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Research and Development

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Offsite Environmental Monitoring Report:

Radiation Monitoring Around United States Nuclear Test Areas, Calendar Year 1991

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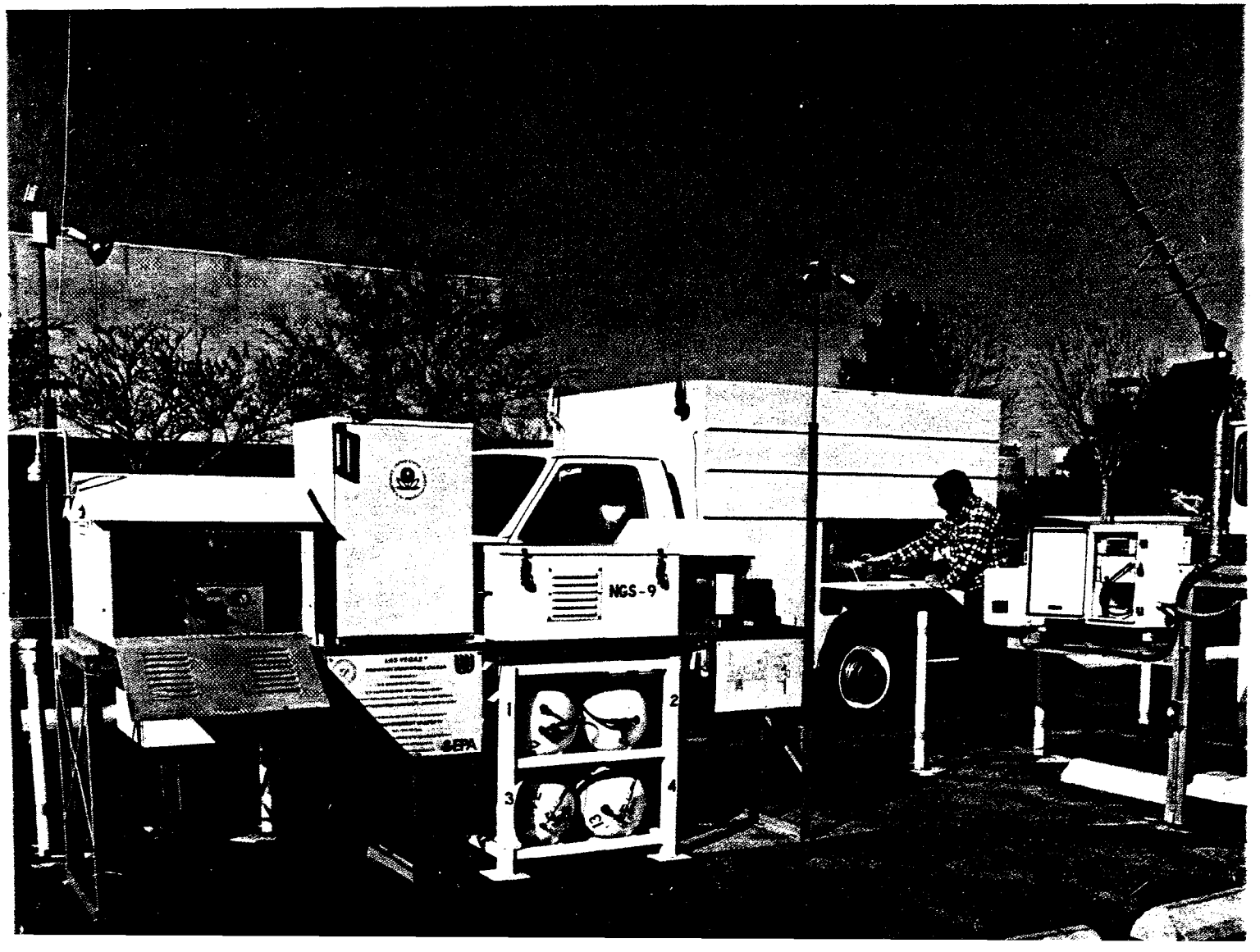

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OCT 26 1993

Dear Reader:

Since 1954, the U.S. Environmental Protection Agency (EPA) and its predecessor the U.S. Public Health Service (PHS) has conducted radiological monitoring in the offsite areas around United States nuclear test areas. The primary objective of this monitoring has been, and continues to be, protection of the health and safety of residents in the unlikely event of release of radioactive material into public areas. Further, the Offsite Environmental Surveillance Program documents and provides independent verification of the safety of the U.S. Nuclear Weapons Testing Program.

The enclosed report documents EPA's monitoring activities for calendar year 1991. Monitoring data are included so that you may personally evaluate the contribution, if any, of nuclear testing to man's radiation exposure. The total radiation exposure man receives includes external exposure from naturally occurring and manmade materials in our environment and internal exposure from natural and manmade radioactive materials in the air we breathe, the water we drink, and the food we eat. In 1991, there was no radioactivity detected offsite by the various EPA monitoring networks and no exposure above natural background to the population living in the vicinity of the Nevada Test Site (NTS) that could be attributed to current NTS activities.

If you have any questions regarding EPA's monitoring of radiation in areas around U.S. nuclear test areas, please feel free to contact me at the above address.

Sincerely yours,

Paul J. Weeden
Director
Nuclear Radiation Assessment Division

Enclosure

Offsite Environmental Monitoring Report:

Radiation Monitoring Around United States
Nuclear Test Areas, Calendar Year 1991

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Notice

This report has been reviewed in accordance with the U.S. Environmental Protection Agency's peer and administrative review policies and approved for publication. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

Abstract

This report describes the Offsite Radiation Safety Program conducted during 1991 by the Environmental Protection Agency's (EPA's) Environmental Monitoring Systems Laboratory-Las Vegas. This laboratory operates an environmental radiation monitoring program in the region surrounding the Nevada Test Site (NTS) and at former test sites in Alaska, Colorado, Mississippi, Nevada, and New Mexico. The surveillance program is designed to measure levels and trends of radioactivity, if present, in the environment surrounding testing areas to ascertain whether current radiation levels and associated doses to the general public are in compliance with existing radiation protection standards. The surveillance program additionally has the responsibility to take action to protect the health and well being of the public in the event of any accidental release of radioactive contaminants. Offsite levels of radiation and radioactivity are assessed by sampling milk, water, and air; by deploying thermoluminescent dosimeters (TLDs) and using pressurized ion chambers (PICs); and by biological monitoring of animals, food crops, and humans. Personnel with mobile monitoring equipment are placed in areas downwind from the test site prior to each nuclear weapons test to implement protective actions, provide immediate radiation monitoring, and obtain environmental samples rapidly after any occurrence of radioactivity release.

Comparison of the measurements and sample analysis results with background levels and with appropriate standards and regulations indicated that there was no radioactivity detected offsite by the various EPA monitoring networks and no exposure above natural background to the population living in the vicinity of the NTS that could be attributed to current NTS activities. Annual and long-term (10 year) trends were evaluated in the Noble Gas, Tritium, Milk Surveillance, Biomonitoring, TLD, PIC networks, and the Long-Term Hydrological Monitoring Program. All evaluated data were consistent with previous data history. No radiation directly attributable to current NTS activities was detected in any samples. Monitoring network data indicate the greatest population exposure came from naturally occurring background radiation, which yielded an average exposure of 123 mrem/yr. Worldwide fallout accounted for about 0.05 mrem/yr. Calculation of potential dose to offsite residents based on onsite source emission measurements provided by the Department of Energy (DOE) resulted in a maximum calculated dose of 0.009 mrem/yr. These were insignificant contributors to total exposure as compared to natural background.

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Abbreviations, Acronyms, Units of Measure, and Conversions

ABBREVIATIONS and ACRONYMS

ALARA -- As Low as Reasonably Achievable
ALI -- Annual Limit on Intake
ASN -- Air Surveillance Network
ANSI -- American National Standards Institute
BLM -- Bureau of Land Management
BOMAB -- Bottle Mannequin Absorber
CEDE -- Committed Effective Dose Equivalent
CFR -- Code of Federal Regulations
CG -- Concentration Guide
CMS -- Community Monitoring Station
CP-1 -- Control Point One
DAC -- Derived Air Concentration
DOE -- U.S. Department of Energy
DOELAP -- Department of Energy, Laboratory Accreditation Program
DQO -- data quality objective
DRI -- Desert Research Institute
EML -- Environmental Monitoring Laboratory
EMSL-LV -- Environmental Monitoring Systems Laboratory, Las Vegas
EPA -- U.S. Environmental Protection Agency
FDA -- Food and Drug Administration
Ge(Li) -- lithium-drifted germanium detector
GOES -- Geostationary Operational Environmental Satellite
HTO -- tritiated water
ICRP -- International Commission on Radiological Protection
IG -- intrinsic germanium
I -- liter
LCL -- lower control limit
LTHMP -- Long-Term Hydrological Monitoring Program
LWL -- lower working limit
MCD -- minimum detectable concentration
MSL -- mean sea level
MSN -- Milk Surveillance Network
NCRP -- National Council of Radiation Protection and Measurement
NIST -- National Institute of Standards and Technology
NGTSN -- Noble Gas and Tritium Surveillance Network
NPDWR -- National Primary Drinking -- Water Regulation
NTS -- Nevada Test Site
NRD -- Nuclear Radiation Assessment Division
ORSP -- Offsite Radiological Safety Program
PIC -- pressurized ion chamber
QA -- quality assurance
QAMS -- Quality Assurance Management Staff
QC -- quality control
RAWS -- Remote Automatic Weather Station
RCF -- reference correction factor
SAIC -- Science Applications International Corporation
S.D. -- standard deviation
SMSN -- Standby Milk Surveillance Network
SOP -- standard operating procedure
STDMS -- sample tracking data management system
TLD -- thermoluminescent dosimeter
UCL -- upper control limit
USGS -- U.S. Geological Survey
UWL -- upper working limit

Abbreviations, Acronyms, Units of Measure, and Conversions (continued)

UNITS OF MEASURE

Bq	--	Becquerel, one disintegration per second
C	--	coulomb
•C	--	degrees centigrade
Ci	--	curie
cm	--	centimeter, 1/100 meter
eV	--	electron volt
•F	--	degrees Fahrenheit
g	--	gram
hr	--	hour
keV	--	one thousand electron volts
kg	--	kilogram, 1000 grams
km	--	kilometer, 1000 meters
L	--	liter
lb	--	pound
m	--	meter
meV	--	one million electron volts
mg	--	milligram, 10^{-3} gram
min	--	minute
mL	--	milliliter, 10^{-3} liter
mo	--	month
mR	--	milliroentgen, 10^{-3} roentgen
mrem	--	millirem 10^{-3} rem
mSv	--	millisievert 10^{-3} sievert
pCi	--	picocurie, 10^{-12} curie
qtr	--	quarter
R	--	roentgen
rad	--	unit of absorbed dose, 100 ergs/g
rem	--	dose equivalent, the rad adjusted for biological effect
Sv	--	sievert, equivalent to 100 rem
wk	--	week
yr	--	year
µ	--	microcurie, 10^{-6} curie
µR	--	microroentgen, 10^{-6} roentgen
%	--	percent
±	--	plus or minus
<	--	less than
=	--	equals
≅	--	approximately equals

PREFIXES

a	atto	=	10^{-18}
f	femto	=	10^{-15}
p	pico	=	10^{-12}
n	nano	=	10^{-9}
µ	micro	=	10^{-6}
m	milli	=	10^{-3}
k	kilo	=	10^{3}

CONVERSIONS

Multiply	by	To Obtain
Concentrations		
µCi/mL	10^{9}	pCi/L
µCi/mL	10^{12}	pCi/m^3
SI Units		
rad	10^{-2}	Gray (Gy=1 Joule/kg)
rem	10^{-2}	Sievert (Sv)
pCi	3.7×10^{-2}	Becquerel (Bq)
mR/yr	2.6×10^{-7}	Coulomb (C)/kg-yr

List of Elements

ATOMIC NUMBER	SYMBOL	NAME	ATOMIC NUMBER	SYMBOL	NAME
1	H	hydrogen	47	Ag	silver
2	He	helium	48	Cd	cadmium
3	Li	lithium	49	In	indium
4	Be	beryllium	50	Sn	tin
5	B	boron	51	Sb	antimony
6	C	carbon	52	Te	tellurium
7	N	nitrogen	53	I	iodine
8	O	oxygen	54	Xe	xenon
9	F	fluorine	55	Cs	cesium
10	Ne	neon	56	Ba	barium
11	Na	sodium	57	La	lanthanum
12	Mg	magnesium	58	Ce	cerium
13	Al	aluminum	59	Pr	praseodymium
14	Si	silicon	60	Nd	neodymium
15	P	phosphorus	41	Pm	promethium
16	S	sulfur	62	Sm	samarium
17	Cl	chlorine	63	Eu	europium
18	Ar	argon	64	Gd	gadolinium
19	K	potassium	65	Tb	terbium
20	Ca	calcium	66	Dy	dysprosium
21	Sc	scandium	67	Ho	holmium
22	Ti	titanium	68	Er	erbium
23	V	vanadium	69	Tm	thulium
24	Cr	chromium	70	Yb	ytterbium
25	Mn	manganese	71	Lu	lutetium
26	Fe	iron	72	Hf	hafnium
27	Co	cobalt	73	Ta	tantalum
28	Ni	nickel	74	W	tungsten
29	Cu	copper	75	Re	rhenium
30	Zn	zinc	76	Os	osmium
31	Ga	gallium	77	Ir	iridium
32	Ge	germanium	78	Pt	platinum
33	As	arsenic	79	Au	gold
34	Se	selenium	80	Hg	mercury
35	Br	bromine	81	Tl	thallium
36	Kr	krypton	82	Pb	lead
37	Rb	rubidium	83	Bi	bismuth
38	Sr	strontium	84	Po	polonium
39	Y	yttrium	85	At	astatine
40	Zr	zirconium	86	Rn	radon
41	Nb	niobium	87	Fr	francium
42	Mo	molybdenum	88	Ra	radium
43	Tc	technetium	89	Ac	actinium
44	Ru	ruthenium	90	Th	thorium
45	Rh	rhodium	91	Pa	protactinium
46	Pd	palladium	92	U	uranium

List of Elements (continued)

ATOMIC NUMBER	SYMBOL	NAME
93	Np	neptunium
94	Pu	plutonium
95	Am	americium
96	Cm	curium
97	Bk	berkelium
98	Cf	californium
99	ES	einsteinium
100	Fm	fermium
101	Md	mendelevium
102	No	nobelium
103	Lr	lawrencium

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The authors would like to thank Paul J. Weeden for his advice and assistance in the coordination and preparation of this report. We also want to thank the Field Monitoring Branch for collecting samples, maintaining the equipment, and interfacing with offsite residents; and the Radioanalysis Branch for analyzing the samples. Appreciation is also extended to P.O. Cobb, U.S. Environmental Protection Agency (Las Vegas, Nevada), for his preparation of graphs, and to T.L. Mouck, U.S. Environmental Protection Agency (Las Vegas, Nevada), for desktop publishing support.

1 Introduction

The U.S. Atomic Energy Commission used the Nevada Test Site (NTS), between January 1951 and January 1975, for conducting nuclear weapons tests, nuclear rocket engine development, nuclear medicine studies, and for other nuclear and non-nuclear experiments. Beginning in mid-January 1975, these activities became the responsibility of the U.S. Energy Research and Development Administration. Two years later this organization was merged with other energy-related agencies to form the U.S. Department of Energy (DOE).

Atmospheric weapons tests were conducted periodically at the NTS from January 1951 through October 1958, followed by a test moratorium which was in effect until September 1961. Since then all nuclear detonations at the NTS have been conducted underground, with the expectation of containment, except the above-ground and shallow underground tests of Operation Sunbeam and in cratering experiments conducted under the Plowshare program between 1962 and 1968.

Prior to 1954, an offsite radiation surveillance program was performed by personnel from the Los Alamos Scientific Laboratory and the U.S. Army. Beginning in 1954, and continuing through 1970, this program was conducted by the U.S. Public Health Service (PHS). When the U.S. Environmental Protection Agency (EPA) was formed in December 1970, certain radiation responsibilities from several federal agencies were transferred to it, including the Offsite Radiological Safety Program (ORSP) of the PHS. Since 1970, the EPA, Environmental Monitoring Systems Laboratory-Las Vegas (EMSL-LV) has conducted the ORSP, both in Nevada and at other U.S. nuclear test sites, under interagency agreements (IAGs) with the DOE or its predecessor agencies.

Since 1954, the three major objectives of the ORSP have been:

- Measuring and documenting levels and trends of environmental radiation or radioactive contaminants in the vicinity of atomic testing areas.
- Verifying compliance with applicable radiation protection standards, guidelines, and regulations.
- Assuring the health and safety of the people living near the NTS.

Offsite levels of radiation and radioactivity are assessed by gamma-ray measurements using pressurized ion chambers (PICs) and thermoluminescent dosimeters (TLDs); by sampling air, water, milk, food crops, other vegetation, soil, animals; and by human exposure and biological assay procedures.

Before each nuclear test at the NTS, EPA radiation monitoring technicians are stationed in offsite areas most likely to be affected by an airborne release of radioactive material. These technicians use trucks equipped with radiation detectors, samplers, and supplies and are directed by two-way radio from the control center at the NTS.

1.1 Program Description

The EPA, EMSL-LV, Nuclear Radiation Assessment Division (NRD) provides scientific and technical support to the DOE's nuclear weapons testing program at the NTS and other nuclear testing sites through an IAG. The primary objective of EPA's activities is protection of the health and safety of the offsite resident population. This objective is accomplished through monitoring and documentation environmental levels of radiation in the areas around the NTS, monitoring of people in the offsite area, calculating committed effective radiation dose to the most potentially exposed of the offsite population, maintaining emergency response capabilities, and fostering community involvement and education in radiation-related issues.

Emergency response capabilities are maintained in readiness for each nuclear weapons test conducted at the NTS. Monitoring technicians are deployed for each test and senior EPA personnel serve on the Test Controller's Scientific Advisory Panel. Tests are only conducted when meteorological conditions are such that any release would be carried towards sparsely populated, controllable

areas. Should a release occur, EPA monitoring technicians would deploy mobile monitoring instruments, assist state and local officials in implementing protective actions, and collect samples for prompt analysis. Hours before each test, Weather Service Nuclear Support Office personnel and, if requested, an instrumented aircraft gather meteorological data for use by the Test Controller's Advisory Panel in judging the safety of executing the test. A second aircraft carries radiation detectors. In the unlikely event of a significant release of radioactivity following a nuclear weapons test, the equipment on the aircraft would enable rapid sampling and analysis of a radioactive cloud. Data gathered by the aircraft are used to assist in deploying field monitoring technicians to downwind areas, to help determine appropriate protective actions, and to perform radiation monitoring and environmental sampling (EPA, 1988a).

The IAG also requires EPA monitoring technicians to conduct monitoring during tests conducted at the Liquefied Gaseous Fuels Spill Test Facility (LGFS-TF) located on the NTS. These spills involve non-radioactive hazardous materials.

Environmental radiation levels are continuously monitored and documented through an extensive environmental surveillance program conducted by EPA in the offsite areas surrounding the NTS. This program is an outgrowth of environmental surveillance activities conducted by the PHS before 1970. The original PHS surveillance program, initiated in 1954, was limited to offsite surveillance during testing activities. Since 1954, the program has grown and evolved to its present configuration. Many historical sampling locations have been retained, resulting in a continuous data record of three decades or longer.

The ORSP consists of several networks to monitor concentrations of radioactive materials (radioisotopes) in air, atmospheric moisture, milk, local foodstuffs and surface and groundwater. Ambient radiation levels are continuously monitored at selected locations using PICs and TLDs. Atmospheric monitoring includes air samplers, noble gas samplers, and atmospheric moisture (tritium-in-air) samplers. Milk, wildlife, domestic animals, and fruits and vegetables are routinely sampled and analyzed. Some residents in the offsite areas participate in TLD and internal dosimetry networks. Groundwater on and in the vicinity of the NTS is monitored in the Long-Term Hydrological Monitoring Program (LTHMP); additional monitoring of surface and groundwater is conducted under the LTHMP at sites of previous nuclear weapons tests in Alaska, Colorado, Nevada, New Mexico, and Mississippi. Results obtained from these networks are used to calculate an annual radiation dose to the offsite residents.

Another function of the ORSP is to conduct dairy animal and human population censuses. This type of information would be necessary in the unlikely event of a release from the NTS. A dairy animal and population census is continuously updated for areas within 240 miles north and east, and 125 miles south and west of the Control Point One (CP-1). The location of CP-1 is shown in Figures 3 and 6, Chapter 2. The remainder of the Nevada counties and the western-most Utah counties are scheduled for dairy animal and population census updates every other year. The next complete census is scheduled for Fall 1992. The locations of processing plants and commercial dairy herds in Idaho and the remainder of Utah are obtained from the milk and food sections of the respective state governments.

Community information programs are an integral component of the EPA activities. Town hall meetings or presentations are held at the request of various civic groups. These meetings and presentations provide a forum for increasing public awareness of NTS activities, disseminating radiation monitoring results, and addressing concerns of residents related to environmental radiation and possible health effects. In addition, tours of the NTS are arranged for interested parties. In nineteen of the communities around the NTS, Community Radiation Monitoring Program (CRMP) stations have been established. The CRMP stations are established in prominent locations in the offsite communities and include samplers for several of the surveillance networks (PIC, TLD, and air samplers; many also include noble gas and tritium-in-air samplers). At each CRMP, a local resident serves as the station manager. The CRMP is a collaborative effort of EPA EMSL-LV, the Desert Research Institute (DRI), the University of Utah, and DOE.

1.2 Report Description

Beginning with operation Upshot-Knothole in 1953, a report summarizing the monitoring data obtained from each test series was published by the U.S. Public Health Service. For the reactor tests in

1959 and the weapons and Plowshare tests in 1962, data were published only for the tests in which detectable amounts of radioactivity were measured in an offsite area. Publication of the summary data for each six-month period was initiated in 1964. In 1971, the Atomic Energy Commission implemented a requirement (AEC71), subsequently incorporated into Department of Energy Order 5484.1(DOE85), that each agency or contractor involved in major nuclear activities provide an annual comprehensive radiological monitoring report. In 1988, DOE Order 5484.1 was superseded by the General Environmental Protection Program Requirements (Order 5400.1) of the DOE (DOE, 1988). Each annual report summarizes the radiation monitoring activities of the EPA in the vicinity of the NTS and at former nuclear testing areas in the United States. This report summarizes those activities for calendar year 1991.

Chapter 2 of this report contains a physical description of the NTS and the surrounding areas. Chapter 3 discusses the external ambient gamma monitoring networks including the TLD Network, the PIC network and a comparison of the two monitoring technologies. Chapter 4 discusses the atmospheric monitoring networks including the Air Surveillance Network, the Tritium in Atmospheric Moisture Network, and the Noble Gas Sampling Network. Chapter 5 addresses foodstuffs that could be consumed by residents living close to the NTS. This includes the Milk Surveillance Network, the Animal Investigation Program, and a discussion of fruits and vegetables. Chapter 6 discusses the Internal Dosimetry Program. The LTHMP is discussed in Chapter 7. Each of the monitoring network sections includes a description of the network design, a discussion of the procedures, a presentation of the results, and a section on quality assurance/quality control methods. Chapter 8 contains a calculation of potential radiation dose to residents living in the off-site area. Chapter 9 contains a discussion of the support the ORSP provides for weapons testing and liquified gaseous fuels spill tests. Chapter 10 describes the CRMP and lists the town hall meetings and NTS tours conducted in 1991. A detailed description of the Quality Assurance (QA) program including a discussion of data quality objectives and of QA data analysis is provided in Chapter 11. Chapter 12 contains a discussion of the sample analysis procedures. Chapter 13 contains radiation protection standards for external and internal exposure. Chapter 14 contains the summary and conclusions.

Although written to meet the terms of the IAG between the EPA and the DOE as well as the requirements of DOE Order 5400.1, this report also should be of interest and use to the citizens of Nevada, Utah, and California. State, federal, and local agencies involved in protecting the environment and the health and well-being of the public, and individuals and organizations concerned with environmental quality and the possible release of radioactive contaminants into the biosphere, also may find the contents of this report of interest.

2 Description of the Nevada Test Site

The principal activity at the NTS is the testing of nuclear devices to aid in the development of nuclear weapons, proof testing of weapons, and weapons safety and effects studies. The major activity of the EPA's ORSP is radiation monitoring around the NTS. This section provides an overview of the climate, geology and hydrology, and land uses in this generally arid and sparsely populated area of the southwestern United States (Figure 1). The information included should provide an understanding of the environment in which nuclear testing and monitoring activities take place, the reasons for the location of instrumentation, the weather extremes to which both people and equipment are subjected, and the distances traveled by field monitoring technicians in collecting samples and maintaining equipment.

2.1 Location

The NTS is located in Nye County, NV, with its southeast corner about 54 miles (90 km) northwest of Las Vegas (Figure 2). It occupies an area of about 1,350 square miles (3,750 square km), varies from 28 to 35 miles (46 to 58 km) in width (east-west) and from 49 to 55 miles (82 to 92 km) in length (north-south). This area consists of large basins or flats about 2,970 to 3,900 feet (900 to 1,200 m) above mean sea level (MSL) surrounded by mountain ranges rising from 5,940 to 7,590 feet (1,800 to 2,300 m) above MSL.

The NTS is surrounded on three sides by exclusion areas, collectively named the Nellis Air Force Base Range Complex, which provides a buffer zone between the test areas and privately owned lands. This buffer zone varies from 14 to 62 miles (24 to 104 km) between the test area and land that is open to the public. In the unlikely event of an atmospheric release of radioactivity (venting), two to more than six hours would elapse, depending on wind speed and direction, before any release of airborne radioactivity would reach private lands.

2.2 Climate

The climate of the NTS and surrounding area is variable, due to its wide range in altitude and its rugged terrain. Most of Nevada has a semi-arid climate characterized as mid-latitude steppe. Throughout the year, there is insufficient water to support the growth of common food crops without irrigation.

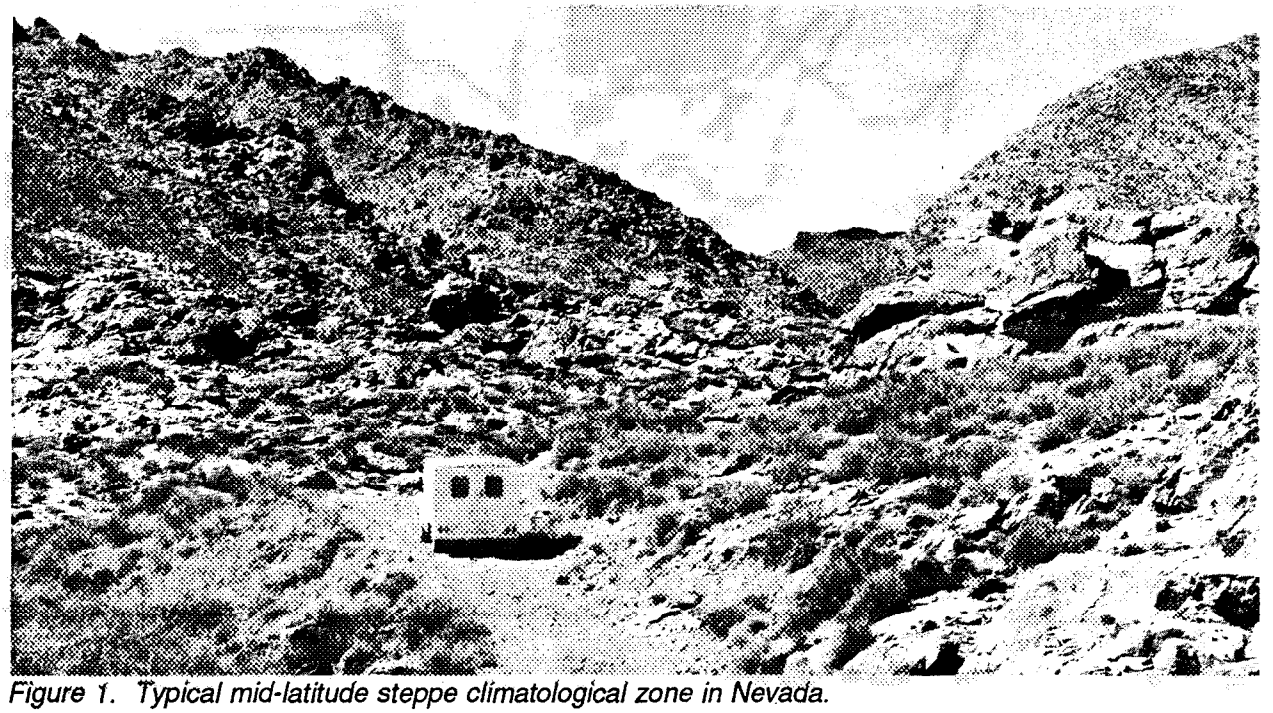

Figure 1. Typical mid-latitude steppe climatological zone in Nevada.

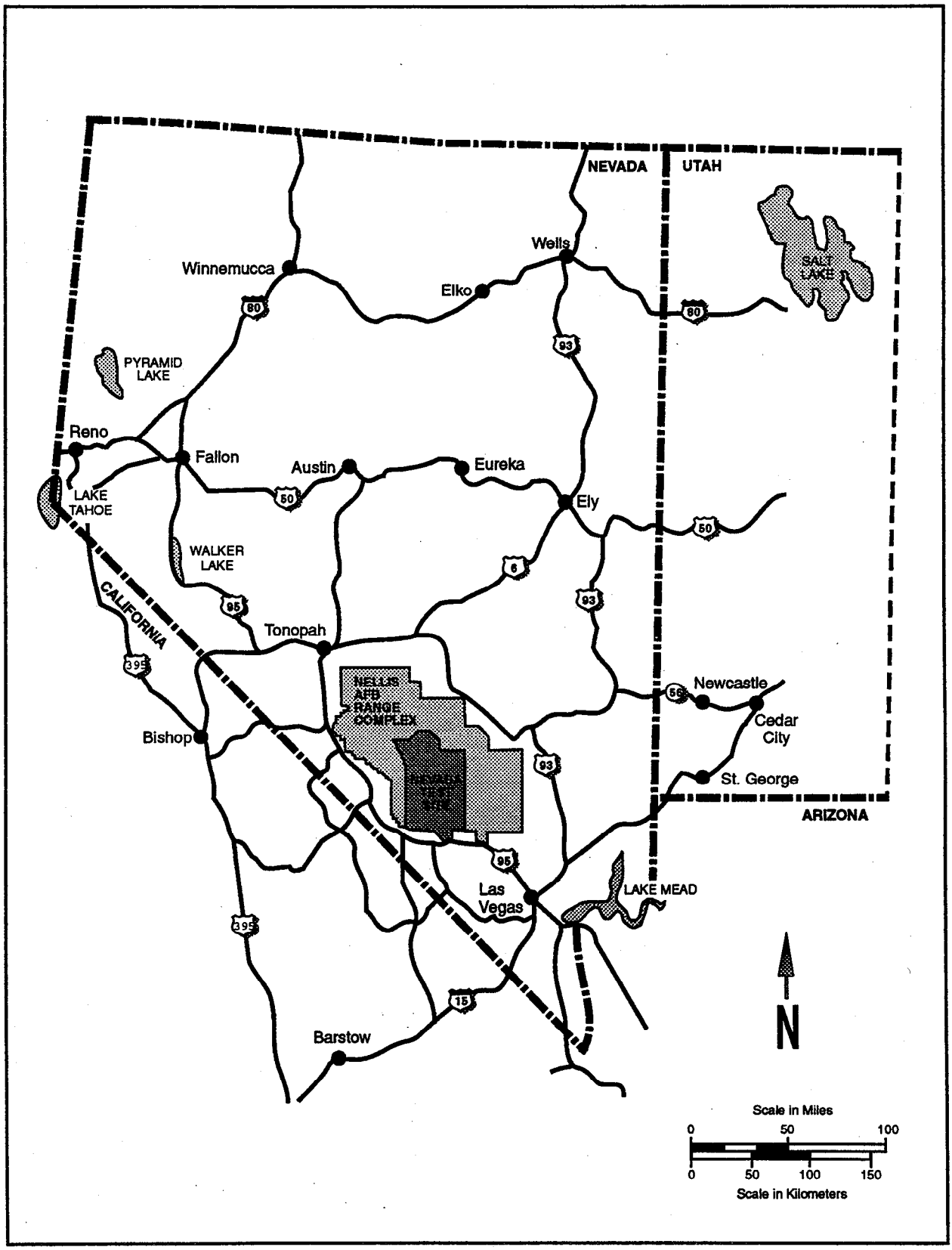

Figure 2. Location of the Nevada Test Site.

Climate may be classified by the types of vegetation indigenous to an area. According to *Nevada Weather and Climate* (Houghton et al., 1975), this method of classification developed by Köppen is further subdivided on the basis of "...seasonal distribution of rainfall and the degree of summer heat or winter cold." Table 1 summarizes the characteristics of climatic types for Nevada.

According to Quiring (Quiring, 1968), the NTS average annual precipitation ranges from about 4 inches (10 cm) at the lower elevations to around 10 inches (25 cm) at the higher elevations. During the winter months, the plateaus may be snow-covered for a period of several days or weeks. Snow is uncommon on the flats. Temperatures vary considerably with elevation, slope, and local air currents. The average daily temperature ranges at the lower altitudes are around 50 to 25°F (10 to -4°C) in January and 95 to 55°F (35 to 13°C) in July, with extremes of 120°F (49°C) and -15°F (-26°C). Corresponding temperatures on the plateaus are 35 to 25°F (2 to -4°C) in January and 80 to 65°F (27 to 18°C) in July with extremes of 115°F (46°C) and -30°F (-34°C).

The wind direction, as measured on a 98 ft (30 m) tower at an observation station approximately 7 miles (11 km) north-northwest of CP-1, is predominantly northerly except during the months of May through August when winds from the south-southwest predominate (Quiring, 1968). Because of the prevalent mountain/valley winds in the basins, south to southwest winds predominate during daylight hours of most months. During the winter months, southerly winds predominate slightly over northerly winds for a few hours during the warmest part of the day. These wind patterns may be quite different at other locations on the NTS because of local terrain effects and differences in elevation.

2.3 Hydrology

Two major hydrologic systems shown in Figure 3 exist on the NTS (U.S. Energy Research and Development Administration, 1977). Ground water in the northwestern part of the NTS or in the Pahute Mesa area flows at a rate of 6.6 to 600 feet (2 to 180 m) per year to the south and southwest toward the Ash Meadows discharge area in the Amargosa Desert. Ground water to the east of the

Table 1. Characteristics of Climatic Types in Nevada (from Houghton et al. 1975)

Climate Type	Mean Annual Temperature °F (°C) Winter	Summer	Precipitation inches (cm) Total*	Snowfall	Dominant Vegetation	Percent of Area
Alpine tundra	0 to 15 (-18 to -9)	40 to 50 (4 to 10)	15 to 45 (38 to 114)	Medium to heavy	Alpine meadows	--
Humid continental	10 to 30 (-12 to -1)	50 to 70 (10 to 21)	25 to 45 (64 to 114)	Heavy	Pine-fir forest	1
Subhumid continental	10 to 30 (-12 to -1)	50 to 70 (10 to 21)	12 to 25 (30 to 64)	Moderate	Pine or scrub woodland	15
Mid-latitude steppe	20 to 40 (-7 to 4)	65 to 80 (18 to 27)	16 to 15 (15 to 38)	Light to moderate	Sagebrush, grass, scrub	57
Mid-latitude desert	20 to 40 (-7 to 4)	65 to 80 (18 to 27)	3 to 8 (8 to 20)	Light	Greasewood, shadscale	20
Low-latitude desert	40 to 50 (-4 to 10)	80 to 90 (27 to 32)	2 to 10 (5 to 25)	Negligible	Creosote bush	7

* Limits of annual precipitation overlap because of variations in temperature which affect the water balance.

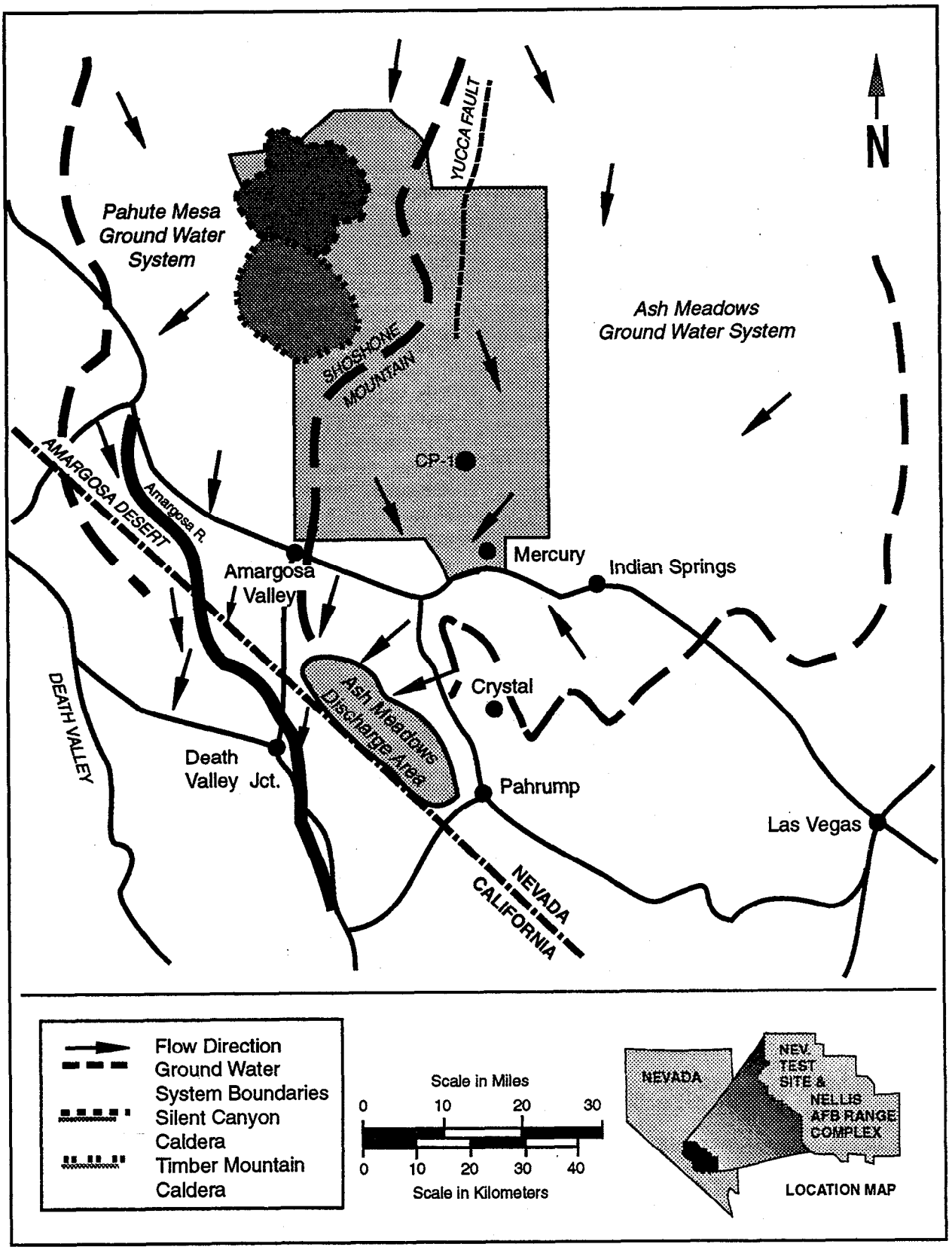

Figure 3. Ground water flow systems around the Nevada Test Site.

NTS moves from north to south at a rate of not less than 6.6 feet (2 m) nor greater than 730 feet (220 m) per year. Carbon-14 analyses of this eastern ground water indicate that the lower velocity is nearer the true value. At Mercury Valley in the extreme southern part of the NTS, the eastern ground water flow shifts to the southwest, toward the Ash Meadows discharge area.

2.4 Land Use Of Nevada Test Site Region

Figure 4 is a map of the off-NTS area showing a wide variety of land uses, such as farming, mining, grazing, camping, fishing, and hunting within a 180-mile (300 km) radius of the NTS operations control center, located at CP-1 (the location of CP-1 is shown on Figures 3 and 6). West of the NTS, elevations range from 280 feet (85 m) below MSL in Death Valley to 14,600 feet (4,420 m) above MSL in the Sierra Nevada Range. Portions of two major agricultural valleys (the Owens and San Joaquin) are included. The areas south of the NTS are more uniform since the Mojave Desert ecosystem (mid-latitude desert) comprises most of this portion of Nevada, California, and Arizona. The areas east of the NTS are primarily mid-latitude steppe with some of the older river valleys, such as the Virgin River Valley and the Moapa Valley, supporting irrigation for small-scale but intensive farming of a variety of crops. Grazing is also common in this area, particularly to the northeast. The area north of the NTS is also mid-latitude steppe, where the major agricultural activity is grazing of cattle and sheep. Minor agriculture, primarily the growing of alfalfa hay, is found in this portion of Nevada within 180 miles (300 km) of the CP-1. Many of the residents have access to locally grown fruits and vegetables.

Recreational areas lie in all directions around the NTS (Figure 4) and are used for such activities as hunting, fishing, and camping. In general, the camping and fishing sites to the northwest, north, and northeast of the NTS are closed during winter months. Camping and fishing locations to the southeast, south, and southwest are utilized throughout the year. The peak of the hunting season is from September through January.

2.5 Population Distribution

Knowledge of population densities and spatial distribution of farm animals is necessary to assess protective measures required in the event of an accidental release of radioactivity at the NTS. Figure 5 shows the current population of counties surrounding the NTS based on 1990 Bureau of Census (BOC) count (BOC, 1990). Excluding Clark County, the major population center (approximately 741,459 in 1990), the population density of counties adjacent to the NTS is about 0.7 persons per square mile (0.4 persons per square kilometer). For comparison, the population density of the 48 contiguous states was 70.3 persons per square mile (27 persons per square kilometer) (BOC, 1990). The estimated average population density for Nevada in 1980 was 1.1 persons per square mile (0.4 persons per square kilometer) (BOC, 1986).

The offsite area within 48 miles (80 km) of CP-1 (the primary area in which the dose commitment must be determined for the purpose of this report) is predominantly rural. Several small communities are located in the area, the largest being in Pahrump Valley. Pahrump, a growing rural community with a population of 7,425 (BOC, 1990), is located 48 miles (80 km) south of the NTS CP-1. The small residential community of Crystal, Nevada, also located in the Pahrump Valley, is several miles north of the town of Pahrump. The location of Crystal, Nevada, is shown in Figure 3. The Amargosa farm area, which has a population of about 950, is located 30 miles (50 km) southwest of CP-1. The largest town in the near offsite area is Beatty, which has a population of about 1,500 and is located approximately 39 miles (65 km) to the west of CP-1.

The Mojave Desert of California, which includes Death Valley National Monument, lies along the southwestern border of Nevada. The National Park Service (NPS) estimated that the population within the Monument boundaries ranges from a minimum of 200 permanent residents during the summer months to as many as 5,000 tourists including campers on any particular day during the major holiday periods in the winter months, and as many as 30,000 during "Death Valley Days" in the month of November (NPS, 1990). The next largest town and contiguous populated area, about 40 square miles (about 111 square km) in the Mojave Desert, Barstow, California, located 159 miles (265

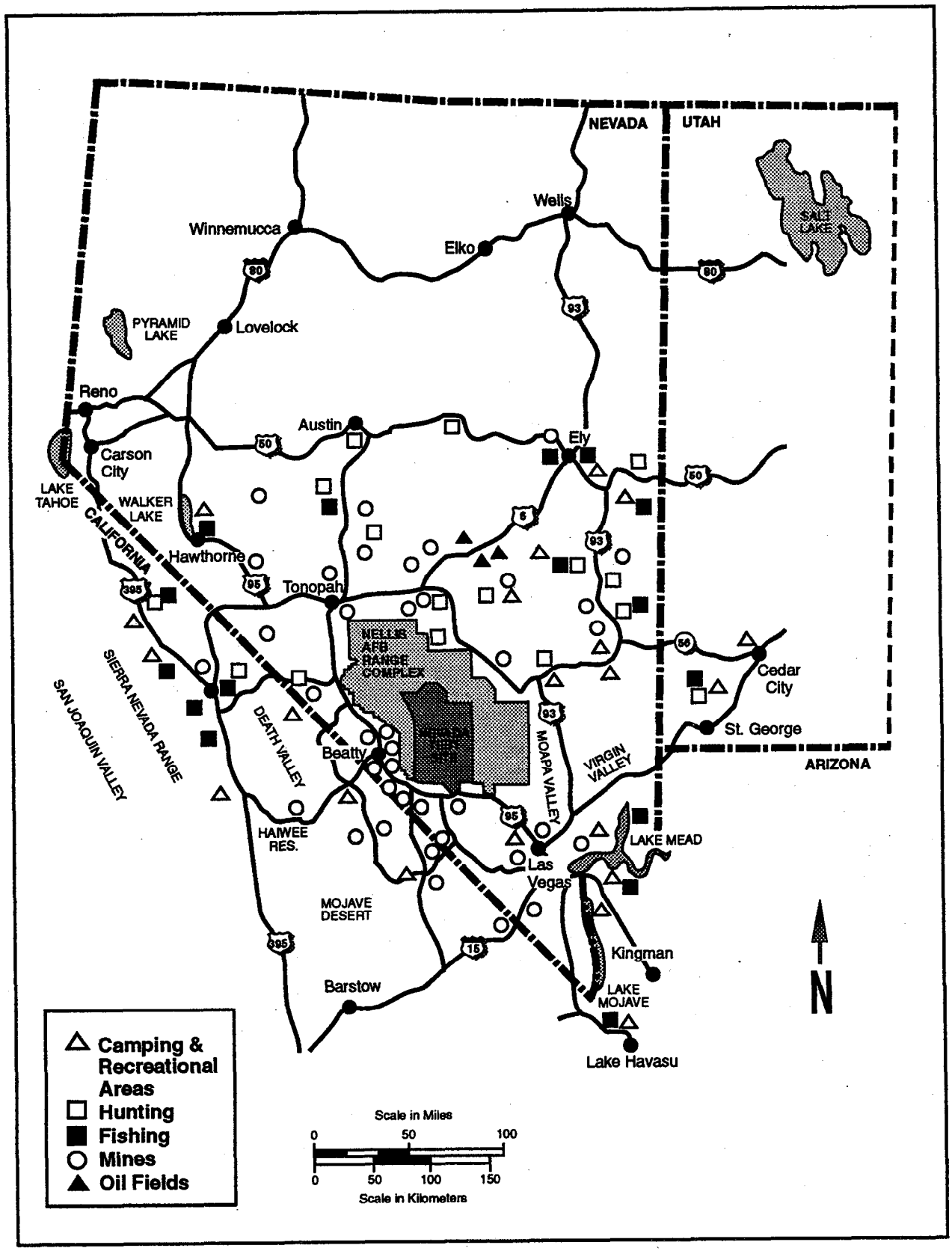

Figure 4. General land use within 180 miles (300 km) of the Nevada Test Site.

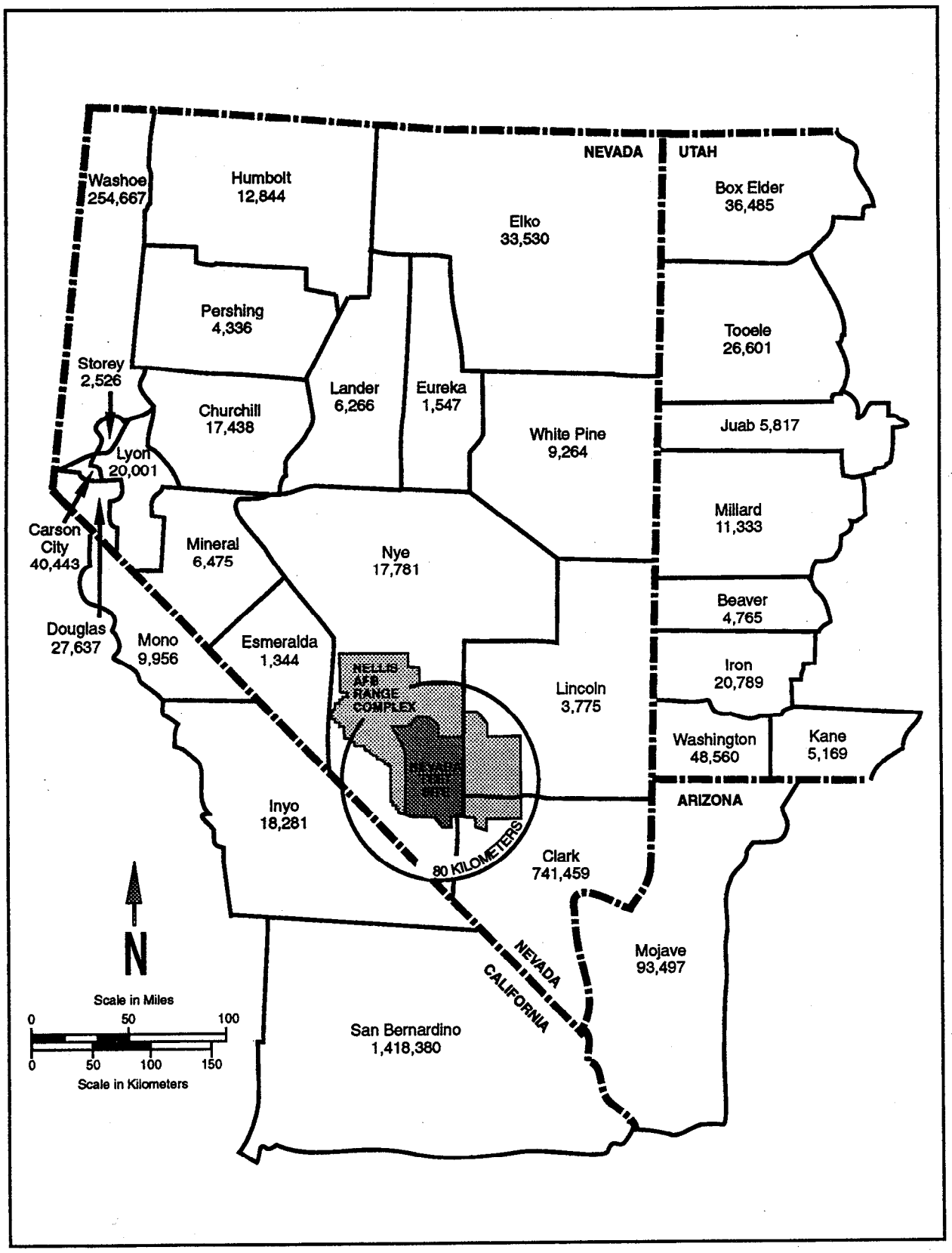

Figure 5. Population of Arizona, California, Nevada, and Utah counties near the Nevada Test Site.

km) south-southwest of the NTS, with a 1990 population of 21,472. The largest populated area is the Ridgecrest, California area, which has a population of 27,725 and is located 114 miles (190 km) southwest of the NTS. The Owens Valley, where numerous small towns are located, lies 30 miles (50 km) west of Death Valley. The largest town in the Owens Valley is Bishop, California, located 135 miles (225 km) west-northwest of the NTS, with a population of 3,475 (BOC, 1990).

The extreme southwestern region of Utah is more developed than the adjacent part of Nevada. The largest community is St. George, located 132 miles (220 km) east of the NTS, with a 1990 population of 28,502. The next largest town, Cedar City, with a population of 13,443, is located 168 miles (280 km) east-northeast of the NTS (BOC, 1990).

The extreme northwestern region of Arizona is mostly range land except for that portion in the Lake Mead Recreation Area. In addition, several small communities lie along the Colorado River. The largest towns in the area are Bullhead City, 99 miles (165 km) south-southeast of the NTS, with a 1990 population of 21,951 and Kingman, located 168 miles (280 km) southeast of the NTS, with a population of 12,722 (BOC, 1990).

Figures 6 through 9 show the most recent estimates of the domestic animal populations in the counties near the NTS. Domestic animal numbers are updated through interim survey as part of routine monitoring and by resurvey periodically. The numbers given in Figure 6, showing distribution of family milk cows and goats, are determined from these interim surveys. The numbers in Figures 7 to 9 were compiled for Nevada and Utah from the Nevada Agricultural Statistics 1992 report (Nevada Agricultural Statistics Service, 1992) and from the 1992 Utah Agricultural Statistics report (Utah Agricultural Statistics Service, 1992). The numbers in Figures 7 to 9 pertaining to counties in California were received verbally from personnel at the California Agricultural Statistics Service.

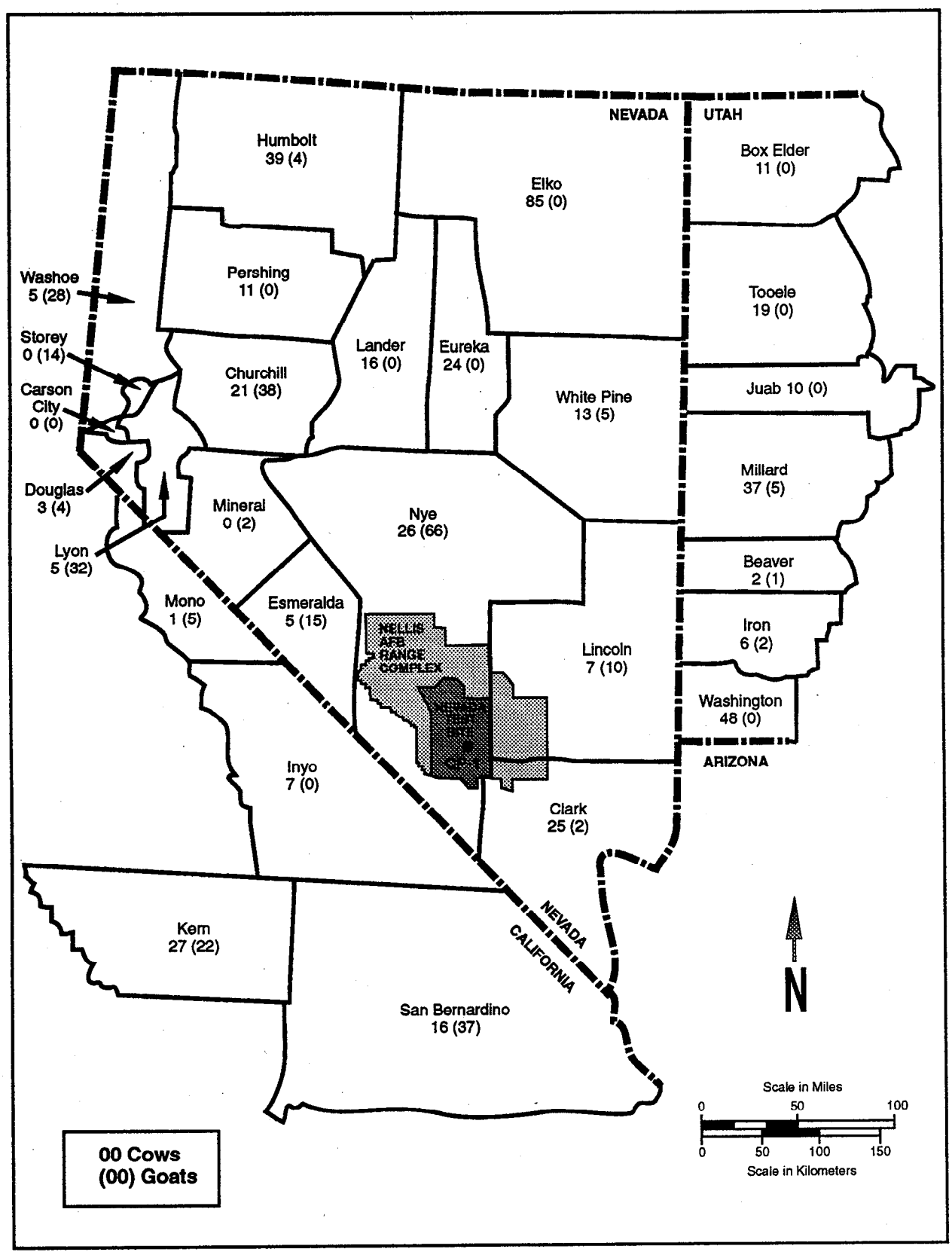

Figure 6. Distribution of family milk cows and goats, by county.

