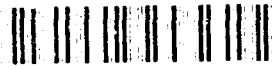


AD-A241 874



Air Force Health Study

*An Epidemiologic Investigation of
Health Effects in Air Force Personnel
Following Exposure to Herbicides*

MORTALITY UPDATE - 1991

WILLIAM H. WOLFE, COLONEL, USAF, MC
JOEL E. MICHALEK, PhD
JUDSON C. MINER, COLONEL, USAF, BSC

Prepared for:
THE SURGEON GENERAL
UNITED STATES AIR FORCE
WASHINGTON, DC 20314

DTIC
SELECTE
OCT 22 1991
S D

EPIDEMIOLOGIC RESEARCH DIVISION
ARMSTRONG LABORATORY
HUMAN SYSTEMS DIVISION (AFSC)
BROOKS AIR FORCE BASE, TX 78235

DISTRIBUTION STATEMENT A

Approved for public release;
Distribution Unlimited

91-13660



UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

Form Approved
OMB No 0704-0183

| | | | | | |
|---|-------|---|---|---|---------------------------------|
| 1a REPORT SECURITY CLASSIFICATION UNCLASSIFIED | | | 1b RESTRICTIVE MARKINGS | | |
| 2a SECURITY CLASSIFICATION AUTHORITY | | | 3 DISTRIBUTION/AVAILABILITY OF REPORT | | |
| 2b DECLASSIFICATION/DOWNGRADING SCHEDULE | | | Approved for public release; distribution is unlimited | | |
| 4 PERFORMING ORGANIZATION REPORT NUMBER(S) AL-TR-1991-0132 | | | 5 MONITORING ORGANIZATION REPORT NUMBER(S) | | |
| 6a NAME OF PERFORMING ORGANIZATION Armstrong Laboratory Epidemiologic Research Division | | 6b OFFICE SYMBOL (If applicable) USAF AL/AOEP | 7a NAME OF MONITORING ORGANIZATION The Surgeon General | | |
| 6c ADDRESS (City, State, and ZIP Code) Human Systems Division (AFSC) Brooks Air Force Base, Texas 78235-5301 | | | 7b ADDRESS (City, State, and ZIP Code) United States Air Force Holling Air Force Base, D.C. 20332-6188 | | |
| 8a NAME OF FUNDING SPONSORING ORGANIZATION Armstrong Laboratory Epidemiologic Research Division | | 8b OFFICE SYMBOL (If applicable) USAF AL/AOEP | 9 PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER | | |
| 8c ADDRESS (City, State, and ZIP Code) Human Systems Division (AFSC) Brooks Air Force Base, Texas 78235-5301 | | | 10 SOURCE OF FUNDING NUMBERS | PROGRAM ELEMENT NO | PROJECT NO |
| | | | 65306F | 2767 | TASK NO 00 |
| | | | | | WORK UNIT ACCESSION NO 01 |
| 11 TITLE (Include Security Classification) An Epidemiologic Investigation of Health Effects in Air Force Personnel Following Exposure to Herbicides - Mortality Update 1991 | | | | | |
| 12 PERSONAL AUTHOR(S) Wolfe, William H., Michalek, Joel E., Miner, Judson C. | | | | | |
| 13a TYPE OF REPORT Interim | | 13b TIME COVERED FROM 1979 TO 1989 | | 14 DATE OF REPORT (Year, Month, Day) 1991 October 15 | 15 PAGE COUNT 32 |
| 16 SUPPLEMENTARY NOTATION | | | | | |
| 17 COSAT CODES | | | 18 SUBJECT TERMS (Continue on reverse if necessary and identify by block number) | | |
| FIELD | GROUP | SUB-GROUP | Epidemiologic Investigation; Air Force Health Study; Matched Cohort Design; Nonconcurrent Prospective Design; Mortality Study | | |
| 06 | 05 | | | | |
| 19 ABSTRACT (Continue on reverse if necessary and identify by block number) The purpose of the Air Force Health Study is to determine whether those individuals involved in the spraying of herbicides in Vietnam during the Ranch Hand operation have experienced any adverse health effects as a result of their participation in that program. The study is designed to evaluate both the mortality (death) and morbidity (disease) in these individuals over a 20-year period beginning in 1982. The Baseline Mortality Report was released in June 1983, the Baseline Morbidity Report in February 1984. Follow-up mortality reports were released in 1984, 1985, 1986, and 1989. This study has not demonstrated health effects which can be conclusively attributed to herbicide or dioxin exposure. | | | | | |
| (Continued) | | | | | |
| 20 DISTRIBUTION STATEMENT OF ABSTRACT <input checked="" type="checkbox"/> UNCLASSIFIED, LIMITED <input type="checkbox"/> SAME AS RPT <input type="checkbox"/> DTIC USERS | | | 21 ABSTRACT SECURITY CLASSIFICATION UNCLASSIFIED | | |
| 22a NAME OF RESPONDER INDIVIDUAL WILLIAM H. WOLFE, Col, USAF, MC | | | 22b TELEPHONE (Include Area Code) (512) 536-2604 | 22c OFFICE SYMBOL USAF AL/AOE | |

(Continuation Block 19.)

This report contains analyses of cumulative deaths occurring up to 31 December 1989. These data show no statistical difference between the cumulative mortality of 1,261 Ranch Hands and that expected based on a population of 19,080 Comparisons

The overall all-cause mortality experience of the Ranch Hands is not significantly different from that expected; 91 (7.2%) of the Ranch Hands have died; the expected number of deaths is 88.4. The overall observed and expected numbers of deaths were not significantly different for accidental deaths and suicides and for deaths caused by malignant neoplasm and heart disease. However, there were significantly increased Ranch Hand deaths due to digestive system diseases and, in nonflying enlisted personnel, circulatory system diseases. The increase in deaths caused by diseases of the digestive system has been previously noted is currently under investigation. The increased number of deaths due to circulatory system diseases among nonflying enlisted personnel is a new finding and is, as yet, unexplained.

| Accession For | |
|--------------------|-------------------------------------|
| NTIS GRAB | <input checked="" type="checkbox"/> |
| DTIC TAB | <input type="checkbox"/> |
| Unannounced | <input type="checkbox"/> |
| Justification | |
| By | |
| Distribution/ | |
| Availability Codes | |
| Dist. | Availability |
| A-1 | |



EXECUTIVE SUMMARY

An evaluation of cumulative all-cause Ranch Hand mortality through 31 December 1989 revealed no statistically significant difference between the observed and expected number of deaths (SMR=1.03, 95% CI 0.82-1.24, p=0.79). The indirectly standardized all-cause Ranch Hand death rate is 3.04 deaths per 1000 person-years; the Comparison rate is 2.95 deaths per 1000 person-years. Furthermore, the observed number of deaths is not statistically significantly different from the expected number in any of the subgroups of Ranch Hands determined by rank (officer, enlisted) and job (flyer, nonflyer).

Adjusted cause-specific analyses revealed no overall significant difference between the observed and expected numbers of deaths for accidental deaths (SMR=1.06), suicides (SMR=0.79), deaths due to malignant neoplasm (SMR=0.82), or deaths due to circulatory disease (SMR=1.14). However, there is a significant excess of deaths from circulatory disease among nonflying enlisted personnel (SMR=1.68, 95% CI 1.01-2.62, p=0.02).

There is a significant excess of Ranch Hand deaths caused by diseases of the digestive system (SMR=2.68, 95% CI 1.22-5.09, p=0.005). To date, 9 Ranch Hands have died of digestive diseases. These data could not be adjusted for alcohol use. Except for alcoholic cirrhosis of the liver and acute alcoholic hepatitis, the Ranch Hand deaths were caused by a variety of unrelated digestive system diseases. At the last analysis [5], there was also a significant excess of digestive disease deaths in Ranch Hands. At that time there were 6 deaths caused by digestive system disease (SMR=2.69, 95% CI 1.00-5.85, p=0.01).

The increased number of circulatory deaths in Ranch Hand nonflying enlisted personnel was not noted in the last report because previous reports incorporated a calculated dioxin exposure index. The index has since been found only weakly correlated with current or extrapolated dioxin body burden and has therefore been dropped from these mortality assessments. A reanalysis using 31 December 1987 as the cut point (as was used in the last mortality report) reveals a borderline significant increase in this stratum (SMR=1.59, 95% CI 0.79-2.40, p=0.07). Thus, the SMR for circulatory deaths has increased from 1.59 to 1.68 during the 2-year period from the end of 1987 to the end of 1989. This increase is of concern because Ranch Hand nonflying enlisted personnel have higher current dioxin levels than Ranch Hands in the other strata [7] and because current and extrapolated initial dioxin levels are significantly associated with diabetes and increased cholesterol, HDL cholesterol and triglyceride abnormalities. While there is no association

between dioxin and cardiovascular disease in the examined Ranch Hands, this increase in circulatory disease deaths could be dioxin-related through its association with diabetes and serum lipids. This possibility is being explored by review of the individual medical records of all Ranch Hands who have died of circulatory disease.

