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MORTALITY STUDIES OF HANFORD WORKERS

E. S. Gilbert

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To be presented at Symposium on Hanford
The Public Health and the Law
Spokane, Washington
May 3, 1986

Pacific Northwest Laboratory
Richland, Washington 99352

MORTALITY STUDIES OF HANFORD WORKERS

The assessment of health effects from low-level exposure to radiation is a matter of considerable interest and controversy these days. My own involvement in this field started in 1975 when I began analyzing data on Hanford workers. This study will be the focus of my presentation today.

Hanford, as most of you know, was established in the 1940's as an installation for plutonium production. Since this time, efforts have been diversified considerably to include a variety of research activities and nuclear power production. Thousands of workers have been employed at Hanford, many in jobs involving some exposure to radiation.

Radiation exposures at Hanford have been deliberately limited as a protection to the worker. This means that if current estimates of radiation risks, which have been determined by national and international groups, are correct, it's highly unlikely that noticeable radiation-induced health effects will be identified among Hanford workers.

Before getting into the data on Hanford workers, I'd like to say just a few words about the source of the estimates that provide the basis for our radiation protection standards. These estimates come primarily from studies of groups of people who have been exposed at very high levels of radiation. A study of particular importance in determining these estimates is that of the Japanese atomic bomb survivors in Hiroshima and Nagasaki. Extensive efforts have been made to estimate the doses of these individuals and to determine whether or not they eventually develop cancer and other diseases. Because of these efforts, we have fairly good estimates of the health effects resulting from high level radiation exposure.

In my first slide, I've tried to illustrate the way these data are used to obtain estimates of the effects of low level exposure, such as that received by Hanford workers, for example. Here we have an effect, such as cancer mortality, plotted against exposure, which I've simply indicated as "high" and "low". The dots represent the observed data at high levels, while the two solid lines represent attempts to extrapolate in order to estimate the effects of low level exposure. Most official risk estimates, and resulting radiation protection standards, have been based on a linear function, which provides higher estimates at low doses than the alternative linear-quadratic function. However, data from animal and other laboratory experiments indicate that the lower estimates provided by the linear-quadratic may be more appropriate.

The point I want to make here is that based on linear extrapolation from effects observed at high level exposure, we would expect only one or two radiation induced leukemia deaths among Hanford workers, and one or two radiation induced deaths from other types of cancer. With the linear-quadratic model, even fewer radiation induced cancer deaths would be expected. Since radiation-induced cancers are indistinguishable from cancers caused by other factors, it is highly unlikely that such a small number would be noticeable in contrast to the several hundred cancer deaths that would be expected in any group of the size and age structure of the Hanford worker population.

Although most experts in the field of radiation risk assessment are confident that estimates based on extrapolation of the sort I've just described are appropriate, it is obviously desirable to evaluate the adequacy of these estimates by directly examining death rates of workers at Hanford, as well as other groups who have been exposed at low levels. That's what I've been doing for the past few years, and I'd like to share some of the findings.

There's not time to describe all the analyses that we've conducted, but I would like to present a few results that I think capture the essence of our findings. In my next slide (#2), I've presented cancer death rates for about 13,500 males who were employed at Hanford for at least two years. This is the group that has received most of the radiation exposure at Hanford. These death rates are presented as deaths per 100,000 per year, and are calculated in a way that adjusts for differences in age and calendar year among the groups being compared. Confidence intervals are also presented, which reflect the uncertainty in these rates.

Because radiation exposure at Hanford varies considerably from worker to worker, rates are presented for three categories defined by cumulative occupational radiation exposure. These categories are 0-2 rem, 2-5 rem, and 5 or more rem; a minimal ten-year latent period is allowed for in defining these categories. Note that the majority of deaths fall in the lowest exposure category, reflecting the fact that there are more workers in this category since most Hanford workers do not regularly work with radiation. At the bottom of the slide, I've presented, for comparison, the rate based on vital statistics for all U.S. white males.

As you see, for all three exposure categories, the death rates for Hanford workers are lower than the U.S. rate. This finding is fairly typical of a population employed in an industry free from serious hazard, and reflects what is sometimes called the "healthy worker effect," which results primarily because you have to have a certain level of health to be eligible for a job. The medical surveillance program at Hanford, health insurance, and a variety of other factors connected with a steady state of employment may also play a role.

Of more importance than the demonstration of the "healthy worker effect" is the fact that these rates show no particular tendency to increase with increasing radiation exposure. If radiation were a strong factor in causing cancer in this population, we would expect cancer rates to increase as exposure increases. The slight differences that you see in these rates can be accounted for by chance or random fluctuation.

We've carried out separate analyses for many different causes of death. I'll present a few additional results. In my next slide (#3), I've presented the same sort of analysis based on all causes of death, not just cancer. Here, again we see the "healthy worker effect", but no indication of a statistically significant trend in either the positive or the negative direction with radiation exposure.

The next slide (#4) shows an analysis of leukemia, the disease that has been most strongly linked with radiation in studies of populations exposed at high levels. Thus leukemia is the disease that would be most likely to show evidence of a correlation in Hanford workers. The number of deaths is small so that calculated rates are more variable than for cancer or for all causes. However, there is no evidence of an increase in leukemia mortality with increasing radiation exposure.

The lack of correlation for leukemia and for all cancers with radiation exposure may be surprising to some of you. Actually this is exactly what we would expect if the estimates that form the basis for our radiation protection standards are correct. As I noted earlier, radiation exposures at Hanford have been deliberately limited in order to conform to these standards with the expectation that risks would be minimal.

I'd like to emphasize that we're not claiming that there have been no radiation induced cancers in Hanford workers. What we are saying, however, is that our findings are not out of line with what we would expect, and that the Hanford data provide no reason to think that the risk estimates that form the basis for our radiation protection standards are too low.

I've shown you results of analyses of all cancer and of leukemia. We've analyzed 17 different categories of cancer. The only cancer type showing evidence of a statistically significant association with radiation exposure is multiple myeloma. This correlation results because of three deaths from this cause at relatively high exposures as can be seen from the next slide (#5). Because we have no a priori reason to expect a correlation for this particular cancer and no other, it is possible that this represents a so-called statistical fluke. If, for example, we examined the correlation of the occurrence of 17 types of cancer with the last digit of the Social Security Number, there's a good chance that at least one type of cancer would show a significant correlation. It's at least possible that this is the sort of thing that is going on with multiple myeloma, although obviously radiation provides a more plausible explanation than would the last digit of one's Social Security Number.

I'd like to note that we've done many analyses that I have not had time to discuss here. In particular, we have considered exposure in a far more detailed way than just the three categories that I've presented, and we've conducted analyses that have included females and short term workers. Finally, we've given careful consideration to a number of factors that might potentially bias these analyses. We've examined the relationship of both cancer mortality and radiation exposure with variables such as age, sex, calendar year, follow-up time, length of employment, initial year of employment, and job category. We've conducted analyses that take these factors into account; the results are similar to those I've presented.