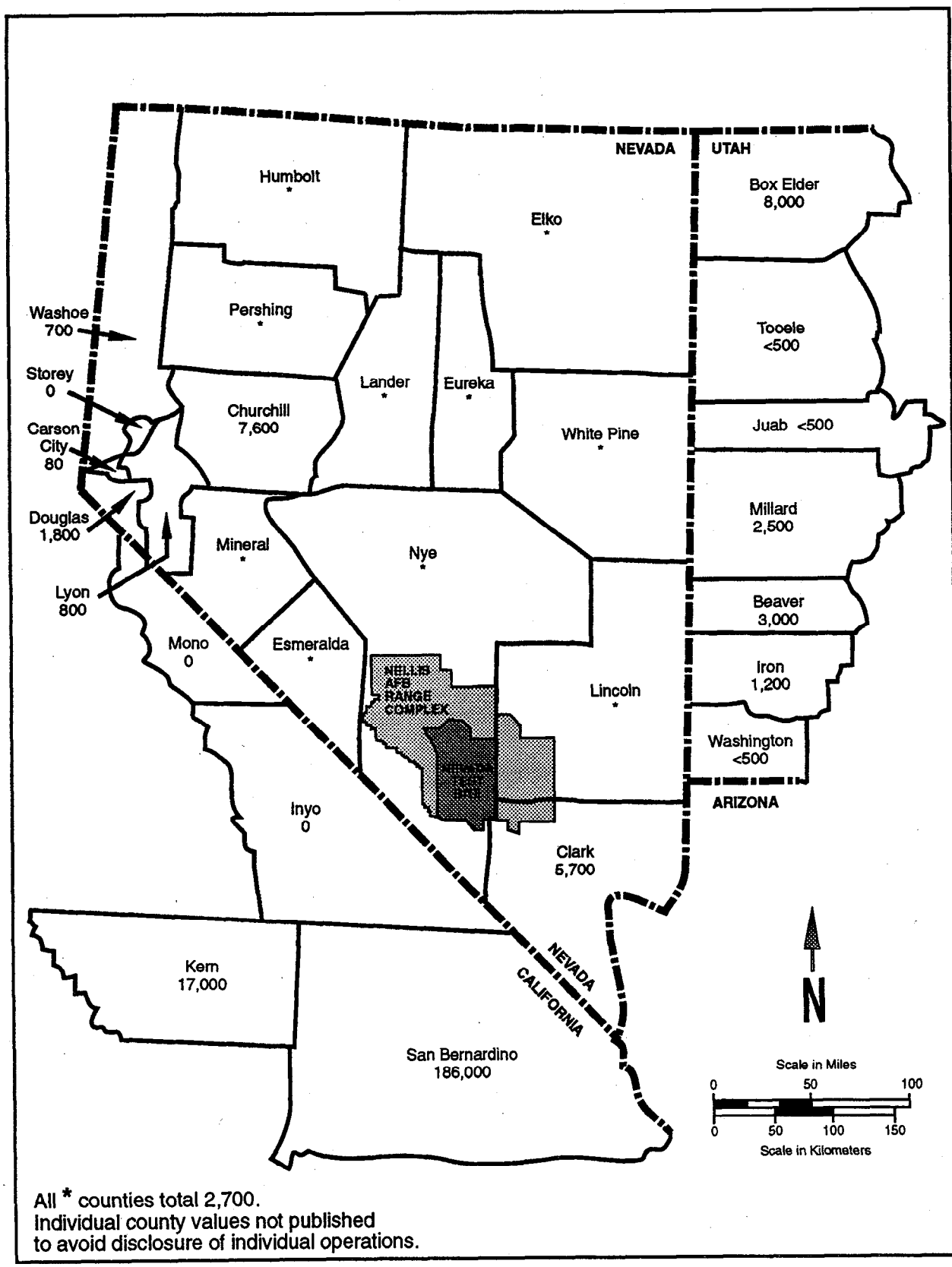

Figure 7. Distribution of dairy cows, by county.

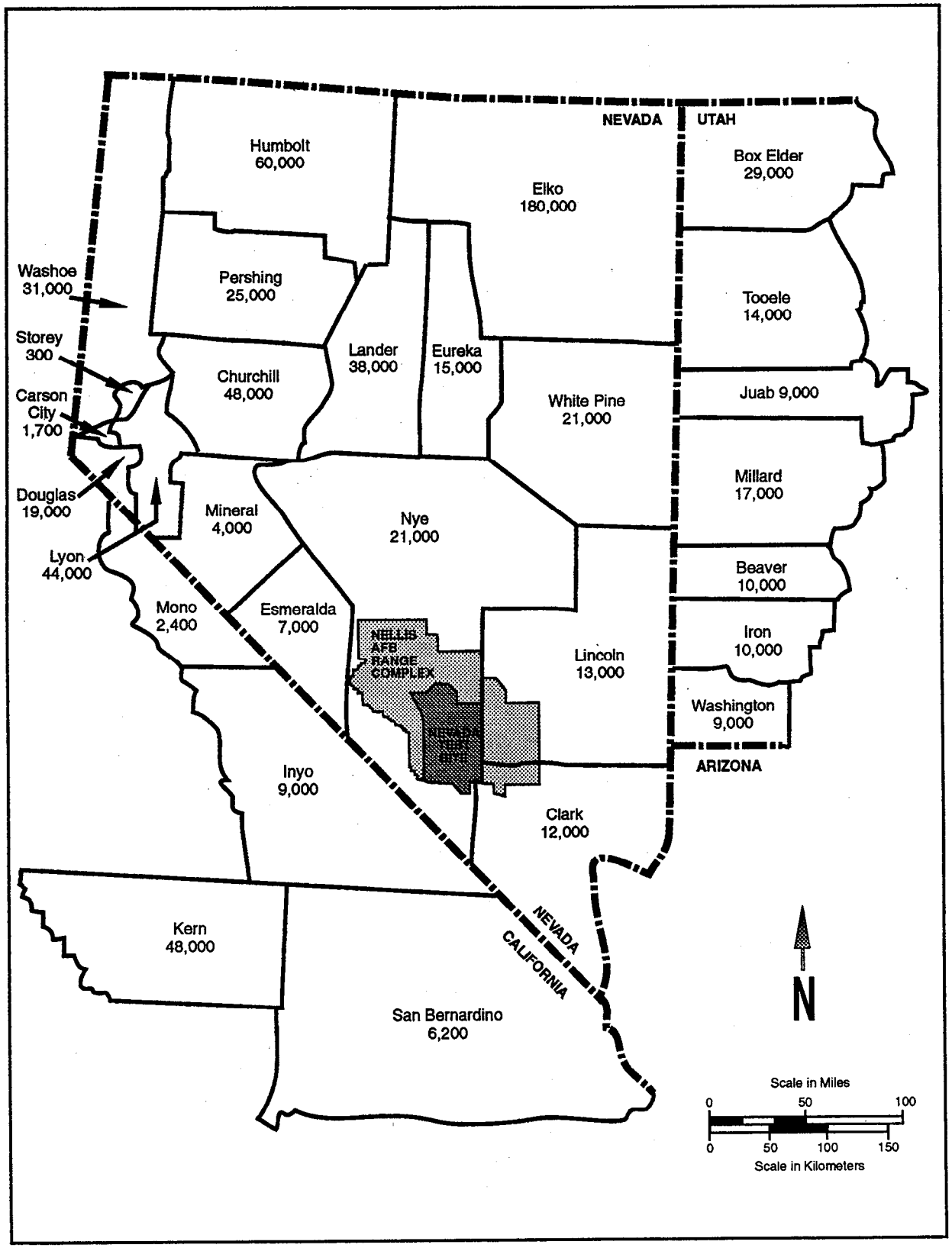

Figure 8. Distribution of beef cattle, by county.

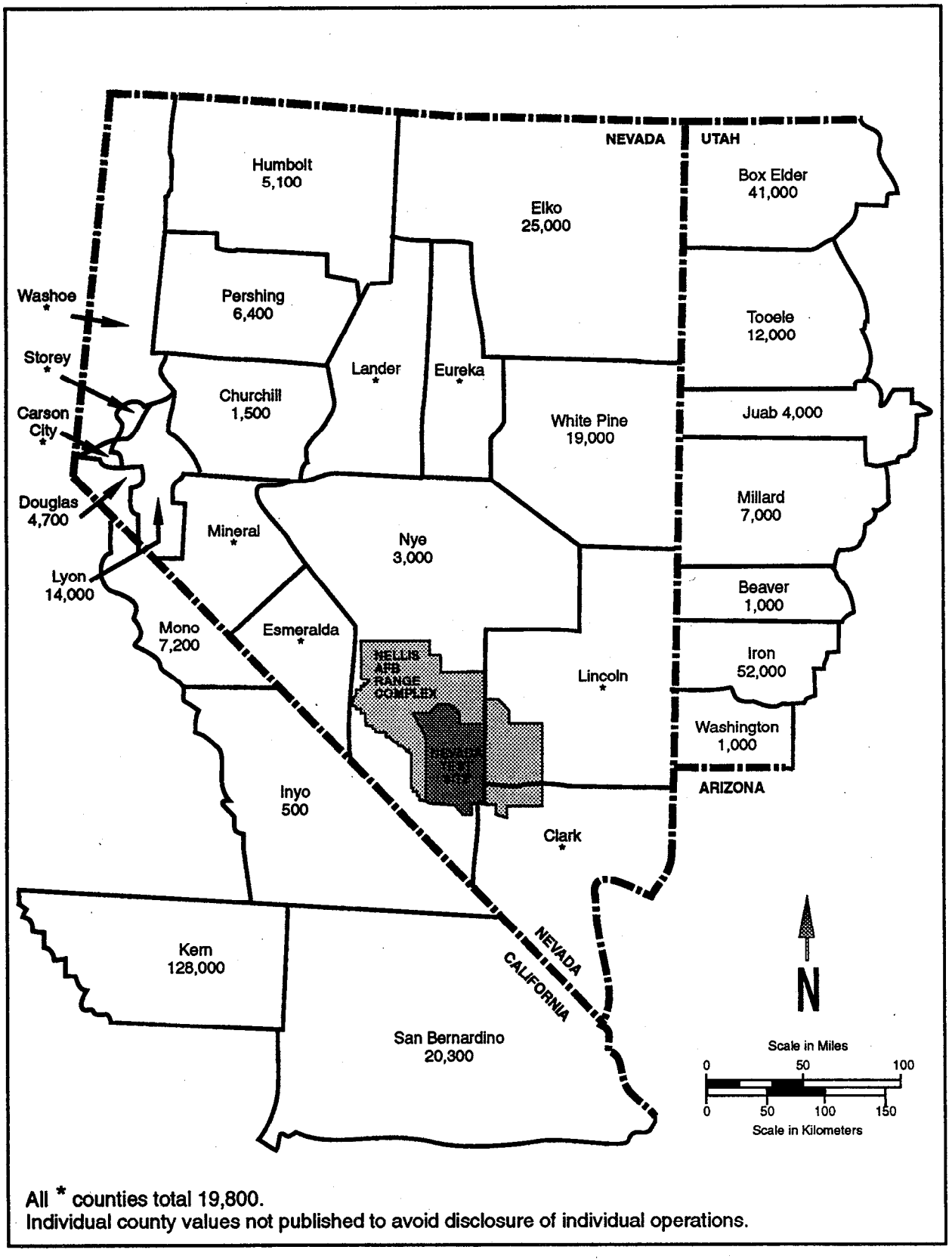

Figure 9. Distribution of sheep, by county.

3 External Ambient Gamma Monitoring

External ambient gamma radiation is measured by the Thermoluminescent Dosimetry (TLD) network and also by the Pressurized Ion Chamber (PIC) network. The primary function of the two networks is to detect changes in ambient gamma radiation. In the absence of man's activities (e.g., nuclear testing), ambient gamma radiation rates naturally differ among locations as rates vary with altitude (cosmic radiation) and with radioactivity in the soil (terrestrial radiation). Ambient gamma radiation will also vary slightly at a location due to weather patterns.

3.1 Thermoluminescent Dosimetry Network

The TLD network is designed primarily to measure total ambient gamma exposures at fixed locations. A secondary function of the network is the measurement of exposures to specific individuals living within and outside estimated fallout zones from past atmospheric nuclear tests at the Nevada Test Site (offsite residents). Measuring environmental ambient gamma exposures at fixed locations provides a reproducible index which can then easily be correlated to the maximum exposure an individual would have received were he continuously present at that location. Monitoring of individuals makes possible an estimate of individual exposures and helps to confirm the validity of correlating fixed-site ambient gamma measurements to projected individual exposures.

Since 1987, environmental and personnel monitoring for ambient gamma exposures has been accomplished using the Panasonic TLD system. This system provides tissue equivalence for personnel TLDs which facilitates correlating individual measured exposures with the absorbed biological dose equivalent.

During 1991, the EMSL-LV TLD Laboratory was awarded accreditation as a processor of personnel TLDs by the Department of Energy Laboratory Accreditation Program (DOELAP). This accreditation was the culmination of a process extending over a period of approximately one year. The accreditation process began with three rounds of blind exposures to a variety of radiation types and levels ranging from occupational levels through the accident range and included both "pure" and mixed radiation fields. The purpose of these blind exposures was to test the accuracy, precision, and long-term consistency of overall laboratory performance. The performance testing phase was followed by a rigorous on-site appraisal of laboratory operations, procedures, and quality control both from the perspective of routine operations and to ensure that operations as conducted were appropriate to the overall EMSL-LV radiation safety management mission.

3.1.1 Design

During 1991, 130 offsite stations (excluding the Nevada Low Level Waste Site station) encircling the NTS and 72 offsite residents were monitored by the TLD program. Locations monitored in 1991 are shown in Figure 10. This network allows estimation of average background exposures as well as detection of any increases.

The personnel TLDs are sensitive to beta, gamma, neutron, and to low and high energy x-ray radiations. All personnel exposures are presumed to be due to gamma or high energy x-ray radiation. Exposures of this type are numerically equivalent to absorbed dose. The TLDs used to monitor fixed environmental stations are sensitive only to gamma and high-energy x-ray radiations.

The personnel TLDs are provided in holders which are designed to be worn on the front of an individual's body, between the neck and the waist. When worn in this manner, the TLD may be used to estimate not only ambient gamma radiation exposure but to characterize the absorbed radiation dose an individual may have received. Figure 11 illustrates a typical personnel TLD holder as it would be issued to a monitored individual. TLDs issued to individuals are normally deployed and collected monthly.

Each fixed environmental station has a custom designed holder that can hold from one to four TLDs. Normal operations involve packaging two TLDs in a heat-sealed bag to provide protection from the environmental elements and placing the dosimeter packet into the fixed station holder. Fixed environmental monitoring TLDs are normally

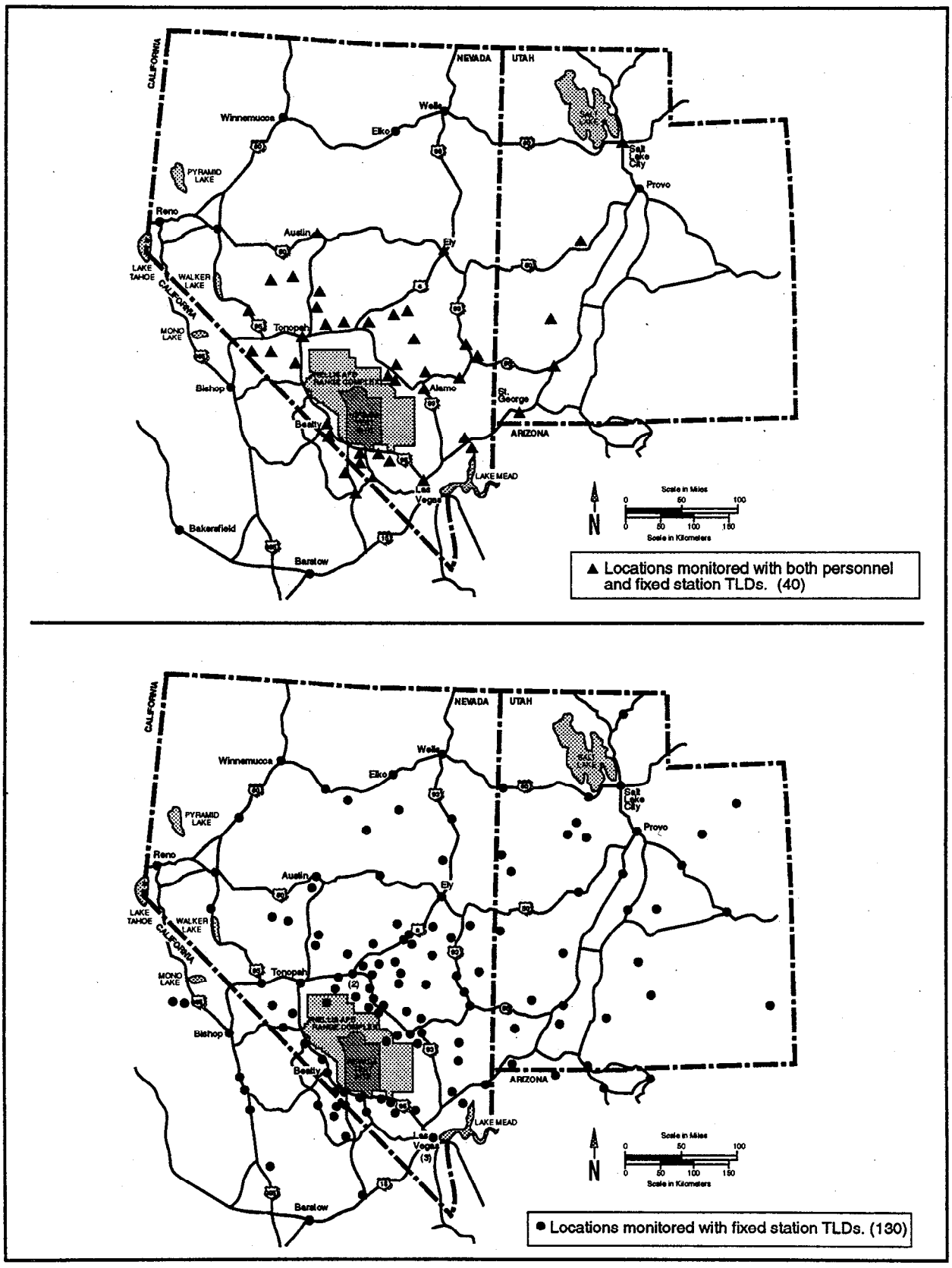

Figure 10. Locations monitored with thermoluminescent dosimeters.

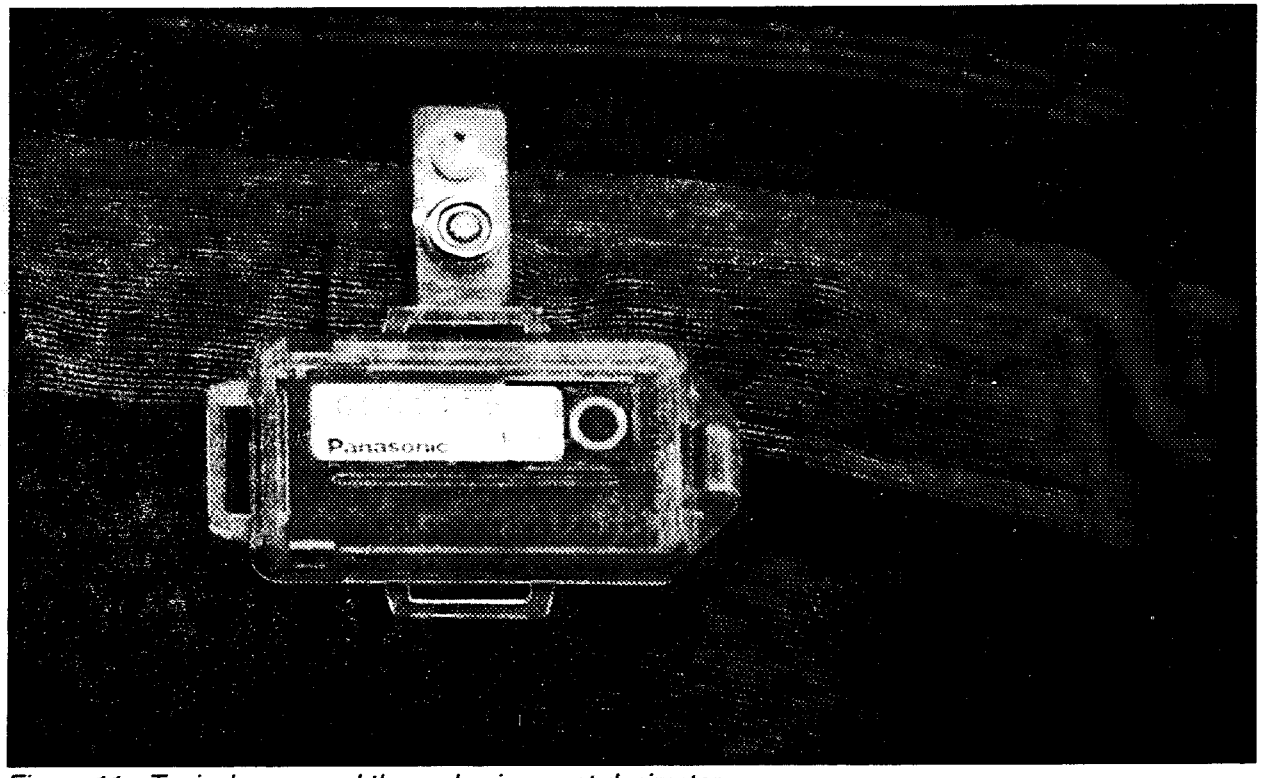

Figure 11. Typical personnel thermoluminescent dosimeter.

deployed for a period of approximately three months (one calendar quarter).

3.1.2 Procedures

The EPA TLD program utilizes the Panasonic Model UD-802 and UD-814 thermoluminescent dosimeters and Model UD-710A automatic dosimeter reader.

Monitoring of offsite personnel is accomplished with the Panasonic UD-802 dosimeter/UD-874A hanger combination. This dosimeter badge contains two elements of $Li_2B_4O_7$:Cu and two of $CaSO_4$:Tm phosphors. The use of different filtration elements makes possible a close estimation of the type of radiation to which the dosimeter was exposed, data that are essential to assess the absorbed dose equivalent for the individual wearing the dosimeter. Monitoring of offsite environmental stations is accomplished with the Panasonic UD-814 dosimeter. This dosimeter contains a single element of $Li_2B_4O_7$:Cu and three replicate $CaSO_4$:Tm elements. The first element is filtered by 17 mg/cm^2 of plastic and the remaining three are filtered by 1,020 mg/cm^2 of plastic and lead. The use of three replicate phosphors provides greater precision of the measurement.

The Panasonic Model UD-710A automatic dosimeter reader consists of a badge transport and insertion mechanism, a heat source, a carbon-14 (^{14}C) activated reference light source, a light measurement system, and a microprocessor controller. Up to 500 TLDs may be loaded in 50-dosimeter magazines into the automatic sample changer attached to each reader. Each magazine is automatically advanced to admit dosimeters into the reading mechanism. In the mechanism, the dosimeter portion containing the four phosphors is withdrawn from the holder. Each element is then heated and its light output measured. When all four elements have been read, the card is reinserted into its holder, the holder is returned to the magazine, and the process is repeated for the next dosimeter. Figure 12 illustrates the general mechanism of the dosimeter reader.

3.1.3 Results of TLD Monitoring

A portion of the 1991 TLD data are not included in this report due to a data retrieval problem with the network software. The problem affects only the ability to retrieve data, not the quality of the data reported. The measurement period dates given in

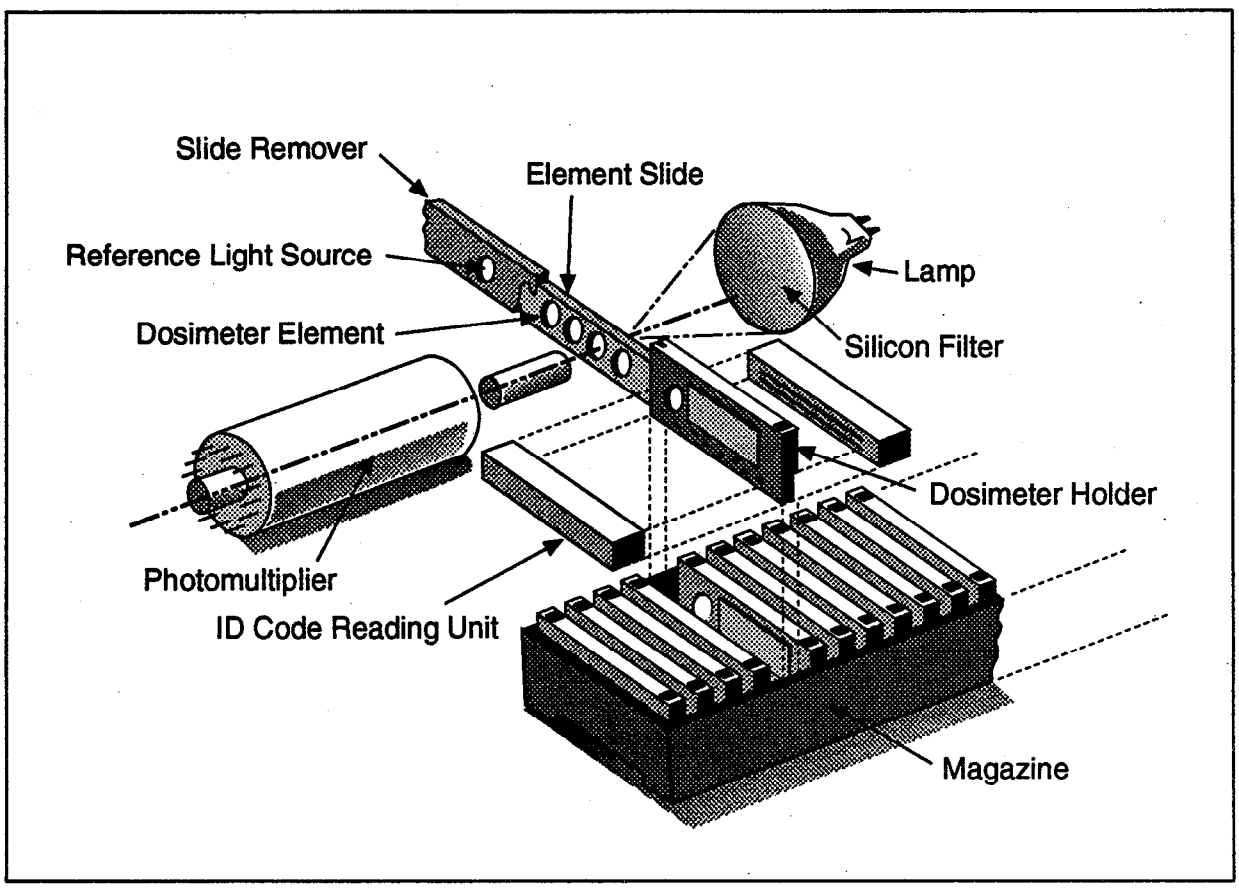

Figure 12. Illustration of a Panasonic UD 710 Dosimeter Reader.

the tables in this section indicate which data are not included. The 1992 report will include all 1991 data that are not presented in this report.

As stated above, the primary function of the fixed environmental station TLDs is to characterize background gamma radiation fields. Daily exposure rates are obtained by dividing the total exposure from each TLD by the number of days in the monitoring period. Annual adjusted ambient gamma exposures at fixed stations (mR in one year) are calculated by multiplying the mean daily rate for each individual station by 365.25. Individual measurements can be compared to historical data to evaluate whether that measurement varies significantly from the historical background for that location.

Annual exposures measured at fixed environmental TLD stations during 1991 ranged from 47 to 377 mR, with a median of 87 mR. Results obtained at each of the fixed environmental stations monitored with TLDs are summarized in Appendix A, Table A-1. The data are presented alphabetically by state. During 1991, the maximum net annual exposure of 377 mR was measured at Warm Springs, Nevada, located east of Tonopah on Highway 6. This exposure, at Warm Springs #2, was determined to be due to elevated levels of naturally occurring radioactive material present in a hot springs-fed stream adjacent to the monitoring location. Radiation levels measured in a nearby parking lot (Warm Springs #1) indicated an annual net exposure of 116 mR. A detailed evaluation of the Warm Springs #1 and Warm Springs #2 monitoring locations was included in the 1989 Annual Report (EPA90). These values represent gross ambient gamma radiation levels measured at the respective locations.

Figure 13 shows 10 years of TLD exposure data expressed as annual means of all stations. The figure shows the mean ± two standard deviations. The range of exposures observed at fixed environmental monitoring locations during 1991 was similar to that observed in the previous ten years. The range of exposures was consistent with that expected from background radiation in the United States with the exception of Warm Springs #2, discussed above.

For each resident participating in the TLD Network, the measured exposure can be compared to an associated reference background. An average for all offsite station TLDs is not an appropriate reference background because environmental ambient radiation levels vary markedly with natural radioactivity in the soil, altitude, and other factors. Therefore, results obtained at the fixed environmental station closest to that individual are the most appropriate reference point. Daily dose rates are obtained by dividing the total dose from each TLD by the number of days in the monitoring period. Annual adjusted ambient gamma doses to personnel (mrem in one year) are calculated by multiplying the mean daily rate for each individual by 365.25.

Of the 72 individuals monitored, 52 (73.2%) received exposures varying from the associated reference background location by less than 20 mR in one year. Sixty-eight of the 72 (94.4%) received exposures varying from associated reference background by less than 50 mR in one year. In no case did any individual or cumulative exposure exceed regulatory or as low as reasonably achievable (ALARA) investigation limits. The distribution of personnel exposures as compared to associated reference background exposures is shown in Figure 14. The results of offsite personnel TLD monitoring for 1991 are summarized in Appendix A, Table A-2. Annual equivalent doses ranged from 31 mrem in an individual from St. George, Utah to 167 mrem in an individual from Stone Cabin Ranch, Nevada. The median value was 76. Absorbed radiation dose to personnel is calculated at three depths in tissue: 17mg/cm^2, 300mg/cm^2, and 1,000mg/cm^2. These are by convention referred to as "shallow," "eye," and "deep." Appendix A, Table A-2 lists the deep absorbed dose equivalent in mrem because this is most representative of the dose to the whole body, including the dose to blood forming organs.

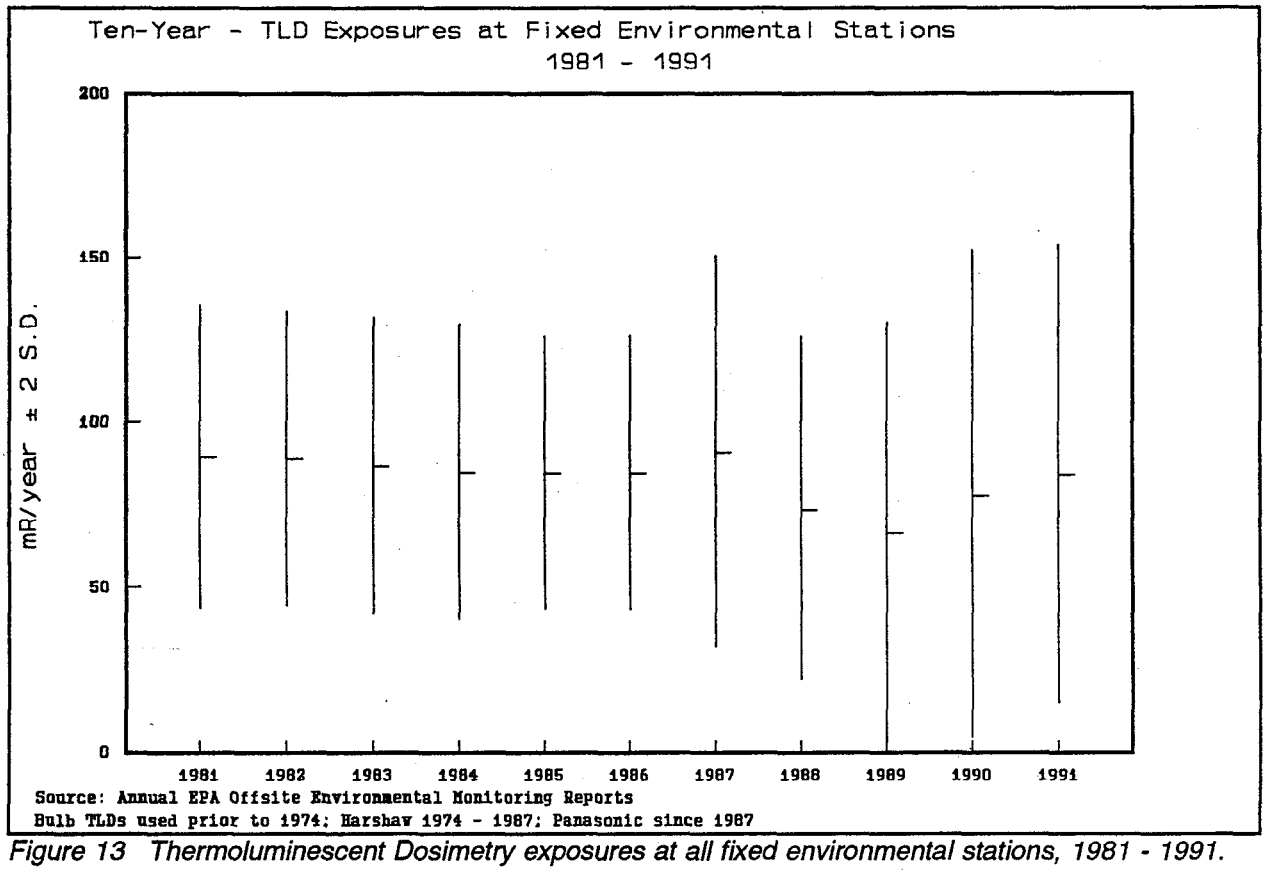

Figure 13 Thermoluminescent Dosimetry exposures at all fixed environmental stations, 1981 - 1991.

3.1.4 Quality Assurance/Quality Control

During 1991, two calibration instruments were available to support the program. One uses a panoramic style irradiator containing a ^{137}Cs source which delivers an exposure rate of approximately 87 mR/hour at 100 cm from the source. The other is a 10 Ci well-type ^{137}Cs irradiator, delivering approximately 60 mR/minute at 100 cm. Exposures given to irradiated control TLDs are monitored using Victoreen model #570 or Victoreen Radocon-III electrometers with appropriate ionization chambers having calibrations traceable to the National Institute of Standards and Technology (NIST). The ionization chamber is placed in the center of the radiation field. The exposure rates of both irradiators have been confirmed by measurement using precision electrometers and ionization chambers having calibrations traceable to NIST. Panasonic UD-800 dosimeters exposed by these irradiators are used to calibrate the TLD readers and to verify TLD reader linearity. Control dosimeters of the same type as field dosimeters (UD-802 or UD-814) are exposed and read together with the field dosimeters. This provides daily on-line process quality control checks in the form of irradiated controls.

Each magazine containing TLDs to be read normally contains three irradiated control TLDs that have been exposed to a nominal 200 mR at least 24 hours prior to the reading. After the irradiated controls have been read, the ratio of recorded exposure to delivered exposure is calculated and recorded for each of the four elements of the dosimeter. This ratio is applied to all raw element readings from field and unirradiated control dosimeters to automatically compensate for reader variations.

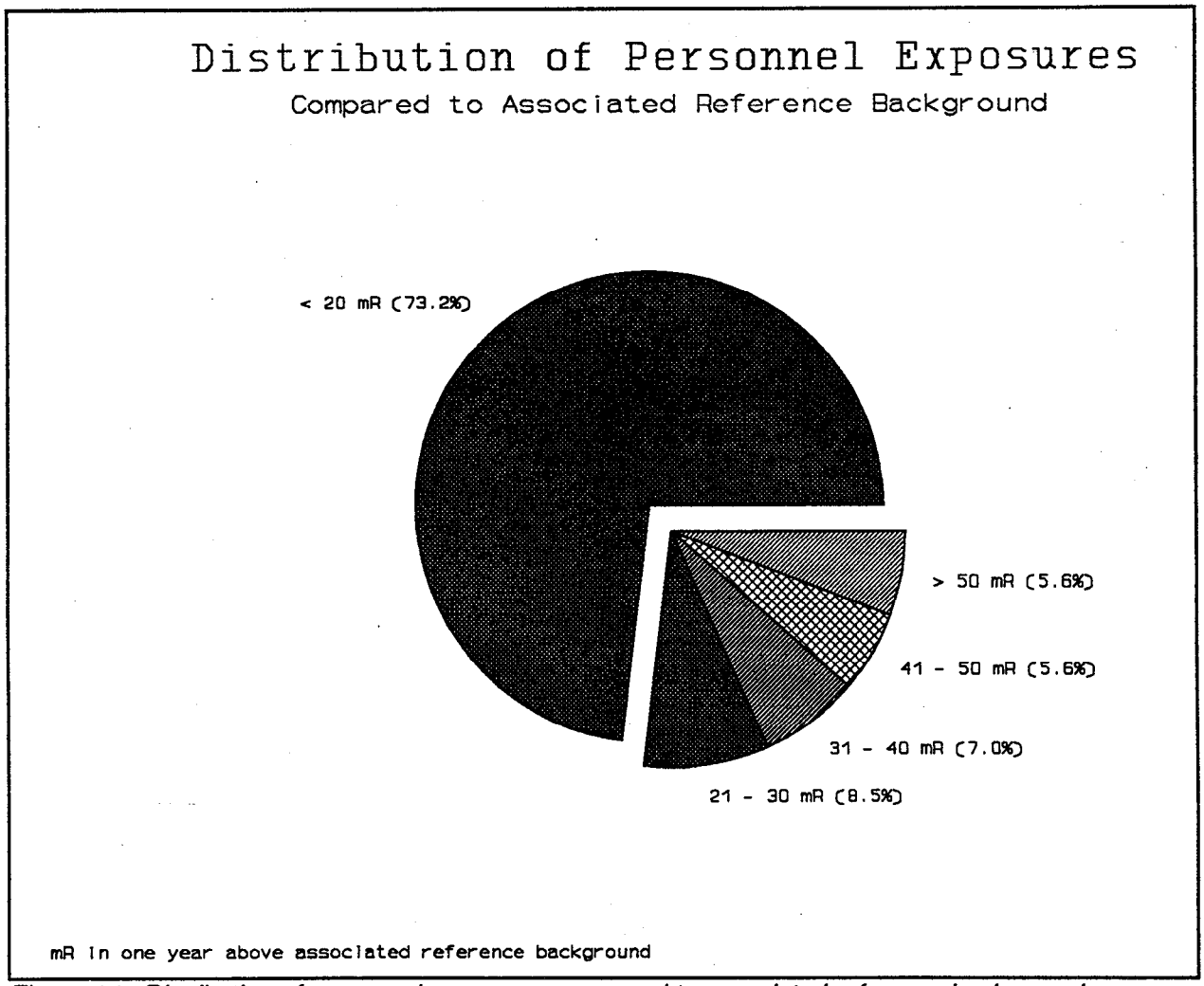

Figure 14 Distribution of personnel exposures compared to associated reference background.

Prior to being placed in service, element correction factors (ECFs) are determined for all dosimeters. Whenever a dosimeter is read, the mean of the three most recent ECF determinations is applied to each element to compensate for normal variability (caused primarily by the TLD manufacturing process) in individual dosimeter response.

In addition to irradiated controls, each group of field dosimeters normally contains three transit and three unirradiated background dosimeters. Thus, each magazine of 50 dosimeters may contain up to nine QC dosimeters. Field dosimeters receive exposure while in transit as well as while deployed at the monitoring location. To determine the field exposure, it is necessary to estimate this additional exposure, which is designated "transit exposure". Transit control dosimeters are shipped with each batch of field dosimeters. Exposures received while in storage are determined by using unirradiated background dosimeters. Unirradiated background dosimeters are held in shielded storage at the EPA TLD processing laboratory. The exposure while in transit is estimated by taking the difference between the exposures measured on transit dosimeters and those measured on unirradiated background dosimeters. The exposure to unirradiated background dosimeters is essentially due only to the cosmic ray component of the local natural background radiation. Likely sources of transit exposure include shipments of medical and other radioisotopes in the mail and natural terrestrial and cosmic radiation.

An assessment of TLD data quality is based on the presumption that exposures measured at an individual fixed location will remain substantially constant over an extended period of time. A number of factors will combine to affect the certainty of measurements. The total uncertainty of the reported exposures is a combination of random and systematic components of uncertainty. The random component is primarily the statistical uncertainty in the reading of the TLD elements themselves. Based on repeated known exposures, this random uncertainty for the calcium sulfate elements used to determine exposure at fixed environmental stations is estimated to be approximately ± 3 to 5%. There are also several systematic components of exposure uncertainty, including energy-directional response, fading, calibration, and exposures received while in storage. These uncertainties are estimated according to established statistical methods for propagation of uncertainty.

A study conducted by the Nuclear Regulatory Commission (NRC-1991) indicated an average total net field exposure uncertainty across fixed environmental station TLDs deployed for a period of 90 days of 21.1% relative standard deviation (RSD). A review of fixed environmental station TLD results obtained by the EPA network in 1991 showed an average of 21.6 % RSD across all stations, virtually identical to the results reported by NRC. Also, the NRC reported an average net field exposure of 22.8 mR in 90 days. Results observed in the EPA monitoring network averaged 21.6 mR when adjusted to the same length monitoring period. Net field exposure uncertainty for exposures at the occupational and accident range of 30 mR to 500 R would be significantly lower when compared to natural background or transit exposure levels.

Accuracy of the overall TLD deployment and processing cycle has been evaluated via the DOELAP accreditation process. This process concluded that procedures and practices utilized by the EPA EMSL-LV TLD Laboratory are adequate to detect exposures to individuals greater than 3 mrem above background at the 95% confidence level. This is referred to as the lower limit of detectability. Tests using dosimeters exposed to known radiation levels both in-house and by external organizations have confirmed that the TLD readers exhibit linear performance from the lower limit of detectability through the accident range (500 rads).

3.1.5 Data Management

The TLD data base resides on a Digital Equipment Corporation (DEC). MicroVAX II, directly connected to the two Panasonic TLD readers. Samples are tracked using field data cards and an issue data base tracking system incorporated into the reader control software. Two major software packages are utilized by the TLD network. The first, a proprietary package written and supported by International Science Associates (ISA), controls the TLD readers, tracks dosimeter performance, completes necessary calculations to determine absorbed dose equivalent, performs automated QA/QC functions, and generates raw data files and reports. The second software package, locally developed, maintains privacy act information and the identifying data, generates reports in a number of predefined formats, and provides archival storage of TLD results dating to 1971.

3.2 Pressurized Ion Chambers

The Pressurized Ion Chamber (PIC) network continuously measures ambient gamma radiation exposure rates, and because of its sensitivity, may detect low-level exposures not detected by other monitoring methods.

3.2.1 Network Design

Excluding the Nevada Low Level Waste Site, 29 Pressurized Ion Chambers (PICs) are stationed in communities around the NTS. The PICs provide near real-time estimates of gamma exposure rates. The locations of the PICs are shown in Figure 15 Nineteen of the PICs are located at Community Radiation Monitoring Program Stations (CRMPS), which are discussed in Section 10.1.

To expand the network, EPA added PICs to ten of the Remote Automatic Weather Stations (RAWS) in the spring of 1991. The RAWS are owned and operated by the Bureau of Land Management and the U.S. Forest Service and are maintained by the Boise Interagency Fire Center. The locations of all the PICs, including the RAWS PICs, are shown in Figure 16.

Two PICs were relocated during 1991. The PIC at Holloway's Ranch (near Scotty's Junction, NV) was relocated about one-half mile to Terrell's Ranch on June 24, 1991. The results discussion in Section 3.2.3 combines the results from Holloway's and Terrell's Ranches and refers to the station as Terrell's Ranch. The station in St. George, Utah was relocated on September 4, 1991 approximately one-half mile from the high school to Dixie College.

3.2.2 Procedures

The network utilizes Reuter-Stokes models 1011, 1012, and 1013 PICs. The PIC is a spherical shell filled with argon gas to a pressure 25 times that of atmospheric. In the center of the chamber is a spherical electrode with a charge opposite to the outer shell. When gamma radiation penetrates the sphere, ionization of the gas occurs and the ions are collected by the center electrode. The electrical current generated is measured, and the intensity of the radiation field is determined from the magnitude of this current. Figure 17 shows a typical PIC unit in the field.

Data are retrieved from the PICs shortly after measurements are made. The near real-time telemetry-based data retrieval is achieved by the connection of each PIC to a Data Collection Platform (DCP) which collects and transmits the data. Gamma exposure measurements are transmitted via the Geostationary Operational Environmental Satellite (GOES) directly to a receiver earth station at the NTS and from there to the EMSL-LV by dedicated telephone line. Each station routinely transmits data every four hours (i.e., 4-hour average, 1-minute maximum, and 1-minute minimum values) unless the gamma exposure rate exceeds the currently established threshold of 50 μR/hr. When the 50 μR/hr is exceeded for two consecutive 1-minute samples, the system goes into the alarm mode and transmits a string of nine consecutive 1-minute values every 2 to 15 minutes. Additionally, the location and status (i.e., routine or alarm mode) of each station are shown on a map display in the Control-Point-One (CP-1) control room at the NTS and at the EMSL-LV. Thus, the PIC network is able to provide immediate documentation of radioactive cloud passage in the unlikely event of an accidental release from the NTS.

Parameters affecting the physical status of the station equipment are also transmitted along with exposure rates. This allows staff in EMSL-LV to identify equipment problems (e.g., low battery,) with the PICs soon after they occur. All data transmitted via the telemetry system are stored on a DEC microVAX II computer which is managed by Los Alamos National Laboratory.

In addition to telemetry retrieval, PIC data are also recorded on both magnetic tapes and hard-copy strip charts at 27 of the 29 EPA stations and on magnetic cards for the other two EPA stations. The magnetic tapes and cards, which are collected weekly, provide a backup to the telemetry data and are also useful for investigating anomalies because the data are recorded in smaller increments of time (5 minute averages). Summarized data from the 5-minute averages are stored on a personal computer in dBASE files. Raw 5-minute averages are stored in ASCII files on floppy diskettes. The PICs also contain a liquid crystal display, permitting interested persons to monitor current readings.

The data are evaluated weekly by EMSL-LV personnel. Trends and anomalies are investigated and equipment problems are identified and corrected. Weekly averages are stored in Lotus files on

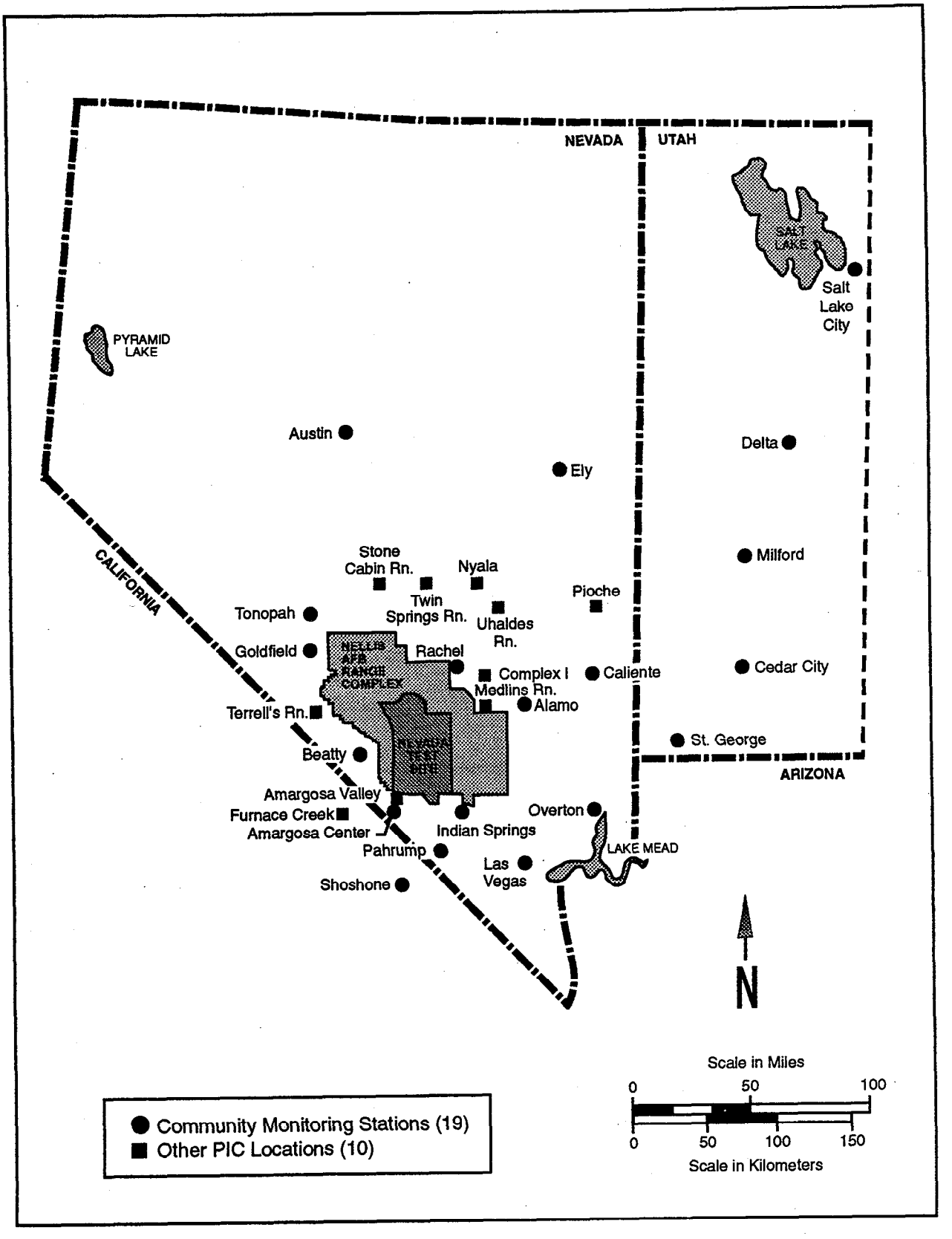

Figure 15 Locations of Pressurized Ion Chamber network stations.

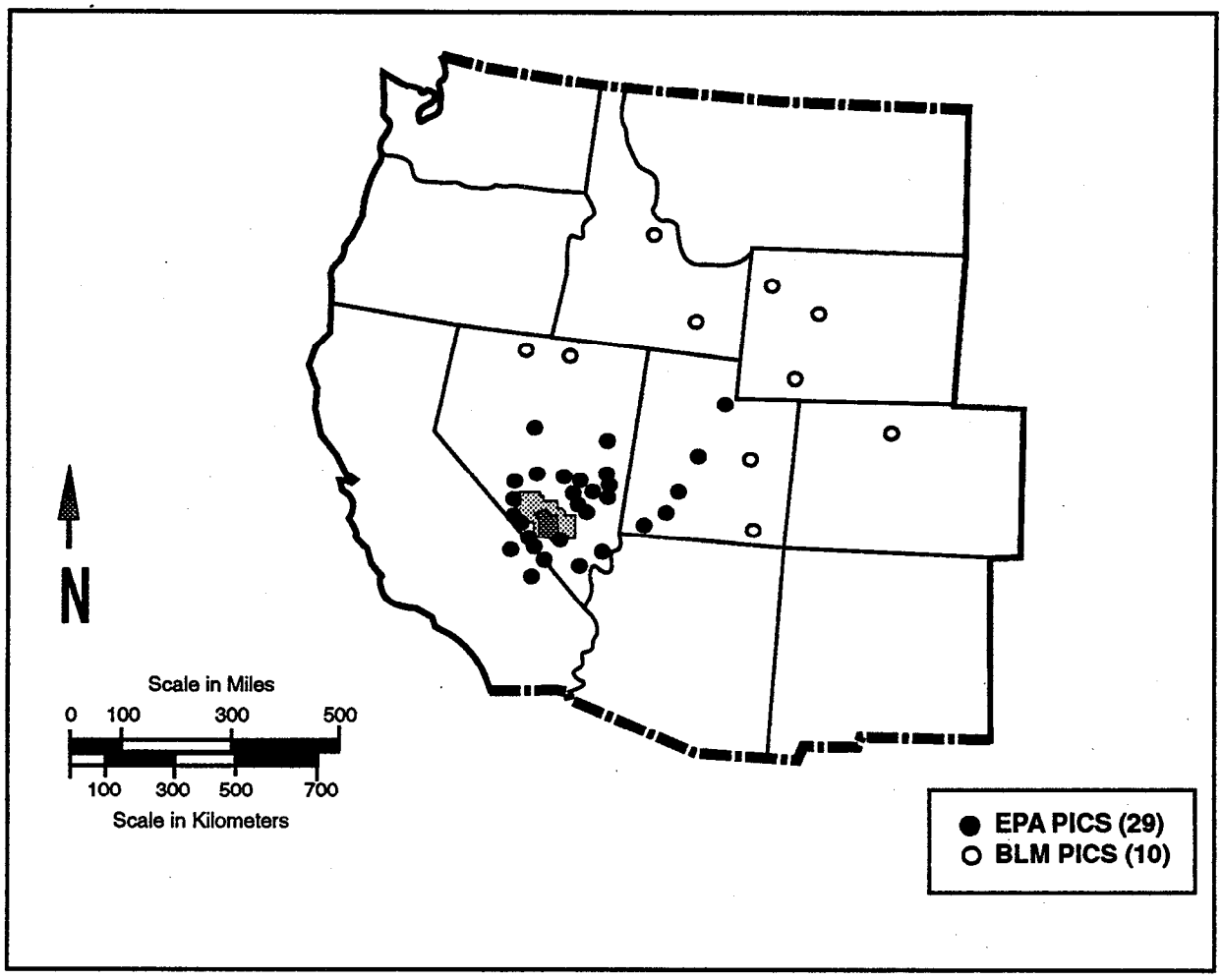

Figure 16. Pressurized Ion Chamber Network, including remote automatic weather stations operated by the Bureau of Land Management.

a PC. These weekly averages are compiled from the 4-hour averages from the telemetry data when available and from the 5-minute averages from the magnetic tapes or cards when the telemetry data are unavailable. Computer-generated reports of the PIC weekly average data are issued weekly for posting at each station. These reports indicate the current week's average gamma exposure rate, the previous week's and year's averages, and the maximum and minimum background levels in the U.S.