In summary, the overall all-cause mortality experience of the Ranch Hands is not significantly different from that expected. As of 31 December 1989, 91 (7.2%) of the Ranch Hands had died; the expected number of deaths is 88.4. The overall observed and expected numbers of deaths were not significantly different for accidental deaths, suicides, and deaths caused by malignant neoplasms or circulatory diseases. However, there were significantly increased Ranch Hand deaths due to digestive diseases and, in nonflying enlisted personnel, circulatory system diseases. The increase in deaths caused by diseases the digestive system has been previously noted is currently under investigation. The increased number of deaths due to circulatory system diseases among nonflying enlisted personnel is a new finding and is, as yet, unexplained.

TABLE OF CONTENTS

| | Page |
|---------------------------------------|------|
| EXECUTIVE SUMMARY | i |
| TABLE OF CONTENTS | iii |
| 1. INTRODUCTION | 1 |
| 2. ALL-CAUSE MORTALITY | 2 |
| 3. CAUSE-SPECIFIC MORTALITY | 16 |
| 4. CONCLUSIONS | 22 |
| REFERENCES | 25 |
| PRINCIPAL INVESTIGATORS | 26 |
| ADVISORY COMMITTEE MEMBERS | 27 |

1. INTRODUCTION

This report updates the findings of prior Air Force Health Study mortality reports released in 1983 [1], 1984 [2], 1985 [3], 1986 [4], and 1989 [5]. The reader is referred to the baseline report [1] for information regarding the study design and the mortality determination process.

This report contrasts cumulative Ranch Hand mortality through 31 December 1989 (verified as of 15 March 1991) with that expected based on the mortality experience of the Comparison population of 19,080 Air Force veterans who flew or serviced C-130 cargo aircraft in Southeast Asia (SEA) during the same calendar period that the Ranch Hand unit was active in Vietnam.

Table 1 shows summary counts, person-years and death rates by group (Ranch Hand, Comparison). A person-year is the length of time lived by one person in one year. Persons surviving to the time of data analysis contribute the time, in years, between the dates of entry into follow-up and data analysis. Persons known to have died before the date of data analysis contribute the time, in years, between the dates of entry into follow-up and death. In this study, the date of entry into follow-up is the date of the start of duty in SEA. The date of data analysis is 31 December 1989. All analyses are based on regression analyses of the Standardized Mortality Ratio (SMR), the ratio of the observed to the expected number of deaths [6]. Because the statistical procedures produce inconsistent results when the expected number of deaths is small, a confidence interval and p-value are not provided when the expected number of deaths is less than 3. Expected deaths are additive across strata but not across different causes of death [6]. Except when otherwise noted, all death rates (per 1000 person-years), expected deaths and SMR's are adjusted for year of birth, rank (officer, enlisted) and military occupation in SEA (flyer, nonflyer).

In the hypothetical case that the Ranch Hand mortality experience is the same as that of the Comparisons, about 5% of the many statistical analyses shown in this report should be expected to produce p-values less than 0.05. The observation of significant results due to multiple testing on the same data, even when there is no group difference, is known as the multiple testing artifact and is common to all large studies. Hence, each significant result is scrutinized with regard to concomitant information to determine whether it can be reasonably attributed to herbicide exposure.

In all previous mortality assessments, a calculated dioxin exposure index was used to evaluate dose-response. Since the last mortality report [5], the index has been found to be only weakly correlated with actual dioxin body burden, expressed in parts per trillion (ppt), in Ranch Hands [7,8] and has therefore been dropped. Because none of the 91 dead Ranch Hands have been assayed for dioxin and 238 others have not been assayed or do not have a quantifiable result, the dioxin assay cannot be used to

assess dose-response patterns in the mortality data. The best indicators of dioxin exposure for mortality assessment are military rank and occupation in SEA. Of 932 living Ranch Hands who provided blood for dioxin testing, 866 had quantifiable dioxin levels and were fully compliant to the 1987 physical examination. The median dioxin level of those 866 was 12.8 ppt (range: 0-617.8). The median and range for flying officers (n=300), nonflying officers (n=19), flying enlisted personnel (n=148) and nonflying enlisted personnel (n=399) were 7.9 ppt (0-42.6), 6.7 ppt (3.1-24.9), 18.1 ppt (0-195.5) and 24.0 ppt (0-617.8). The median dioxin level of 804 Comparisons was 4.2 ppt and median dioxin levels among Comparisons did not vary significantly with rank or occupation.

At the last report, dates of military service in SEA for 8968 Comparisons were not available. Hence, dates for these Comparisons were randomly generated. In the interim, the service dates for 8937 of the 8968 were retrieved from military personnel records; the tour dates of 31 could not be verified due to missing records. Because their dates of service could not be verified, these 31 were declared ineligible and were excluded from the Comparison population. Additionally, one veteran previously included in the Comparison population was verified as ineligible and 11 veterans were newly verified as eligible Comparisons. The total number of Comparisons is now 19,080, 21 less than the 19,101 represented in the last mortality report.

The 31 Comparisons with missing personnel records are distributed by military occupation as follows: Nonblack flying officer; 1, Nonblack navigator; 3, Nonblack enlisted flight engineer; 3, Black enlisted flight engineer; 1, Nonblack nonflying enlisted personnel; 19, Black nonflying enlisted personnel; 4.

2. ALL-CAUSE MORTALITY

Summary mortality statistics for both populations are given in Table 1. In Table 1 and throughout this report, flying officers are pilots and navigators. Officers are flying officers and nonflying officers. Flying enlisted personnel are enlisted flight engineers. Nonflying enlisted personnel are enlisted ground personnel. Enlisted personnel are flying enlisted and nonflying enlisted personnel. All Ranch Hand death rates in Table 1 are adjusted via indirect standardization. Each indirectly standardized rate is the product of the Comparison death rate and the adjusted SMR (Table 3). The result is then multiplied by 1000 to give a death rate per 1000 person-years.

Table 1
Summary Counts and Adjusted Death Rates
By Rank and Occupation

| Stratum | Ranch Hand | | | | Comparison | | | |
|--------------------|------------|------|--------------|------|------------|------|--------------|------|
| | At Risk | Dead | Person Years | Rate | At Risk | Dead | Person Years | Rate |
| Flying Officers | 441 | 32 | 9555 | 3.37 | 5242 | 376 | 114858 | 3.27 |
| Flying Enlisted | 207 | 13 | 4503 | 2.45 | 2829 | 230 | 61059 | 3.77 |
| All Flyers | 648 | 45 | 14058 | 3.03 | 8071 | 606 | 175918 | 3.44 |
| Nonflying Officers | 26 | 2 | 562 | 3.50 | 284 | 20 | 6392 | 3.13 |
| Nonflying Enlisted | 587 | 44 | 12696 | 3.20 | 10725 | 615 | 238078 | 2.58 |
| All Nonflyers | 613 | 46 | 13256 | 3.19 | 11009 | 635 | 244470 | 2.60 |
| All Officers | 467 | 34 | 10118 | 3.40 | 5526 | 396 | 121250 | 3.27 |
| All Enlisted | 794 | 57 | 17199 | 2.91 | 13554 | 845 | 299137 | 2.82 |
| Total | 1261 | 91 | 27316 | 3.04 | 19080 | 1241 | 420388 | 2.95 |

Unadjusted occupation and race-specific mortality is summarized in Table 2. Some Ranch Hand death rates in Table 2 appear unusually high. For example, the Ranch Hand death rate among Black enlisted flight engineers is 12.52 deaths per 1000 person-years and the corresponding rate for all Comparison deaths in this stratum is 5.24 deaths per 1000 person-years. The four Ranch Hand deaths in this stratum have occurred since 1980. One of the 4 deaths was a suicide, 1 was accidental, 1 was due to a digestive system disease and 1 was due to ill-defined causes. An adjusted analysis shows that this increase is not statistically significant (SMR=2.23, 95% CI 0.61-5.71, p=0.100). In general, a death rate based on only a few deaths is not a reliable measure of mortality experience because one additional death can produce large changes in the death rate and in the SMR.