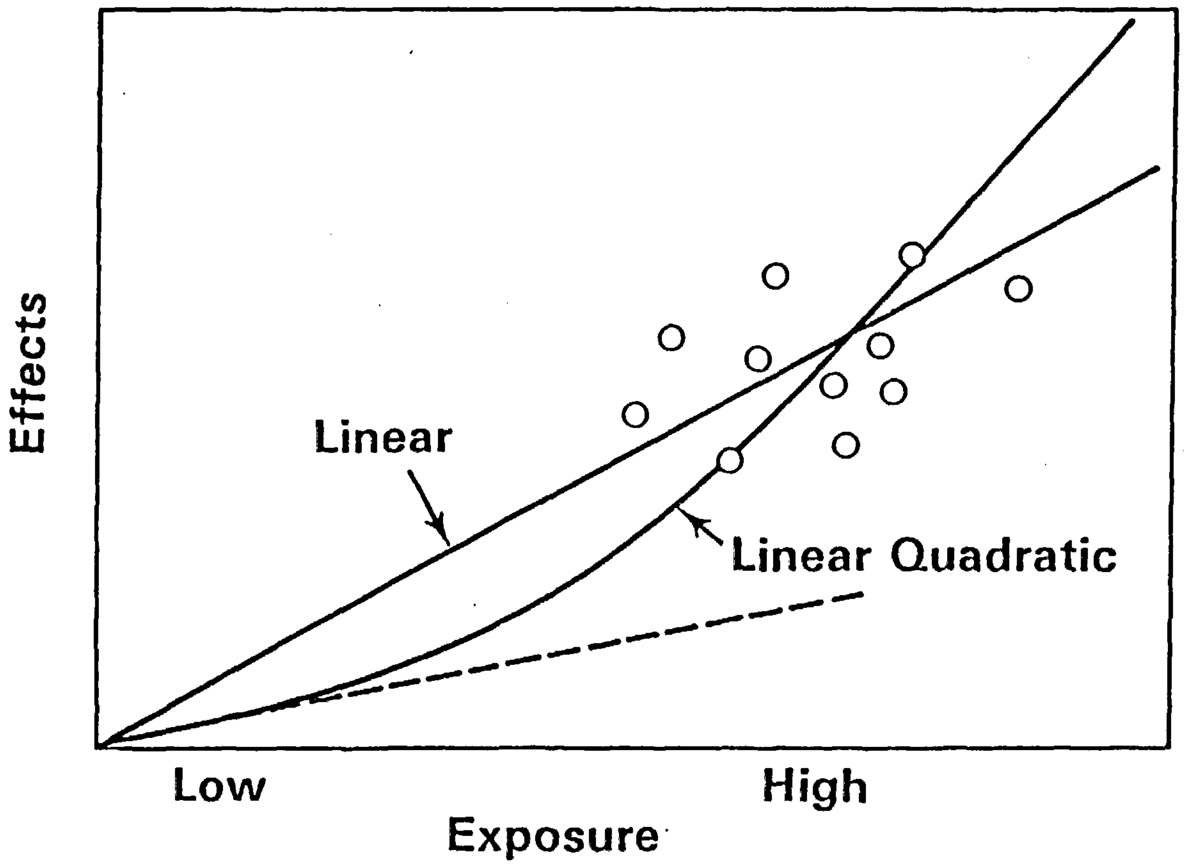
As some of you may know, the Hanford mortality data have been analyzed by other scientists. In particular, analyses by Mancuso, Stewart and Kneale have received considerable attention by the press. These investigators maintain that the Hanford data provide support for the claim that health effects due to radiation are 10 or more times what would be expected based on currently accepted estimates. I can't provide an adequate critique of the Mancuso-Stewart-Kneale analyses without getting into some fairly technical statistical arguments. However, their work has been severely criticized in print by a large number of scientists including many with no Hanford or DOE associations. Their findings have been rejected by a major committee of the National Academy of Sciences concerned with the estimation of risks due to low levels of radiation, and also in a report on this issue by the General Accounting Office.

In addition to the much publicized Mancuso-Stewart-Kneale analyses, the Hanford data have been analyzed by scientists at the National Radiological Protection Board in Great Britain and published in the Journal of the Royal Statistical Society. The data have also been analyzed by a group of four scientists from the National Cancer Institute, the National Academy of Sciences, and Harvard University. It's been analyzed by Dr. Sanders who was associated with Dr. Mancuso for several years, and by a statistician at MIT for the General Accounting Office. The results of all these analyses have been published. All are consistent with our own findings; none support the conclusions of Mancuso, Stewart, and Kneale.

It is of course important that a study such as this one be conducted in an objective manner. I'd like to note that we have a very high level of oversight for this project. We have a permanent advisory committee composed of prominent statisticians and epidemiologists. Because of the controversial nature of this study, our work has been reviewed by other special committees. None have found fault with our objectivity or the adequacy of our analytical approach.

To conclude, I'd like to note that even though there are unanswered questions regarding health effects due to radiation, we do know a great deal, probably more than we know about the effects of exposure to almost any other potentially harmful agent. There is a large body of data on populations that have been exposed at relatively high levels, and I think we have good reason to have confidence in the approaches that have been used to estimate risks resulting from exposure at the low levels received by Hanford workers, for example.

Slide #1



Slide #2:

Age- calendar year- adjusted death rates for Hanford workers

ALL CANCER

Cumulative Radiation Exposure	Death Rate (per 100,000 per year)	90% Confidence Limits	Number of Deaths
0-2 rem	260.3	(237.2, 283.5)	349
2-5 rem	255.2	(192.8, 317.5)	52
5+ rem	238.4	(169.8, 307.1)	45
All U.S. White Males	319.1		

Slide #3:

Age- calendar year- adjusted death rates for Hanford workers

ALL CAUSES

Cumulative Radiation Exposure	Death Rate (per 100,000 per year)	90% Confidence Limits	Number of Deaths
0-2 rem	1181.9	(1133.0, 1230.8)	1612
2-5 rem	1134.8	(988.2, 1281.5)	207
5+ rem	1144.5	(803.6, 1485.4)	189
All U.S. White Males	1517.0		

Slide #4:

Age- calendar year- adjusted death rates for Hanford workers

LEUKEMIA

Cumulative Radiation Exposure	Death Rate (per 100,000 per year)	90% Confidence Limits	Number of Deaths
0-2 rem	6.3	(3.0, 9.6)	10
2-5 rem	0.0	--	0
5+ rem	5.3	(0, 12.0)	2
All U.S. White Males	9.6		

Slide #5:

Age- calendar year- adjusted death rates for Hanford workers

MULTIPLE MYELOMA

Cumulative Radiation Exposure	Death Rate (per 100,000 per year)	90% Confidence Limits	Number of Deaths
0-2 rem	2.9	(0.5, 5.3)	4
2-5 rem	0.0	--	0
5+ rem	23.5	(1.0, 46.0)	3
All U.S. White Males	4.2		

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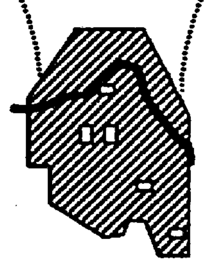
"Regional Environmental Radiation Monitoring"

Robert R. Mooney

Hanford Health Effects Panel Meeting

Richland, Washington

September 22, 1986



Quality Assurance Task Force

§ Established December, 1985

§ 1985 Legislation

§ Purpose:

Assess adequacy and accuracy of environmental radiation monitoring programs

Quality Assurance Task Force Members

- § Washington Health Division, Chair
- § Oregon Health Division
- § U.S. Department of Energy
- § Battelle Pacific Northwest Laboratory
- § Supply System (WNP-2)
- § Portland General Electric (Trojan)
- § Washington State Public Health Association
- § Washington Department of Ecology
  (Nuclear Waste Board)

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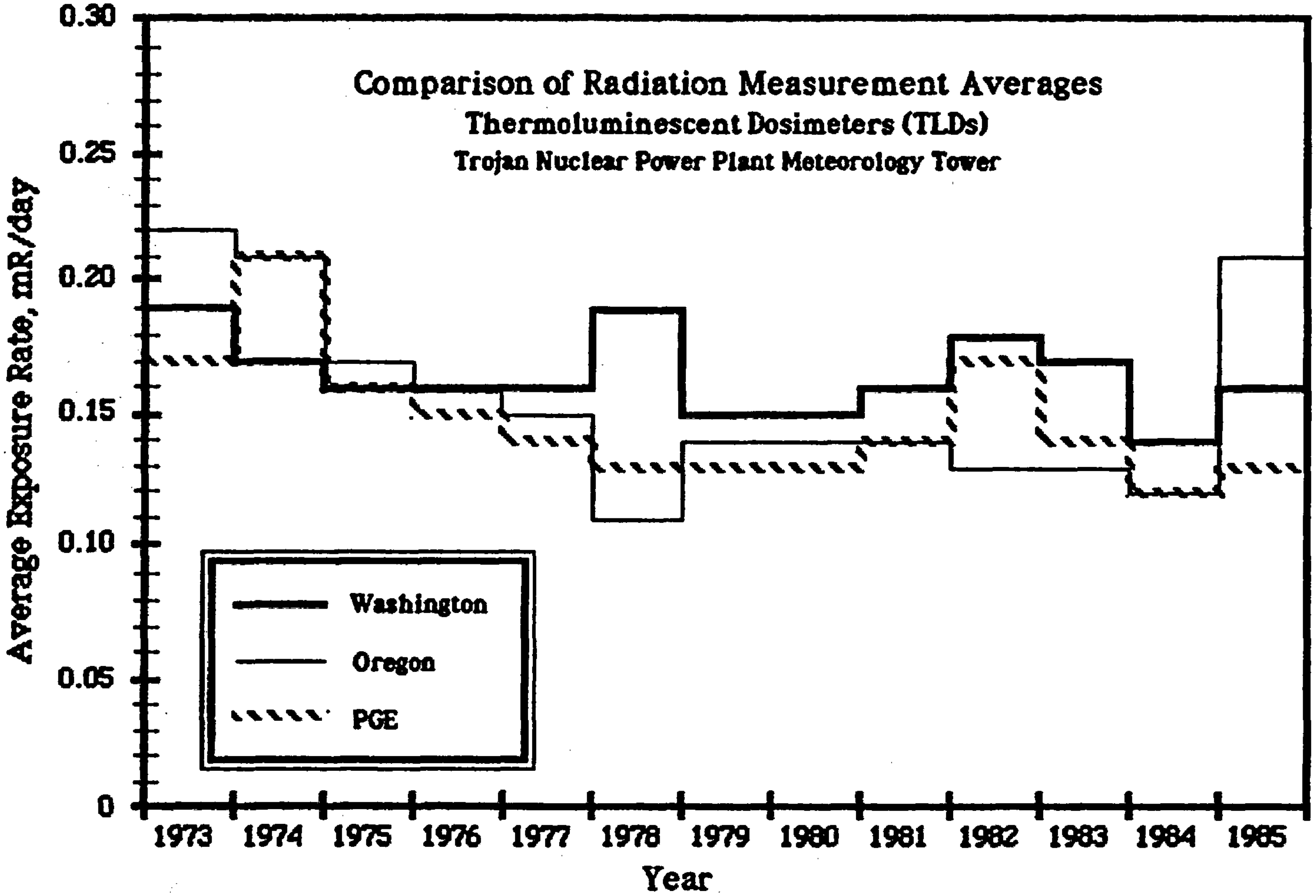

