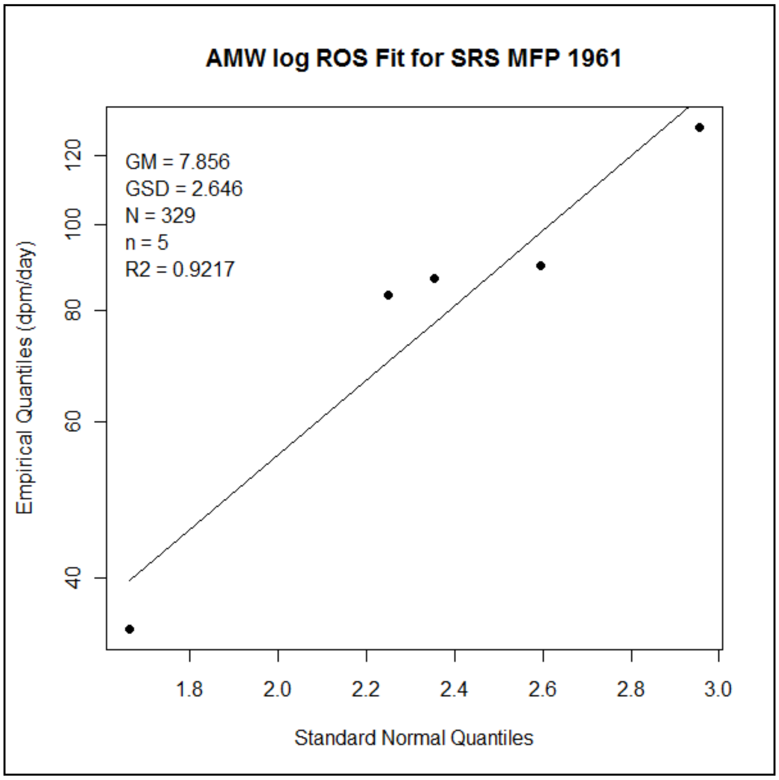

Figure A-7. MFP ROS fit for AMWs, 1961.

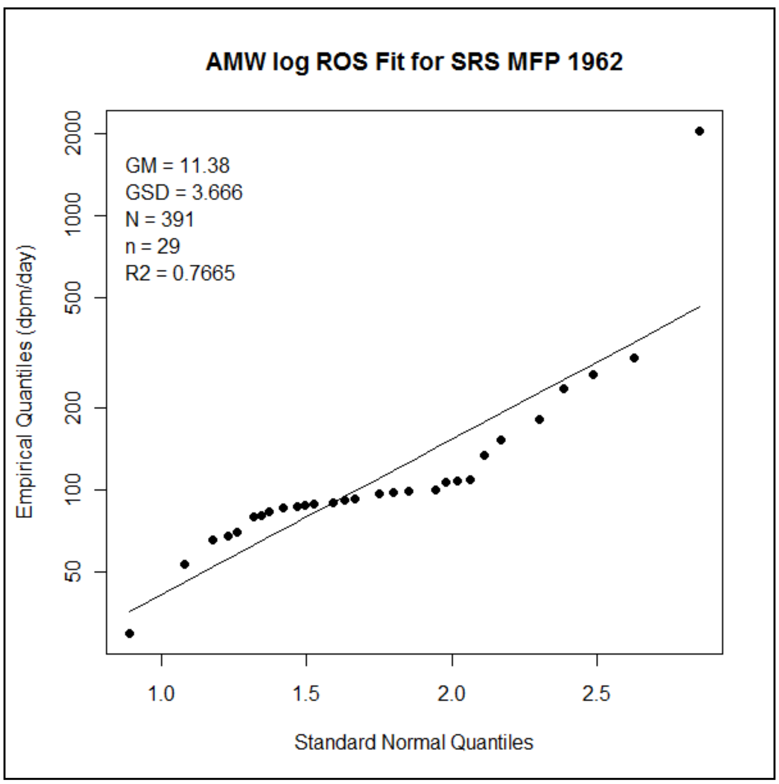

Figure A-8. MFP ROS fit for AMWs, 1962.

ATTACHMENT A
ROS AND BINOMIAL FIT PLOTS FOR AMWS, CTWS, AND NONCTWS

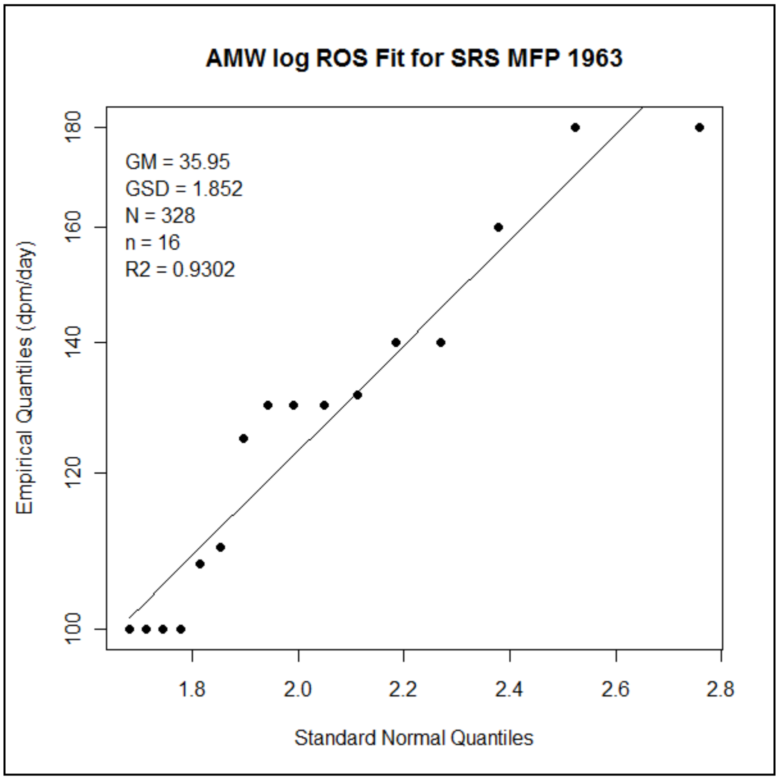

Figure A-9. MFP ROS fit for AMWs, 1963.

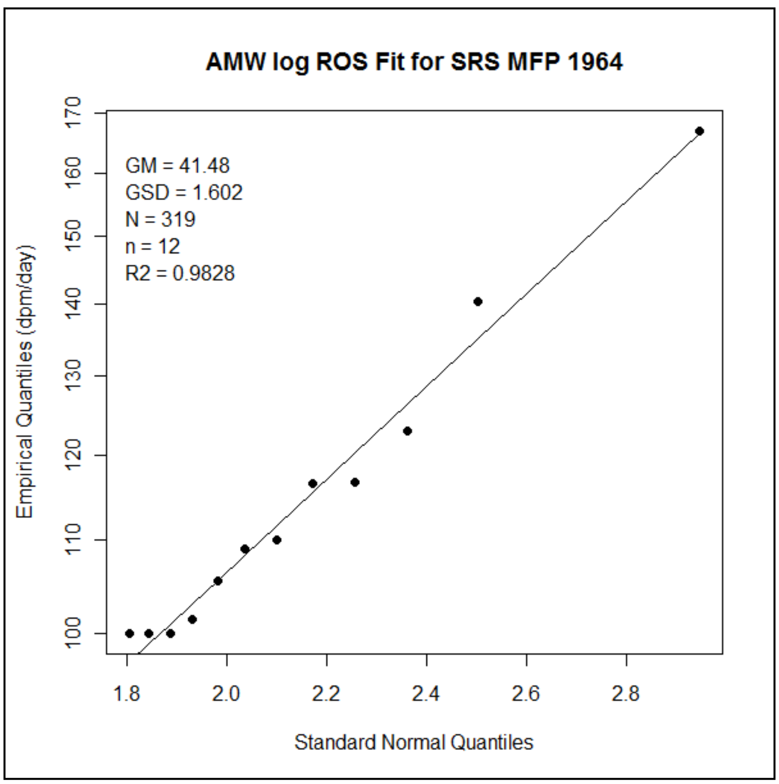

Figure A-10. MFP ROS fit for AMWs, 1964.

ATTACHMENT A
ROS AND BINOMIAL FIT PLOTS FOR AMWS, CTWS, AND NONCTWS

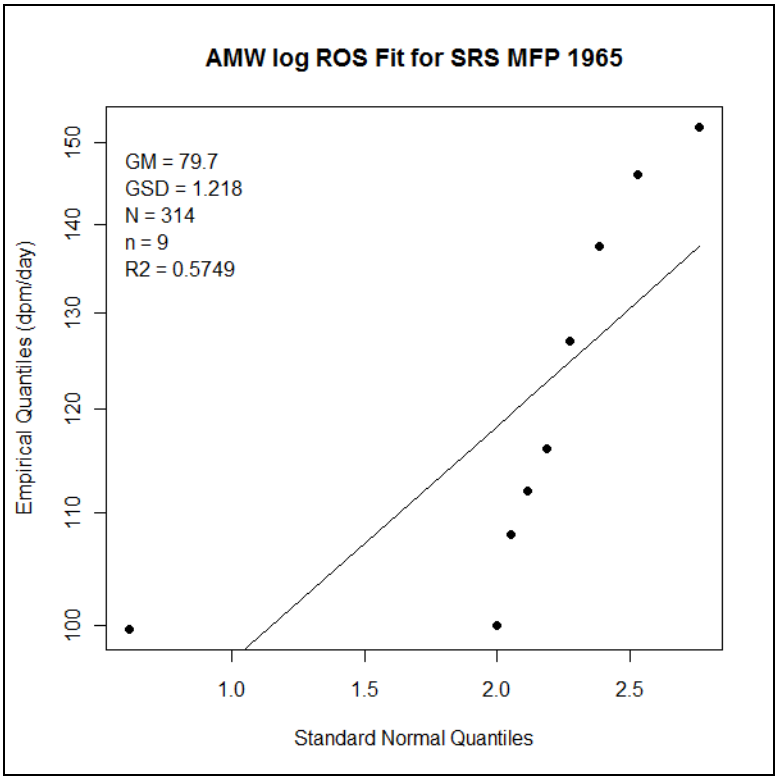

Figure A-11. MFP ROS fit for AMWs, 1965.

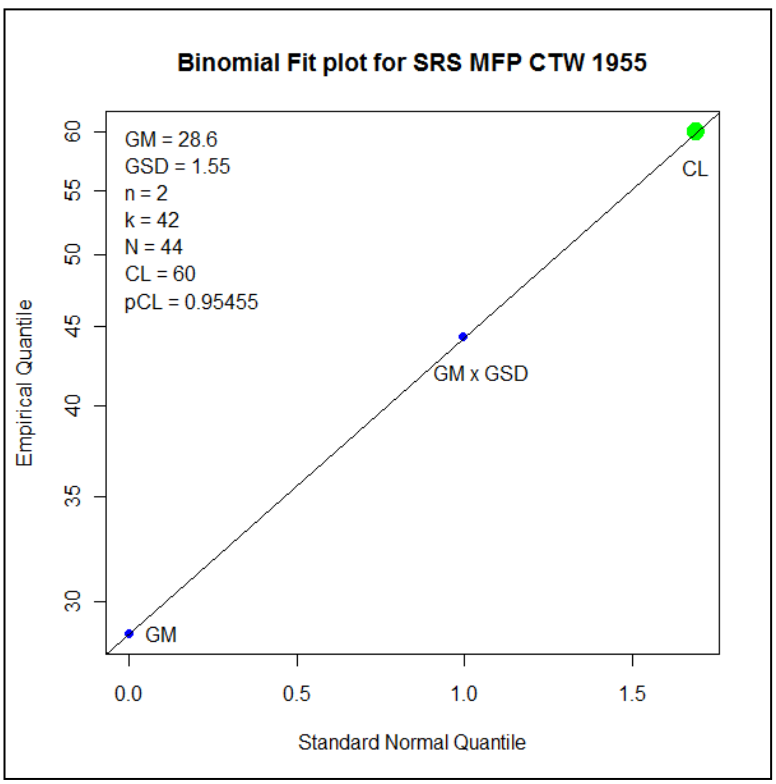

Figure A-12. MFP Binomial fit for CTWs, 1955.

ATTACHMENT A
ROS AND BINOMIAL FIT PLOTS FOR AMWS, CTWS, AND NONCTWS

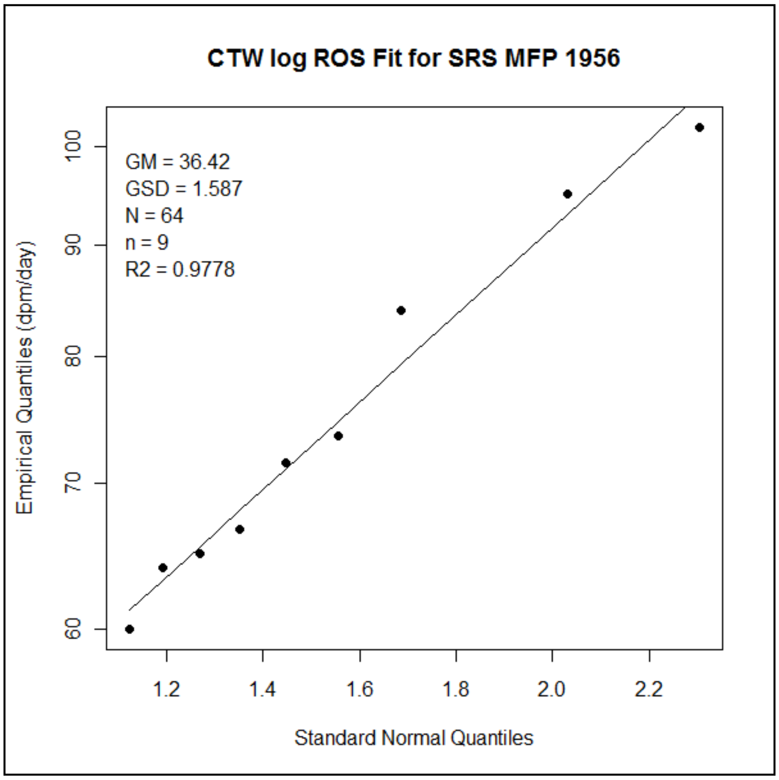

Figure A-13. MFP ROS fit for CTWs, 1956.

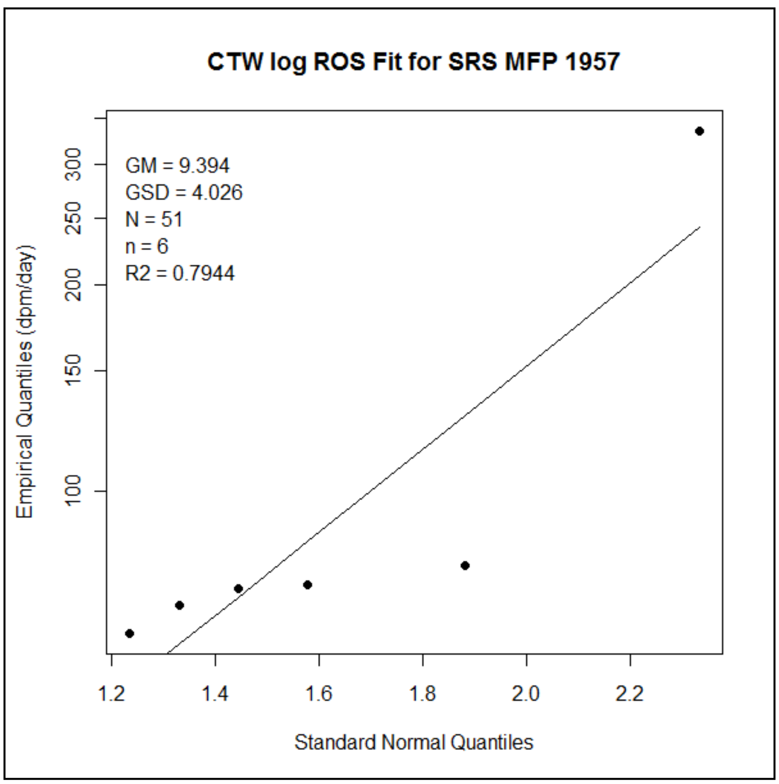

Figure A-14. MFP ROS fit for CTWs, 1957.

ATTACHMENT A
ROS AND BINOMIAL FIT PLOTS FOR AMWS, CTWS, AND NONCTWS

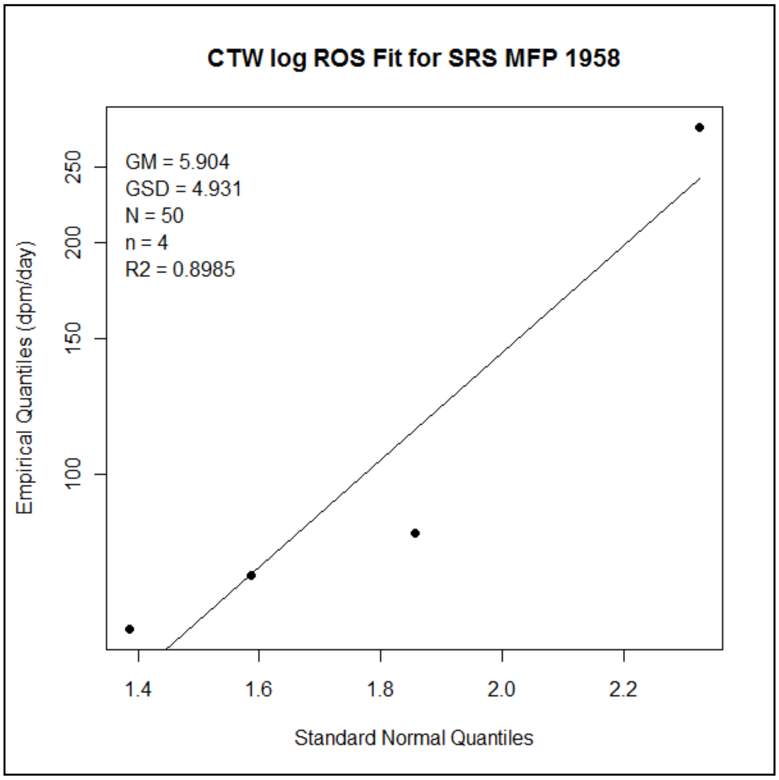

Figure A-15. MFP ROS fit for CTWs, 1958.

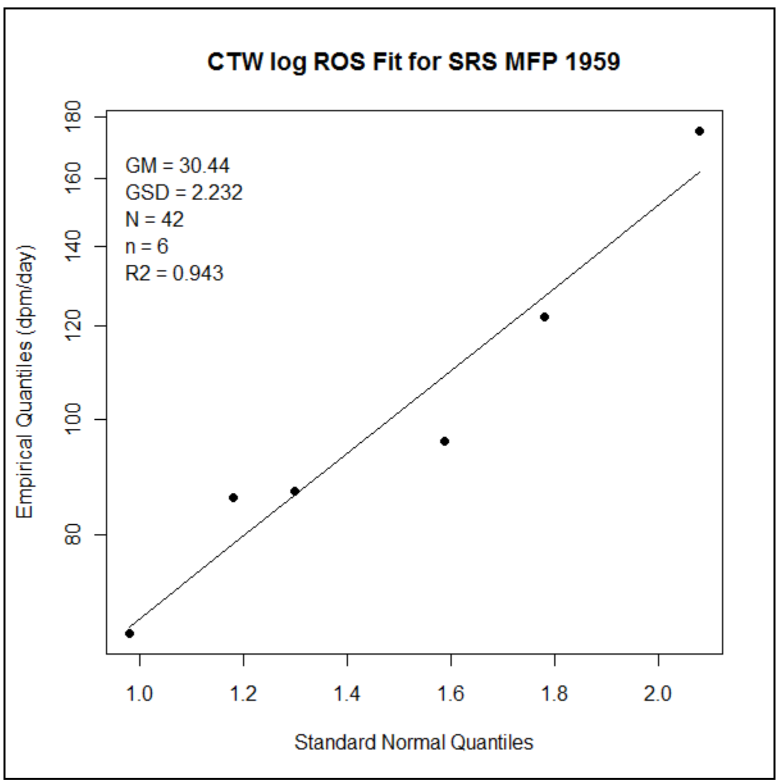

Figure A-16. MFP ROS fit for CTWs, 1959.

ATTACHMENT A
ROS AND BINOMIAL FIT PLOTS FOR AMWS, CTWS, AND NONCTWS

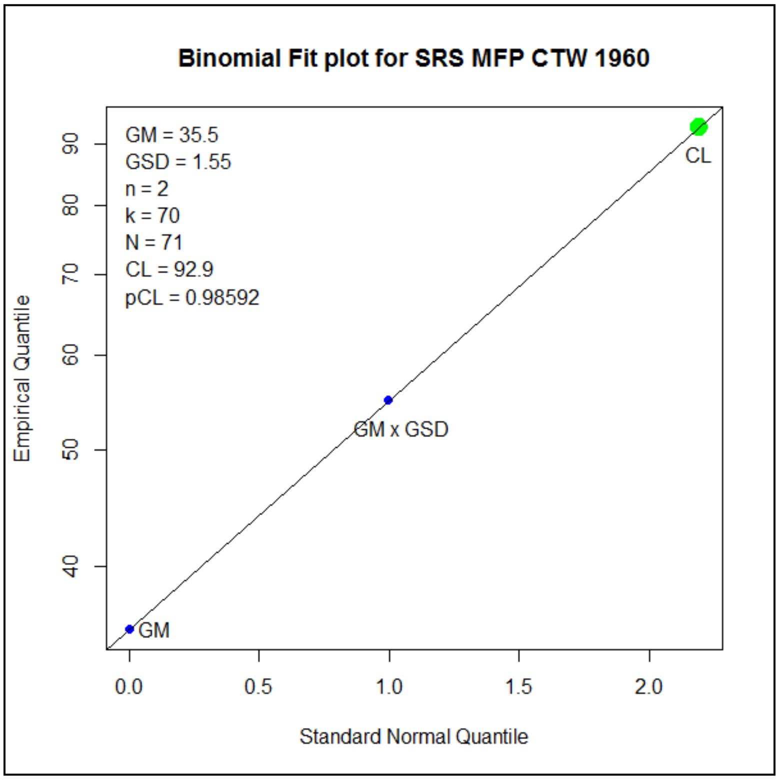

Figure A-17. MFP Binomial fit for CTWs, 1960.

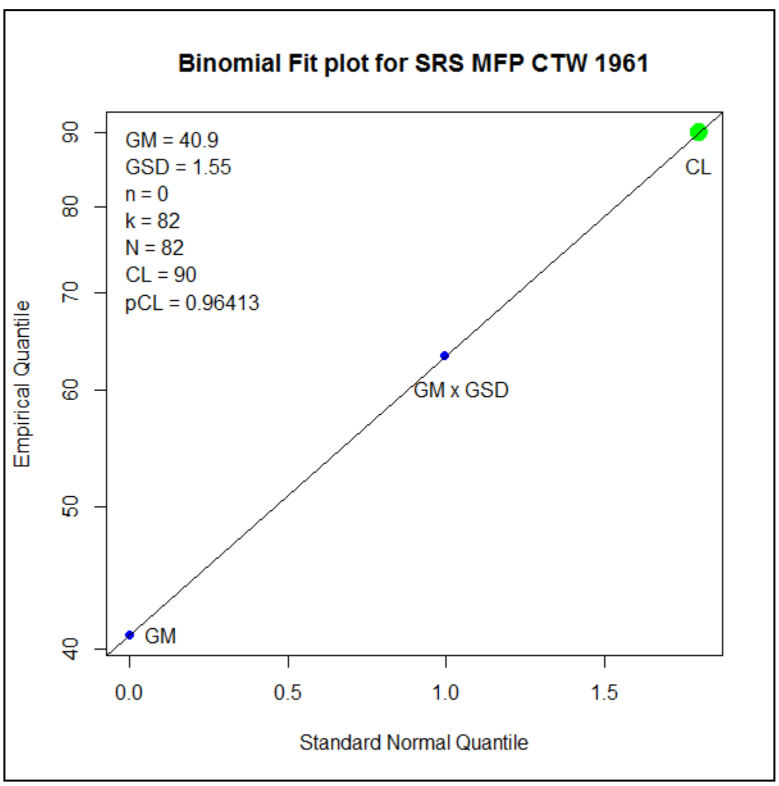

Figure A-18. MFP Binomial fit for CTWs, 1961.

ATTACHMENT A
ROS AND BINOMIAL FIT PLOTS FOR AMWS, CTWS, AND NONCTWS

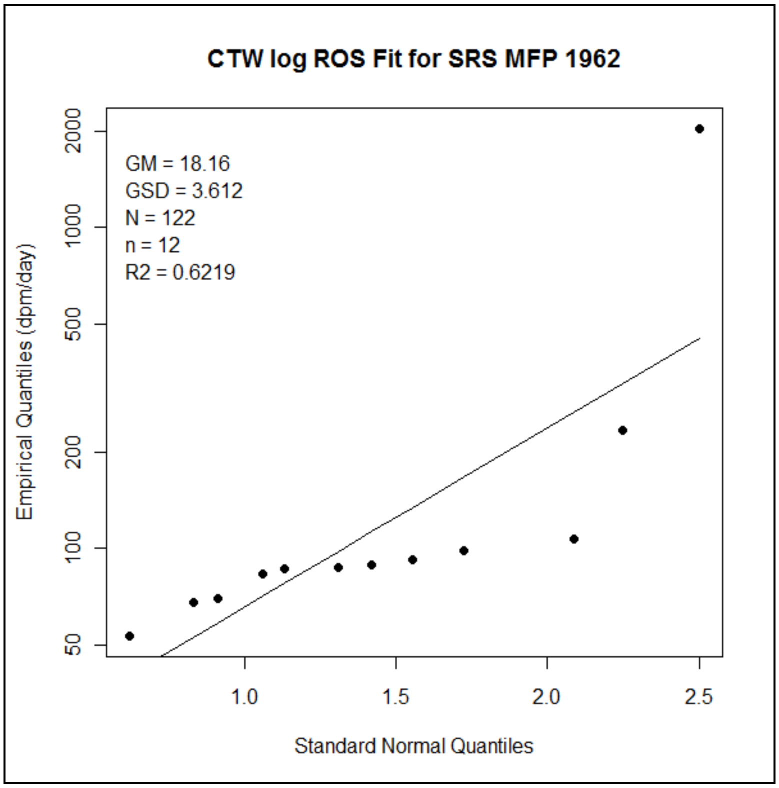

Figure A-19. MFP ROS fit for CTWs, 1962.

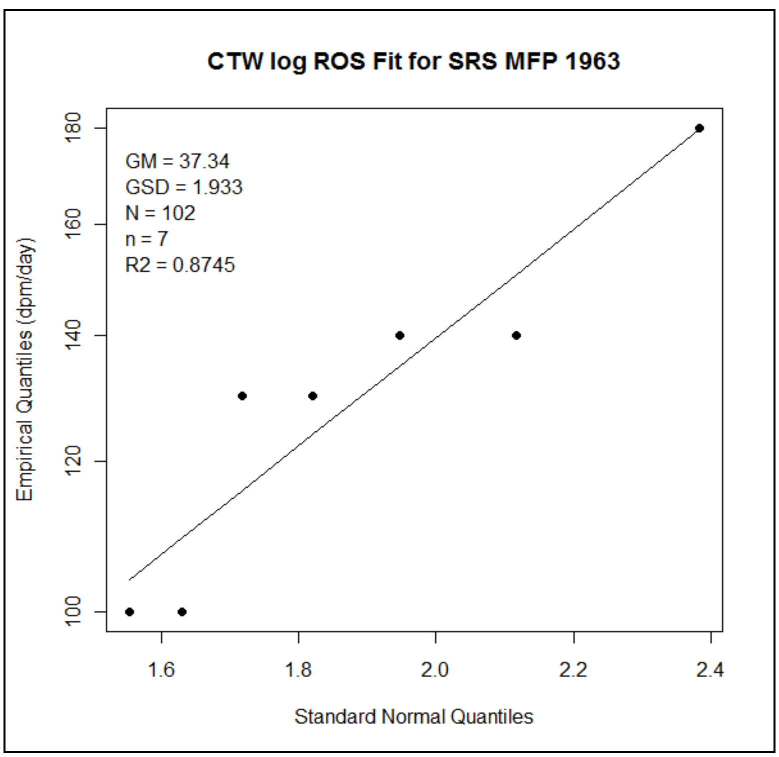

Figure A-20. MFP ROS fit for CTWs, 1963.

ATTACHMENT A
ROS AND BINOMIAL FIT PLOTS FOR AMWS, CTWS, AND NONCTWS

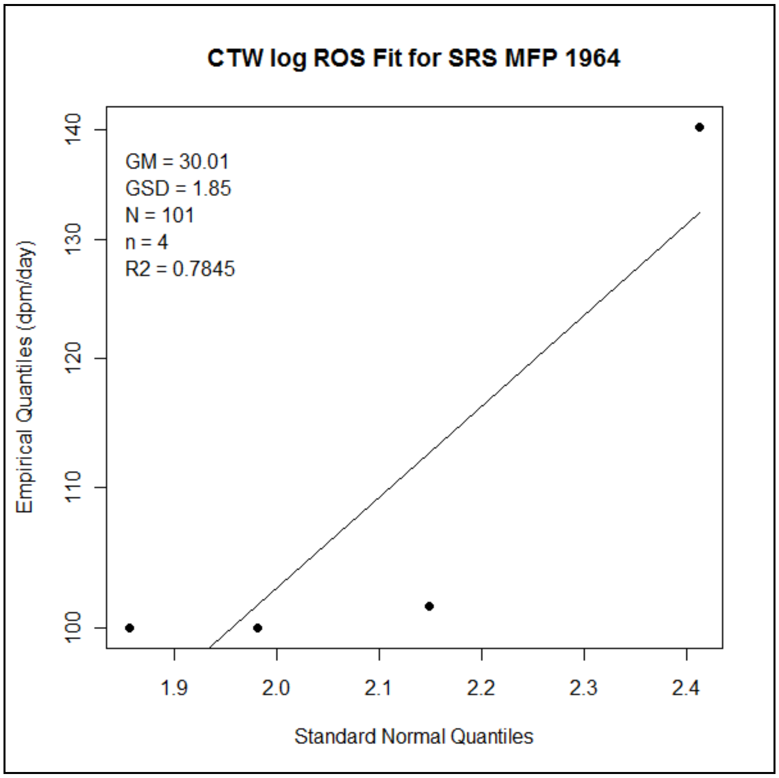

Figure A-21. MFP ROS fit for CTWs, 1964.