Table 2

Unadjusted Occupation and Race Specific Cumulative
All-Cause Mortality

a) Nonblack personnel

| Stratum | Ranch Hand | | | | Comparison | | | |
|--------------------|------------|------|--------------|------|------------|------|--------------|------|
| | At Risk | Dead | Person Years | Rate | At Risk | Dead | Person Years | Rate |
| Pilots | 351 | 25 | 7589 | 3.29 | 3417 | 270 | 74630 | 3.62 |
| Navigators | 82 | 7 | 1798 | 3.89 | 1773 | 105 | 39036 | 2.69 |
| Nonflying Officers | 25 | 2 | 541 | 3.70 | 280 | 20 | 6304 | 3.17 |
| Flying Enlisted | 192 | 9 | 4184 | 2.15 | 2606 | 205 | 56287 | 3.64 |
| Nonflying Enlisted | 534 | 40 | 11550 | 3.46 | 9689 | 541 | 215408 | 2.51 |
| Total | 1184 | 83 | 25662 | 3.23 | 17765 | 1141 | 391665 | 2.91 |

b) Black personnel

| Stratum | Ranch Hand | | | | Comparison | | | |
|--------------------|------------|------|--------------|-------|------------|------|--------------|------|
| | At Risk | Dead | Person Years | Rate | At Risk | Dead | Person Years | Rate |
| Pilots | 6 | 0 | 127 | 0.00 | 20 | 1 | 452 | 2.21 |
| Navigators | 2 | 0 | 42 | 0.00 | 32 | 0 | 740 | 0.00 |
| Nonflying Officers | 1 | 0 | 21 | 0.00 | 4 | 0 | 88 | 0.00 |
| Flying Enlisted | 15 | 4 | 320 | 12.52 | 223 | 25 | 4772 | 5.24 |
| Nonflying Enlisted | 53 | 4 | 1146 | 3.49 | 1036 | 74 | 22670 | 3.26 |
| Total | 77 | 8 | 1656 | 4.83 | 1315 | 100 | 28722 | 3.48 |

Table 2 (Continued)

c) All personnel

| Stratum | Ranch Hand | | | | Comparison | | | |
|--------------------|------------|------|--------------|------|------------|------|--------------|------|
| | At Risk | Dead | Person Years | Rate | At Risk | Dead | Person Years | Rate |
| Pilots | 357 | 25 | 7716 | 3.24 | 3427 | 271 | 75082 | 3.61 |
| Navigators | 84 | 7 | 1840 | 3.80 | 1805 | 105 | 39776 | 2.64 |
| Nonflying Officers | 26 | 2 | 562 | 3.56 | 284 | 20 | 6392 | 3.13 |
| Flying Enlisted | 207 | 13 | 503 | 2.89 | 2829 | 230 | 61059 | 3.77 |
| Nonflying Enlisted | 587 | 44 | 12696 | 3.47 | 10725 | 615 | 238078 | 2.58 |
| Total | 1261 | 91 | 27316 | 3.33 | 19080 | 1241 | 420388 | 2.95 |

Survival analyses were carried out to assess Ranch Hand all-cause mortality with that expected relative to the Comparison population. All analyses were adjusted for rank (officer, enlisted), occupation (flying, ground) and date of birth in five-year intervals. The results are shown in Table 3. The expected numbers of deaths in Table 3 are sums of expected numbers of deaths within five-year intervals of year of birth. Each summand (not shown) is the product of the Ranch Hand person-years and the Comparison death rate.

Table 3

Adjusted All-Cause Standardized Mortality Ratios
by Rank and Military Occupation Among Ranch Hands

| Stratum | Dead | Expected | SMR | 95% C.I. | p-value |
|-------------------------|------|----------|------|-----------|---------|
| | | Deaths | | | |
| Flying Officers | 32 | 31.07 | 1.03 | 0.67-1.39 | 0.87 |
| Nonflying Officers | 2 | 1.78 | 1.12 | | |
| All Officers | 34 | 32.85 | 1.04 | 0.69-1.38 | 0.84 |
| Flying Enlisted | 13 | 20.00 | 0.65 | 0.35-1.11 | 0.12 |
| Nonflying Enlisted | 44 | 35.60 | 1.24 | 0.87-1.60 | 0.16 |
| All Enlisted | 57 | 55.60 | 1.03 | 0.76-1.30 | 0.85 |
| All Flying Personnel | 45 | 51.07 | 0.88 | 0.63-1.44 | 0.41 |
| All Nonflying Personnel | 46 | 37.38 | 1.23 | 0.87-1.59 | 0.16 |
| All Ranch Hands | 91 | 88.45 | 1.03 | 0.82-1.24 | 0.79 |

There are no overall differences between the observed and expected number of deaths from all causes in any stratum. The overall adjusted SMR for all Ranch Hands for all causes of death is 1.03, 95% CI 0.82-1.24, $p=0.79$.

Chi-square tests for trend were applied to all strata to assess the significance of trends in the SMR since 1985. These analyses were carried out twice, first with each of the years 1985 through 1989 separately contributing to the statistic and again with 1985 through 1987 collapsed to a single stratum and 1988 and 1989 collapsed to a second stratum. All analyses are conditioned on survival to 1 January 1985 and due to sparseness were not adjusted for date of birth. The tests are two-tailed and therefore would detect upward or downward trends in the SMR. Test results for detecting upward trends in the SMR may be derived from these results by dividing the p-value by 2 when the data indicate an increasing trend and replacing the p-value by 1.00 when the data indicate a decreasing trend. The results are shown in Table 4.

Table 4

Ranch Hand Mortality
Five-Year Trend Analysis

Flying Officers

One-Sample Chi-square(single year)=0.23 p=0.63
One-Sample Chi-square(85-87,88,89)=0.29 p=0.59

| | Dead | Rate | Expected Deaths | SMR |
|------|------|-------|-----------------|------|
| 1985 | 1 | 2.35 | 1.45 | 0.69 |
| 1986 | 5 | 11.84 | 1.79 | 2.80 |
| 1987 | 5 | 11.94 | 2.54 | 1.96 |
| 1988 | 5 | 12.11 | 2.69 | 1.86 |
| 1989 | 1 | 2.44 | 1.76 | 0.57 |

Enlisted Flyers

One-Sample Chi-square(single year)=0.11 p=0.74
One-Sample Chi-square(85-87,88,89)=0.10 p=0.75

| | Dead | Rate | Expected Deaths | SMR |
|------|------|------|-----------------|------|
| 1985 | 1 | 5.07 | 0.89 | 1.12 |
| 1986 | 1 | 5.08 | 1.26 | 0.79 |
| 1987 | 1 | 5.11 | 0.82 | 1.22 |
| 1988 | 0 | 0.00 | 1.42 | 0.00 |
| 1989 | 1 | 5.13 | 0.75 | 1.34 |

All Flyers

One-Sample Chi-square(single year)=0.22 p=0.64
One-Sample Chi-square(85-87,88,89)=0.42 p=0.52

| | Dead | Rate | Expected Deaths | SMR |
|------|------|------|-----------------|------|
| 1985 | 2 | 3.21 | 2.36 | 0.85 |
| 1986 | 6 | 9.70 | 3.09 | 1.94 |
| 1987 | 6 | 9.77 | 3.33 | 1.80 |
| 1988 | 5 | 8.22 | 4.12 | 1.21 |
| 1989 | 2 | 3.31 | 2.51 | 0.80 |

Table 4 (Continued)

Nonflying Officers

One-Sample Chi-square(single year)=2.93 p=0.09
 One-Sample Chi-square(85-87,88,89)=0.03 p=0.87

| | Dead | Rate | Expected Deaths | SMR |
|------|------|-------|-----------------|-------|
| 1985 | 0 | 0.00 | 0.09 | 0.00 |
| 1986 | 0 | 0.00 | 0.18 | 0.00 |
| 1987 | 0 | 0.00 | 0.37 | 0.00 |
| 1988 | 0 | 0.00 | 0.37 | 0.00 |
| 1989 | 1 | 40.54 | 0.09 | 10.73 |

Nonflying Enlisted Personnel

One-Sample Chi-square(single year)=0.02 p=0.89
 One-Sample Chi-square(85-87,88,89)=0.17 p=0.68

| | Dead | Rate | Expected Deaths | SMR |
|------|------|-------|-----------------|------|
| 1985 | 2 | 3.59 | 2.16 | 0.93 |
| 1986 | 3 | 5.42 | 1.89 | 1.59 |
| 1987 | 2 | 3.63 | 2.37 | 0.84 |
| 1988 | 6 | 10.96 | 2.69 | 2.23 |
| 1989 | 1 | 1.84 | 2.47 | 0.41 |

All Nonflyers

One-Sample Chi-square(single year)=0.04 p=0.83
 One-Sample Chi-square(85-87,88,89)=0.19 p=0.66

| | Dead | Rate | Expected Deaths | SMR |
|------|------|-------|-----------------|------|
| 1985 | 2 | 3.44 | 2.26 | 0.89 |
| 1986 | 3 | 5.19 | 2.03 | 1.48 |
| 1987 | 2 | 3.47 | 2.63 | 0.76 |
| 1988 | 6 | 10.48 | 2.96 | 2.03 |
| 1989 | 2 | 3.52 | 2.57 | 0.78 |

Table 4 (Continued)

All Officers

One-Sample Chi-square(single year)=0.02 p=0.89
 One-Sample Chi-square(85-87,88,89)=0.32 p=0.57

| | Dead | Rate | Expected Deaths | SMR |
|------|------|-------|-----------------|------|
| 1985 | 1 | 2.22 | 1.54 | 0.65 |
| 1986 | 5 | 11.18 | 1.97 | 2.54 |
| 1987 | 5 | 11.27 | 2.90 | 1.73 |
| 1988 | 5 | 11.42 | 3.05 | 1.64 |
| 1989 | 2 | 4.60 | 1.86 | 1.08 |

All Enlisted Personnel

One-Sample Chi-square(single year)=0.07 p=0.79
 One-Sample Chi-square(85-87,88,89)=0.27 p=0.61

| | Dead | Rate | Expected Deaths | SMR |
|------|------|------|-----------------|------|
| 1985 | 3 | 3.98 | 3.02 | 0.99 |
| 1986 | 4 | 5.33 | 3.02 | 1.32 |
| 1987 | 3 | 4.02 | 3.19 | 0.94 |
| 1988 | 6 | 8.08 | 4.00 | 1.50 |
| 1989 | 2 | 2.71 | 3.25 | 0.62 |

All Ranch Hands

One-Sample Chi-square(single year)=0.05 p=0.82
 One-Sample Chi-square(85-87,88,89)=0.57 p=0.45

| | Number Dead | Rate Per 1000 Person Years | Expected Deaths | SMR |
|------|-------------|----------------------------|-----------------|------|
| 1985 | 4 | 3.32 | 4.63 | 0.86 |
| 1986 | 9 | 7.52 | 4.95 | 1.82 |
| 1987 | 8 | 6.72 | 5.86 | 1.36 |
| 1988 | 11 | 9.32 | 6.89 | 1.60 |
| 1989 | 4 | 3.41 | 5.12 | 0.78 |

The significant increasing trend in the SMR among flying officers noted in previous mortality reports is no longer present due to a decrease in the SMR since 1986. There are no apparent trends in the other strata.