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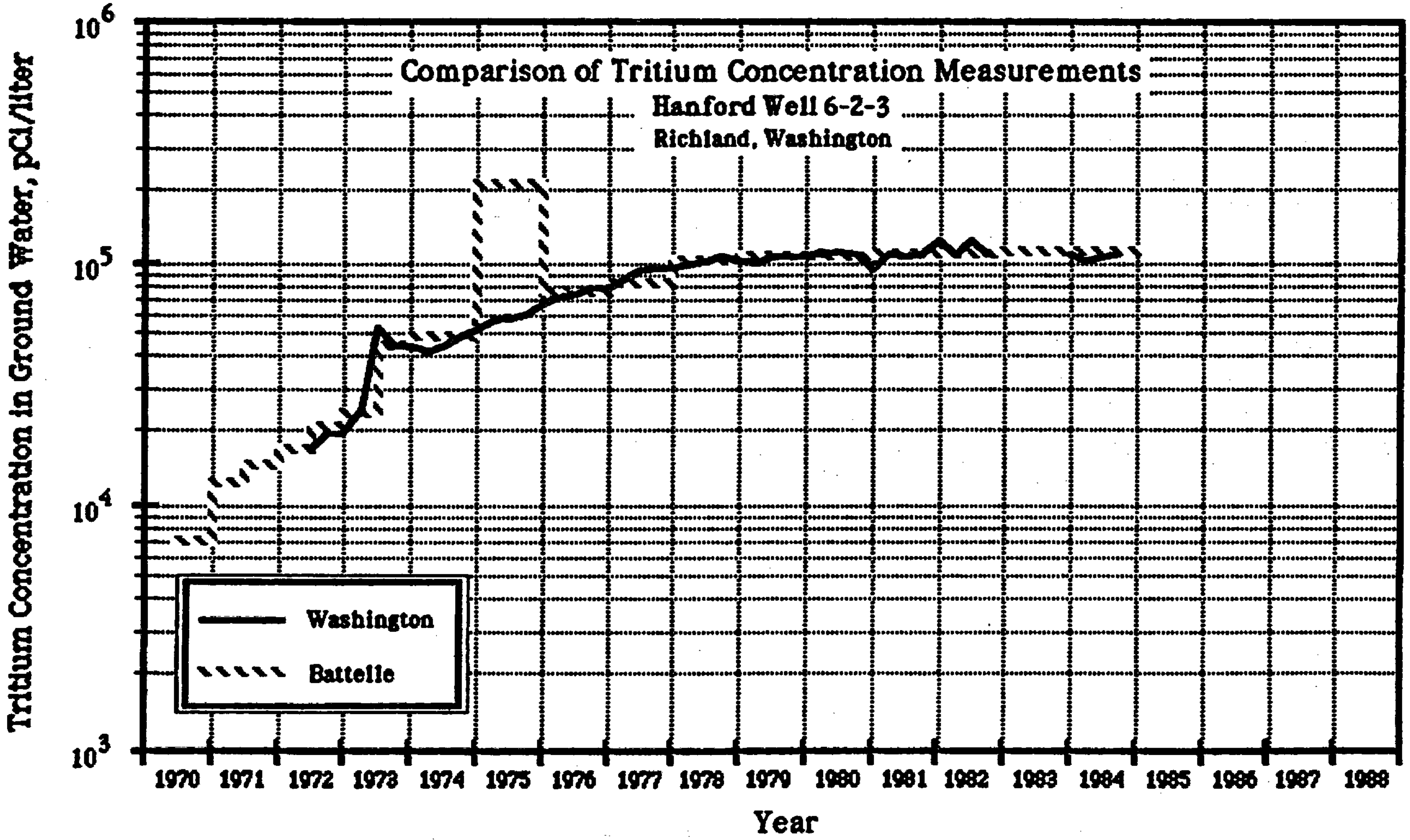

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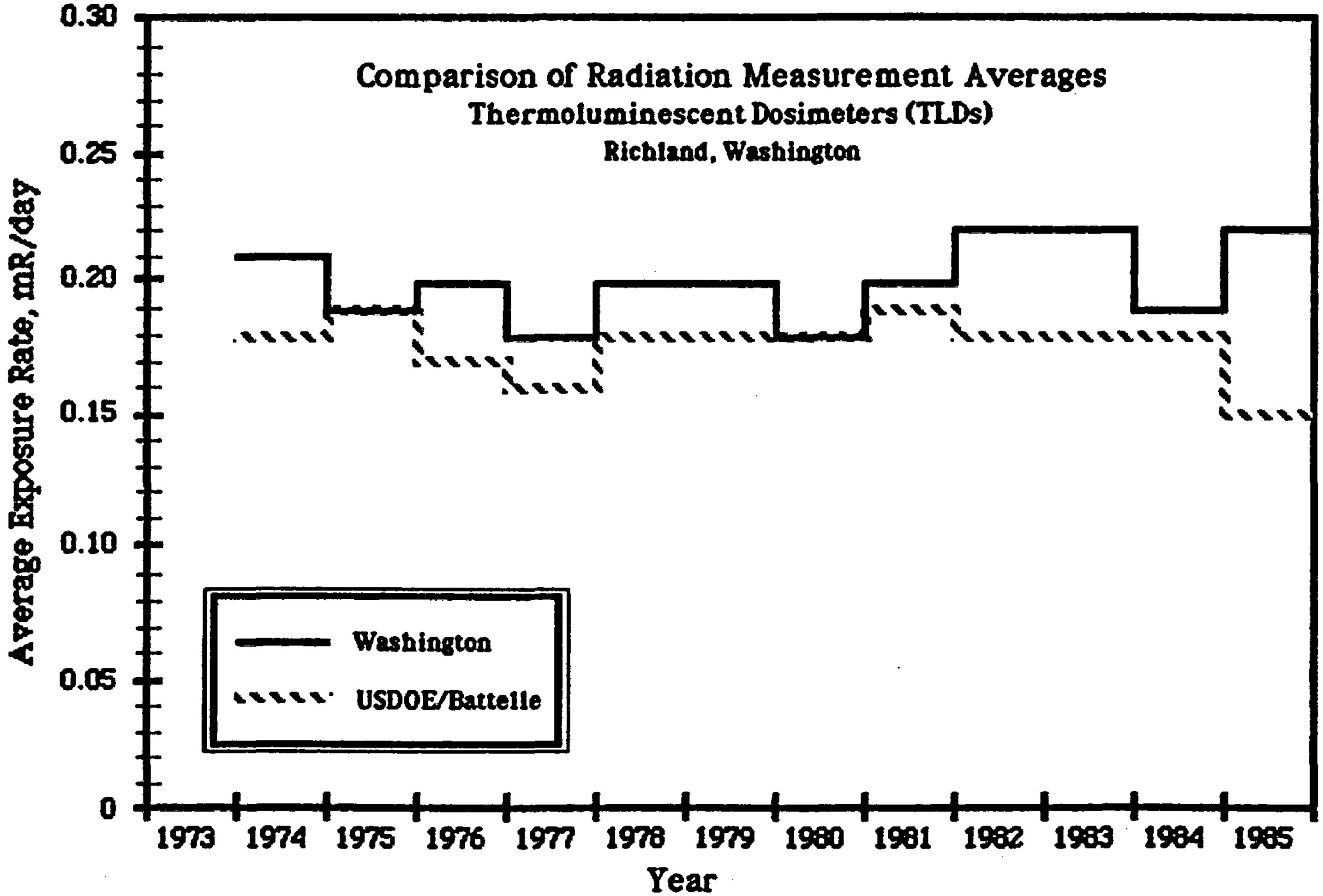