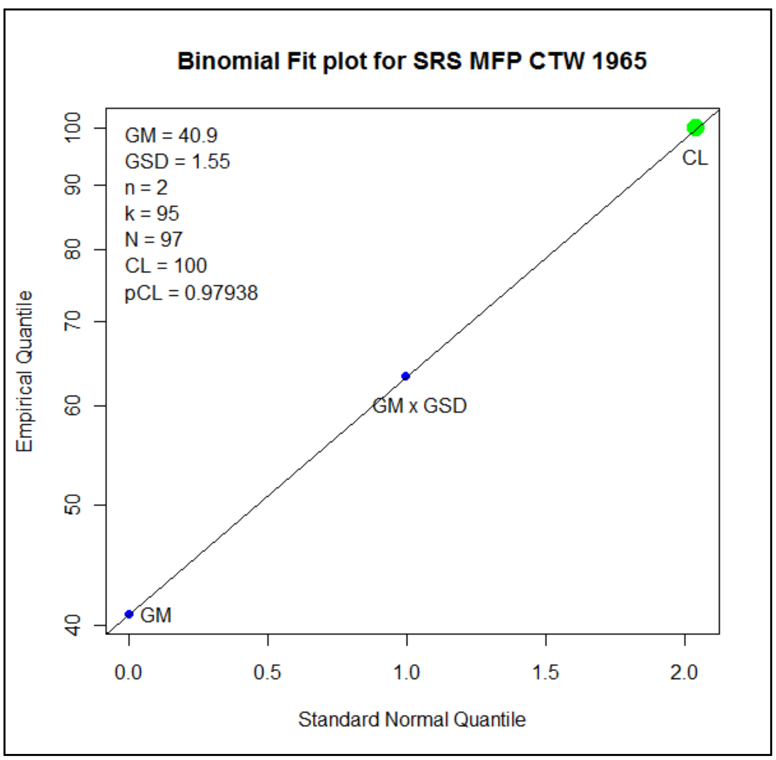

Figure A-22. MFP Binomial fit for CTWs, 1965.

ATTACHMENT A
ROS AND BINOMIAL FIT PLOTS FOR AMWS, CTWS, AND NONCTWS
Page 12 of 50

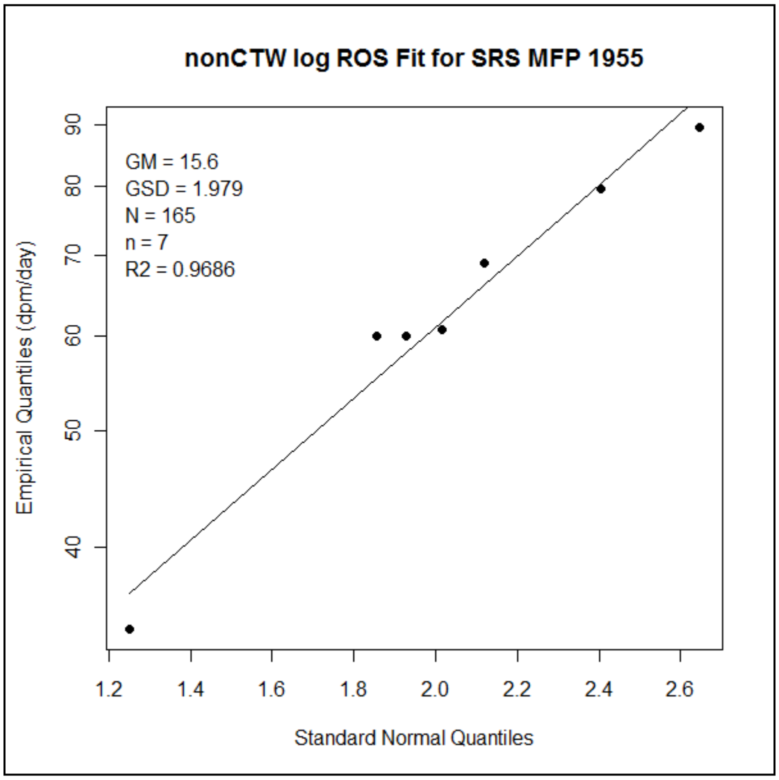

Figure A-23. MFP ROS fit for nonCTWs, 1955.

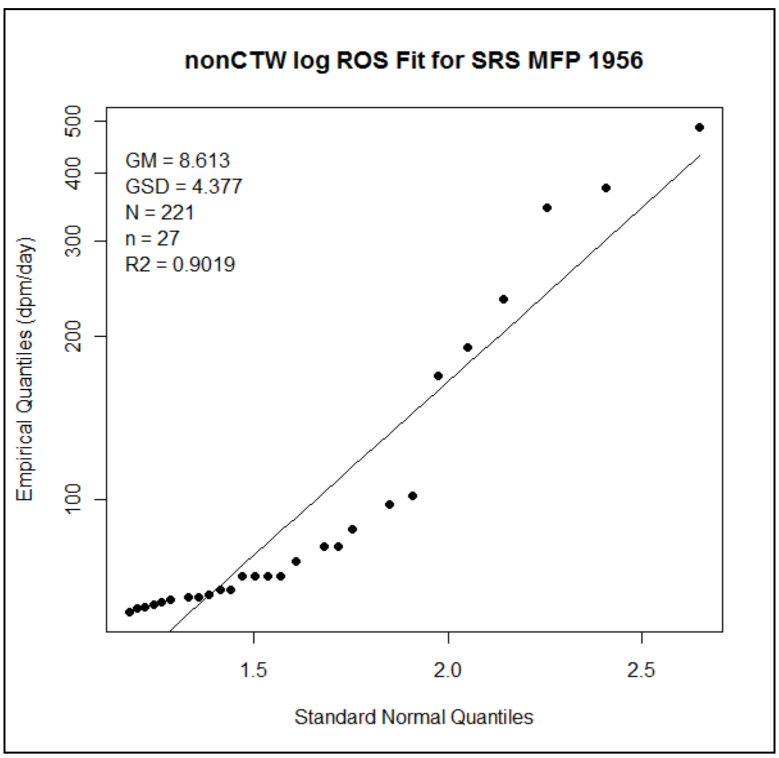

Figure A-24. MFP ROS fit for nonCTWs, 1956.

ATTACHMENT A
ROS AND BINOMIAL FIT PLOTS FOR AMWS, CTWS, AND NONCTWS

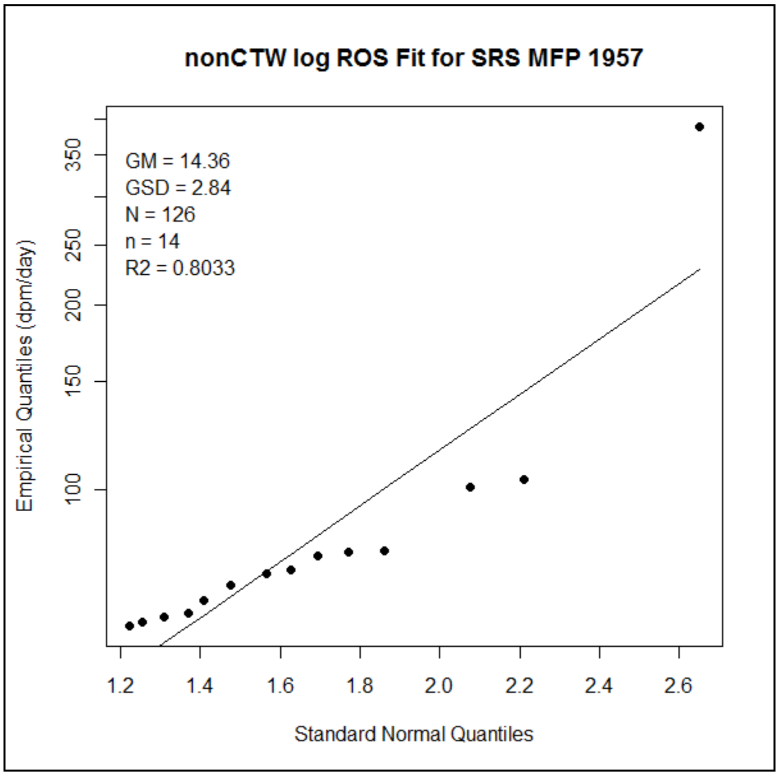

Figure A-25. MFP ROS fit for nonCTWs, 1957.

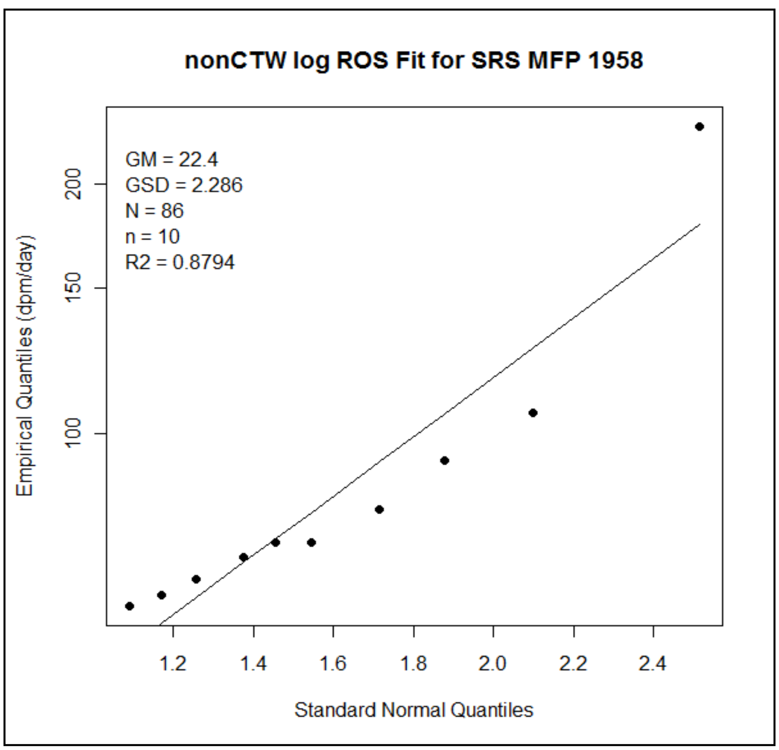

Figure A-26. MFP ROS fit for nonCTWs, 1958.

ATTACHMENT A
ROS AND BINOMIAL FIT PLOTS FOR AMWS, CTWS, AND NONCTWS

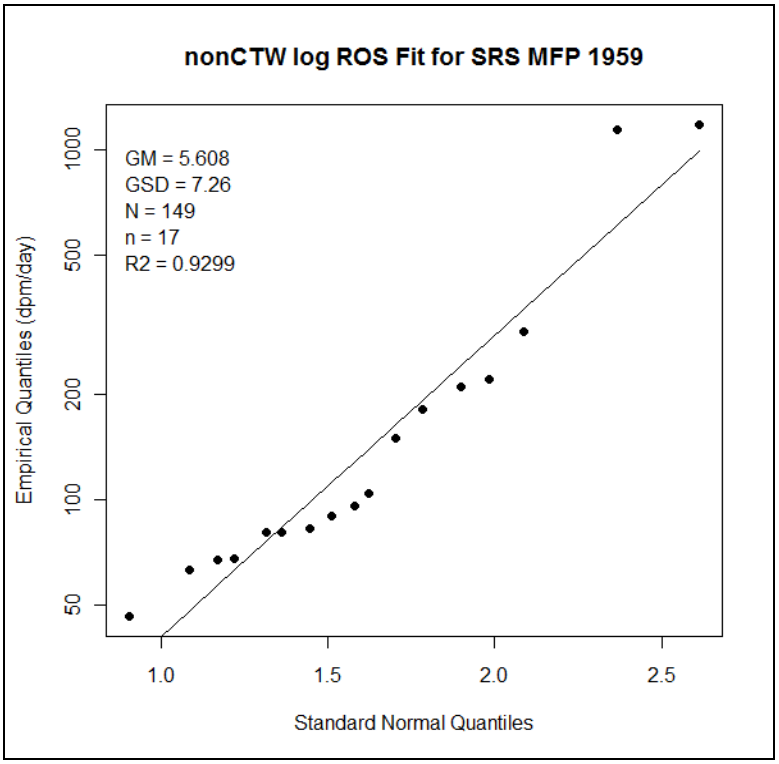

Figure A-27. MFP ROS fit for nonCTWs, 1959.

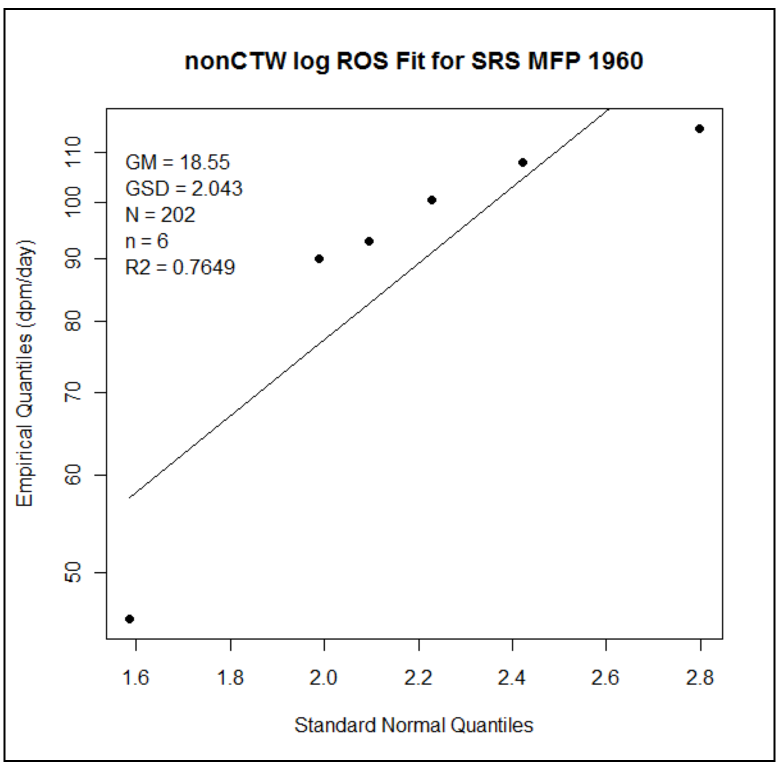

Figure A-28. MFP ROS fit for nonCTWs, 1960.

ATTACHMENT A
ROS AND BINOMIAL FIT PLOTS FOR AMWS, CTWS, AND NONCTWS

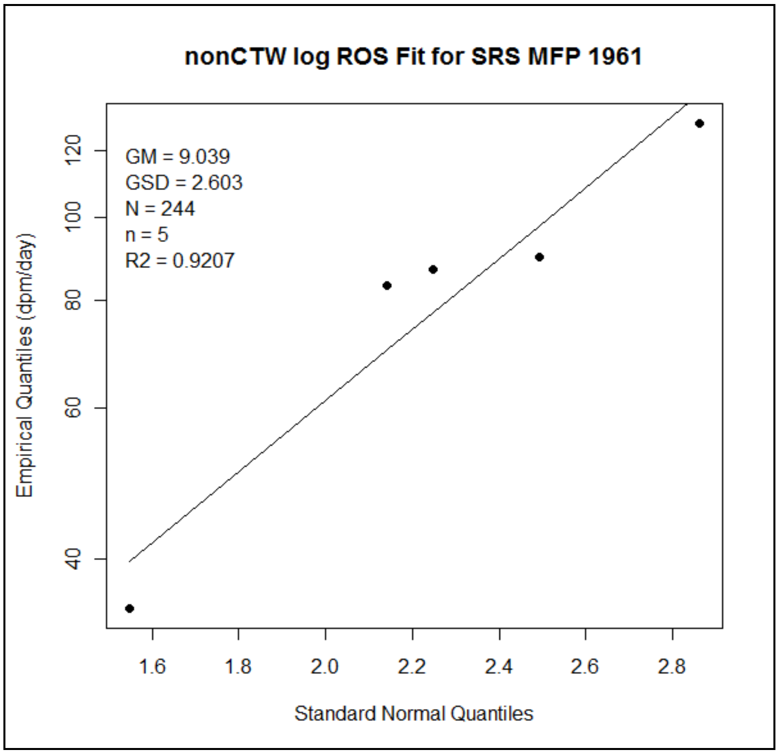

Figure A-29. MFP ROS fit for nonCTWs, 1961.

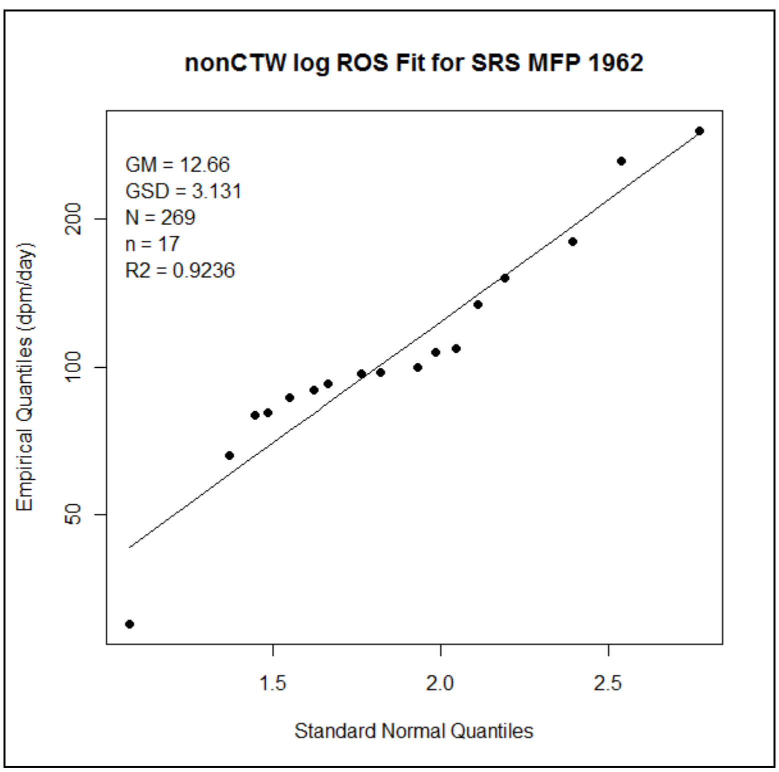

Figure A-30. MFP ROS fit for nonCTWs, 1962.

ATTACHMENT A
ROS AND BINOMIAL FIT PLOTS FOR AMWS, CTWS, AND NONCTWS

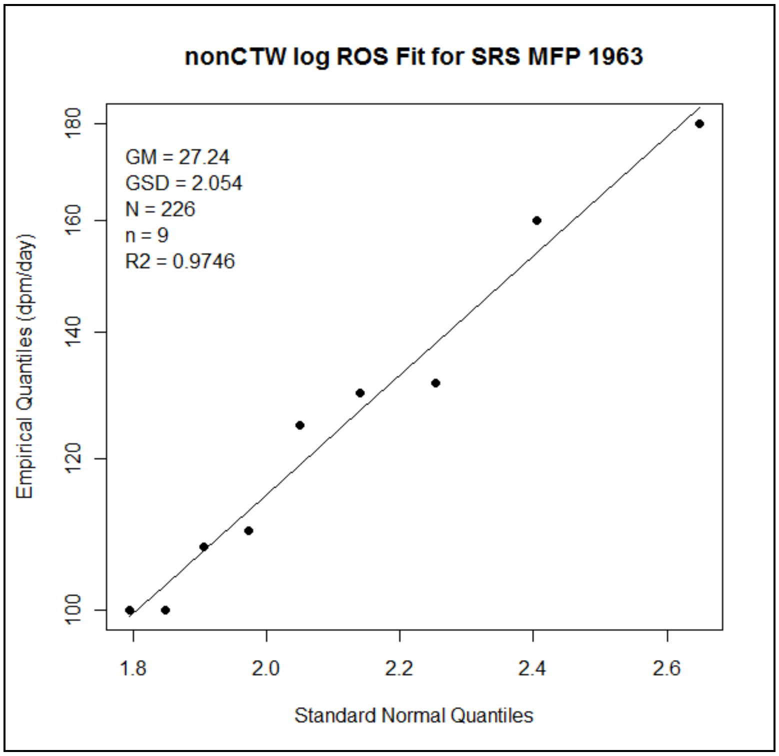

Figure A-31. MFP ROS fit for nonCTWs, 1963.

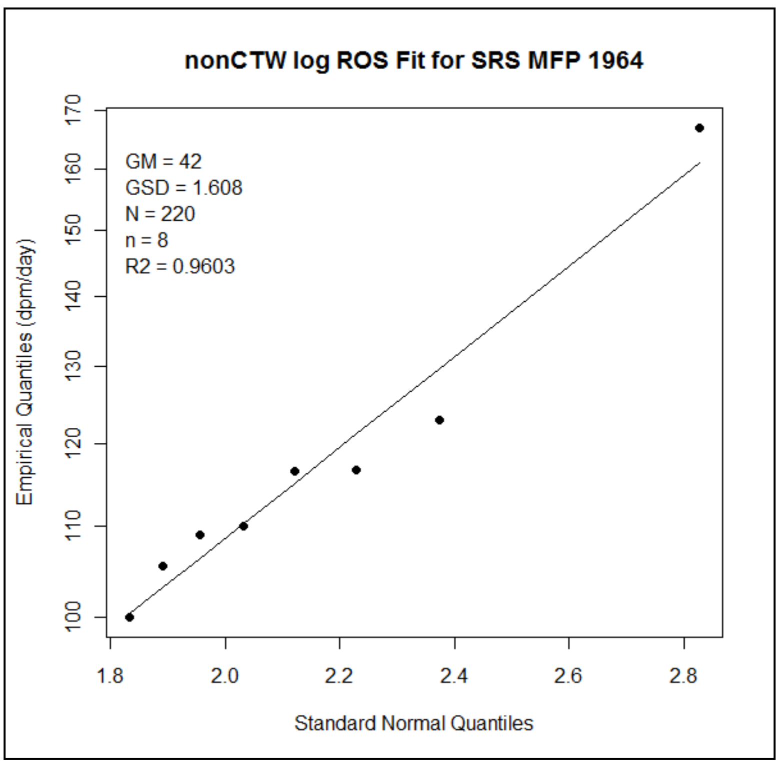

Figure A-32. MFP ROS fit for nonCTWs, 1964.

ATTACHMENT A
ROS AND BINOMIAL FIT PLOTS FOR AMWS, CTWS, AND NONCTWS

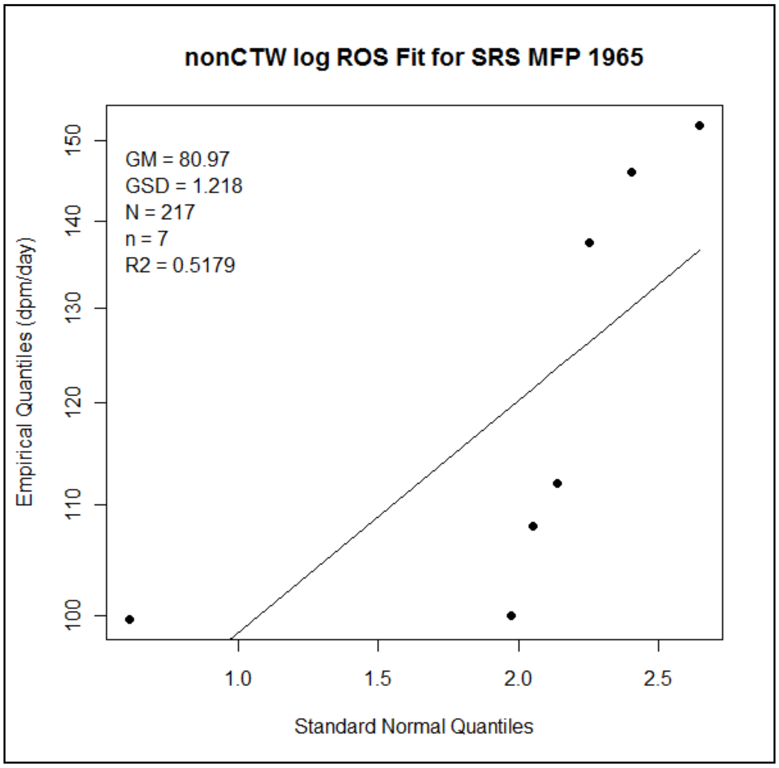

Figure A-33. MFP ROS fit for nonCTWs, 1965.

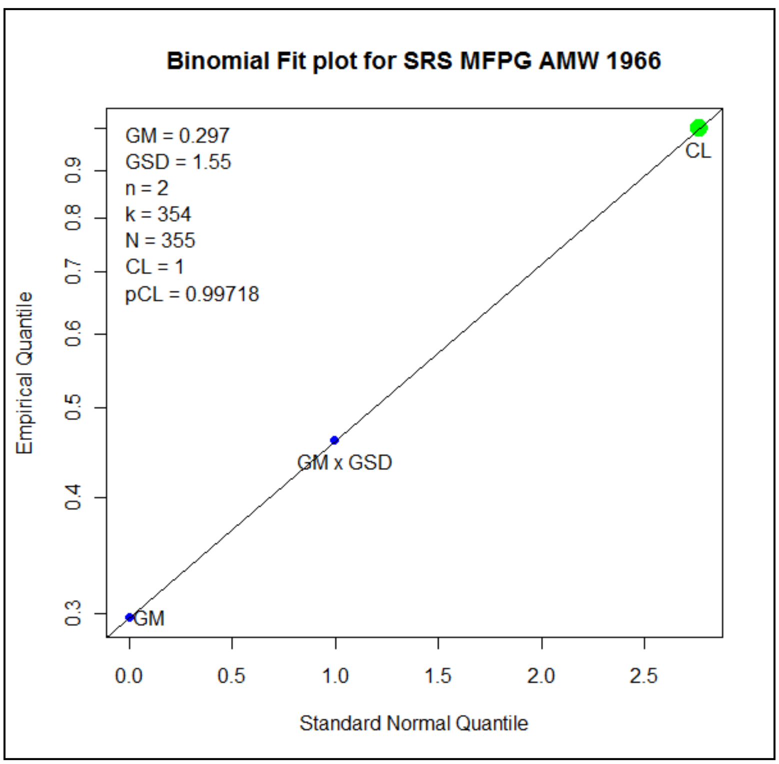

Figure A-34. MFPG Binomial fit for AMWs, 1966.

ATTACHMENT A
ROS AND BINOMIAL FIT PLOTS FOR AMWS, CTWS, AND NONCTWS

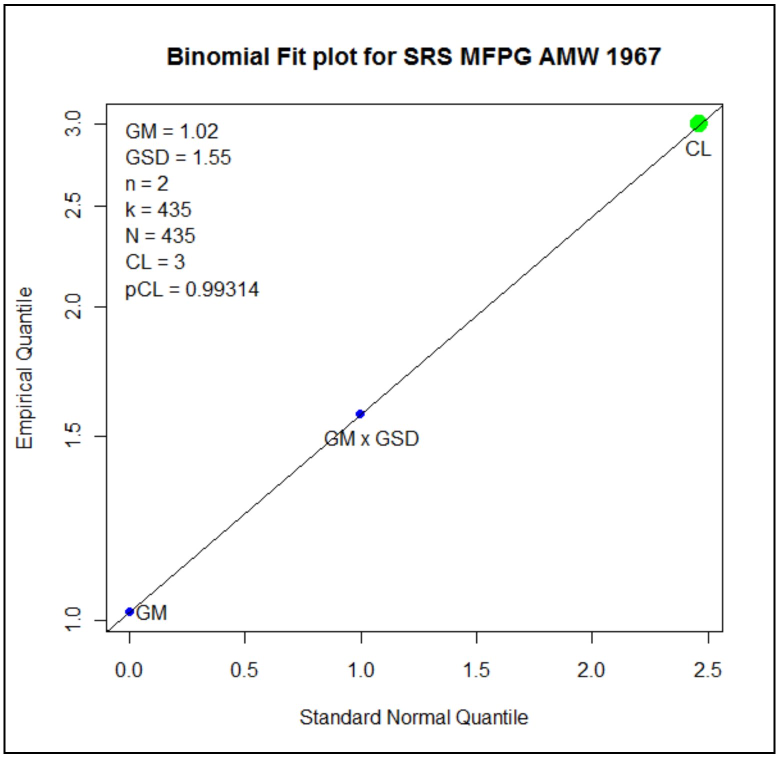

Figure A-35. MFPG Binomial fit for AMWs, 1967.

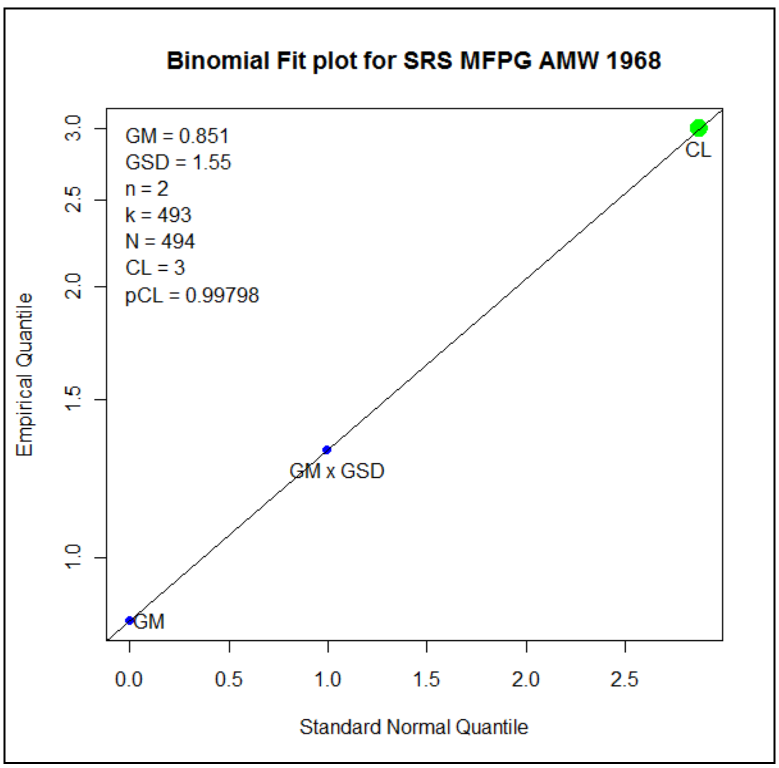

Figure A-36. MFPG Binomial fit for AMWs, 1968.