A lexis diagram [9] for Ranch Hand flying officers is shown in Figure 1. Follow-up time is indicated for each living subject with a straight line beginning at his age and the beginning of his first qualifying tour of duty in SEA and ending with his age at 31 December 1989. Follow-up lines for deceased subjects end with a square at the subject's age at death and date of death. The corresponding diagram without the follow-up lines is shown in Figure 2. Lexis diagrams for nonflying officers, flying enlisted and nonflying enlisted personnel, without the follow-up lines, are shown in Figures 2 through 5.

Lexis diagrams provide another view of the data that permits a visual assessment of mortality clustering with respect to age and calendar time. A strong latency effect, for example, might be revealed by a cluster of deaths approximately 20 years after entry into follow-up. No such clusters are apparent in these data.

Figure 1
Lexis Diagram
Ranch Hand Flying Officers

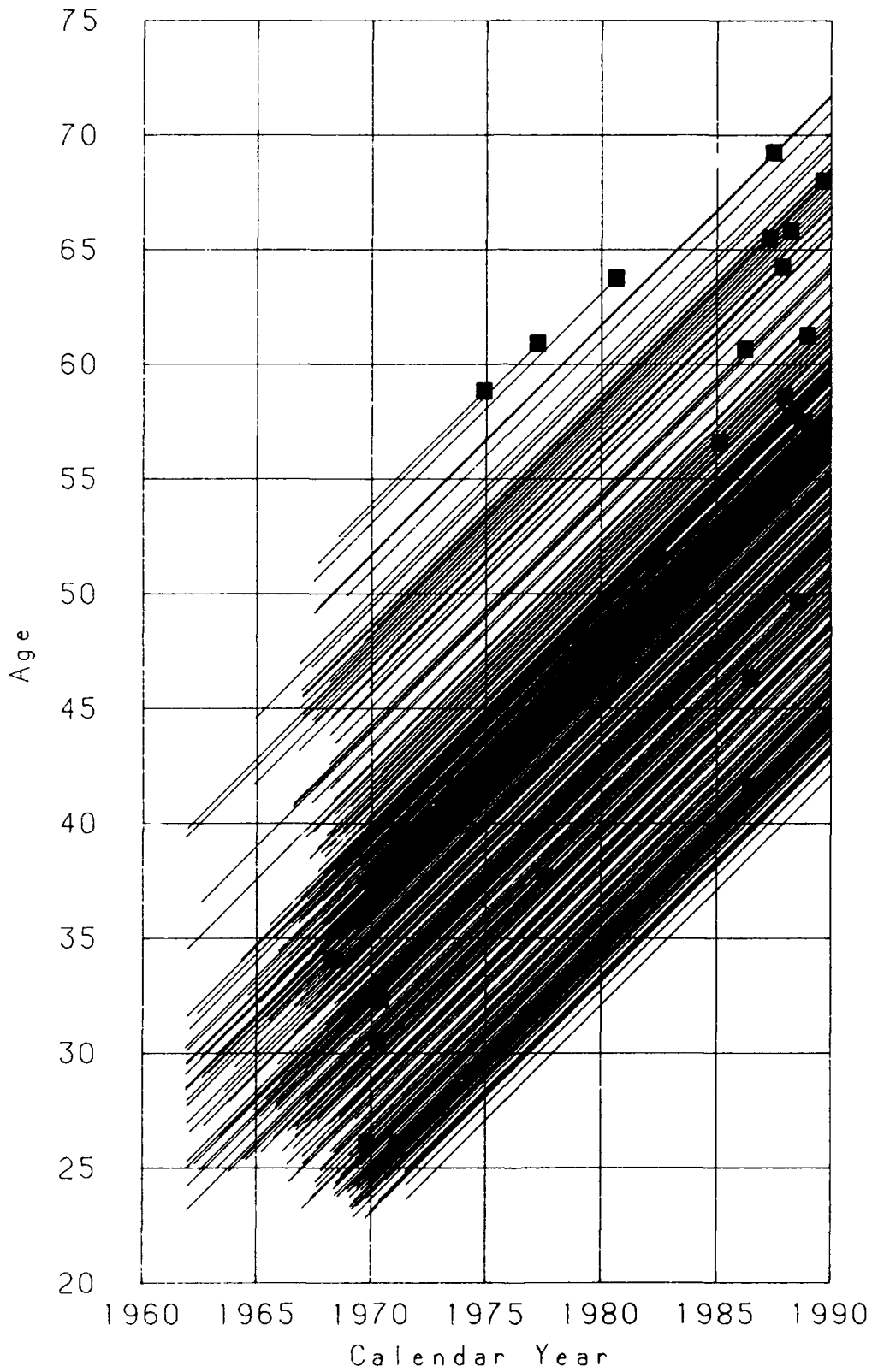


Figure 2
Lexis Diagram
Ranch Hand Flying Officers

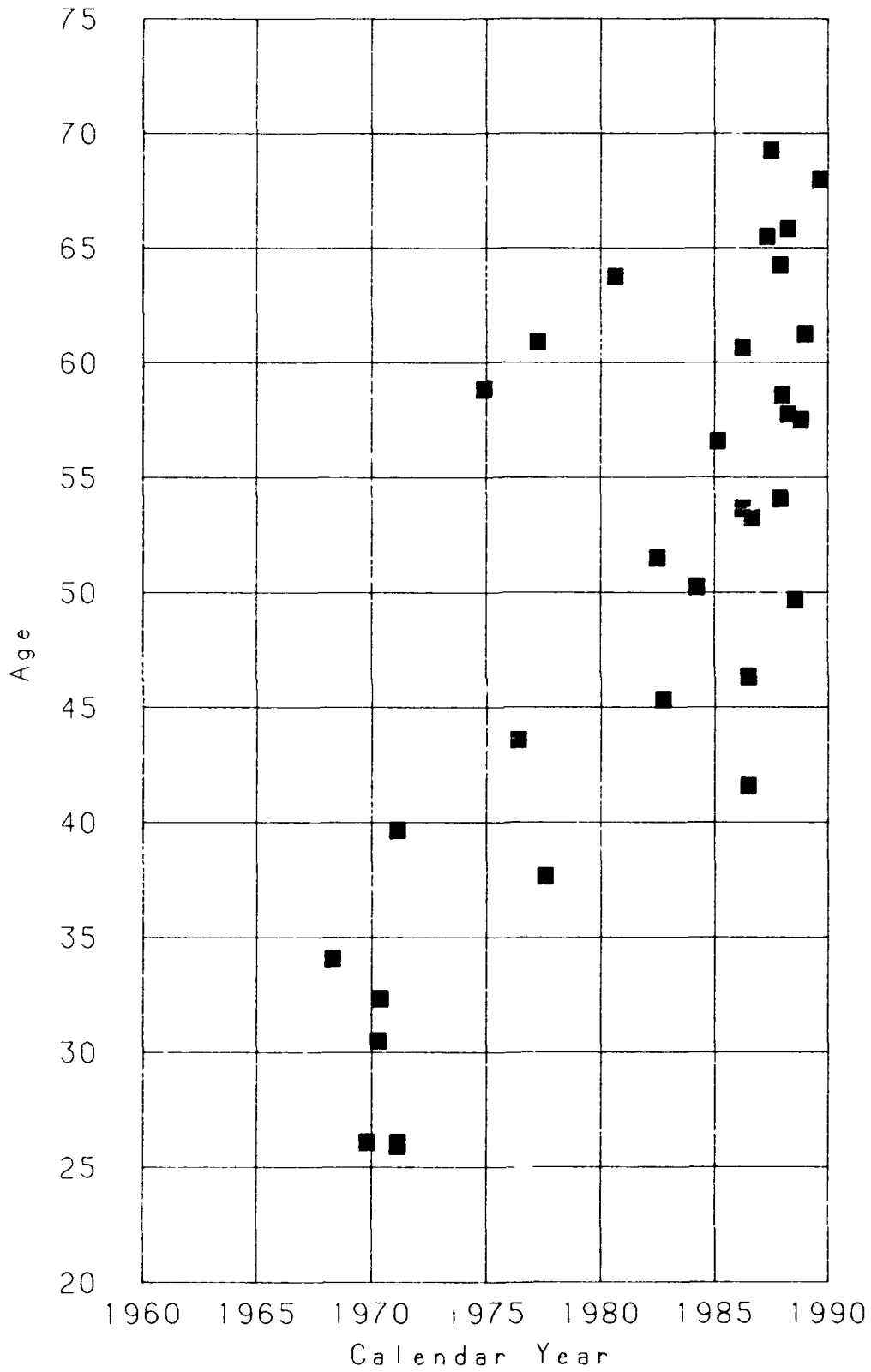


Figure 3
Lexis Diagram
Ranch Hand Nonflying Officers

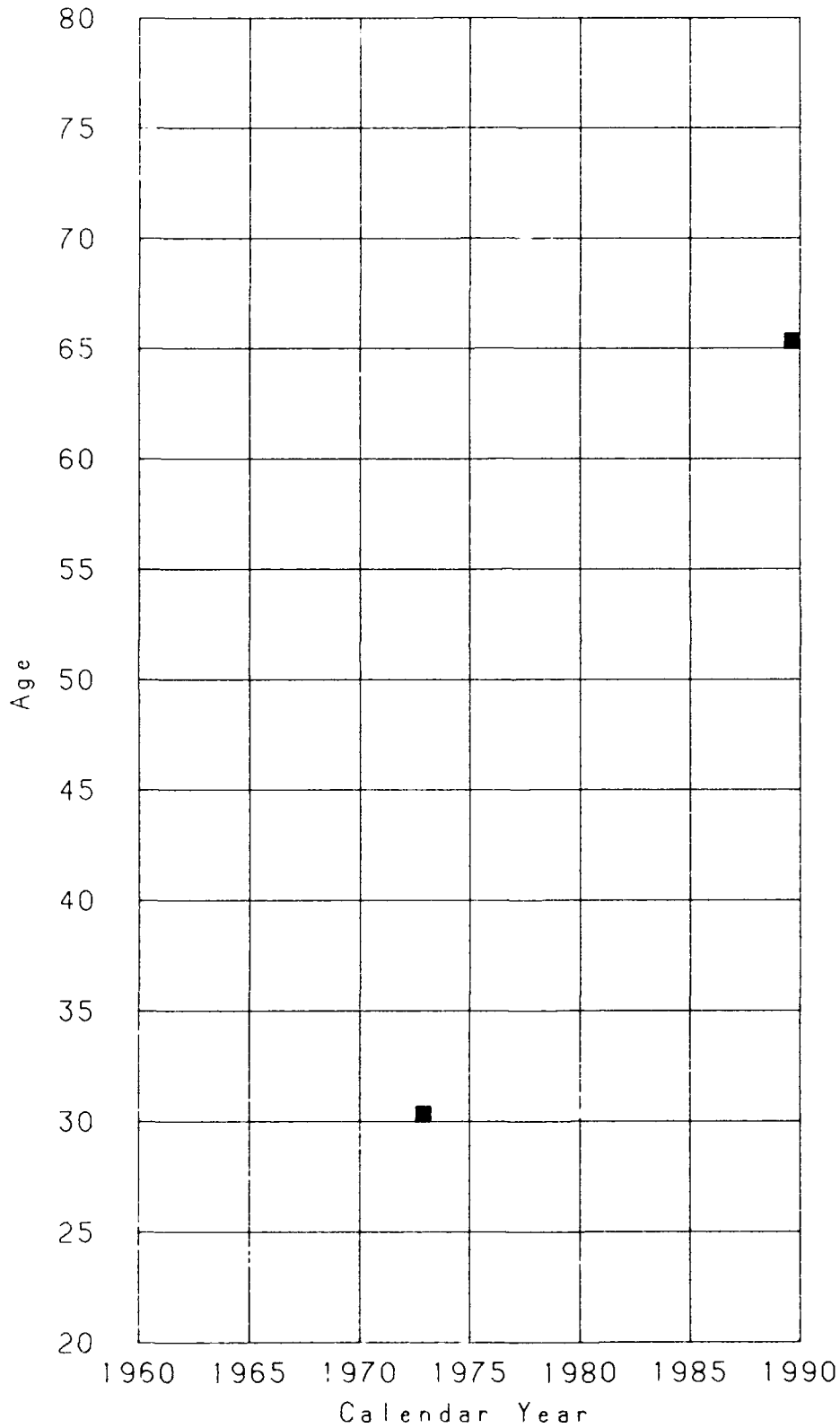


Figure 4
Lexis Diagram
Ranch Hand Flying Enlisted

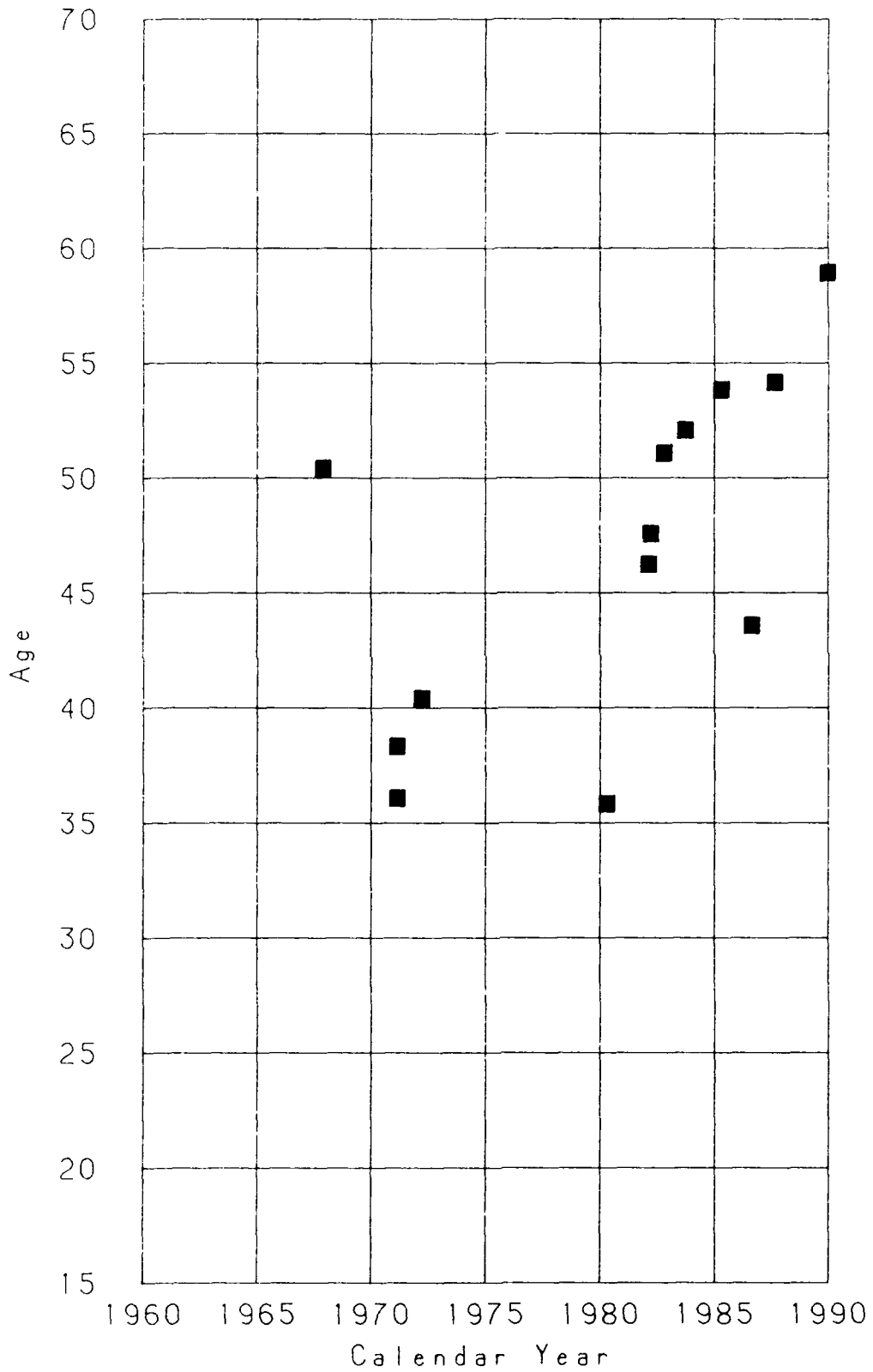
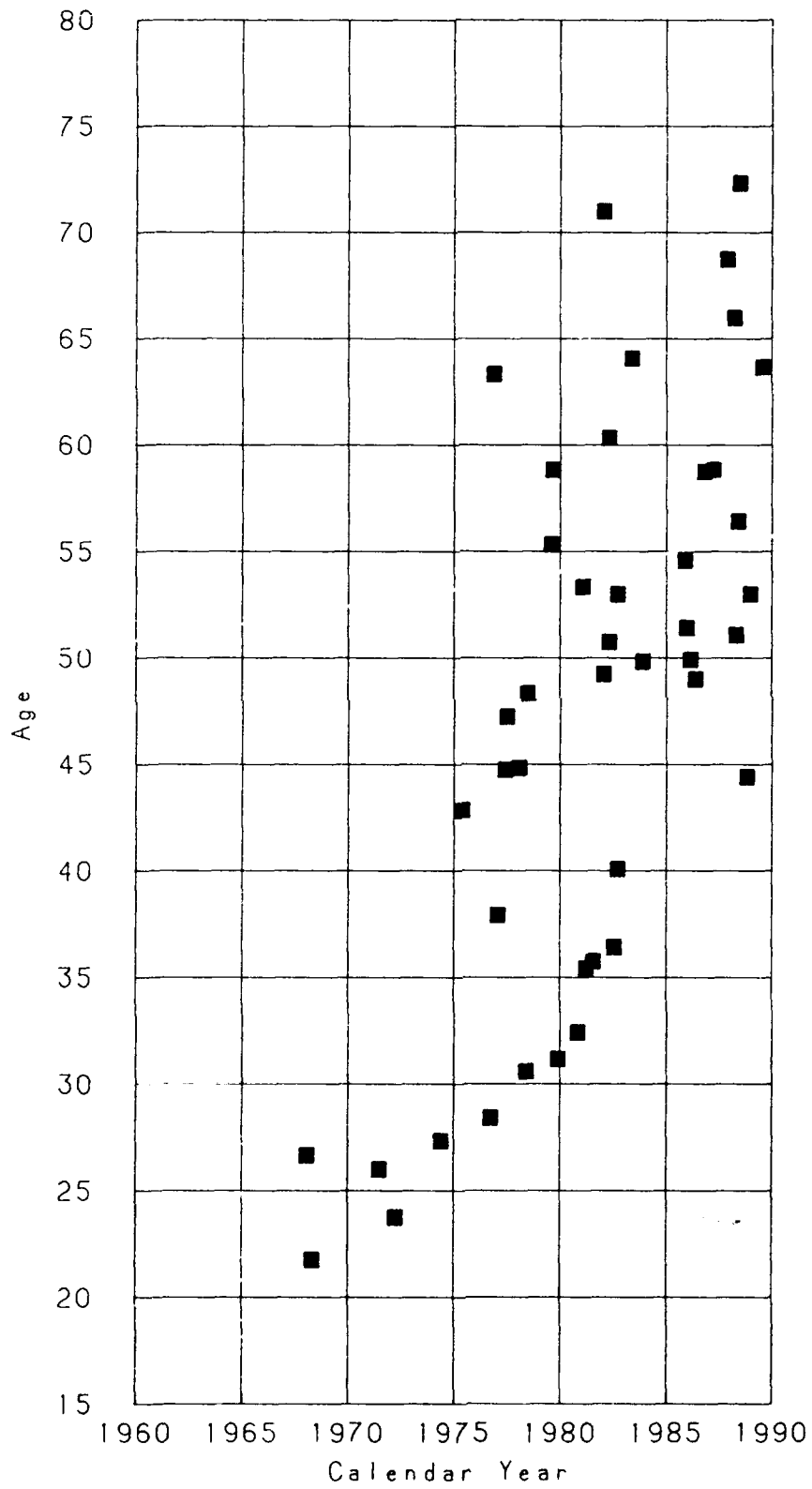