3.2.3 Results

The Pressurized Ion Chamber data presented in this section are based on weekly averages of gamma exposure rates from each station. Weekly averages were compiled for every station, for every week during 1991 with the exception of the weeks listed in Table 2. Data were unavailable during these weeks due to equipment failure. Data are not presented for the RAWS PICs. The RAWS data are not yet processed and maintained with the data from the other stations. Data from the RAWS will be included in future reports.

Table 3 contains the number of weekly averages available from each station and the mean, standard deviation, minimum, maximum, and median of the weekly averages. The mean ranged from 5.9 μR/hr at Las Vegas, NV to 17.6 μR/hr at Stone Cabin Ranch, NV. For each station, this table also shows the total mR/yr (calculated based on mean of the weekly averages) and the average gamma exposure rate from 1990. Total mR/yr measured

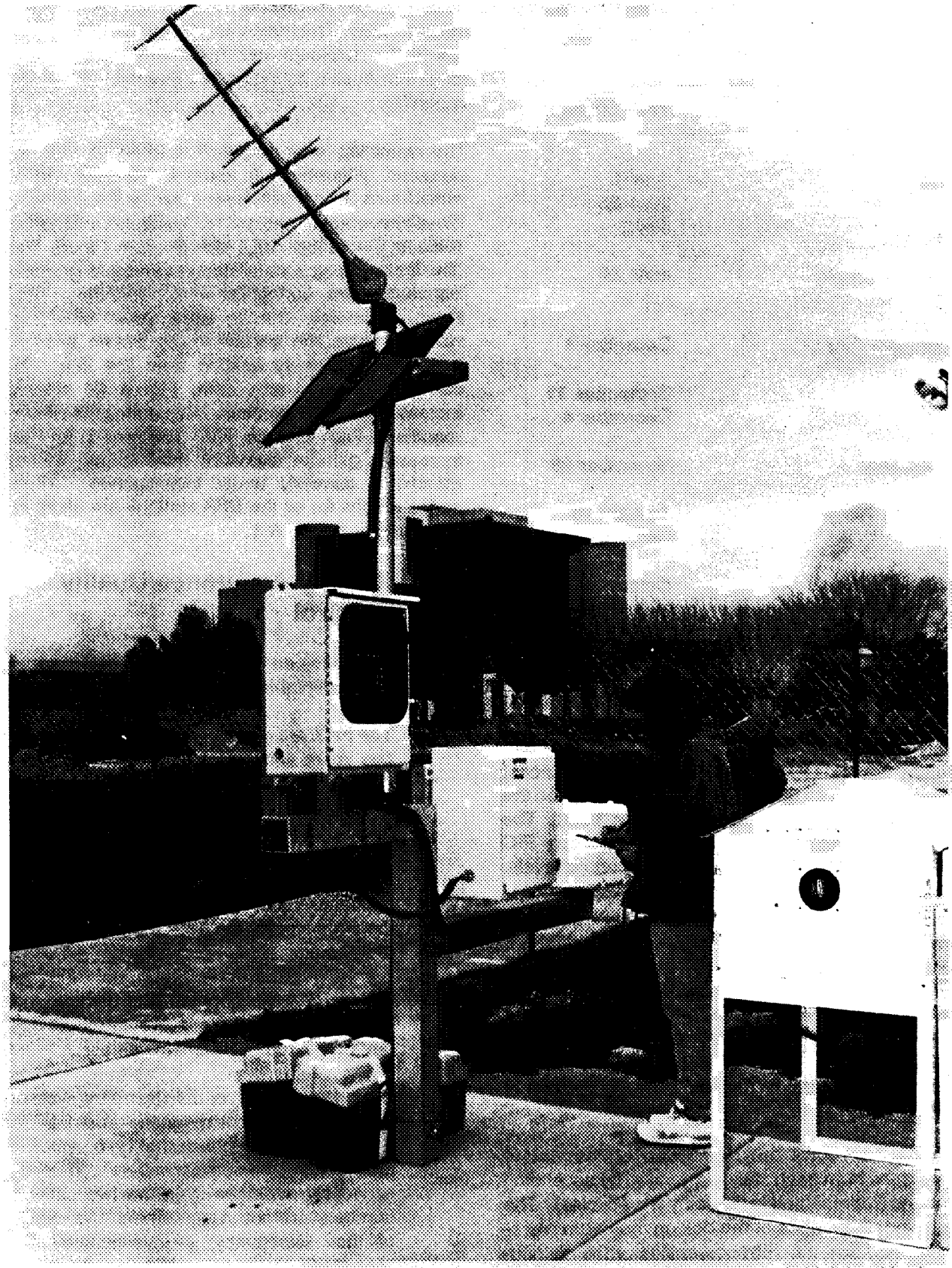

Figure 17. Pressurized ion chamber (left), gamma-rate recorder remote processor unit (right), with chart recorder, digital readout, and telemetry antenna with solar panel (top center).

Table 2. Weeks for which there were no Pressurized Ion Chamber Data collected for given stations.

Station	Week Ending
Austin	June 6 June 26 July 2
Furnace Creek	June 26 July 2
Salt Lake City	December 4
St. George	September 11 December 4
Shoshone	November 13
Terrell's Ranch	January 16 December 17
Uhalde's Ranch	October 1

by this network ranged from 52 mR/yr at Las Vegas, Nevada, to 154 mR/yr at Stone Cabin Ranch, Nevada. U.S. background levels of environmental gamma exposure rates (from the combined effects of terrestrial and cosmic sources) vary between 49 and 247 mR/yr (Committee on the Biological Effects of Ionizing Radiation, 1980). The annual exposure levels observed at each PIC station are well within the U.S. background levels.

The PIC data from 1991 are consistent with data from previous years. The greatest difference in averages between 1990 and 1991 was seen at Goldfield, NV. This was probably because the sensor unit, which was exchanged in February of 1992, was slightly underestimating the gamma exposure rate. The 1992 exposure rates at Goldfield are expected to resemble the levels seen in 1990.

Figure 18 shows the distribution of the weekly averages from each station arranged by ascending means (represented in figure by filled circles). The left and right edges of the box on the graph represent the 25th and 75th percentiles of the distribution of the weekly averages (i.e., 50% of the data falls within this region). The vertical line drawn inside the box represents the 50th percentile or the median value. The horizontal lines extend from the box to the minimum and maximum values. The data from Austin, NV show the greatest amount of variability.

The variability seen at Austin is probably due to seasonal differences in gamma exposure rates which have historically been seen at this station. Weekly averages reported for Austin from January 1988 to December 1991 are given in Figure 19. The figure shows a consistent decrease in gamma exposure rates during the winter months. This trend is possibly due to snow cover shielding radiation from the ground or to frozen ground preventing radon emanation from the soil. In contrast to the Austin data, Figure 20 shows increasing gamma exposure rates during the winter months at Twin Springs, NV. The reason for the increasing gamma exposure rates during winter months is currently under investigation. Time series graphs for all the EPA stations are given in Appendix A, Figure A-1.

3.2.4 Quality Assurance/Quality Control

Several measures are taken to ensure that the PIC data are of acceptable quality:

- The PICs are calibrated at least once every two years and usually once a year. The DOE requires that the PICs be calibrated every two years. However, the calibration is usually done annually.
- Radiation monitoring technicians place a radioactive source of a known exposure on the PICs weekly to check the performance of the units.
- Source check calibration and background exposure rate data are evaluated weekly and compared to historical values.
- Data transmitted via the telemetry system are compared to the magnetic tape data on a weekly basis to check that both systems are reporting the same numbers. Whenever weekly averages from the two sets of numbers are not in agreement, the cause of the discrepancy is investigated and corrected.

Table 3. Summary of weekly Gamma Exposure Rates as Measured by Pressurized Ion Chambers, 1991

Station	Number of Weekly Averages	Gamma Exposure Rate (μR/hr)						1990 Mean (μR/hr)
		Mean	Std. Dev.	Minimum	Maximum	Median	mR/yr	
Alamo, NV	52	13.4	0.39	12.9	14.1	13.3	118	13
Amargosa Center, NV	52	11.0	0.16	10.0	11.4	11.0	96	11
Amargosa Valley, NV	52	14.0	0.24	13.2	14.5	14.0	122	14
Austin, NV	49	17.4	2.19	12.4	20.0	18.1	152	19
Beatty, NV	52	16.3	0.38	15.6	17.0	16.0	142	17
Caliente, NV	52	14.3	0.29	13.7	15.1	14.4	126	14
Cedar City, UT	52	10.6	0.43	9.9	11.4	10.8	93	10
Complex I, NV	52	15.9	0.42	15.1	16.6	16.0	139	16
Delta, UT	52	11.9	0.33	11.0	12.4	12.0	104	11
Ely, NV	52	12.3	0.57	11.2	13.3	12.4	108	13
Furnace Creek, CA	50	10.1	0.26	9.8	11.0	10.0	89	10
Goldfield, NV	52	12.8	0.52	11.7	14.0	12.8	112	15
Indian Springs, NV	52	8.7	0.38	8.0	9.7	8.8	76	9
Las Vegas, NV	52	5.9	0.23	5.0	6.2	6.0	52	6
Medlins Ranch, NV	52	15.8	0.33	15.0	16.5	16.0	139	16
Milford, UT	52	17.4	0.49	15.8	18.2	17.4	152	17
Nyala, NV	52	12.4	0.39	11.7	13.4	12.5	109	13
Overton, NV	52	8.9	0.31	8.2	9.6	9.0	78	9
Pahrump, NV	52	7.9	0.27	7.0	8.1	8.0	69	8
Pioche, NV	52	11.8	0.35	11.0	12.5	12.0	104	12
Rachel, NV	52	15.9	1.23	13.7	18.0	16.2	139	16
Salt Lake City, UT	51	10.9	0.48	10.0	13.1	11.0	96	11
Shoshone, CA	51	11.8	0.40	11.0	12.9	11.8	103	12
St. George, UT	50	8.9	0.44	7.6	9.8	9.0	78	9
Stone Cabin Ranch, NV	52	17.6	0.66	16.3	18.8	17.4	154	17
Terrels Ranch, NV	50	15.2	0.43	14.2	16.0	15.1	133	NA
Tonopah, NV	52	16.7	0.39	15.7	17.4	16.8	146	16
Twin Springs, NV	52	16.7	0.64	15.4	18.3	16.8	146	17
Uhaldes Ranch, NV	51	17.0	0.38	16.0	17.8	17.0	149	17

Note: Multiply μR/hr by 2.6×10^{-10} to obtain $C \cdot kg^{-1} \cdot h^{-1}$.
NA = Not available.

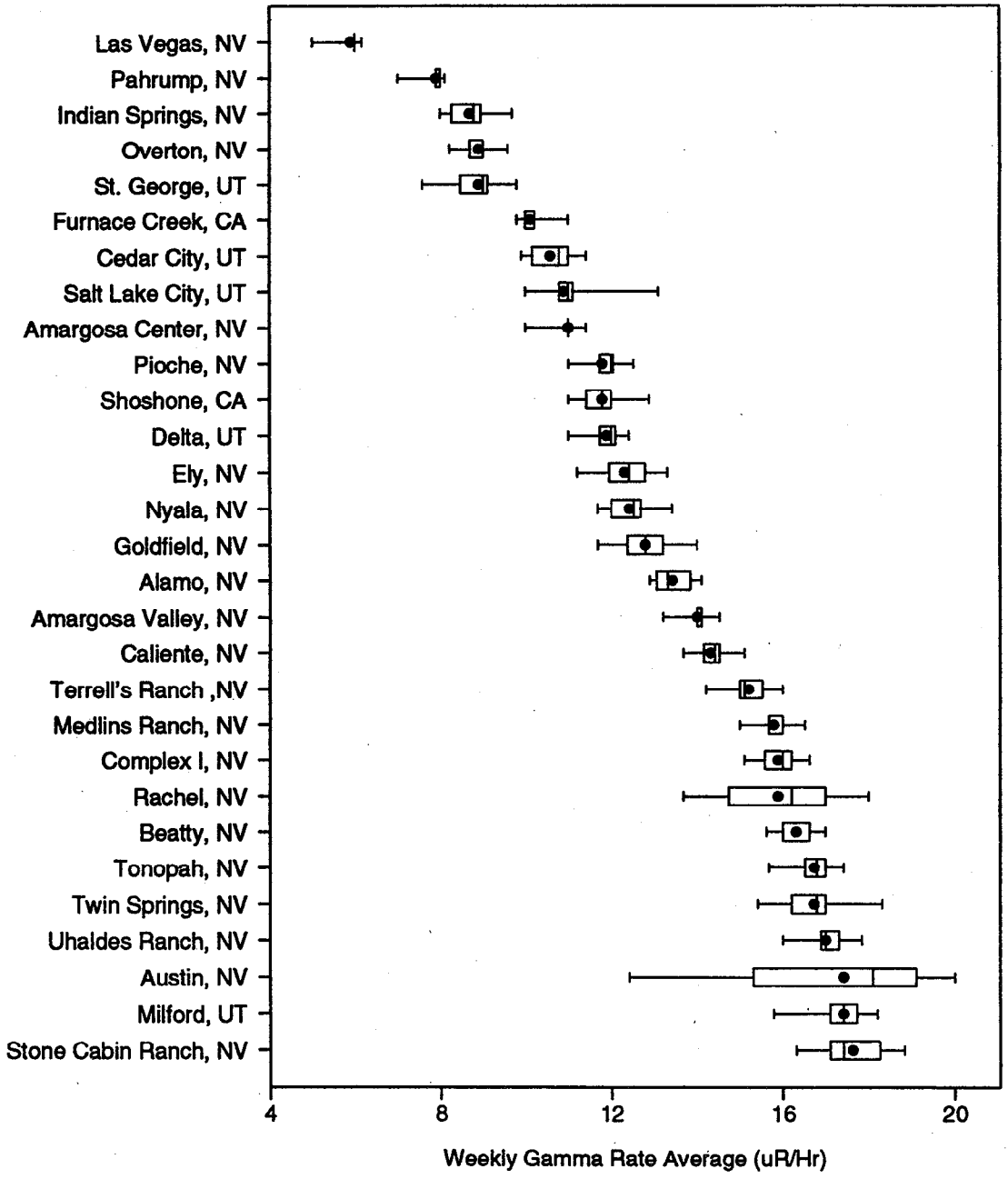

Figure 18. Distribution of weekly averages from the Pressurized Ion Chamber Data. Figure shows minimum, 25th percentile, mean, median, 75th percentile, and maximum values.

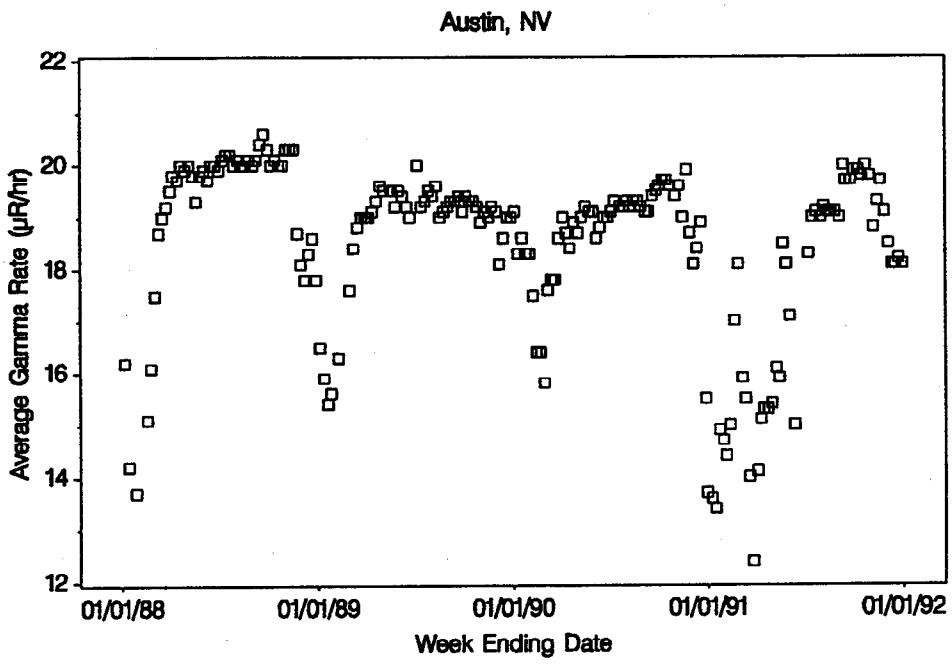

Figure 19. Weekly averages from Austin, Nevada, January 1988 to December 1991.

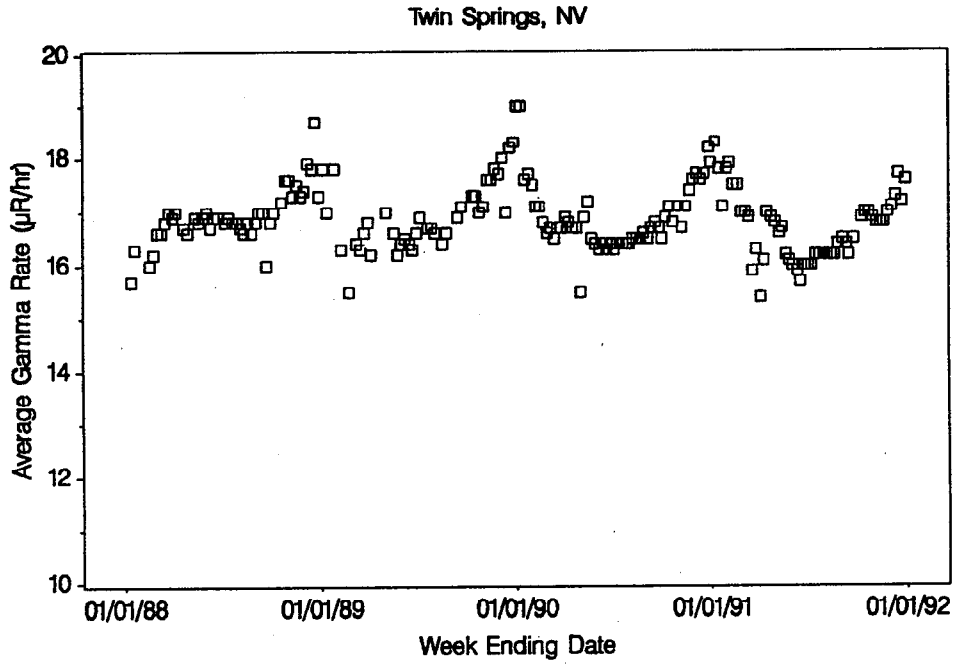

Figure 20. Weekly averages from Twin Springs, Nevada, January 1988 to December 1991.

A data quality assessment of the PIC data is given in Section 11, Quality Assurance.

3.3 Comparison of TLD Results to PIC Measurements

When calculated TLD exposures are compared with results obtained from collocated PICs (see Figure 21), a uniform under-response of TLDs was noted. This difference, which has been observed in previous years, is attributed primarily to the differing energy response of the two systems. The PICs have a greater sensitivity to lower energy gamma radiation than the TLDs and hence will normally record a higher apparent exposure. This difference is attributed to three primary factors:

(1) PICs are more sensitive to lower energy gamma radiation than are the TLDs. A review of manufacturer's specifications for the PIC and TLD systems shows their responses to be close to linear above approximately 80 and above approximately 150 keV, respectively; and

(2) The PIC units are calibrated by the manufacturer against ^{60}Co, while the TLDs are calibrated using ^{137}Cs. No adjustment is made to account for the differing energies at which the two systems are calibrated.

(3) The PIC is an exposure rate measuring device, sampling every five seconds, while the TLD as an integrating dosimeter is analyzed approximately once each quarter. Some reduction in TLD results may be due to a small amount of loss due to normal fading (studies by Panasonic have shown this loss to be minimal over the sampling period used). A six-month fade study was conducted by the EMSL-LV TLD Laboratory. This study confirmed that, over the normal sampling period, fading is negligible.

Although these known systematic differences occur, both the TLD and PIC networks serve as valuable components of an overall environmental radiation monitoring program, each with unique capabilities.

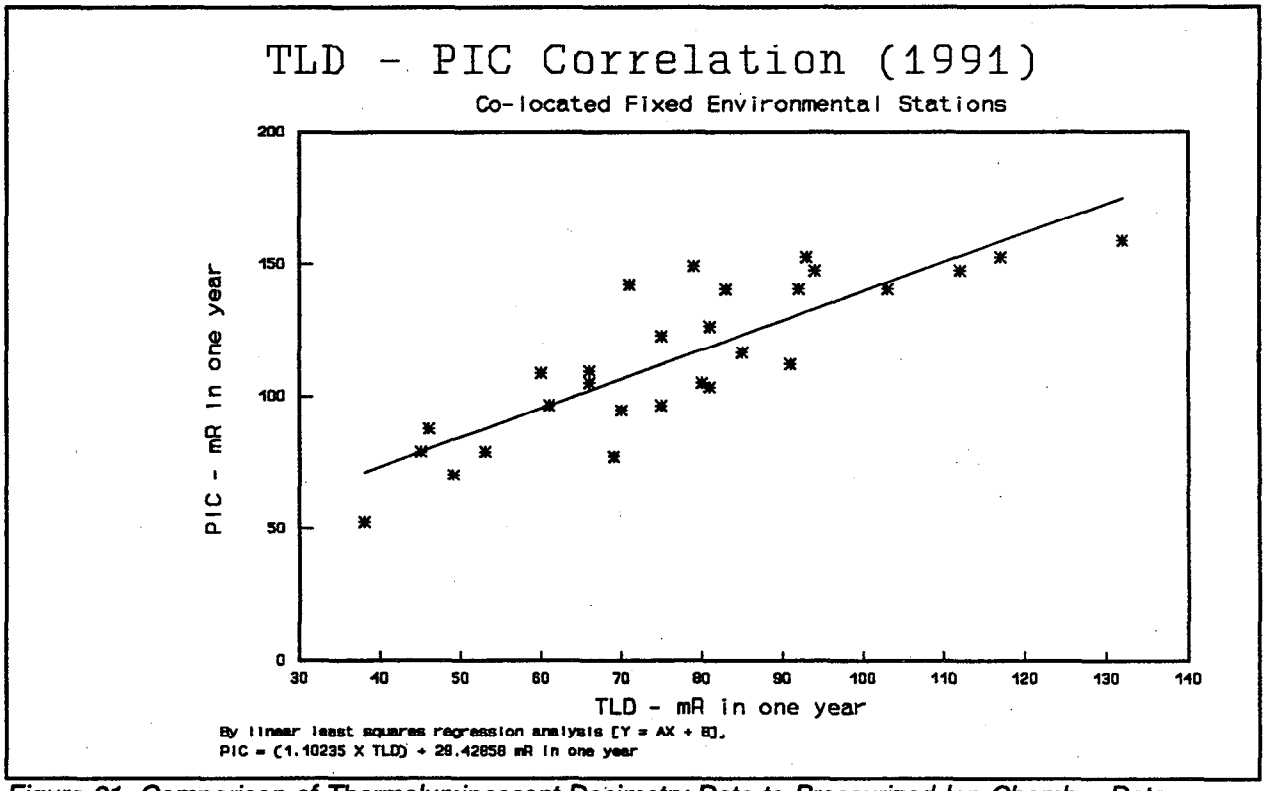

Figure 21. Comparison of Thermoluminescent Dosimetry Data to Pressurized Ion Chamber Data.

4 Atmospheric Monitoring

The inhalation of radioactive airborne particles can be a major pathway for human exposure to radiation. The atmospheric monitoring networks are designed to detect environmental radiation from NTS and non-NTS activities. Data from atmospheric monitoring can determine the concentration and source of airborne radioactivity and can project the fallout patterns and durations of exposure to man. Atmospheric monitoring networks include the Air Surveillance, Noble Gas, and Atmospheric Moisture (Tritium-in-Air) networks.

The atmospheric monitoring networks were designed to monitor the areas within 350 kilometers (210 miles) of the NTS. These continuously operating networks are supplemented by standby networks which cover the contiguous states west of the Mississippi River.

Many of the data collected from the atmospheric monitoring networks fall below the minimum detectable concentration (MDC). Averages of data presented in this chapter were calculated including measured results below MDCs. All of the data collected from the atmospheric monitoring networks reside on a VAX computer in the Sample Tracking Data Management System (STDMS).

4.1 Air Surveillance Network

4.1.1 Design

In 1991, the Air Surveillance Network (ASN) consisted of 33 continuously operating sampling stations located in areas surrounding the NTS (see Figure 22 for sampling locations). Complementing the ASN, the Standby Air Surveillance Network (SASN) consisted of 76 samplers located in contiguous states west of the Mississippi River (see Figure 23 for standby station locations). Each state had at least one standby sampler which was operated continuously for one week each quarter by local residents or state and municipal health department personnel. Locations of stations were dependent upon the availability of electrical power and the willingness of a local resident to operate the equipment at stations distant from the NTS.

Changes to the ASN during 1991 included the relocation of the Scotty's Junction station from Holloway's Ranch approximately one-half mile to Terrell's Ranch on June 24. This station, the Amargosa Valley Community Center Station (Amargosa Valley, Nevada), and the G. L. Coffer-Fleur-de-Lis Ranch (Beatty, Nevada) were reassigned to the Yucca Mountain Project ASN on December 1, 1991. High-volume air samplers were also installed and operated in May at Amargosa Valley, Nevada and from May 28 through July 8 at Rachel, Nevada. The high volume air samplers were evaluated as part of a special study. The results from the high-volume air samplers are presented in conjunction with the results from the routine air samplers.

The air sampler at each station was equipped to collect particulate radionuclides on fiber prefilters and gaseous radioiodines in charcoal cartridges. Prefilters and charcoal cartridges collected from all ASN and prefilters collected from all SASN stations received complete analyses at EMSL-LV. Charcoal cartridges are collected from the SASN stations and would be available for analyses should the need arise.

4.1.2 Procedures

At each ASN station, samples of airborne particulates are collected as air is drawn through 5 cm (2.1 in) diameter, glass-fiber filters (prefilters) at a flow rate of about 80 m^3 (2800 ft^3) per day. Filters are exchanged after sampler operation periods of about one week (approximately 560 m^3 or 20,000 ft^3).

Activated charcoal cartridges placed directly behind the filters to collect gaseous radioiodines are exchanged at the same time as the filters.

Duplicate air samples were obtained weekly from various stations. Four air samplers, which are identical to the ASN station samplers, were rotated between ASN stations for three to four week periods. The results of the duplicate field sample analyses are given in Chapter 11 as part of the data quality assessment.

The samplers used at the standby stations are identical to those used at the continuously operating stations. Results were not provided for Oregon

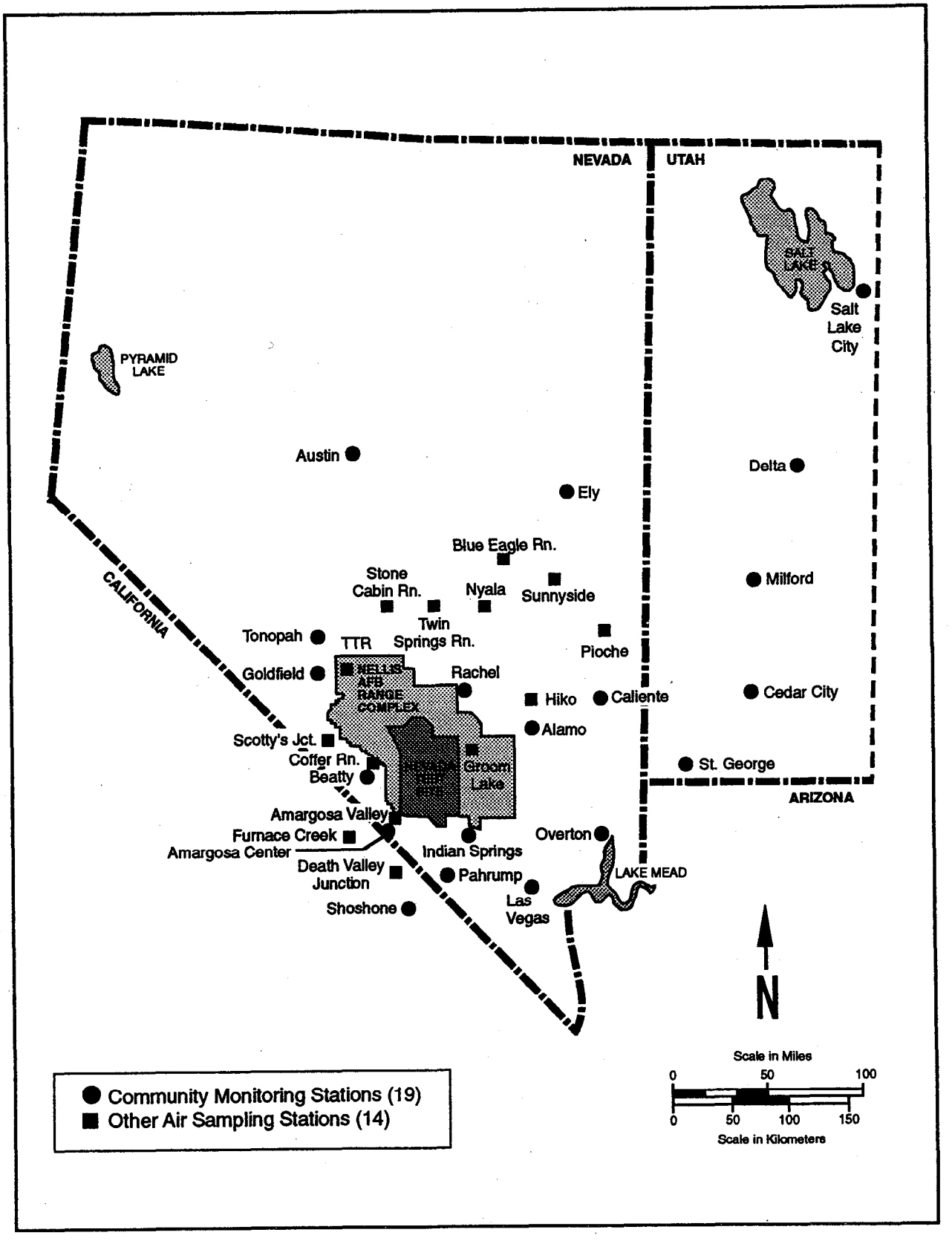

Figure 22. Air Surveillance Network stations, 1991.

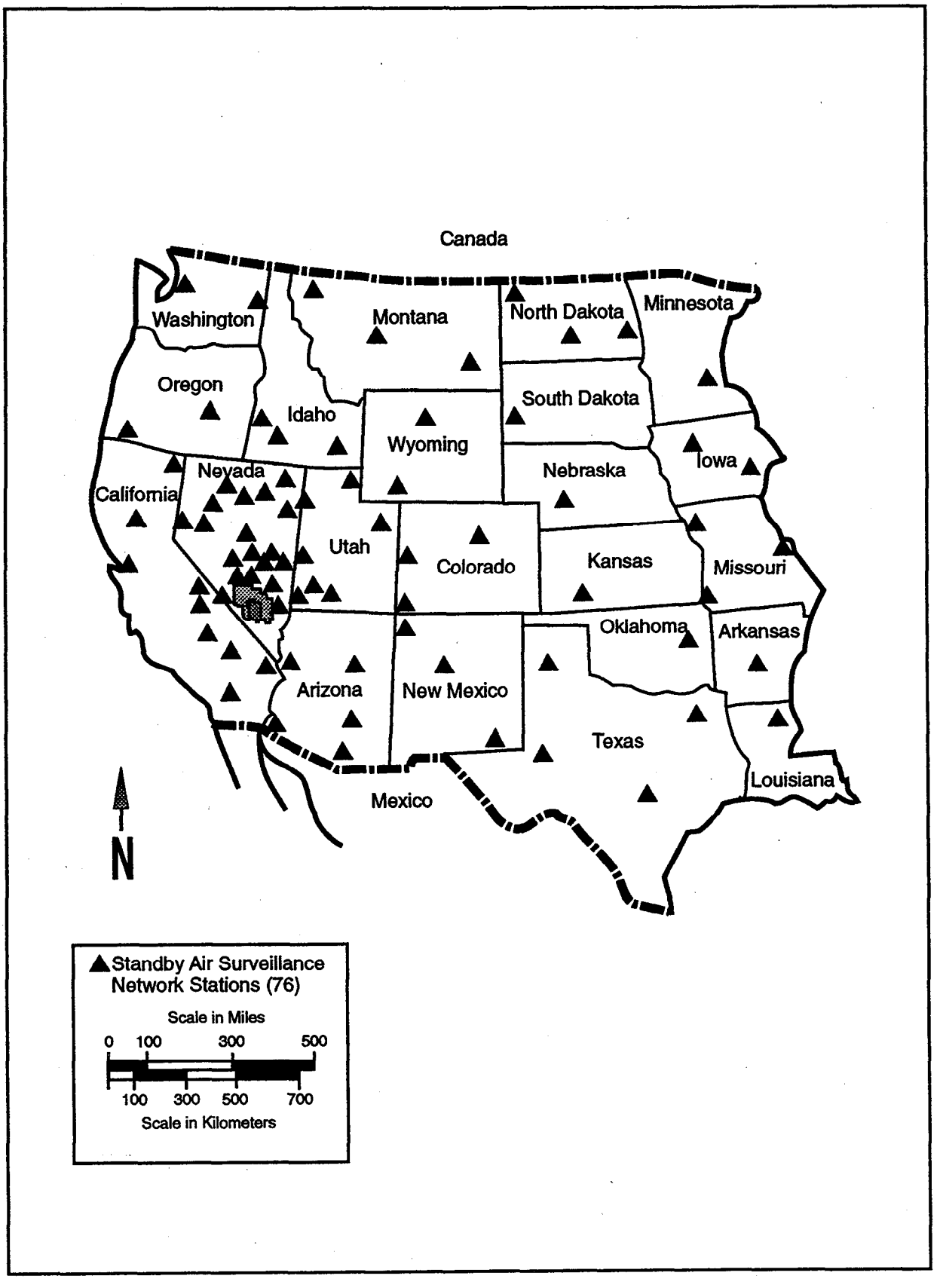

Figure 23. Standby Air Surveillance Network stations, 1991.

for the 1991 second quarter because the two SASN samplers in this state were not operated.

At EMSL-LV, both the prefilters and the charcoal cartridges are initially analyzed by high resolution gamma spectrometry. Each of the prefilters is then analyzed for gross beta activity. Gross beta analysis is performed on the prefilters 7 to 14 days after sample collection to allow time for the decay of naturally occurring radon-thoron daughter products. Gross beta analysis is used to detect trends in atmospheric radioactivity since it is more sensitive than gamma spectrometry for this purpose. Selected prefilters are then composited (combined) and analyzed for plutonium isotopes. Details of the analytical procedures are provided in Chapter 12.

In 1991, prefilters from five ASN stations were composited monthly: Alamo, Amargosa Valley, Las Vegas, and Rachel, Nevada; and Salt Lake City, Utah. Prefilters from Alamo were composited for plutonium analysis beginning in January 1991 because this station is located in the prevailing downwind direction from areas on the NTS undergoing or scheduled for remediation activities. Plutonium analysis will no longer be performed on the prefilters from Salt Lake City effective January 1992.

For the thirteen states which contain two SASN stations, the prefilters from the two stations are composited quarterly. These states are Arizona, California, Colorado, Idaho, Missouri, Montana, New Mexico, North Dakota, Oregon, Texas, Utah, Washington and Wyoming.

4.1.3 Results

The majority of all ASN and SASN prefilters and cartridges analyzed by gamma spectrometry were gamma-spectrum negligible (i.e., no gamma emitting radionuclides were detected). Naturally occurring ^{7}Be averaging 0.23 X 10^{-12} µCi/mL was the only radionuclide occasionally detected. The principal means of ^{7}Be production is from spallation (splitting) of ^{16}O and ^{14}N by cosmic rays in the atmosphere.

As in previous years, the majority of the gross beta results exceeded the MDC. Gross beta results for the ASN and the SASN are summarized in Table 4 and Appendix B, Table B-1 respectively. The average gross beta activity in 1991 (calculated as an average of the average activity from each station) was 0.0176 X 10^{-12} µCi/mL. As a comparison, the 1990 average was 0.0224 X 10^{-12} µCi/mL.

Figures 24, 25, and 26 show the distribution of the gross beta values from each ASN station for 1989, 1990, and 1991 respectively. The stations are ordered by ascending means of the data values. The mean values are represented by the filled circles (black dots). The left and right edges of the box on the graph represent the 25th and 75th percentiles of the distribution of the values (i.e., 50% of the data falls within this region). The vertical line drawn inside the box represents the 50th percentile or the median value. The horizontal lines extend from the box to the minimum and maximum values. The averages of the quarterly gross beta values from the SASN stations, arranged by ascending values, are shown in Appendix B, Figure B-1.

Figure 27 shows the distribution of the mean monthly gross beta averages from 1989 through 1991 for Alamo, Amargosa Valley, Beatty, Goldfield, Indian Springs, Rachel, and Tonopah, Nevada combined. The distribution of the data is presented by the same conventions as in Figure 24. These stations were selected for the graph as they are located in close proximity to the NTS. The figure indicates little change in regional gross beta activity over the last several years. The mean quarterly gross beta averages for the SASN stations divided into three regions are provided in Figures 28, 29, and 30. The Mid-West region included Louisiana, Texas, Arkansas, Oklahoma, Missouri, Kansas, Iowa, Nebraska, Minnesota, South and North Dakota. The Mountain region included New Mexico, Arizona, Colorado, Utah, Wyoming, Idaho and Montana. The Western region included California, Nevada, Washington and Oregon. The gross beta data from 1991 are consistent with data from previous years.

The ^{238}Pu and $^{239+240}Pu$ results from January through December 1991 for the ASN and the SASN are listed in Appendix B, Table B-2. The collection date associated with the results refers to the collection date of the last (most recent) sample included in the composite. The plutonium results from four of the samples exceeded the MDC. Two of these were very close to the MDC: ^{238}Pu results from Las Vegas, Nevada for February 25; and ^{238}Pu results from Logan and Vernal, Utah for June 27, 1991. The other two values exceeding the MDC were the $^{239+240}Pu$ results from the high-

Table 4. Gross Beta results for the Air Surveillance Network, 1991

Sampling Location	Number of days Sampled[b]	Gross Beta Concentration x 10^{-12} µCi/mL[a]			
		Maximum	Minimum	Mean	Std. Dev.
Death Valley Junction, CA	365	0.036	0.004	0.017	0.009
Furnace Creek, CA	365	0.100	0.003	0.026	0.019
Shoshone, CA	365	0.056	0.005	0.019	0.010
Alamo, NV	365	0.027	-0.011	0.015	0.006
Amargosa Valley, NV	364	0.036	0.007	0.017	0.007
Amargosa Valley Community Center, NV	336	0.042	0.004	0.019	0.008
Austin, NV	365	0.035	0.001	0.014	0.007
Beatty, NV	359	0.036	0.008	0.018	0.006
Beatty, NV Coffer-Fleur-de-Lis Ranch	335	0.032	0.001	0.013	0.007
Caliente, NV	365	0.039	0.002	0.018	0.007
Clark Station, NV Stone Cabin Ranch	365	0.033	0.006	0.016	0.006
Currant, NV Blue Eagle Ranch	365	0.050	0.006	0.018	0.009
Ely, NV	365	0.023	0.004	0.014	0.004
Goldfield, NV	358	0.032	0.007	0.017	0.006
Groom Lake, NV	345	0.033	0.006	0.017	0.006
Hiko, NV	358	0.032	0.003	0.017	0.006
Indian Springs, NV	365	0.037	0.009	0.019	0.006
Las Vegas, NV	360	0.100	0.008	0.022	0.014
Nyala, NV	358	0.041	0.007	0.013	0.007
Overton, NV	365	0.042	0.008	0.021	0.009
Pahrump, NV	365	0.043	0.005	0.018	0.008
Pioche, NV	364	0.036	0.005	0.017	0.005
Rachel, NV	365	0.053	0.005	0.019	0.009
Scotty's Junction, NV Holloway's Ranch	175[c]	0.039	0.006	0.018	0.008
Scotty's Junction, NV Terrell's Ranch	161[d]	0.037	0.003	0.022	0.008
Sunnyside, NV	365	0.040	0.002	0.015	0.008
Tonopah, NV	365	0.027	0.006	0.015	0.005
Tonopah Test Range, NV	365	0.039	0.000	0.016	0.008
Twin Springs, NV Fallini's Ranch	365	0.104	0.010	0.022	0.015
Cedar City, UT	365	0.034	0.007	0.016	0.006
Delta, UT	365	0.066	0.010	0.021	0.012
Milford, UT	365	0.059	0.003	0.021	0.011
St. George, UT	364	0.043	0.005	0.019	0.009
Salt Lake City, UT	365	0.037	0.008	0.017	0.006

[a] 10^{-12} µCi/mL = pCi/m^3; multiply µCi/mL result by 0.037 to obtain Bq/m^3.
[b] Days sampled are determined from filter change dates.
[c] Station moved to Terrell's Ranch on June 24, 1991.
[d] Station moved from Holloway's Ranch on June 24, 1991.

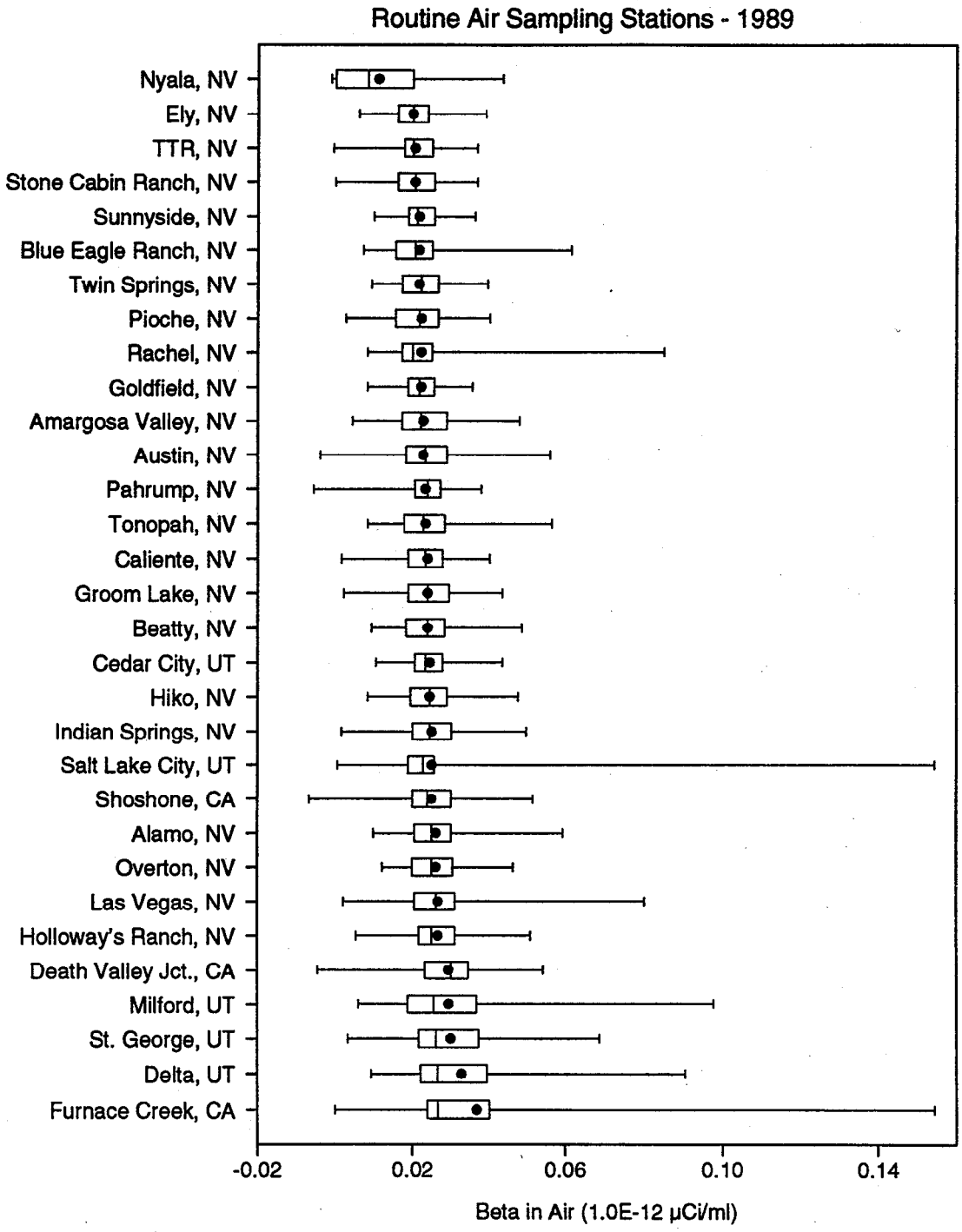

Figure 24. Distribution of gross beta values from air surveillance network stations, 1989. Figure shows minimum, 25th percentile, mean, median, 75th percentile, and maximum values.

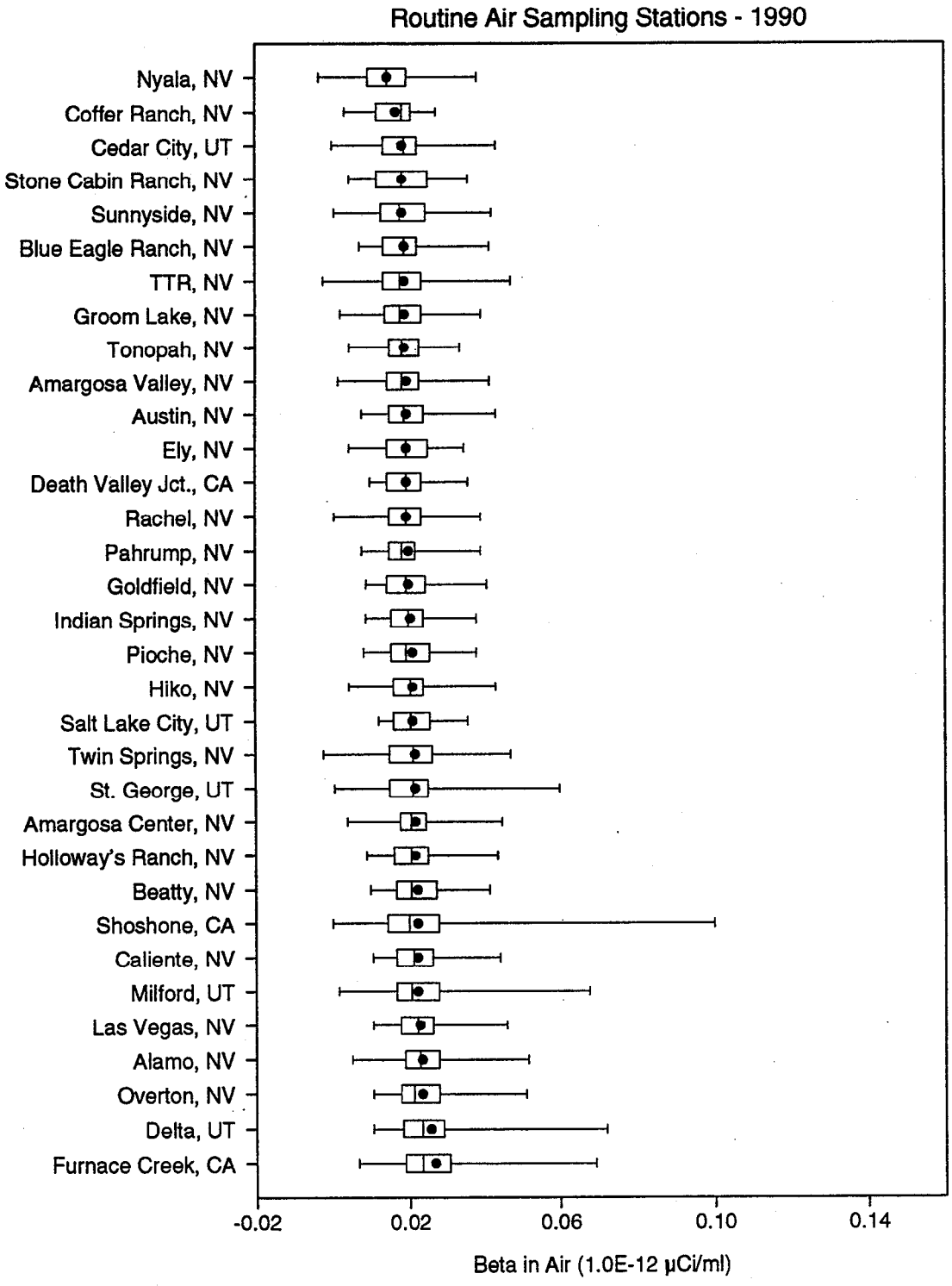

Figure 25. Distribution of gross beta values from air surveillance network stations, 1990. Figure shows minimum, 25th percentile, mean, median, 75th percentile, and maximum values.

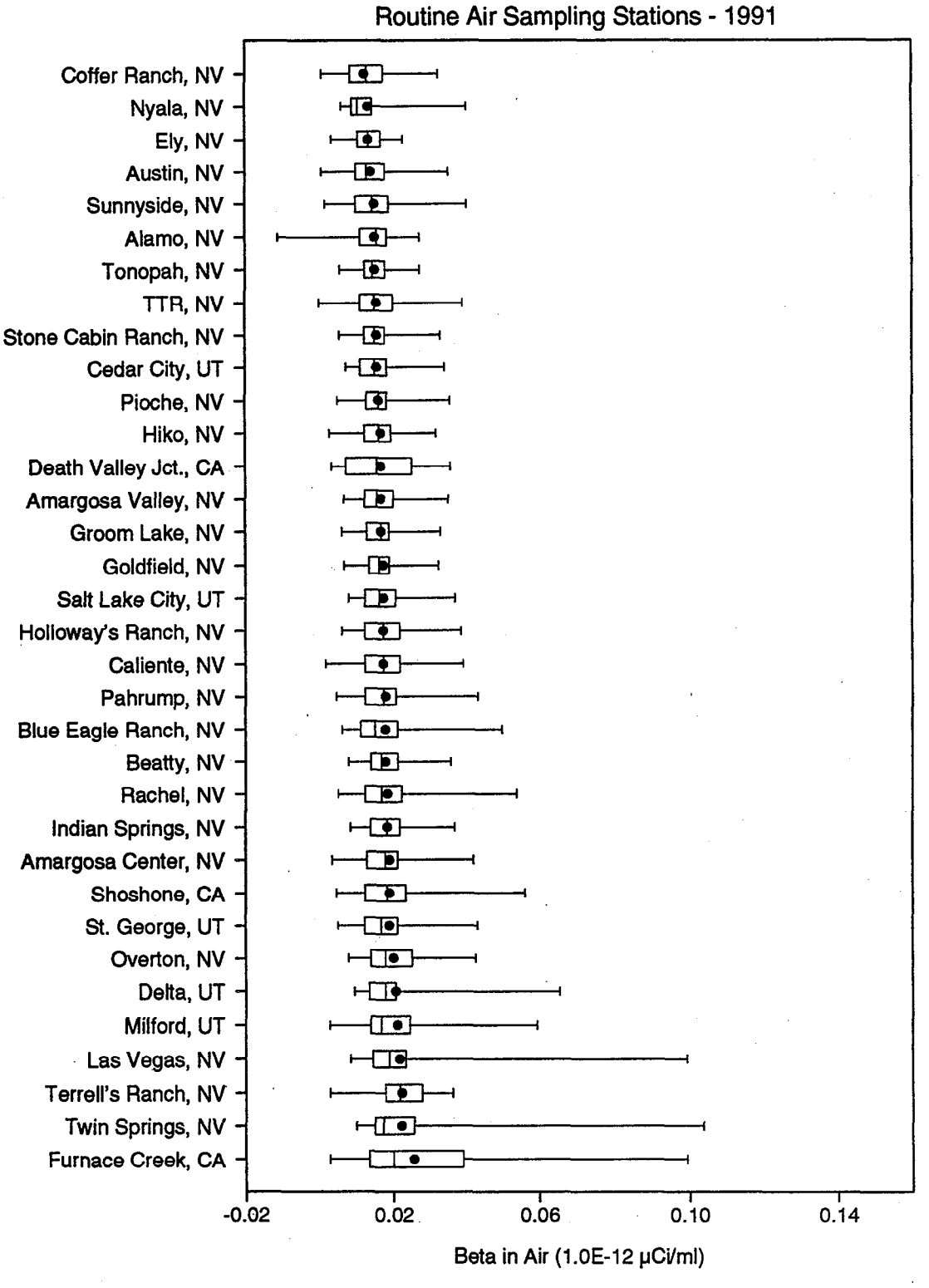

Figure 26. Distribution of gross beta values from air surveillance network stations, 1991. Figure shows minimum, 25th percentile, mean, median, 75th percentile, and maximum values.

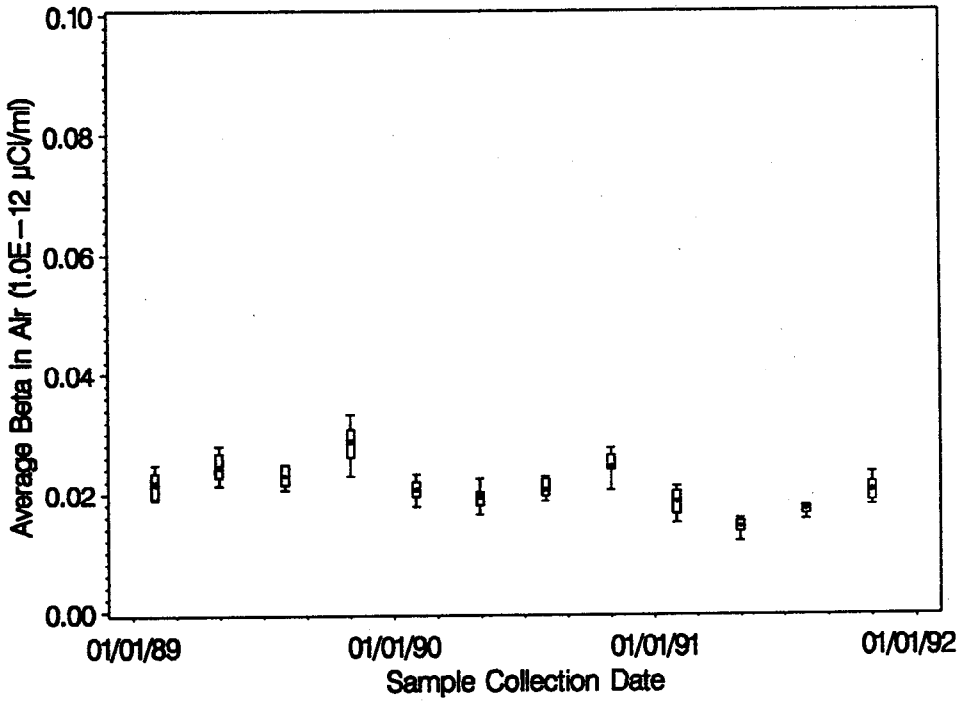

Figure 27. Distribution of the mean quarterly gross beta averages for seven stations surrounding the NTS.