ATTACHMENT A
ROS AND BINOMIAL FIT PLOTS FOR AMWS, CTWS, AND NONCTWS

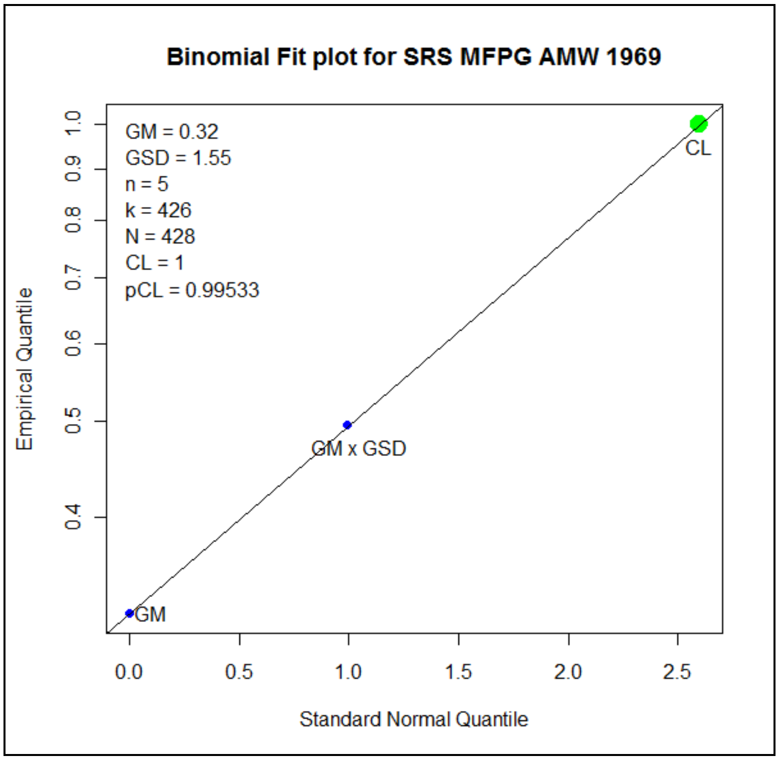

Figure A-37. MFPG Binomial fit for AMWs, 1969.

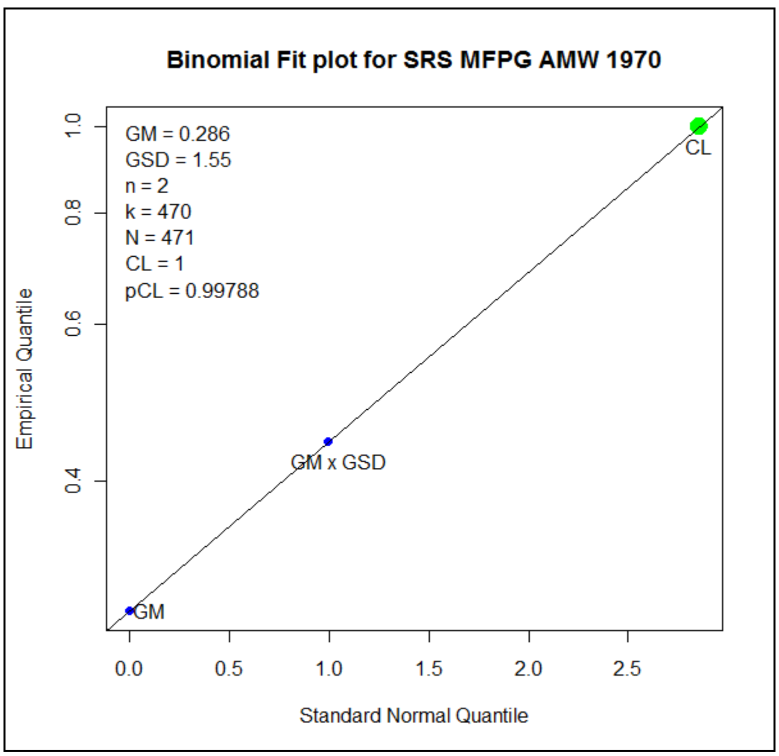

Figure A-38. MFPG Binomial fit for AMWs, 1970.

ATTACHMENT A
ROS AND BINOMIAL FIT PLOTS FOR AMWS, CTWS, AND NONCTWS

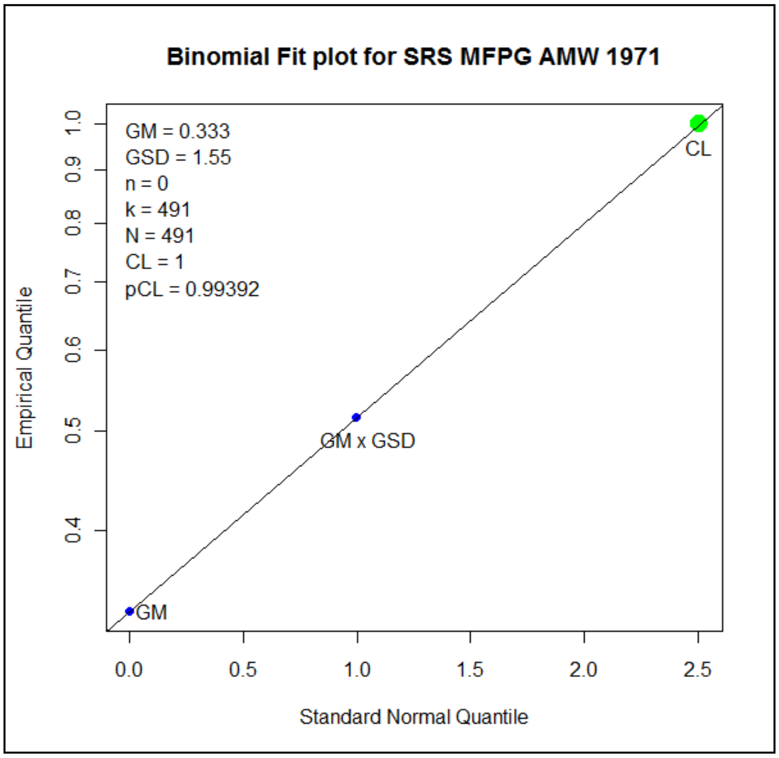

Figure A-39. MFPG Binomial fit for AMWs, 1971.

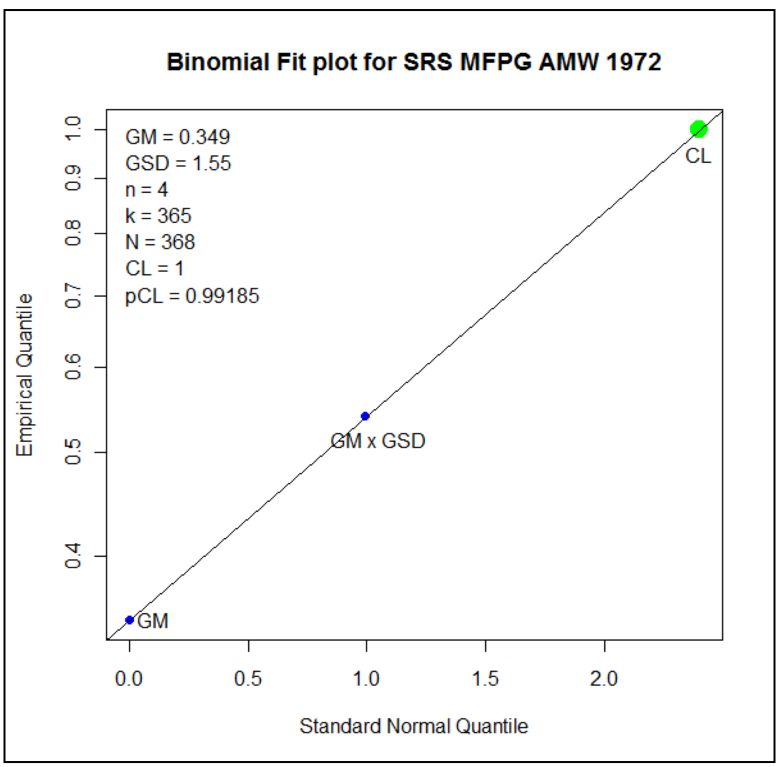

Figure A-40. MFPG Binomial fit for AMWs, 1972.

ATTACHMENT A
ROS AND BINOMIAL FIT PLOTS FOR AMWS, CTWS, AND NONCTWS

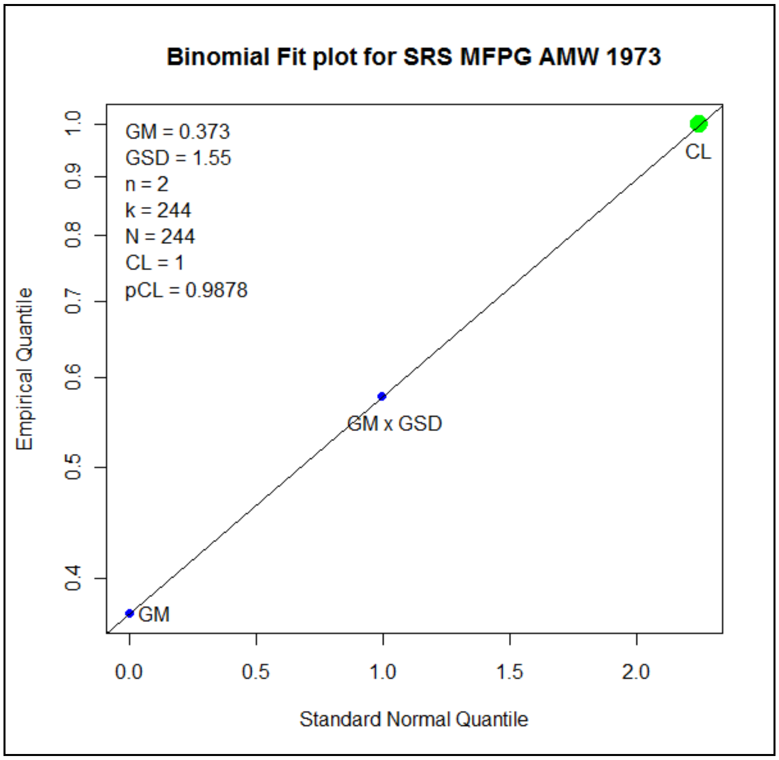

Figure A-41. MFPG Binomial fit for AMWs, 1973.

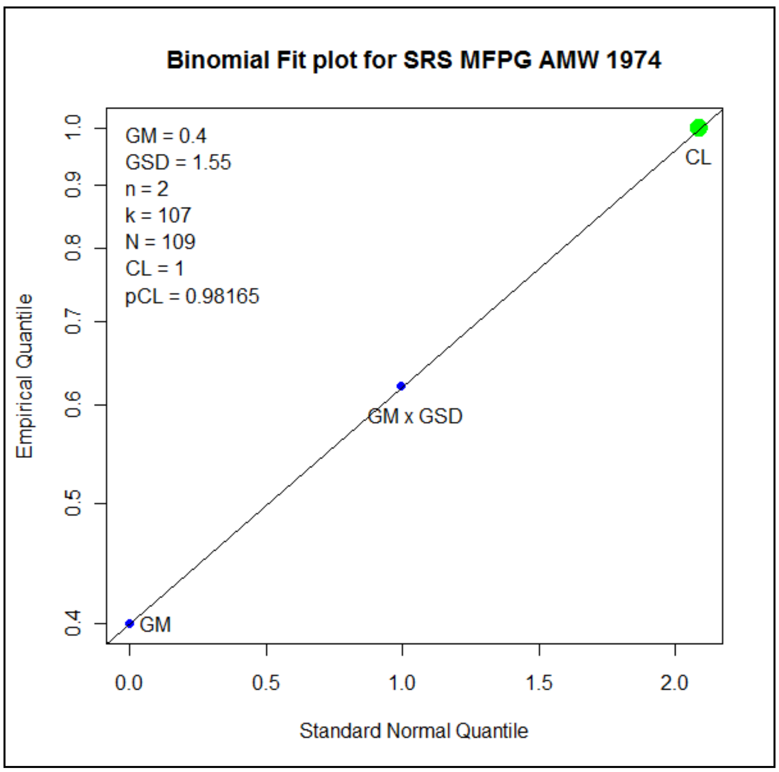

Figure A-42. MFPG Binomial fit for AMWs, 1974.

ATTACHMENT A
ROS AND BINOMIAL FIT PLOTS FOR AMWS, CTWS, AND NONCTWS

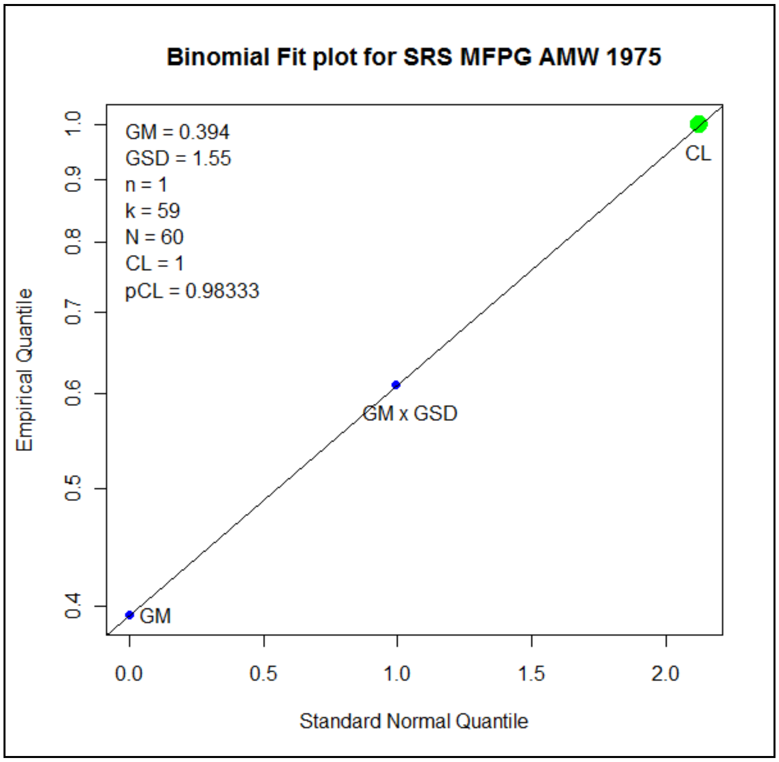

Figure A-43. MFPG Binomial fit for AMWs, 1975.

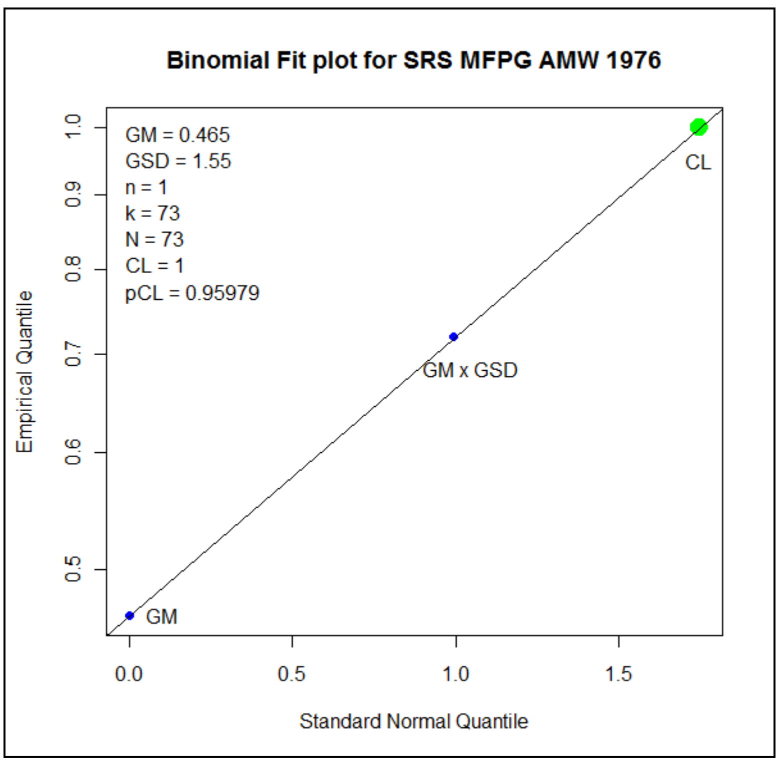

Figure A-44. MFPG Binomial fit for AMWs, 1976.

ATTACHMENT A
ROS AND BINOMIAL FIT PLOTS FOR AMWS, CTWS, AND NONCTWS

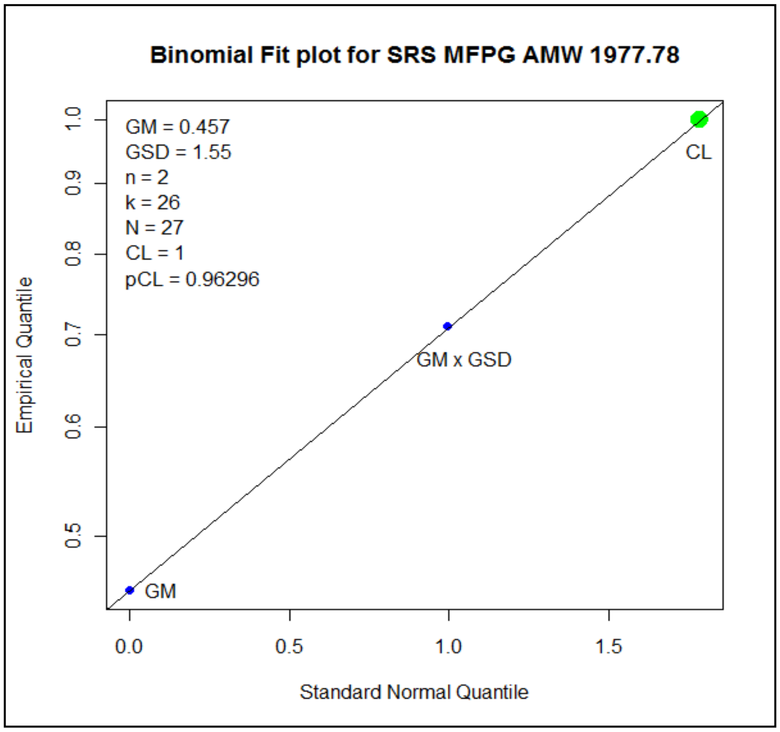

Figure A-45. MFPG Binomial fit for AMWs, 1977 to 1978.

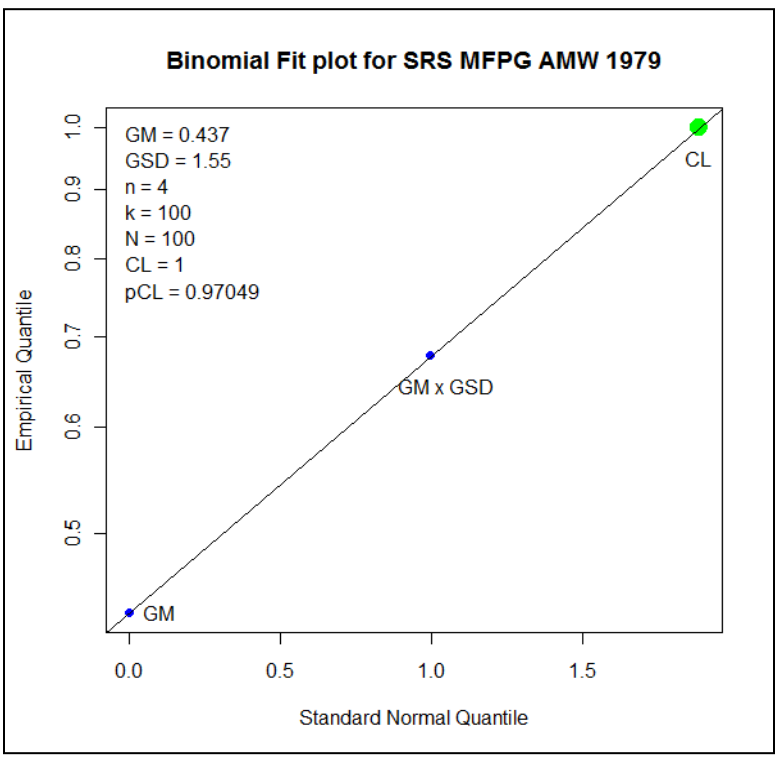

Figure A-46. MFPG Binomial fit for AMWs, 1979.

ATTACHMENT A
ROS AND BINOMIAL FIT PLOTS FOR AMWS, CTWS, AND NONCTWS
Page 24 of 50

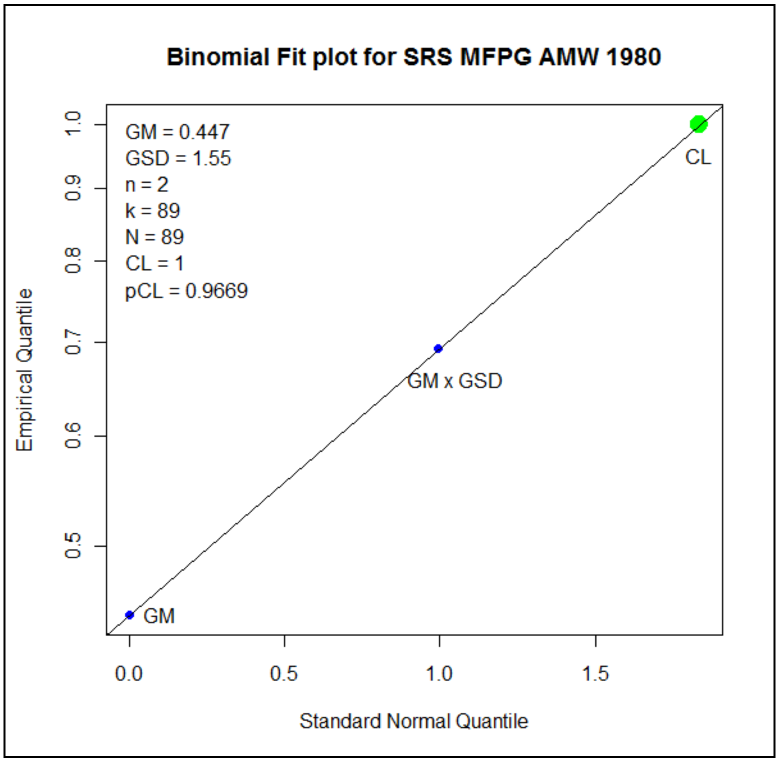

Figure A-47. MFPG Binomial fit for AMWs, 1980.

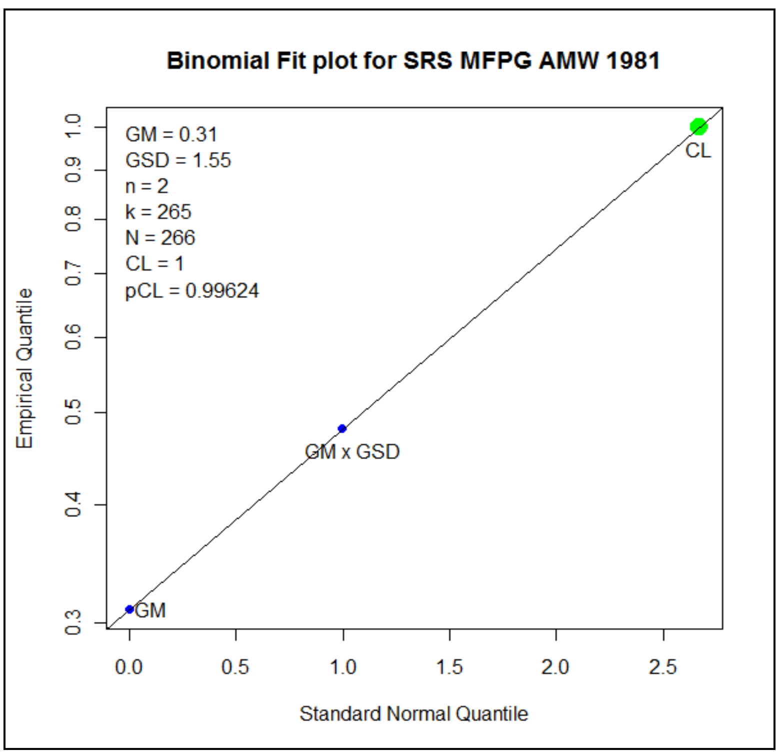

Figure A-48. MFPG Binomial fit for AMWs, 1981.

ATTACHMENT A
ROS AND BINOMIAL FIT PLOTS FOR AMWS, CTWS, AND NONCTWS

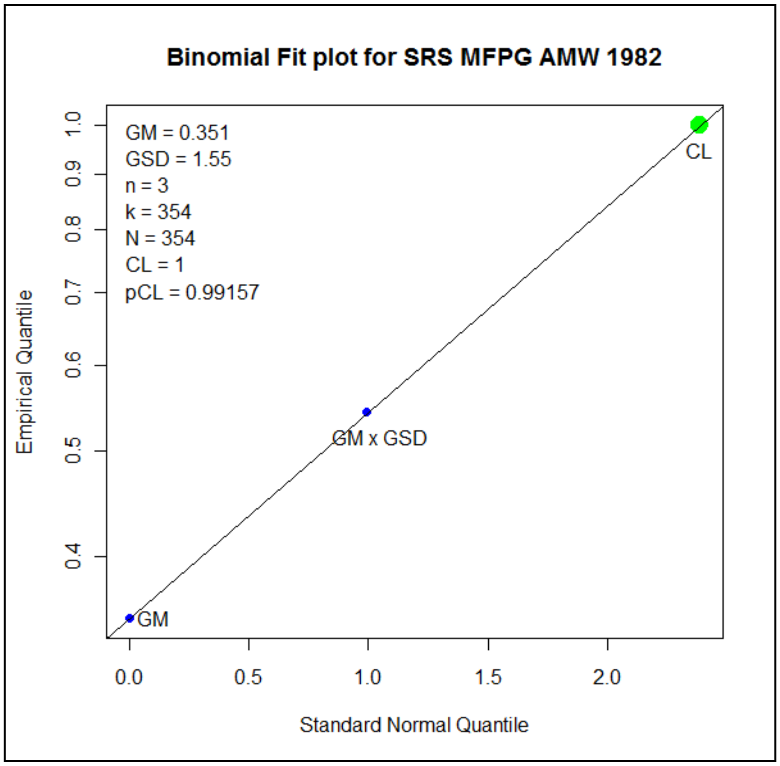

Figure A-49. MFPG Binomial fit for AMWs, 1982.

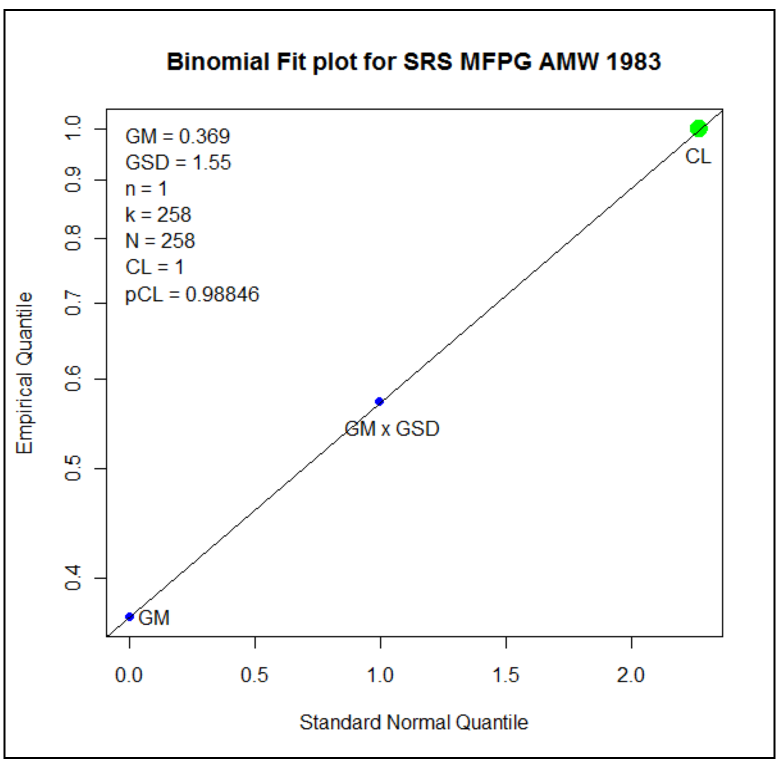

Figure A-50. MFPG Binomial fit for AMWs, 1983.

ATTACHMENT A
ROS AND BINOMIAL FIT PLOTS FOR AMWS, CTWS, AND NONCTWS

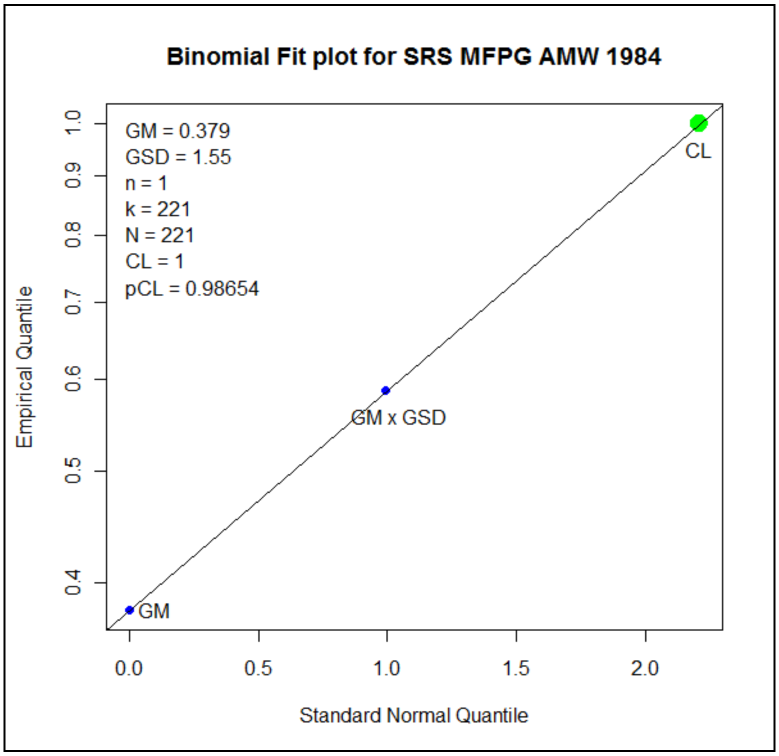

Figure A-51. MFPG Binomial fit for AMWs, 1984.

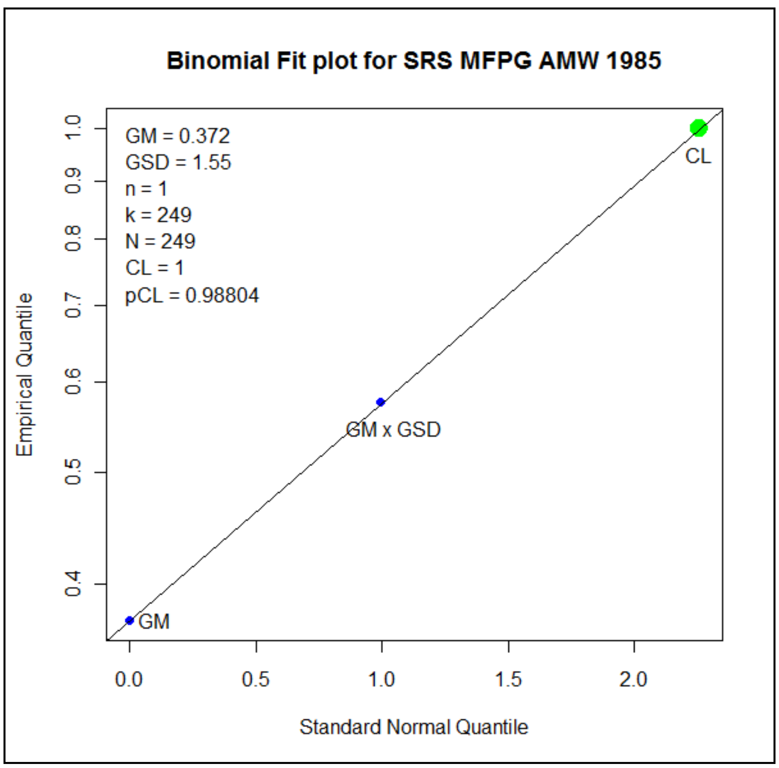

Figure A-52. MFPG Binomial fit for AMWs, 1985.