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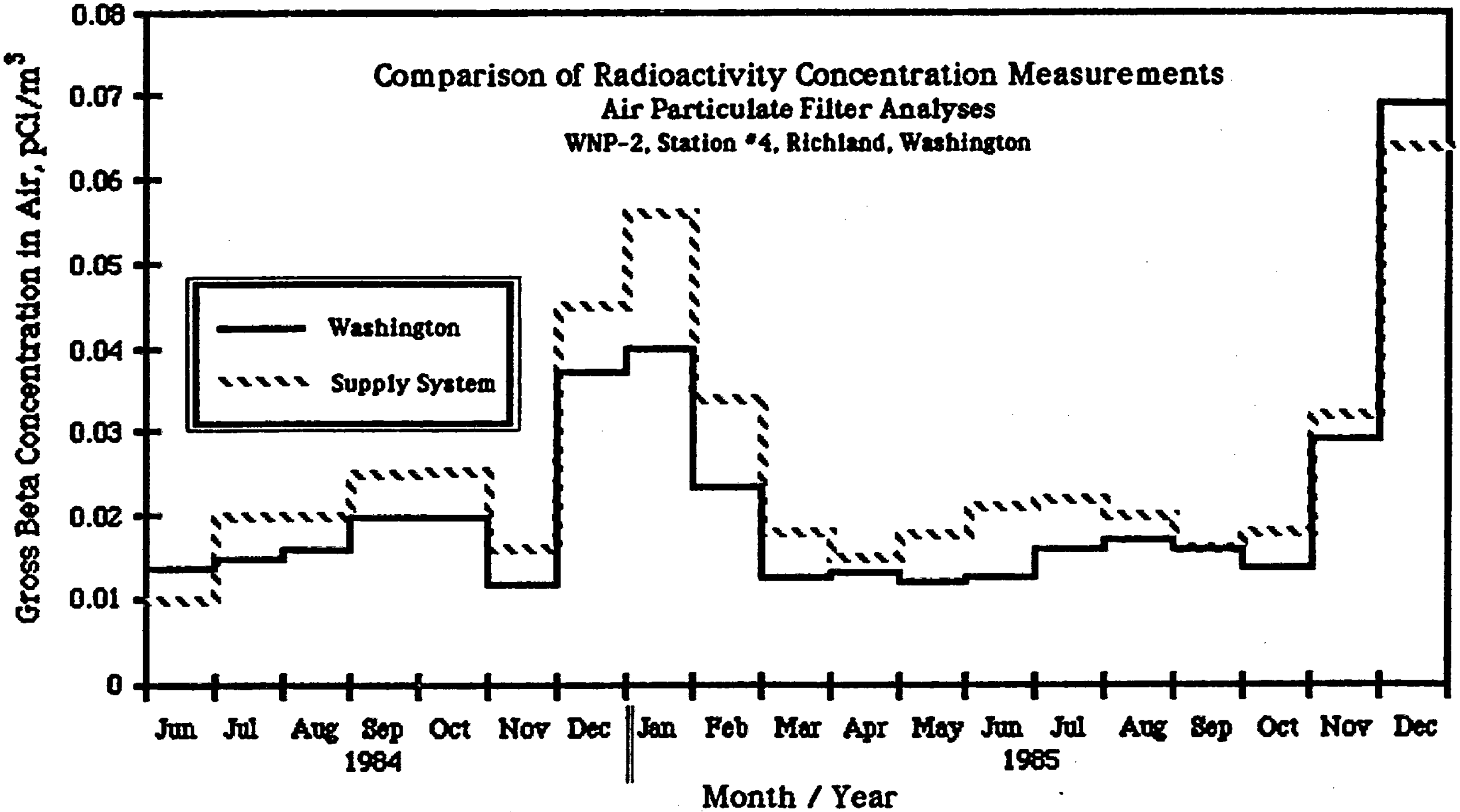

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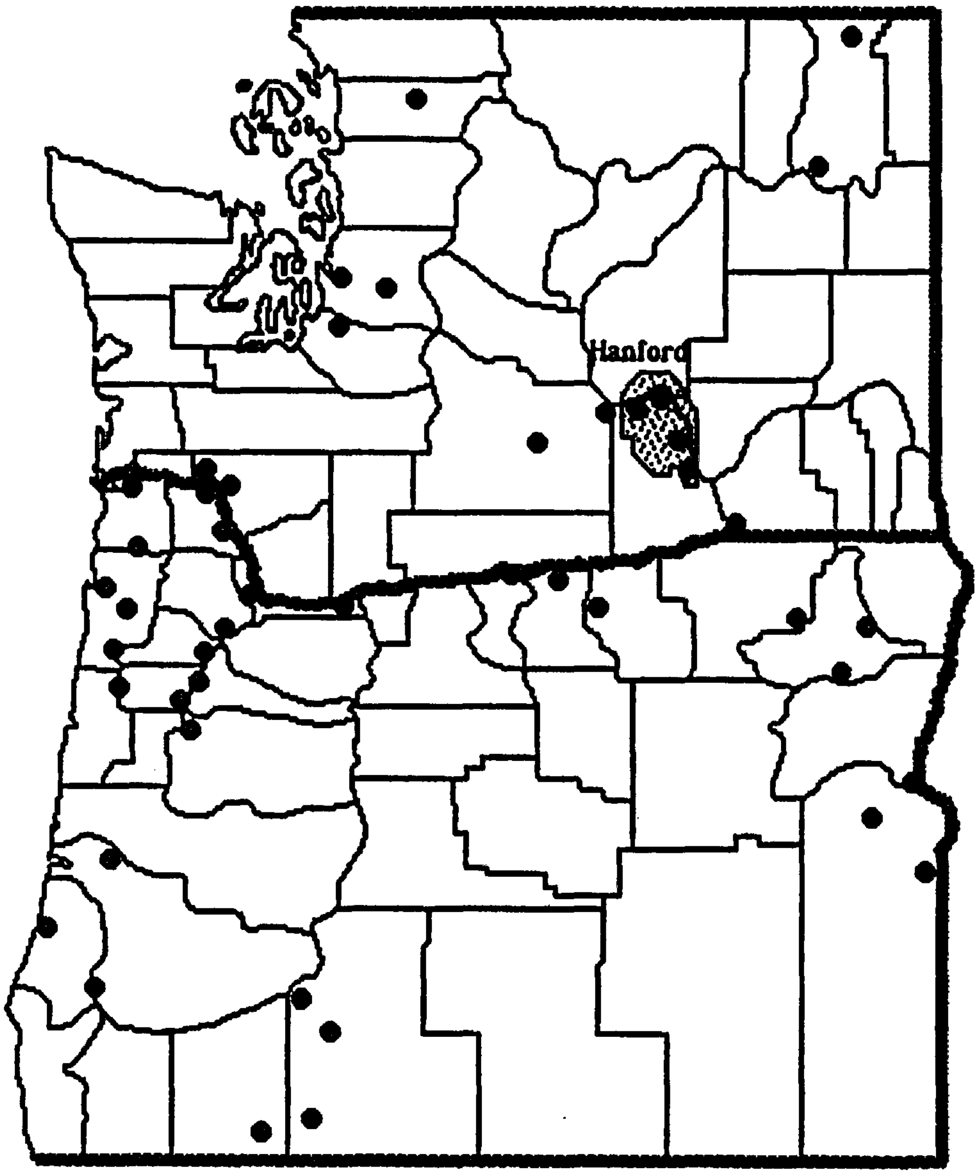
Regional Environmental Radiation Surveillance Network
Surface Water Sample Stations