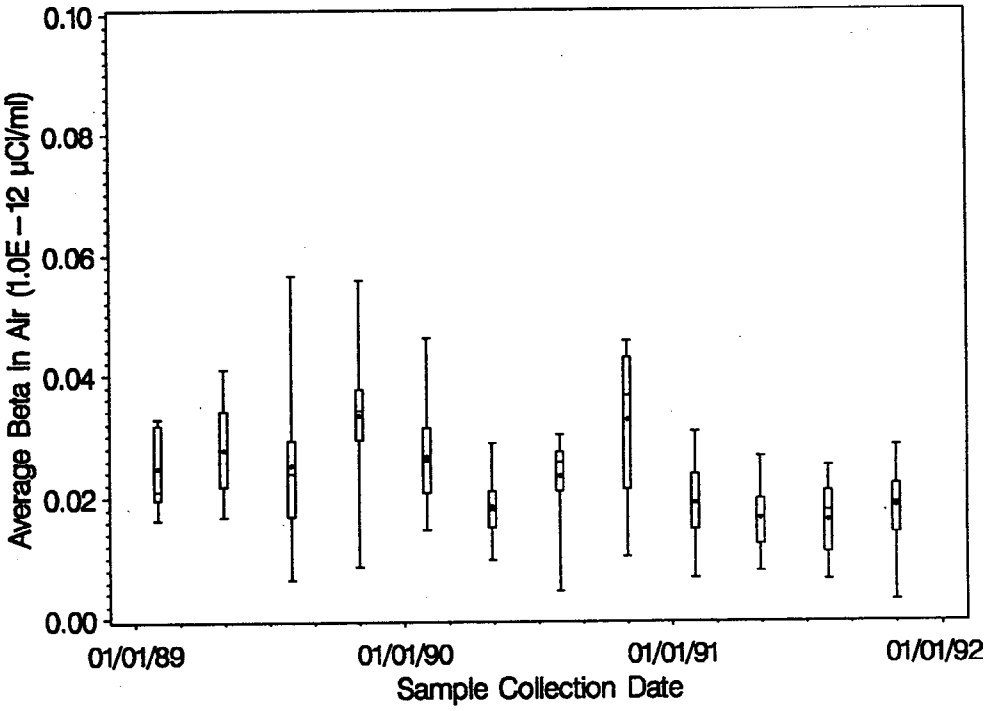

Figure 28. Distribution of the mean quarterly gross beta averages from standby stations in the midwest region.

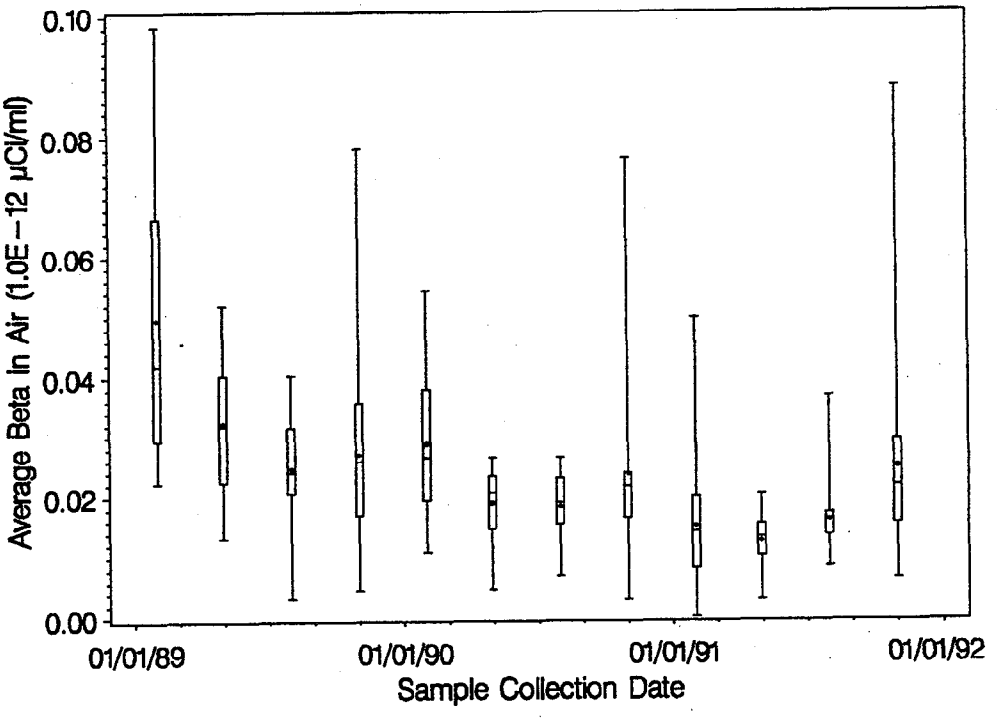

Figure 29. Distribution of the mean quarterly gross beta averages from standby stations in the mountain region.

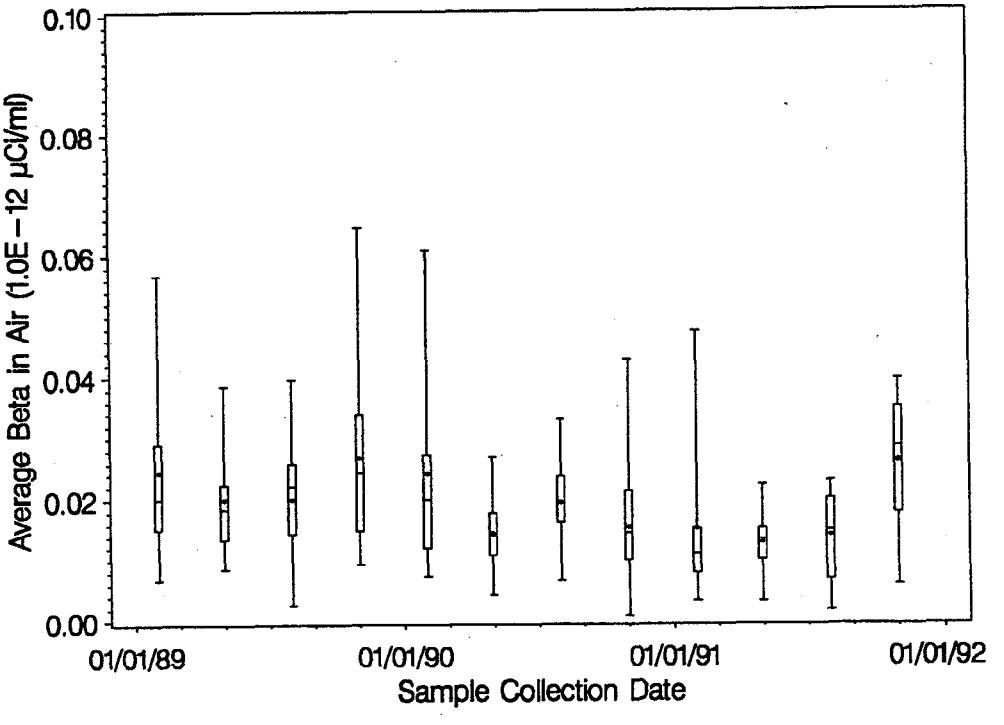

Figure 30. Distribution of the mean quarterly gross beta averages from standby stations in the western region.

volume air samples collected from Amargosa Valley on May 28; and from Rachel, Nevada on July 8, 1991. The MDCs associated with the high-volume air samples are very low compared to the MDCs associated with the routine air samplers because of the larger volume of air collected. Equipment problems (e.g., motor failure at high temperatures) with the high-volume samplers precluded any further high-volume sampling. The use of other, more durable high-volume samplers is currently being investigated. The plutonium results from 1991 are consistent with data from previous years.

4.2 Tritium In Atmospheric Moisture

4.2.1 Design

At the beginning of 1991, the tritium network consisted of 20 continuously operated and two standby stations. A number of changes were made to the tritium network in 1991: the station at Pioche, Nevada, was discontinued November 12; a new station at Fallini's Ranch, Twin Springs, Nevada, was activated November 19; and the St. George, Utah, sampler was relocated September 4 from the high school to Dixie Junior College. The following six stations were converted from routine to standby status effective with their last sampling collection periods in November, 1991: Shoshone, California; Salt Lake City and Cedar City, Utah; and Austin, Ely, and Caliente, Nevada. The two standby stations (Delta and Milford, Utah,) were not activated during 1991. Figure 31 shows the locations of the tritium network sampling stations in conjunction with the noble gas sampling network stations.

4.2.2 Procedures

A column filled with molecular sieve pellets is used to collect moisture from the air. Approximately 6 m^3 (212 ft^3) of air is drawn through the column during a typical 7-day sampling period. The water absorbed in the pellets is recovered and measured and the concentration of ^3H is determined by liquid scintillation counting. The volume of recovered water and the ^3H concentration is then used to calculate the concentration of HTO, the vapor form of tritium. HTO is the most common form of tritium encountered in the environment.

4.2.3 Results

Of the 957 samples collected in 1991, 23 were of insufficient volume to permit analysis. Six of the 934 analyses performed exceeded the MDC. Three of these six results were very close to the MDC: Shoshone, California for January 28 through February 4 was 1.70 X 10^{-12} µCi/mL with a two sigma value of 1.02 and an MDC of 1.64; Goldfield, Nevada for June 18 through June 26 was 4.53 X 10^{-12} µCi/mL with a two sigma value of 2.43 and an MDC of 3.91; Rachel, Nevada for June 17 through June 24 was 2.43 X 10^{-12} µCi/mL with a two sigma value of 1.38 and an MDC of 2.22.

Of the other three results above MDC, one sample was collected from the Salt Lake City, Utah, station for the week of March 11 through March 18 and had a result of 10.2 X 10^{-12} µCi/mL with a two sigma value of 2.57 and an MDC of 3.99. This station is adjacent to the engineering nuclear reactor complex. A telephone conversation with personnel at the reactor complex verified that tritium was present at the time of sample collection. The two other results above MDC were from samples collected from the Las Vegas, Nevada, station for the weeks of June 24 through July 1 and July 19 through July 22. These samples had results of 15.0 X 10^{-12} µCi/mL with a two sigma value of 6.78 and an MDC of 10.80, and 8.46 X 10^{-12} µCi/mL with a two sigma value of 4.07 and an MDC of 4.07 respectively. The highest value of 15.0 x 10^{-12} µCi/mL is approximately 0.01% of the concentration guide. This station is adjacent to the EPA Radioanalysis Laboratory. The HTO average concentration for the Las Vegas, Nevada, station was 1.69 X 10^{-12} µCi/mL as compared to the 1990 average of 0.42 X 10^{-12} µCi/mL. (Note: Averages include results which are less than MDC). The overall HTO network average concentration, including values below MDC, was 0.496 X 10^{-12} µCi/mL as compared to the 1990 average of 0.591 X 10^{-12} µCi/mL.

The HTO data are summarized in Table 5. The distribution of the HTO data from each station is shown in Figure 32. The graph is presented using the same conventions as in Figure 24. The 1991 tritium data appear to be consistent with data from previous years.

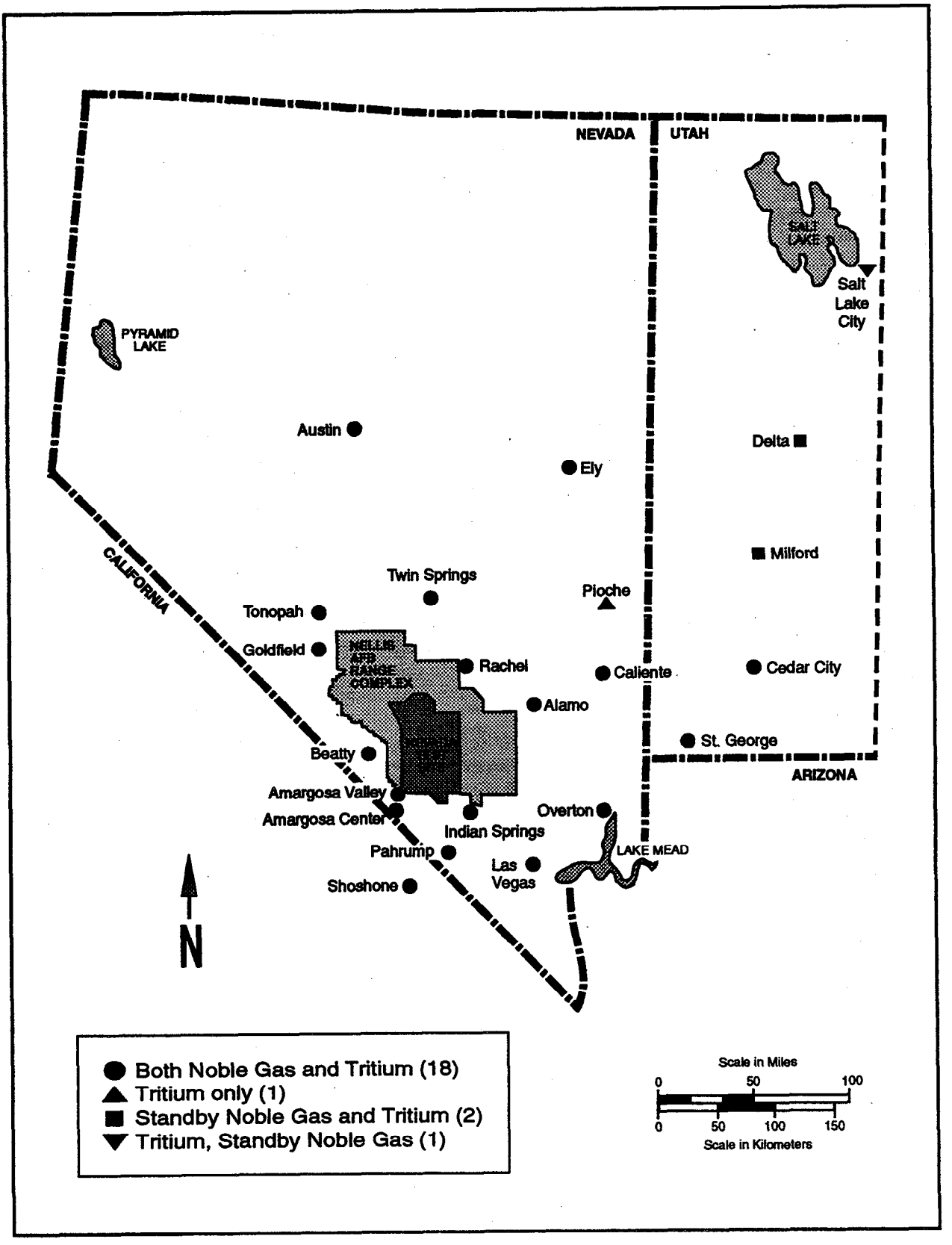

Figure 31. Offsite noble gas and tritium surveillance network sampling locations, 1991.

4.3 Noble Gas Sampling Network

4.3.1 Design

At the beginning of 1991, the Noble Gas Sampling Network consisted of 16 continuously operated and three standby stations. Noble gas samplers were added to the Amargosa Valley Community Center and to the Twin Springs, NV (Fallini's Ranch), Station in May of 1991, increasing the number of routinely operated stations to 18. Samples were collected approximately once a week from the routinely operated stations and between 1 and 4 times during the year from the standby stations. Samples collected were analyzed for ^{85}Kr and ^{133}Xe. The locations of the noble gas sampling stations are shown in Figure 31.

Noble gases may be released into the atmosphere from research and power reactor facilities, fuel reprocessing facilities, and from nuclear testing. Noble gases may also be released during drill-backs and tunnel purgings which take place after nuclear tests. Environmental levels of the xenons, with their very short half-lives, are normally below

Table 5. Atmospheric Tritium Results, 1991

Sampling Location	Number of Samples Analyzed	Concentration (10^{-12} µCi/mL)[a]				Percent of the Concentration Guide[b]
		Maximum	Minimum	Mean	Std. Dev.	
Shoshone, CA	45	2.9	-4.6	0.12	1.51	<0.01
Alamo, NV	52	7.2	-4.3	0.79	2.24	<0.01
Amargosa Center, NV	51	6.1	-9.2	0.47	2.20	<0.01
Amargosa Valley, NV	49	2.7	-3.0	0.27	1.24	<0.01
Austin, NV	46	4.0	-2.0	0.50	1.26	<0.01
Beatty, NV	51	3.8	-1.0	0.60	1.07	<0.01
Caliente, NV	46	9.7	-10.2	0.42	3.27	<0.01
Ely, NV	45	4.4	- 4.3	0.50	1.74	<0.01
Goldfield, NV	53	14.3	-7.0	0.42	2.98	<0.01
Indian Springs, NV	48	9.2	-3.7	0.86	2.37	<0.01
Las Vegas, NV	53	15.0	-2.9	1.69	2.92	<0.01
Overton, NV	53	2.8	-3.9	0.40	1.34	<0.01
Pahrump, NV	52	5.9	-3.0	0.26	1.67	<0.01
Pioche, NV	46	8.4	-3.1	0.61	2.14	<0.01
Rachel, NV	50	2.4	-4.6	0.40	1.21	<0.01
Tonopah, NV	52	11.6	-6.1	0.79	2.95	<0.01
Twin Springs, NV	6	2.2	-1.6	0.14	1.63	<0.01
Cedar City, UT	45	3.9	-7.0	0.11	1.68	<0.01
St. George, UT	51	5.2	-2.6	0.36	1.59	<0.01
Salt Lake City, UT	41	10.2	-3.3	0.97	2.16	<0.01

(a) 10^{-12} µCi/mL = pCi/m^3; multiply µCi/mL result by 0.037 to obtain Bq/m^3.

(b) The concentration guide referenced is calculated from the dose conversion factors for inhalation as listed in DOE Order 5400.5 (DOE, 1988b), adjusting to 10 mrem effective dose equivalent as required by 40 CFR 61 (CFR, 1989) for nonoccupational exposure to radionuclides in air. Concentration guides are listed in Chapter 13.

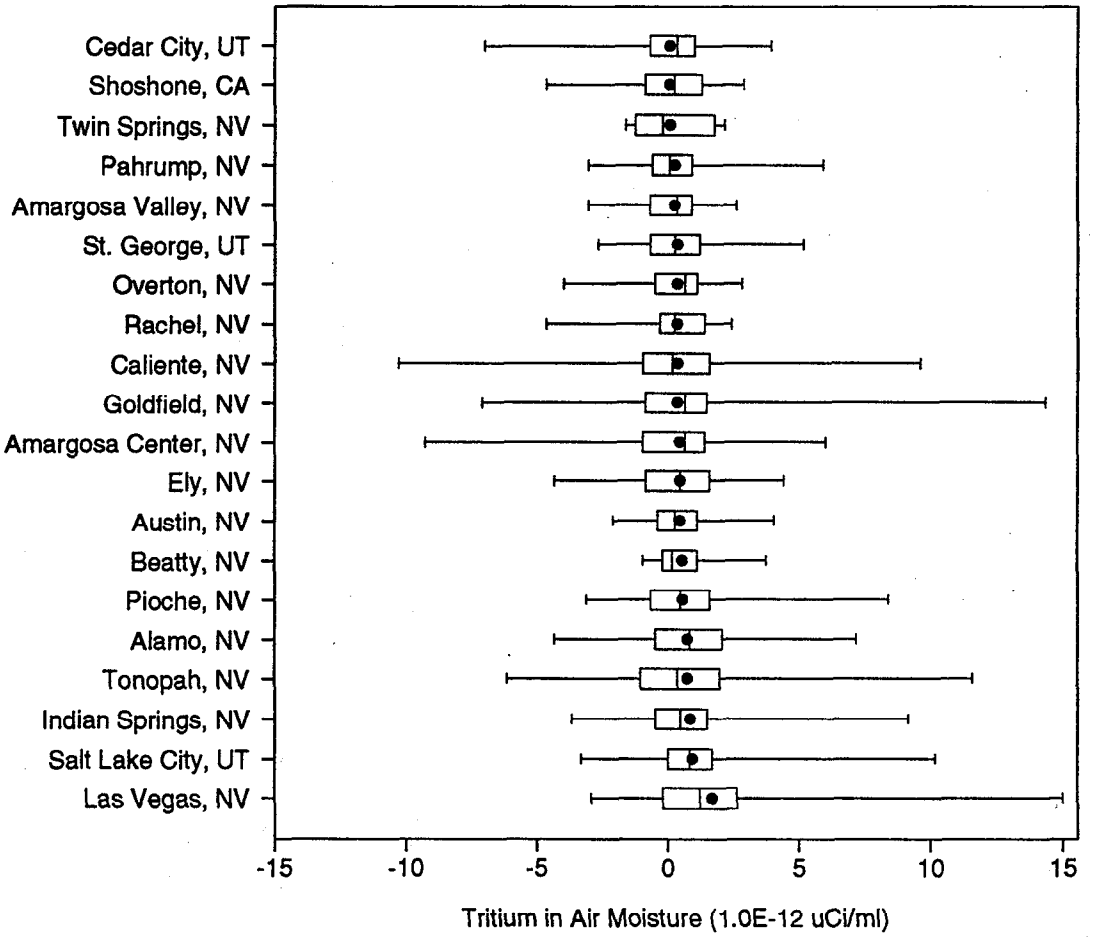

Figure 32. Distribution of HTO data, 1991. Figure shows minimum, 25th percentile, mean, median, 75th percentile, and maximum values.

the MDC. Krypton-85 disperses more or less uniformly over the entire globe because of its half-life, 10.7 years, and the lack of significant sinks (NCRP, 1975). For these reasons, ^{85}Kr results are expected to be above the MDC.

A number of changes were made to the network during 1991 in addition to installing noble gas samplers at two stations. In November, the following five stations were converted from routine to standby status: Austin, Caliente, and Ely, Nevada; Shoshone, California; and Cedar City, Utah. All of the existing noble gas samplers, used since 1974, were replaced with newly designed samplers during 1991. The first replacement was completed at the Las Vegas station in March. After a successful evaluation period, replacement was initiated at the remaining stations in May. An essential part of the development included comparison testing of the old and new model systems to ensure data comparability. The results of the comparison testing are discussed in Section 11.4.4.

4.3.2 Procedures

Noble gas samples are collected by compressing air into storage tanks (bottles). Air is continuously sampled over a 7-day period, collecting approximately 0.6 m^3 (21.2 ft^3) of air. The tanks are returned to the Radioanalysis Laboratory for analysis. The old noble gas samplers consisted of a two-bottle system; both bottles were filled simultaneously during the entire sampling period (i.e., one bottle was a duplicate of the other). The new noble gas samplers consist of a four-bottle system. One bottle is filled over the entire sampling period. The other three bottles are filled consecutively over the same sampling period in 56-hour increments. The bottle containing the sample from the entire

sampling period is the only sample which is routinely analyzed. If xenons or abnormally high levels of ^{85}Kr were detected in this sample, then the other three samples would be analyzed. For the analysis, samples are condensed at liquid nitrogen temperature. Gas chromatography is then used to separate the various radionuclides. The radioactive gases are dissolved in liquid scintillation "cocktails," then counted to determine activity.

4.3.3 Results

Table 6 summarizes the ^{85}Kr and ^{133}Xe results for all routine and standby sampling locations. The table contains the number of samples analyzed and the minimum, maximum, mean, and standard deviation of the concentrations measured at each station. The number of samples analyzed is frequently less than 52 because samples are occasionally lost in analysis, lost due to equipment failure, or the sample volume collected is insufficient to permit analysis. Some of the data losses were due to problems experienced with the new noble gas samplers. These problems are discussed further in Section 11.

All of the ^{85}Kr results exceeded the MDC and were within the range anticipated. Activities ranged from 20.5 to 32.3 pCi/m^3. This activity range is virtually identical to that observed in 1990. All of the ^{133}Xe results were below the MDC. The MDC for ^{133}Xe varied but was generally about 14 pCi/m^3. Figure 33 shows the distribution of the ^{85}Kr data from each routine sampling location arranged by ascending means. Those stations for which the status changed from routine to standby in November are included in the graph as they were routinely sampled throughout the majority of the year. The graph is presented using the same conventions as in Figure 24. The graph shows that ^{85}Kr results are very consistent among stations. Figure 34 shows the annual average ^{85}Kr value from 1972 through 1991. The graph shows that the levels of ^{85}Kr have remained consistent over the past several years. The results for ^{133}Xe are not graphed as all the values were below the MDC.

4.4 Quality Assurance/ Quality Control

General quality assurance/quality control guidelines for the atmospheric monitoring networks are as follows:

- Maintaining a current calibration decal on all field sampling and laboratory instruments.
- Maintaining a file of calibration records, control charts, and log books.
- Assigning unique sample numbers.
- Obtaining laboratory supervisor approval of all analytical results before they are entered into the permanent data base.
- Maintaining files of QA data, which includes raw analytical data, intermediate calculations, and review reports.
- Performing analysis of blanks to verify that method interferences caused by contaminants in solvents, reagents, glassware, and other sample processing hardware are known and minimized.
- Estimating analytical accuracy with performance evaluation samples. For the gamma analysis of fiber filters, spiked samples should be within ± 10% of the known value. Gross beta analysis should be within ± 20%. Plutonium analysis of internal spikes should produce results within ± 20% of the known value. For the noble gases, spiked samples should be within ± 20% of the known value.
- Estimating precision of laboratory analytical techniques and total precision for the entire system (both analytical and sampling error) using replicates. Field duplicate air samples as well as internal laboratory replicates are analyzed for the ASN. Only internal laboratory replicates are analyzed for the noble gas and the HTO samples.
- Determining bias (the difference between the value obtained and the true or reference value) by participating in intercomparison studies.

Further discussion of the QA program and the data quality assessment is given in Chapter 11.

Table 6. Noble Gas Sampling Network - ^{85}Kr and ^{133}Xe Results, 1991

Station Name	# of Samples	Minimum	Maximum	Mean	Std. Dev.
		^{85}Kr Concentration (pCi/m^3)			
Alamo, NV	44	22.4	30.7	26.26	1.99
Amargosa Center, NV	24[a]	24.0	31.0	27.46	2.16
Amargosa Valley, NV	42	23.5	30.2	26.55	1.73
Austin, NV	32[b]	22.3	30.9	26.52	2.25
Beatty, NV	52	22.2	30.9	26.32	1.92
Caliente, NV	37[b]	21.9	29.7	25.85	1.85
Cedar City, UT	33[b]	22.4	29.2	25.96	1.82
Delta, UT	4[c]	25.0	30.0	27.28	1.92
Ely, NV	38[b]	21.3	31.1	26.30	2.03
Goldfield, NV	51	22.6	31.1	26.99	1.96
Indian Springs, NV	48	20.8	31.0	26.78	2.02
Las Vegas, NV	45	22.3	31.0	26.83	1.98
Milford, UT	3[c]	22.5	28.3	26.17	3.19
Overton, NV	53	21.2	32.3	26.44	2.08
Pahrump, NV	46	21.3	30.7	26.50	2.14
Rachel, NV	45	21.6	30.5	26.82	1.95
Salt Lake City, UT	1[c]	23.8	23.8	23.80	N/A
Shoshone, CA	38[b]	20.5	28.9	25.86	2.00
St. George, UT	46	21.1	30.2	26.16	2.26
Tonopah, NV	46	20.9	30.6	26.22	2.15
Twin Springs, NV	28[a]	21.5	30.1	26.76	1.90
		^{133}Xe Concentration (pCi/m^3)			
Alamo, NV	45	-12.40	12.70	-1.14	5.65
Amargosa Center, NV	26[a]	-13.00	16.00	-2.37	6.51
Amargosa Valley, NV	41	- 7.29	4.10	-1.36	3.03
Austin, NV	32[b]	-19.20	9.50	-2.06	6.02
Beatty, NV	52	-13.60	7.06	-0.88	4.33
Caliente, NV	37[b]	-20.90	13.40	-2.51	7.21
Cedar City, UT	33[b]	-13.90	5.52	-2.23	4.97
Delta, UT	4[c]	6.2	10	8.50	1.46
Ely, NV	38[b]	-18.90	12.40	-1.39	6.64
Goldfield, NV	51	-11.40	9.75	-0.86	4.26
Indian Springs, NV	49	-6.88	5.29	-0.64	3.12
Las Vegas, NV	47	-7.55	13.90	-0.84	3.71
Milford, UT	3[c]	-6.68	8.93	-1.15	8.74
Overton, NV	53	-9.70	13.40	-1.48	4.30
Pahrump, NV	47	-7.88	4.30	-1.42	3.14
Rachel, NV	46	-15.00	15.00	-1.08	5.72
Salt Lake City, UT	1[c]	-1.63	-1.63	-1.63	N/A
Shoshone, CA	39[b]	-9.18	3.81	-1.48	3.44
St. George, UT	49	-12.40	14.40	-2.16	4.49
Tonopah, NV	46	-13.80	7.20	-1.41	4.64
Twin Springs, NV	27[a]	-15.30	5.91	-2.56	5.72

[a] Installed in May 1991
[b] Standby status as of November 1991
[c] Standby Stations

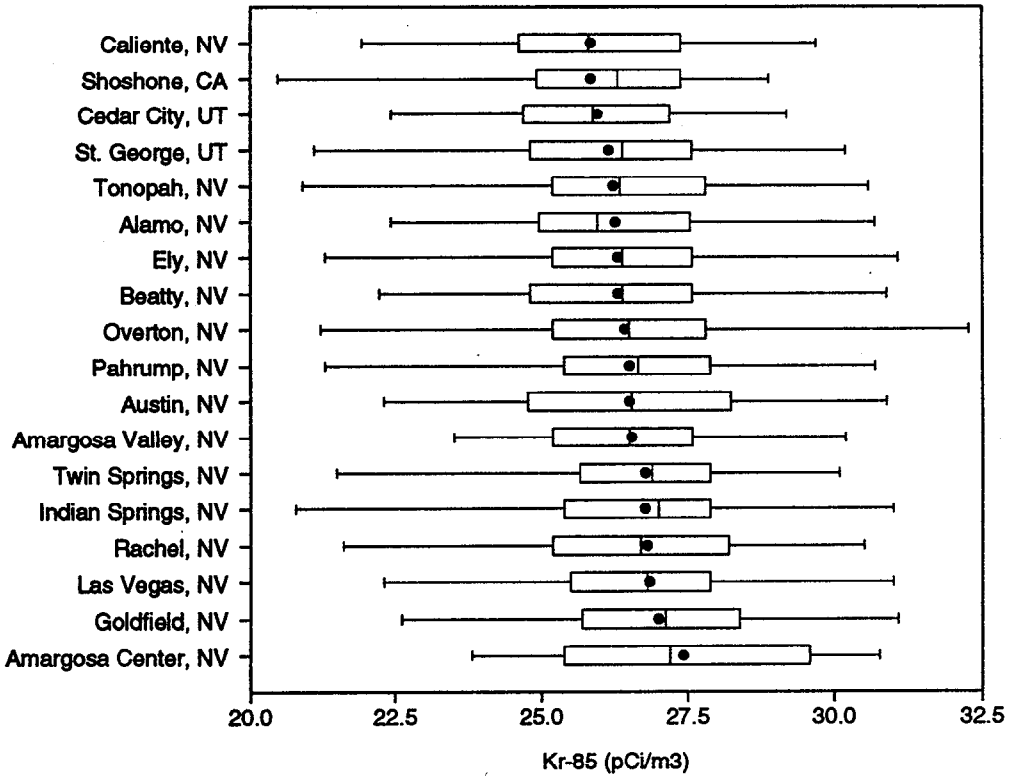

Figure 33. Distribution of krypton data from routine sampling stations, 1991. Figure shows minimum, 25th percentile, mean, median, 75th percentile, and maximum values.

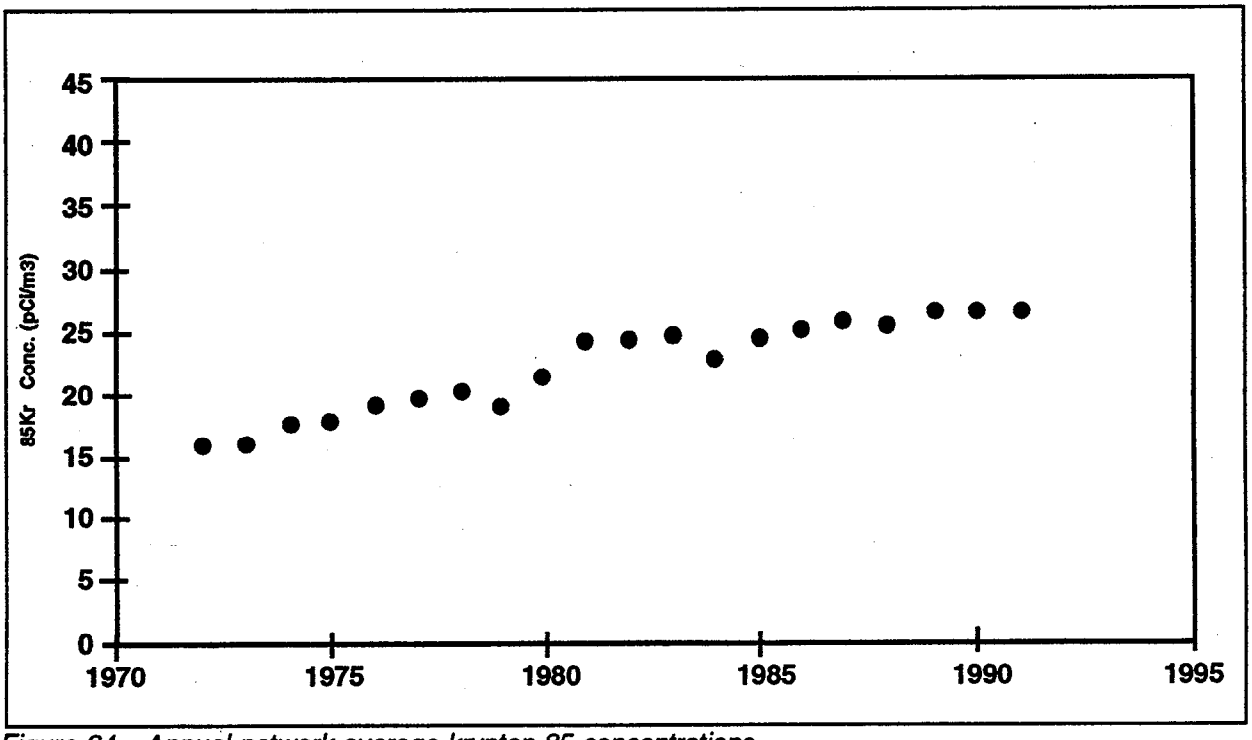

Figure 34. Annual network average krypton 85 concentrations.

5.0 Foodstuffs

Ingestion is one of the critical transport pathways for radionuclides to humans. Food crops may absorb radionuclides from the soil in which they are grown. Radionuclides may be found on the surface of fruits and vegetables from atmospheric deposition, resuspension, or in particles of soil adhering to vegetable surfaces. Weather patterns, especially precipitation, can affect soil inventories of radionuclides. Grazing animals ingest radionuclides which may have been deposited on forage grasses and, while grazing, ingest soil which may contain radionuclides.

Certain organs in the grazing animal, such as liver and muscle, may bioaccumulate radionuclides. These radionuclides are transported to humans by consumption of meat and meat products. In the case of milk cattle, ingested radionuclides may be transferred to milk. This is particularly true of radioiodine isotopes, which, when consumed by children, can cause significant impairment of thyroid function. Water is another significant ingestion transport pathway of radionuclides to humans.

To monitor the ingestion pathways, milk surveillance and biomonitoring networks are operated within the Offsite Radiological Safety Program (ORSP). Drinking water is monitored under the Long-Term Hydrological Monitoring Program (LTHMP), discussed in Chapter 7. The Milk Surveillance Network (MSN) includes commercial dairies and family-owned milk cows and goats representing the major milksheds within 180 miles (300 km) of the NTS. The MSN is supplemented by the Standby Milk Surveillance Network (SMSN) which includes all states west of the Mississippi. The biomonitoring network includes the animal investigation program and monitoring of radionuclides in locally grown fruits and vegetables. The biomonitoring network also includes special studies, such as collection and analysis of forage and grains. No such special studies were conducted in 1991.

5.1 Milk Surveillance Network

Milk is particularly important in assessing levels of radioactivity in a given area and, especially, the exposure of the population as a result of ingesting milk or milk products. It is one of the most universally consumed foodstuffs and certain radionuclides are readily traceable through the food chain from feed or forage to the consumer. Because dairy animals consume vegetation representing a large area of ground cover and because many radionuclides are transferred to milk, analysis of milk samples may yield information on the deposition of small amounts of radionuclides over a relatively large area. Accordingly, milk is closely monitored by EMSL-LV through the MSN and the SMSN.

5.1.1 Design

As in other networks, MSN collection locations are distributed around the NTS in those places that have family dairy cows or goats or where commercial dairies exist. MSN stations are located within a 180 mile radius of the NTS. Figure 35 shows the 23 MSN stations for which milk was collected in 1991. Samples from these stations were collected monthly.

Samples were not collected from the Susie Scott and the Jane Frayne ranches near Goldfield, Nevada in 1991 because the goats were dry. These two ranches will remain in the MSN. Three ranches were deleted from the network during 1991: McKays Ranch, Ely, Nevada (deleted in January); Twin Springs Ranch, Warm Springs, Nevada (deleted in December); and Blue Jay Springs Ranch, Blue Jay, Nevada (deleted in September). Of these three ranches, only Blue Jay Springs Ranch provided milk in 1991. Four MSN stations were added to the network in 1991: John Deer (in March) and Bar-B-Cue (in July) Ranches, Amargosa Valley, Nevada; Karen Harper property (in October), Tonopah, Nevada; and Bradshaw's Ranch (in November), Duckwater, Nevada. The SMSN consists of 115 dairies or processing plants located in all states west of the Mississippi River and is activated annually to monitor trends and ensure proper operation of the network in case of an emergency. The SMSN is activated by a written request for samples from EMSL-LV. The request is sent to the five federal Food and Drug Administration (FDA) regional offices covering the western states and to state representatives for each state. The FDA regulates

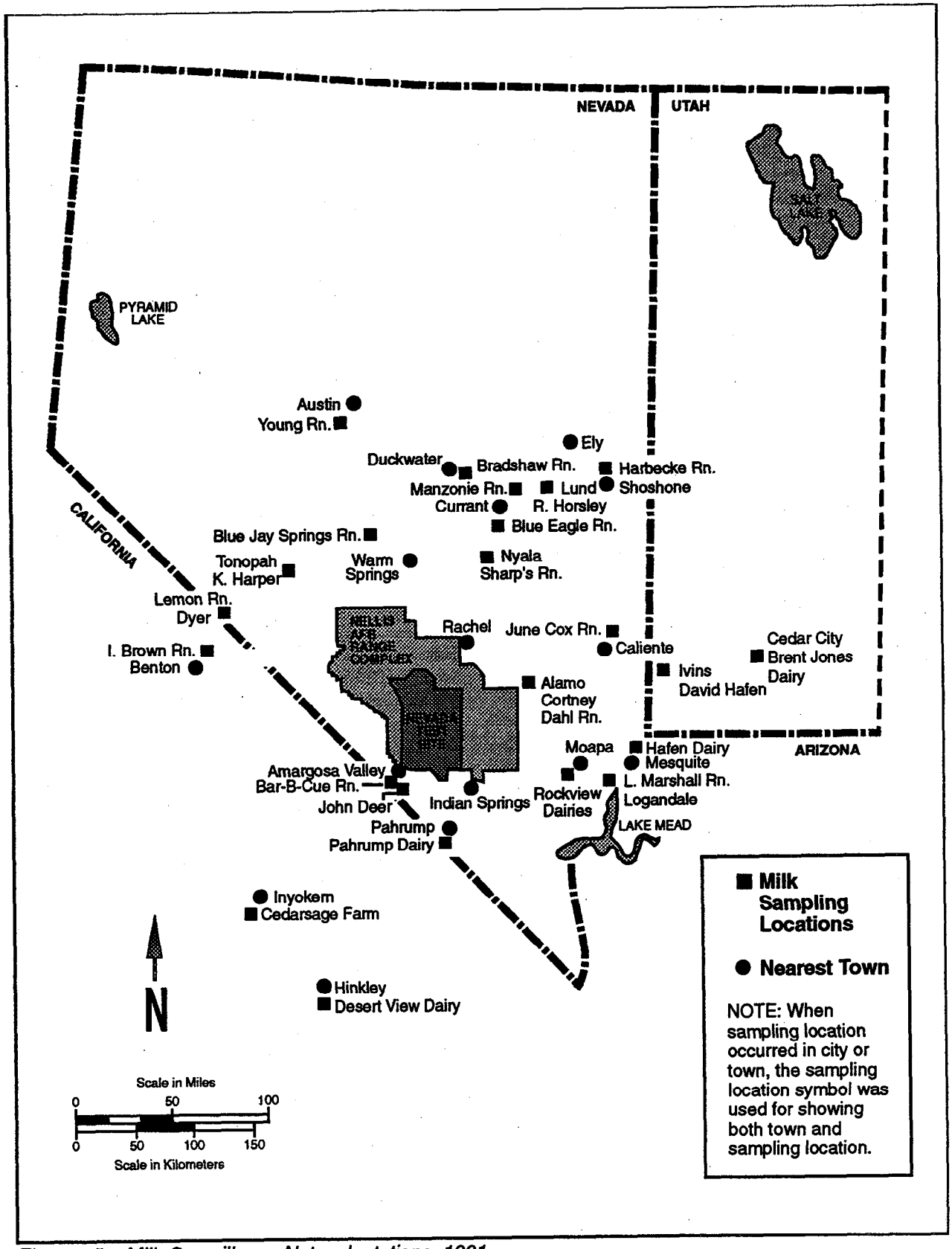

Figure 35. Milk Surveillance Network stations, 1991.

the dairy industry. The state representatives are responsible for the collection, the preservation, and the shipment of the samples to EMSL-LV for analysis. The locations of the SMSN stations are shown in Figure 36.

Six stations in Texas were added to the SMSN during 1991. Prior to 1991, Texas had not been part of the SMSN. Samples were not received from the Lompoc, California SMSN station in 1991.

5.1.2 Procedures

Raw milk is collected in 1-gallon (3.8 L) collapsible Cubitainers and preserved with formaldehyde. Routine sampling is conducted monthly for the MSN and annually for the SMSN, or whenever local or worldwide radiation events suggest possible radiation concerns, such as the Chernobyl incident or nuclear testing by foreign nations.

All samples are analyzed by high resolution gamma spectroscopy to detect gamma-emitting radionuclides. One sample per quarter from each MSN location and the annual samples from two of the SMSN locations in each western state (excluding Nevada) are evaluated by radiochemical analysis. These samples are analyzed for ^{3}H by liquid scintillation counting and for ^{89}Sr and ^{90}Sr by radiochemical purification and beta counting.

5.1.3 Results

For both MSN and SMSN samples, only naturally occurring ^{40}K averaging 2.17 gm/L was detected by gamma spectroscopy. Appendix C, Table C-1 contains the ^{3}H, ^{89}Sr, and ^{90}Sr quarterly results for the MSN samples. The ^{3}H, ^{89}Sr, and ^{90}Sr results for the SMSN are provided in Appendix C, Table C-2. A list of the SMSN station samples which received gamma spectroscopy analysis only is provided in Appendix C, Table C-3.

The majority of the ^{3}H, ^{89}Sr, and ^{90}Sr results were below the MDC. Table 7 summarizes the number of values which exceeded the MDC for ^{3}H, ^{89}Sr, and ^{90}Sr analysis for 1991 and compares them to the 1990 data for both MSN and SMSN stations. The values exceeding the MDC are also annotated in the tables listing the data in Appendix C. For the MSN, one sample result from the June Cox Ranch, Caliente, Nevada and one from the Harbecke Ranch, Shoshone, Nevada exceeded the MDC for ^{3}H. For both of these results, the MDC falls within or very close to one standard deviation of the analysis indicating the result is within expected statistical variation. For ^{89}Sr, one result from the David Hafen Ranch, Ivens, Utah was the only value which exceeded the MDC. The MDC for this result was also within one standard deviation of the analysis result. For ^{90}Sr results, two samples from the Harbecke Ranch, Shoshone, Nevada and two samples from the Karen Harper Ranch, Tonopah, Nevada exceeded the MDC. Values above MDC have been observed at the Harbecke Ranch in previous years. The higher values have generally occurred during the summer months, indicating those values may be associated with feeding patterns during those months. The Karen Harper Ranch has not been sampled in previous years so there is no historical record from that ranch. One ^{3}H result, three ^{89}Sr results, and 17 ^{90}Sr results were above the MDC for samples from the SMSN stations. This is consistent with the number of values exceeding the MDC in 1990.

Table 7. Summary of Radionuclides Detected in Milk Samples

Radionuclide	Year	Avg. Conc. (pCi/L)	# of Stations with results > MDC
Milk Surveillance Network			
^{3}H	1990	129	0
	1991	152	2
^{89}Sr	1990	0.179	0
	1991	0.303	1
^{90}Sr	1990	0.585	4
	1991	0.546	4
Standby Milk Surveillance Network			
^{3}H	1990	159	1
	1991	153	1
^{89}Sr	1990	-0.161	0
	1991	0.420	3
^{90}Sr	1990	1.324	17
	1991	1.236	17

Time series of the ^{90}Sr and ^{3}H data for 1982 through 1991 are provided in Appendix C, Figures C-1 and C-2 for those MSN stations for which there are historical data. The graphs show the result, the standard deviation, and the MDC for each analysis. The distribution of the past ten

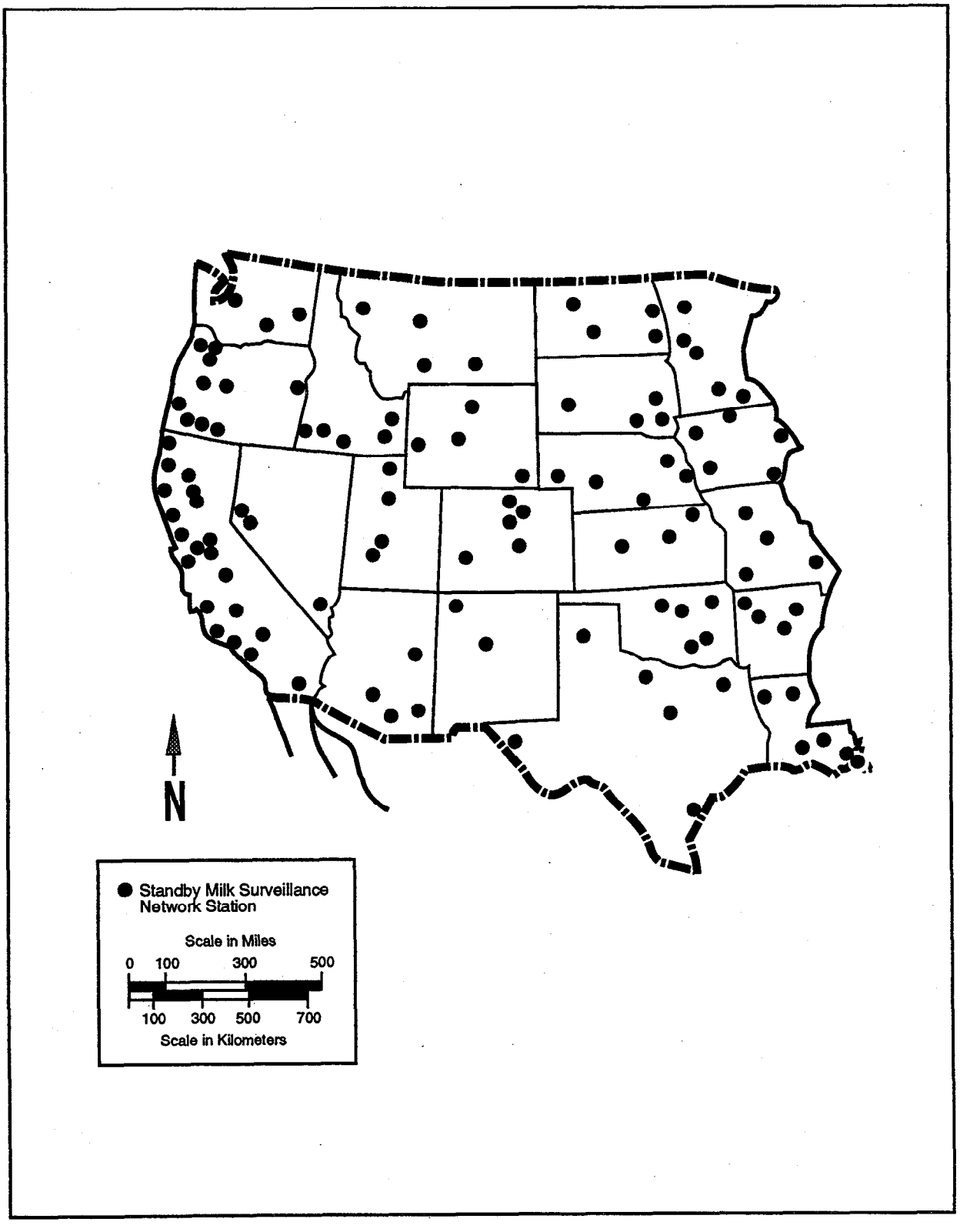

Figure 36. Standby Milk Surveillance Network stations, 1991.

years of ^{90}Sr and ^{3}H data for the SASN stations are provided in Appendix C, Figures C-3 to C-8. The stations were divided into three regions for the graphs: the Mid-West region including Louisiana, Texas, Arkansas, Illinois, Oklahoma, Missouri, Kansas, Iowa, Nebraska, Minnesota, South and North Dakota; the Mountain region including New Mexico, Arizona, Colorado, Utah, Wyoming, Idaho and Montana; and the Western region including California, Nevada, Washington and Oregon. It should be noted that the data presented in these graphs include many values which are below the MDC. Values below the MDC were reported as measured.

In conclusion, the MSN and SMSN data are consistent with previous years and are not indicative of increasing or decreasing trends. No radioactivity directly related to current NTS activities was evident.

5.1.4 Quality Assurance/Control

Procedures for the operation, maintenance and calibration of laboratory counting equipment, the control and statistical analysis of the sample and the data review and records are documented in approved SOP's. External and internal comparison studies were performed and field and internal duplicate samples obtained for precision and accuracy assessments. Analytical results are reviewed for completeness and comparability. Trends are identified and potential risks to humans and the environment are determined based on the data. The data quality assessment is given in Chapter 11.

5.2 Animal Investigation Program

The primary purpose of the animal investigation program is monitoring of the ingestion transport pathway to humans. Therefore, animals which are likely to be consumed by humans are targeted by the program. These are bighorn sheep, mule deer, and beef cattle. Occasionally, other animals are analyzed. In 1991, tissue samples from a mountain lion shot in Area 12 of the NTS were analyzed.

A veterinarian retained through EPA EMSL-LV investigates any claims of damage to animals caused by radiation. No such claims were received in 1991.

5.2.1 Network Design

The objective of the animal investigation program is to determine whether there is any potential for radionuclides to reach humans through the ingestion pathway. To that end, the program is based upon what is considered to be a worst-case scenario. Mule deer are migratory; the ranges of the herds which inhabit the NTS include lands outside the federal exclusionary area in which hunting is permitted. Therefore, it is theoretically possible for a resident to consume meat from a deer which had become contaminated with radionuclides during its inhabitation of the NTS. During the years of atmospheric testing, fission products were carried outside the boundaries of the NTS and deposited in the offsite area. Longer-lived radionuclides, particularly plutonium and strontium isotopes, are still detected in soil in the area. Some of these radionuclides may be ingested by animals residing in those areas. Cattle are purchased from ranches where atmospheric tests are known to have deposited radionuclides. The continued monitoring of bighorn sheep provides a long-term history for examination of radioactivity trends in large grazing animals.

The collected animals are not selected to be representative of average radionuclide levels in animals residing in the offsite area, nor are they designed to be necessarily representative of the herd from which they are drawn. However, selection is not random. There is an inherent nonrandom selection in hunting and the ranchers select the cattle to be sold. Because the program is not statistically based, no conclusions can or should be drawn regarding average concentrations of radionuclides in animals in the offsite area, nor should any conclusions be drawn regarding average radionuclide ingestion by humans. The collection sites for the bighorn sheep, deer, and cattle analyzed in 1991 are shown in Figure 37.

5.2.2 Sample Collection and Analysis Procedures

During the bighorn sheep season in November and December, licensed hunters in Nevada are asked to donate one leg bone and one kidney from each bighorn sheep taken. The location where the sheep was taken and any other available information are recorded on the field data form. The bone and kidney samples are weighed, sealed in labeled sample bags, and stored in a controlled freezer

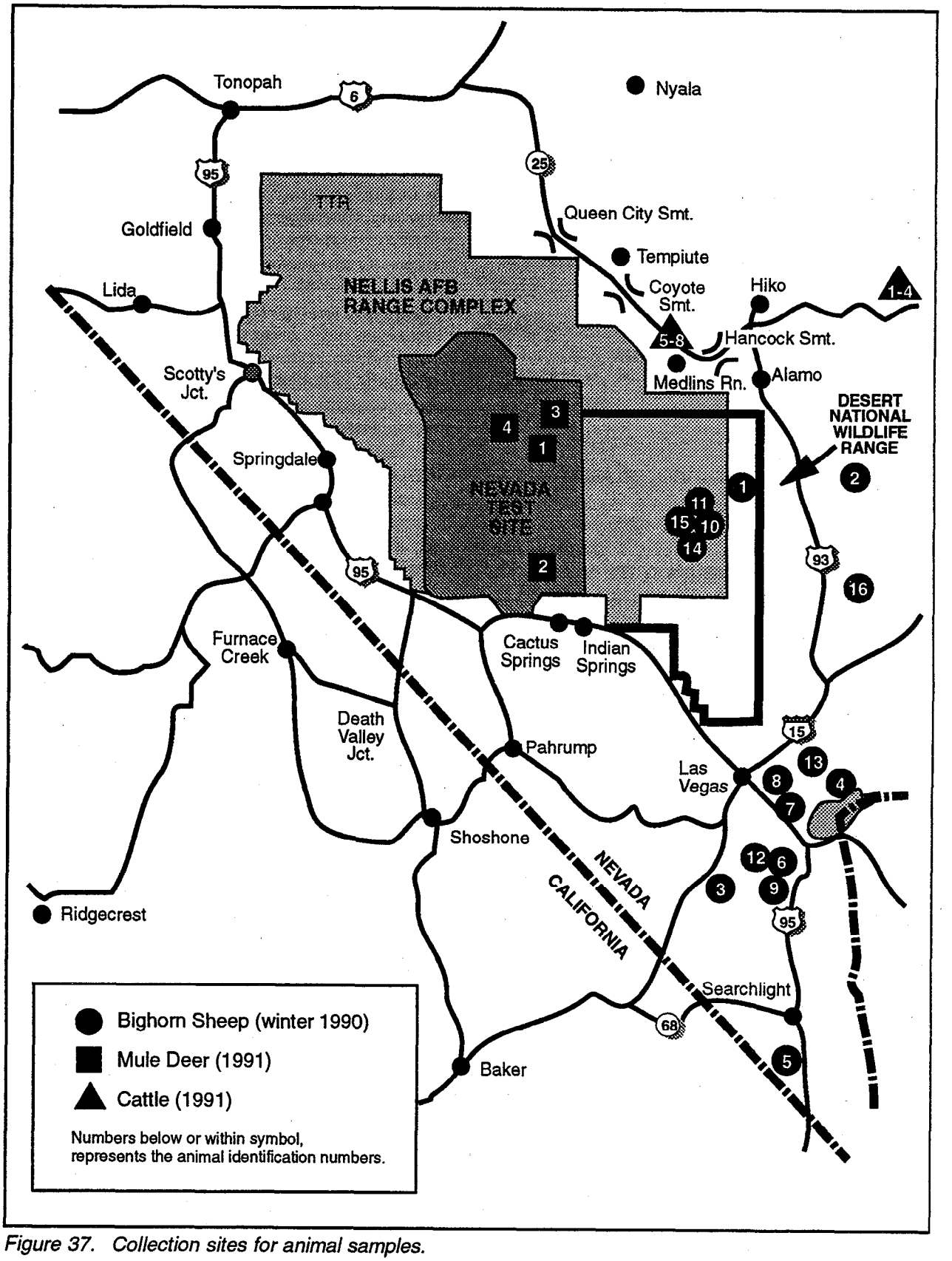

Figure 37. Collection sites for animal samples.

until processing takes place. Weights are recorded on the field data form. After completion of the hunting season, a subset of the samples is selected to represent areas around the NTS. The kidney is divided into two samples. One kidney sample is delivered to the EPA EMSL-LV Radioanalysis Laboratory for analysis of gamma-emitting radionuclides. The second kidney sample and all bone samples are shipped in a single batch to a contract laboratory for ashing. Upon completion of ashing, both the kidney and the bone samples are analyzed for plutonium isotopes and the bone samples are additionally analyzed for strontium. All results are reported in units of pCi/g of ash. The ash weight to wet weight ratios (percent ash) are also reported, to permit conversion of radionuclide activity to a wet weight basis for use in dose calculations.