ATTACHMENT A
ROS AND BINOMIAL FIT PLOTS FOR AMWS, CTWS, AND NONCTWS

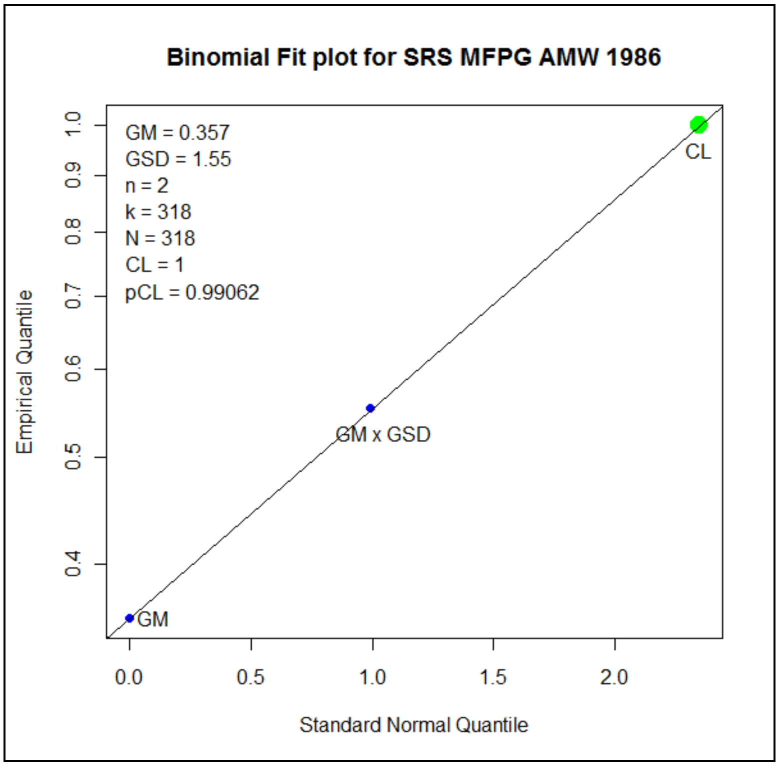

Figure A-53. MFPG Binomial fit for AMWs, 1986.

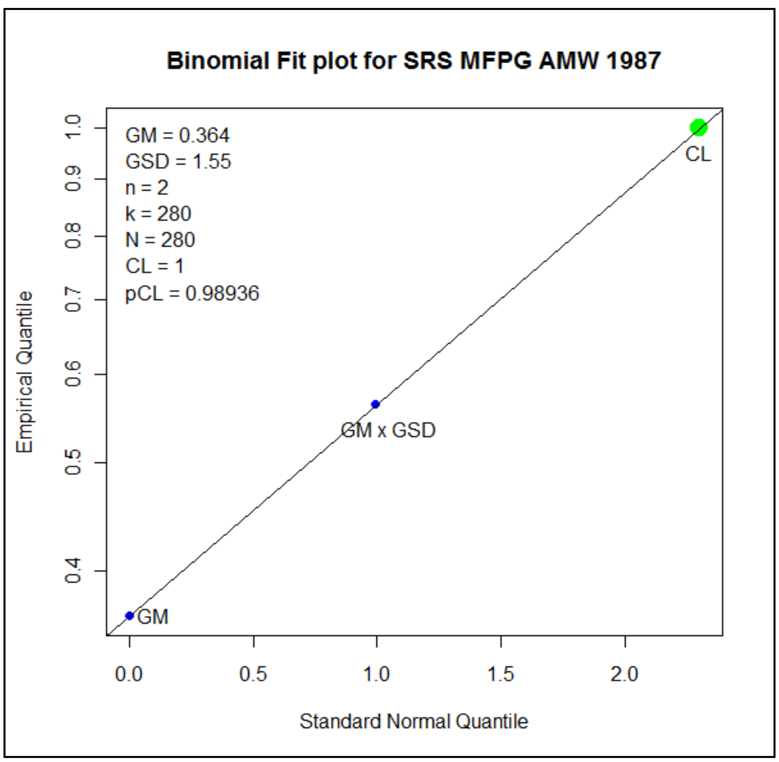

Figure A-54. MFPG Binomial fit for AMWs, 1987.

ATTACHMENT A
ROS AND BINOMIAL FIT PLOTS FOR AMWS, CTWS, AND NONCTWS

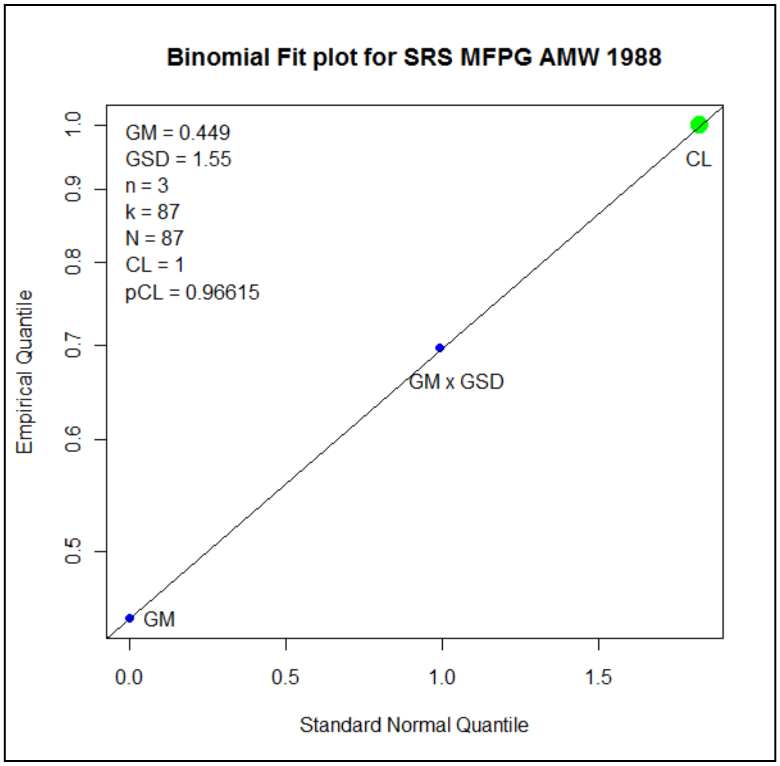

Figure A-55. MFPG Binomial fit for AMWs, 1988.

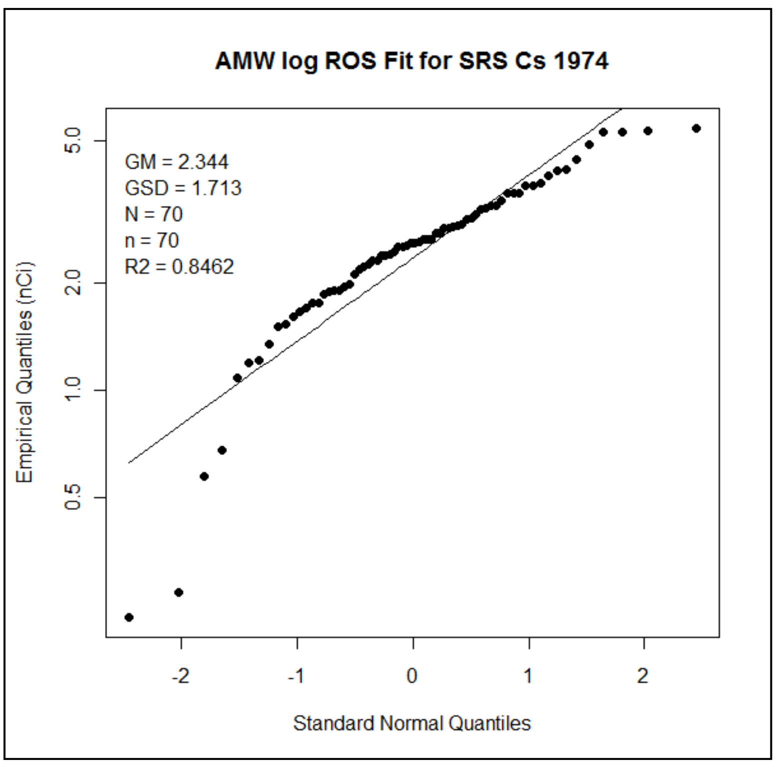

Figure A-56. ROS fit for AMW WBC data, 1974.

ATTACHMENT A
ROS AND BINOMIAL FIT PLOTS FOR AMWS, CTWS, AND NONCTWS
Page 29 of 50

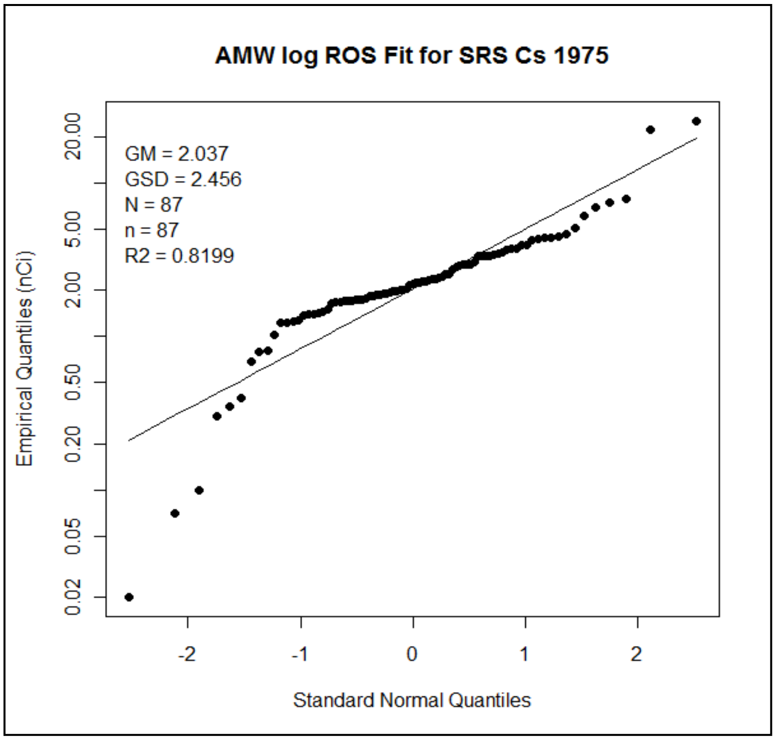

Figure A-57. ROS fit for AMW WBC data, 1975.

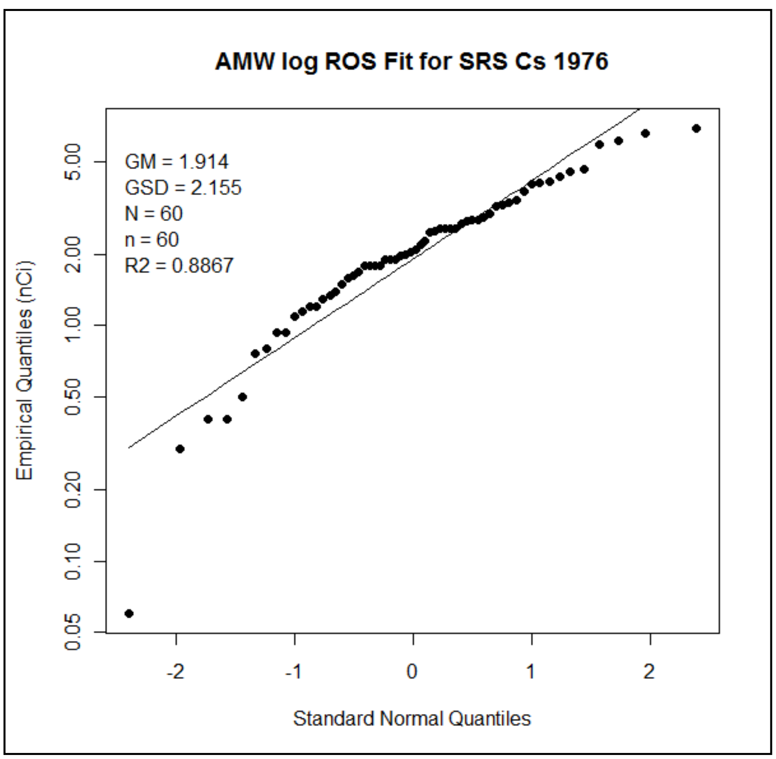

Figure A-58. ROS fit for AMW WBC data, 1976.

ATTACHMENT A
ROS AND BINOMIAL FIT PLOTS FOR AMWS, CTWS, AND NONCTWS

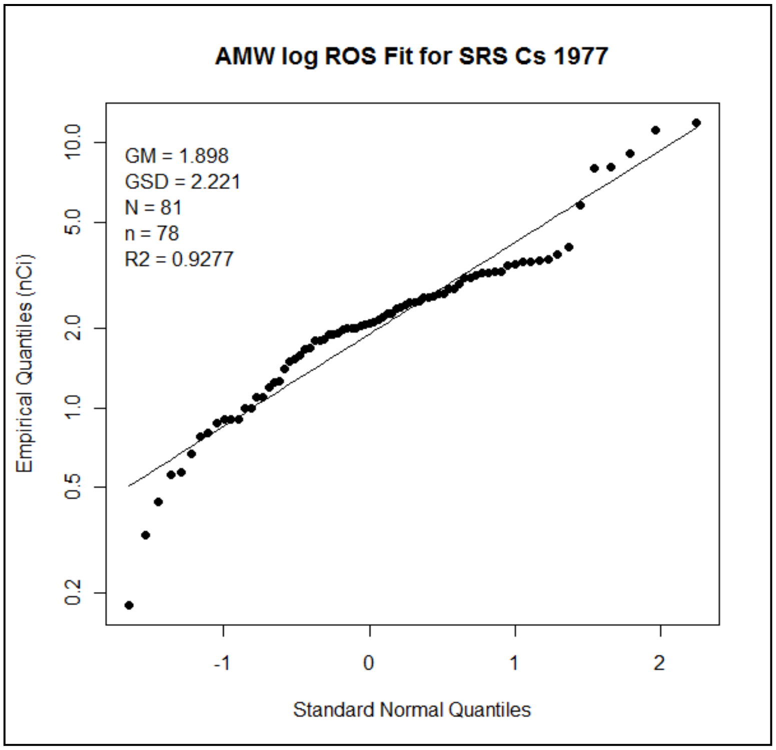

Figure A-59. ROS fit for AMW WBC data, 1977.

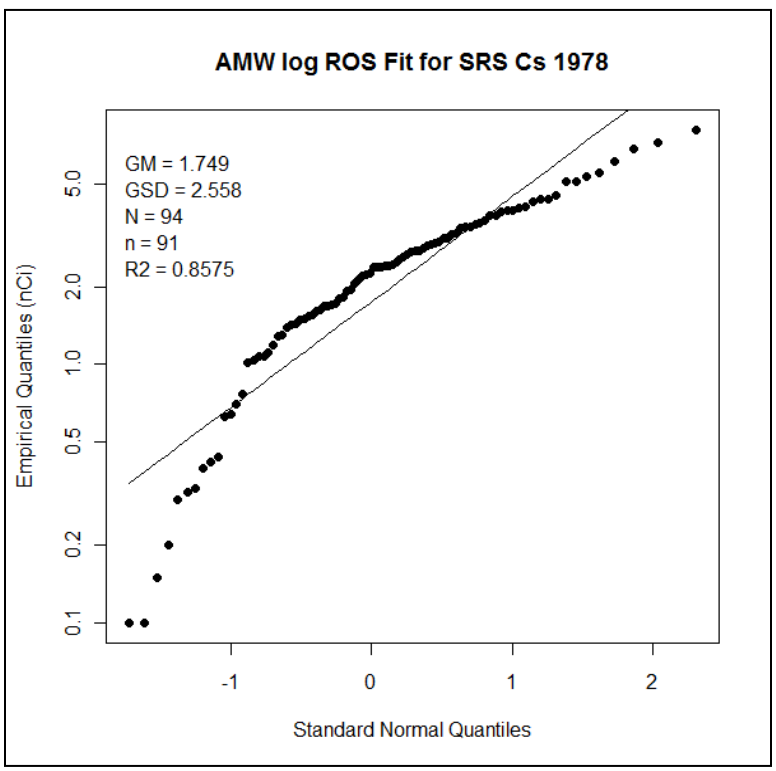

Figure A-60. ROS fit for AMW WBC data, 1978.

ATTACHMENT A
ROS AND BINOMIAL FIT PLOTS FOR AMWS, CTWS, AND NONCTWS

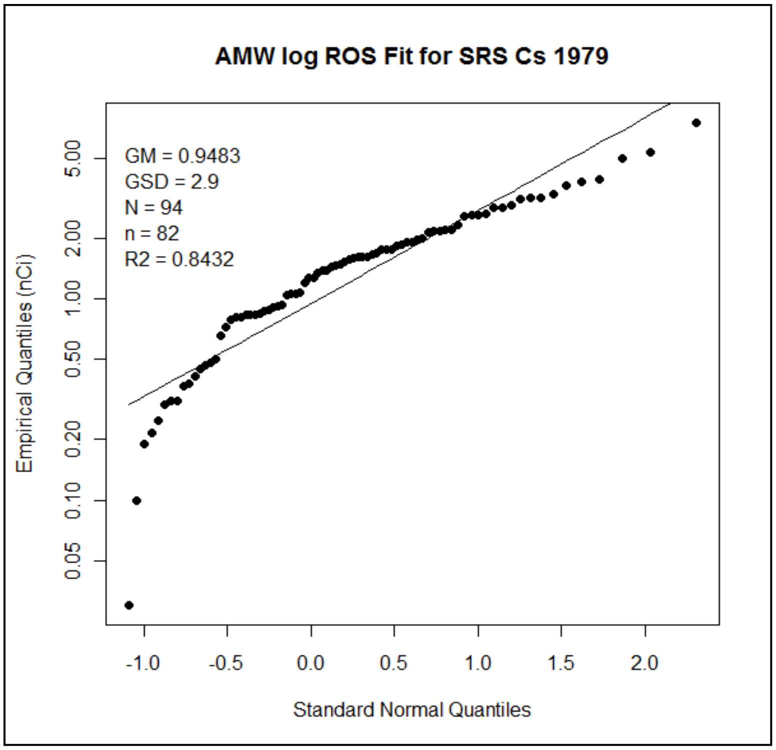

Figure A-61. ROS fit for AMW WBC data, 1979.

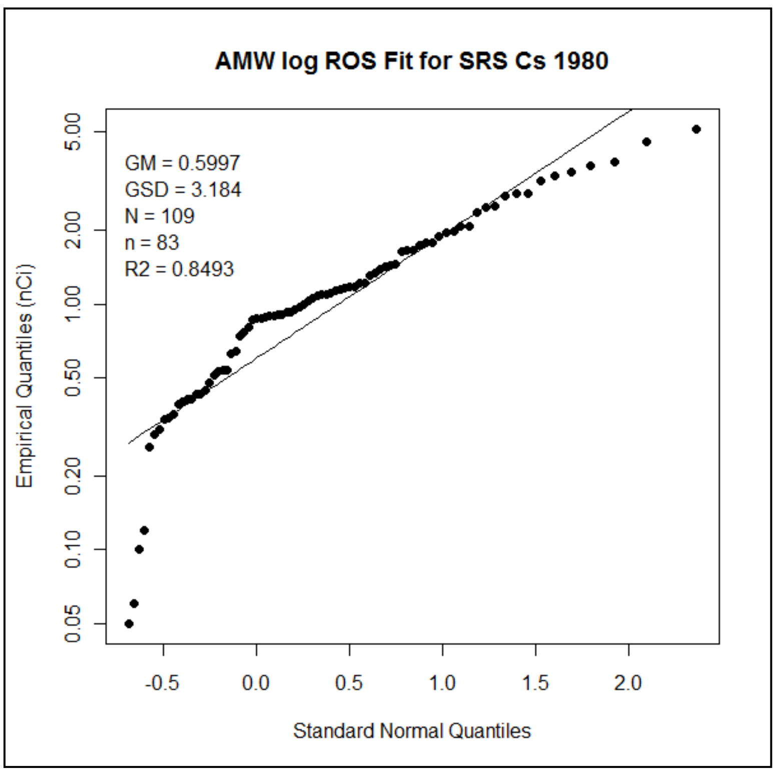

Figure A-62. ROS fit for AMW WBC data, 1980.

ATTACHMENT A
ROS AND BINOMIAL FIT PLOTS FOR AMWS, CTWS, AND NONCTWS

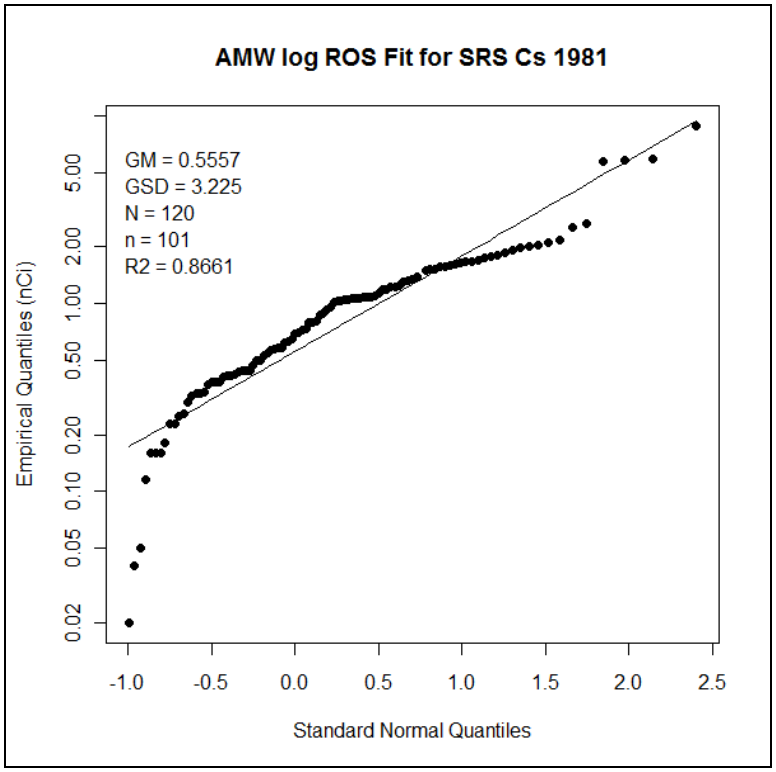

Figure A-63. ROS fit for AMW WBC data, 1981.

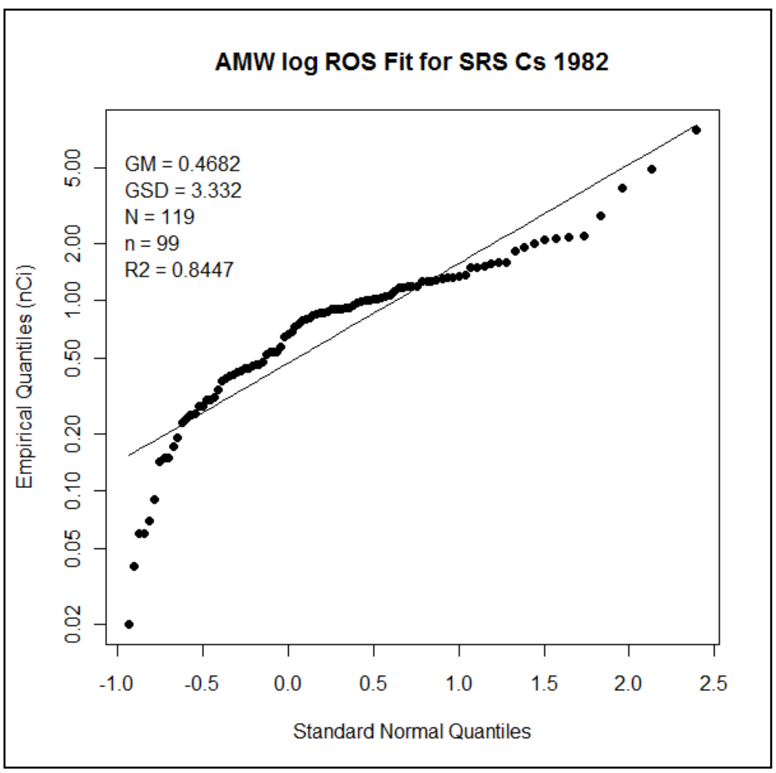

Figure A-64. ROS fit for AMW WBC data, 1982.

ATTACHMENT A
ROS AND BINOMIAL FIT PLOTS FOR AMWS, CTWS, AND NONCTWS
Page 33 of 50

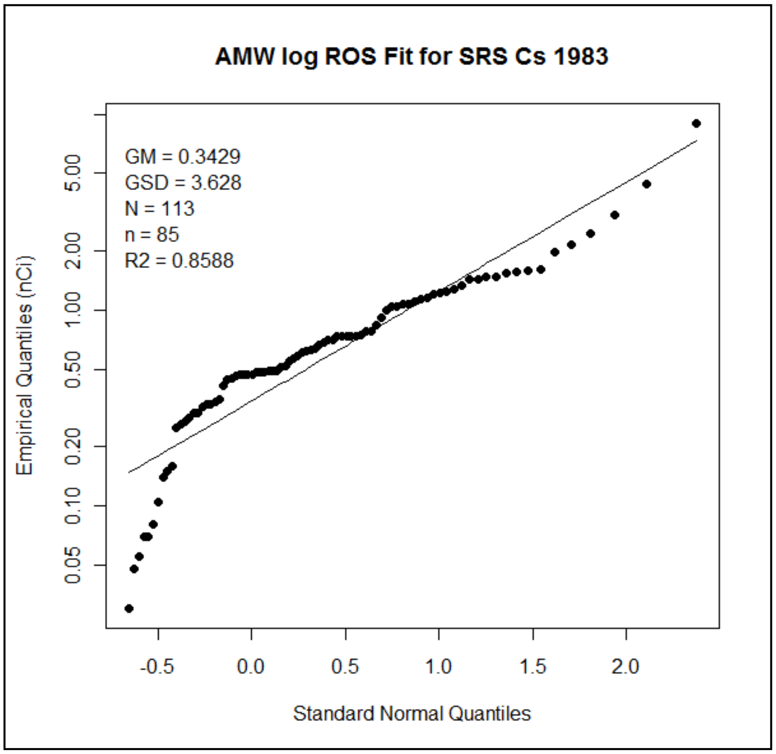

Figure A-65. ROS fit for AMW WBC data, 1983.

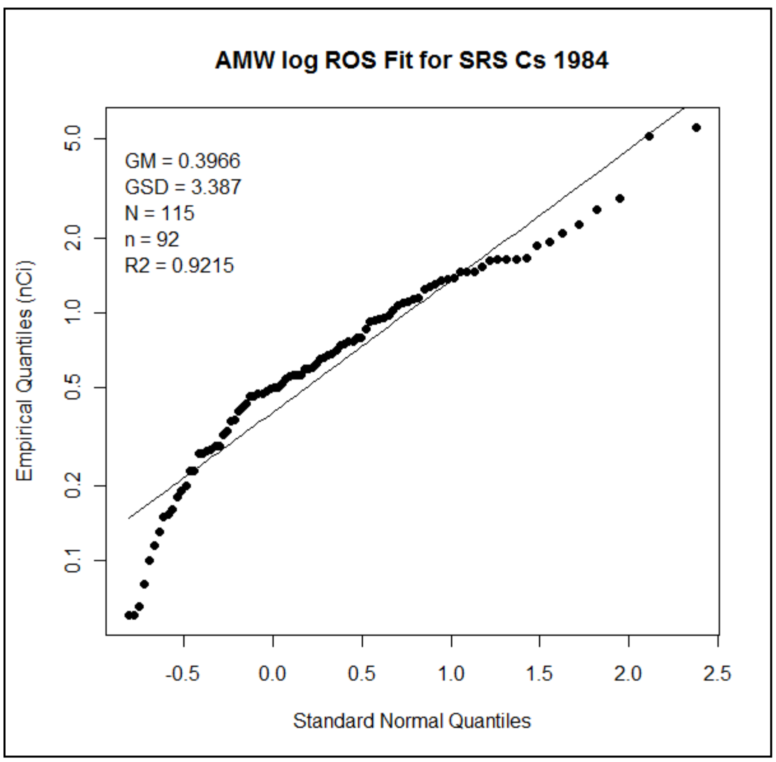

Figure A-66. ROS fit for AMW WBC data, 1984.

ATTACHMENT A
ROS AND BINOMIAL FIT PLOTS FOR AMWS, CTWS, AND NONCTWS

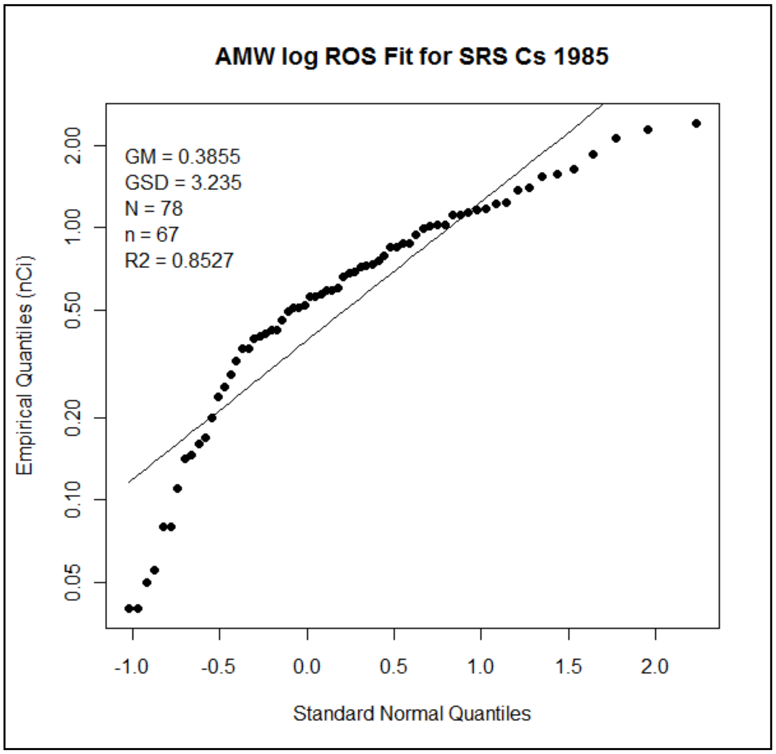

Figure A-67. ROS fit for AMW WBC data, 1985.