Figure 5
 Lexis Diagram
 Ranch Hand Nonflying Enlisted



3. CAUSE-SPECIFIC MORTALITY

Observed and adjusted expected Ranch Hand deaths by cause and stratum of rank and occupation are summarized in Table 5.

Table 5

Adjusted Cause-Specific Ranch Hand Mortality by Rank and Occupation

| Cause | Stratum | Dead | Expected | | 95% CI | p-value |
|-----------------------------|--------------------|------|----------|------|-----------|---------|
| | | | Deaths | SMR | | |
| Accidents | Flying officer | 9 | 7.65 | 1.18 | 0.53-2.23 | 0.63 |
| | Nonflying officer | 0 | 0.10 | 0.00 | | |
| | Flying enlisted | 4 | 5.32 | 0.75 | | |
| | Nonflying enlisted | 9 | 7.64 | 1.18 | | |
| | All Ranch Hands | 22 | 20.71 | 1.06 | | |
| Suicides | Flying officer | 0 | 1.20 | 0.00 | 0.22-2.03 | 0.64 |
| | Nonflying officer | 1 | 0.12 | 8.64 | | |
| | Flying enlisted | 2 | 1.34 | 1.49 | | |
| | Nonflying enlisted | 1 | 2.38 | 0.42 | | |
| | All Ranch Hands | 4 | 5.04 | 0.79 | | |
| Malignant Neoplasm | Flying officer | 7 | 8.61 | 0.81 | 0.21-1.42 | 0.58 |
| | Nonflying officer | 1 | 0.58 | 1.73 | | |
| | Flying enlisted | 1 | 4.39 | 0.23 | | |
| | Nonflying enlisted | 9 | 8.30 | 1.09 | | |
| | All Ranch Hands | 18 | 21.88 | 0.82 | | |
| Endocrine Disease | Flying officer | 0 | 0.12 | 0.00 | | |
| | Nonflying officer | 0 | 0.00 | | | |
| | Flying enlisted | 0 | 0.10 | 0.00 | | |
| | Nonflying enlisted | 1 | 0.21 | 4.72 | | |
| | All Ranch Hands | 1 | 0.43 | 2.32 | | |
| Circu- latory Disease | Flying officer | 11 | 10.09 | 1.10 | 0.45-1.74 | 0.77 |
| | Nonflying officer | 0 | 0.78 | 0.00 | | |
| | Flying enlisted | 2 | 5.98 | 0.33 | | |
| | Nonflying enlisted | 19 | 11.32 | 1.68 | | |
| | All Ranch Hands | 32 | 28.17 | 1.14 | | |
| Digestive Disease | Flying officer | 4 | 1.01 | 3.95 | 1.22-5.09 | 0.005 |
| | Nonflying officer | 0 | 0.10 | 0.00 | | |
| | Flying enlisted | 2 | 1.33 | 1.51 | | |
| | Nonflying enlisted | 3 | 0.92 | 3.24 | | |
| | All Ranch Hands | 9 | 3.36 | 2.68 | | |

There are no overall or within-stratum significant differences between the observed and expected numbers of deaths due to accidents or malignant neoplasms (Table 5). One Ranch Hand died from endocrine disease (expected=0.1, SMR=3.32). There is also no significant difference between the observed and expected number of suicides in all Ranch Hands.

There is a significantly increased number of deaths caused by diseases of the circulatory system among Ranch Hand nonflying enlisted personnel (SMR=1.68, 95% CI 1.01-2.62, p=0.02) and significantly increased number of deaths due to digestive diseases in all Ranch Hands (SMR=2.68, 95% CI 1.22-5.09, p=0.005).

Additionally, 2 Ranch Hands were murdered (expected=1.60, SMR=1.25) and 3 died of unknown or ill-defined causes (expected=1.23, SMR=2.44).

Table 6 shows cumulative site-specific malignant neoplasm mortality among Ranch Hands.