Each year, attempts are made to collect four mule deer from the NTS, on a one per quarter schedule. If a deer is killed on the road, that animal is used. If road kills are not available, a deer is hunted by personnel with a special permit to carry weapons on the NTS. The deer is usually dressed in the field, with precautions taken to minimize risk of contamination. The location of the deer, weight, sex, condition, and other information are recorded on a field data form. Organs are removed, weighed, and sealed in labeled sample bags. Soft tissue organs, including lung, liver, muscle, and rumen contents are divided into two samples, one for analysis of gamma-emitting radionuclides and one which is ashed prior to analysis for plutonium isotopes. Thyroid and fetus (when available), because of their small size, are analyzed only for gamma-emitting radionuclides. Samples of blood are analyzed for gamma-emitting radionuclides and tritium. Bone samples are ashed and analyzed for plutonium isotopes and strontium. The samples requiring ashing are shipped in a single batch each quarter to a contract laboratory. Analyses are completed in the EPA EMSL-LV Radioanalysis Laboratory. Results for ashed samples are reported in units of pCi/g ash; the percent ash is also reported to permit conversion to wet weight activity for calculation of dose assessments.

Four cattle are purchased from ranches in the offsite area around the NTS each spring and another four are purchased each fall. Generally, two adult cattle and two calves are acquired in each purchase. The facility at the old EPA farm on the NTS is used for the slaughter. This facility is designed to minimize risk of contamination. As with the bighorn sheep and mule deer, sampling information and sample weights are recorded on a field data form and samples are sealed in labeled sample bags. Samples of blood and soft tissues (lung, muscle, liver, thyroid, and kidney) are analyzed for gamma-emitting radionuclides; blood is also analyzed for tritium activity. A second kidney sample and bone samples are sent to a contract laboratory for ashing. Ashed kidney samples are analyzed for plutonium isotopes; bone ash samples are analyzed for plutonium isotopes and strontium.

On occasion, other animals become available for analysis. Such was the case when a mountain lion which had been menacing the NTS Area 12 camp was shot in March 1991. As with the other animals, selected soft tissue and blood samples were analyzed for gamma-emitting radionuclides and blood samples were additionally analyzed for tritium. Selected soft tissue and bone samples were ashed by a contract laboratory and analyzed for plutonium isotopes; bone samples were additionally analyzed for strontium.

5.2.4 Sample Results for Bighorn Sheep

Licensed hunters in Nevada donated a kidney and leg bone from bighorn sheep collected in November and December of 1990. From these, a subset was selected representing areas around the NTS. The kidney samples were analyzed for gamma-emitting radionuclides and for tritium. The bone samples were ashed prior to analysis of ^{90}Sr, ^{238}Pu, and $^{239+240}Pu$. The results obtained from analysis of bighorn sheep bone and kidney are shown in Table 8. The numbers in the first column of the table refer to the numbered sample locations shown in Figure 37. Other than naturally occurring ^{40}K, neither gamma-emitting radionuclides nor tritium were detected at activities greater than the MDC in any of the kidney samples. All of the bone tissue samples, however, yielded ^{90}Sr activities greater than the MDC of the analysis. The range and median values for ^{90}Sr, shown in Table 9 and in Table 10, were similar to those obtained last year. The average ^{90}Sr levels found in animal bone ash since 1956 are shown in Figure 38. None of the bone samples yielded ^{238}Pu results greater than the MDC of the analysis and only one sample (Bighorn sheep No. 5) yielded a $^{239+240}Pu$ result greater than the MDC. This animal was collected in Area 287, south of Searchlight, Nevada. Medians and ranges of plutonium isotopes,

Table 8. Radionuclide Concentrations in Desert Bighorn Sheep Samples taken in Winter 1990

Bighorn Sheep Identification #	Percent Ash	Bone ^{90}Sr Concentration ± 1 s pCi/g Ash)	Bone ^{238}Pu Concentration ± 1 s (10^{-3}pCi/g Ash)[b]	Bone $^{239+240}Pu$ Concentration ± 1 s (10^{-3}pCi/g Ash)[b]	Kidney[a] ^{3}H Concentration ± 1 s (pCi/L)[c]
1	33	*1.8 ± 0.1	-1.3 ± 0.9	0.7 ± 1.5	-50 ± 140
2	34	*1.7 ± 0.1	0.0 ± 0.6	0.4 ± 0.7	130 ± 140
3	32	*2.0 ± 0.2	-1.3 ± 1.8	0.6 ± 1.4	-30 ± 140
4	27	*1.2 ± 0.2	1.0 ± 1.3	0.0 ± 1.0	30 ± 140
5	30	*2.0 ± 0.2	-0.4 ± 0.4	*4.5 ± 1.6	220 ± 140
6	36	*0.5 ± 0.1	0.0 ± 1.1	-1.0 ± 0.8	100 ± 140
7	33	*1.1 ± 0.1	0.6 ± 2.1	-0.6 ± 1.1	170 ± 140
8	34	*1.4 ± 0.1	0.7 ± 1.7	0.7 ± 1.7	-80 ± 140
9	32	*1.2 ± 0.1	-1.1 ± 1.1	4.5 ± 2.8	60 ± 140
10	36	*1.0 ± 0.1	0.8 ± 1.0	-0.4 ± 0.7	110 ± 140
11	34	*1.2 ± 0.1	-0.4 ± 0.4	-0.4 ± 0.4	-10 ± 140
12	35	*1.8 ± 0.1	-0.6 ± 1.8	-0.6 ± 1.0	-50 ± 140
13	34	*1.7 ± 0.1	0.0 ± 1.0	2.5 ± 1.5	NC
14	Bone sample not collected				-30 ± 140
15	Bone sample not collected				-10 ± 140
16	Bone sample not collected				150 ± 140
Median	34	1.4	0.0	0.4	30
Range	27 to 36	0.5 to 2.0	-1.3 to 1.0	-1.0 to 4.5	-80 to 220

[a] Aqueous portion of the kidney tissue.
[b] To convert pCi/g to Bq/kg, multiply the concentration by 37.
[c] To convert pCi/L to Bq/L, multiply the concentration by 0.037.
NC = Not collected.
* = greater than minimum detectable concentration.

given in Table 9 and in Table 9, were similar to those obtained in the previous year.

5.2.5 Sample Results for Mule Deer

One mule deer was obtained, either by hunting or road kill, each quarter from areas on the NTS. Collection sites are shown on Figure 37, numbered by quarter of collection. Blood samples were analyzed for gamma-emitting radionuclides and tritium. Soft tissue samples (lung, muscle, liver, thyroid, rumen contents, and fetus, when available) were analyzed for gamma-emitting radionuclides. Additionally, samples of soft tissues and bones were ashed and then analyzed for plutonium isotopes; ashed bone samples were also analyzed for ^{90}Sr. Samples of thyroid and fetus tissue were not ashed due to their small size.

The mule deer collected in the first quarter of 1991 was a pregnant female in poor condition obtained by hunting in Area 12. Analysis of blood, soft tissue, and bone samples indicated the animal had been contaminated by radioactivity, as shown in Appendix C, Table C-4. No gamma-emitting radionuclides other than naturally occurring ^{40}K were detected in soft tissues; however, $^{239+240}Pu$ was detected in all of the ashed soft tissue samples, ranging from 0.008 ± 0.003 pCi/g ash in the liver sample to 1.2 ± 0.1 Pci/g ash in the muscle sample. Concentrations of ^{238}Pu greater than the MDC of the analysis were also obtained in the lung and rumen contents samples. The bone sample also yielded 0.9 ± 0.2 pCi/g ash of ^{90}Sr. The tritium activity in the blood sample was 420,000 ± 1000 pCi/L, indicating the animal probably drank from the NTS Area 12 ponds. The area 12 containment ponds are catchment basins which contain impounded waters from tunnel test areas. All active containment ponds are restricted access areas posted with radiological warning signs.

The mule deer collected in the second quarter also showed indications of contamination (see Appendix C, Table C-4). This animal was obtained as a road kill in the southeast portion of the NTS (see Figure 37). Although the blood sample was negative for

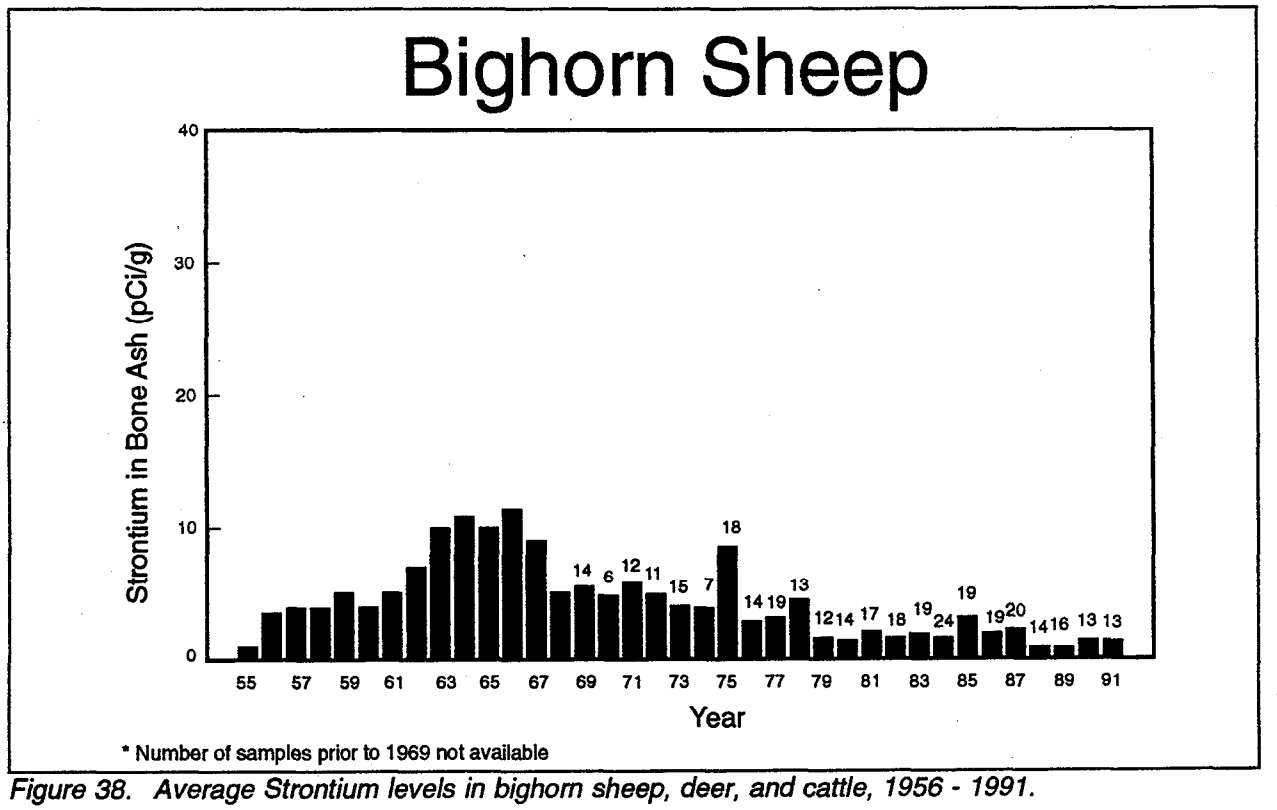

Figure 38. Average Strontium levels in bighorn sheep, deer, and cattle, 1956 - 1991.

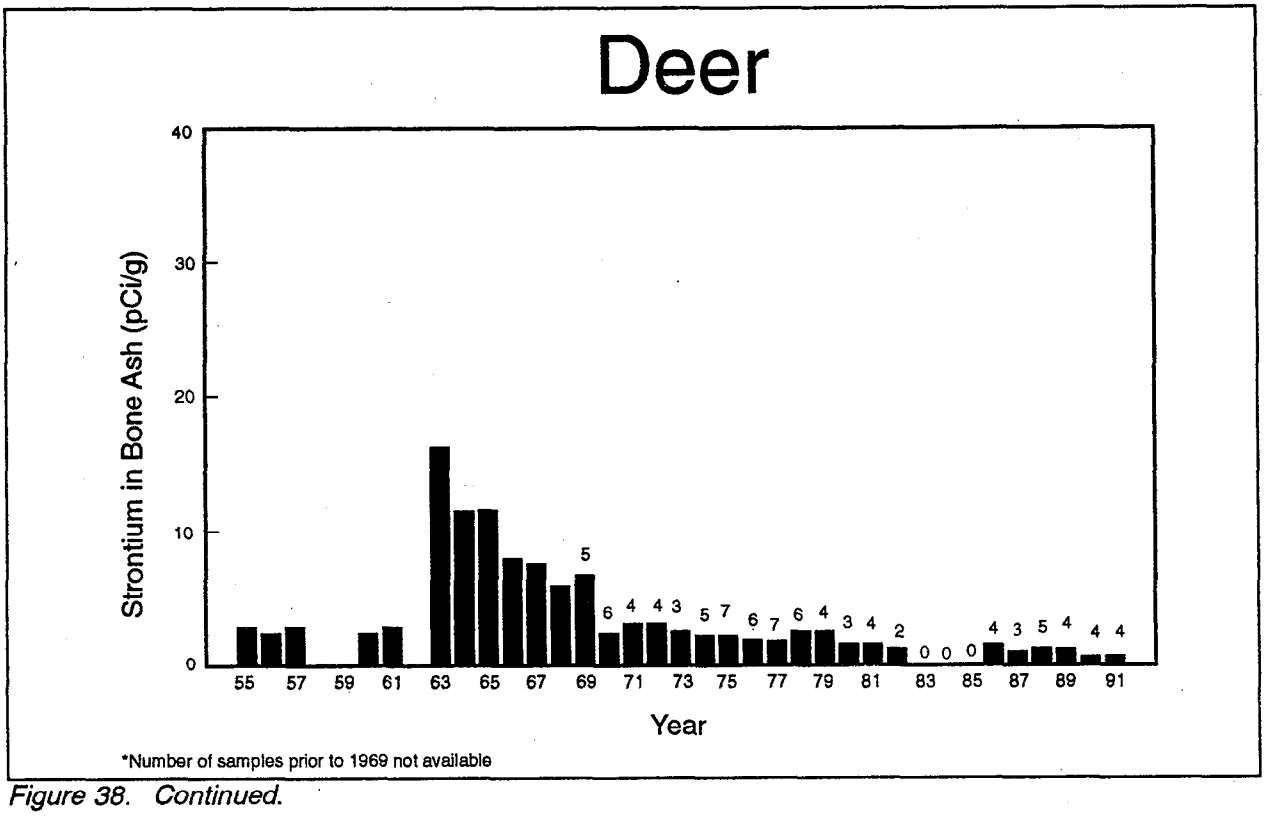

Figure 38. Continued.

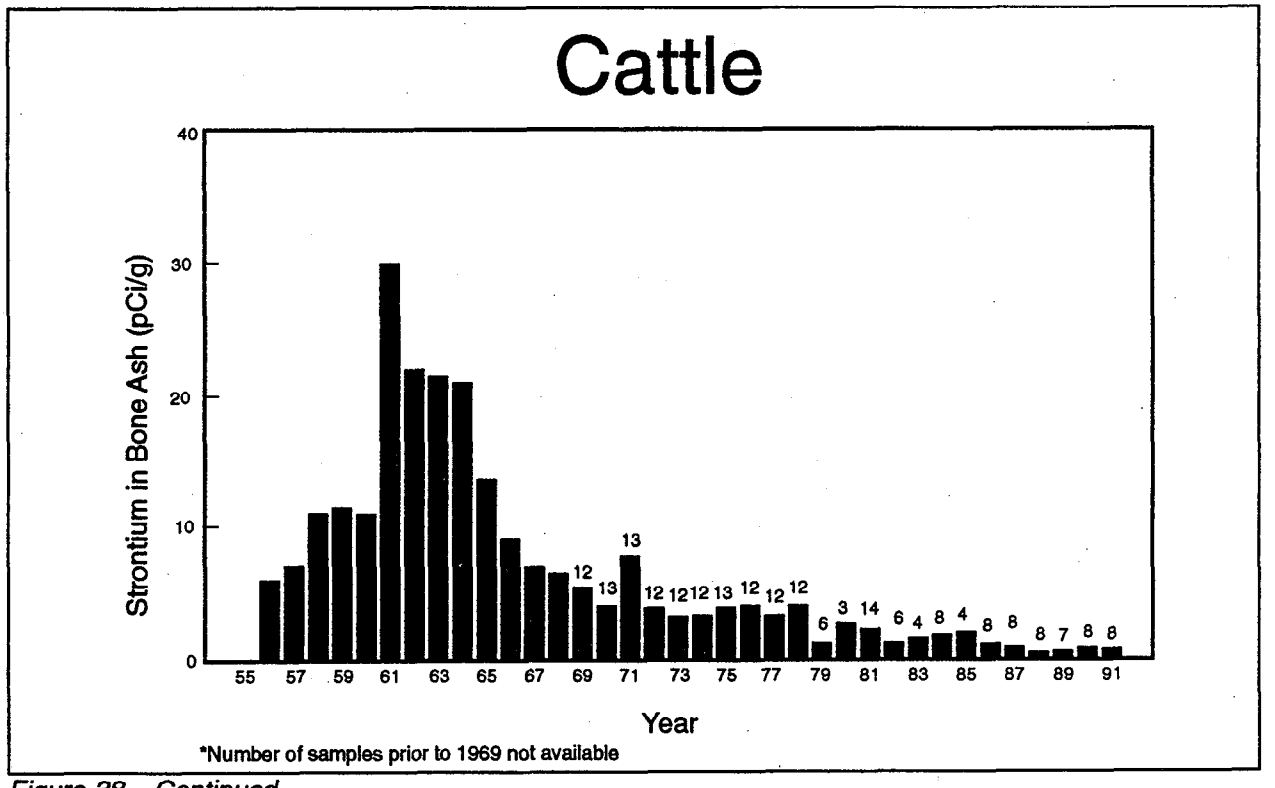

Figure 38. Continued.

tritium and no gamma-emitting radionuclides other than ^{40}K were found in the soft tissue samples, all of the ashed soft tissue samples contained $^{239+240}Pu$ at concentrations greater than the MDC of the analysis. The $^{239+240}Pu$ activities in ashed soft tissues ranged from 0.09 ± 0.01 pCi/g ash in the rumen contents to 0.8 ± 0.1 pCi/g ash in the muscle sample. In addition, ^{238}Pu was detected at activities greater than the MDC of the analysis in the lung and liver samples. The bone sample results were less than the analysis MDC for plutonium isotopes and 0.5 ± 0.1 pCi/g ash for ^{90}Sr.

The other two mule deer, obtained in the third and fourth quarters of 1991, yielded results less than the analysis MDC for most analyses, with the exceptions of a tritium activity of 1000 ± 150 pCi/L in the blood sample from mule deer No. 3, a ^{238}Pu activity of 0.012 ± 0.002 pCi/g ash in the rumen contents of mule deer No. 4, and greater-than-MDC $^{239+240}Pu$ activities in the rumen contents of both animals. Mule deer No. 3 was collected in Area 12, and may have drunk from the Area 12 ponds. Mule deer No. 4 was obtained near Echo Peak on the NTS.

The medians and ranges of the 1991 mule deer analyses, presented in Table 10, are similar to those reported for mule deer collected in 1990 for bone tissue analyses and ^{238}Pu analyses in all tissues. The average ^{90}Sr levels found in animal bone ash since 1955 are shown in Figure 38. Marked differences between years are observed in the medians of tritium activity in blood and $^{239+240}Pu$ in ashed soft tissues. These differences are due to the fact that two contaminated animals were collected in 1991. In past years, none or, at most, one of the mule deer have shown evidence of radioactive contamination and, thus, a contaminated sample had no impact on the median.

5.2.6 Sample Results for Cattle

Four cattle were purchased from the Courtney Dahl ranch in Delamar Valley (near Alamo, Nevada) in the spring of 1991 and another four were purchased from the William Agee ranch near Rachel, Nevada in the fall of 1991. Figure 37 shows the locations of these ranches. Both adult and juvenile cattle were purchased. The animals were slaughtered and necropsied at the EPA farm facility on the NTS. Blood and soft tissues (lung, muscle, liver, thyroid, and kidney) were analyzed for gamma-emitting radionuclides; blood was also analyzed for tritium activity. Samples of kidney

Table 9. Summarized Radiochemical Results for Animal Samples 1991

Sample	Number of Samples	% ash Median Range	^{90}Sr Median Range (pCi/g)	^{238}Pu Median Range (10^{-3}pCi/g ash)	$^{239+240}Pu$ Median Range (10^{-3}pCi/g ash)	^{3}H Median Range (pCi/L)
Cattle Blood	8					241 (120 to 360)
Cattle Liver	8	1.3 (1.0 to 1.4)		2.4 (-0.0001 to 60)	35 (-0.0001 to 3400)	
Deer Muscle	4	1.0 (1.0 to 1.1)		7.2 (-1.1 to 18)	402 (-0.7 to 1200)	
Deer Lung	4	1.0 (0.9 to 1.0)		1.3 (-17 to 10)	10.7 (-0.8 to 350)	
Deer Liver	4	1.3 (0.9 to 1.4)		2.4 (0.7 to 6.0)	5.2 (2.2 to 170)	
Deer Rumen Content	4	3.9 (1.7 to 21)		5.0 (2.0 to 12)	73 (17 to 110)	
Deer Blood	4					504 (-28 to 420,000)
Deer Bone	4	33 (30 to 35)	0.7 (0.5 to 0.9)	0.5 (-0.7 to 2.1)	0.7 (-0.0002 to 5.9)	
Cattle Bone	8	34 (19 to 47)	0.8 (0.3 to 1.3)	-0.5 (-3.1 to 0.7)	0.0 (-0.7 to 5.1)	
Sheep Bone	13	34 (27 to 26)	1.4 (0.5 to 2.0)	-0.0001 (-1.3 to 1.0)	0.4 (-1.0 to 4.5)	
Sheep Kidney	15					30 (-80 to 220)
Mt. Lion Muscle	1	1.2		-3.0	18	
Mt. Lion Bone	1	20	1.1	1.1	-3.3	2.6
Mt. Lion Blood	1					71,300

and bone were ashed and analyzed for plutonium isotopes; bone samples were also analyzed for ^{90}Sr. Duplicate kidney and bone samples from one animal in each group of four were prepared and analyzed.

All four of the cattle purchased from the Courtney Dahl ranch (Bovine 1 to 4) yielded detectable concentrations of ^{90}Sr in bone ash samples, ranging from 0.29 ± 0.04 pCi/g ash to 1.00 ± 0.07 pCi/g ash, as shown in Appendix C, Table C-5. None of the four cattle purchased from the William Agee ranch yielded concentrations of ^{90}Sr greater than the MDC; however, the MDC of the analysis was higher for these analyses (approximately 1.4 pCi/g ash as compared to approximately 0.13 pCi/g ash for the spring samples)[1]. The average ^{90}Sr levels found in animal bone ash since 1956 are shown in Figure 38. All of the liver ash samples, with the exception of the sample from Bovine No. 4, yielded greater-than-MDC concentrations of $^{239+240}Pu$, ranging from 0.015 ± 0.007 pCi/g ash to 3.4 ± 0.2 pCi/g ash[2]. Bovine No. 4 was a young calf, approximately seven months in age and still receiving milk as a part of its diet. Absorbed plutonium is concentrated in the liver of cattle ingesting plutonium oxide (EPA 1980). The only bone ash sample with a $^{239+240}Pu$ result greater than the MDC of the analysis was in the sample from Bovine No. 6, with a value of 0.005 ± 0.002 pCi/g ash.

Medians and ranges, given in Table 10, are similar to those reported for animals collected in 1990, with the exception of cattle liver. The 1991 cattle liver median is greater than the upper end of the range in 1990. It should be noted that in 1990, cattle were purchased from the Agee Ranch and the Medlins Ranch and not from the Courtney Dahl Ranch. An investigation was conducted of all procedures from sampling through data reporting. No evidence of uniform contamination could be found, either in sample preparation or analysis. Results of QA/QC samples analyzed with the animal tissue samples were within specified control limits, with the exception of the duplicate pair discussed in the preceding footnote. The possibility of sample contamination occurring during the ashing process could not be ruled out, although other tissues and mule deer samples submitted for ashing in the same batch yielded results similar to those obtained in previous years, and any source of contamination would have to have affected two different batches of cattle samples submitted at different times. Prior to 1991, plutonium analyses of ashed tissue samples were completed by a contract laboratory. Analysis of samples collected in 1991 was completed by the EPA EMSL-LV Radioanalysis Laboratory. Although the methods used by the two laboratories are similar and should produce comparable data, the possibility of laboratory bias cannot be eliminated. This possibility is unlikely, however, since medians and ranges for other tissues and other animal types were similar for 1990 and 1991 data.

5.2.7 Sample Results for the Mountain Lion

A mountain lion which had been menacing the Area 12 camp was killed by an NTS-authorized hunter in the spring of 1991. Kidney, lung, muscle, blood, and liver samples were analyzed for gamma-emitting radionuclides; only naturally occurring ^{40}K was detected. A blood sample analyzed for tritium activity yielded a result of 71,300 ± 400 pCi/L, indicating the animal probably drank from the Area 12 ponds. Muscle and bone samples were ashed and analyzed for plutonium isotopes; the bone sample was also analyzed for ^{90}Sr. Results are given in Table 10. The only results greater than the MDC of the analysis were ^{90}Sr in bone, with a result of 1.09 ± 0.07 pCi/g ash, and $^{239+240}Pu$ in muscle, with a result of 0.018 ± 0.009 pCi/g ash.

5.2.8 Quality Assurance

Standard operating procedures (SOPs) detail sample collection, preparation, storage, analysis, and data review procedures to ensure comparability among operators. Field personnel complete a standardized necropsy protocol form to ensure that all relevant information is recorded, such as date and location of collection, history and condition of the animals and tissues, and sample weights and assigned identification numbers. Standardized forms accompany each shipment of samples sent to the contract laboratory for ashing and are also used for analyses conducted in the Radioanalysis Laboratory. All information entered into the data base management system by Sample Control and the radioanalysis chemists is checked and verified by the Group Leader and assigned media expert.

An estimate of system precision is obtained from results of duplicate samples. Matrix spike samples are used to verify analytical accuracy. Matrix blank samples monitor any contamination resulting from sample preparation and analysis. The entire

sample set analyzed in any given year is quite small (usually four or five sample batches) and, as a consequence, the quality assurance/quality control (QA/QC) sample results set contains fewer values than is considered minimal for statistical uses. Therefore, the results of QA/QC samples are considered to provide only an indication or estimate of true precision and accuracy. This is considered adequate because the animal investigation program itself is not statistically based.

Prior to 1991, analyses of animal tissue samples were performed by a contract laboratory. The EPA EMSL-LV Radioanalysis Laboratory assumed responsibility for sample analysis beginning with the results contained in this report. The change of laboratories raised concerns about comparability of analyses, so a special QA review was conducted. The procedures used by each laboratory are comparable, as are results of matrix spike samples. Generally, the result ranges obtained in 1991 were similar to those obtained in previous years when samples were analyzed by the contract laboratory. Finally, results of QA/QC samples, with the exception of one routine-duplicate pair, were within established control limits. Although a direct comparability study was not undertaken (i.e., analysis of replicate samples by both laboratories), the results of the QA review indicate the data obtained for 1991 analyses are comparable to data obtained in previous years.

The QA review also resulted in recommendations for some changes in the animal investigation program to be implemented in 1992. These recommendations included preparation of a large stock of matrix spike and blank sample material and addition of a system blank. The single stock of matrix spike sample material will permit an additional estimate of precision, in this case analytical precision, to be obtained. The system blank will be a bone sample known to contain no detectable concentrations of radionuclides (with the possible exception of strontium) processed with each tissue sample batch to provide a check of possible contamination during the ashing and sample preparation processes.

5.3 Fruits And Vegetables Monitoring

Another possible pathway of radionuclide ingestion is through produce: fruits, vegetables, and grains. Commercial farming, other than alfalfa, is not a major industry in the offsite area around the NTS. Therefore, monitoring is limited to fruits and vegetables grown in local gardens for family consumption. In the event of a release of radioactivity from the NTS, monitoring of produce would be extended to include alfalfa, forage grasses, and feed grain supplies. No such extensive monitoring was required in 1991.

5.3.1 Network Design

Like the animal investigation program, fruit and vegetable monitoring is based on a worst-case scenario. Local residents living in areas known to have received fallout from past atmospheric testing are asked to donate produce from their family gardens. These areas which received fallout are also the areas in the preferred downwind direction during current underground testing. As sample collection is not statistically based, no inference should be drawn regarding the representativeness of the sampled materials to concentrations of radionuclides in produce as a whole, nor should any conclusions be drawn regarding the average consumption of radionuclides from produce.

5.3.2 Sample Collection and Analysis Procedures

Sample collection is a strictly voluntary contribution by the offsite residents. Sampling is done only once per year, in the late summer. Fruits and vegetables harvested at that time generally include root crops (onions, carrots, potatoes), melons and squash, and some leafy vegetables (e.g., cabbage). A unique sample number is assigned and pertinent information, such as date and place of collection, is recorded on the sample collection tag. Following receipt in Sample Control, the available information is entered into the sample tracking data management system (STDMS).

Processing of the samples includes washing the material as it would be washed by residents prior to eating or cooking. This washing procedure introduces an element of variability, as the thoroughness of washing varies by individual. Potatoes and carrots are not peeled. Further processing generally includes cutting the material into small pieces and/or blending in a mixer or food processor. Splits are prepared for analysis of gamma-emitting radionuclides and tritium. Other sample splits are ashed and analyzed for ^{90}Sr, ^{238}Pu, and $^{239+240}Pu$.

5.3.3 Quality Assurance

The fruits and vegetables are considered to be a batch within the animal investigation program. The same QA/QC samples are used, including matrix-spikes and matrix blanks (NOTE: animal bone ash is the matrix). If sufficient material is received, at least one of the samples may be analyzed in duplicate, however, in many years not enough of any one type of material is received from any one source to permit preparation of replicates. As with the animal investigation program, the QA/QC samples provide only an estimate or indication of the analytical precision and accuracy.

5.3.4 Sample Results

In the fall of 1991, fifteen samples of locally grown fruits and vegetables were donated by offsite residents in Utah, Arizona, and Nevada. Fruits and vegetables sampled included cabbage, cantaloupes, zucchini and summer squash, onions, carrots, beets, and potatoes. All samples were analyzed for gamma-emitting radionuclides and only naturally occurring ^{40}K was detected. All samples were also analyzed for tritium; no results greater than the MDC of the analysis were obtained. Ashed samples were analyzed for ^{90}Sr, ^{238}Pu, and $^{239+240}Pu$. None of the ^{90}Sr results were greater than the MDC of the analysis. Concentrations of ^{238}Pu greater than the analysis MDC were found in two samples, both from Fallis Ranch near Rachel, Nevada, and concentrations of $^{239+240}Pu$ greater than the analysis MDC were found in seven samples. These results are given in Table 10. No consistent correlations of greater-than-MDC results with sample location or with vegetable mode of growth (i.e., surface crops as opposed to root crops) were evident.

Table 10. Detectable Plutonium Concentrations in Vegetable 1991

Vegetable	Collection Location	$^{239-240}Pu \pm 1\sigma$ (pCi/g) ash	$^{239-240}Pu$ MDC[a]	$^{238}Pu \pm 1\sigma$ (pCi/g) ash	^{238}Pu MDC[a]
Onions	Beaver Dam, AZ (Meddibow Farms)	0.004 ± 0.002	0.002		
Zucchini Squash	Enterprise, UT (Deward Terry)	0.006 ± 0.003	0.005		
Summer Squash (Yellow)	Rachel, NV (Fallis Ranch)	0.029 ± 0.006	0.005	0.008 ± 0.003	0.005
Summer Squash	Rachel, NV (Penoyer Farms)	0.010 ± 0.005	0.008		
Potatoes	Rachel, NV (Fallis Ranch)	0.051 ± 0.005	0.002	0.008 ± 0.002	0.003
Beets	Rachel, NV (Penoyer Farms)	0.007 ± 0.003	0.005		
Red and Green Cabbage	St. George, UT (Jeff Layne)	0.002 ± 0.001	0.002		

[a] MDC = minimum detectable concentration.

1. Reanalysis was conducted on the Agee Ranch samples due to the high MDC. The high MDC was the result of 1 g rather than 10 g of sample being used in the first analysis. The reanalysis results were nearly identical to those obtained in the first analysis. All were above the MDC, which was about 0.7 pCi/g ash for the second analysis.

2. The highest result obtained in Bovine No. 2, 3.4 pCi/g ash, is suspect. A duplicate sample prepared from the same liver yielded a greater-than-MDC result of 0.04 ± 0.01 pCi/g ash for $^{239+240}$Pu. Additionally, this sample yielded the only ^{238}Pu result greater than the MDC of the analysis, a result of 0.059 ± 0.007 pCi/g ash, while the duplicate sample ^{238}Pu result was less than the MDC. Repeated analyses yielded similar results. However, an investigation of the sample could not identify a source of contamination. Additionally, the possibility of differing activities in separate liver lobes could not be ruled out as a possible explanation for the observed difference in analytical results. Therefore, the value cannot be invalidated, but should be regarded as suspect.

6.0 Internal Dosimetry

Internal exposure is caused by ingested, absorbed, or inhaled radionuclides that remain in the body either temporarily or for longer periods of time because of storage in tissues. At EMSL-LV, two methods are used to detect body burdens: whole-body counting and urinalysis. These two methods constitute the Internal Dosimetry Program.

6.1 Network Design

The Internal Dosimetry Program consists of two components, the Offsite Internal Dosimetry Program and the Radiological Safety Program. The Offsite Internal Dosimetry Program is designed to: (1) measure radionuclide body burdens in a representative number of families who reside in areas that were subjected to fallout during the early years of nuclear weapons tests, and (2) provide a biological monitoring system for present nuclear testing activities. A few families who reside in areas not affected by such fallout were selected for comparative study. Members of the general public concerned about possible exposure to radionuclides are also counted periodically as a public service. The Radiological Safety Program is designed to assess internal exposure for EPA employees, DOE contractor employees, and, by special request, for employees of companies or government agencies who may have had an accidental exposure to radioactive material.

The Offsite Internal Dosimetry Program was initiated in December 1970 to determine levels of radionuclides in some of the families residing in communities and ranches surrounding the NTS. For these families, biannual counting is performed in the spring and fall of each year. This program started with 34 families (142 individuals). In 1991, 15 of these families (35 individuals) were still active in the program. When the CRMP network was started in 1981, the families of the station managers interested in participating were added to the program. As additional station managers joined the program, the number of families in the program in 1991 has increased to 58. Although there are 58 families in the program, only 34 of them actually participated in 1991. These families are counted in the winter and summer of each year. The number of individuals participating in the program varies as children leave home to attend school or obtain employment. The geographical locations of the participating families are shown in Figure 39. Although most families are able to come into the laboratory as scheduled, some are unable to participate in a particular year due to distance, weather, or family commitments. All families currently in residence would presumably be available following any accidental release of radioactivity.

Individuals with potential for occupational exposure are counted at the request of their employers as part of the Radiological Safety Program. Counting is done routinely for DOE contractors. EPA personnel in radiation programs or who work with radioactive materials undergo a whole body count and a urinalysis annually.

6.2 Procedures

The whole-body counting facility has been maintained at EMSL-LV since 1966 and is equipped to determine the identity and quantity of gamma-emitting radionuclides that may have been inhaled, absorbed, or ingested. Routine examinations consist of a 2,000 second count in each of the two shielded examination vaults. In one vault, a single intrinsic germanium coaxial detector positioned over an adjustable chair allows detection of gamma radiation with energies ranging from 60 keV to 2.0 meV in the whole body. The other vault contains an adjustable chair with six intrinsic germanium semi-planar detectors mounted above the chest area. The semi-planar array is designed for detection of gamma and X-ray emitting radionuclides with energy ranges from 10 to 300 keV. Specially designed software allows individual detector spectra to be analyzed to obtain a summation of left- or right-lung arrays and of the total lung area. This provides much greater sensitivity for the transuranic radionuclides while still maintaining the ability to pinpoint "hot spots." Custom-designed detector mounts allow maximum flexibility for the placement of detectors in various configurations for skull, knee, ankle, or other geometries.

Individuals travel to EMSL-LV where a whole-body count and a lung count of each person are performed. A urine sample is collected for ^{3}H analy-

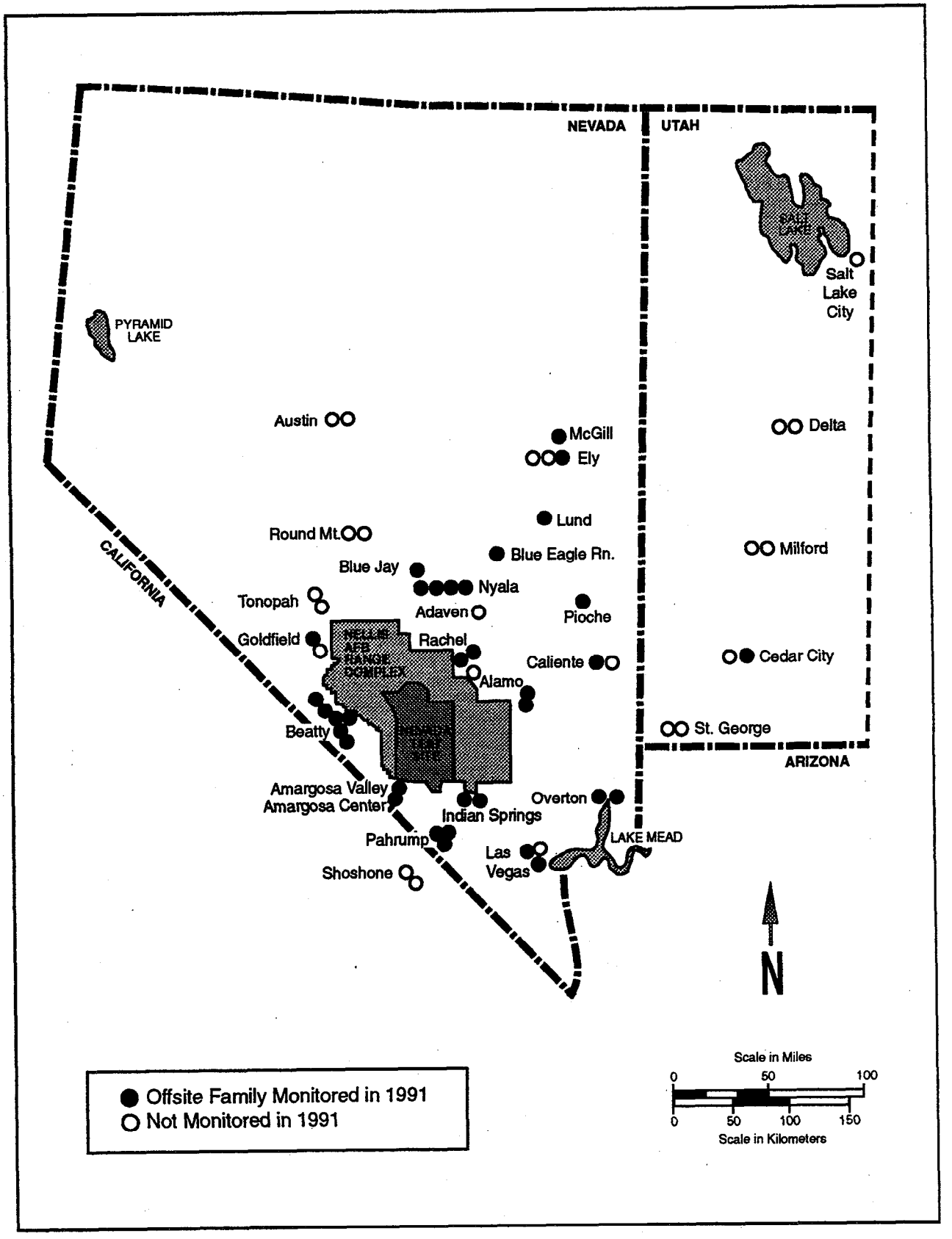

Figure 39. Location of families in the Offsite Internal Dosimetry Program.

sis. Not all participants of the Radiological Safety Program submit urine samples for ^{3}H analysis.

Results of the whole-body and lung counts are available before the Offsite Internal Dosimetry Program participants leave the facility and are discussed with the subjects. Results of the urine ^{3}H analysis are submitted later if the result is abnormal. At 18-month intervals, a physical exam, health history, and the following are performed: a complete urinalysis, complete blood count, serology, chest x-ray (3-year intervals), sight screening, audiogram, vital capacity, EKG (for individuals over 40 years old), and thyroid panel. The individual is then examined by a physician. The results of the examination can be requested for use by the individual's family physician.

6.3 Results

During 1991, a total of 2,800 gamma spectra were obtained from whole-body counting of 350 persons (including those individuals who were counted twice). One hundred and six of the counts were on participants of the Offsite Internal Dosimetry Program. All spectra were representative of normal background and showed only naturally occurring ^{40}K. No transuranic radionuclides were detected in any lung-counting data. No internal exposure above applicable regulatory limits was detected in either occupationally exposed individuals or members of the general public who participated in the Internal Dosimetry Program at EMSL-LV.

Bioassay results for the Offsite Internal Dosimetry Program showed that the concentration of tritium in single urine samples collected at random periods of time (i.e., whenever the individual was able to come to EMSL-LV) varied from below the MDC average value of 2.7×10^{-7} µCi/mL to 3.8×10^{-7} µCi/mL. The average value for 98 samples analyzed for tritium in urine was 8.9×10^{-8} µCi/mL. The bioassay results for the Offsite Internal Dosimetry Program are listed in Appendix D, Table 1. Two values were slightly above the MDC. The MDCs for these values were within one standard deviation of the result. The highest value of 3.8×10^{-7} µCi/mL is only 0.01 percent of the annual limit of intake for the general public. As no accidental or planned releases from NTS were reported in 1991, no additional bioassay sampling was performed. As reported in previous years, medical examinations of the offsite families revealed a generally healthy population. The blood examinations and thyroid profiles showed no symptoms which could be attributed to past or present NTS testing operations.

Of the 87 bioassay samples obtained from individuals with potential for occupational exposure, five were over the MDC. The MDCs for all of these results were within one standard deviation of the result. The highest value, 3.6×10^{-7} µCi/mL is less than 0.001 percent of the annual limit for occupationally exposed individuals. The bioassay results for occupationally exposed individuals are given in Appendix D, Table 2.

Some members of the general public request whole body counts because they are concerned about possible radiation exposure. Such was the case of two men using heavy equipment in the vicinity of a mine thought to have a high percentage of thorium in the ore. One of the men had returned home from work after dark and removed a fluorescent tube from the trunk of his car. The tube glowed when he picked it up by the end. He thought the glowing was caused by radiation in his body. He had demonstrated this to his partner and other people who all became convinced that he was contaminated. He brought the tube with him to EMSL-LV, along with a soil sample. It was easy to demonstrate how the tube would glow from a static charge. He had inadvertently rubbed the tube across the carpet in his truck and upon his trousers, causing the tube to glow. The soil did not contain enough thorium to be detectible. Although the incident that caused their anxiety was easily explained scientifically, they were concerned enough to seek assistance and relieved that they were not contaminated.

Another man was referred to EMSL-LV by his employer after his wife became upset when she learned he had been checking equipment on the NTS during a nuclear event. Although he had been working in the vicinity, he was not in the exclusion zone and was a number of miles away from the event. He had not been notified by his employer of the pending event and became concerned when his wife heard that there had been an event. When he was counted, no internally deposited radioactive material was detected. No release of radioactivity had occurred and he had actually been in his car headed off the site at the time of the event.

Numerous employees of DOE contractors were counted as part of the Radiological Safety Program. All of these were routine counts with the exception of two employees who were flown in after separate incidents. One was a mechanic who had been working on forklifts. The forklifts had been contaminated with uranium prior to procurement from excess property. No uranium or other radionuclides, except naturally occurring potassium, were detected. The minimum detectible activity (MDA) for ^{238}U in the lungs is 1.8 μCi and for ^{235}U, is 0.12 μCi. The other person was involved in a filter incident at Rocky Flats, a DOE facility in Colorado. He had been given chelation therapy after having a positive nasal swipe. Subsequent urine samples had tested positive for ^{239}Pu and ^{241}Am. He had been counted at Rocky Flats but had requested another count by someone else to verify the negative results. Lung and whole body counts at this facility detected no radionuclides other than naturally occurring ^{40}K. The MDA for his chestwall thickness is 0.35 μCi of ^{241}Am. The annual limit of intake (ALI) for ^{241}Am is 5.4 μCi.

6.4 Quality Assurance/Quality Control

Quality Assurance procedures consist of daily equipment operations checks using QA software obtained specifically for this program. Some of the parameters monitored daily include energy calibration of each detector using a NIST-traceable point source to check for zero, gain shift, and resolution over a wide range of energies. A background measurement is also taken once or twice daily depending on the count schedule.

The whole-body detector efficiency is calibrated annually using a Bottle Mannequin Absorber (BOMAB) phantom containing a NIST-traceable mixed radionuclide source. The lung counter is also calibrated annually with a male realistic lung phantom. A separate set of efficiency calibration data is kept for each combination of sample shape/organ geometry.

The following MDAs were calculated following recalibration of the lung counting system in February, 1992: ^{241}Am, 0.2 μCi; ^{238}Pu, 18 μCi; and ^{239}Pu, 130 μCi. There were no significant differences from previous MDA's. These were calculated for a standard chestwall thickness of 3 cm. The MDAs for the whole-body counting system for 1991 were as follows: ^{60}Co, 10 nCi; ^{137}Cs, 14 nCi; Cs-134, 11 nCi; and ^{131}I, 13 nCi.

All efficiency curves are generated by the vendor-supplied whole-body counting and lung counting software. Daily performance and background routines are completed. QA software is used to monitor the systems by performing out-of-range tests for predetermined parameters. Results are plotted and reports are generated daily and monthly. All data are stored in the computer. Replicate counting of the standard BOMAB phantom provides a measure of consistency. Replicate counts of blind intercalibration phantoms and of people counted previously in other facilities provide additional measurements of precision and accuracy. Verification and validation are completed before results are entered into a data base. Calculation of internal dose is done utilizing software based on the International Commission on Radiological Protection (ICRP) methodology (ICRP, 1979). Dose calculation is verified using ICRP and National Council of Radiation Protection and Measurement (NCRP) guidelines (NCRP, 1989). Preventive maintenance and repair of analytical equipment are done by the vendor service representative. Data are retained permanently. Subject confidentiality and data security are maintained through well-established procedures. EPA whole-body counting technicians participate in DOE and EPA QA training programs.

7.0 Long-Term Hydrological Monitoring Program

One of the concerns of underground nuclear weapons testing is the possibility of radionuclide contamination of groundwaters. Underground nuclear weapons tests are currently conducted only on the Nevada Test Site (NTS). Between 1961 and 1973, eleven tests were conducted in eight other locations in the United States. The initial ground and surface water monitoring program was established by the U.S. Public Health Service (USPHS) in the early 1950s. Pretest and posttest monitoring for the locations off the NTS were conducted by USPHS, the U.S. Geological Survey (USGS), and Teledyne Isotopes, Inc. In 1972, the Long-Term Hydrological Monitoring Program (LTHMP) was established by the Nevada Operations Office (NV) of the Atomic Energy Commission (AEC), a predecessor agency to DOE. Through an interagency agreement between AEC (later DOE) and EPA, responsibility for operation of the LTHMP was assigned to the U.S. EPA's Environmental Monitoring Systems Laboratory in Las Vegas, Nevada (EMSL-LV). The LTHMP is only one component of the total surface and ground water monitoring program conducted under the auspices of DOE/NV.

Under the LTHMP, routine monitoring is conducted of specific wells on the NTS and of wells, springs, and surface waters in the offsite area around the NTS. In addition, LTHMP sampling is conducted at the eight other locations in the U.S. where nuclear weapons tests have been conducted. These locations include sites in Nevada, Colorado, New Mexico, Mississippi, and Alaska.

7.1 Network Design

The LTHMP was instituted because AEC (later DOE/NV) acknowledged its responsibility for obtaining and disseminating data acquired from all locations where nuclear devices have been tested. The three objectives originally established for the LTHMP were to:

- Assure public safety.
- Inform the public, news media, and scientific community about any radiological contamination.
- Document compliance with existing federal, state, and local antipollution requirements.

Another objective which has been incorporated into the LTHMP is to, where possible, detect trends in radionuclide activities which may be indicative of migration from the test cavity.

The primary radionuclide analyzed in the LTHMP is tritium. As a product of nuclear weapons testing, high levels of tritium are found in test cavities. Because tritium can be incorporated into water molecules, it is expected to be the first radionuclide to migrate from a test cavity. Therefore, tritium serves as an indicator of radionuclide migration. Atmospheric tritium may also be deposited into water, primarily by precipitation scavenging. Tritium arising from this source is primarily found in surface waters, surficial aquifers, and springs closely connected to surficial aquifers.

7.1.1 Sampling Locations

In order to meet the objective of assuring public safety, monitoring is conducted of drinking water supply wells and springs around the NTS and in the vicinity of surface ground zero (SGZ) at the other locations. The majority of these sampling sites are privately owned and participation in the LTHMP is voluntary. Municipal drinking water supplies are also represented. Regardless of the number of individuals served by a particular water supply, the National Primary Drinking Water Regulation[1] (NPDWR) pertaining to radioactivity is used as the compliance standard.[2]

All of the nuclear weapons tested at locations other than the NTS were emplaced at depths of greater than 1200 feet. Nuclear weapons tested on the NTS are also emplaced at great depths, with the exception of some shallow underground tests conducted in the early 1960s. Most of the drinking water supply wells tap shallow aquifers and, consequently, do not represent groundwater in the geologic strata containing the test cavities. Therefore, wherever possible, deep wells are included in the monitoring program. These wells include some which were specifically drilled soon after a nuclear test to monitor activities in or near the test cavity

and others which can be considered only as "targets of opportunity"; e.g., existing wells for which sampling permission has been obtained. Most of the deep wells tap nonpotable water sources. Monitoring design standards, such as those in the Resource Conservation and Recovery Act (RCRA), did not become available until long after the LTHMP deep wells had been drilled. Cost has delayed emplacement of new wells, although a program to drill more than 90 new wells on the NTS was initiated in 1990. The sampling locations not associated with the NTS are defined by DOE as inactive hazardous waste sites and, therefore, exempt from the RCRA monitoring design requirements.

7.1.2 Sampling and Analysis Procedures

At nearly all LTHMP locations, the standard operating procedure is to collect three samples from each source. Two samples are collected in 500-mL glass bottles to be analyzed for tritium. The results from analysis of one of these samples are reported while the other sample serves as a backup in case of loss or as a duplicate sample. The third sample is collected in a 3.8-L plastic container (Cubitainer) for gamma spectroscopy analysis. At LTHMP sites other than the NTS and vicinity, two Cubitainer samples are collected. One is analyzed by gamma spectrometry and the other is stored as a backup or for duplicate analysis. At a few locations, because of limited source of water supply, only 500-mL samples for tritium analysis are collected.

For wells with operating pumps, the samples are collected at the nearest convenient outlet. If the well has no pump, a truck-mounted sampling rig is used. With this rig it is possible to collect three-liter samples from wells as deep as 1800 meters. At each sample collection site, the pH, conductivity, water temperature, and sampling depth are measured when the sample is collected.

The first time samples are collected from a well, ^{89}Sr, ^{90}Sr, ^{226}Ra, and plutonium and uranium isotopes are determined by radiochemistry as time permits. Prior to 1979, the first samples from a new location were analyzed for 15 stable elements; anions, nitrates, ammoniacal nitrogen, silica; uranium, plutonium and strontium isotopes; and ^{226}Ra. Most of these analyses can still be completed by special request.

At least one of the 3.8-L samples from each site is analyzed by gamma spectroscopy. One of the 500-mL samples from each site is analyzed for tritium. Two tritium analysis methods are employed in the LTHMP: the standard or conventional method and an enrichment method developed by EMSL-LV. In the enrichment method, the sample is concentrated, resulting in an MDC of approximately 7 to 10 pCi/L, as compared to the MDC for the conventional method of approximately 250 to 700 pCi/L. Most of the LTHMP samples are analyzed by the enrichment method, unless past years' data have indicated activities are within the detectable range of the conventional method. Additionally, semiannually sampled wells on and in the vicinity of the NTS are analyzed once per year by the enrichment method and once per year by the conventional method.

7.1.3 Quality Assurance/Quality Control Samples

Sample collection and analysis procedures are described in standard operating procedures (SOPs). Data base management and data analysis activities are described in the Quality Assurance Plan (EPA, 1992). Use of standardized procedures ensures comparability of operations and data among monitoring locations and across temporal intervals.

Annual data quality assessments of precision, accuracy, and comparability are based on the results of quality assurance/quality control samples. The data quality assessment results for 1991 are given in Section 11.0. Overall system precision is estimated from the results of field duplicates. A field duplicate is a second sample collected from a sampling location immediately following collection of the routine sample using identical procedures. Field duplicates are collected from sampling locations on the NTS and in the vicinity of the NTS according to a schedule established by the LTHMP Technical Leader. Generally, all samples from the other locations are collected in duplicate; the second sample may be used as a duplicate or may be used as a replacement for the routine sample, if necessary.