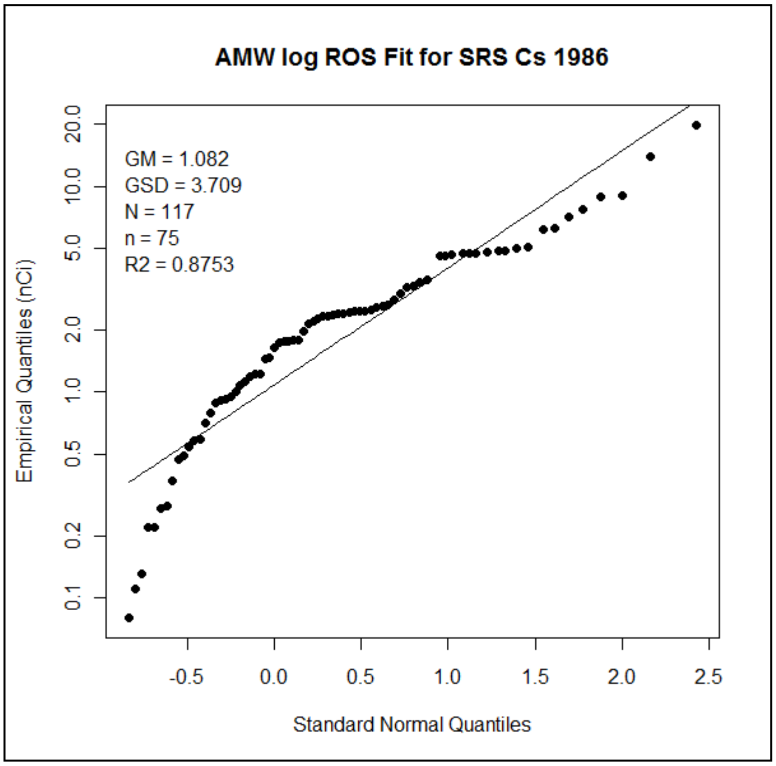

Figure A-68. ROS fit for AMW WBC data, 1986.

ATTACHMENT A
ROS AND BINOMIAL FIT PLOTS FOR AMWS, CTWS, AND NONCTWS

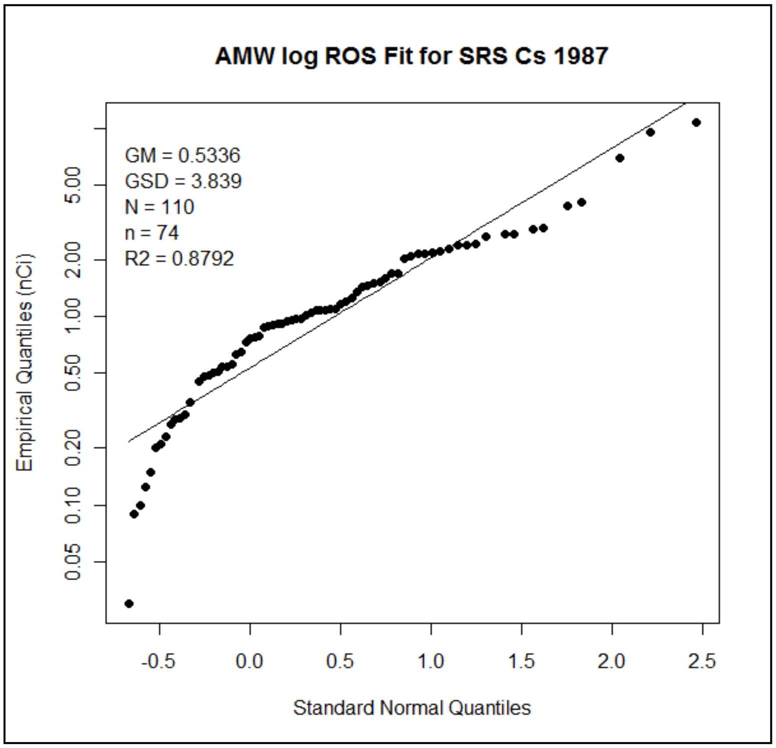

Figure A-69. ROS fit for AMW WBC data, 1987.

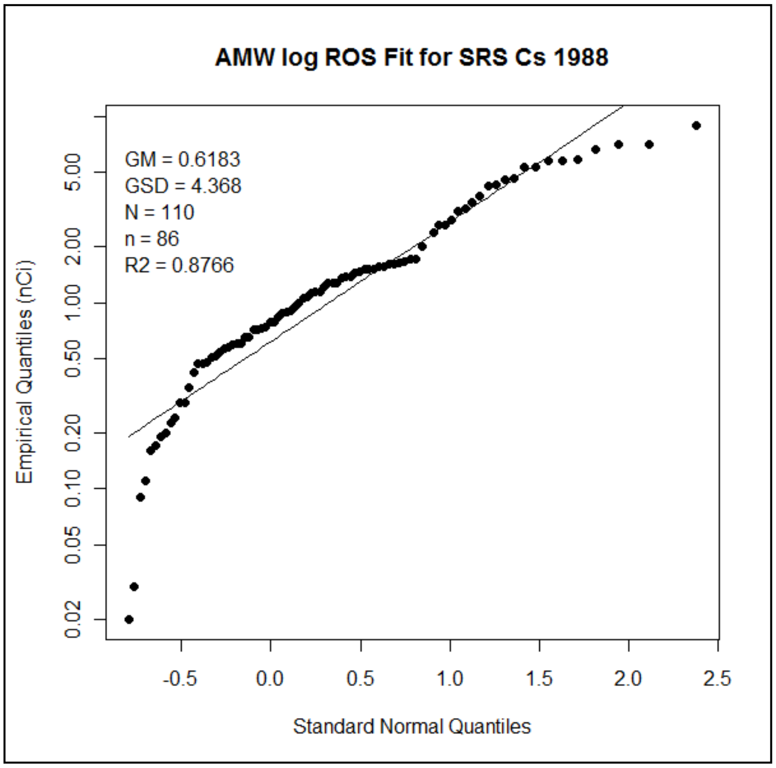

Figure A-70. ROS fit for AMW WBC data, 1988.

ATTACHMENT A
ROS AND BINOMIAL FIT PLOTS FOR AMWS, CTWS, AND NONCTWS

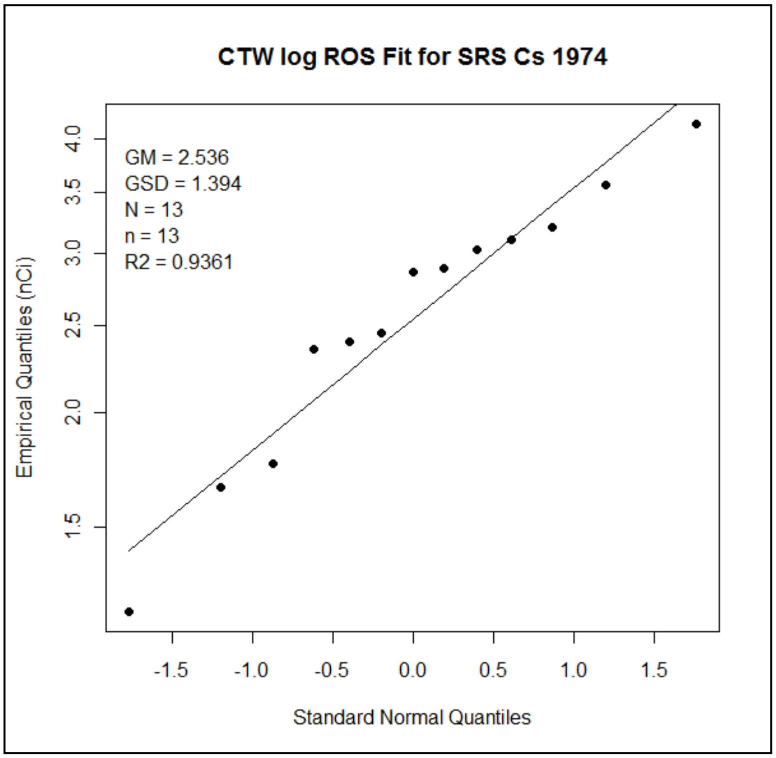

Figure A-71. ROS fit for CTW WBC data, 1974.

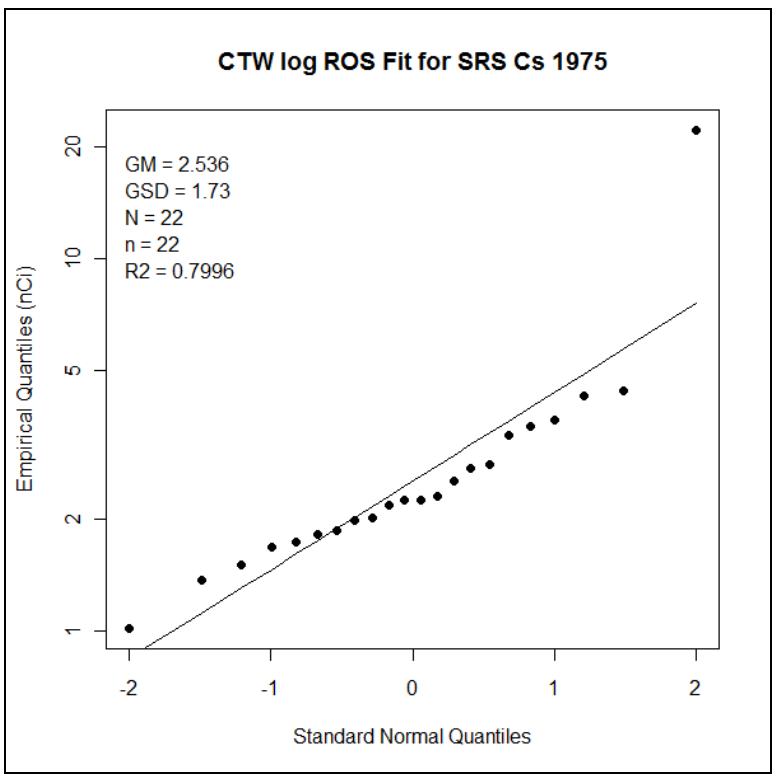

Figure A-72. ROS fit for CTW WBC data, 1975.

ATTACHMENT A
ROS AND BINOMIAL FIT PLOTS FOR AMWS, CTWS, AND NONCTWS

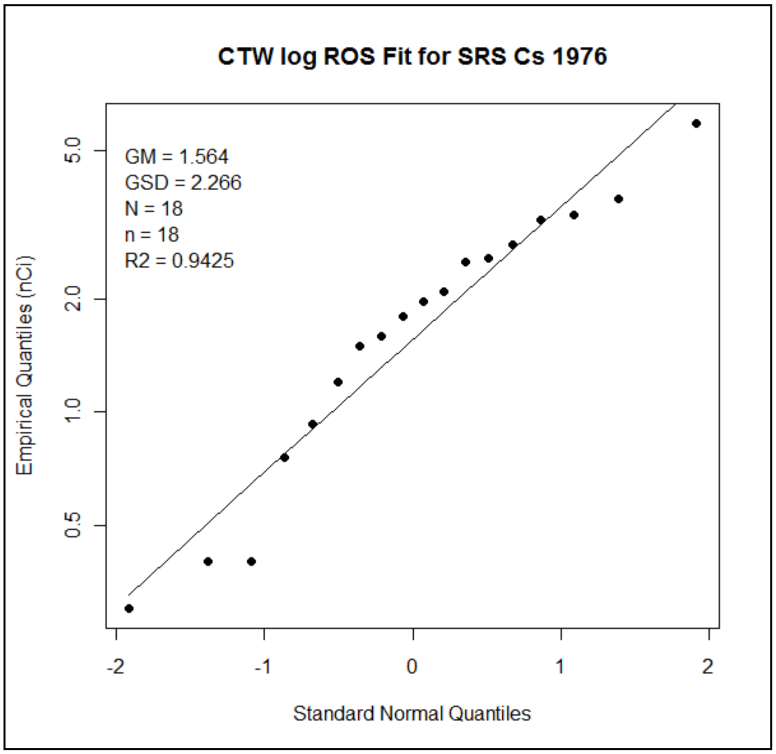

Figure A-73. ROS fit for CTW WBC data, 1976.

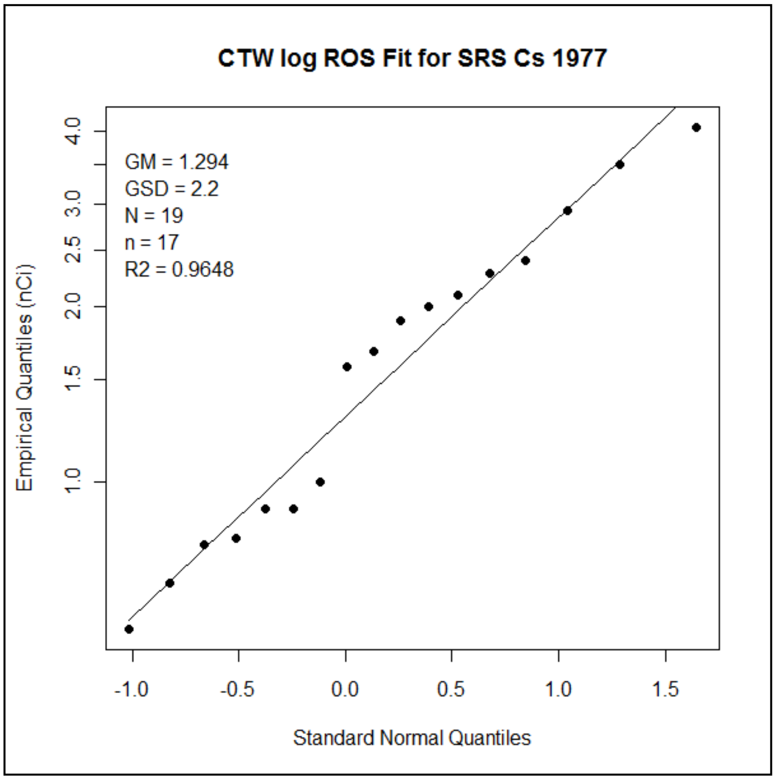

Figure A-74. ROS fit for CTW WBC data, 1977.

ATTACHMENT A
ROS AND BINOMIAL FIT PLOTS FOR AMWS, CTWS, AND NONCTWS

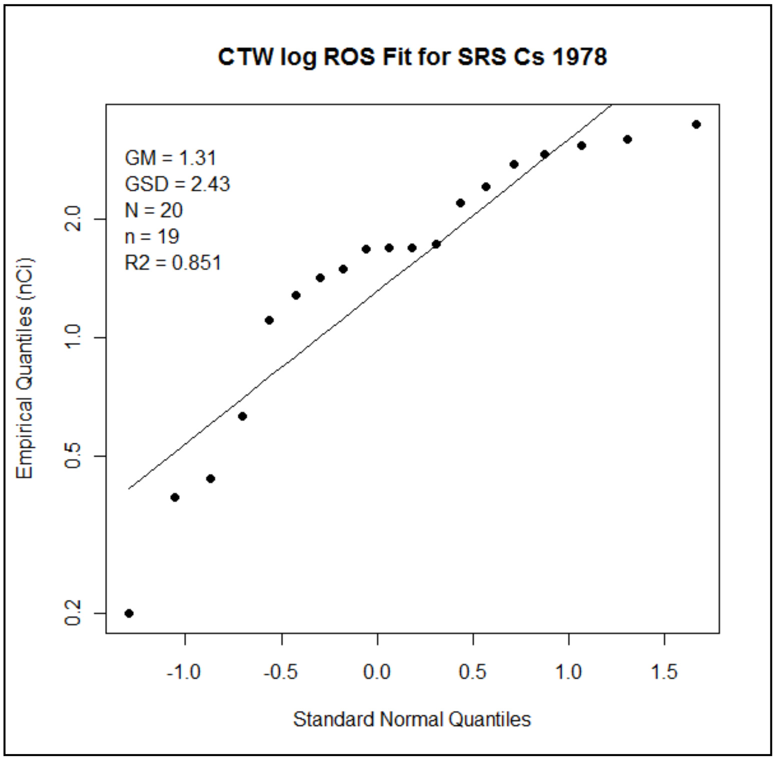

Figure A-75. ROS fit for CTW WBC data, 1978.

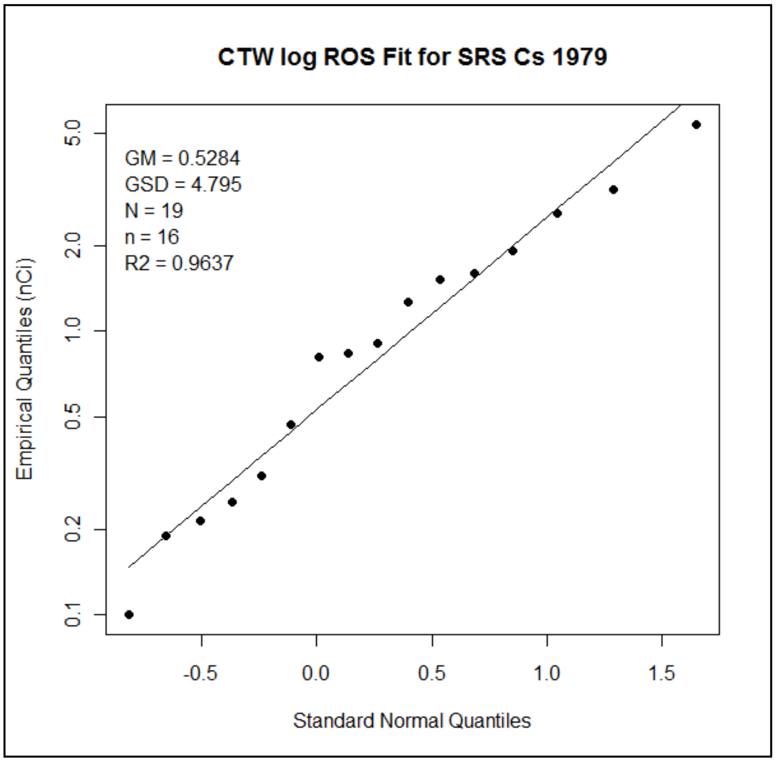

Figure A-76. ROS fit for CTW WBC data, 1979.

ATTACHMENT A
ROS AND BINOMIAL FIT PLOTS FOR AMWS, CTWS, AND NONCTWS

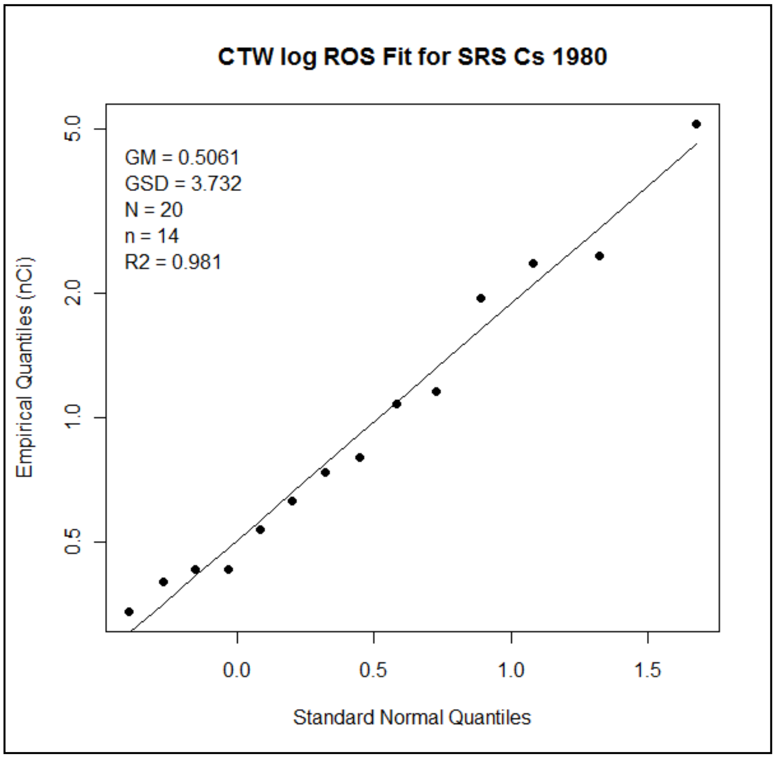

Figure A-77. ROS fit for CTW WBC data, 1980.

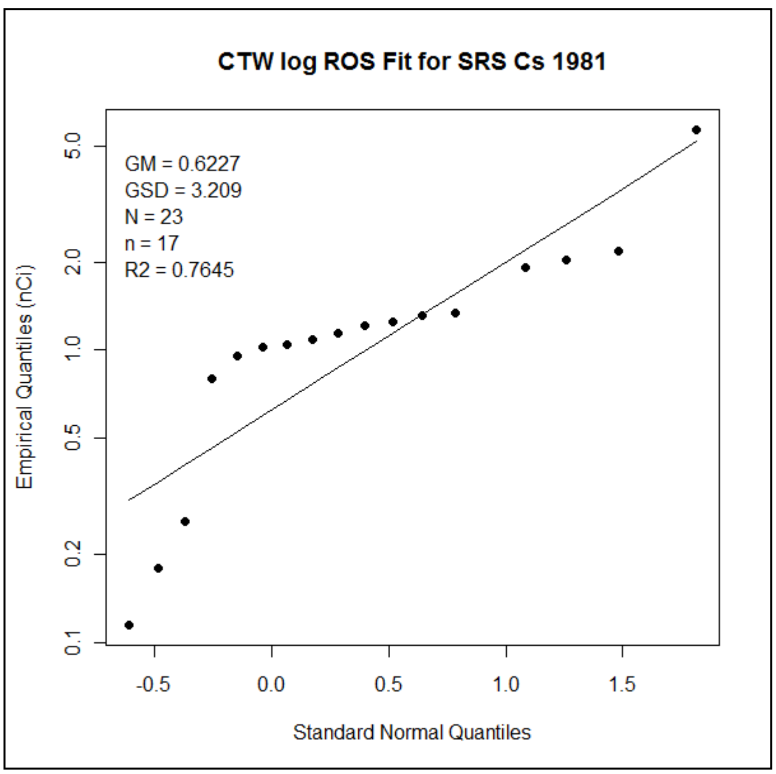

Figure A-78. ROS fit for CTW WBC data, 1981.

ATTACHMENT A
ROS AND BINOMIAL FIT PLOTS FOR AMWS, CTWS, AND NONCTWS

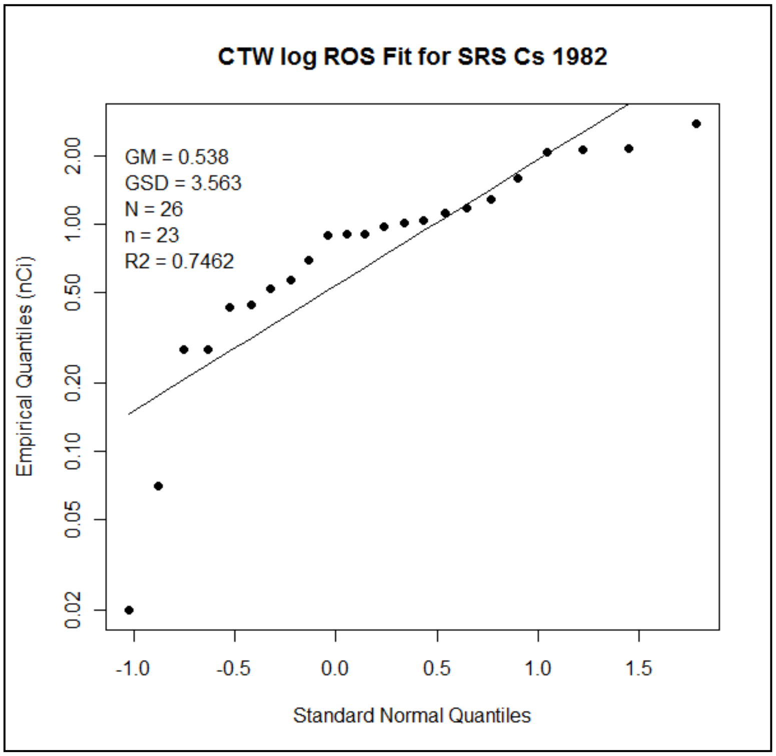

Figure A-79. ROS fit for CTW WBC data, 1982.

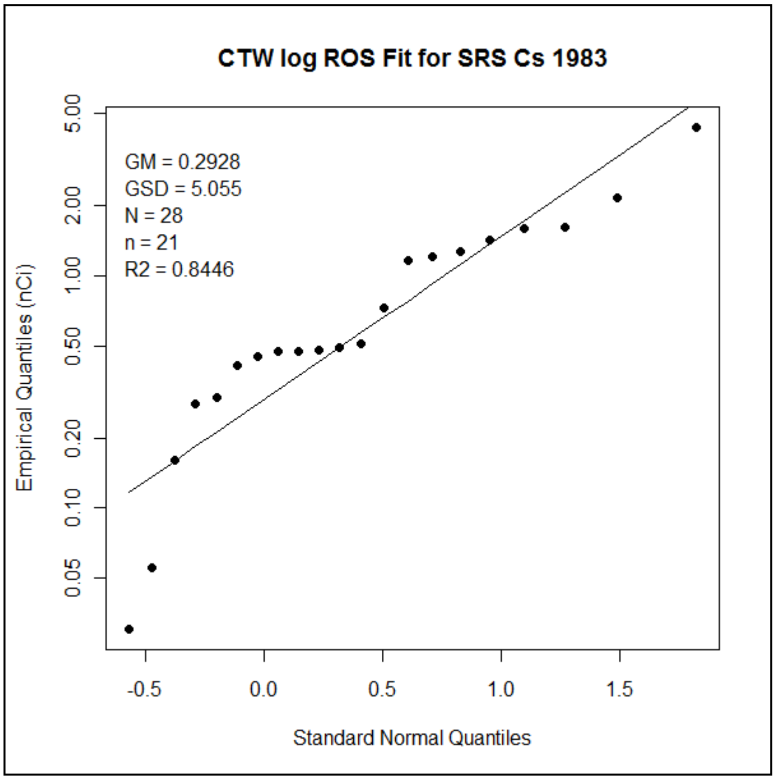

Figure A-80. ROS fit for CTW WBC data, 1983.

ATTACHMENT A
ROS AND BINOMIAL FIT PLOTS FOR AMWS, CTWS, AND NONCTWS

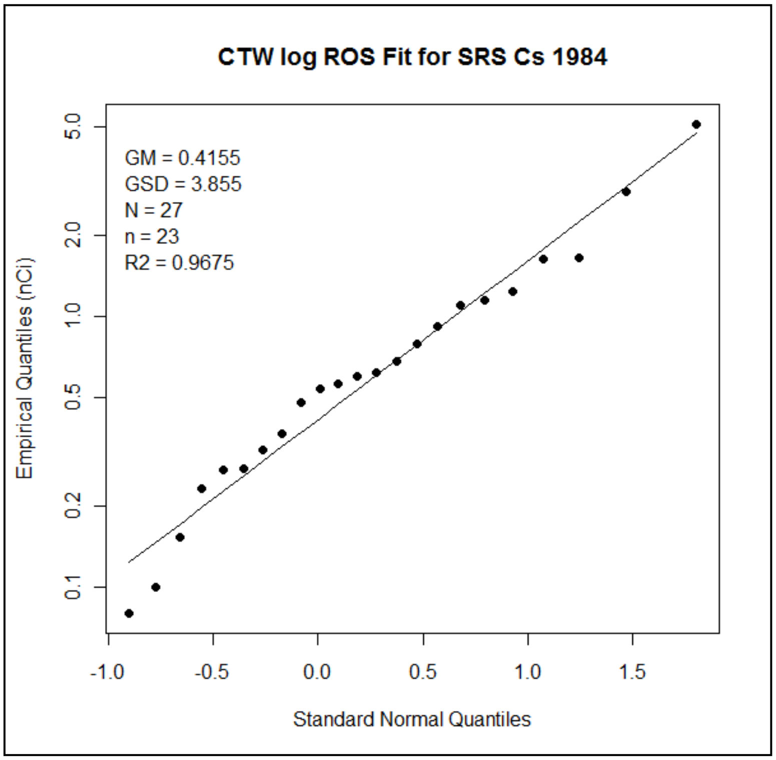

Figure A-81. ROS fit for CTW WBC data, 1984.

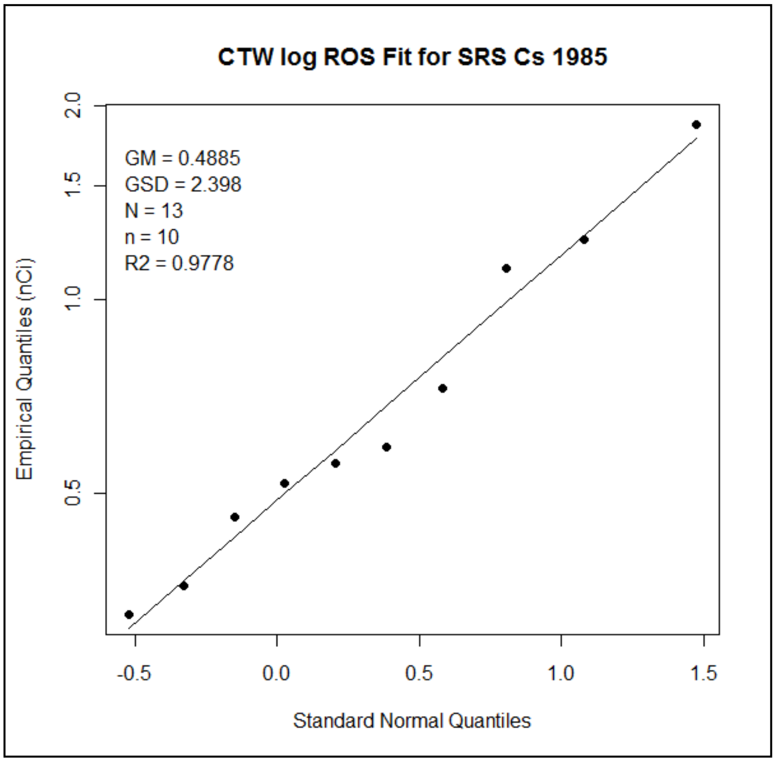

Figure A-82. ROS fit for CTW WBC data, 1985.