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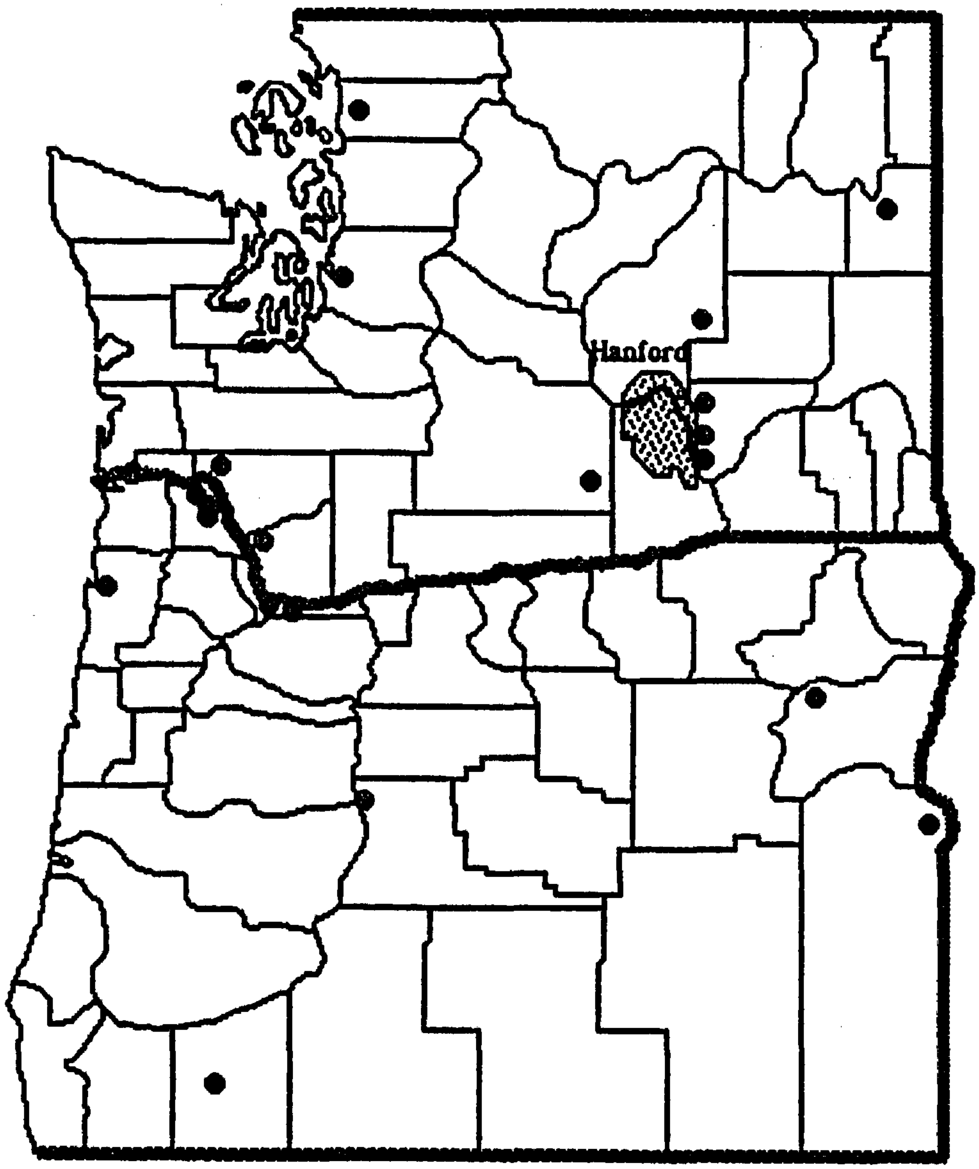
Regional Environmental Radiation Surveillance Network

Milk Sample Stations



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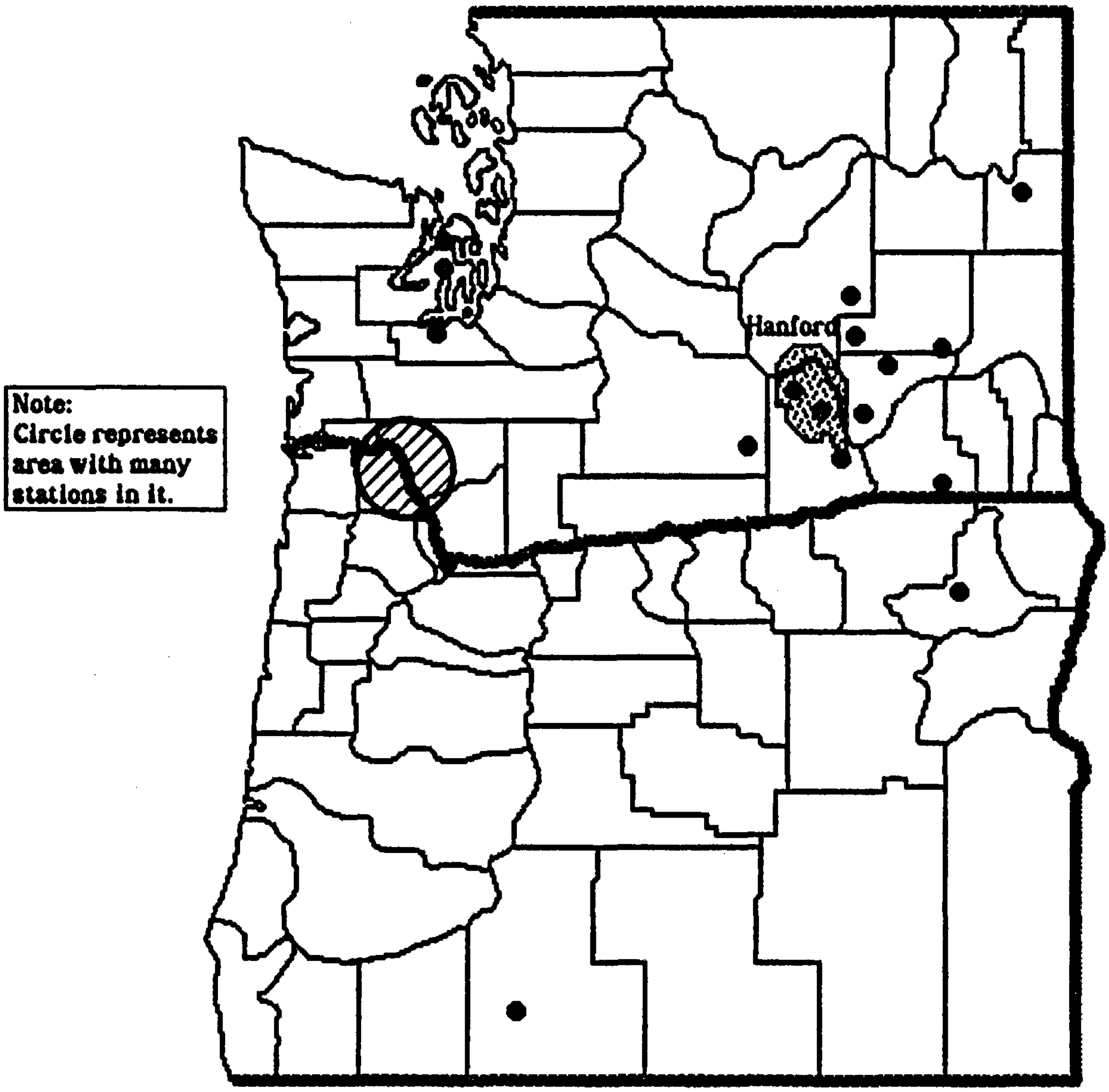
Regional Environmental Radiation Surveillance Network