Accuracy is estimated from results of intercomparison study samples. These intercomparison study samples are spiked samples (i.e., a water sample to which a known amount of particular radionuclide(s) have been added). Intercomparison

study programs managed by EMSL-LV and DOE's Environmental Monitoring Laboratory (EML) both include water matrix samples. The EMSL-LV intercomparison study samples are also used as an estimate of comparability. Generally, sixty to more than 100 laboratories participate in a given intercomparison study. Results for each laboratory are reported, as are pooled results (mean, standard deviation). Comparison of the Radioanalysis Laboratory to the mean for all laboratories provides an estimate of the comparability of results.

In addition to the above-described QA/QC samples which are used in annual data quality assessments, the Radioanalysis Laboratory employs a number of internal QC samples and procedures to ensure data quality on a day-to-day basis. Internal QC samples include blanks, regular calibrations, matrix spike samples, and duplicate analyses (gamma spectroscopy only). If results of these internal QC samples fall outside prescribed control limits, corrective actions are implemented; analysis is stopped until the cause of the discrepant data is found and resolved.

7.1.4 Data Management and Analysis

In the spring of 1991, the LTHMP was selected as the pilot program to test the use of bar code sample labels. Bar code labels were prepared prior to each sampling excursion, based on the sampling schedule prepared by the LTHMP Technical Leader. Upon receipt of samples in Sample Control, the bar code label was read and the information transferred into the Sample Tracking Data Management System (STDMS), along with information from the field data card. This pilot program was extremely successful and is being continued for the LTHMP and expanded to other monitoring networks.

Analysis data were entered into STDMS after they had been generated and reviewed by the analyst and Group Leader. Special software written in Fortran (referred to as "Chemistry Programs") is used for a majority of the radiochemical data reduction. The Chemistry Programs are used for calculating final data such as activity per unit volume, MDC and 2-sigma error terms. All hand-entered data were checked for transcription errors. Once data had been entered and checked, they were transferred from a "review" data base to a permanent data base, i.e., further changes may be made only by authorized personnel.

On a periodic basis, the assigned media expert reviewed the data base and checked for completeness of sample collection, transcription errors, completion of analysis of samples and QA/QC samples, and accuracy of information input. All discrepancies were resolved and corrected. Once the data base was complete for a given location, time series plots were generated. Any discernable trends were discussed at an annual data review attended by management and scientific personnel. Another data review of the LTHMP was held with DOE and Desert Research Institute (DRI) hydrology personnel. The time series plots which indicated consistent data trends are included as figures in the subsections which follow. The filled circles on the time series plots represent the result values, the error bars indicate ± one standard deviation of the analysis, and the (x) represents the MDC value.

7.2 Nevada Test Site Monitoring

The present makeup of the LTHMP for the NTS onsite network is displayed in Figure 40. The onsite network includes sample locations on the NTS or immediately outside its borders on federally owned land. In 1991, samples were collected monthly from 14 onsite wells and semiannually from 15 others. An additional five wells could not be sampled at any time in 1991 and one well became inoperative midway through 1991. These are listed in Table 11. Two new wells were added in 1991; Well 6 located in the immediate offsite area near wells 3, 4, and 5 and Well UE6D located in Area 6. Well 6 has been sampled monthly, beginning in September. Radionuclide analysis completed on the first sample collected from this well indicated detectable activities of ^{234}U, ^{235}U, and ^{238}U. These results were: 1.6 ± 0.2 pCi/L of ^{234}U, 0.063 ± 0.027 pCi/L of ^{235}U, and 0.51 ± 0.08 pCi/L of ^{238}U. Attempts were made to sample Well UE6D in March and September, but it was not possible to collect a sample due to insufficient water in the well.

All LTHMP samples are analyzed for gross gamma and tritium. All of the gross gamma results were negligible. Of the samples collected semiannually, one sample is analyzed for tritium by the conventional method and the other is analyzed by the

Table 11. Inoperative and Closed LTHMP Wells

Well Identification	Sampling Schedule	Last Sampled
Well 2 monthly	December 1990	
Well 5B	semiannually	July 1988
Well 20	monthly	April 1991
Well A monthly	October 1988	
Well U3CN-5	monthly	December 1981
Well UE7NS	semiannually	September 1987

enrichment method. All of the monthly samples are analyzed for tritium by the enrichment method. None of the samples analyzed by the conventional tritium method in 1991 exceeded the MDC. The greatest tritium activity measured in the LTHMP NTS sampling network in 1991 was 156 ± 3 pCi/L in the September sample from Well UE18T. This activity is 0.8 percent of the NPDWR.

Twelve of the fourteen onsite wells sampled on a monthly basis did not exhibit tritium activities exceeding the MDC of the enrichment analysis at any time during 1991. These included Well 6, added to the sampling directory in September 1991, and Well J-12 which has never yielded a detectable tritium activity; the remaining wells have been sampled for a period of years and have only on rare occasions exhibited tritium activity at detectable levels (greater than approximately 7 to 10 pCi/L). Five of the 15 other wells sampled semiannually also did not exhibit tritium activity greater than the MDC of the enrichment method. Like the monthly sampled wells, these five wells have rarely exhibited detectable tritium activity using the enrichment analysis method. Another three of the semiannually sampled wells were only analyzed by the conventional method in 1991, with all results less than the MDC. Of these, Well UE6E had shown tritium activities of 33 to 48 pCi/L in 1989 and 1990, Test Well 7 had only been sampled twice, in 1989 and 1991, with both samples analyzed by the conventional method. Well UE4T was sampled for the first time in 1991.

Tritium activities greater than the MDC of the enrichment method were observed only in Test Well B and Well C in the monthly sampled sites. Test Well B averaged 115 pCi/L for 1991 (range of 99 to 128 pCi/L); the long-term trend for this site indicates the tritium activity is decreasing, as shown in Figure 41. The average for Well C for 1991 was 23 pCi/L (range 9 to 62 pCi/L); the sampling history indicates a slightly decreasing trend consistent with tritium decay.

Tritium activities greater than the MDC of the enrichment method were also found in Well C-1, Test Well D, and wells HTH-1, UE15D, UE16D, UE16F, and UE18T in the semiannually sampled sites. The 1991 tritium activity for Well C-1 was 22 ± 4 pCi/L and was the first time a result greater than the MDC had been obtained since 1983, although the long-term sampling history indicates greater-than-MDC tritium activities have occasionally been observed. The result for Test Well D was 7.6 ± 2.3 pCi/L, which was only slightly greater than the MDC of 7.4 pCi/L. Like Well C-1, Test Well D results had not exceeded the MDC of the tritium enrichment analysis since 1983, although greater-than-MDC results had occasionally been obtained in the years prior to 1983. Both of the samples collected from Well HTH-1 were analyzed by the enrichment method. The June sample was below the MDC and the December sample was 35 ± 2 pCi/L. Sampling of this well was initiated in 1989; tritium activity in the June 1990 sample was similar to that observed in the December 1991 sample, although the number of data points is insufficient to discern any trend. The May 1991 tritium result for Well UE16D was 31 ± 3 pCi/L and was the first time that this well has displayed a detectable tritium activity since sampling began in 1982. The second sample from Well UE16D, collected in November 1991, was also analyzed for tritium by the enrichment method with a result less than the MDC. Both samples collected from Well UE16F in 1991 were analyzed for tritium by the enrichment method, yielding results greater than the MDC. The May 1991 sample showed tritium activity of 11 ± 3 pCi/L and tritium activity in the November 1991 sample was 10 ± 2 pCi/L. These were the first detectable tritium activities observed at Well UE16F since sampling began in 1989. The sample collected in April from Well UE15D yielded

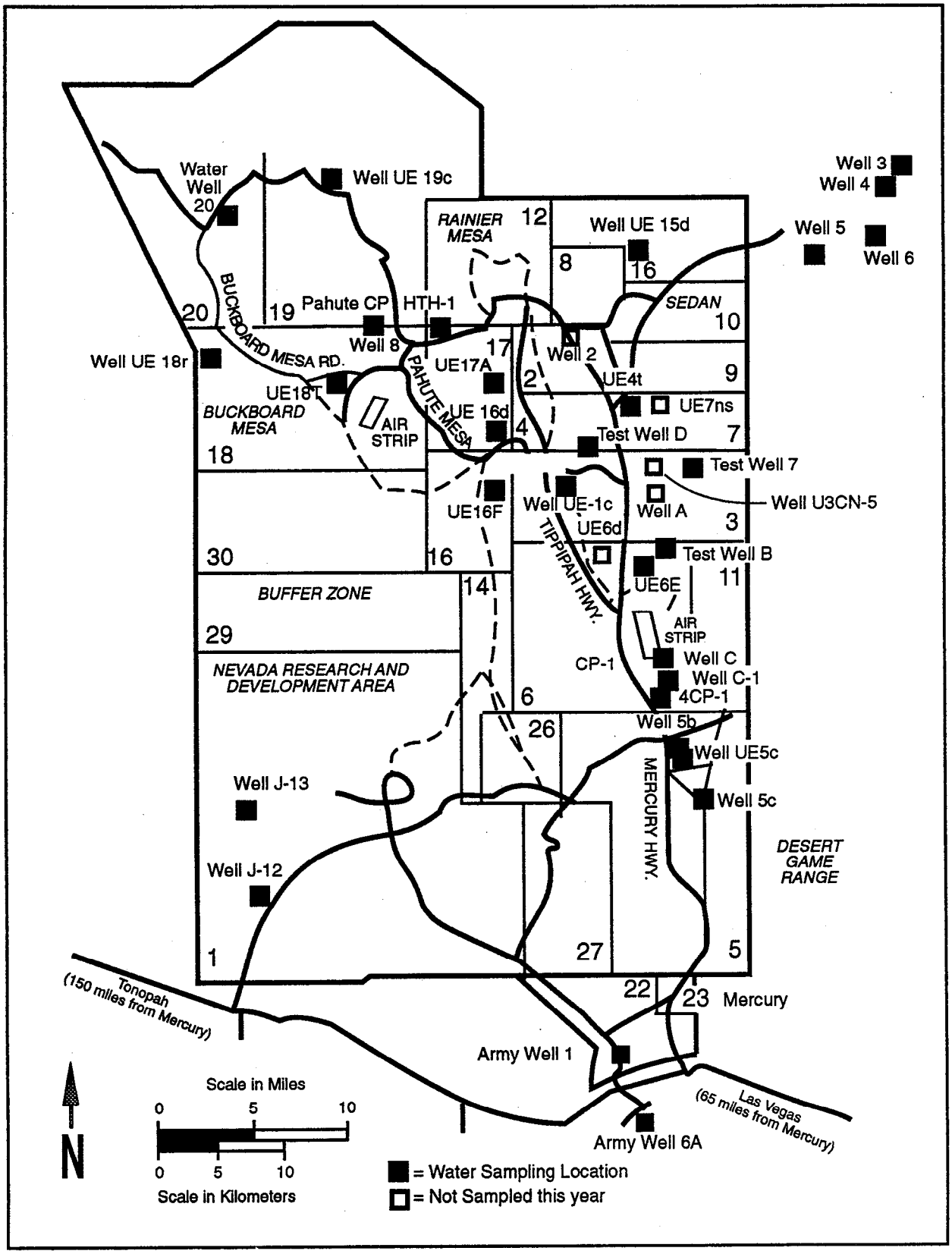

Figure 40. Long-Term Hydrological Monitoring Program sampling locations on the Nevada Test Site.

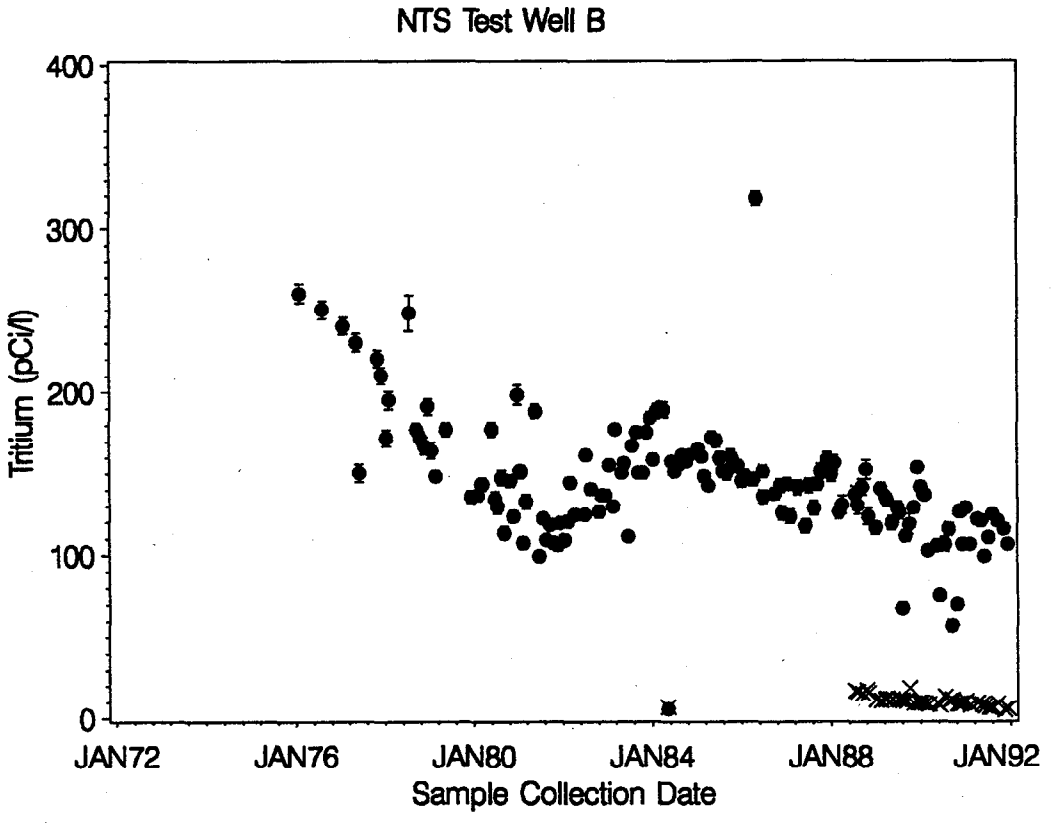

Figure 41. Tritium results ± standard deviation for Nevada Test Site Test Well B, January 1976 through December 1991. The X indicates the MDC value.

a tritium activity of 76 ± 3 pCi/L; the sampling history for this well indicates high variability in tritium activity, ranging from below the MDC to greater than 100 pCi/L. Sampling at Well UE18T has only been conducted since 1989, thus, only three analyses of tritium by the enrichment method have been completed. The 1991 result was 156 ± 3 pCi/L, the highest tritium activity measured in any of the LTHMP samples from the NTS onsite network in 1991. This result is approximately 0.8 percent of the NPDWR.

Analytical results for all samples are provided in Appendix E.

7.3 Offsite Monitoring In The Vicinity Of The Nevada Test Site

The monitoring sites located in the offsite area around the NTS are shown in Figure 42. Most of the sampling locations represent drinking water sources for rural residents in the offsite area and public drinking water supplies in most of the communities in the area. The sampling sites include 22 wells, seven springs, and two surface water sites. Twenty-nine of the locations are routinely sampled every month. Samples are collected each month for gamma spectroscopy analysis. The remaining two sites, Penoyer Well 13 and Penoyer Wells 7 and 8, are in operation only part of the year; samples are collected whenever the wells are in operation. All of the gross gamma results were negligible. Samples for tritium analysis are collected on a semiannual basis. One of these semiannual tritium analyses is done by the conventional tritium analysis method, the other is analyzed by the enrichment method.

Few of the sites have yielded detectable tritium levels (greater than approximately 7 to 10 pCi/L) over the last decade. Only three sites have evidenced detectable tritium activity on a relatively consistent basis. These three sites are Lake Mead

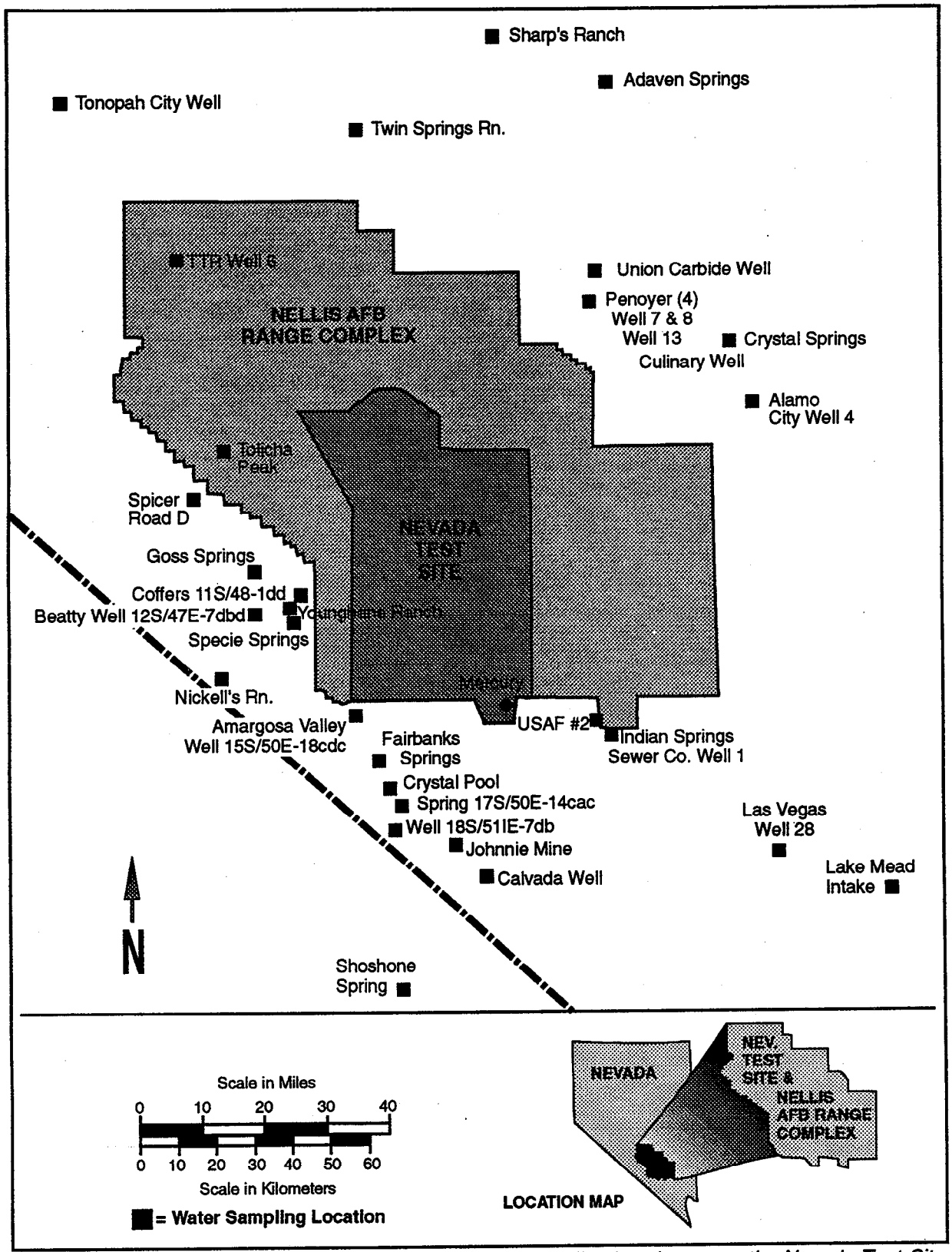

Figure 42. Long-Term Hydrological Monitoring Program sampling locations near the Nevada Test Site.

Intake (Boulder City, NV), Adaven Springs (Adaven, NV), and Specie Springs (Beatty, NV). In all three cases, the tritium activity has been generally decreasing over time. The 1991 sample results for Specie Springs were less than the MDC, as shown in Figure 43.

In 1991, only four of the samples analyzed for tritium by the enrichment method yielded detectable tritium activities. These were the January sample from Adaven Spring, the February sample from Shoshone Springs, CA, and two samples from the Lake Mead Intake collected in September and October. The Adaven Spring result of 27 ± 4 pCi/L (0.1 percent of the NPDWR) was consistent with the generally decreasing trend observed at this site, as shown in Figure 44. Tritium has occasionally been observed at detectable activities in Shoshone Springs, CA, samples, but a consistent trend is not evident. The 1991 result was 33 ± 3 pCi/L, which is less than 0.2 percent of the NPDWR. The results for the Lake Mead Intake were 69 ± 3 pCi/L and 65 ± 2 pCi/L for September and October, respectively. These results, which are 0.3 percent of the NPDWR, were greater than results obtained in 1990, as indicated in Figure 45. This surface water site may be impacted by rainfall containing scavenged atmospheric tritium to a greater extent than the well and spring sites in the offsite network.

Analytical results for all samples are contained in Appendix E.

7.4 Hydrological Monitoring At Other United States Nuclear Weapons Testing Locations

In addition to the groundwater monitoring conducted on and in the vicinity of the NTS, monitoring is conducted under the LTHMP at sites of past nuclear weapons testing in other parts of the U.S.

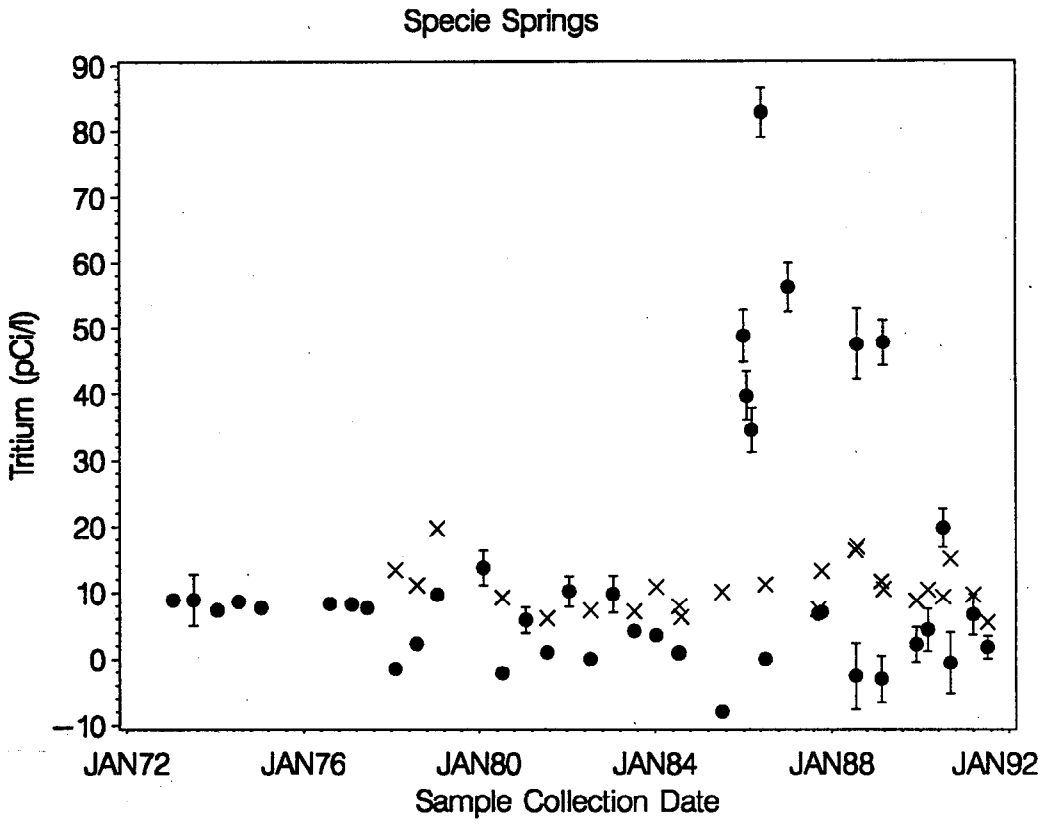

Figure 43. Tritium results ± 1 standard deviation for Specie Springs, January 1972 through December 1991. The x indicates the MDC value.

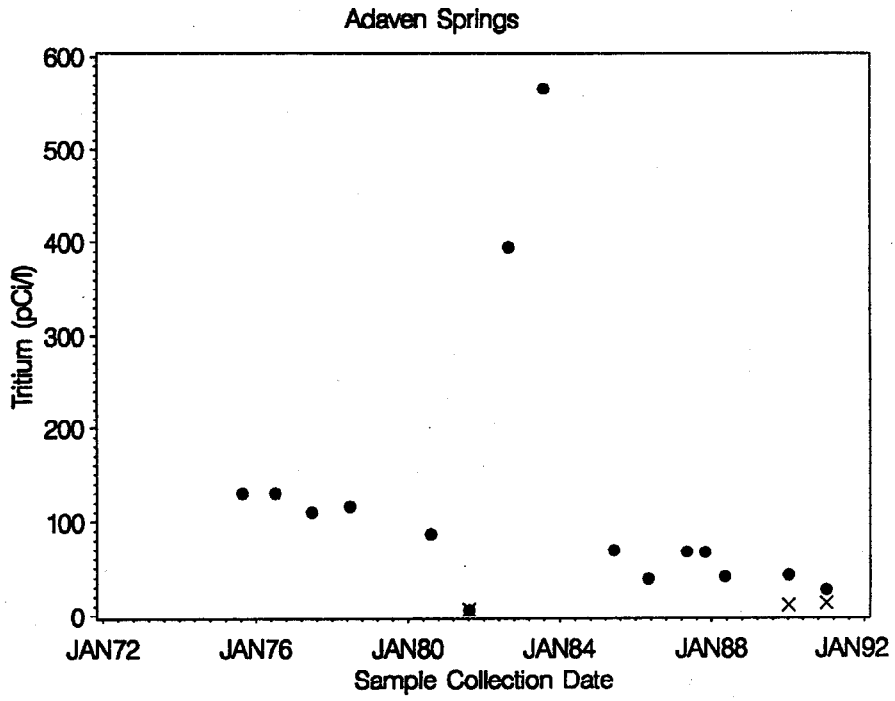

Figure 44. Tritium results for Adaven Springs, January 1975 through December 1991. The x indicates the MDC value. Error bars are within circles.

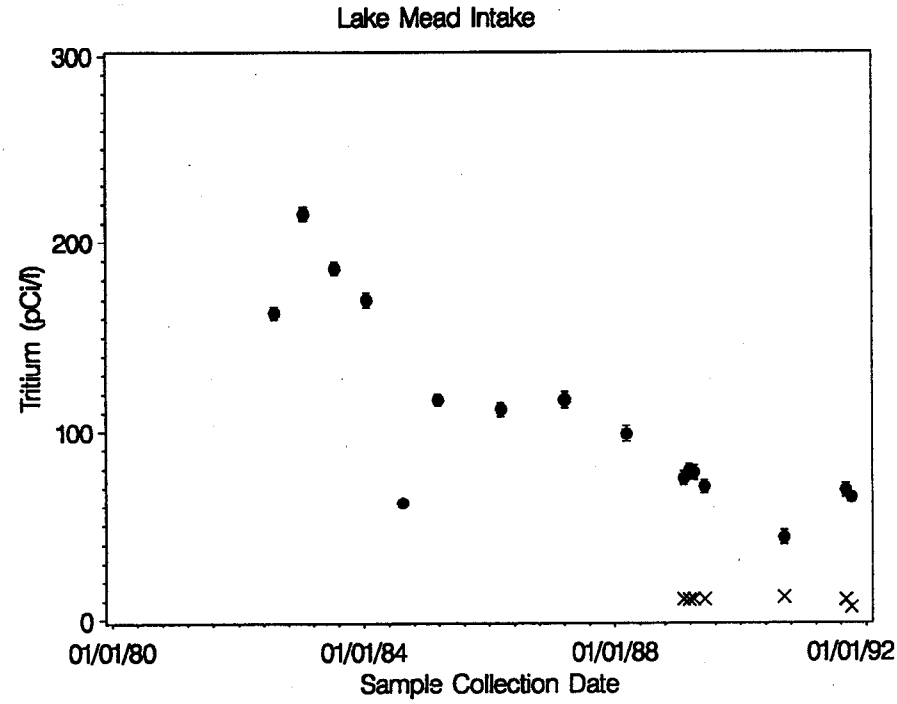

Figure 45. Tritium results ± 1 standard deviation for Lake Mead Intake, January 1982 through December 1991. The x indicates the MDC value.

Annual sampling of surface and ground waters is conducted at the Projects SHOAL and FAULTLESS sites in Nevada, the Projects GASBUGGY and GNOME sites in New Mexico, the Projects RULISON and RIO BLANCO sites in Colorado, and the Project DRIBBLE site in Mississippi. Additionally, sampling is conducted every two years on Amchitka Island, Alaska, site of Projects CANNIKIN, LONG SHOT, and MILROW. The primary purposes of this portion of the LTHMP are to ensure the safety of public drinking water supplies and, where suitable sampling points are available, to monitor any migration of radionuclides from the test cavity. The following subsections summarize results of sampling conducted in 1991; analytical results for all samples are provided in Appendix E.

The sampling procedure is the same as that used for sites on the NTS and offsite areas (described in Section 7.1.2), with the exception that two 3.8-L samples are collected in Cubitainers. The second sample serves as a backup or as a duplicate sample. Because of the variability noted in past years in samples obtained from the shallow monitoring wells near Project DRIBBLE ground zero (GZ), the sampling procedure was modified. A second sample is taken after pumping for a specified period of time or after the well has been pumped dry and permitted to refill with water. Both samples are analyzed. The second samples may be more representative of formation water, whereas the first samples may be more indicative of recent area rainfall. The gross gamma results for all the projects discussed in the following sections were negligible with the exception of Project GNOME. The results for Project GNOME are discussed in Section 7.4.5.

7.4.1 Project FAULTLESS

Project FAULTLESS was a "calibration test" conducted on January 19, 1968, in a sparsely populated area near Blue Jay Maintenance Station, Nevada. The test had a yield of less than 1 megaton and was designed to test the behavior of seismic waves and to determine the usefulness of the site for high-yield tests. The emplacement depth was 3200 ft. A surface crater was created, but as an irregular block along local faults rather than as a saucer-shaped depression. The area is characterized by basin and range topography, with alluvium overlaying tuffaceous sediments. The working point of the test was in tuff. The groundwater flow is generally from the highlands to the valley and through the valley to Twin Springs Ranch and Railroad Valley (Chapman and Hokett, 1991).

Sampling was conducted on March 19, 1991. Sampling locations are shown in Figure 46. Routine sampling locations include one spring and five wells of varying depths. All of the sampling locations are being used as, or are suitable for, drinking water supplies. At least two wells (HTH-1 and HTH-2) are positioned to intercept cavity migration, should it occur (Chapman and Hokett, 1991). All samples yielded negligible gamma spectra and tritium activities were less than the MDC and less than 0.01 percent of the NPDWR. These results are consistent with results obtained in previous years. The consistently below-MDC results for tritium indicate that, to date, migration into the sampled wells has not occurred and no event-related radiation has entered area drinking water supplies.

7.4.2 Project SHOAL

Project SHOAL, a 12 kiloton test emplaced at 1200 ft, was conducted on October 26, 1963, in a sparsely populated area near Frenchman Station, Nevada. The test, a part of the Vela Uniform Program, was designed to investigate detection of a nuclear detonation in an active earthquake zone. The working point was in granite and no surface crater was created. Samples were collected on February 12 and 13, 1991. Five of the six routine sampling locations shown in Figure 47 were sampled. No sample was collected from Well H-3 because the pump was not operational. The routine sampling locations include one spring, one windmill, and four wells of varying depths. At least one location, Well HS-1, should intercept cavity migration, should it occur (Chapman and Hokett, 1991). A tritium result of 67 ± 3 pCi/L was detected in the water sample from Smith/James Spring; all of the remaining samples yielded tritium results less than the MDC. The result for Smith/James Springs is consistent with values obtained in previous years, as shown in Figure 48. It is unlikely that the tritium source is the Project SHOAL cavity; the most probable source is assumed to be rainwater infiltration. The 1991 tritium results are 0.3 percent of the NPDWR for Smith/James Spring and less than 0.01 percent of the NPDWR for the remaining sampling locations.

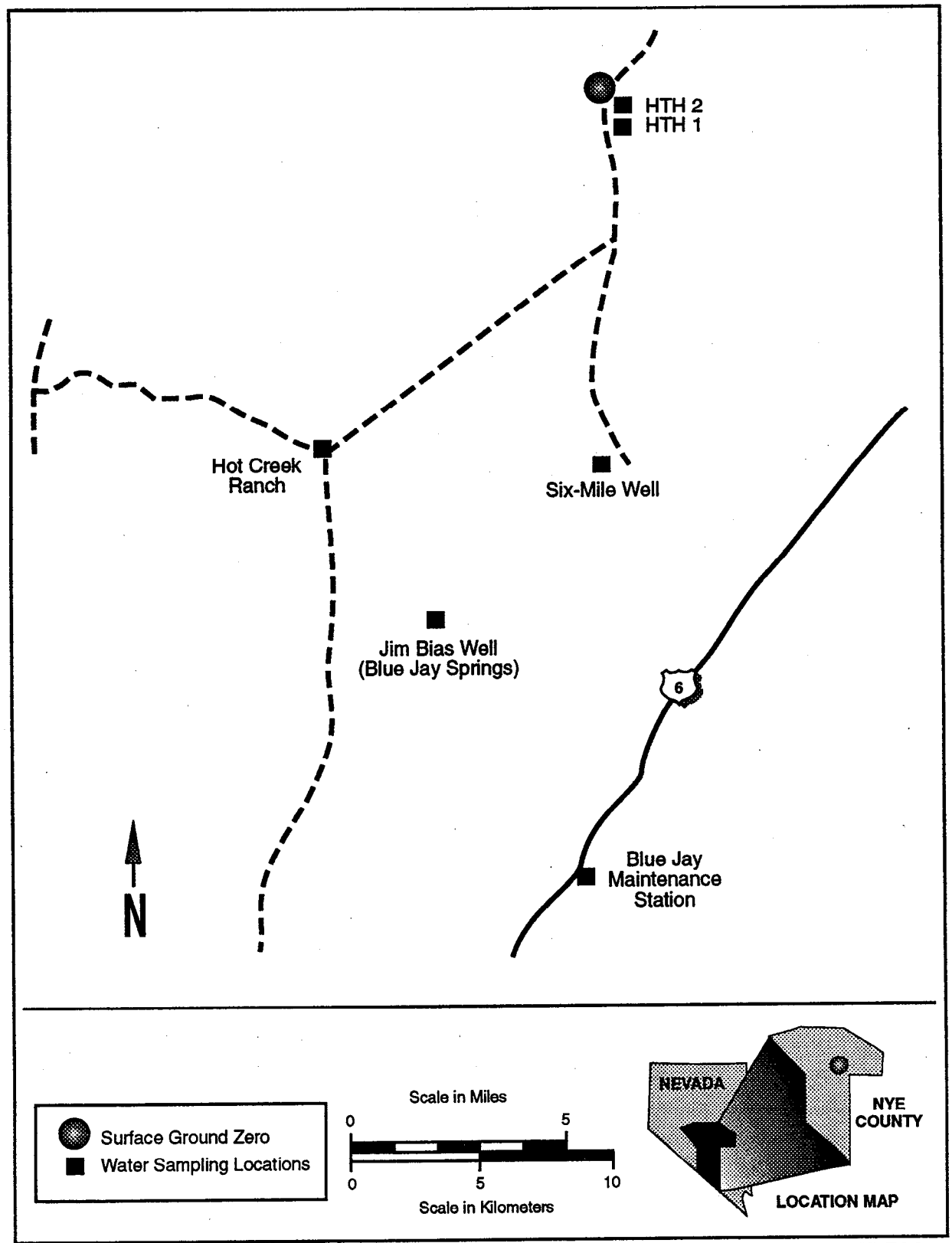

Figure 46. Long-Term Hydrological Monitoring Program sampling locations for Project FAULTLESS.

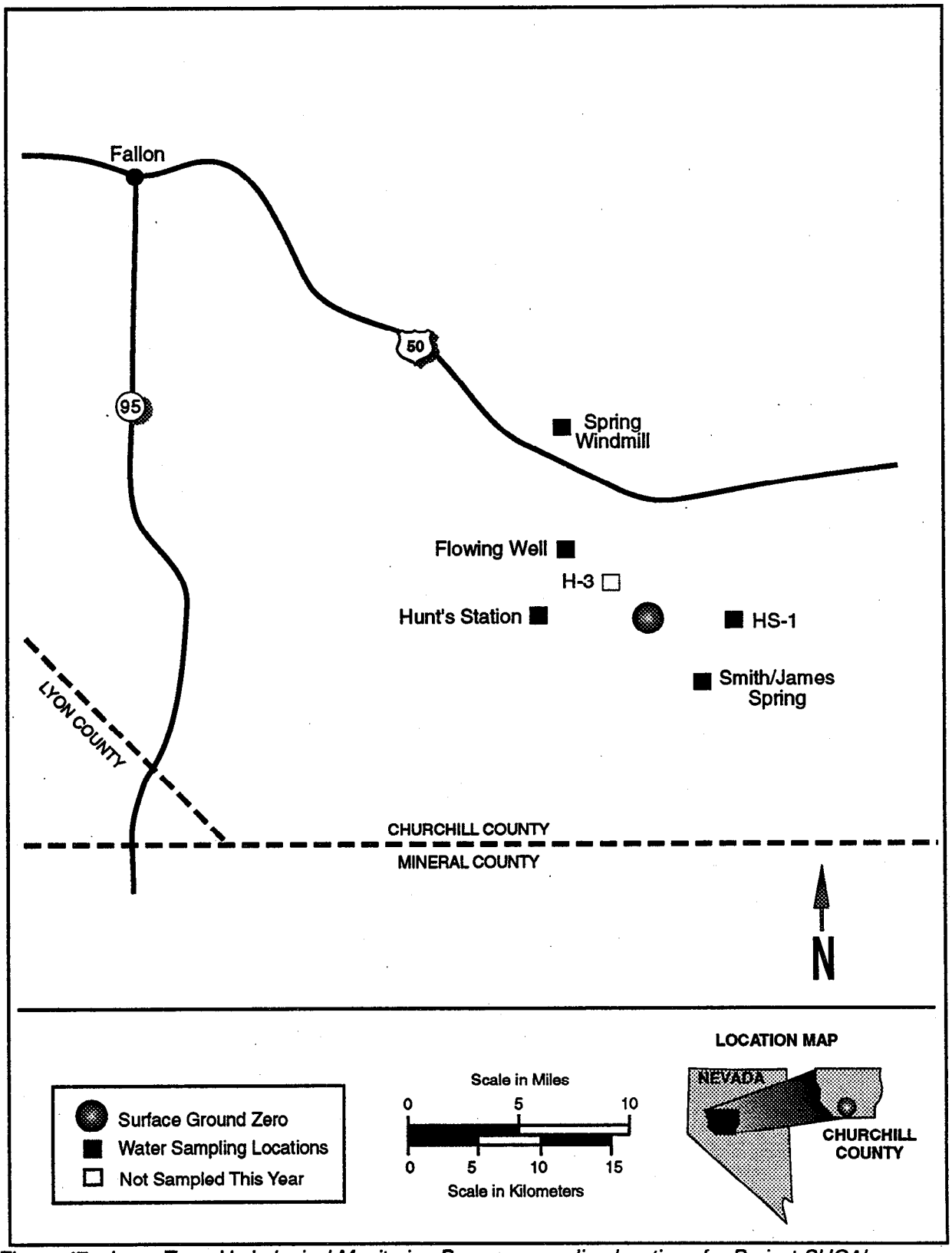

Figure 47. Long-Term Hydrological Monitoring Program sampling locations for Project SHOAL.

7.4.3 Project RULISON

Cosponsored by AEC and Austral Oil Co. under the Plowshare Program, Project RULISON was designed to stimulate natural gas recovery in the Mesa Verde formation. The test, conducted near Rifle, Colorado on September 10, 1969, consisted of a 43 kiloton nuclear explosive emplaced at 8426 ft depth. Production testing began in 1970 and was completed in April 1971. Cleanup was initiated in 1972 and wells were plugged in 1976. Some surface contamination resulted from decontamination of drilling equipment and fallout from gas flaring. Soil was removed during the cleanup operations.

Sampling was completed on June 11, 1991, with the collection of nine samples in the area of Grand Valley and Rulison, CO. Routine sampling locations, depicted in Figure 49, include the Grand Valley municipal drinking water supply springs, water supply wells for five local ranches, and three sites in the vicinity of SGZ, including one test well, a surface-discharge spring, and a surface sampling location on Battlement Creek. An analysis of the sampling locations performed by DRI indicated that none of the sampling locations are likely to detect migration of radionuclides from the test cavity (Chapman and Hokett, 1991). Most of the sampling locations draw water from the surficial aquifer, composed of Quaternary deposits. This aquifer is separated from the test cavity "by great thicknesses of low permeability formations, making transport of contamination through the geologic medium unlikely" (Chapman and Hokett, 1991). Migration up the emplacement hole or drillback well is also thought to be unlikely due to a zone of low pressure at 7200 feet (Chapman and Hokett, 1991).

Tritium has never been observed in measurable concentrations in the Grand Valley City Springs. All of the remaining sampling sites show detectable levels of tritium, which have exhibited a decreasing trend over the last two decades. The range of

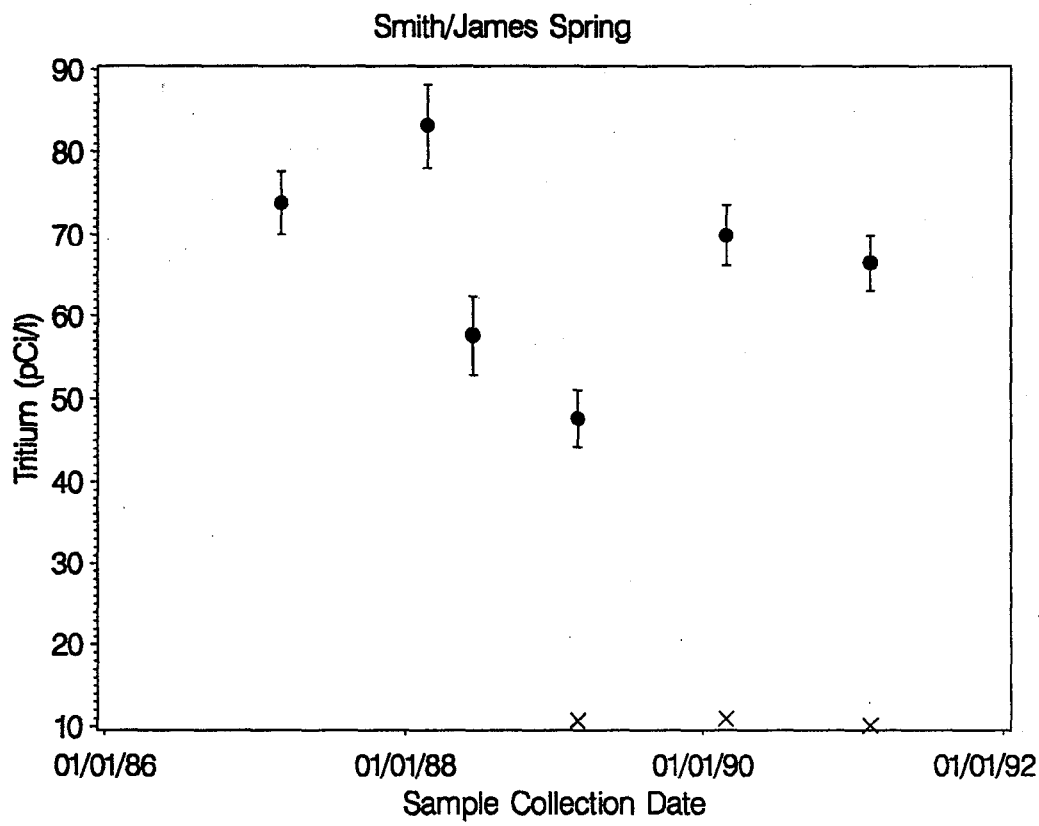

Figure 48. Tritium results ± 1 standard deviation for Smith/James Spring, January 1986 through December 1991. The x indicates the MDC value.

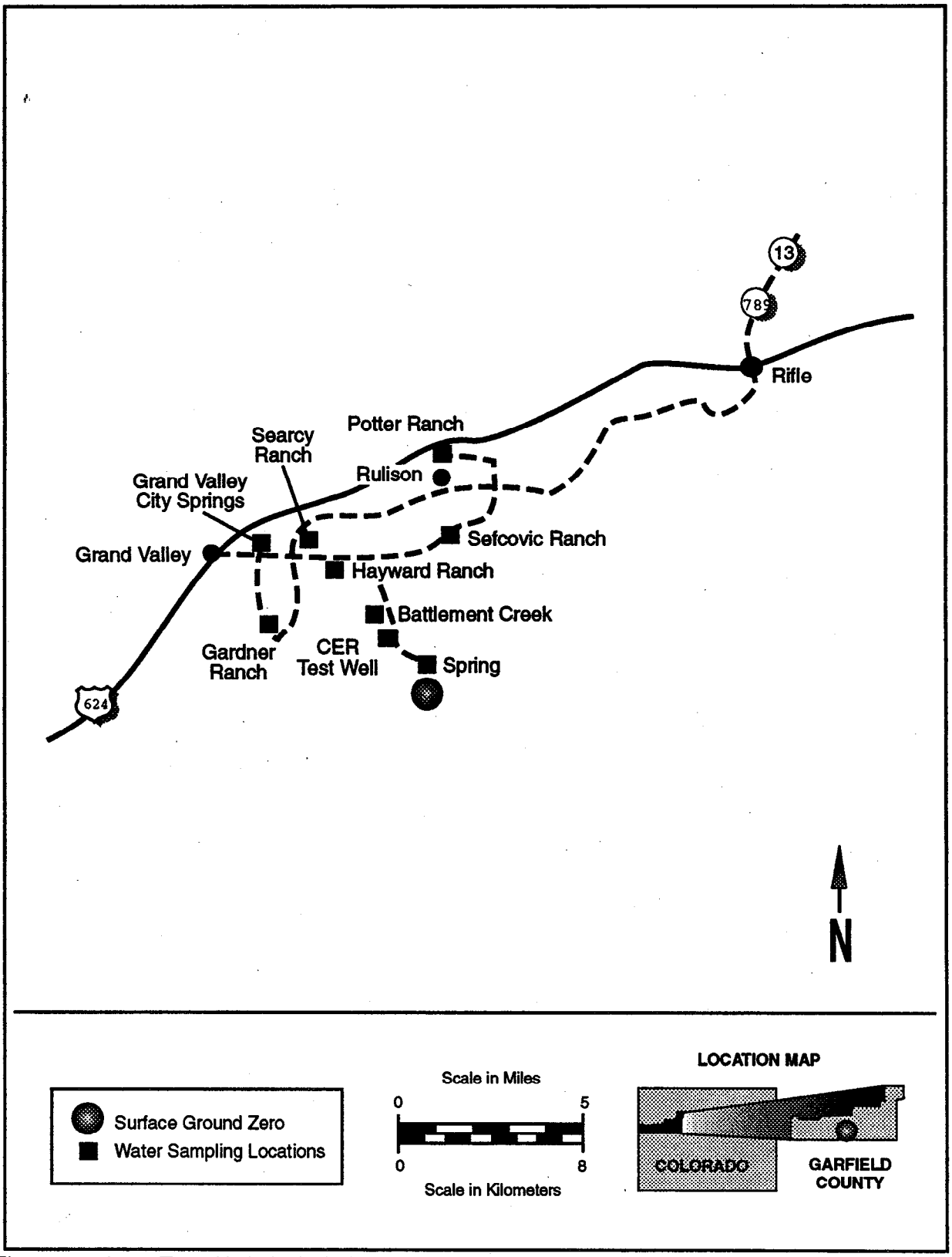

Figure 49. Long-Term Hydrological Monitoring Program sampling locations for Project RULISON.

tritium activity in the 1991 samples was 56 ± 3 pCi/L at Battlement Creek to 187 ± 4 pCi/L at Lee Hayward Ranch. These values are 0.3 to 0.9 percent of the NPDWR. Tritium results for all samples are provided in Appendix E. An analysis by DRI indicated that most of the sampling locations draw water from the surficial aquifer which is unlikely to become contaminated by any radionuclides arising from the Project RULISON cavity (Chapman and Hokett, 1991). Figure 50 displays data for the last 20 years for Lee Hayward Ranch. The low value obtained in 1990 was attributed to analytical bias and was observed consistently for all Project RULISON sampling locations.

7.4.4 Project RIO BLANCO

Like Project RULISON, Project RIO BLANCO was a joint government-industry test designed to stimulate natural gas flow conducted under the Plowshare Program. The test was conducted on May 17, 1973, at a location between Rifle and Meeker, Colorado. Three explosives with a total yield of 90 kt were emplaced in a 7000 ft hole. The explosives were emplaced at 5838, 6229, and 6689 ft depths in the Ft. Union and Mesa Verde formations. Production testing continued to 1976; tritiated water produced during testing was injected to 5600 ft in a nearby gas well. Cleanup and restoration activities were completed by November 1976.

Sampling was completed on June 12 and 13, 1991, with the collection of thirteen samples. One routine sampling location, Brennan Windmill, was not sampled because the windmill was inoperative. The sampling sites, shown in Figure 51, include two shallow domestic water supply wells, six surface water sites along Fawn Creek, three springs, and three monitoring wells located near the cavity. At least two of the monitoring wells (wells RB-D-01 and RB-D-03) are suitable for monitoring possible cavity migration. All of the springs had tritium activities of approximately 60 pCi/L (range 60 to 62 pCi/L). These values are 0.3 percent of the NPDWR. Of two shallow domestic wells located near the Project RIO BLANCO site, one could not be sampled in 1991 and the other yielded no detectable tritium activity. All of the sampling sites along Fawn Creek yielded tritium activities of approximately 30 pCi/L (range 27 to 34 pCi/L), equivalent to 0.1 to 0.2 percent of the NPDWR. There is no statistically significant difference observed between results for sites located upstream and downstream of the cavity area. Figures 52a and 52b depict tritium data for two Fawn Creek sites, one located more than a mile upstream of surface ground zero and the other located 500 ft downstream of surface ground zero. The three monitoring wells all yielded no detectable tritium activity, indicating that migration from the test cavity has not occurred. Tritium analysis results for each sample are contained in Appendix E.

7.4.5 Project GNOME

Project GNOME, conducted on December 10, 1961, near Carlsbad, New Mexico, was a multipurpose test conducted in a salt formation. A slightly more than three kiloton nuclear explosive was emplaced at 1216 ft depth in the Salado salt formation. Oil and gas are produced from the geologic units below the working point. The overlying Rustler formation contains three water-bearing zones: brine located at the boundary of the Rustler and Salado formations, the Culebra Dolomite which is used for domestic and stock supplies, and the Magenta Dolomite which is above the zone of saturation (Chapman and Hokett, 1991). The groundwater flow is generally to the west and southwest.

Radioactive gases were unexpectedly vented during the test. In 1963, USGS conducted a tracer study involving injection of 20 Ci tritium, 10 Ci ^{137}Cs, 10 Ci ^{90}Sr, and 4 Ci ^{131}I in the Culebra Dolomite zone; wells USGS 4 and 8 were used for this tracer study. During remediation activities in 1968-69, contaminated material was placed in test cavity and shaft up to within seven ft of the surface. More material was slurried into the cavity and drifts in 1979. There is a potential for discharge of this slurry to the Culebra Dolomite and to Rustler-Salado brine. This potential may increase as the salt around the cavity will compress, forcing contamination upward and distorting and cracking the concrete stem and grout.

Sampling in the area of Project GNOME was completed between June 22 and 25, 1991. A total of 11 samples were collected from routine sampling locations in Carlsbad, Loving, and Malaga, NM. One location, Well 1 at the Pecos Pumping Station, was not sampled because access could not be obtained. The routine sampling sites, depicted in Figure 53, include nine monitoring wells in the vicinity of surface GZ, the municipal supplies

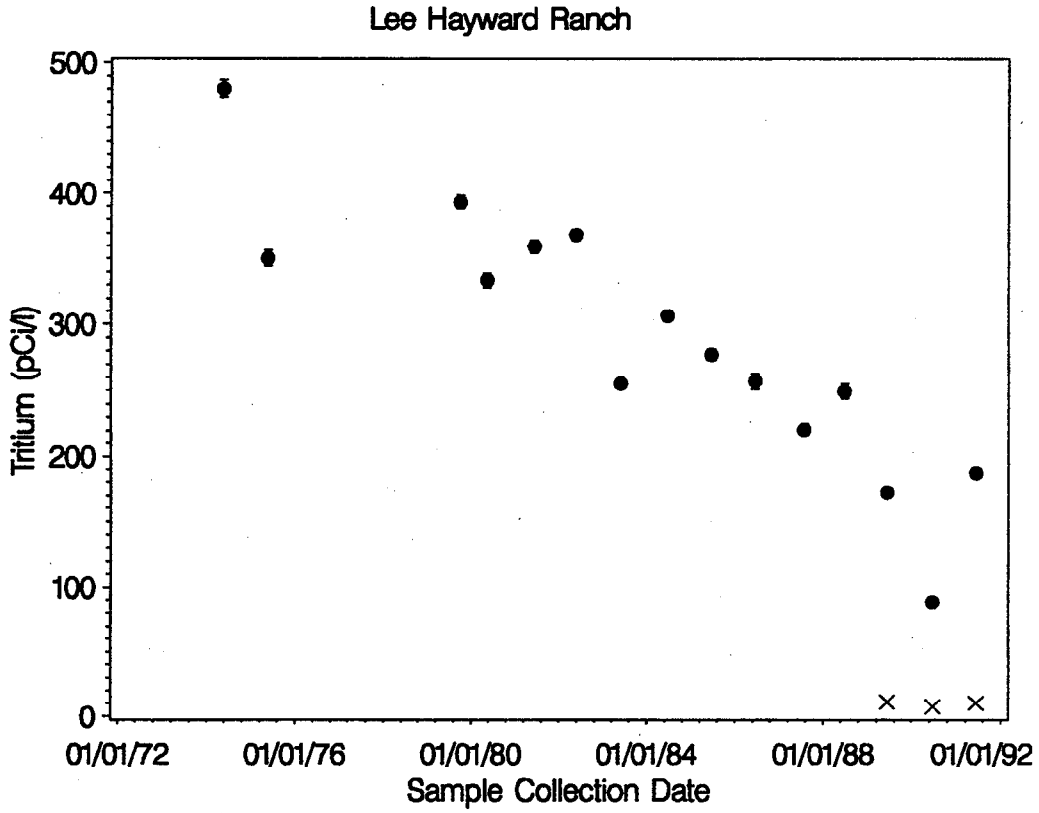

Figure 50. Tritium results ± 1 standard deviation for Lee Hayward Ranch, January 1972 through December 1991. The x indicates the MDC value.

at Loving and Carlsbad, NM, and the Pecos River Pumping Station well. As in previous years, the municipal water supplies indicated no detectable tritium activity. An analysis by DRI (Chapman and Hokett, 1991) indicates the Loving and Carlsbad municipal supply wells, located on the opposite side of the Pecos River from the Project GNOME site, are not connected hydrologically to the site and, therefore, can not become contaminated by Project GNOME radionuclides.