Table 6

Site-specific Malignant Neoplasm Ranch Hand Mortality

| Site | Dead | Expected Deaths |
|---|------|-----------------|
| 140-149 Lip, Oral Cavity and Pharynx | | |
| 140.9 Lip, Unspecified | 0 | 0.060 |
| 141.9 Tongue, Unspecified | 0 | 0.215 |
| 144.9 Floor of Mouth, Unspecified | 0 | 0.057 |
| 145.3 Soft Palate | 0 | 0.122 |
| 145.9 Mouth, Unspecified | 0 | 0.111 |
| 146.0 Tonsil | 0 | 0.143 |
| 147.9 Nasopharynx, Unspecified | 0 | 0.102 |
| 148.1 Pyriform Sinus | 0 | 0.178 |
| 149.0 Pharynx, Unspecified | 0 | 0.115 |
| 150-159 Digestive Organs and Peritoneum | | |
| 150.3 Oesophagus, Upper Third | 0 | 0.045 |
| 150.5 Oesophagus, Lower Third | 0 | 0.070 |
| 150.9 Oesophagus, Unspecified | 1 | 0.745 |
| 151.9 Stomach, Unspecified | 1 | 0.395 |
| 153.4 Colon, Caecum | 0 | 0.146 |
| 153.5 Colon, Appendix | 0 | 0.109 |
| 153.6 Ascending Colon | 0 | 0.045 |
| 153.9 Colon, Unspecified | 0 | 2.019 |
| 154.0 Rectosigmoid Junction | 0 | 0.098 |
| 154.1 Rectum | 0 | 0.215 |
| 154.3 Anus, Unspecified | 0 | 0.105 |
| 157.4 Islets of Langerhans | 0 | 0.109 |
| 157.9 Pancreas, Unspecified | 1 | 0.953 |
| 159.0 Intestinal Tract, Unspecified | 0 | 0.058 |
| 160-165 Respiratory and Intrathoracic Organs | | |
| 160.9 Accessory Sinus, Unspecified | 0 | 0.046 |
| 161.1 Supraglottis | 0 | 0.109 |
| 161.9 Larynx, Unspecified | 0 | 0.221 |
| 162.2 Main Bronchus | 0 | 0.059 |
| 162.3 Upper Lobe, Bronchus or Lung | 0 | 0.120 |
| 162.4 Middle Lobe, Bronchus or Lung | 0 | 0.052 |
| 162.9 Bronchus and Lung, Unspecified | 10 | 8.065 |
| 163.9 Pleura, Unspecified | 0 | 0.055 |
| 164.9 Mediastinum, Unspecified | 1 | 0.000 |
| 170-175 Bone, Connective Tissue, Skin and Breast | | |
| 170.9 Bone and Articular Cartilage, Unspecified | 0 | 0.064 |
| 171.3 Connective, Soft Tissue, Lower Limb, Hip | 1 | 0.000 |
| 171.8 Connective, Soft Tissue, Other | 0 | 0.060 |
| 171.9 Site Unspecified | 0 | 0.185 |
| 172.5 Skin, Trunk | 0 | 0.063 |
| 172.9 Skin, Unspecified | 0 | 0.649 |

Table 6 (Continued)

| Site | Dead | Expected Deaths |
|---|------|-----------------|
| 179-189 Genitourinary Organs | | |
| 185.0 Prostate | 0 | 0.224 |
| 188.9 Bladder, Unspecified | 0 | 0.115 |
| 189.0 Kidney, Except Pelvis | 1 | 0.436 |
| 190-199 Other and Unspecified Sites | | |
| 191.1 Brain, Frontal Lobe | 0 | 0.112 |
| 191.4 Occipital Lobe | 0 | 0.122 |
| 191.7 Brain Stem | 0 | 0.103 |
| 191.9 Brain, Unspecified | 1 | 0.694 |
| 195.0 Head, Face and Neck | 0 | 0.271 |
| 195.8 Other Unspecified Site | 0 | 0.058 |
| 197.0 Lung | 0 | 0.059 |
| 197.5 Large Intestine and Rectum | 0 | 0.061 |
| 199.0 Disseminated, Unspecified | 0 | 0.068 |
| 199.1 Other, Unspecified | 1 | 1.083 |
| 200-208 Lymphatic and Haematopoietic Tissue | | |
| 200.1 Lymphosarcoma | 0 | 0.109 |
| 200.8 Reticuloclymphosarcoma | 0 | 0.102 |
| 201.9 Hodgkin's Disease, Unspecified | 0 | 0.158 |
| 202.8 Other Lymphomas | 0 | 0.455 |
| 203.0 Multiple Myeloma | 0 | 0.401 |
| 204.0 Acute Lymphoid Leukaemia | 0 | 0.051 |
| 204.1 Chronic Lymphoid Leukaemia | 0 | 0.122 |
| 204.9 Lymphoid Leukaemia, Unspecified | 0 | 0.079 |
| 205.0 Acute Myeloid Leukaemia | 0 | 0.133 |
| 205.3 Myeloid Sarcoma | 0 | 0.059 |
| 206.0 Acute Monocytoid Leukaemia | 0 | 0.067 |
| 207.8 Lymphosarcoma Cell Leukaemia | 0 | 0.060 |
| 208.0 Acute Leukaemia, Unspecified | 0 | 0.185 |
| Totals | 18 | 19.497 |

The 18 Ranch Hand deaths due to malignant neoplasm do not appear to aggregate in an unusual pattern relative to that expected (Table 6).

The morphology of cumulative malignant neoplasm deaths is summarized in Table 7.

Table 7

Morphology of Ranch Hand Malignant Neoplasm Deaths

| Morphology | Dead | Expected Deaths |
|--|------|-----------------|
| M800 Neoplasms NOS | | |
| 140-149 Lip, Oral Cavity and Pharynx | 0 | 0.053 |
| 150-159 Digestive Organs and Peritoneum | 1 | 1.974 |
| 160-165 Respiratory and Intrathoracic Organs | 4 | 3.437 |
| 179-189 Genitourinary Organs | 0 | 0.232 |
| 190-199 Other and Unspecified Sites | 1 | 1.005 |
| 239 Neoplasms of Unspecified Nature | 0 | |
| M801-M804 Epithelial Neoplasms NOS | | |
| 140-149 Lip, Oral Cavity and Pharynx | 0 | 0.360 |
| 150-159 Digestive Organs and Peritoneum | 1 | 1.370 |
| 160-165 Respiratory and Intrathoracic Organs | 6 | 3.790 |
| 179-189 Genitourinary Organs | 1 | 0.248 |
| 190-199 Other and Unspecified Sites | 1 | 0.543 |
| M805-M808 Papillary and Squamous Cell Neoplasms | | |
| 140-149 Lip, Oral Cavity and Pharynx | 0 | 0.600 |
| 150-159 Digestive Organs and Peritoneum | 0 | 0.073 |
| 160-165 Respiratory and Intrathoracic Organs | 0 | 0.548 |
| 190-199 Other and Unspecified Sites | 0 | 0.117 |
| M814-M838 Adenomas and Adenocarcinomas | | |
| 140-149 Lip, Oral Cavity and Pharynx | 0 | |
| 150-159 Digestive Organs and Peritoneum | 1 | 1.627 |
| 160-165 Respiratory and Intrathoracic Organs | 0 | 0.792 |
| 179-189 Genitourinary Organs | 0 | 0.960 |
| 190-199 Other and Unspecified Sites | 0 | 0.579 |
| M856-M858 Complex Epithelial Neoplasms | | |
| 190-199 Other and Unspecified Sites | 0 | 0.058 |
| M872-M879 Naevi and Melanomas | | |
| 160-165 Respiratory and Intrathoracic Organs | 1 | 0.000 |
| 170-175 Bone, Connective Tissue, Skin and Breast | 0 | 0.712 |
| M880 Soft Tissue Tumors & Sarcomas NOS | | |
| 170-175 Bone, Connective Tissue, Skin and Breast | 0 | 0.121 |
| 190-199 Other and Unspecified Sites | 0 | 0.052 |
| M881-M883 Fibromatous Neoplasms | | |
| 170-175 Bone, Connective Tissue, Skin and Breast | 1 | 0.000 |
| M885-M888 Lipomatous Neoplasms | | |
| 170-175 Bone, Connective Tissue, Skin and Breast | 0 | 0.064 |
| M905 Mesothelial Neoplasms | | |
| 160-165 Respiratory and Intrathoracic Organs | 0 | 0.113 |
| M906-M909 Germ Cell Neoplasms | | |
| 190-199 Other and Unspecified Sites | 0 | 0.064 |
| M926 Miscellaneous Bone Tumors | | |

Table 7 (Continued)

| Morphology | Dead | Expected Deaths |
|--|------|-----------------|
| 170-175 Bone, Connective Tissue, Skin and Breast | 0 | 0.064 |
| M938-M948 Gliomas | | |
| 190-199 Other and Unspecified Sites | 0 | 0.852 |
| M949-M952 Neuroepitheliomatous Neoplasms | | |
| 170-175 Bone, Connective Tissue, Skin and Breast | 0 | 0.060 |
| M959-M963 Lymphomas NOS or Diffuse | | |
| 200-208 Lymphatic and Haematopoietic Tissue | 0 | 0.557 |
| M964 Reticulosarcomas | | |
| 200-208 Lymphatic and Haematopoietic Tissue | 0 | 0.109 |
| M965-M966 Hodgkin's Disease | | |
| 200-208 Lymphatic and Haematopoietic Tissue | 0 | 0.157 |
| M973 Plasma Cell Tumors | | |
| 200-208 Lymphatic and Haematopoietic Tissue | 0 | 0.401 |
| M980 Leukaemia NOS | | |
| 200-208 Lymphatic and Haematopoietic Tissue | 0 | 0.358 |
| M982 Lymphoid Leukaemias | | |
| 200-208 Lymphatic and Haematopoietic Tissue | 0 | 0.079 |
| M985 Lymphosarcoma Cell Leukaemias | | |
| 200-208 Lymphatic and Haematopoietic Tissue | 0 | 0.060 |
| M986 Myeloid Leukaemias | | |
| 200-208 Lymphatic and Haematopoietic Tissue | 0 | 0.113 |
| M989 Monocytic Leukaemias | | |
| 200-208 Lymphatic and Haematopoietic Tissue | 0 | 0.067 |
| M990 Miscellaneous Leukaemias | | |
| 200-208 Lymphatic and Haematopoietic Tissue | 0 | 0.059 |
| Totals | 18 | 21.878 |

Although the adjusted SMR for deaths due to malignant neoplasm is less than 1.0, there are morphologic subcategories of malignancies for which the SMR is greater than 1.0. For example, there are 9 Ranch Hand deaths from epithelial neoplasms not otherwise specified and the expected number of deaths in this category is 6.311. However, this excess is not significant (SMR=1.43, 95% C.I. 0.65-2.17, p=0.28).