Air Sample Stations



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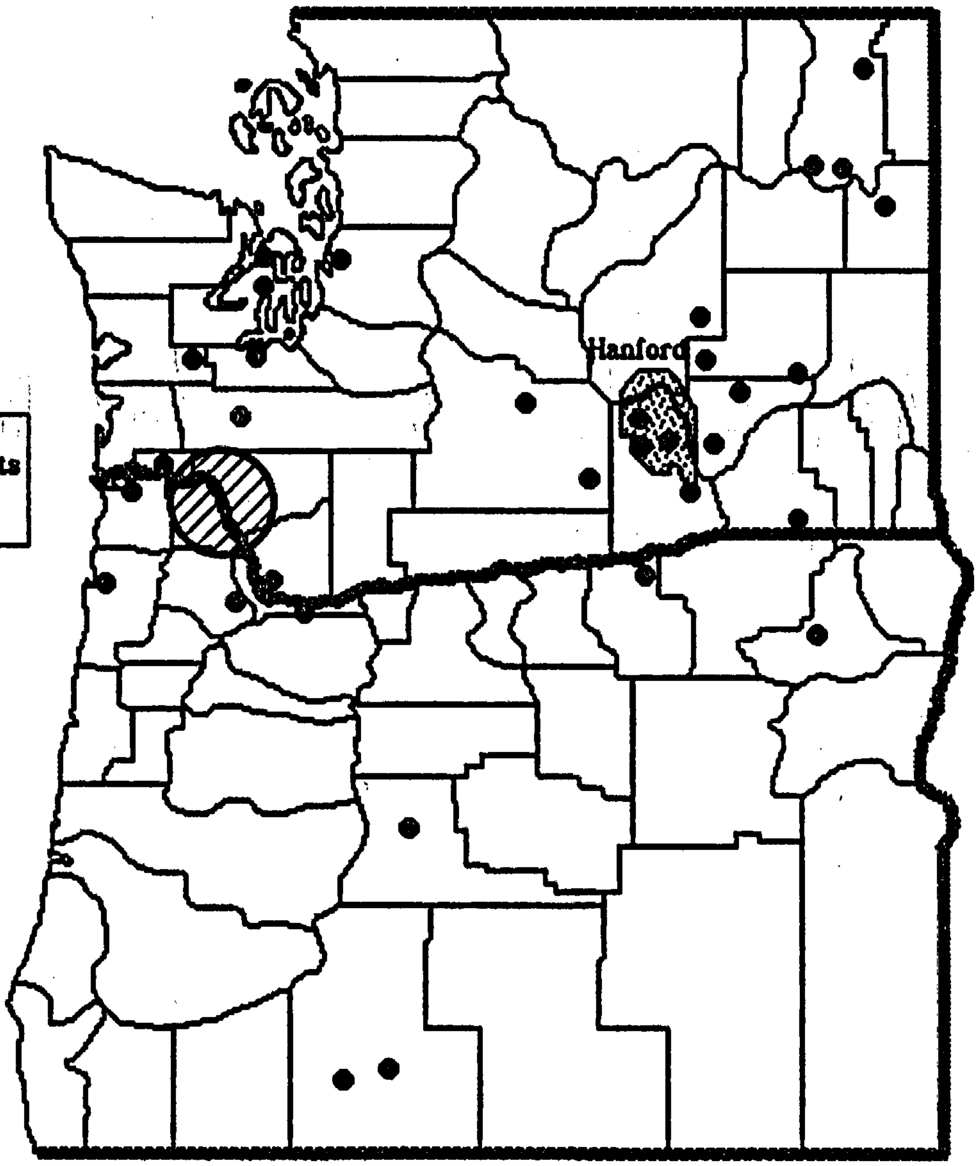
Regional Environmental Radiation Surveillance Network
Thermoluminescent Dosimeter (TLD) Stations



Note:
Circle represents area with many stations in it.

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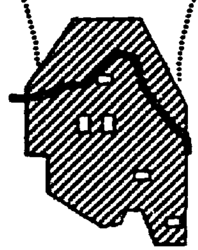
"Environmental Radiation Program"

John Erickson

Hanford Health Effects Panel Meeting

Richland, Washington

September 22, 1986



Program History

- § Established May 1961 by a contract between the U.S. Public Health Service and the Washington State Department of Health.
- § Purpose: To develop a program to collect and analyze samples of water and biological materials in surface waters within the state with major emphasis on the Columbia River.
- § State funds were used to study atmospheric fallout.
- § Initial laboratory capabilities included gross alpha, gross beta, and gamma spectrum analysis.

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Program Expansion During Last 25 Years

§ Increased media sampled to include air particulate, food products, wildlife, milk, soil/vegetation, ambient gamma radiation, and radon.

§ Expanded the quality assurance program to include samples supplied by the EPA Laboratory Intercomparison Program and the DOE Environmental Measurements Laboratory.

- Additional split samples distributed among cooperating federal, state, and private laboratories.
- Continuous checking of internal procedures and techniques.
- Established a regional Quality Assurance Task Force to help verify the adequacy and accuracy of environmental radiation monitoring programs conducted throughout the region.

Program Expansion During Last 25 Years (cont.)

§ Developed additional laboratory capabilities to include:
- Phosphorus-32
- Strontium-90
- Tritium
- Thermoluminescent dosimeters
- Transuranics
- Alpha spectrometry
- Gamma spectroscopy using germanium detectors
- Natural product analyses

§ Analytical methods currently being evaluated include I-129, Tc-99, Kr-85, C-14.

§ Laboratory is located in a new public health facility in north Seattle with approximately $1,000,000 worth of equipment.

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Current Program: Major Objectives

§ To assess potential and actual doses to critical groups and populations from normal operations and from accidents.

§ To verify industry compliance with authorized limits and legal requirements.

§ To audit plant systems and, if necessary, trigger special environmnetal monitoring programs.

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Additional Objectives

§ To maintain a continuing record to evaluate the total environmental and human impact of all sources of radiation.

§ To survey trends in population exposure.

§ To establish and revise standards and regulations.

§ To provide information to the public.

§ To publish periodic reports.

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Facilities Currently Being Monitored

- Hanford (USDOE)
- Low level waste site (U.S. Ecology)
- WNP-2 (Supply System)
- Trojan (PGE)
- Statewide monitoring (fallout, naturally occurring radioactive material)
- Uranium mills (3)
- Major licensees (12)
- Nuclear ships and bases (US Navy)
- Indoor radon

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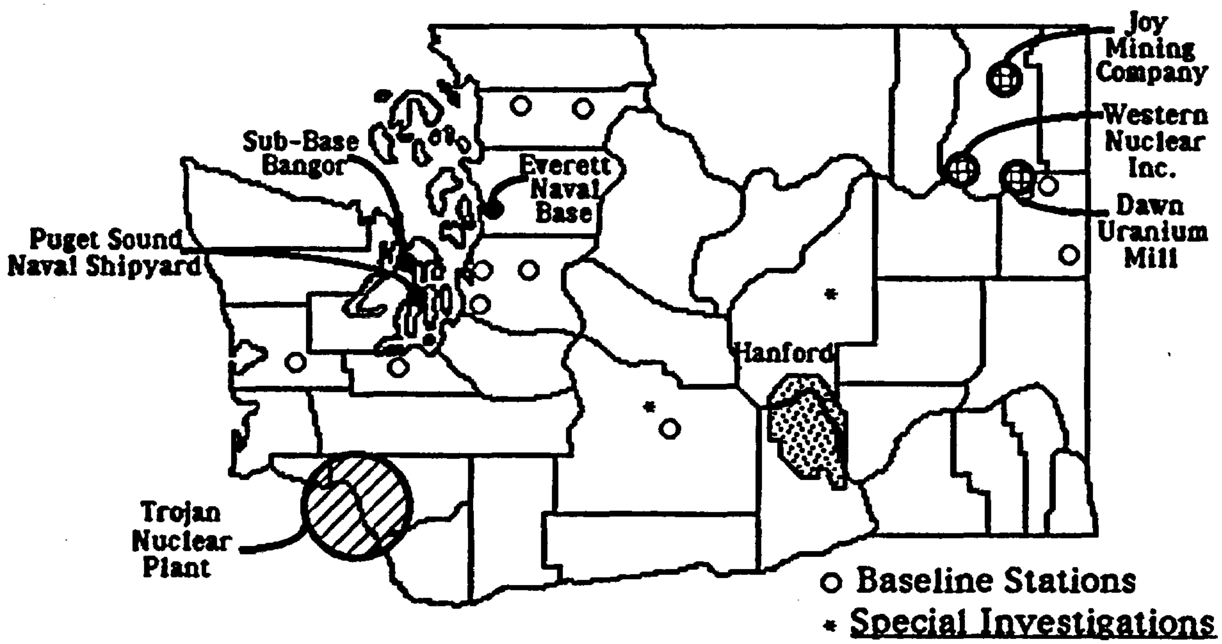
Environmental Radiation Monitoring Stations



1985 Totals		
	Stations	165
	Samples	1050
	Analyses	4800

2. METHOD

As a preliminary test of this hypothesis we have examined the following records of 28 682 Hanford workers: death certificates for the period 1944–77; annual doses of radiation as measured on film badges, urine tests and whole-body counts; the occupations of each worker in each year of the follow-up period; and the census code numbers for each occupation or job title.

Through the census code it was possible to recognize three socio-economic levels of work: professional (001–295), clerical (300–395) and manual (400–946). Therefore, although there were over 8000 job titles and many changes of occupation it was possible for each year's work to be classified, first, according to four danger levels (Table I) and, second, according to three socio-economic levels (Table II). In this way ten occupational groups were formed whose man-years of exposure to each danger level could be ascertained. Finally, for each danger level and occupational group, measures of differential doses and differential mortality were calculated from film badge readings and death certificates.