Tritium results greater than the MDC were detected in water samples from six of the nine sampling locations in the immediate vicinity of GZ. In addition to tritium, detectable concentrations of ^{137}Cs and ^{90}Sr were observed in Well DD-1 which samples water in the test cavity, Well LRL-7 which samples a sidedrift, and wells USGS 4 and 8, which were used in the radionuclide tracer study conducted by USGS. The remaining two wells with detectable tritium concentrations were PHS wells 6 and 8, with results of 41 ± 3 pCi/L and 13 ± 3 pCi/L, respectively. These values are 0.2 and less than 0.1 percent, respectively, of the NPDWR. In all cases, the tritium activities exhibit a decreasing trend, as shown in Figures 54a, 54b, 54c and 54d.

The figures show the normal tritium decay curve as well as the tritium values. No tritium was detected in the remaining Project GNOME samples, including USGS Well 1, which the DRI analysis (Chapman and Hokett, 1991) indicated is positioned to possibly detect cavity migration, should it occur.

7.4.6 Project GASBUGGY

Project GASBUGGY, like Project RULISON, was a Plowshare Program test cosponsored by the U.S. government and El Paso Natural Gas. Conducted near Gobernador, New Mexico on December 10, 1967, the test was designed to stimulate a low productivity natural gas reservoir. A nuclear explosive with a 29-kt yield was emplaced at a depth of 4240 ft in the Lewis Shale formation, with the resultant cavity extending into the overlying

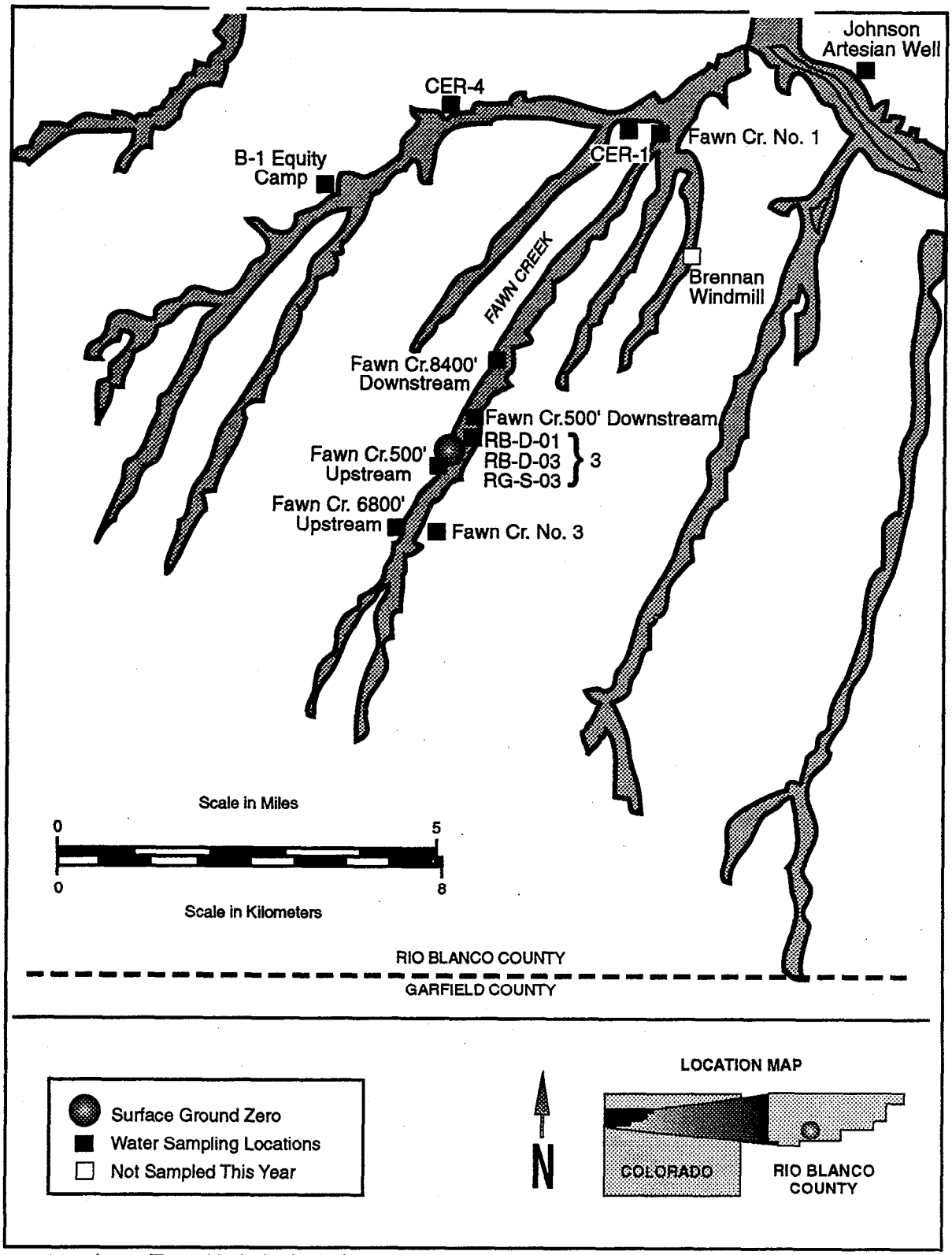

Figure 51. Long-Term Hydrological Monitoring Program sampling locations for Project RIO BLANCO.

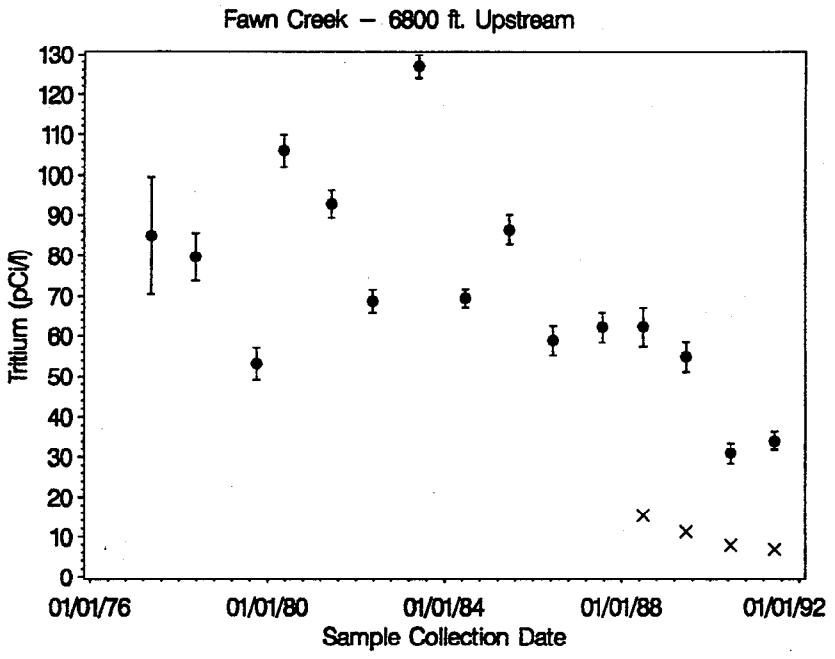

Figure 52a. Tritium results for Fawn Creek - 6800 ft upstream of surface ground zero, January 1976 through December 1991.

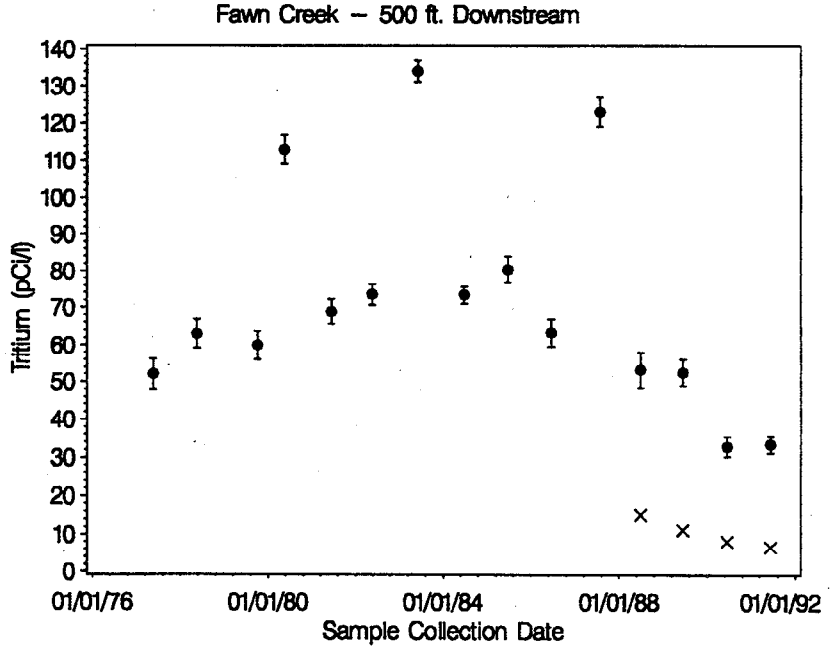

Figure 52b. Tritium results for Fawn Creek - 500 ft downstream of surface ground zero, January 1976 through December 1991.

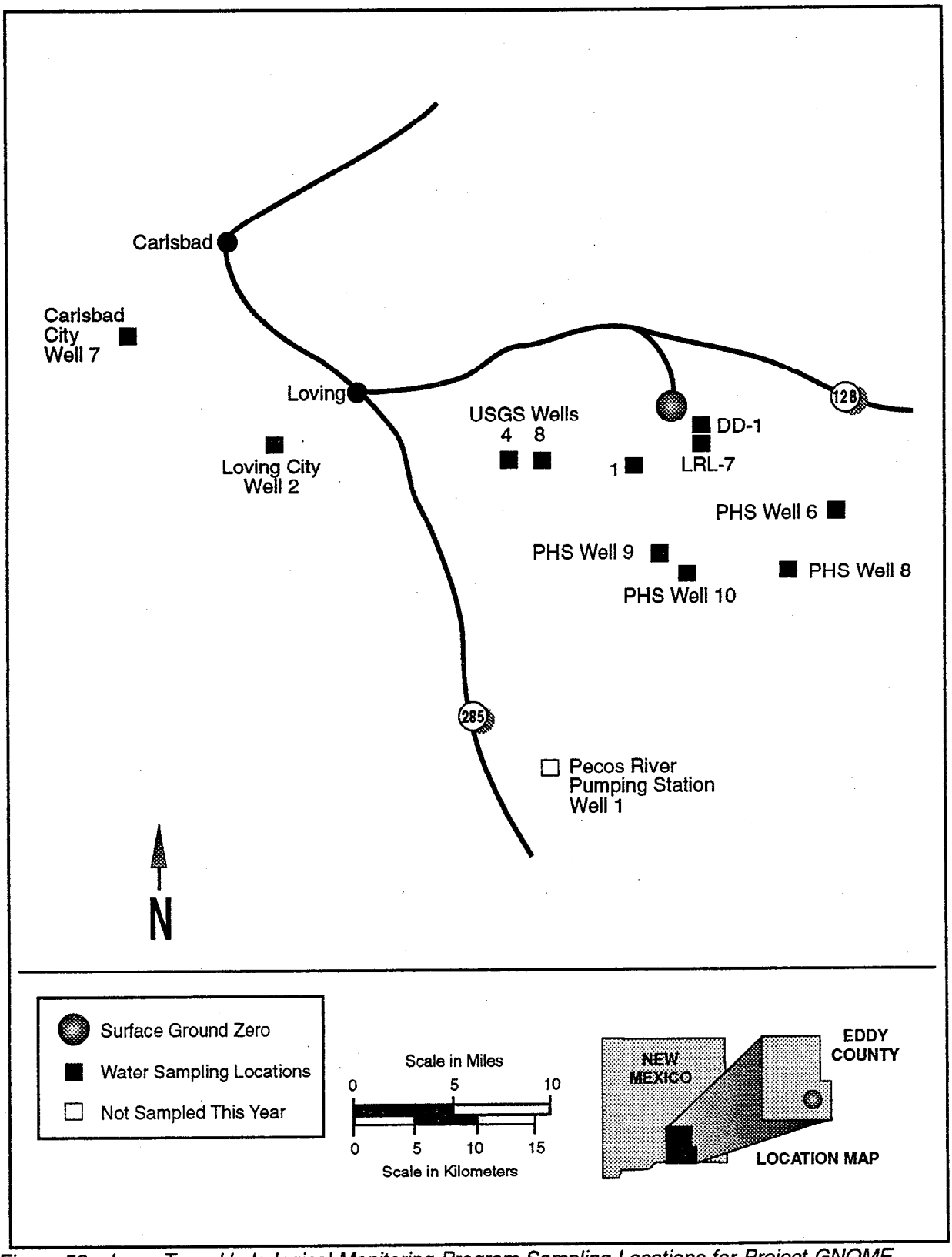

Figure 53. Long-Term Hydrological Monitoring Program Sampling Locations for Project GNOME.

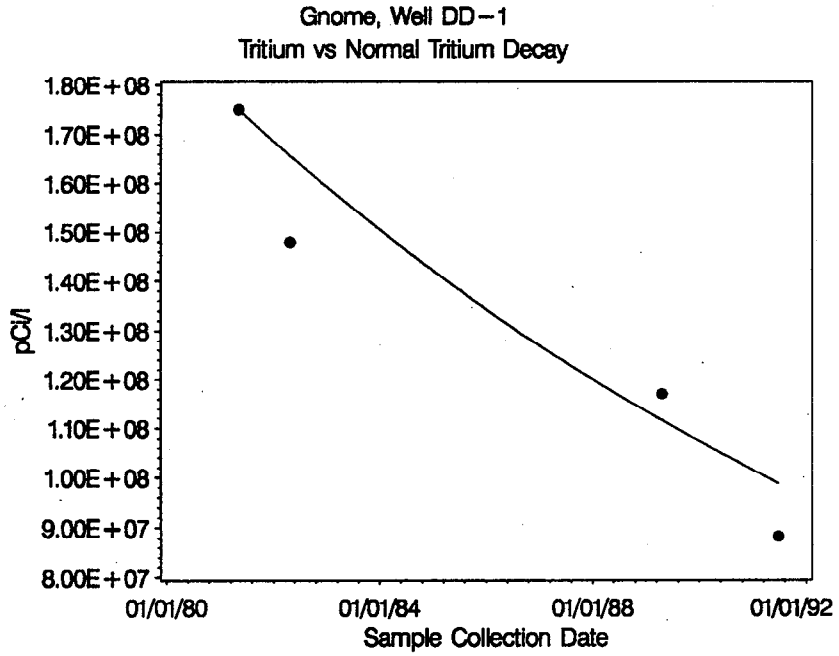

Figure 54a. Tritium results plotted with normal tritium decay curve for Gnome Well DD-1, January 1980 through December 1991.

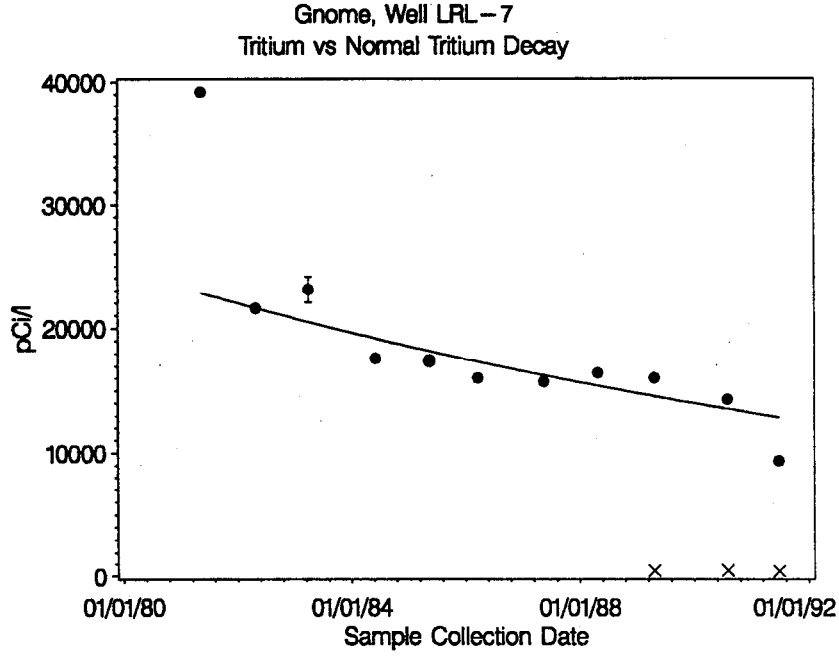

Figure 54b. Tritium results ± 1 standard deviation plotted with normal tritium decay curve for Gnome Well LRL-7, January 1980 through December 1991. The x indicates the MDC value.

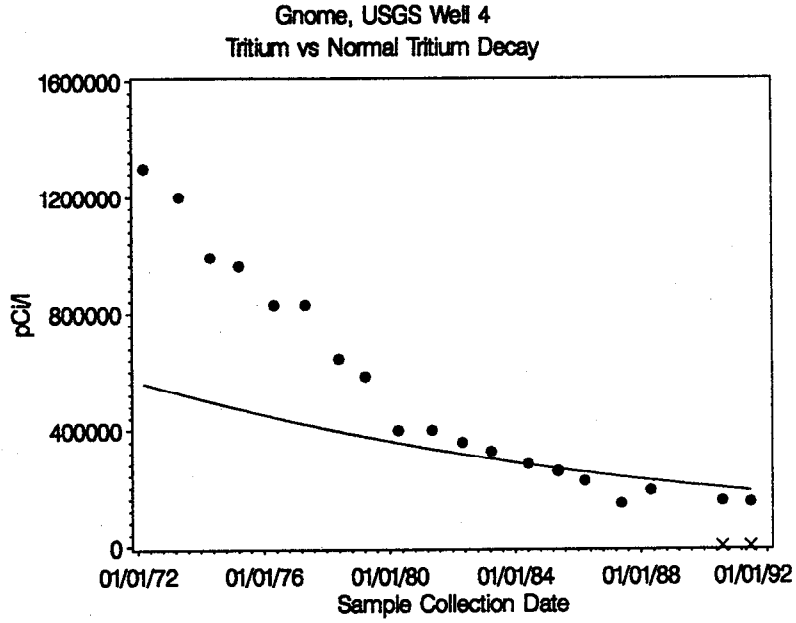

Figure 54c. Tritium results plotted with normal tritium decay curve for Gnome USGS Well 4, January 1972 through December 1991. The x indicates the MDC value.

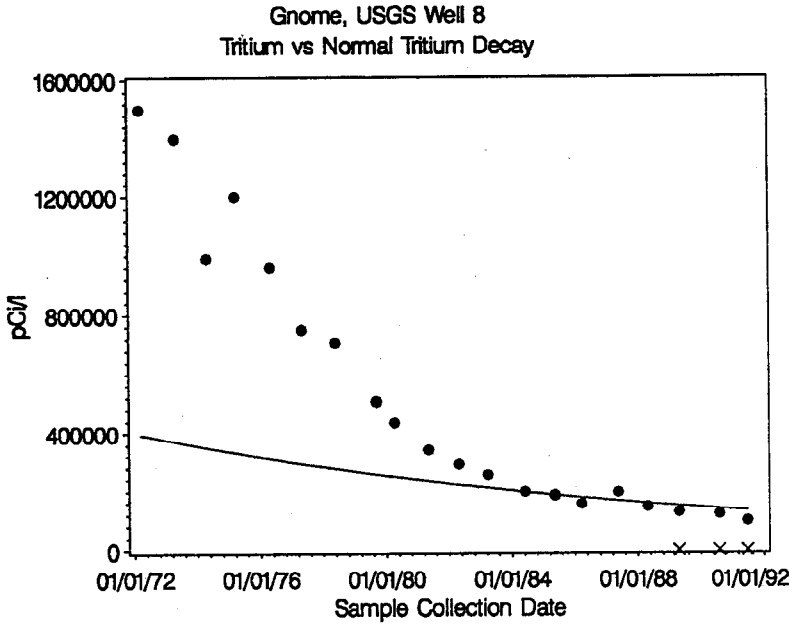

Figure 54d. Tritium results plotted with normal tritium decay curve for Gnome USGS Well 8, January 1972 through December 1991. The x indicates the MDC value.

Painted Cliffs Sandstone. Neither of these formations are major water producers. Production testing was completed in 1976 and restoration activities were completed in July 1978.

The principal aquifers are the Ojo Alamo Sandstone, an aquifer containing nonpotable water located above the test cavity, and the San Jose formation and Nacimiento formation, both surficial aquifers containing potable water. The flow regime of the San Juan Basin is not well known, although it is likely that the Ojo Alamo Sandstone discharges to the San Juan River 50 miles northwest of the Gasbuggy site. Hydrologic gradients in the vicinity are downward, but upward gas migration is possible (Chapman and Hokett, 1991).

Thirteen samples were collected between June 17 to 19, 1991. Well 300.3.32.343 (North) has been removed and, therefore, has been deleted from the routine sampling location directory. A sample was collected from the Old School House Well at the request of the State of New Mexico. This was intended to be a one-time sample only, but the site is being considered for addition to the routine sampling directory due to its location in the probable downgradient direction from the test cavity. The routine sampling locations include seven wells, one windmill, three springs, and two surface water sites, depicted in Figure 55. The two surface water sampling sites yielded tritium activities of 40 ± 2 pCi/L and 46 ± 2 pCi/L; these values may be indicative of concentrations in rainfall and are 0.2 percent of the NPDWR. The three springs yielded tritium activities ranging from 48 ± 3 pCi/L to 71 ± 3 pCi/L, which is 0.2 to 0.4 percent of the NPDWR. Tritium activities in shallow wells varied from less than the MDC to 50 ± 2 pCi/L, which is less than 0.1 to 0.3 percent of the NPDWR.

Well EPNG 10-36, a former gas well located 435 ft northwest of the test cavity with a sampling depth of approximately 3600 ft, yielded a tritium activity of 484 ± 4 pCi/L in 1991. Prior to 1984, all tritium activities measured in this well were less than 45 pCi/L, a value which may be considered the background activity for this location. In 1984 and every year since then, with the exception of 1987, tritium activities have been between 100 and 560 pCi/L, with wide variability sometimes noted between consecutive years. In each of the last three years, the activity in this well has approximately doubled, as shown in Figure 56. The proximity of the well to the test cavity suggests the possibility that the increased activity may be indicative of migration from the test cavity into the Ojo Alamo Sandstone groundwater. Communication between the Ojo Alamo Sandstone and the test cavity has been documented (Power and Bowman 1970) and is probably due to concrete failure. It is also "unlikely but remotely possible" that fracturing around the test cavity extends to the Ojo Alamo Sandstone (DOE, 1986). Representatives of DOE, DRI, and EPA are currently working on a sampling plan for this well to further investigate the increased activity.

7.4.7 Project DRIBBLE

Project DRIBBLE was comprised of four explosive tests, two nuclear and two gas, conducted in the Tatum Salt Dome area of Mississippi under the Vela Uniform Program. The purpose of Project DRIBBLE was to study the effects of decoupling on seismic signals produced by explosives tests. The first test, SALMON, was a nuclear device with a yield of about 5 kt, detonated on October 22, 1964, at a depth of 2710 ft. This test created the cavity used for the subsequent tests, including STERLING, a nuclear test conducted on December 3, 1966, with a yield of about 380 tons, and the two gas explosions, DIODE TUBE, conducted on February 2, 1969, and HUMID WATER, conducted on April 19, 1970. The ground surface and shallow groundwater aquifers were contaminated by disposal of drilling muds and fluids in surface pits. The radioactive contamination was primarily limited to the unsaturated zone and upper aquifers containing nonpotable water. Shallow wells, labeled HMH wells on Figure 57 have been added to the area near surface GZ to monitor this contamination. In addition to the monitoring wells surrounding GZ, extensive sampling is conducted in the nearby offsite area. Most private drinking water supply wells are included, as shown in Figure 58.

Sampling on and in the vicinity of the Tatum Salt Dome was conducted between April 21 and 24, 1991. A total of 104 samples were collected; eight of these were from new sampling locations in Columbia and Lumberton, MS. Eight routine sampling locations were not sampled. In two cases, the residents (Rita Smith and Donald Beach) have moved and the well is not in operation. These sampling locations will not be sampled again unless new residents reopen the well. Another resident (M. Lowe) switched to rural water and is no longer using a well, thus eliminating the need to sample at this location. The other five

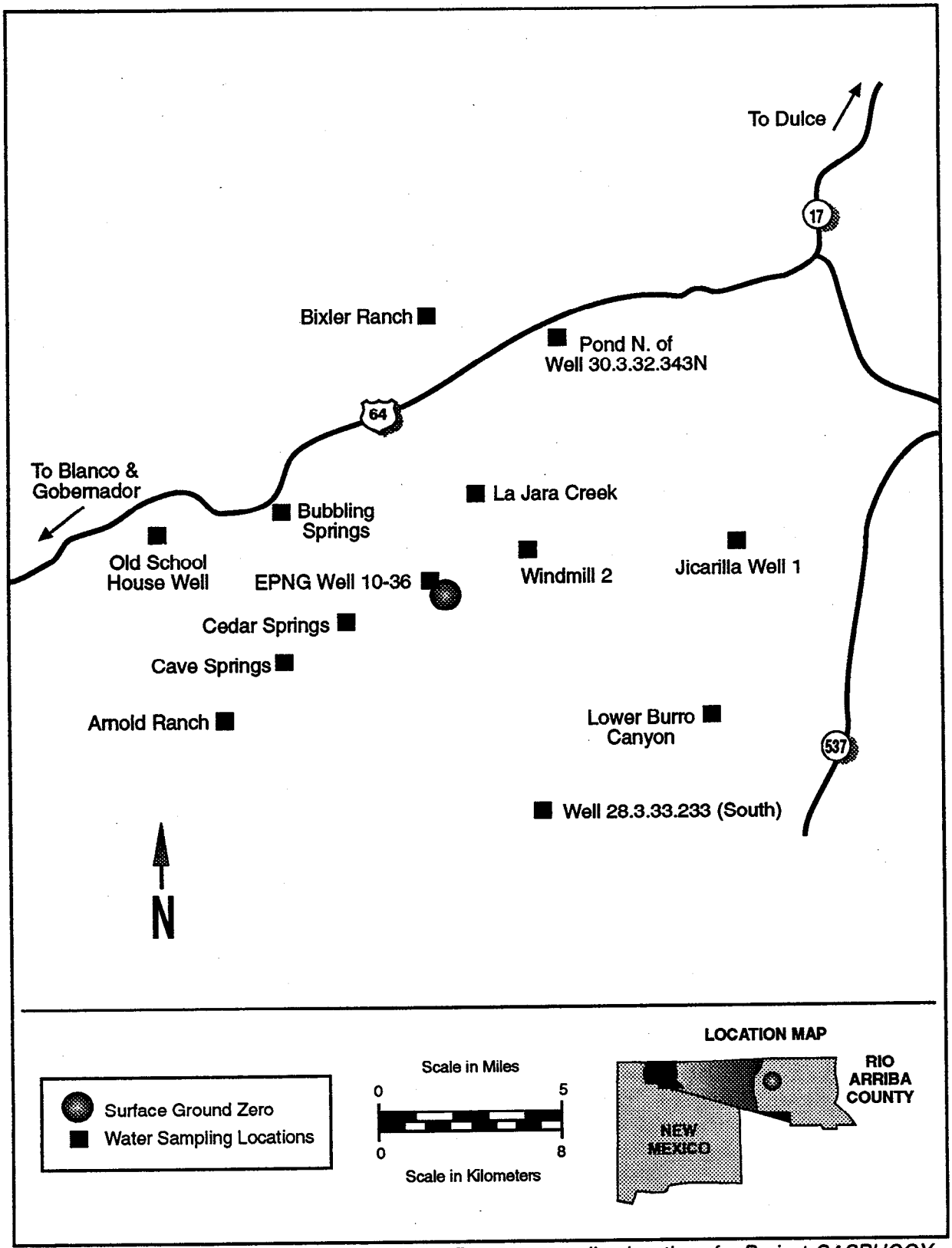

Figure 55. Long-Term Hydrological monitoring Program sampling locations for Project GASBUGGY.

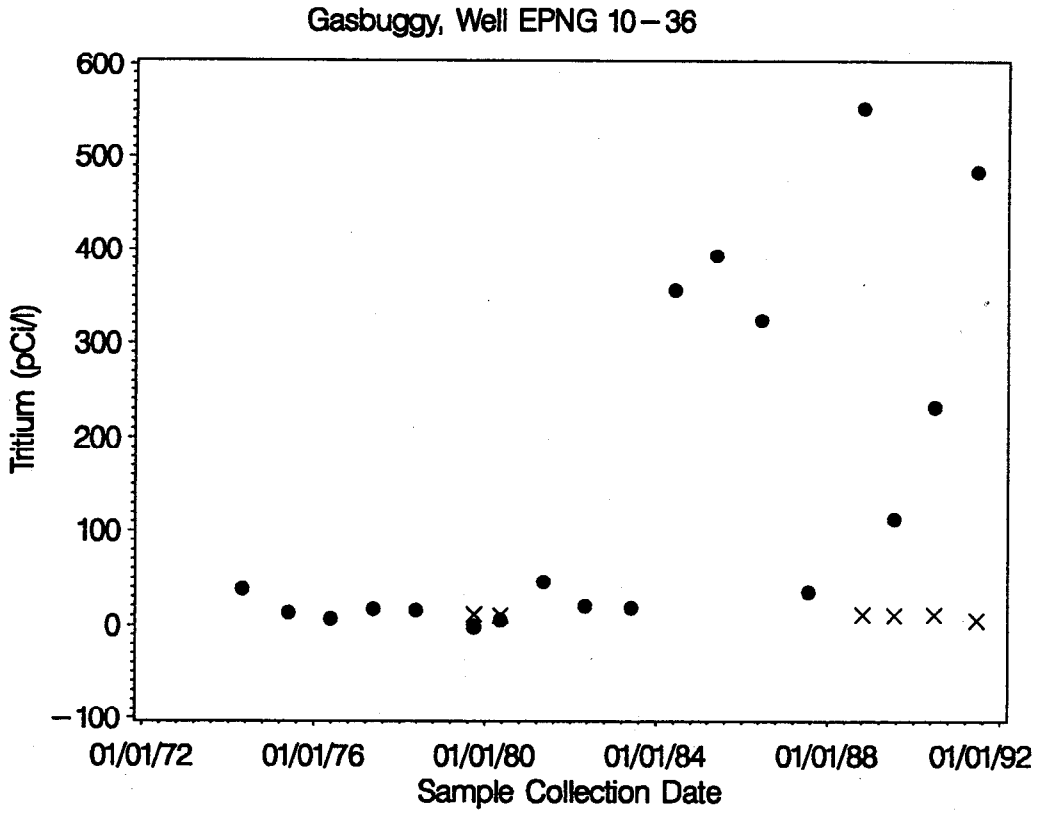

Figure 56. Tritium results for Gasbuggy Well EPNG 10-36, January 1972 through December 1991.

samples were not taken this year either because the site was inaccessible due to local flooding or because the resident was not home.

Of the 47 samples collected from offsite sampling locations, tritium activities ranged from less than the MDC to 48 ± 4 pCi/L, equivalent to less than 0.01 to 0.2 percent of the NPDWR. The results do not exceed the natural tritium activity expected in rainwater in the area. Results for each sample are provided in Appendix E. Uranium-238 was detected at concentrations greater than the MDC in three of the water samples collected from the eight new sampling locations and ^{234}U was greater than the MDC in one sample. The highest ^{238}U was 0.0705 ± 0.0191 pCi/L and the highest ^{234}U was 0.0537 ± 0.0163 pCi/L, both in the water sample collected from the pond on the Howard Smith property in Lumberton, MS. These activities are extremely low and probably of natural origin.

Due to the high rainfall in the area, the normal sampling procedure is modified for the shallow onsite wells. Following collection of a first sample, the well is pumped for a set period of time and permitted to refill and a second sample is collected. The second samples are thought to be more representative of the formation water. Thirty-two locations were sampled in the vicinity of GZ; 23 of these yielded tritium activities greater than the MDC in either the first or second sample. Overall, tritium activities ranged from less than the MDC to $1.44 \times 10^4 \pm 1.95 \times 10^2$ pCi/L. The locations where the highest tritium activities were measured generally correspond to areas of known contamination. None of the samples indicate any migration of radionuclides from the test cavity. Results for all samples are provided in Appendix E. Results of sampling related to Project DRIBBLE are discussed in greater detail in *Onsite and Offsite Environmental Monitoring Report: Radiation Monitoring around Tatum Salt Dome, Lamar County, Mississippi, April 1991* (Thomé et al, in press).

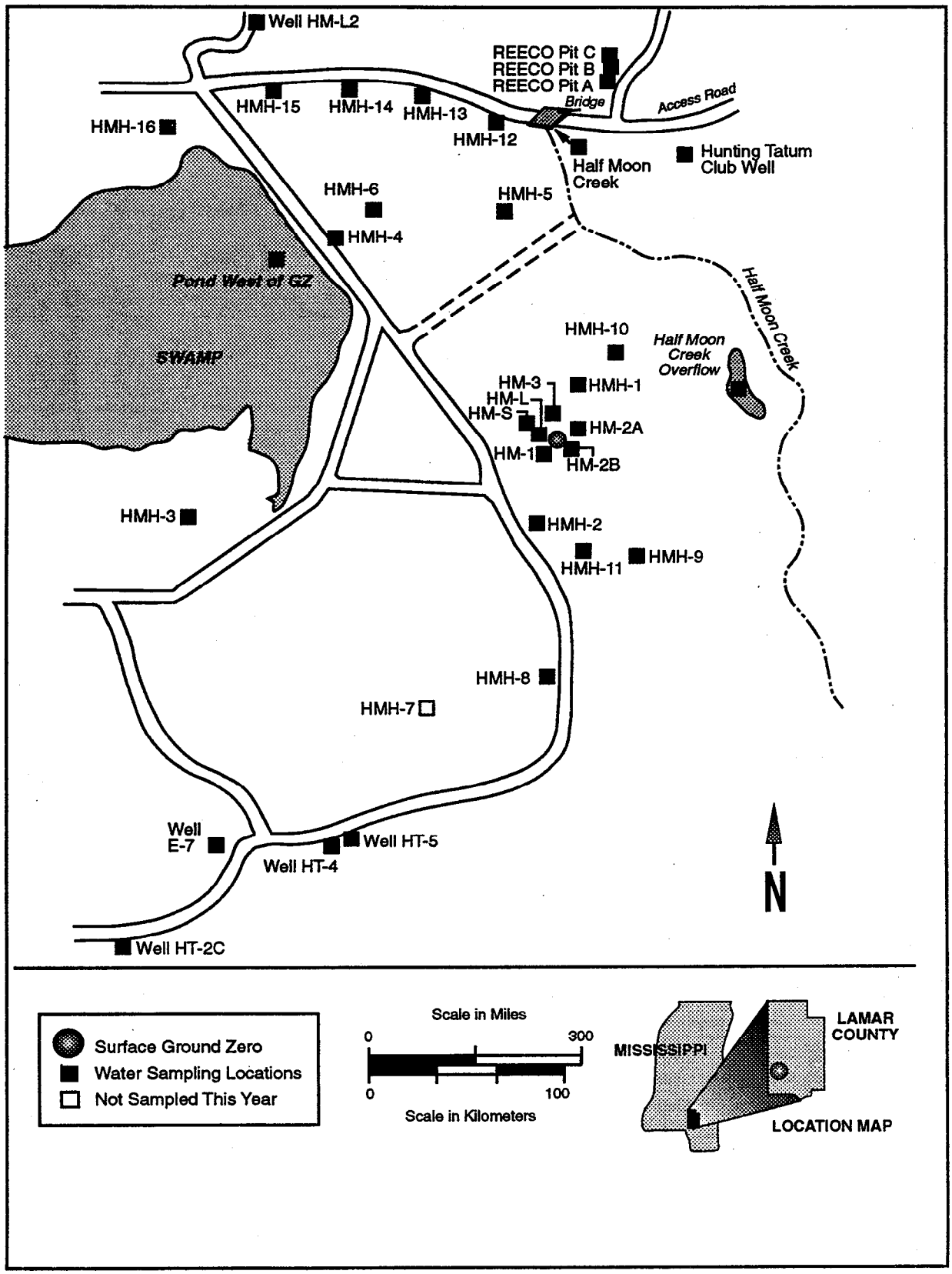

Figure 57. Long-Term Hydrological Monitoring Program sampling locations for Project DRIBBLE-near ground zero.

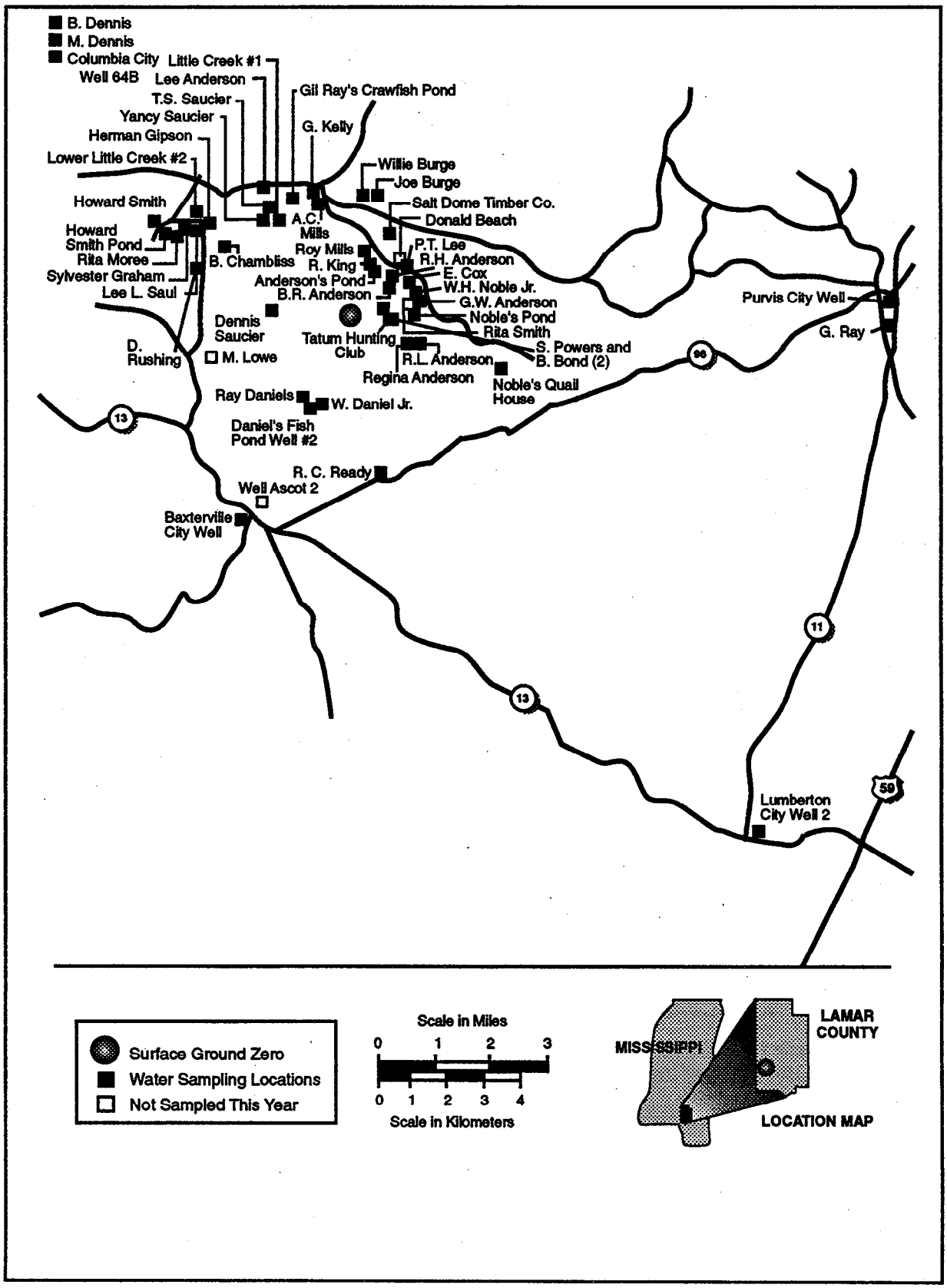

Figure 58. Long-Term Hydrological Monitoring Program sampling locations for Project DRIBBLE-towns and residences.

7.4.8 Amchitka Island, Alaska

Three nuclear detonations were conducted on Amchitka Island in the Aleutian Island chain of Alaska. Project LONG SHOT, conducted on October 29, 1965, was an 85-kt yield test emplaced at 2359 ft depth. It was a Vela Uniform Program test, designed to investigate the travel times of seismic waves. Project MILROW, conducted on October 2, 1969, was an approximately 1-Mt "calibration test" of seismic and environmental response to the detonation of large-yield nuclear explosives. The emplacement depth of Project MILROW was 3990 ft. Project CANNIKIN, conducted on November 6, 1971, was a proof test of the Spartan antiballistic missile warhead with a less than 5-Mt yield emplaced at 5875 ft depth. Project LONG SHOT resulted in some surface contamination, even though the chimney did not extend to the surface.

Amchitka Island is composed of several hundred feet of permeable tundra overlaying tertiary volcanics. The groundwater system consists of a freshwater lens floating on seawater; estimates of the depth to the saline freshwater-interface range from 3900 to 5250 ft (Chapman and Hokett, 1991). It is likely that any migration from the test cavities would discharge to the nearest salt water body, Project MILROW to the Pacific Ocean and Projects LONG SHOT and CANNIKIN to the Bering Sea (Chapman and Hokett, 1991). The sampling locations on Amchitka Island are shallow wells and surface sampling sites. Therefore, the monitoring network for Amchitka Island is restricted to monitoring of surface contamination and drinking water supplies.

Sampling on Amchitka Island, AK, was conducted between September 21 and 24, 1991. Four locations were sampled for the first time. These four new sampling sites are Constantine Spring Pump House, RX-Site Pump House, TX-Site Springs, and TX-Site Water Tank (House). Of the routine sampling locations, nine were not sampled. Army Well 3 and the Site D Hydrological Exploratory Hole are plugged and, therefore, are being eliminated from the routine sampling directory. The Site E Hydrological Exploratory Hole was not sampled due to the presence of oil in the hole. Five EPA wells were not sampled because the wells were in the lake (flooded); these were EPA wells 9, 12, 16, 17, and 19. Another well, EPA 4, was dry. In addition, two sampling locations were deleted from the routine sampling directory prior to the initiation of sampling. These were the Decon Pump and Decon Sump which were eliminated because past data indicates no potential for detection of radioactive contaminants. Background sampling locations are shown in Figure 59, for Projects LONG SHOT and MILROW in Figure 60, and for Project CANNIKIN in Figure 61.

Sample results are consistent with the sampling history for the area. Samples collected from the four new sampling locations yielded gross alpha and gross beta results greater than the MDC for those scans. The highest values were 2.9 ± 0.7 pCi/L alpha and 7.3 ± 0.8 pCi/L beta for the Constantine Spring Pump House. In general, while most samples contain tritium concentrations detectable by the enrichment method of analysis (minimum detectable concentration approximately 7 to 10 pCi/L), the levels are extremely low and continue to evidence the decreasing trend observed throughout the sampling history. With the exception of five of the Project LONG SHOT sampling locations, all tritium results were less than 50 pCi/L. Samples from the three Mud Pits and the stream east of LONG SHOT yielded tritium activities of approximately 225 pCi/L (range 190 ± 3 pCi/L to 282 ± 3 pCi/L). Of these, only the stream east of LONG SHOT has the potential to be used as drinking water. The measured ^{3}H activity for this site was 190 ± 3 pCi/L, which is less than 1 percent of the NPDWR. Well GZ No. 1, located in or near the Project LONG SHOT cavity, had a tritium activity of 1128 ± 99 pCi/L. All of these sampling locations have shown a decreasing trend over time. Analytical results for all samples are contained in Appendix E.

7.5 Summary

None of the domestic water supplies monitored in the LTHMP in 1991 yielded tritium activities of any health concern. The greatest tritium activity measured in any water body which has potential to be a drinking water supply was less than one percent of the NPDWRs. In general, surface water and spring samples yielded tritium activities greater than those observed in shallow domestic wells in the same area. This is probably due to scavenging of atmospheric tritium by precipitation. Where suitable monitoring wells exist, there were no indications that migration from any test cavity is affecting any domestic water supply.

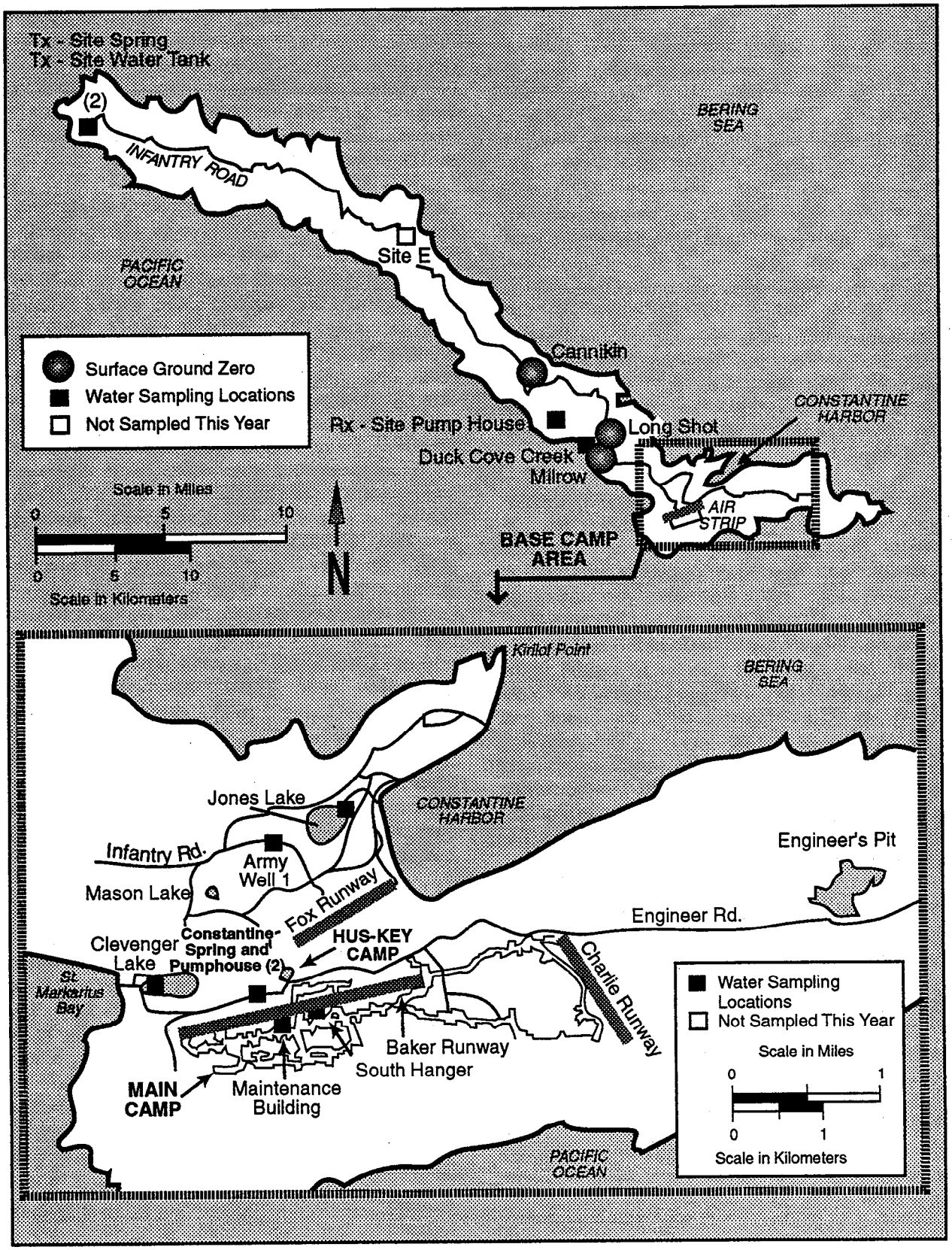

Figure 59. Amchitka Island and Background sampling location for the Long-Term Hydrological Monitoring Program.

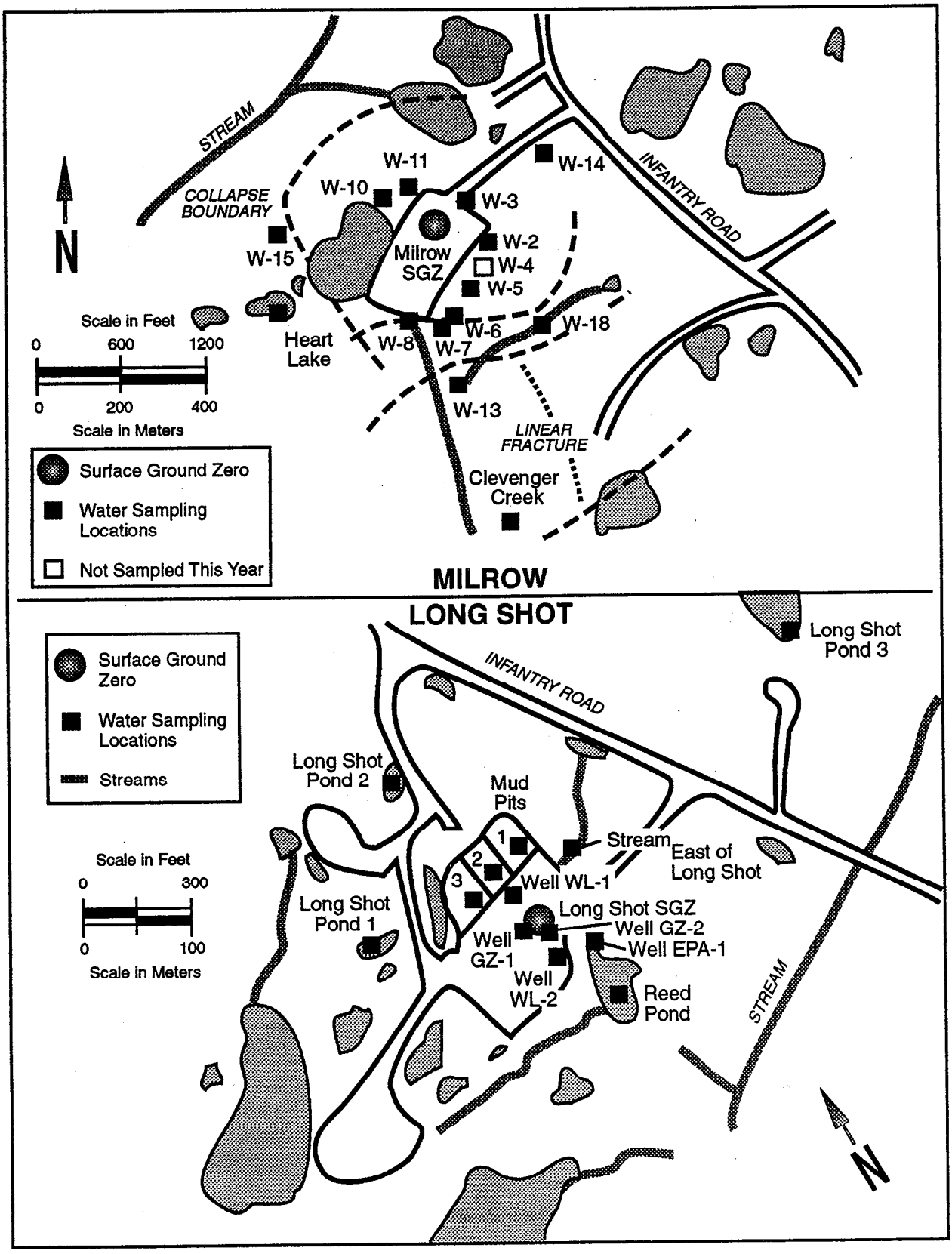

Figure 60. Long-Term Hydrological Monitoring Program sampling locations for Projects MILROW and LONGSHOT.

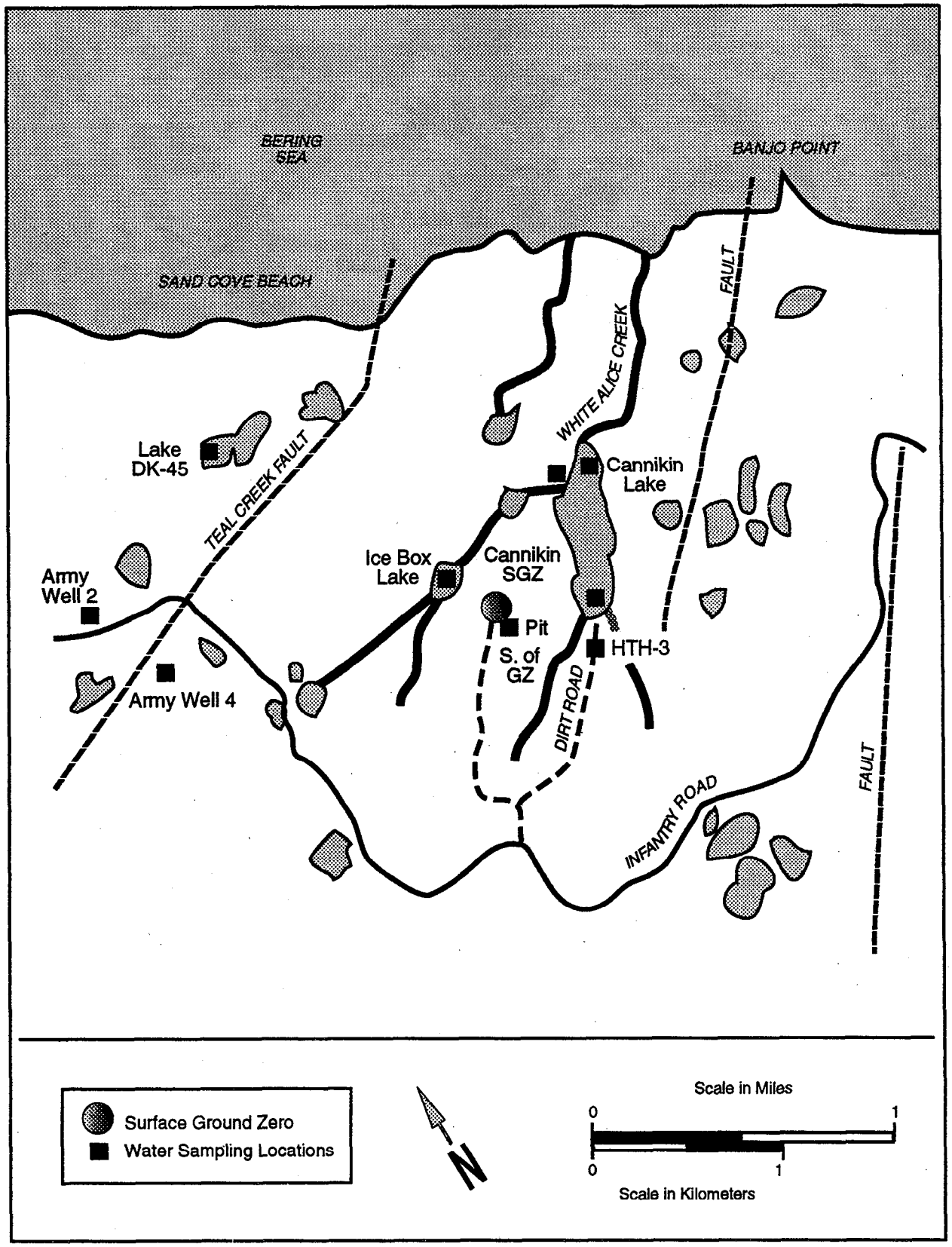

Figure 61. Long-Term Hydrological Monitoring Program sampling locations for Project CANNIKIN.