4. CONCLUSIONS

An evaluation of cumulative all-cause Ranch Hand mortality through 31 December 1989 revealed no statistically significant difference between the observed and expected number of deaths (SMR=1.03, 95% CI 0.82-1.24, p=0.79). The indirectly standardized all-cause Ranch Hand death rate is 3.04 deaths per 1000 person-years; the Comparison rate is 2.95 deaths per 1000 person-years.

Furthermore, the observed number of deaths is not statistically significantly different from the expected number in any of the subgroups of Ranch Hands determined by rank (officer, enlisted) and job (flyer, nonflyer).

Adjusted cause-specific analyses revealed no overall significant difference between the observed and expected numbers of deaths for accidental deaths (SMR=1.06), suicides (SMR=0.79), deaths due to malignant neoplasm (SMR=0.82), or deaths due to circulatory system disease (SMR=1.14). However, there is an excess of deaths from circulatory system disease among nonflying enlisted personnel (SMR=1.68, 95% CI 1.01-2.62, p=0.02).

There is a significant excess of Ranch Hand deaths caused by diseases of the digestive system (SMR=2.68, 95% CI 1.22-5.09, p=0.005). To date, 9 Ranch Hands have died of digestive diseases. Except for alcoholic cirrhosis of the liver and acute alcoholic hepatitis, the Ranch Hand deaths were caused by a variety of unrelated digestive system diseases. At the last analysis [5], there was also a significant excess of Ranch Hand deaths caused by digestive diseases. At that time there were 6 Ranch Hand deaths caused by digestive system disease (SMR=2.69, 95% CI 1.00-5.85, p=0.01). This finding is currently under investigation.

These data could not be adjusted for alcohol use because alcohol consumption is known only for the 995 Ranch Hands and 1299 Comparisons who were fully compliant to the 1987 physical examination. Of the 91 deceased Ranch Hands and 1241 deceased Comparisons, 14 Ranch Hands and 19 Comparisons attended the 1987 physical examination. Thus, alcohol histories are unknown for 77 of the 91 deceased Ranch Hands and 1222 of the deceased Comparisons, as well as for 175 living Ranch Hands and 16,540 living Comparisons who were noncompliant to or ineligible for the 1987 physical examination.

A significant excess of deaths due to digestive system diseases in Army chemical corps veterans has been recently reported [10]. There was a 3-fold increase in digestive deaths in the chemical corps, primarily due to cirrhosis of the liver. Four of the 6 digestive deaths in chemical corps veterans were alcohol-related.

The increased number of deaths caused by circulatory system diseases in Ranch Hand nonflying enlisted personnel was not noted in the last report because previous reports incorporated a calculated dioxin exposure index. The index has since been found to be only weakly correlated with current or extrapolated dioxin body burden [7] and has therefore been dropped from these mortality assessments. A reanalysis using 31 December 1987 as the cut point (as was used in the last mortality report) reveals a borderline significant increase in this stratum (SMR=1.59, 95% CI 0.79-2.40, p=0.07). Thus, the SMR for circulatory deaths has increased from 1.59 to 1.68 during the 2-year period from the end of 1987 to the end of 1989. This increase is of concern because Ranch Hand nonflying enlisted personnel have higher current dioxin levels than Ranch Hands in the other strata [7] and because current and extrapolated initial dioxin levels are significantly associated with diabetes and increased cholesterol, HDL cholesterol and triglyceride abnormalities [7]. While there is no association between dioxin and cardiovascular disease in the examined Ranch Hands, this increase in circulatory disease deaths might be dioxin-related through its association with diabetes and serum lipids. However, only 1 Ranch Hand has died of circulatory system disease with mention of diabetes as contributory on the death certificate, versus 0.52 expected. The number of such deaths among all Ranch Hands is also 1 and the expected number is 1.04. Diabetes, as a secondary cause of death, is generally under-reported on death certificates. This limits the ability of this, or any other mortality study based on death certificates, to assess the possible relationship between dioxin exposure and mortality due to circulatory system diseases through an association between dioxin and diabetes.

In summary, the overall all-cause mortality experience of the Ranch Hands is not significantly different from that expected. As of 31 December 1989, 91 (7.2%) of the Ranch Hands have died; the expected number of deaths is 88.4. The overall observed and expected numbers of deaths were not significantly different for accidental deaths, suicides, and deaths caused by malignant neoplasms and circulatory system diseases. However, there were significantly increased Ranch Hand deaths due to digestive diseases and, in nonflying enlisted personnel, circulatory system diseases. The increase in deaths caused by diseases of the digestive system has been previously noted and is currently under investigation. The increased number of deaths due to circulatory system diseases among nonflying enlisted personnel is a new finding and is, as yet, unexplained.

REFERENCES

1. Lathrop, G.D., Moynahan, P.M., Wolfe, W.H. and Albanese, R.A. (1983). The Air Force Health Study: An epidemiologic investigation of health effects in Air Force personnel following exposure to herbicides: baseline mortality results. NTIS AD A 130 793.
2. Wolfe, W.H., Michalek, J.E. and Albanese, R.A. (1984). The Air Force Health Study: An epidemiologic investigation of health effects in Air Force personnel following exposure to herbicides: mortality update-1984. NTIS AD A 162 687.
3. Wolfe, W.H. and Michalek, J.E. (1985). The Air Force Health Study: An epidemiologic investigation of health effects in Air Force personnel following exposure to herbicides: mortality update-1985. NTIS AD A 163 237.
4. Wolfe, W.H., Michalek, J.E., Miner, J.C. and Peterson, M.R. (1986). The Air Force Health Study: An epidemiologic investigation of health effects in Air Force personnel following exposure to herbicides: mortality update-1986. NTIS AD A 175 453.
5. Wolfe, W.H., Michalek, J.E. and Miner, J.C. (1989). The Air Force Health Study: An epidemiologic investigation of health effects in Air Force personnel following exposure to herbicides: mortality update-1989. NTIS AD A 208 865.
6. Breslow, N.E., Lubin, J.H., Marek, P. and Langholz, B. (1983). Multiplicative models and cohort analysis. Journal of the American Statistical Association 78, 1-12.
7. Roegner, R.H., Grubbs, W.D., Lustik, M.B., Brockman, A.S., Henderson, S.C., Williams, D.E., Wolfe, W.H., Michalek, J.E. and Miner, J.C. (1991). The Air Force Health Study. An Epidemiological Investigation of Health Effects in Air Force Personnel Following Exposure to Herbicides. Serum Dioxin Analysis of 1987 Examination Results. NTIS AD A 237 516 through AD A 237 524. (Volume I through IX)
8. Wolfe, W.H., Michalek, J.E., Miner, J.C., Silva, J., Thomas, W.F., Grubbs, W.D., Lustik, M.B., Karrison, T.G., Roegner, R.H. and Williams, D.E. (1990). Health status of Air Force veterans occupationally exposed to herbicides in Vietnam. Journal of the American Medical Association 264, 1824-1831.
9. Elandt-Johnson, R.C. and Johnson, N.L. (1980). Survival Models and Data Analysis. John Wiley and Sons, New York.
10. Thomas, T.L. and Kang, H.K. (1990). Mortality and morbidity among Army chemical corp Vietnam veterans: a preliminary report. American Journal of Industrial Medicine 18: 665-673.

PRINCIPAL INVESTIGATORS

William H. Wolfe, MD, MPH, FACPM
Colonel, USAF, MC
Chief, Epidemiologic Research Division

Joel E. Michalek, PhD, GM-15
Senior Research Statistician
Epidemiologic Research Division

Judson C. Miner, DVM, MPH, ACVPM
Colonel, USAF, BSC
Chief, Population Research Branch
Epidemiologic Research Division

CONTRIBUTORS

Mr Thomas White
Senior Subject Matter Specialist
QuesTech, Incorporated

Mr Vincent Elequin
Medical Records Administrator
Population Research Branch

Advisory Committee on Special Studies
Relating to the Possible Long-Term Health Effects
of Phenoxy Herbicides and Contaminants:

Earl P. Benditt, MD, University of Washington School of
Medicine

Turner Camp, MD, Veterans of Foreign Wars

Captain Ronald F. Coene, USN, National Center for Toxicological
Research

Michael Gough, PhD, Office of Technology Assessment, Congress of
the United States

Leonard T. Kurland, MD, Mayo Clinic and Mayo Foundation

Peter C. O'Brien, PhD, Mayo Clinic and Mayo Graduate School

Dolores C. Shockley, PhD, Meharry Medical College

Ellen K. Silbergeld, PhD, University of Maryland

Paul D. Stolley, MD, University of Maryland School of
Medicine

M. Donald Whorton, MD, ENSR Health Sciences

John F. Young, PhD, National Center for Toxicological Research