3. RESULTS

The more obvious findings are as follows:

(1) Only 30% of the follow-up period was devoted to work at Hanford.
(2) The ratio of professional to manual workers was roughly the same for each danger level and approximately 40% of the work at all danger levels required professional or technical qualifications.
(3) There was close correspondence between levels of radiation monitoring (i.e. danger levels) and mean doses of external or penetrating radiations.
(4) The highest socio-economic level was associated with much lower rates of mortality than the two lower levels, but the clerical level compared unfavourably with the manual level.
(5) In safe occupations the risk of dying during the follow-up period was much higher for manual than professional workers but in the most dangerous jobs the risk was marginally higher for professional than manual workers.

The findings, as a whole, are suggestive of selective recruitment of the highest level of manual workers (i.e. skilled craftsmen) into the jobs most directly concerned with the manufacture of plutonium. They also show that the proportion of really dangerous work at Hanford performed by workers with professional or technical qualifications was exceptionally high, and that this unusual feature of the work is the reason it is possible for an important occupational hazard to coexist with exceptionally favourable rates of cancer and non-cancer mortality [2].

TABLE I. CRITERIA OF DANGER LEVELS FOR ANNUAL OCCUPATIONS

Man-years		Job-years		
Type of monitoring	Annual score	Danger score[a]	Danger level	External radiation mean dose in mrem[b]
Film badge only	1.0	1.0–2.4	1	57
Film badge with occasional urine test	2.0	2.5–2.8	2	140
Film badge with regular urine tests	3.0	2.9–3.0	3	215
Film badge with whole-body counts	4.0	3.1–4.0	4	752

[a] Average score for all workers in a given job in a given year.
[b] Mean dose for the whole follow-up period.

Reprint from

"BIOLOGICAL EFFECTS OF LOW-LEVEL RADIATION"

INTERNATIONAL ATOMIC ENERGY AGENCY
VIENNA, 1983

JOB-RELATED MORTALITY RISKS OF HANFORD WORKERS AND THEIR RELATION TO CANCER EFFECTS OF MEASURED DOSES OF EXTERNAL RADIATION

G.W. KNEALE, T.F. MANCUSO, A.M. STEWART
Cancer Epidemiology Research Unit,
Department of Social Medicine,
University of Birmingham,
Edgbaston, Birmingham,
United Kingdom

Abstract

JOB-RELATED MORTALITY RISKS OF HANFORD WORKERS AND THEIR RELATION TO CANCER EFFECTS OF MEASURED DOSES OF EXTERNAL RADIATION.

If we exclude all persons who were classified as clerical workers we find that over 40% of the Hanford workers had either professional or technical qualifications (professional workers). The ratio of professional to manual workers was equally high for safe and dangerous occupations but during the period 1944–77 professional workers who were doing the most dangerous work had too many deaths by comparison with other persons with similar qualifications, and manual workers doing equally dangerous work had too few deaths by comparison with other manual workers. In practice, this means that in any analysis of dose-related cancer risks of Hanford workers it is essential to control for job-related mortality risks as well as all the usual factors such as sex, dates of birth and hire and duration of employment. The results of including all these factors in a cohort analysis of Hanford data by the method of regression models in life tables are described and also the reasons why it was concluded that the risk per unit dose is increased at low dose levels (i.e. the dose-response curve is curvilinear downwards).

1. INTRODUCTION

According to a recent life table analysis of Hanford data the dose-response curve for cancer effects of ionizing radiations is more likely to be curvilinear downwards than linear or quadratic, thus implying a greater risk per unit dose (for mutational effects of radiation) at low than high dose levels [1]. This conclusion is difficult to reconcile with the fact that Hanford workers have relatively low rates of cancer and non-cancer mortality [2] unless employment procedures in the nuclear industry are such that it is possible for favourable mortality experiences to coexist with an important occupational hazard.

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Current Projects (Hanford Reservation)

§ Public hearing, September 24, 1986, on the monitoring and enforcement of air quality and emission standards for radionuclides. (Washington state standards established May 1, 1986)

§ Expanded air and ground water monitoring on and around the Hanford Reservation.

§ Continued review of the DOE environmental programs for the existing Defense Waste and Basalt Waste Isolation Projects.

EFFLUENT MONITORING AND CONTROL AT HANFORD

Presented by

S. A. Wiegman

September 22, 1986

EFFLUENT MONITORING AND CONTROL AT HANFORD

Discharges

Control Practices

Discharge Monitoring

Recent Improvements

Further Improvements

DISCHARGES TO THE ENVIRONMENT

DISCHARGES

133 Stack Discharge Points

34 Liquid Discharge Points (8 NPDES Permit)

3 Active Solid Waste Disposal Areas

CONTROL PRACTICES FOR DISCHARGES AND DISPOSALS

CONTROL PRACTICES
Stack Discharges

Filtration

Chemical Treatment

Process Controls

CONTROL PRACTICES
Liquid Discharges

Chemical Treatment

- **Ion exchange**
- **Neutralization**

Filtration

Closed - Loop Cooling

Evaporation

Retention / Diversion

- **Recycle for treatment or reuse**
- **Hold for solidification**

CONTROL PRACTICES
Solid Waste Disposals

Volume Reduction

- **Decontamination**
- **Lifetime extension**

Waste Segregation

- **Radiological / Nonradiological refuse**
- **Identification of incompatible waste**

DISCHARGE MONITORING

DISCHARGE MONITORING
Stacks

Real - Time Monitoring

- Particulate radionuclides
- Radioactive noble gases
- NOx
- Flow rates

Sampling

- Particulate radionuclides
- Radioiodines
- Other volatile radionuclides
- Radioactive noble gases

Opacity Evaluation

DISCHARGE MONITORING
Liquid

Real - Time Monitoring

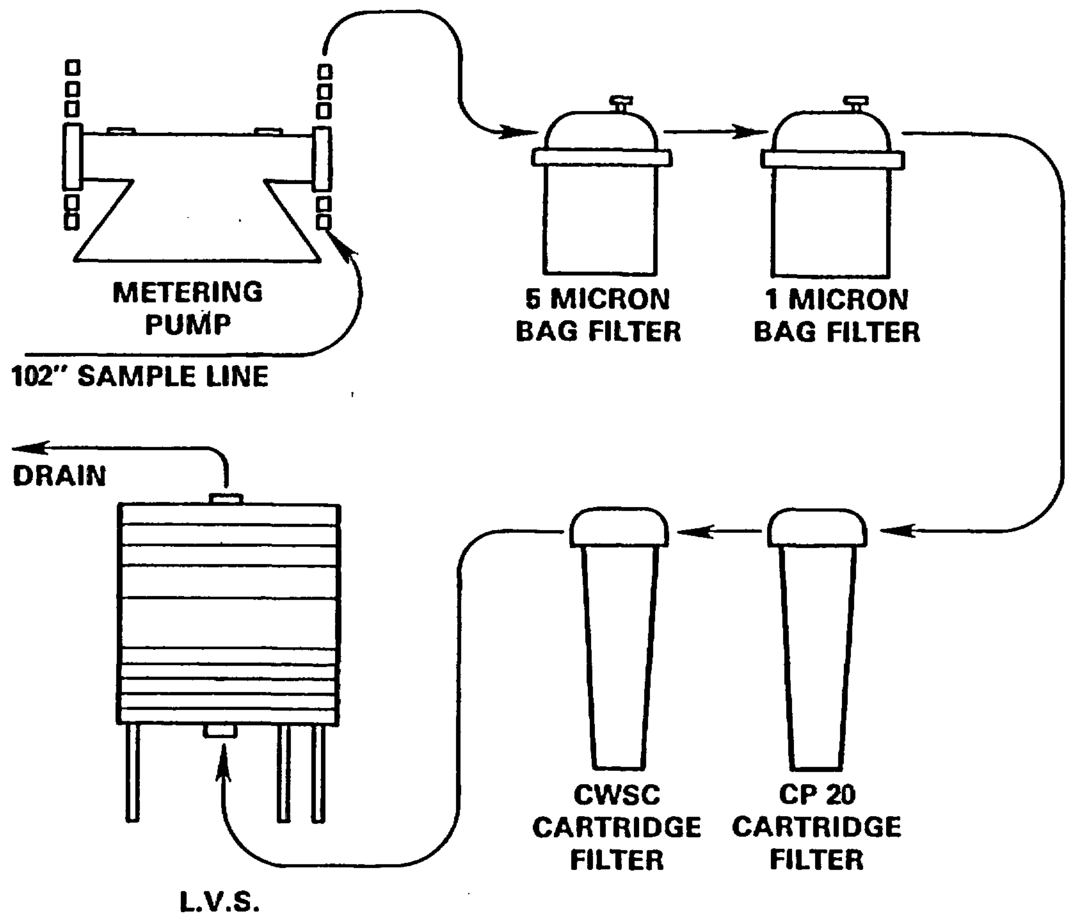
- Radioactivity
- pH
- Temperature
- Flow rates