ATTACHMENT A
ROS AND BINOMIAL FIT PLOTS FOR AMWS, CTWS, AND NONCTWS

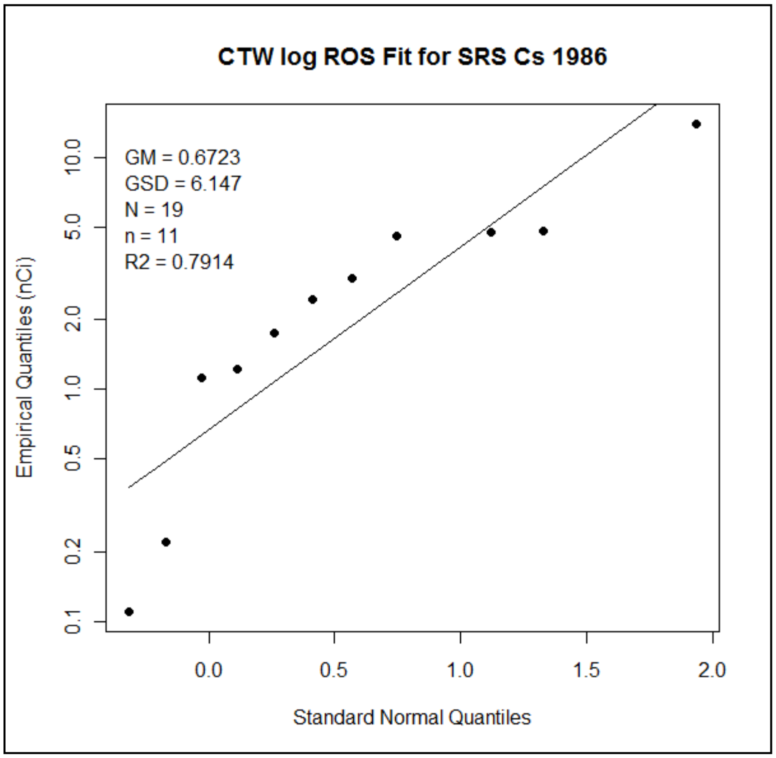

Figure A-83. ROS fit for CTW WBC data, 1986.

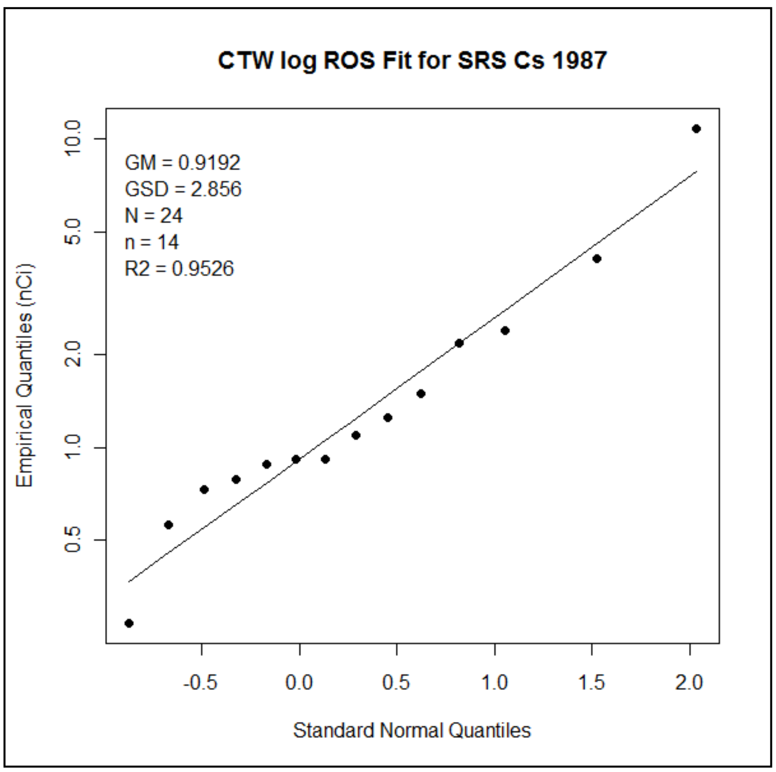

Figure A-84. ROS fit for CTW WBC data, 1987.

ATTACHMENT A
ROS AND BINOMIAL FIT PLOTS FOR AMWS, CTWS, AND NONCTWS

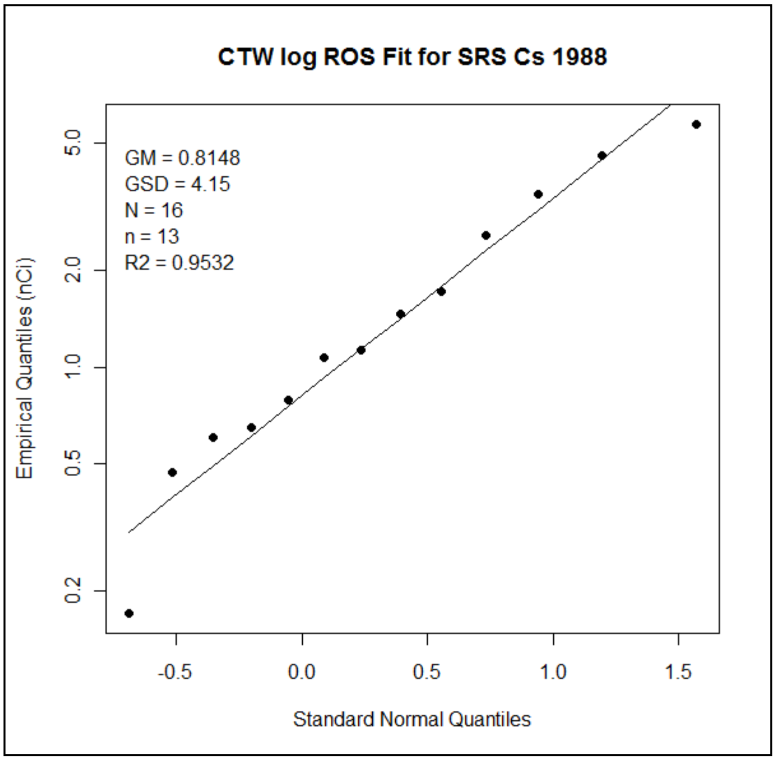

Figure A-85. ROS fit for CTW WBC data, 1988.

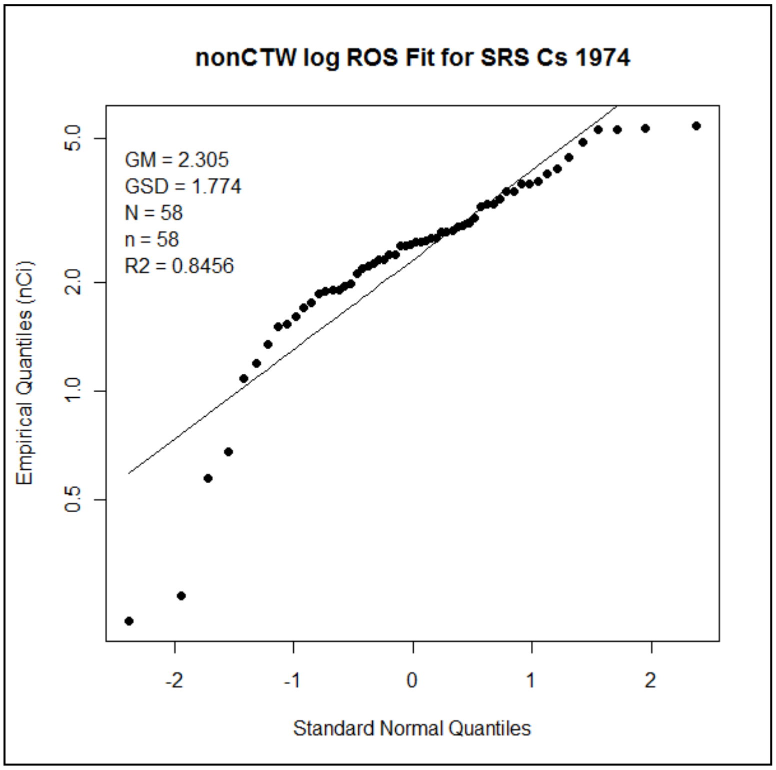

Figure A-86. ROS fit for nonCTW WBC data, 1974.

ATTACHMENT A
ROS AND BINOMIAL FIT PLOTS FOR AMWS, CTWS, AND NONCTWS

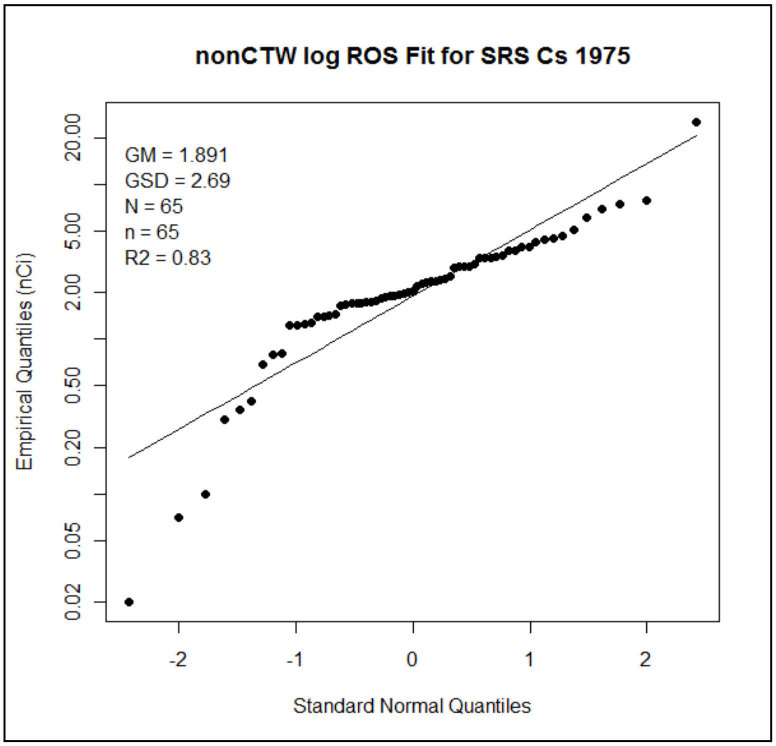

Figure A-87. ROS fit for nonCTW WBC data, 1975.

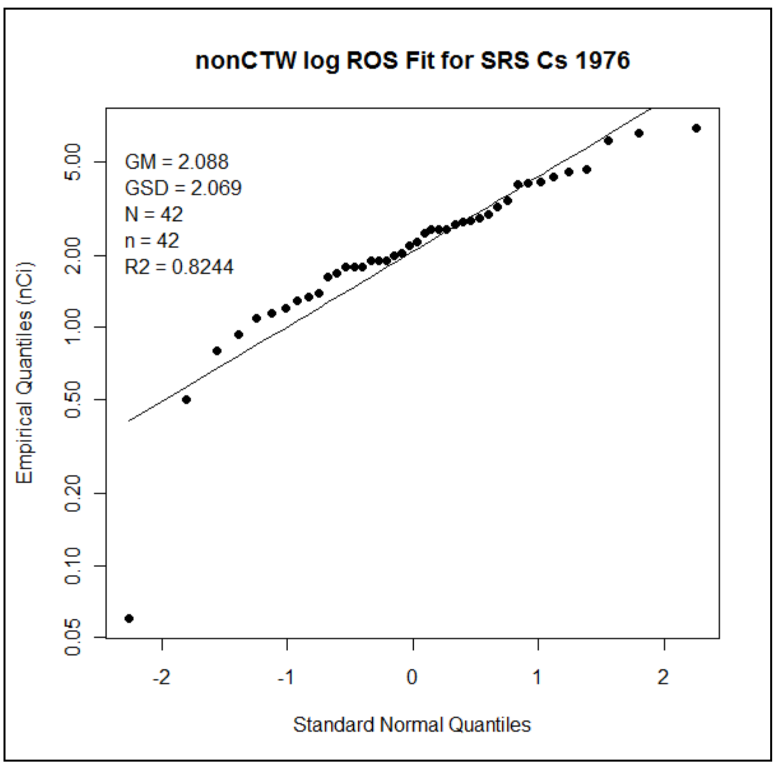

Figure A-88. ROS fit for nonCTW WBC data, 1976.

ATTACHMENT A
ROS AND BINOMIAL FIT PLOTS FOR AMWS, CTWS, AND NONCTWS

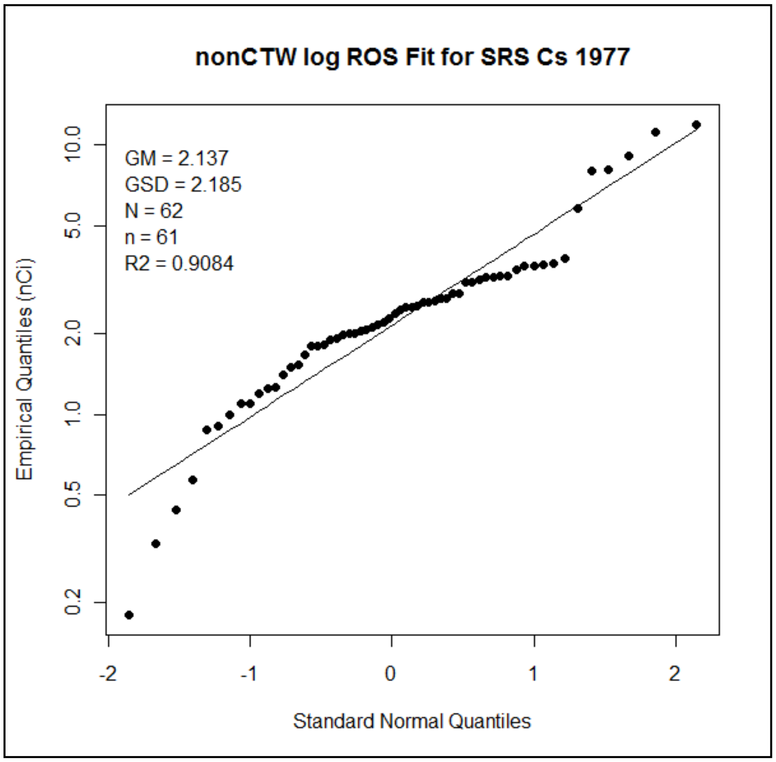

Figure A-89. ROS fit for nonCTW WBC data, 1977.

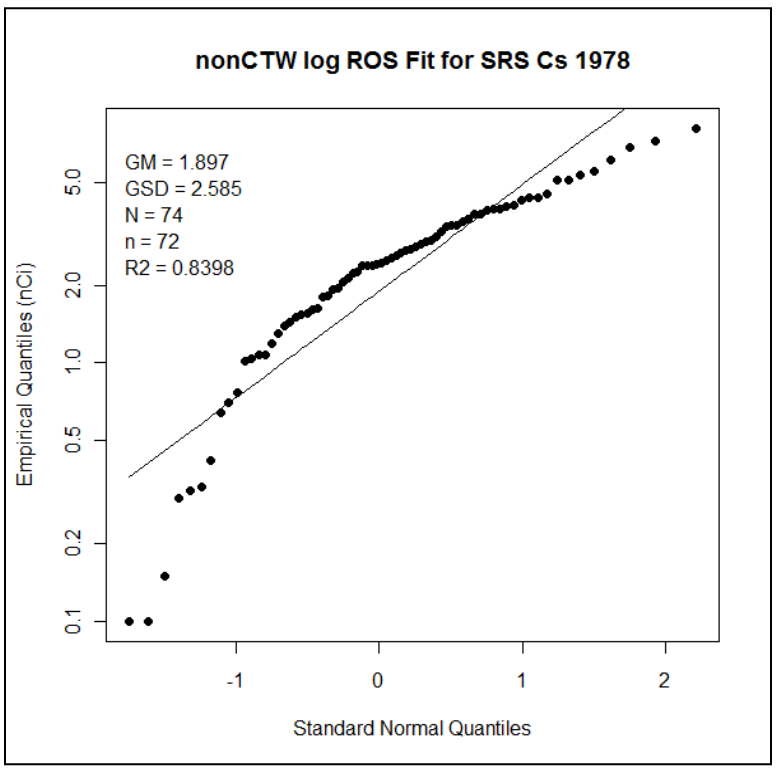

Figure A-90. ROS fit for nonCTW WBC data, 1978.

ATTACHMENT A
ROS AND BINOMIAL FIT PLOTS FOR AMWS, CTWS, AND NONCTWS

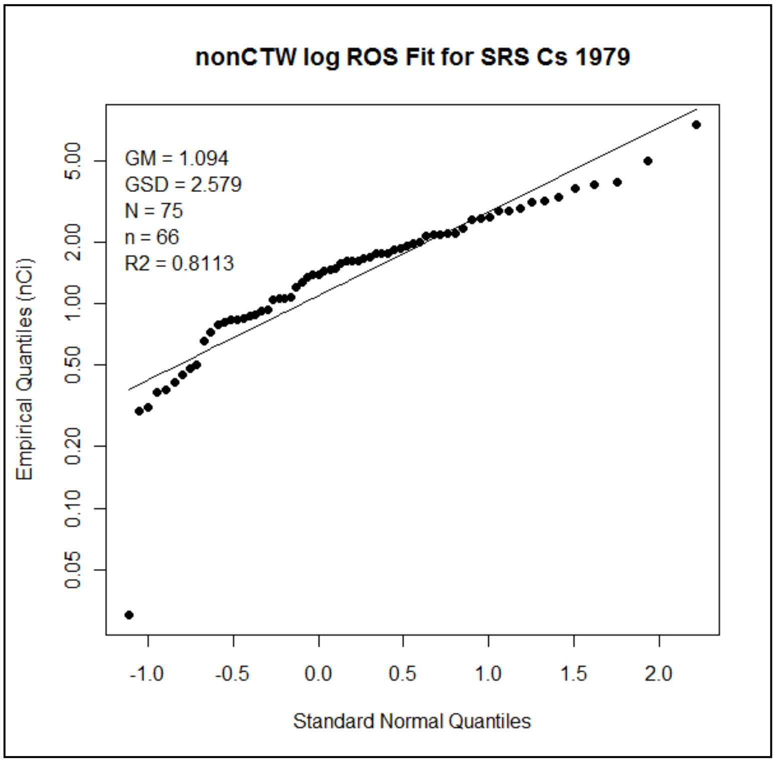

Figure A-91. ROS fit for nonCTW WBC data, 1979.

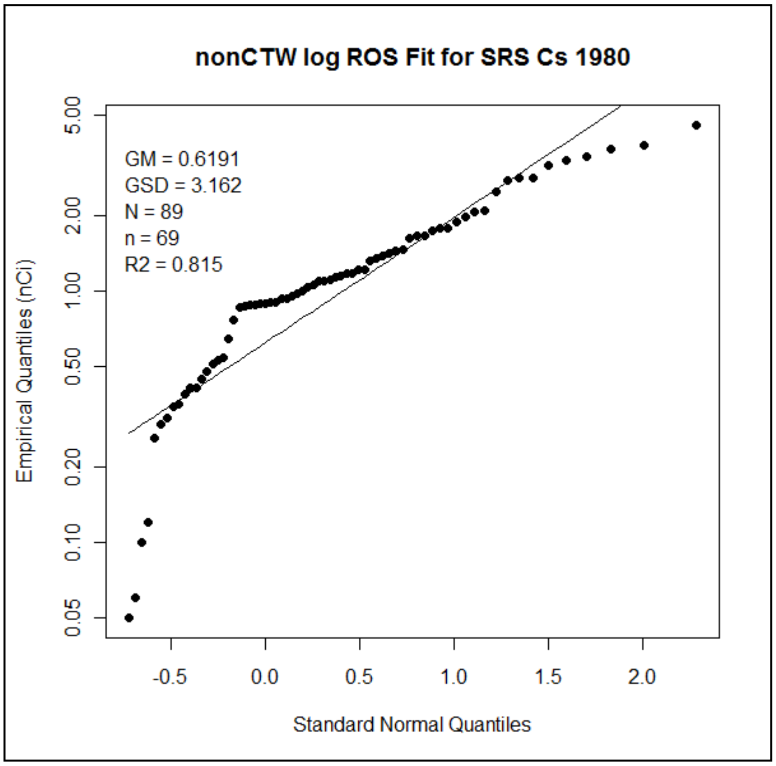

Figure A-92. ROS fit for nonCTW WBC data, 1980.

ATTACHMENT A
ROS AND BINOMIAL FIT PLOTS FOR AMWS, CTWS, AND NONCTWS

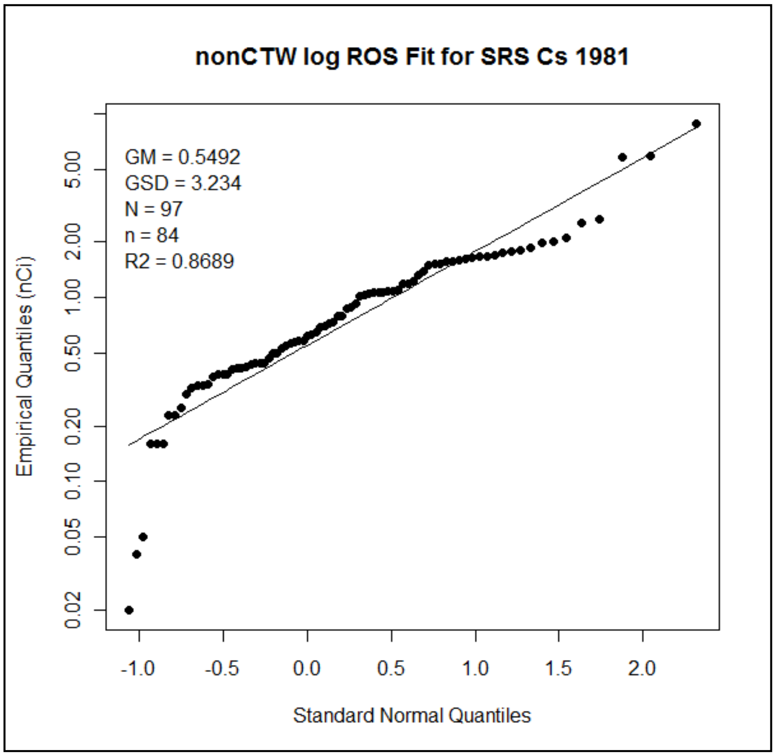

Figure A-93. ROS fit for nonCTW WBC data, 1981.

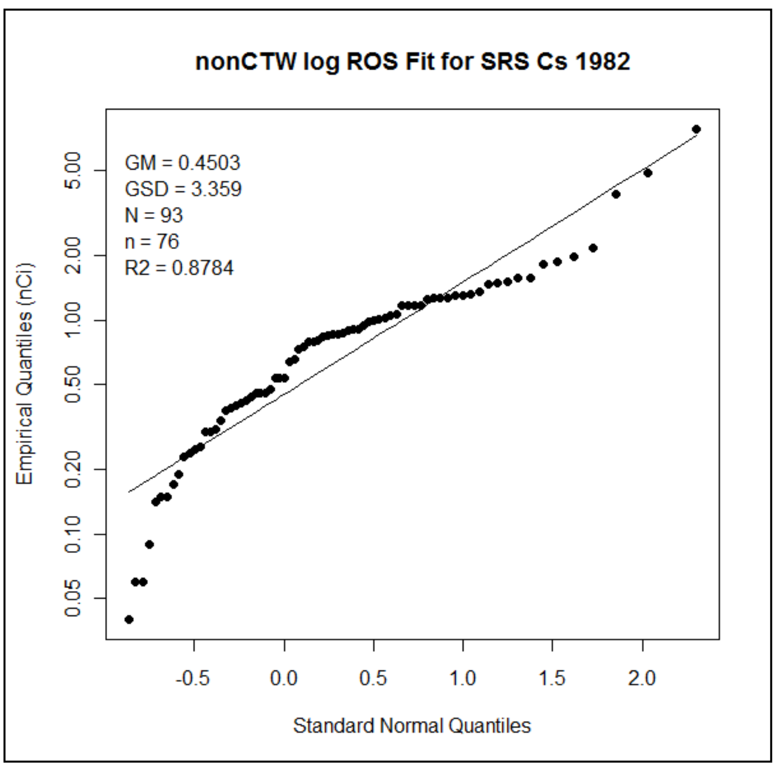

Figure A-94. ROS fit for nonCTW WBC data, 1982.

ATTACHMENT A
ROS AND BINOMIAL FIT PLOTS FOR AMWS, CTWS, AND NONCTWS

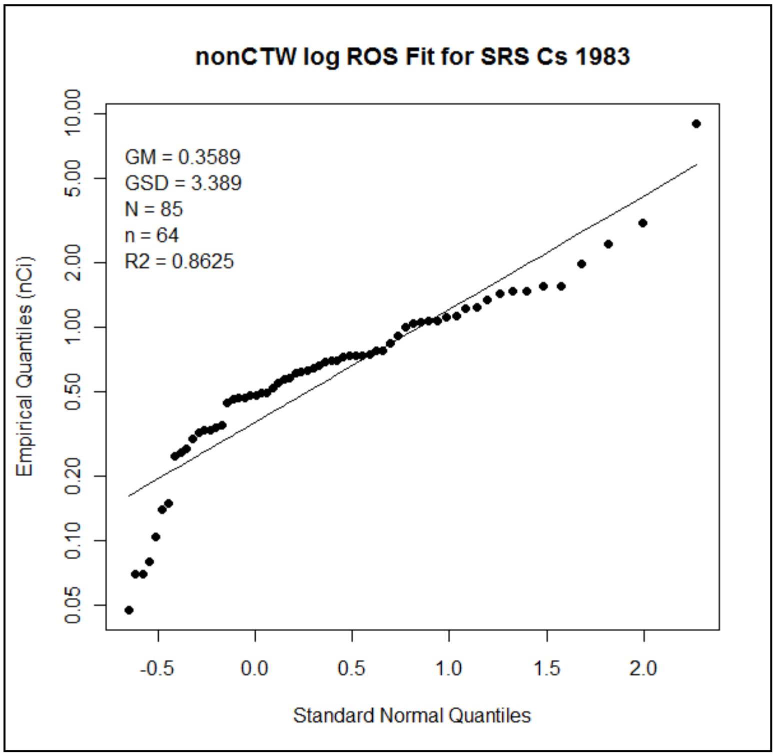

Figure A-95. ROS fit for nonCTW WBC data, 1983.

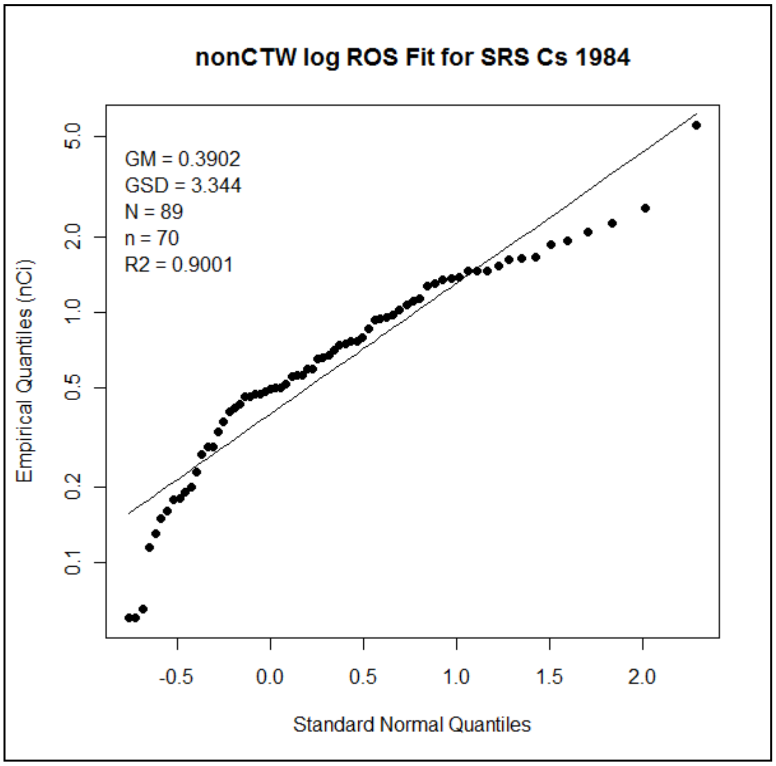

Figure A-96. ROS fit for nonCTW WBC data, 1984.

ATTACHMENT A
ROS AND BINOMIAL FIT PLOTS FOR AMWS, CTWS, AND NONCTWS

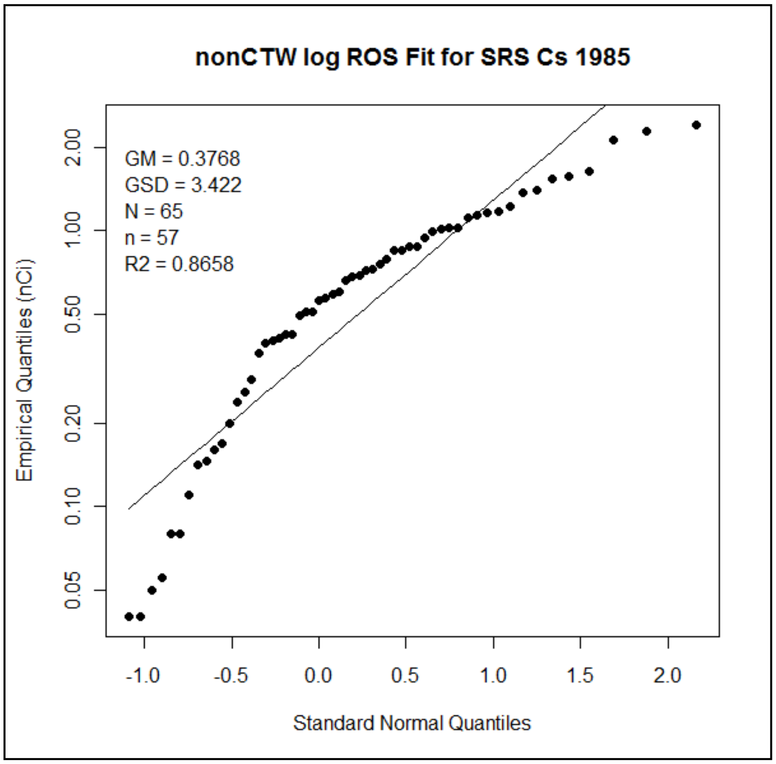

Figure A-97. ROS fit for nonCTW WBC data, 1985.

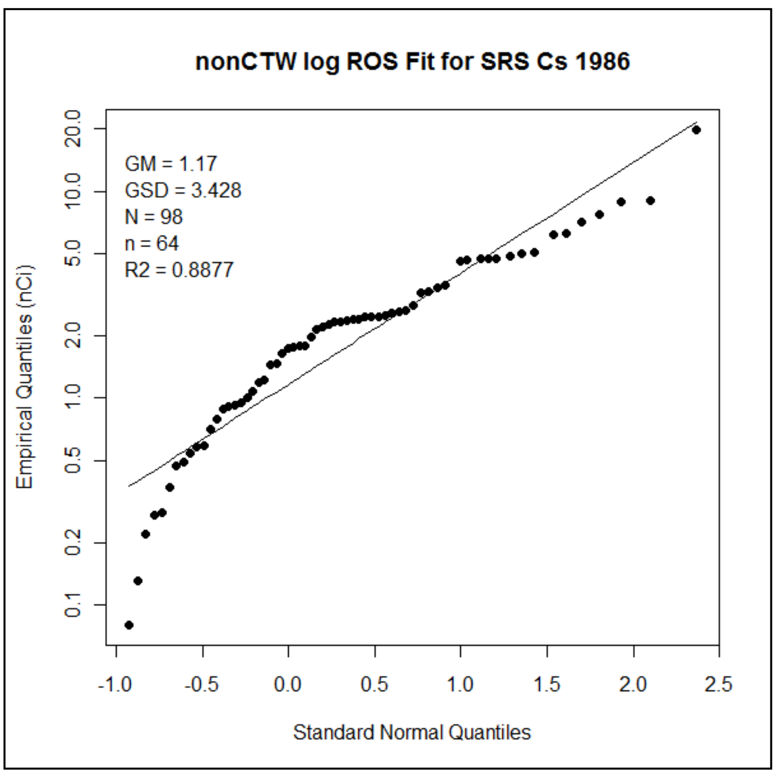

Figure A-98. ROS fit for nonCTW WBC data, 1986.

ATTACHMENT A
ROS AND BINOMIAL FIT PLOTS FOR AMWS, CTWS, AND NONCTWS

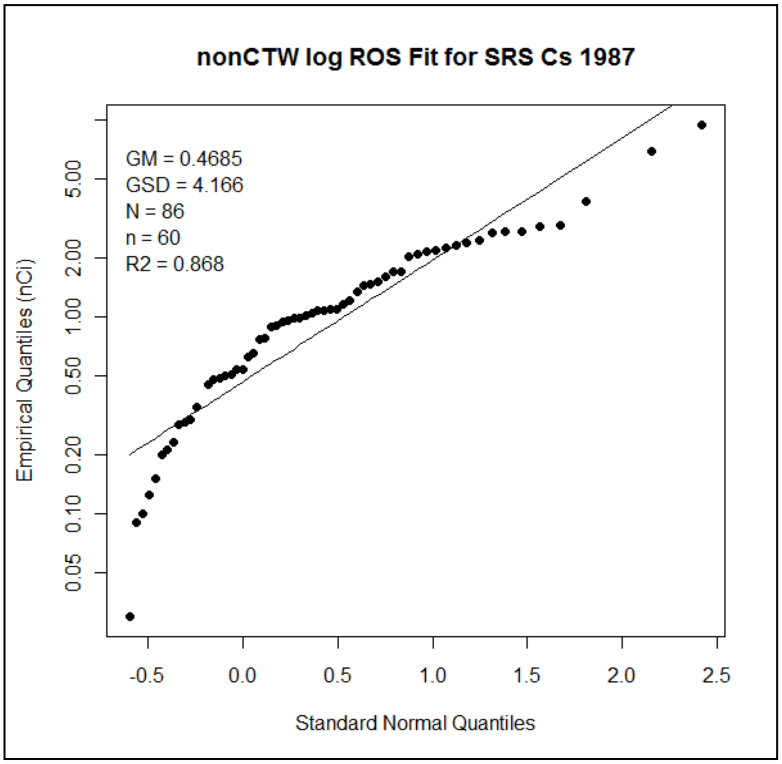

Figure A-99. ROS fit for nonCTW WBC data, 1987.

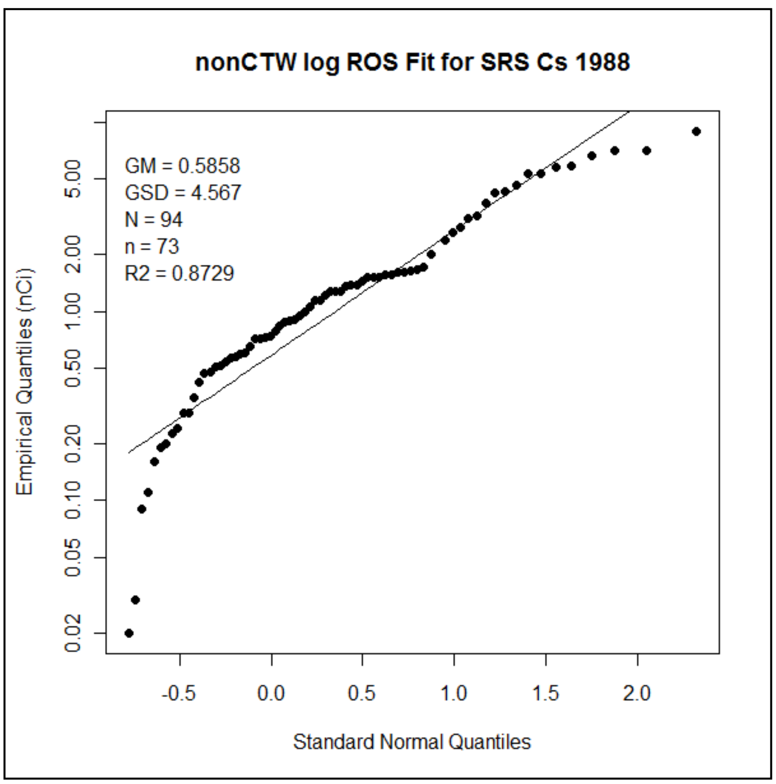

Figure A-100. ROS fit for nonCTW WBC data, 1988.

ATTACHMENT B
MCPT AND PETO-PRENTICE PLOTS FOR CTW:NONCTW COMPARISONS
Page 1 of 15

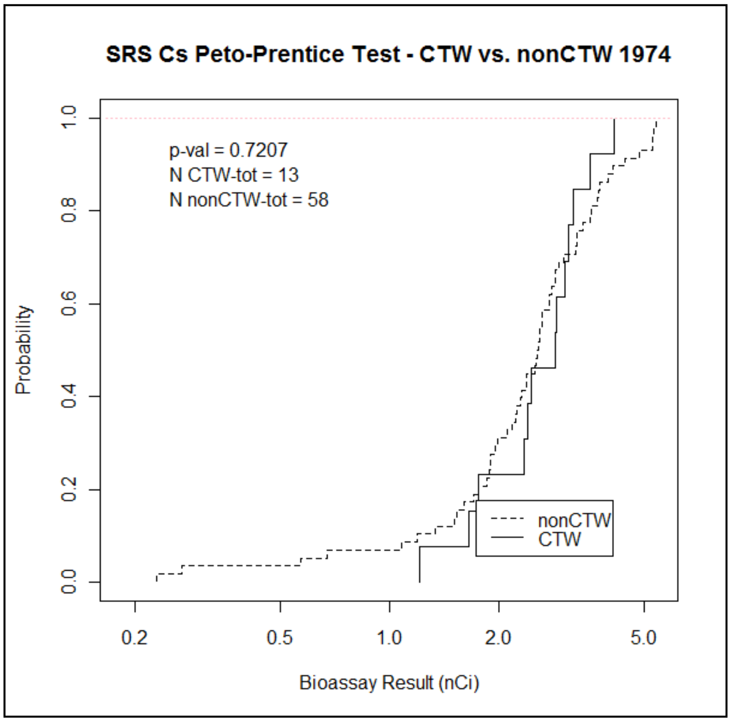

Figure B-1. Peto-Prentice test for CTW:nonCTW WBC data, 1974.

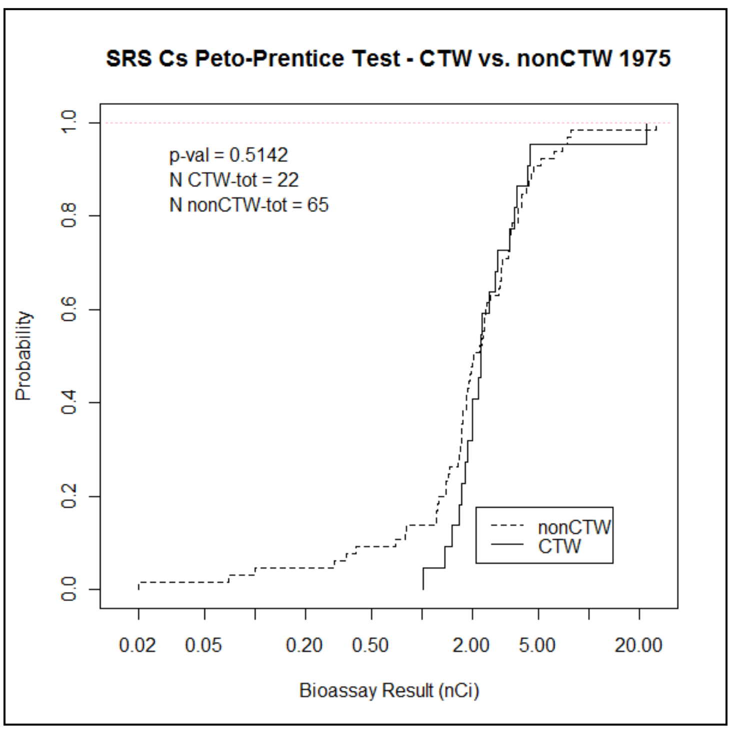

Figure B-2. Peto-Prentice test for CTW:nonCTW WBC data, 1975.

ATTACHMENT B
MCPT AND PETO-PRENTICE PLOTS FOR CTW:NONCTW COMPARISONS

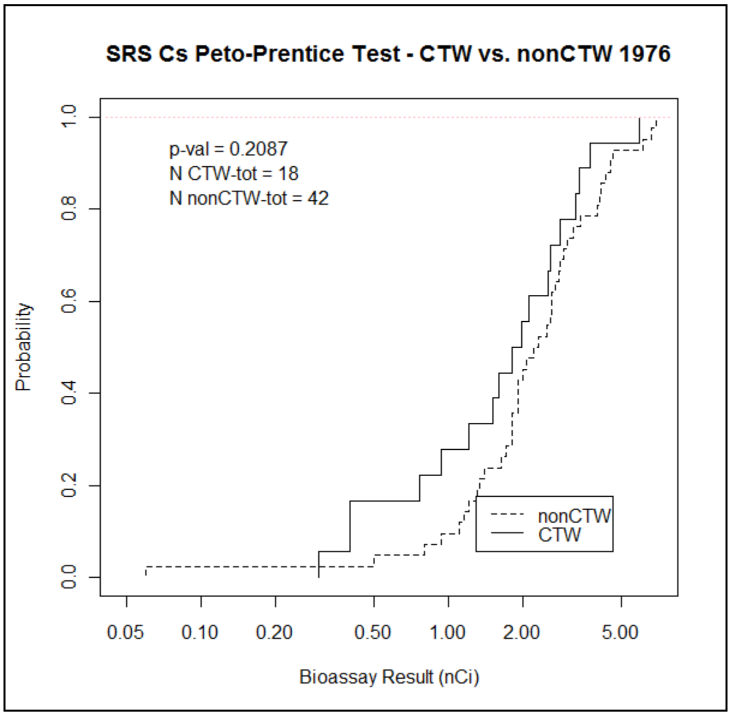

Figure B-3. Peto-Prentice test for CTW:nonCTW WBC data, 1976.

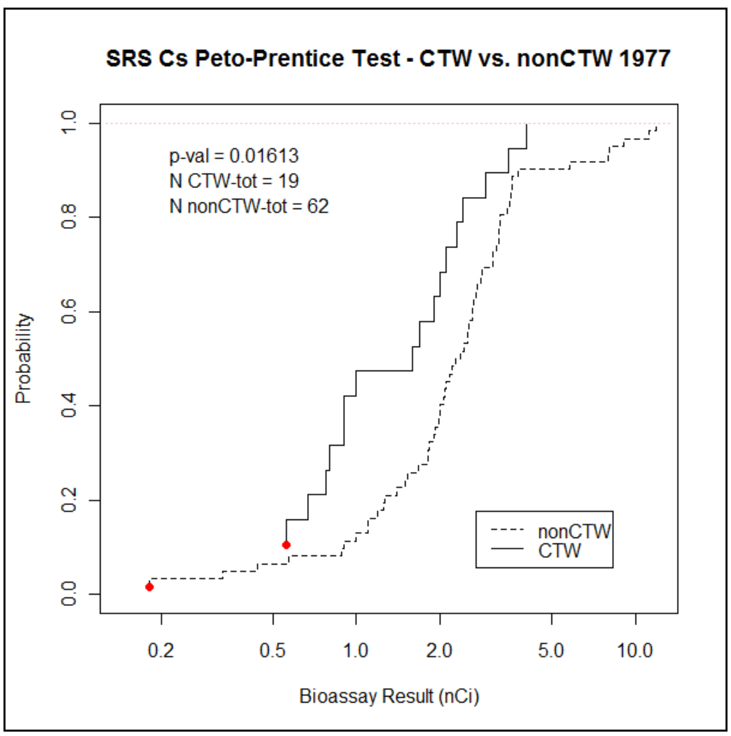

Figure B-4. Peto-Prentice test for CTW:nonCTW WBC data, 1977.

ATTACHMENT B
MCPT AND PETO-PRENTICE PLOTS FOR CTW:NONCTW COMPARISONS

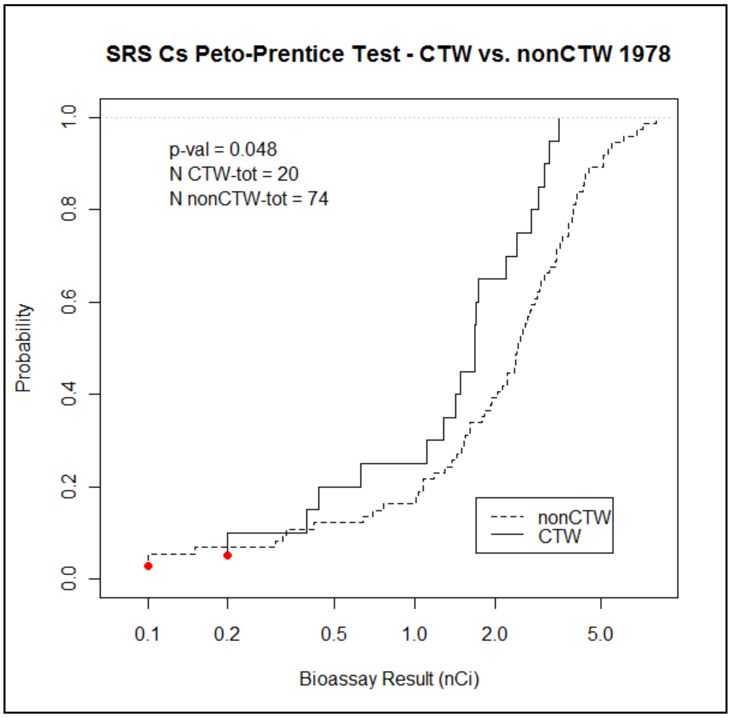

Figure B-5. Peto-Prentice test for CTW:nonCTW WBC data, 1978.

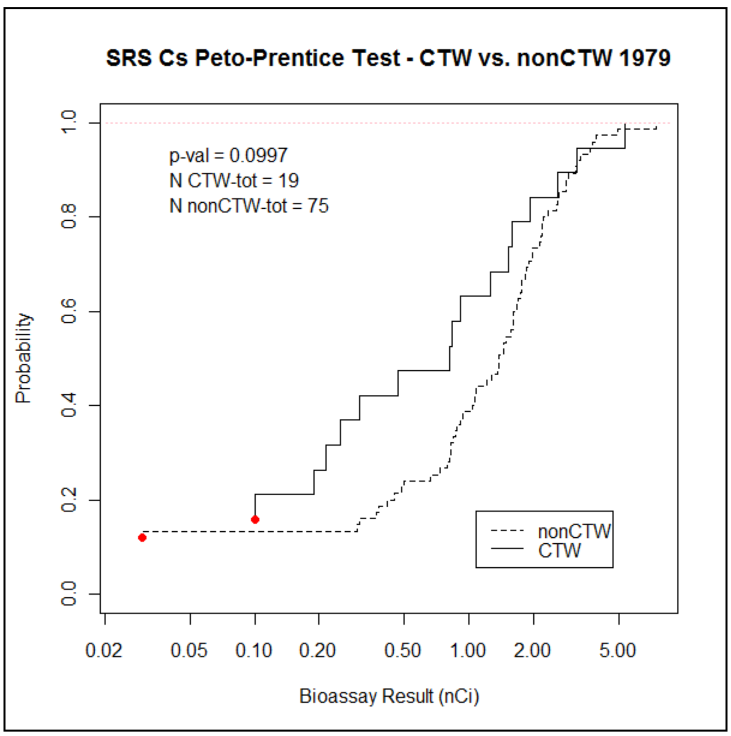

Figure B-6. Peto-Prentice test for CTW:nonCTW WBC data, 1979.

ATTACHMENT B
MCPT AND PETO-PRENTICE PLOTS FOR CTW:NONCTW COMPARISONS

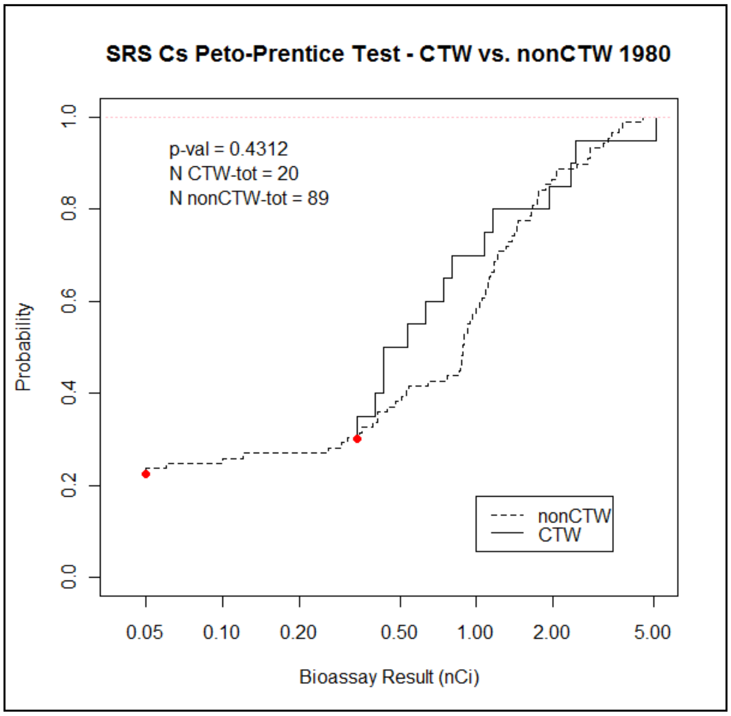

Figure B-7. Peto-Prentice test for CTW:nonCTW WBC data, 1980.

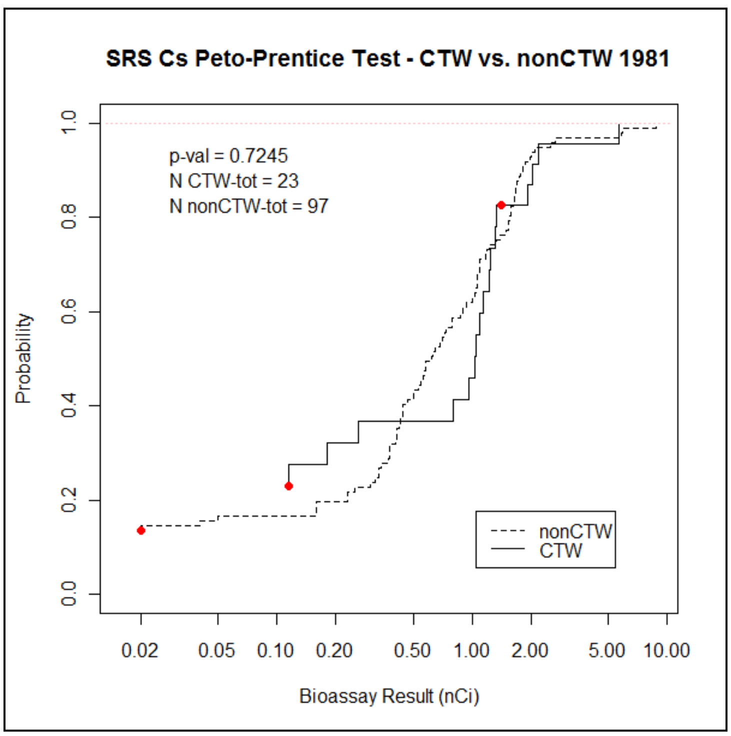

Figure B-8. Peto-Prentice test for CTW:nonCTW WBC data, 1981.

ATTACHMENT B
MCPT AND PETO-PRENTICE PLOTS FOR CTW:NONCTW COMPARISONS
Page 5 of 15

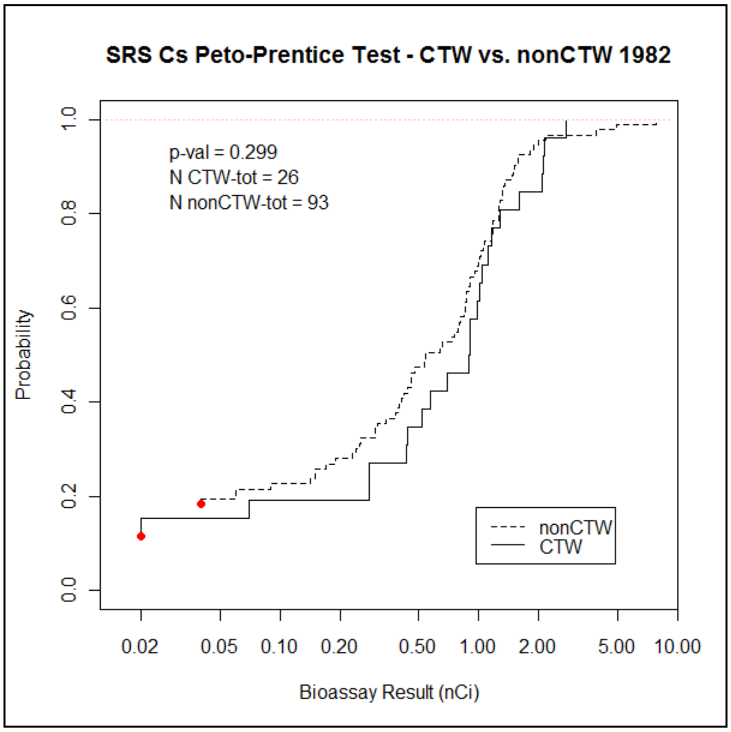

Figure B-9. Peto-Prentice test for CTW:nonCTW WBC data, 1982.

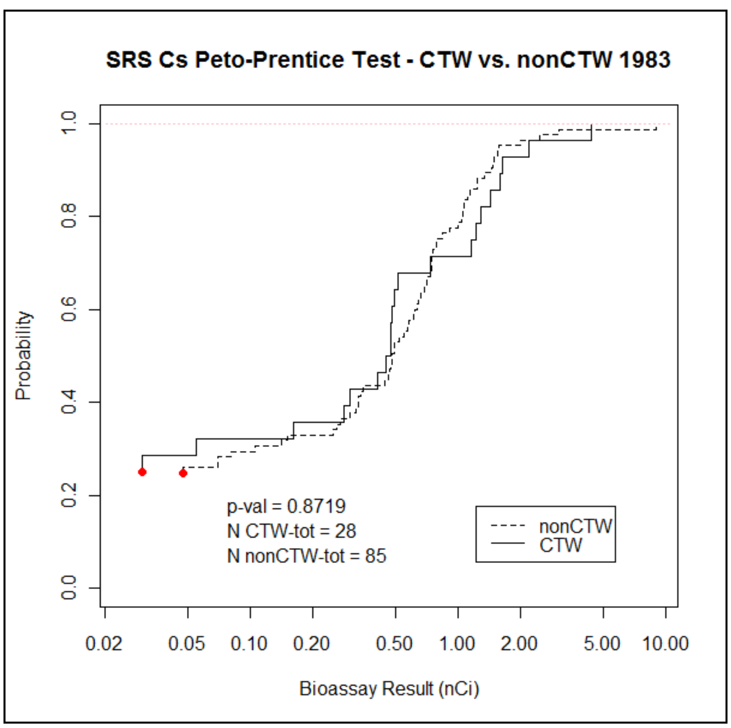

Figure B-10. Peto-Prentice test for CTW:nonCTW WBC data, 1983.

ATTACHMENT B
MCPT AND PETO-PRENTICE PLOTS FOR CTW:NONCTW COMPARISONS

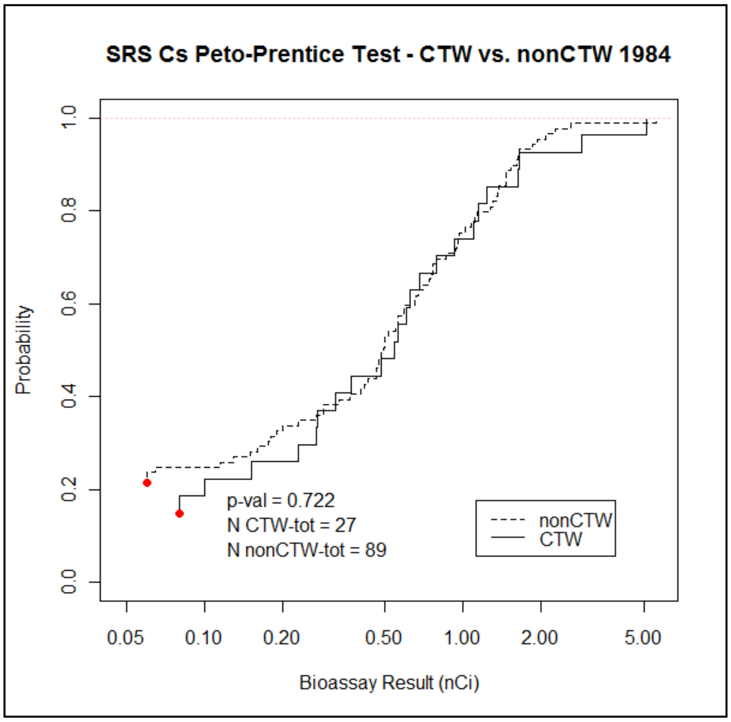

Figure B-11. Peto-Prentice test for CTW:nonCTW WBC data, 1984.

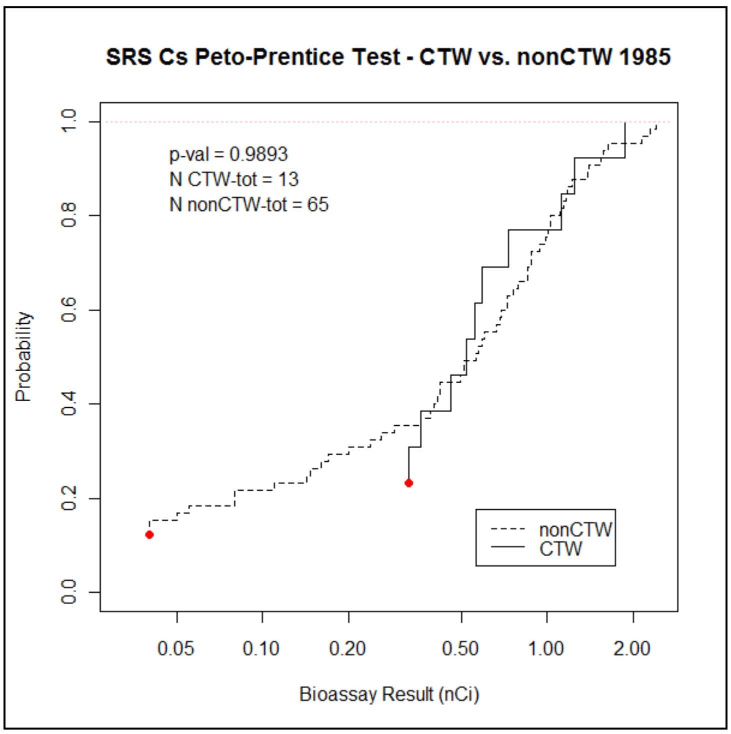

Figure B-12. Peto-Prentice test for CTW:nonCTW WBC data, 1985.

ATTACHMENT B
MCPT AND PETO-PRENTICE PLOTS FOR CTW:NONCTW COMPARISONS

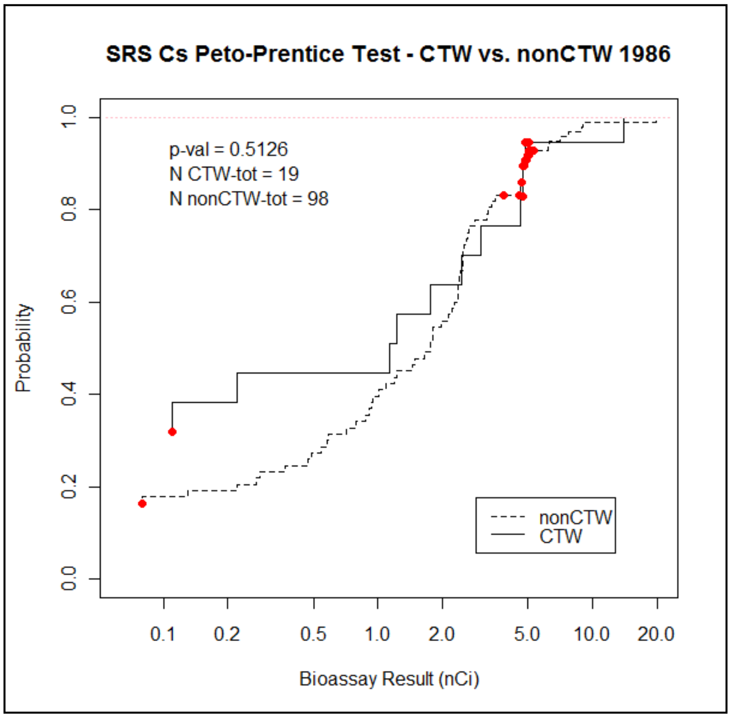

Figure B-13. Peto-Prentice test for CTW:nonCTW WBC data, 1986.

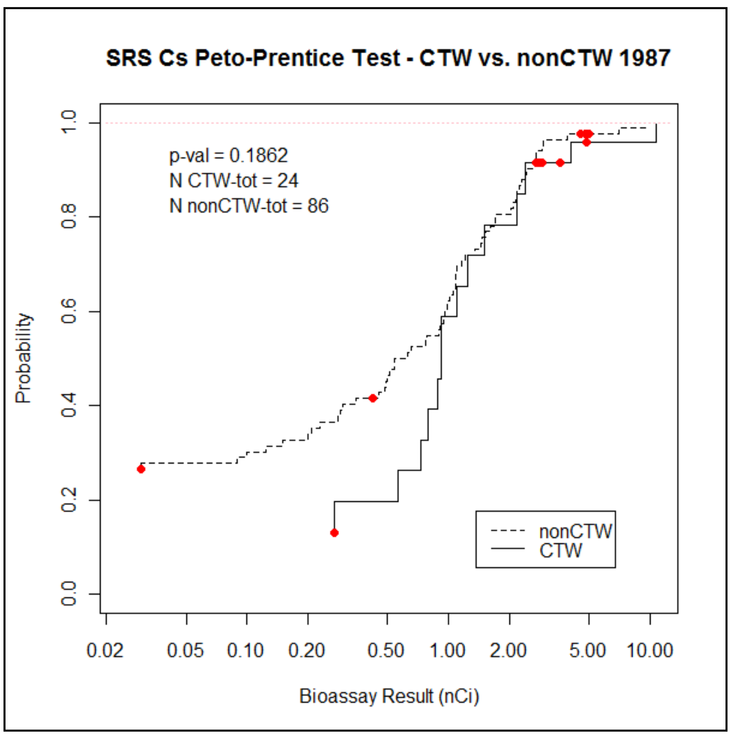

Figure B-14. Peto-Prentice test for CTW:nonCTW WBC data, 1987.