Sampling

- Radionuclides
- Hazardous chemicals - ongoing characterization and development

Groundwater and Vadose Zone Surveillance

102" OUTFALL LVS



UNC 8404-094.17

DISCHARGE MONITORING
Solid Waste Disposals

Waste Characterization

Waste Package Monitoring (NDA)

Inventory Records

RECENT IMPROVEMENTS IN MONITORING AND CONTROL

Sampler / Monitor Upgrade Program

PUREX Fourth Filter on Line

Reduced Effluent to Columbia River

- Reduced N - Spring discharge
- 107 - N Basin recirculation program

Liquid Release Prevention in 300 Area

- Double enclosure lines
- Spill prevention / recovery system in tanker loading area
- Sealed nonradioactive floor drains in radiation areas
- Monitoring / diversion for potentially contaminated streams

Nonradioactive Administrative Controls

PROJECTS AND PROGRAMS TO FURTHER IMPROVE MONITORING AND CONTROL

Continued Sampler / Monitor Upgrade Program

Particulate, Iodine, Noble Gas Monitor for 100 - N and PUREX

D and D of Ponds

Radioactive Waste Compactor

Nonradioactive Hazardous Waste Management Facility (616 bldg.)

Long Term Plan to Eliminate Liquid Discharges

? I dont know who presented this. I believe it was a HEHC (Hanf Env Health Clinic) representative

Hanford Worker Mortality Study

Topics to be covered

1. Description of the Hanford worker data set
2. Approach to analyses assessing the effects of occupational exposure
3. Future directions and other studies
4. Thyroid cancer, and potential for assessing effects of nonoccupational exposure

Occupational Histories

- 44,000 workers initially hired 1944-1978
- Demographic data
  Hire and termination dates
  Sequence of job titles and codes

Occupational External Radiation Exposure Data

- Measured using dosimeters worn by the workers
- 278,000 yearly exposure records for 36,200 workers
- Analyses have been based on estimated whole body penetrating dose

Occupational Internal Radiation Exposure Data

- All workers with potential for internal exposure are monitored through urinanalysis and in vivo counting

- 457 confirmed plutonium deposition cases 1944-1978
  142 exceeding 5% of the maximum permissible body burden (MPBB)

Number of Workers by Sex and Initial Year of Employment

	Males	Females
Terminated before 1945	775	206
Working in 1945	6,708	1,582
Initially Employed 1946-51	8,152	3,706
Initially Employed 1952-78	16,278	7,095
	31,913	12,589

Distribution of Cumulative Doses Through 1978

	Males	Females	Total
0-1 rem	17,795	7,604	25,399 (70%)
1-2 rem	3,497	546	4,043 (11%)
2-5 rem	3,127	191	3,318 (9.2%)
5-15 rem	1,978	102	2,080 (5.7%)
15-25 rem	603	29	632 (1.7%)
25-50 rem	650	3	653 (1.8%)
50+ rem	110	0	110 (0.3%)
Total	27,760	8,475	36,235
Total person-rem	~73,300	~4,000	~77,300

Mortality Data

- Sources:
  - Social Security Administration
  - National Death Index (1979-)
  - Washington State Occupational Mortality Surveillance System (1968-)
  - California Automated Mortality Linkage System (1960-)

- The underlying cause of death is coded using the computerized system at the National Center for Health Statistics

Mortality Ascertainment by Cumulative Radiation Exposure Category for Monitored Workers Dying 1968-1981

	Number of Deaths	% Occurring in Washington	% of Washington Deaths Ascertained by SSA
0-1.99 rem	2856	46	96.9
2-4.99 rem	363	80	98.3
5-14.99 rem	224	81	97.8
15+ rem	174	87	98.0
Total	3617	54	97.3

Approaches Used in Analyzing Hanford Mortality Data

1. Examine the association of radiation exposure and death from several causes. Internal comparisons that do not require the use of an external control

2. Compare Hanford death rates with those of the overall U.S. population by calculating Standardized Mortality Ratios (SMRs)

Internal Comparisons

1. Trend test for the association of radiation exposure and several diseases. (Derived from Cox proportional hazards model with cumulative radiation exposure treated as time dependent variable)

2. Comparison of observed and expected deaths for several exposure categories (Mantel-Haenszel)

3. Estimates and confidence limits for risks (allows comparison with estimates from other sources as well as an assessment of uncertainty)

Treatment of Potentially Confounding Variables

- All analyses include control for
  - Age (serves as the time variable in the Cox model)
  - Calendar year
  - Sex
- Other variables considered
  - Length of employment
  - Job category
  - Initial year of employment
  - Follow-up time

Treatment of Potentially Confounding Variables

Approach includes:

- Examination of the association of cumulative radiation exposure and such variables
- Examination of the association of such variables with mortality from several causes (using same methods used to assess exposure). See "Some Confounding Factors in the Study of Mortality and Occupational Exposures", Am. J. Epid., 1982
- Conducting analyses controlled through stratification for variables that, based on the above, seem likely to be important confounders. Analyses based on several choices are conducted

Results of Analyses of External Occupational Exposure. Exposures Lagged for 10 Years. 1955-1981

Cause of Death	Trend Test p-Value (One-Tailed)	Exposure Category		
		0-5 rem Obs./Exp.	5-15 rem Obs./Exp.	15+ rem Obs./Exp.
All Causes	0.60	4553/4561.3	195/182.7	98/102.0
All Cancers	0.58	1009/1013.1	48/43.4	24/24.5
Leukemia*	0.69	27/26.7	1/1.4	1/0.9
All Digestive Cancers	0.58	280/279.0	10/10.8	6/6.2
Lung Cancer	0.36	304/309.5	20/15.4	10/9.1
All Lymphatic and Haematopoietic Cancers	0.15	89/92.2	5/3.8	4/2.0

* Excluding chronic lymphatic leukemia

Summary of Results of Analyses of Occupational Exposure

- No evidence of either a positive or negative correlation with radiation exposure for ALL CAUSES of death, ALL CANCERS, LEUKEMIA

- Results are consistent with effects expected based on data from population exposed at high levels

- MULTIPLE MYELOMA exhibits a significant correlation with radiation exposure based on 3 deaths with relatively high cumulative exposures

Future Directions: Analyses

1. More emphasis on comparing risk estimates and confidence limits with estimates based on populations exposed at high levels

2. Additional attention to internal exposure

3. Additional attention to subgroups of the population

4. Preliminary assessment of most recent deaths occurring in Washington and California (available 2 or 3 years prior to time that mortality can be considered complete)

5. Analyses to address possible impact of dose measurement errors

Future Directions: Special Studies

1. Lung cancer case-cohort study using smoking data obtained from medical records

2. Study to evaluate dose measurement errors

3. Multiple myeloma study

Other Epidemiological Studies

1. Construction workers

2. Congenital malformation studies

3. Health Surveillance System

Congenital Malformation Studies

- **Case-Control Study:**

  Examine the association of congenital malformation rates with employment and occupational radiation exposure of the parents (1957-1980)

- **Prevalence Study:**

  Compare congenital malformation rates for the Tri-Cities area with appropriate comparison populations (1968-1980)

Thyroid Cancer

- 2 deaths in Hanford worker cohort, both in workers who were employed in 1945
- Number of deaths expected based on U.S. rates applied to entire cohort is 3.62
- Number of deaths expected based on U.S. rates applied to workers employed in 1945 (when largest releases took place) is 1.64

Estimate and Confidence Interval for Thyroid Cancer Relative Risk, for Workers Employed at Hanford in 1945

- Estimate: 1.22 (2 deaths observed/1.64 deaths expected)
- 90% confidence limits: (0.22, 3.8)
- Limits would be higher if "healthy worker effect" allowed for
- Conclusion: The Hanford mortality study tells us very little about thyroid cancer risks

Possible Ways of Using Hanford Mortality Data to Assess Health Effects of ^{131}I Releases

1. Compare death rates for workers employed at Hanford in 1940's and early 1950's with those of the U.S.

2. Conduct internal comparisons with estimates of ^{131}I releases