ATTACHMENT B
MCPT AND PETO-PRENTICE PLOTS FOR CTW:NONCTW COMPARISONS

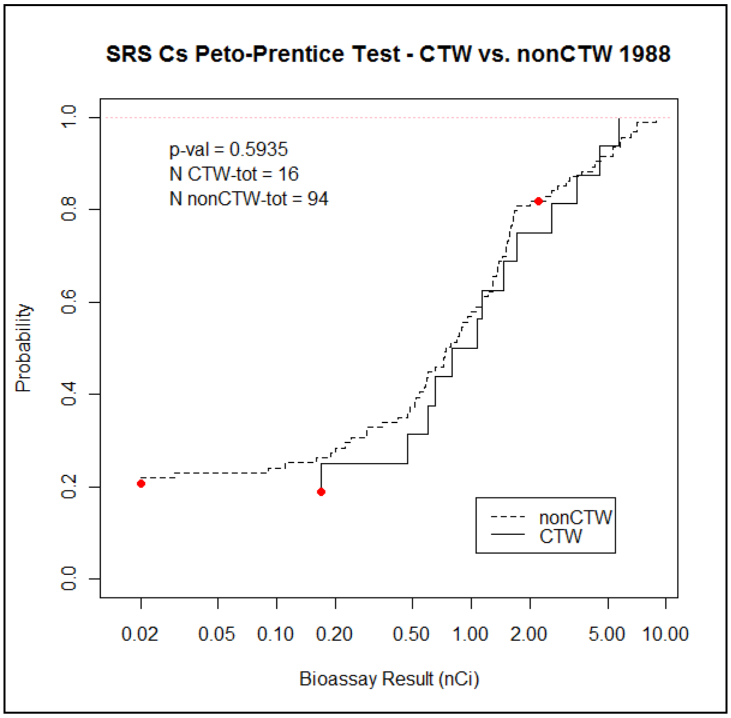

Figure B-15. Peto-Prentice test for CTW:nonCTW WBC data, 1988.

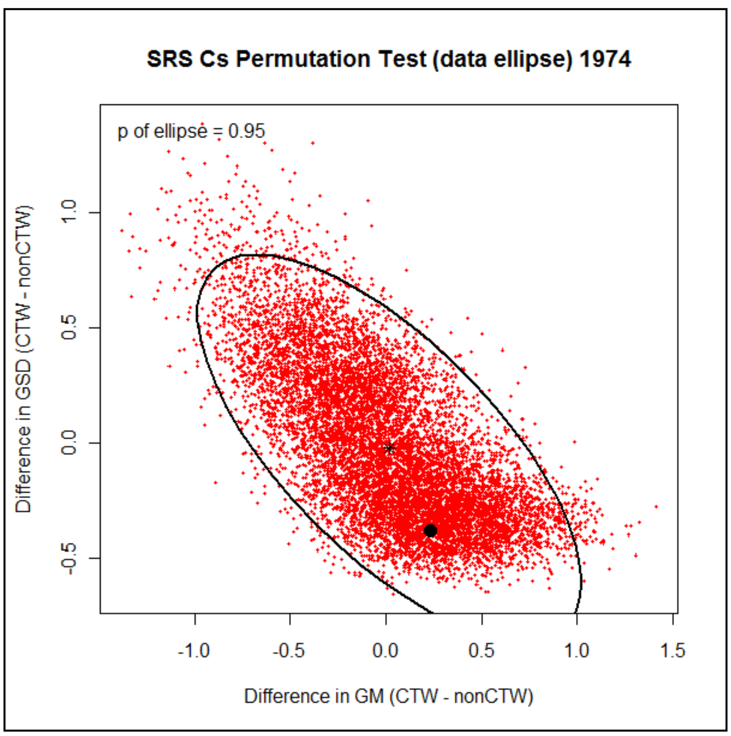

Figure B-16. MCPT test for CTW:nonCTW WBC data, 1974.

ATTACHMENT B
MCPT AND PETO-PRENTICE PLOTS FOR CTW:NONCTW COMPARISONS

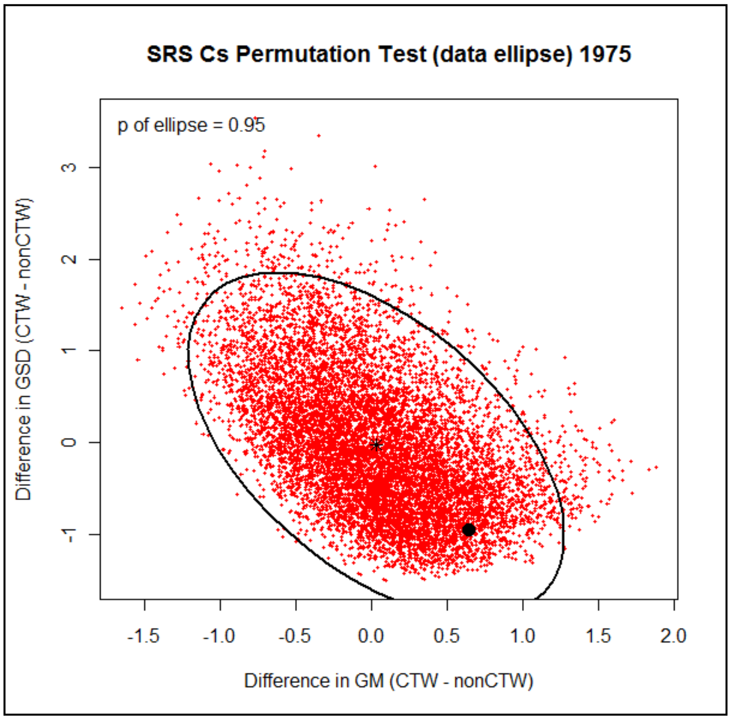

Figure B-17. MCPT test for CTW:nonCTW WBC data, 1975.

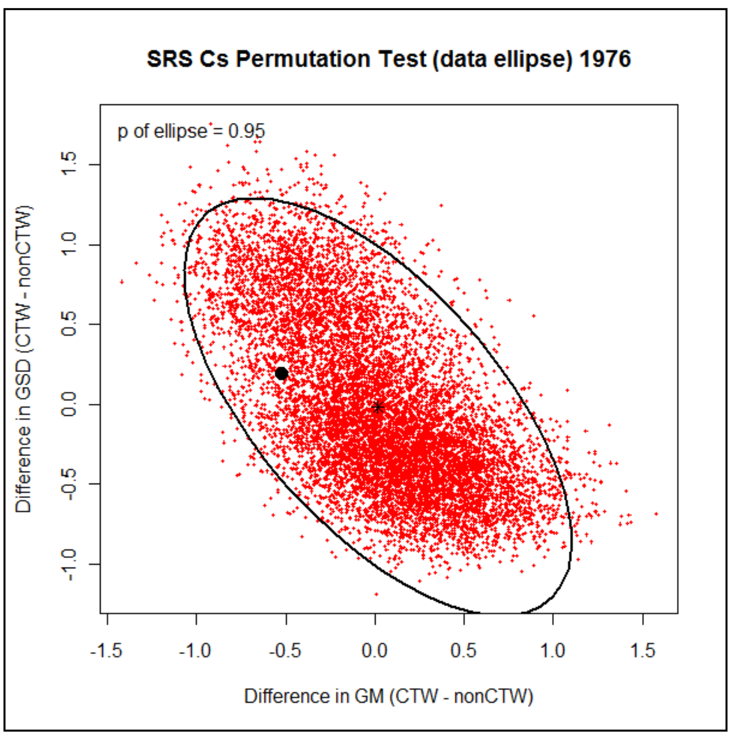

Figure B-18. MCPT test for CTW:nonCTW WBC data, 1976.

ATTACHMENT B
MCPT AND PETO-PRENTICE PLOTS FOR CTW:NONCTW COMPARISONS

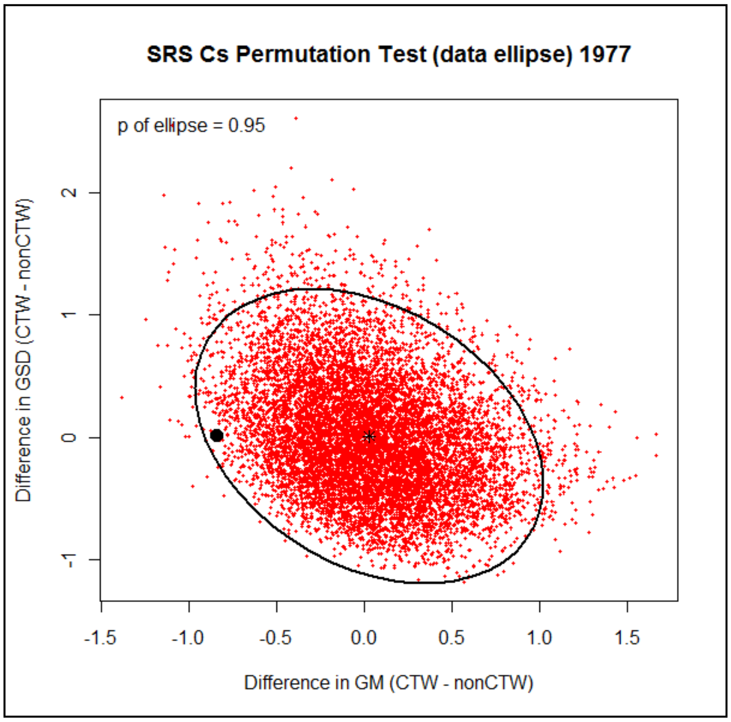

Figure B-19. MCPT test for CTW:nonCTW WBC data, 1977.

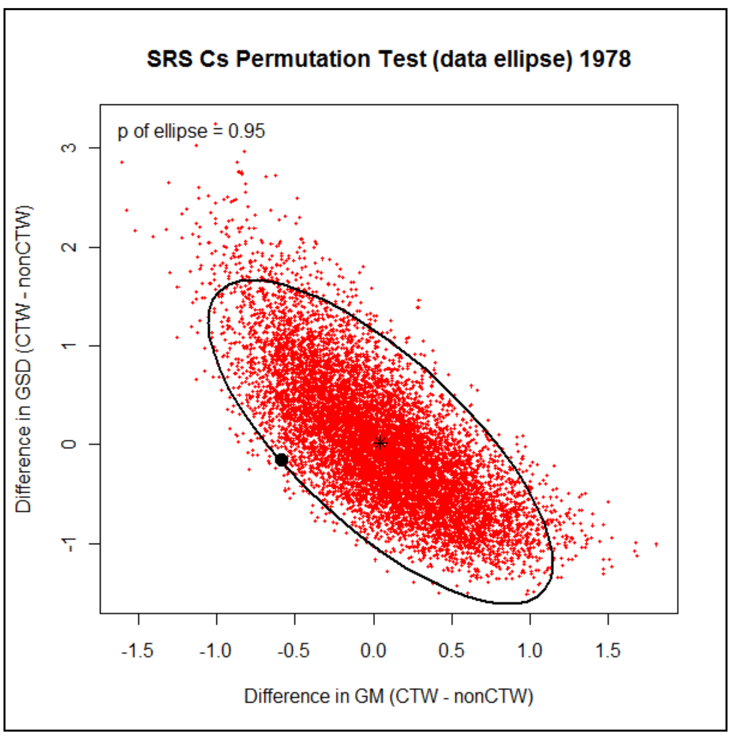

Figure B-20. MCPT test for CTW:nonCTW WBC data, 1978.

ATTACHMENT B
MCPT AND PETO-PRENTICE PLOTS FOR CTW:NONCTW COMPARISONS

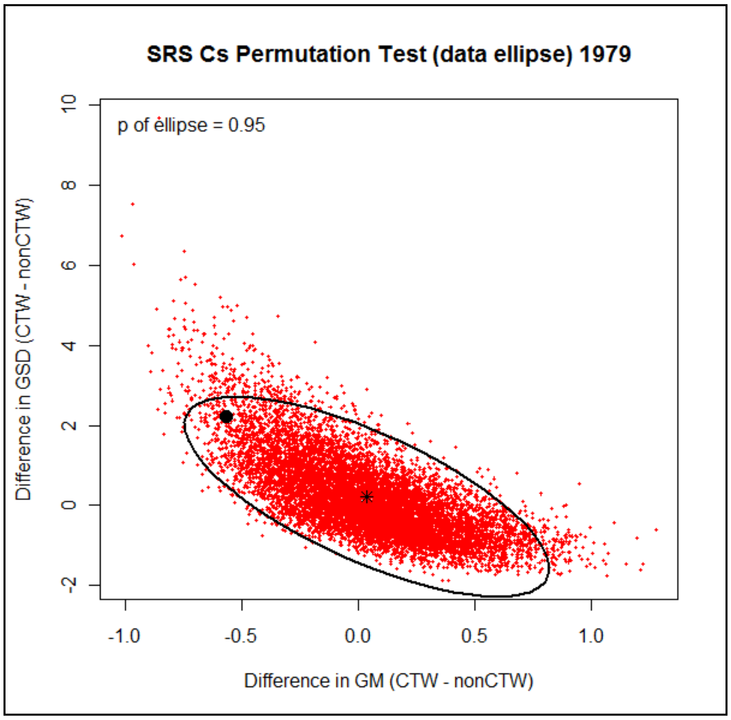

Figure B-21. MCPT test for CTW:nonCTW WBC data, 1979.

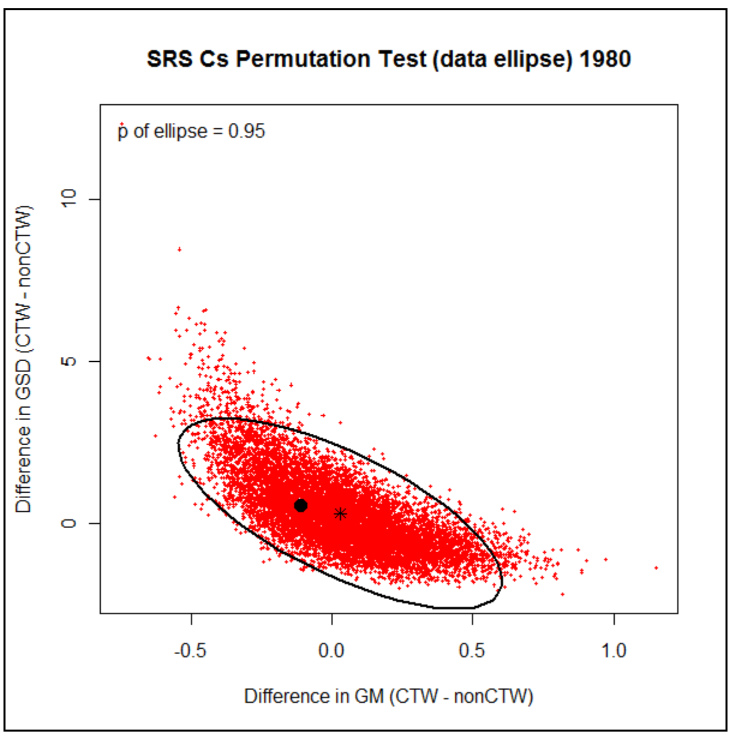

Figure B-22. MCPT test for CTW:nonCTW WBC data, 1980.

ATTACHMENT B
MCPT AND PETO-PRENTICE PLOTS FOR CTW:NONCTW COMPARISONS

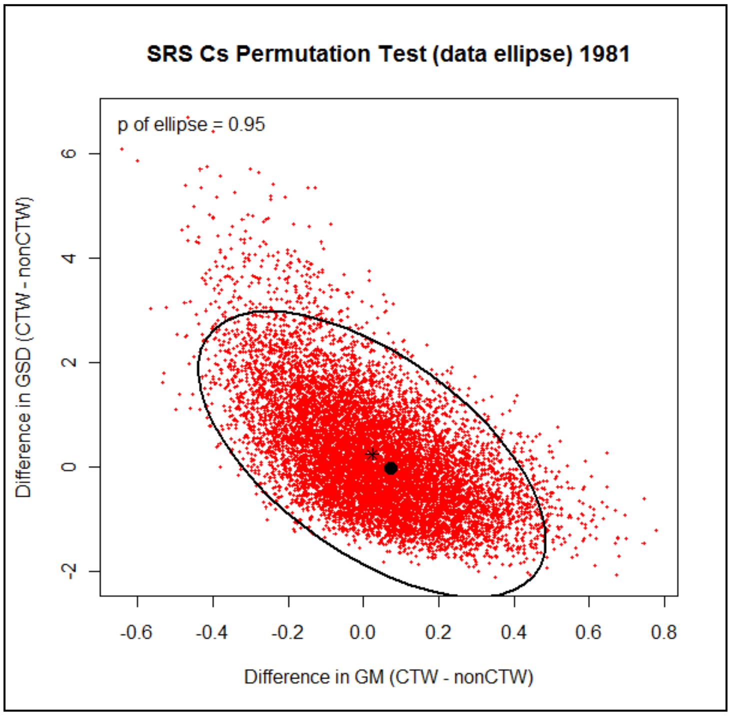

Figure B-23. MCPT test for CTW:nonCTW WBC data, 1981.

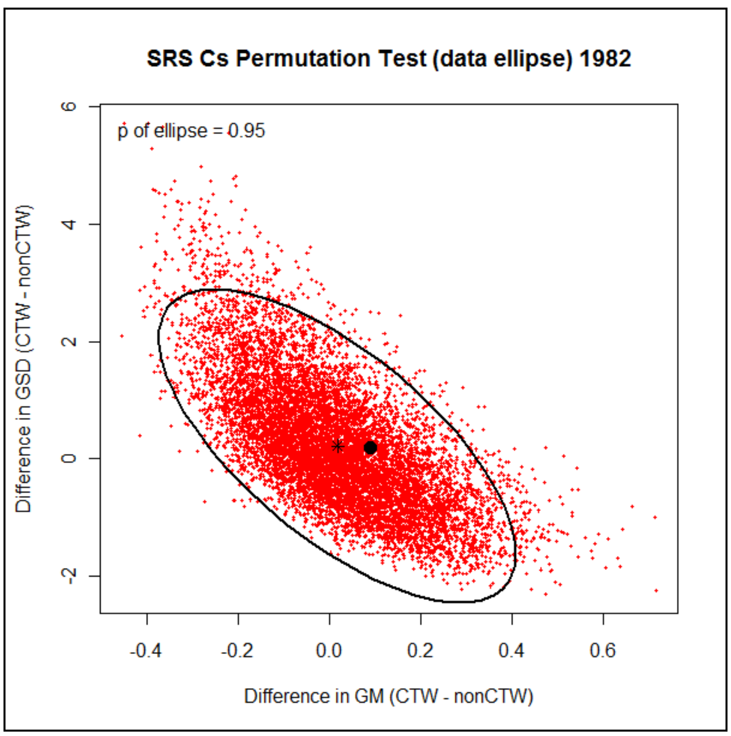

Figure B-24. MCPT test for CTW:nonCTW WBC data, 1982.

ATTACHMENT B
MCPT AND PETO-PRENTICE PLOTS FOR CTW:NONCTW COMPARISONS

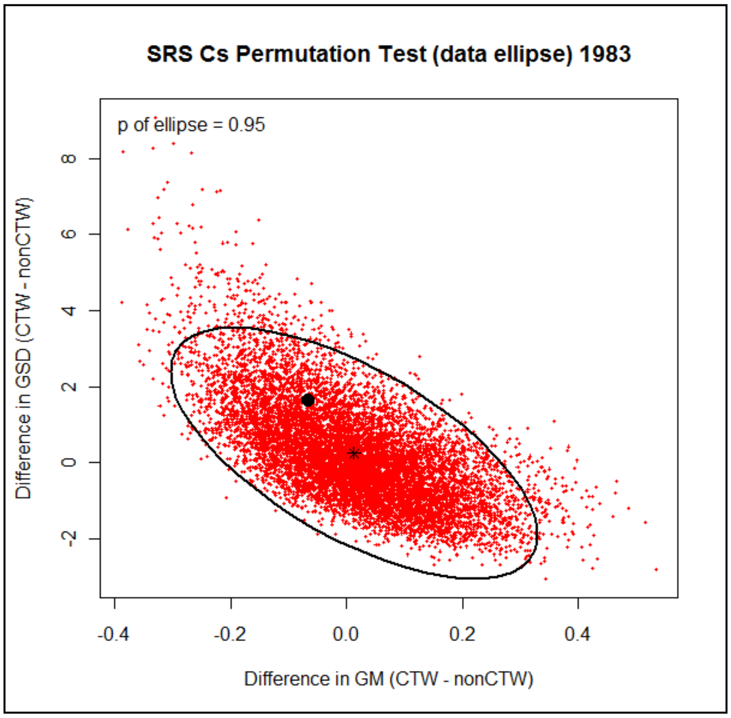

Figure B-25. MCPT test for CTW:nonCTW WBC data, 1983.

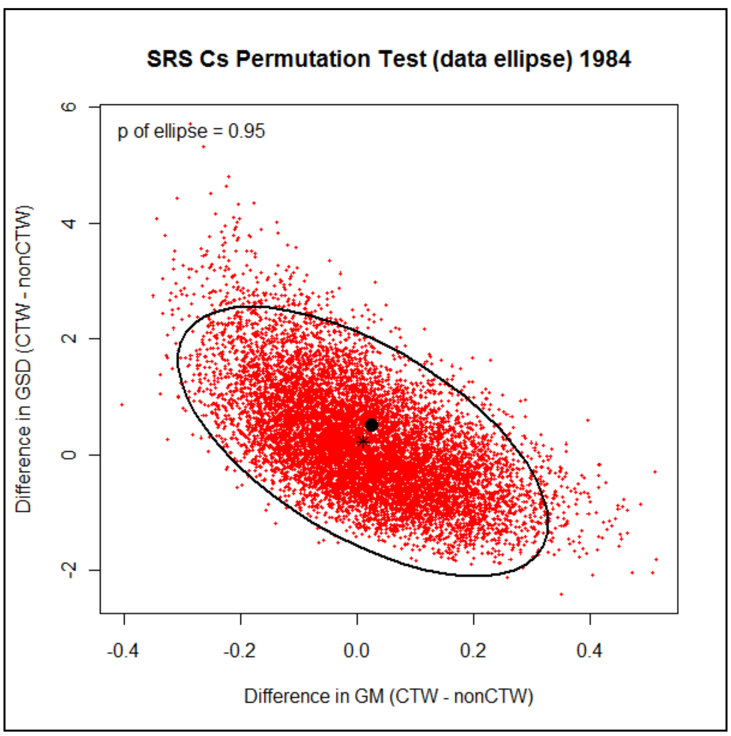

Figure B-26. MCPT test for CTW:nonCTW WBC data, 1984.

ATTACHMENT B
MCPT AND PETO-PRENTICE PLOTS FOR CTW:NONCTW COMPARISONS

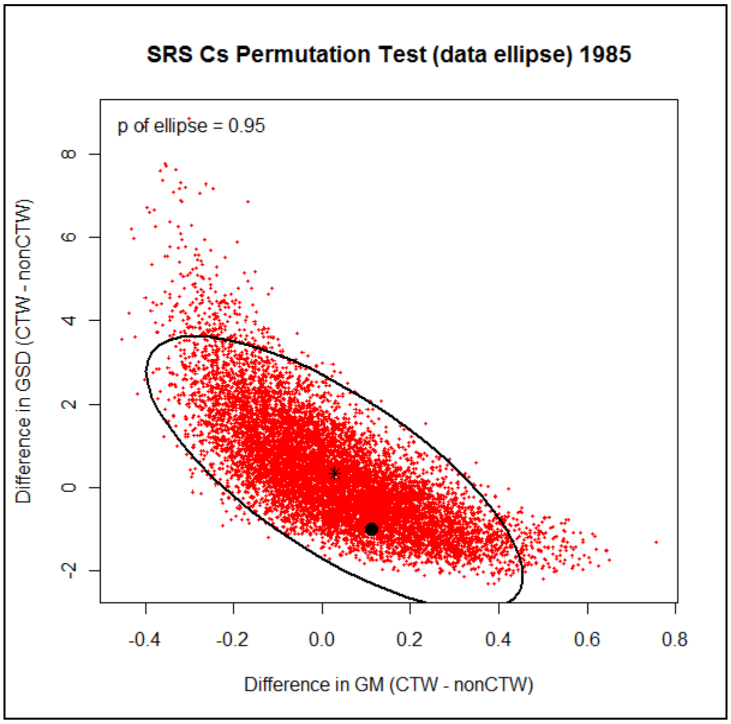

Figure B-27. MCPT test for CTW:nonCTW WBC data, 1985.

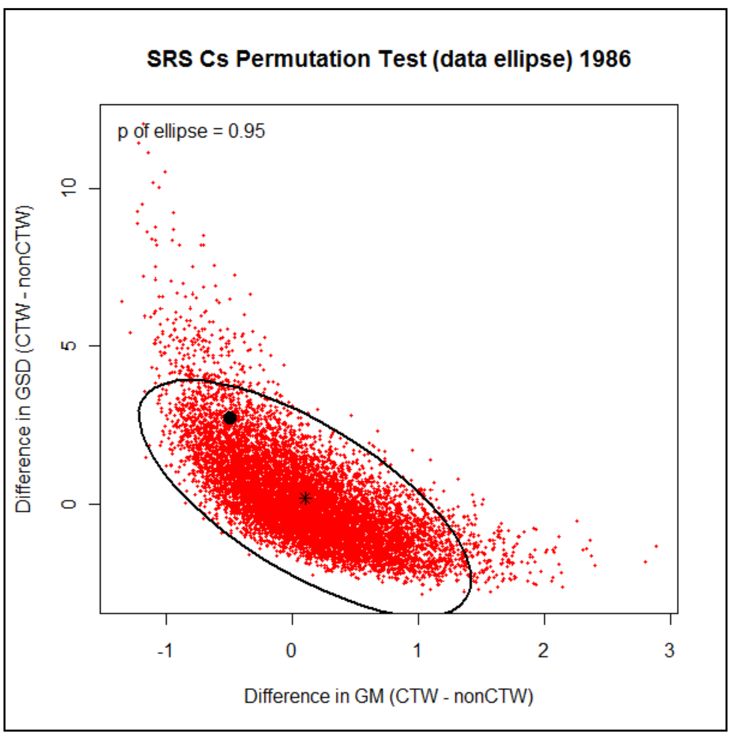

Figure B-28. MCPT test for CTW:nonCTW WBC data, 1986.

ATTACHMENT B
MCPT AND PETO-PRENTICE PLOTS FOR CTW:NONCTW COMPARISONS

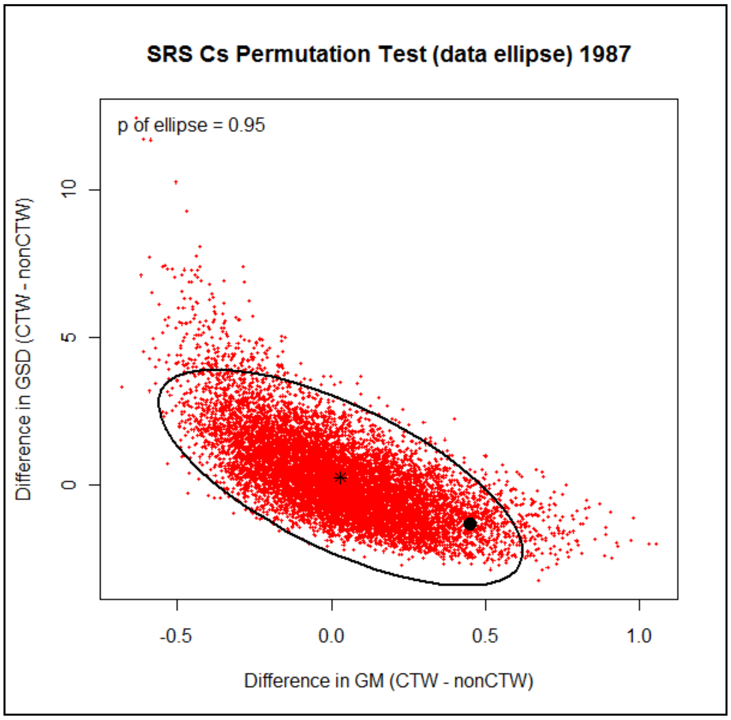

Figure B-29. MCPT test for CTW:nonCTW WBC data, 1987.

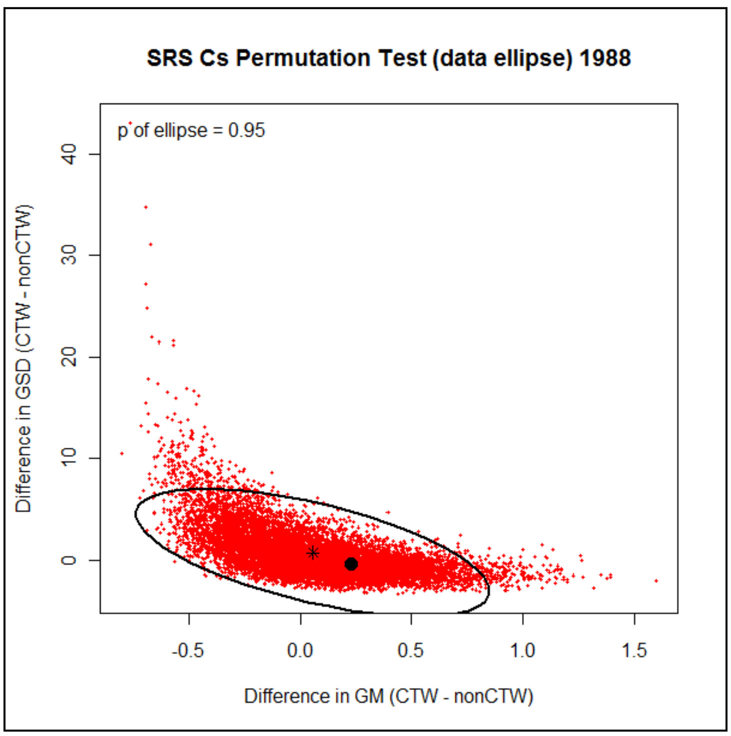

Figure B-30. MCPT test for CTW:nonCTW WBC data, 1988.