In most cases, monitoring wells also yielded no radionuclide activity above the MDC. Exceptions include wells into test cavities, wells monitoring known areas of contamination, and one well at GASBUGGY. Known areas of contamination exist at Project GNOME where USGS conducted a tracer study experiment, some areas onsite at Project DRIBBLE, and a few surface areas near Project LONG SHOT. The 1991 results for these monitoring wells are consistent with decreasing trends observed over time. Monitoring well EPNG 10-36 at Project GASBUGGY was a notable exception to wells evidencing decreasing trends.

This well is a former gas well located 435 feet northwest of SGZ. The sampling depth of this well is approximately 3600 ft in the Ojo Alamo Sandstone, an aquifer containing nonpotable water. The tritium activity in 1991 was 484 ± 4 pCi/L, approximately 10 times the historic background activity. An increase in tritium activity was first observed in 1984, seventeen years after the test was conducted. In every year since then, with the exception of 1987, tritium activities have been between 100 and 560 pCi/L, with wide variability sometimes noted between consecutive years. The proximity of the well to the test cavity suggests the possibility that the increased activity may be indicative of migration from the test cavity.

1. The NPDWR states that the sum of all beta/gamma emitter concentrations in drinking water cannot lead to a dose exceeding 4 mrem/year, assuming a person were to drink two liters per day for a year (40 CFR 141). Assuming tritium to be the only radioactive contaminant yields a maximum allowable concentration of 2×10^4 pCi/L.

2. The NPDWR applies only to public systems with at least 15 hookups or 25 users. Although many of the drinking water supplies monitored in the LTHMP serve fewer users and are therefore exempt, the regulations provide a frame of reference for any observed radionuclide activity.

8. Dose Assessment

There are four pathways of possible radiation exposure to the population of Nevada that were monitored by EPA's offsite monitoring networks during 1991. The four pathways were:

- Background radiation due to natural sources such as cosmic radiation, natural radioactivity in soil, and ^{7}Be in air.
- Worldwide distributions of radioactivity, such as ^{90}Sr in milk, ^{85}Kr in air, and plutonium in soil.
- Operational releases of radioactivity from the NTS, including those from drillback and purging activities.
- Radioactivity that was accumulated in migratory game animals during their residence on the NTS.

8.1 Estimated Dose From Nevada Test Site Activity Data

The estimated Committed Effective Dose Equivalent (CEDE) to the offsite population due to NTS activities was based on the total release of airborne radioactivity from the NTS in 1991. Onsite source emission measurements, as provided by DOE, are listed in Table 12. Because no radioactivity of recent NTS origin was detectable offsite by the various EPA monitoring networks, no measurable exposure to the population living around the NTS was expected from the sources listed in Table 12. To confirm this expectation, a calculation of estimated dose from NTS effluent estimates was performed using EPA's CAP88-PC model (EPA 1992). A population totaling 21,752 individuals living within a radius of 80 km (50 mi) of any of the sources was included in the calculation. Excluding Clark County, the population density of counties adjacent to the NTS is about 0.7 persons per square mile (0.4 persons per square kilometer) (BOC, 1990). Section 2.5 of this report details the population distribution in areas surrounding the NTS. The results of the model indicated that a hypothetical individual with the maximum calculated dose from airborne NTS radioactivity would have been continuously present at Springdale, Nevada, 72 kilometers (45 miles) west of CP-1. The maximum possible dose to that individual was 8.6×10^{-3} mrem (8.6×10^{-5} mSv). Data from the PIC monitoring network indicated a 1991 dose of 143 mrem from background gamma radiation occurring in the Beatty area near Springdale. The collective population dose within 80 km (50 mi) from the airborne emission sources was calculated to be 4.2×10^{-2} person-rem (4.2×10^{-4} person-Sv). Activity concentrations in air that would cause these calculated doses are too small to be detected by the offsite monitoring network. Table 13 summarizes the annual contributions to the CEDEs due to 1991 NTS operations as calculated by use of CAP88-PC and the released radionuclides listed in Table 12.

Input data for the CAP88-PC model include meteorological data from Weather Service Nuclear Support Office (WSNSO) and effluent release data reported to DOE by organizations conducting operations at the NTS. The effluent release data are known to be estimates and the meteorological data are mesoscale; e.g., representative of an area approximately 40 km (25 mi) or less around the point of collection. However, these data are considered sufficient for model input, primarily because the model itself is not designed for complex terrain such as that on and around the NTS. Errors introduced by the use of the effluent and meteorological data are small compared to the errors inherent in the model. Results obtained by using the CAP88-PC model are considered estimates only of the dose to offsite residents.

8.2 Estimated Dose From ORSP Monitoring Network Data

Potential CEDEs to individuals may be estimated from the concentrations measured by the EPA monitoring networks during 1991. Actual results obtained in analysis are used; the majority of which are less than the reported MDC. Precision and accuracy DQOs are, by necessity, less stringent for values near the MDC and consequently, confidence intervals around the input data are broad. Table 14 and Table 15 describes the concentra-

Table 12. NTS Radionuclide Emissions 1991

Airborne Effluent Releases

Event or Facility Name (Airborne Releases)	Curies[a]									
	^{3}H	^{37}Ar	^{39}Ar	^{85}Kr[b]	^{127}Xe	^{129}Xe	^{131}Xe	^{133}Xe	^{133}Xe	^{131}I
Area 5, RWMS	5.0×10^{-1}									
Area 3, LUBBOCK								8.3×10^{-2}		
Area 12, P Tunnel	1.4×10^{-5}	4.5×10^{-1}	2.1×10^{-4}	6.6×10^{-3}	6.6×10^{-6}	5.2×10^{-5}	7.0×10^{-3}	2.7×10^{-1}	3.8×10^{-3}	
Area 19, BEXAR								5.0×10^{-1}		1.0×10^{-4}
TOTAL	5.0×10^{-1}	4.5×10^{-1}	2.1×10^{-4}	6.6×10^{-3}	6.6×10^{-6}	5.2×10^{-5}	7.0×10^{-3}	8.5×10^{-1}	3.8×10^{-3}	1.0×10^{-4}

Liquid Effluent Releases

Containment and Radionuclide Migration (RNM) Ponds	Curies[a]				
	Gross Beta	^{3}H	^{90}Sr	^{137}Cs	^{238}Pu	$^{239+240}Pu$
Area 5, U5eRNM2S		1.2×10^{2}				
Area 6, Decontamination Pad Pond	2.6×10^{-4}	1.8×10^{-2}	1.0×10^{-5}		2.7×10^{-7}	3.0×10^{-7}
Area 12, E Tunnel	1.9×10^{-3}	5.0×10^{1}	1.1×10^{-4}	2.7×10^{-3}	1.7×10^{-5}	1.4×10^{-4}
Area 12, N Tunnel	1.3×10^{-3}	1.9×10^{1}			1.8×10^{-6}	1.4×10^{-6}
Area 12, T Tunnel	3.7×10^{-2}	1.7×10^{3}	4.4×10^{-4}	1.0×10^{-2}	7.7×10^{-6}	1.3×10^{-4}
TOTAL	4.0×10^{-2}	1.8×10^{3}	5.6×10^{-4}	1.3×10^{-2}	2.7×10^{-5}	2.7×10^{-4}

(a) Multiply by 3.7×10^{10} to obtain Bq.

(b) Environmental monitoring in Area 20 detected an average ^{85}Kr of 8 pCi/m^3 above the network average. Probably due to seepage as source term is indeterminate. A person standing at the sampler location all year would have received a dose of only 2.7×10^{-4} mrem.

Table 13. Summary of Committed Effective Dose Equivalents from NTS Operations during 1991

	Maximum CEDE at NTS Boundary[a]	Maximum CEDE to an Individual[b]	Collective CEDE to Population within 80 km of the NTS Sources	
Dose[c]	9.4 x 10^{-3} mrem (9.4 x 10^{-5} mSv)	8.6 ± 0.8 x 10^{-3} mrem (8.6 x 10^{-5} mSv)	4.2 x 10^{-2} person-rem (4.2 x 10^{-4} person-Sv)	
Location	Site boundary 42 km WSW of NTS Area 12	Springdale, NV, 56 km WSW of NTS Area 12	21,700 people within 80 km of NTS Sources	
NESHAP* Standard		10 mrem per year (0.1 mSv per yr)	10 mrem per year (0.1 mSv per yr)	-----
Percentage of NESHAP*		9.4 x 10^{-2}	8.6 x 10^{-2}	-----
Background		143 mrem (1.4 mSv)	143 mrem (1.4 mSv)	1660 person-rem (16.6 person Sv)
Percentage of Background		6.6 x 10^{-3}	6 x 10^{-3}	2.5 x 10^{-3}

(a) The maximum boundary CEDE is to a hypothetical individual who remains in the open continuously during the year at the NTS boundary located 42 km WSW from the Area 12 tunnel ponds.
(b) The maximum individual CEDE is to a person outside the NTS boundary at a residence where the highest dose-rate occurs using NTS effluents listed in Table 13.
(c) Maximum CEDEs are calculated using CAP88-PC (Version 1.0). The calculations assume all tritiated water input to the area 12 containment ponds was evaporated.
* National Emmission Standards for Hazardous Air Pollutants.

tions from the monitoring networks used in the calculation of potential CEDEs.

The dose to an individual then is estimated from the concentrations given in Table 14 and Table 15 by using the assumptions and dose conversion factors described below. The dose conversion factors assume continuous presence at a fixed location and no loss of radioactivity in meat and vegetables through storage and cooking.

- Adult respiration rate = 8400 m^3/yr (ICRP 1975).
- Milk intake for a normal child = 164 L/yr (ICRP 1975).
- Consumption of beef liver = 0.5 lb/wk (11.5 kg/yr).
- An average deer has 100 lb (45 kg) of meat.
- Water consumption = 2 L/day (ICRP 1975).
- Fresh vegetable consumption = 516 g/day (1.1 lb/day) for a four-month growing season (ICRP 1975).

The Committed Effective Dose Equivalent (CEDE) conversion factors are derived from EPA-520/1-88-020 (Federal Guidance Report No. 11). Those used are:

- ^{3}H: 6.4 x 10^{-8} mrem/pCi (ingestion or inhalation).
- ^{90}Sr: 1.4 x10^{-4} mrem/pCi (ingestion).
- ^{85}Kr: 1.5 x 10^{-5} mrem/yr per pCi/m^3 (submersion).
- $^{238,239+240}Pu$: 5.0 x 10^{-5} mrem/pCi (ingestion). 3.1 x 10^{-1} mrem/pCi (inhalation).

Table 14. Concentrations from Monitoring Networks 1991

Medium	Radionuclide	Concentration	Comment
Animals			
Beef Liver	$^{238,239+240}Pu$	4.4×10^{-2} pCi/g (1.6×10^{-3} Bq/g)	Concentrations are the maximum concentrations observed for each animal tissue type.
Deer Muscle	$^{238,239+240}Pu$	1.2×10^{-2} pCi/g (4.4×10^{-4} Bq/g)	
Deer Blood	^{3}H	4.2×10^{5} pCi/L	
Deer Liver	$^{238,239+240}Pu$	2.2×10^{-3} pCi/g (8.2×10^{-5} Bq/g)	
Milk	^{90}Sr	0.6 pCi/L (2.2 x 10^{-2} Bq/L)	Concentration is the average of all strontium results from network.
	^{3}H	152 pCi/L (5.6 Bq/L)	Concentration is the average of all tritium results from network.
Drinking Water	^{3}H	3.4 pCi/L	Concentration is the average of results from Coffer's, Spicer's, Younghans' and Beatty City wells, all of which are near Springdale, Nevada.
Vegetables			
Potatoes	$^{239+240}Pu$	6×10^{-4} pCi/g	Concentrations are from vegetables from Rachel; all other vegetables ranged from approximately 4×10^{-5} to 1×10^{-4} pCi/g.
Summer Squash	$^{239+240}Pu$	2×10^{-4} pCi/g	
Air	^{3}H	0.5 pCi/m^3 (1.8×10^{-2} Bq/m^3)	Concentration is the average of all tritium results from network.
	^{85}Kr	26.4 pCi/m^3 (1 Bq/m^3)	Concentration is the average of all krypton results from network.
	$^{239+240}Pu$	1.1×10^{-6} pCi/m^3 (4×10^{-8} Bq/m^3)	Concentration is the highest result from High-volume sampler at Amargosa Valley station. Used as it is the highest detectable result near Springdale, Nevada.

Table 15. Dose Calculations from the Monitoring Networks

Medium	Route of Exposure	Radionuclide	Calculation	Dose (CEDE)
Milk				
	Ingestion	^{90}Sr	(0.6 pCi/L) x (164 L/yr) x (1.4×10^{-4} mrem/pCi)	1.38×10^{-2} mrem/yr
		^{3}H	(152 pCi/L) x (164 L/yr) x (6.4×10^{-8} mrem/pCi)	1.6×10^{-3} mrem/yr
Total from milk consumption				1.5×10^{-2} mrem/yr
Water				
	Ingestion	^{3}H	(3.4 pCi/L) x (730 L/yr) x (6.4×10^{-8} mrem/PCi)	1.6×10^{-4} mrem/yr
Animals (Beef Liver)	Ingestion	$^{238, 239+240}Pu$	(4.4×10^{-2} pCi/g) x (11.5×10^{3} g/yr) x (5.0×10^{-5} mrem/pCi)	2.5×10^{-2} mrem/yr
Vegetables (at Rachel)	Ingestion	$^{239+240}Pu$	(6×10^{-4} pCi/g) x (6.2×10^{4} g/yr) x (5.0×10^{-5} mrem/pCi)	2×10^{-3} mrem/yr
Vegetables (other locations)	Ingestion	$^{239+240}Pu$	(1×10^{-4} pCi/g) x (6.2×10^{4} g/yr) x (5.0×10^{-5} mrem/pCi)	3×10^{-4} mrem/yr
Air				
	Submersion	^{85}Kr	(26.4 pCi/m^3) x (1.5×10^{-5} mrem/yr per pCi/m^3)	4.0×10^{-4} mrem/yr
Air				
	Inhalation	$^{239+240}Pu$	(1.1×10^{-6} pCi/m^3) x (8400 m^3/yr) x (3.1×10^{-1} mrem/pCi)	2.9×10^{-3} mrem/yr
	Inhalation & Absorption	^{3}H	(0.5 pCi/m^3) x (8400 m^3/yr) x (6.4×10^{-8} mrem/pCi) x 1.5	4.0×10^{-4} mrem/yr
Total from inhalation and absorption of air				3.3×10^{-3} mrem/yr

As an example calculation, the following is the result of breathing background levels of tritium in air:

- (0.5 pCi/m^3) x (8400 m^3/yr) x (6.4 x 10^{-8} mrem/pCi) = 2.7 x 10^{-4} mrem/yr.

  OR

  (concentration) x (volume/unit time) x (CEDE conversion factors) = CEDE

However, in calculating the inhalation CEDE from ^3H, the value is increased by 50% to account for absorption through the skin. The total dose in one year, therefore, is 4.0 x 10^{-4} mrem. Dose calculations from the monitoring networks are given in Table 16.

The individual CEDEs from the various pathways can be added together for a total of 5 x 10^{-2} mrem including the vegetables from Rachel. Total CEDEs can be calculated based on different combinations of data. If an individual were interested in just one area for example, the concentrations from those stations closest to that area could be substituted into the equation.

The highest measured concentrations of radionuclides in tissue occurred in deer collected on the NTS. The highest deer muscle sample measured 1.2 x 10^{-2} pCi/g of $^{239+240}Pu$. In the event that one such deer were collected and eaten by a resident in an offsite area, the consumer's dose can be estimated. Assuming 45 kg (100 lb) of meat with these plutonium concentrations, the CEDE from plutonium would be:

- (1.2 x 10^{-2} pCi/g) x (45 x 10^3 g) x (5 x 10^{-5} mrem/pCi) = 2.7 x 10^{-2} mrem.

The tritium concentration in the blood of the same mule deer was 4.2 x 10^5 pCi/L. If one asumes that the ^3H concentration in tissue equals that of the blood and that the density of tissue equals that of blood, i.e. 1 g/ml, then 45 kg of tissue equals 45 liters. The CEDE from tritium would be:

- (4.2 x 10^5 pCi/L) x (45 L) x (6.4 x 10^{-8} mrem/pCi) = 1.2 mrem

The sum of the doses from $^{239+240}$ Pu and ^3H is 1.2 mrem showing that the total is completely dominated by the ^{3} H concentration.

8.3 Dose from Background Radiation

In addition to external radiation exposure due to cosmic rays and gamma radiation from naturally occurring radionuclides in soil (e.g., ^{40}K, uranium and thorium daughters), there is a contribution from ^7Be that is formed in the atmosphere by cosmic ray interactions with oxygen and nitrogen. The annual average ^7Be concentration measured by the offsite surveillance network was 0.23 pCi/m^3. With a dose conversion factor for inhalation of 3.2 x 10^{-7} mrem/pCi, this equates to a dose of 6 x 10^{-4} mrem. This is a negligible quantity when compared with the PIC network measurements that vary from 52 to 154 mR/year, depending on location.

8.4 Summary

The extensive offsite environmental surveillance system operated around the NTS by EPA EMSL-LV measured no radiological exposures that could be attributed to recent NTS operations. Calculation with the CAP88-PC model resulted in a maximum inhalation dose of 8.6 x 10^{-3} mrem (8.6 x 10^{-5} mSv) to a hypothetical resident of Springdale, NV, 72 kilometers (45 miles) west of the NTS CP-I. The calculated dose to this individual from worldwide distributions of radioactivity as measured from surveillance networks was 5 x 10^{-2} mrem (including vegetables from Rachel). If this individual were to additionally collect and consume an NTS deer such as the one discussed above, the estimated CEDE would increase by another 1.2 mrem to a total possible CEDE of slightly over 1.2 mrem. All of these maximum dose estimates are approximately 1% of the International Commission on Radiation Protection (ICRP) recommendation of an annual effective dose equivalent not to exceed 100 mrem/yr (ICRP 1985). The calculated population dose (collective committed effective dose equivalent) to the approximately 21,752 residents living within 80 km (50 mi.) of each of the NTS airborne emission sources was 4.2 x 10^{-2} person-rem (4.2 x 10^{-4} person-sievert).

Data from the PIC gamma monitoring indicated a 1991 dose of 143 mrem from background radiation occurring in the Beatty area near Springdale. The 143 mrem background value is derived from an average PIC field measurement of 16.3 μR/hr. The 1.2 mrem CEDE calculated from the monitoring networks discussed above is a negligible amount compared to the background dose of 143 mrem. Both the NTS and worldwide distributions contribute a negligible amount of exposure compared to natural background.

9.0 Weapons Test and Liquefied Gaseous Fuels Spills Facility Support

The EPA participates in the execution of every nuclear test conducted at the NTS. For each test, the EPA performs a pre-test census of the offsite area population, is directly involved in the nuclear test itself, and is prepared to take protective actions in the event they are necessary. The EPA also provides offsite safety monitoring in support of chemical spill tests conducted at the Liquified Gaseous Fuels Spill Test Facility (LGFSTF) on the NTS. For each test, the EPA performs a pre-test inspection of the routes to sampling locations, is directly involved with the test itself, and collects samples.

9.1 Weapons Tests Support

Two days prior to each nuclear test, mobile teams of radiation monitoring technicians are dispatched to the counties surrounding the NTS. These technicians perform a census of the offsite areas to determine the locations and numbers of residents, work crews, and domestic animal herds. This information would be essential to providing protective actions in the event of a radiation release from a test. Additionally, the technicians monitor the seasonal population such as hunters and shepherds to ensure that they too can be notified if necessary. After the census is completed, the information is presented by the EPA to the Test Controllers Science Advisory Panel.

Senior EPA personnel serve as members of the Test Controller's Science Advisory Panel to provide advice on possible public and environmental impact of each test and on feasible protective actions in the event that an accidental release of radioactivity should occur.

At the time of each test, approximately 20 radiation monitoring technicians are positioned in the downwind areas of the test. Each technician is equipped with a variety of radiation survey instruments, dosimeters, portable air samplers, and supplies for collecting environmental samples. The technicians are in constant radio contact with CP-1 which enables them to provide monitoring information and to receive operational instructions from the EPA staff. In the unlikely occurrence of any release of radioactivity, the technicians are prepared to initiate all manner of protective actions to assure the health and safety of those people in the offsite areas. They are also prepared to conduct a radiological monitoring and sampling program to document the radiation levels in the environment. The radiological safety criteria, or protective action guides, used by the EPA are based on those specified in NVO-176 (EPA, 1991a).

If an underground nuclear test is expected to cause detectable ground motion offsite, EPA monitoring technicians are stationed at locations where hazardous situations might occur, such as underground mines. At these locations, occupants are notified of potential hazards so they can take precautionary measures. Miners, for example, are brought above ground before such a test.

Remedial actions that EPA could recommend or implement to reduce exposures include: evacuation, shelter, access control, livestock feeding practices control, milk control, and food and water control. Which action would be appropriate depends largely upon the type of accident and the magnitude of the projected exposures and doses, the response time available for carrying out the action, and local constraints associated with a specific site.

An important factor affecting the effectiveness of the remedial actions is the degree of credibility EPA personnel maintain with offsite residents. Credibility is created and maintained by routine personal contacts made with local officials and law enforcement personnel as well as with the ranchers, miners, and others living in the offsite areas close to the NTS.

To determine the feasible remedial actions for an area, EPA uses its best judgment based on experience gained during atmospheric tests and from those tests conducted in the 1960s that contaminated offsite areas. No remedial actions have been necessary since 1970, so there is no recent experience by which to test this judgment. However, through routine contact with offsite residents and through continuing population and road surveys, EPA maintains a sense of the degree to

which it could implement remedial actions and the kind of cooperation that would be provided by officials and residents of the area.

During 1991, EMSL-LV personnel were deployed for all nuclear tests conducted at the NTS, none of which released radioactivity that could be detected offsite.

9.2 Liquefied Gaseous Fuels Spills Test Facility Support

The EPA provides offsite safety monitoring in support of chemical spill tests conducted at the LGFSTF on the NTS. This is one of the few non-nuclear related activities conducted at the NTS. A scientist from the EPA is a member of the Spill Test Advisory Panel for each test. For each test, the EPA also conducts monitoring in the downwind direction at the boundary of the NTS.

Prior to the initial test of any given series of tests, and during operational trials by the spill sponsors, an EPA technician inspects the unmaintained jeep-trail routes to the predetermined sampling location to assure ready access. Since each test is contingent on compatible technical and ambient conditions, including wind direction and speed, the technician remains at the Test Facility Control Center until the Advisory Panel authorizes initiation of the test. The EPA Advisory Panel representative then dispatches the technician to the sampling location, as close as accessible to the downwind trajectory. When the spill test is in progress, the EPA representative, in coordination with the Advisory Panel meteorologist, determines the travel time of gases from the spill to the sampling location of the monitor. The EPA representative then gives the technician specific clock time(s) to collect gas samples.

Samples are collected using a Model 31 Drager hand pump into which is inserted a Drager tube for the type of chemical gases to be detected. The technician remains at the sampling location until the Advisory Panel determines that further offsite monitoring is no longer required for that day's testing.

Testing during 1991 occurred on May 1, and May 7, and involved hydrogen fluoride (HF) protective suit evaluations. The tests were conducted by the Lawrence Livermore National Laboratory. The EPA monitor was positioned approximately 4.7 km (3.5 miles) downwind of the point of release, at the border between NTS and Air Force property. The results of air monitoring indicated that HF was not detected at the NTS boundary. In addition, no odors attributable to test chemicals were noted by field monitoring personnel.

10. Public Information and Community Assistance Programs

In addition to its many monitoring and data analysis activities, the EPA EMSL-LV conducts a comprehensive program designed to provide information and assistance to individual citizens, organizations, and local government agencies in communities near the NTS. Activities in 1991 included: participation in public hearings, "town hall" meetings, continued support of the Community Radiation Monitoring Program (CRMP) and a variety of tours, lectures, and presentations.

10.1 Community Radiation Monitoring Program

Beginning in 1981, DOE and EPA established a network of CRMP stations in the offsite areas to perform radiological sampling and monitoring to increase public awareness, and to disseminate the results of radiation monitoring activities to the public. These stations continued operation in 1991. The DOE, through an interagency agreement with EPA, sponsors the program. The EPA provides technical and scientific direction, maintains the instrumentation and sampling equipment, analyzes the collected samples, and interprets and reports the data. The Desert Research Institute of the University of Nevada System administers the program by hiring the local station managers and alternates, securing rights-of-way and utility meters, and by providing QA checks of the data. The University of Utah provides in-depth training for station managers and alternates twice a year on issues related to nuclear science, radiological health, and radiation monitoring. In each community, EPA and DRI work with civic leaders to select and hire a local manager and an alternate. Whenever possible, they choose residents with some scientific training, such as a high school or university science teacher.

All of the 19 CRMP stations contain one each of the samplers for the Air, Noble Gas, and Tritium networks discussed in the previous chapters. Each station also contains a TLD and a PIC with a recorder for immediate readout of external gamma exposure, and a recording barograph. Figure 3.9 shows the layout of the equipment at a typical CRMP. At Milford and Delta the atmospheric moisture samplers for tritium analysis were on standby and the noble gas samplers were placed on standby following installation in July 1991. All the equipment is mounted on a stand at a prominent location in each community so the residents are aware of the surveillance and, if interested, can have ready access to the PIC and barometric data. The locations of the CRMP stations are shown in Figure 3.7, Chapter 3. The data from these stations were discussed in Chapters 3 and 4.

Computer-generated reports for each station are issued weekly. These reports indicate the current weekly average gamma exposure rate as measured by the PICs, the average over the previous week, and the average for the previous year. For comparison these reports additionally show the maximum and minimum background concentrations in the U.S. These reports are distributed to each CRMP station for public display.

10.2 Town Hall Meetings

Ninety-four town hall meetings have been conducted since 1982. These meetings provide an opportunity for the public to meet directly with EPA, DOE, and DRI personnel, ask questions, and express their concerns regarding nuclear testing. During a typical meeting, the procedures used and the safeguards in place during every nuclear test are described. The EPA's radiological monitoring and surveillance networks are explained and the proposed High Level Waste Repository at Yucca Mountain is discussed.

Similar presentations and presentations devoted solely to EPA's ORSP were presented to various groups such as chambers of commerce, schools, Rotary clubs and professional workshops. A town meeting was held in Baxterville, Mississippi to explain the results of EPA's annual monitoring on and around the Tatum Dome Nuclear Test Area located in Lamar County, Mississippi. The Tatum Dome Nuclear Test Area was the site of two nuclear and two non-nuclear experimental detonations conducted in the Tatum Salt Dome between 1964 and 1970. This meeting was held in response to concerns expressed by residents about

possible health effects originating from the Tatum Dome site. The locations of the 1991 meetings were as follows:

Location	Date
Las Vegas, NV - Gilbert Sixth Grade Center	01/91
Las Vegas, NV - Clark County Science Teachers	03/91
Boise, ID - Workshop on Low-Level Radiation	05/91
Ely, NV - Chamber of Commerce	08/91
Denver, CO - Radiation Monitoring Workshop	11/91
Overton, NV - Rotary Club	12/91
Baxterville, MS	12/91

10.3 Nevada Test Site Tours

To complement the town hall meetings and to familiarize citizens with both the DOE testing program at the NTS and the Environmental Radiological Monitoring Program conducted by EPA, tours of the NTS are arranged for business and community leaders and individuals from towns around the NTS, as well as for government employees and for the news media. During 1991, the following tours were sponsored by the EPA:

EPA Program Headquarters Director and Staff	02/07/91
EPA Regional Directors, Office of Pesticides & Toxic Substances	04/05/91
EPA Headquarters Office of The Comptroller	05/20/91
EPA Headquarters Staff	06/04/91
Residents of Rachel, NV	06/18 & 19/91
NRD Employees	10/22 & 23/91
EPA Employees and Dependents	10/29/91

11 Quality Assurance

11.1 Policy

One of the major goals of the U.S. Environmental Protection Agency (EPA) is to ensure that all EPA decisions which are dependent on environmental data are supported by data of known quality. Agency policy initiated by the Administrator in memoranda of May 30, 1979, and June 14, 1979, requires participation in a centrally managed Quality Assurance (QA) Program by all EPA Laboratories, Program Offices, Regional Offices, and those monitoring and measurement efforts supported or mandated through contracts, regulations, or other formalized agreements. Further, by EPA Order 5360.1, Agency policy requires participation in a QA Program by all EPA organizational units involved in environmental data collection.

The QA policies and requirements of EPA's Environmental Monitoring Systems Laboratory in Las Vegas (EMSL-LV) are summarized in the *Quality Assurance Program Plan* (EPA, 1987). Policies and requirements specific to the Offsite Radiological Safety Program (ORSP) are documented in the *Quality Assurance Program Plan for the Nuclear Radiation Assessment Division Offsite Radiation Safety Program* (EPA, 1992). The requirements of these documents establish a framework for consistency in the continuing application of quality assurance standards and implementing procedures in support of the ORSP. Administrative and technical implementing procedures based on these QA requirements are maintained in appropriate manuals or are described in standard operating procedures (SOPs). It is NRD policy that personnel adhere to the requirements of the QA Plan and all SOPs applicable to their duties to ensure that all environmental radiation monitoring data collected by the EPA EMSL-LV in support of the ORSP are of adequate quality and properly documented for use by the DOE, EPA, and other interested parties.

11.2 Data Quality Objectives

Data quality objectives (DQOs) are statements of the quality of data a decision maker needs to ensure that a decision based on that data is defensible. Data quality objectives are defined in terms of representativeness, comparability, completeness, precision, and accuracy. Representativeness and comparability are generally qualitative assessments while completeness, precision, and accuracy may be quantitatively assessed. In the ORSP, representativeness, comparability, and completeness objectives are defined for each monitoring network. Precision and accuracy are defined for each analysis type or radionuclide.

Achieved data quality is monitored continuously through internal QC checks and procedures. In addition to the internal quality control procedures, NRD participates in external intercomparison programs. One such intercomparison program is managed and operated by a group within EPA EMSL-LV. These external performance audits are conducted as described in and according to the schedule contained in "Environmental Radioactivity Laboratory Intercomparison Studies Program" (EPA, 1991). The analytical laboratory also participates in the DOE Environmental Measurements Laboratory (EML) Quality Assurance Program in which real or synthetic environmental samples that have been prepared and thoroughly analyzed are distributed to participating laboratories. External external systems and performance audits are conducted for the TLD network as part of the certification requirements for DOE's Laboratory Accreditation Program (DOELAP) (DOE, 1986a, DOE 1986b). These external intercomparison and audit programs are used to monitor analysis accuracy.

11.2.1 Representativeness, Comparability, and Completeness Objectives

Representativeness is defined as "the degree to which the data accurately and precisely represent a characteristic of a parameter, variation of a property, a process characteristic, or an operation condition" (Stanley and Verner, 1985). In the ORSP, representativeness may be considered to be the degree to which the collected samples represent the radionuclide activity concentrations in the offsite environment. Collection of samples representative of all possible pathways to human exposure as well as direct measurement of offsite

resident exposure through the TLD and internal dosimetry monitoring programs provides assurance of the representativeness of the calculated exposures.

Comparability is defined as "the confidence with which one data set can be compared to another" (Stanley and Verner, 1985). Comparability of data is assured by use of SOPs for sample collection, handling, and analysis; use of standard reporting units; and use of standardized procedures for data analysis and interpretation. In addition, another aspect of comparability is examined through long term comparison and trend analysis of various radionuclide activity concentrations, TLD and PIC data. Use of SOPs, maintained under a document control system, is an important component of comparability, ensuring that all personnel conform to a unified, consistent set of procedures.

Completeness is defined as "a measure of the amount of data collected from a measurement process compared to the amount that was expected to be obtained under the conditions of measurement" (Stanley and Verner, 1985). Data may be lost due to instrument malfunction, sample destruction, loss in shipping or analysis, analytical error, or unavailability of samples. Additional data values may be deleted due to unacceptable precision, accuracy, or detection limit or as the result of application of statistical outlier tests. The completeness objective for all networks except the LTHMP is 90%. The completeness objective for the LTHMP is 80%; a lower objective has been established because dry wells or access restrictions occasionally preclude sample collection.

11.2.2 Precision and Accuracy Objectives of Radioanalytical Analyses

Measurements of sample volumes should be accurate to ± 5% for aqueous samples (water and milk) and to ± 10% for air and soil samples. The sensitivity of radiochemical and gamma spectrometric analyses must allow no more than a 5 percent risk of either a false negative or false positive value. Precision to a 95% confidence interval, monitored through analysis of duplicate and blind samples, must be within ± 10% for activities greater than 10 times the minimum detectable concentration (MDC) and ± 30% for activities greater than the MDC but less than 10 times the MDC. There are no precision requirements for activity concentrations below the MDC, which by definition, cannot be distinguished from background at the 95% confidence interval. Control limits for accuracy, monitored with matrix spike samples, are required to be no greater than ± 20% for all gross alpha, gross beta, and gamma spectrometric analyses, depending upon the media type.

At concentrations greater than 10 times the MDC, precision is required to be within ± 10% for:

- Conventional Tritium Analyses
- Uranium
- Thorium (all media)
- Strontium

and within ± 20% for:

- Enriched Tritium Analyses
- Strontium (in milk)
- Noble Gases
- Plutonium.

At concentrations less than 10 times the MDC, both precision and accuracy are expressed in absolute units, not to exceed 30% of the MDC for all analyses and all media types.

11.2.3 Quality of Exposure Estimates

The allowable uncertainty of the effective dose equivalent to any human receptor is ± 0.1 mrem annually. This uncertainty objective is based solely upon the precision and accuracy of the data produced from the surveillance networks and does not apply to uncertainties in the model used, effluent release data received from DOE, or dose conversion factors. Generally, effective dose equivalents must have an accuracy (bias) of no greater than 50% for annual exposures greater than or equal to 1 mrem but less than 5 mrem and no greater than 10% for annual exposures greater than or equal to 5 mrem.

11.3 Data Validation

Data validation is defined as "A systematic process for reviewing a body of data against a set of criteria to provide assurance that the data are adequate for their intended use. Data validation consists of data editing, screening, checking, auditing, verification, certification, and review"

(Stanley et al, 1983). Data validation procedures are documented in SOPs. All data are reviewed and checked at various steps in the collection, analysis, and reporting processes.

The first level of data review consists of sample tracking; e.g., that all samples planned to be collected are collected or reasons for noncollection are documented, that all collected samples are delivered to Sample Control and are entered into the appropriate data base management system, and that all entered information is accurate. Next, analytical data are reviewed by the analyst and by the laboratory supervisor. Checks at this stage include verifying that all samples received from Sample Control have been analyzed or reasons for nonanalysis have been documented, that data are "reasonable" (e.g., within expected range), and that instrumentation operational checks indicate the analysis instrument is within permissible tolerances. Discrepancies indicating collection instrument malfunction are reported to the Field Operations Branch. Analytical discrepancies are resolved; individual samples or sample batches may be reanalyzed if required.

Raw data are reviewed by a designated media expert. A number of checks are made at this level, including:

1. Completeness - all samples scheduled to be collected have, in fact, been collected and analyzed or the data base contains documentation explaining the reasons for noncollection or nonanalysis.

2. Transcription errors - checks are made of all manually entered information to ensure that the information contained in the data base is accurate.

3. Quality control data - field and analytical duplicate, audit sample, and matrix blank data are checked to ensure the collection and analytical processes are within specified QC tolerances.

4. Analysis schedules - lists of samples awaiting analysis are generated and checked against normal analysis schedules to identify backlogs in analysis or data entry.

5. Unidentified malfunctions - sample results and diagnostic graphics of sample results are reviewed for reasonableness. Conditions indicative of instrument malfunction are reported to Field and/or Laboratory Operations.

Once the data base has been finalized, the data are compared to the DQOs. Completeness, accuracy, and precision statistics are calculated. The achieved quality of the data is reported annually, at a minimum. If data fail to meet one or more of the established DQOs, the data may still be used in data analysis; however, the data and any interpretive results are to be qualified.

All sample results exceeding the traditional-natural background activity range are investigated. If data are found to be associated with a nonenvironmental condition, such as a check of the instrument using a calibration source, the data are flagged and are not included in calculations of averages, etc. Only data verified to be associated with a nonenvironmental condition are flagged; all other data are used in calculation of averages and other statistics, even if the condition is traced to a source other than the NTS (for example, higher-than-normal activities were observed for several radionuclides following the Chernobyl accident). When activities exceeding the expected range are observed for one network, the data for the other networks at the same location are checked. For example, higher-than-normal-range PIC values are compared to data obtained by the air, noble gas, TLD, and tritium-in-air samplers at the same location.

Data are also compared to previous years' data for the same location using trend analysis techniques. Other statistical procedures may be employed as warranted to permit interpretation of current data as compared to past data. Trend analysis is made possible due to the length of the sampling history which, in some cases, is 30 years or longer.

Data from the offsite networks are used, along with NTS source emission estimates prepared by DOE, to calculate or estimate annual committed effective dose equivalents to offsite residents. Surveillance network data are the primary tools for the dose calculations. Additionally, EPA's CAP88-PC model (EPA, 1992) is used with local meteorological data to predict doses to offsite residents from NTS source term estimates. An assessment of the uncertainty of the dose estimate is made and reported with the estimate.

11.4 Quality Assessment Of 1991 Data

Data quality assessment is associated with the regular QA and QC practices within the radioanalytical laboratory. The analytical quality control plan, documented in SOPs, describes specific procedures used to demonstrate that data are within prescribed requirements for accuracy and precision. Duplicate samples are collected or prepared and analyzed in the exact manner as the regular samples for that particular type of analysis. Data obtained from duplicate analyses are used for determining the degree of precision for each individual analysis. Accuracy is assessed by comparison of data from spiked samples with the "true" or accepted values. Spiked samples are either in-house laboratory blanks spiked with known amounts of radionuclides, or QC samples prepared by other organizations in which data are compared between several laboratories and assessed for accuracy.

On a quarterly and annual basis, achieved data quality statistics are compiled. This data quality assessment is performed as part of the process of data validation, described in Section 11.3. The following subsections describe the achieved data quality for 1991.

11.4.1 Completeness

Completeness is calculated as:

$$\%C = \left(\frac{V}{n}\right) x\ 100$$

where:
***%C** = percent completeness*
***V** = number of measurements judged valic*
***n** = total number of measurements*

The percent completeness of the 1991 data are given in Table 16. Reasons for sample loss include instrument malfunction, inability to gain site access, monitoring technician error, or laboratory error.

A number of the families who normally participate in the Internal Dosimetry Network were unable to participate in 1991 due to scheduling difficulties. As a consequence, the completeness objective of 90 percent was not achieved and some areas were not well represented. In 1992, efforts will be made to increase the level of participation.

The achieved completeness of over 93 percent for the LTHMP exceeds the DQO of 80 percent; however, if the wells which have been shut down by DOE are included, the achieved completeness drops to 75 percent for the LTHMP overall and 54 percent for sites sampled on the NTS.

The completeness achieved overall in the ASN was 99.3 percent. There were no data gaps for twenty three stations (100 percent completeness). All of the ASN stations had data recoveries greater than 90 percent for 1991, exceeding the DQO of 90 percent completeness. The achieved completeness for plutonium isotopes in air was 97.2 percent, greater than the DQO of 90 percent. All but three sites achieved a 100 percent recovery. The standby stations in Oregon failed to collect samples in the second quarter and one composite sample from Amargosa Valley was lost in the process of chemical analysis.

The achieved completeness for the noble gas network overall was less than the DQO of 90 percent. A new model of sampler was installed at each station in the spring of 1991. These new units exhibited a number of malfunctions in the first several months of operation, resulting in low sample recovery. The only stations to meet or exceed the 90 percent DQO on an individual basis were Beatty, Goldfield, Indian Springs, and Overton, Nevada. The standby station at Delta, Utah achieved a 100 percent recovery for the 26 days it was in operation. Due to sample loss in the Radioanalysis Laboratory, the achieved recovery for the St. George, Utah station was greater than 90 percent for ^{133}Xe, but less than 90 percent for ^{85}Kr. Completeness was less than 75 percent for noble gases at Austin and Amargosa Valley Community Center, Nevada and Milford and Salt Lake City, Utah; consequently, the samples cannot be considered representative of activities at these sites for 1991.

Each of the tritium-in-air stations achieved sample recoveries of greater than the 90 percent DQO. Completeness was 100 percent at eight stations: Shoshone, California and Austin, Caliente, Las Vegas, Overton, Pahrump, Pioche, and Twin Springs, Nevada. The tritium-in-air sampler was installed at Twin Springs in November; therefore, even though sample recovery was 100 percent for

Table 16. Data Completeness of Offsite Radiological Safety Program Networks

Network	No. of Sampling Locations	Total Samples Possible	Valid Samples Collected	Percent Completeness
LTHMP	256[a]	466[a]	436	93.6[a]
Air	33	11,722 days[b]	11,640	99.3
Surveillance	18 ($^{238,239+240}$Pu)	109	106	97.2
Noble Gas	21	6133 days[b]	5243 (^{85}Kr) 5309 (^{133}Xe)	85.5 (^{85}Kr) 86.6 (^{133}Xe)
Tritium in Air	20	6670 days[b]	6460	96.9
Milk Surveillance	25	277	223	80.5
Animal Investigation	3	12[c]	12	100.0
PIC	29	1508 weeks[d]	1496	99.2

[a] Does not include wells which have been shut down by DOE (see Section 7.2)
[b] Continuous samplers with samples collected at intervals of approximately one week. Days used as units to account for differences in sample interval length.
[c] Includes four mule deer from the Nevada Test Site and four cows from each of two locations. Does not include bighorn sheep, fruits and vegetables, and other animals which are "samples of opportunity."

the period of operation, the activities cannot be considered to be representative of all of 1991.

Overall completeness for the MSN was 80.5 percent. Samples were obtained every month (i.e., 100 percent recovery) from 14 of the 25 sampling locations. Another two sites had an achieved completeness of greater than the DQO of 90 percent. Three of the family-owned cow or goat sampling locations yielded no samples in 1991 (i.e., 0 percent completeness) and another two had an achieved completeness of 50 percent or less. In the majority of the cases, samples could not be collected because the cow or goat was unable to produce milk.

In the Animal Investigation program, one mule deer is harvested each quarter from the NTS. Four cows are purchased in the spring and another four are purchased in the fall from ranches in the offsite area around the NTS. Overall completeness for 1991 was 100 percent. Hunters in the state of Nevada donate the kidney and one leg bone from bighorn sheep harvested during the winter hunting season and offsite residents donated locally grown fruits and vegetables. Because these are voluntary contributions, no expected number of samples can be determined for estimation of completeness. Occasionally, road kills or other animals from the NTS are included in the Animal Investigation program, such as the mountain lion obtained by hunting in 1991. These "targets of opportunity" are not included in calculation of percent completeness.

Completeness for the PIC network can be quantified by the number of weeks for which there are average gamma exposure rates recorded for the 29 PICs. Completeness would be 100% if there were 1,508 (29 stations multiplied by 52 weeks) recorded weekly averages. Using this method, the PIC data is 99.2% complete. The stations for which data were unavailable for specific weeks are listed in Section 3.2.

11.4.2 Precision

Precision is monitored through analysis of duplicate samples. Field duplicates (e.g., a second sample

collected immediately after the routine sample) are collected in the LTHMP and Milk Surveillance networks. Two TLDs, each with three identical phosphors, are deployed to each fixed station, providing a total of six replicates. Noble gas samples are split to provide duplicate samples for analysis. Animal tissue, vegetable, and human urine samples are also split after processing. A second air sampler is collocated with the routine sampler to provide a field duplicate. A total of four samplers are used; these second samplers are moved to various site locations throughout the year. In lieu of field duplicates, precision for the PICs is determined by the variance of measurements over a specific time interval when only background activities are being measured. Precision may also be determined for repeated analyses of laboratory spiked samples. These QC samples are generally not blind to the analyst; e.g., the analyst both recognizes the sample as a QC sample and knows the expected (theoretical) activity of the sample.

Precision is expressed as percent relative standard deviation (%RSD), also known as coefficient of variation, and is calculated by:

$$\%RSD = \left(\frac{std.\ dev.}{mean}\right) x\ 100$$

For duplicate sample pairs, the standard deviation is equal to the absolute value of the difference between the analytical results. The precision or %RSD is not reported for duplicate pairs in which one or both results are less than the MDC of the analysis. For most analyses, the DQOs for precision are defined for two ranges: values greater than or equal to the MDC but less than 10 times the MDC and values equal to or greater than 10 times the MDC.

Figure 62 displays %RSDs for LTHMP field and spiked sample duplicate pairs analyzed by the conventional tritium method. Three field duplicate pair %RSDs are not included in the figure; these three pairs had means of 5046; 98,470; and 144,650 pCi/L and %RSDs of 12.3, 0.3, and 0.2 percent, respectively. All pairs yielded %RSDs of less than 20 percent. Only three pairs were greater than 10 times the MDC; the %RSDs for these pairs were less than 2 percent. These results are better than the DQOs of 30 percent for values equal to or greater than the MDC but less than 10 times the MDC and 10 percent for values equal to or greater than 10 times the MDC. Figure 63 displays %RSDs for duplicate pairs analyzed by the enriched tritium method. Only three %RSDs exceeded the DQO of 30 percent for values greater than or equal to the MDC but less than 10 times the MDC and all of the duplicate pairs greater than or equal to 10 times the MDC yielded %RSDs less than the DQO of 20 percent. Two pairs with means of 836 and 521 pCi/L and %RSDs of 1.0 and 5.2 percent, respectively, are not shown in the figure.

In the ASN, field duplicate pairs are analyzed for gross alpha and gross beta and laboratory spiked sample pairs are analyzed for $^{239+240}Pu$. Gross alpha analysis was initiated late in the year and only 7 sets of duplicates were analyzed, only one of which was greater than or equal to 10 times the MDC. The %RSDs were generally less than 30 percent, although there are an insufficient number of points to draw definitive conclusions regarding achieved precision. As shown in Figure 64, gross beta analyses yielded %RSDs ranging from less than one percent to greater than 95 percent for duplicate pairs greater than or equal to the MDC but less than 10 times the MDC. With the exception of one pair, all of the %RSDs for pairs greater than 10 times the MDC were less than 20 percent. All of the spiked sample pairs analyzed for $^{239+240}Pu$ were greater than or equal to 10 times the MDC. All %RSDs were less than the DQO of 20 percent, as shown in Figure 65.

All of the noble gas sample splits analyzed for ^{85}Kr had activities greater than or equal to the MDC but less than 10 times the MDC. All %RSDs were less than 20 percent, better than the DQO of 30 percent for sample pairs in this activity range. The %RSDs for ^{85}Kr are shown in Figure 66.

Only four of the duplicate pairs analyzed in the tritium-in-air network yielded results greater than the MDC. The %RSDs for these were all less than 20 percent, but the number of points is insufficient to draw definitive conclusions regarding achieved precision. None of the duplicate pairs from the MSN analyzed for tritium yielded results greater than the MDC. Similarly, because only four animal tissue duplicate pairs were analyzed, insufficient information was available to determine achieved precision.

Precision for the PIC data was estimated by the agreement between continuous background gamma radiation measurements for given periods of

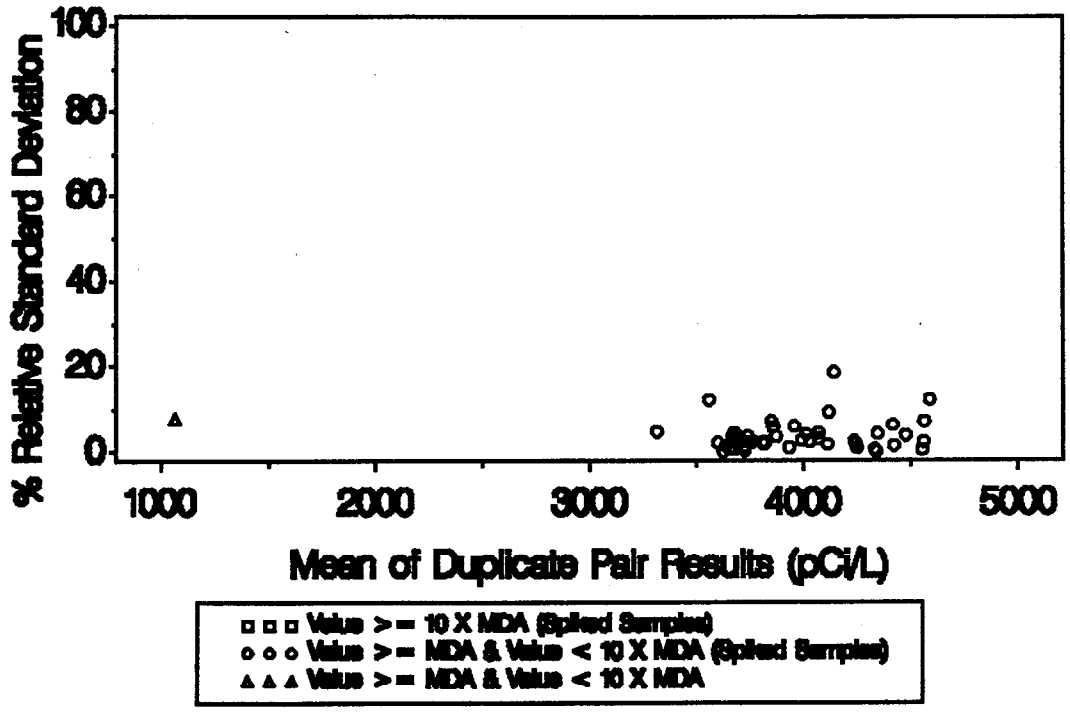

Figure 62. Precision results for conventional method tritium in water.

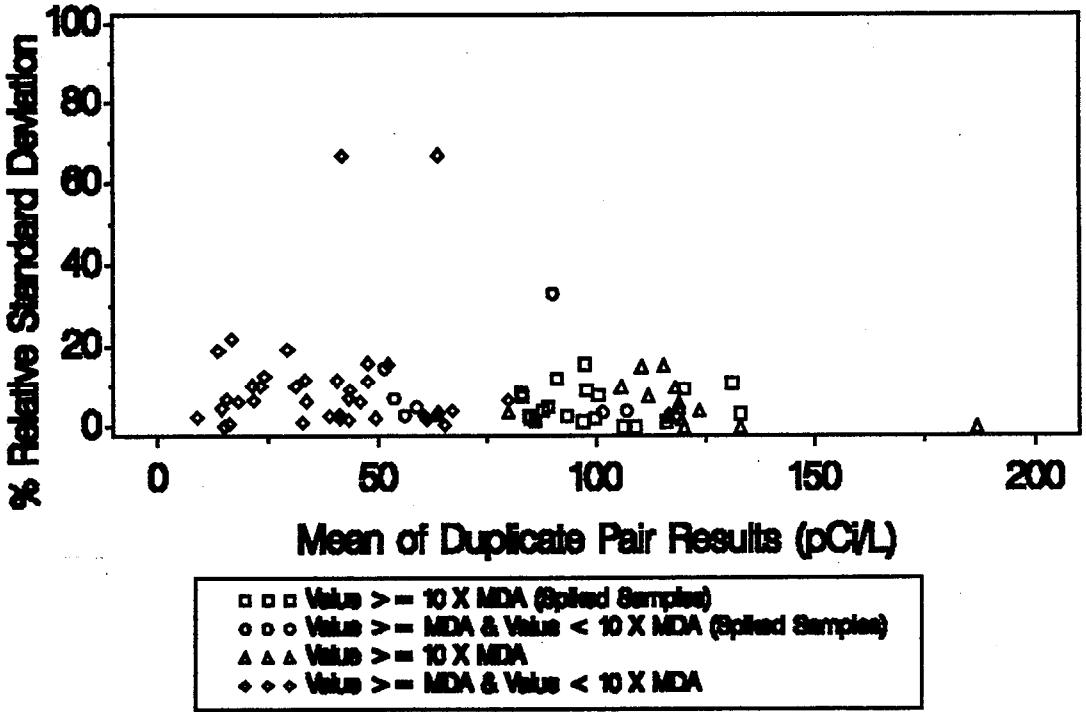

Figure 63. Precision results for enriched method tritium in water.

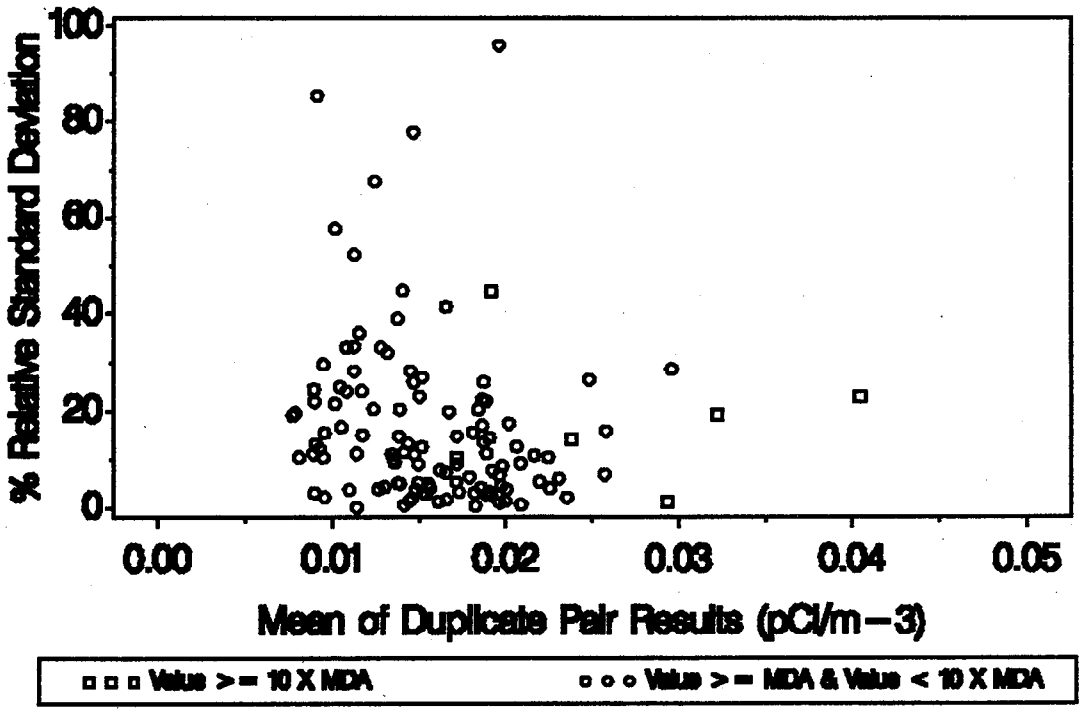

Figure 64. Precision results for beta in air.

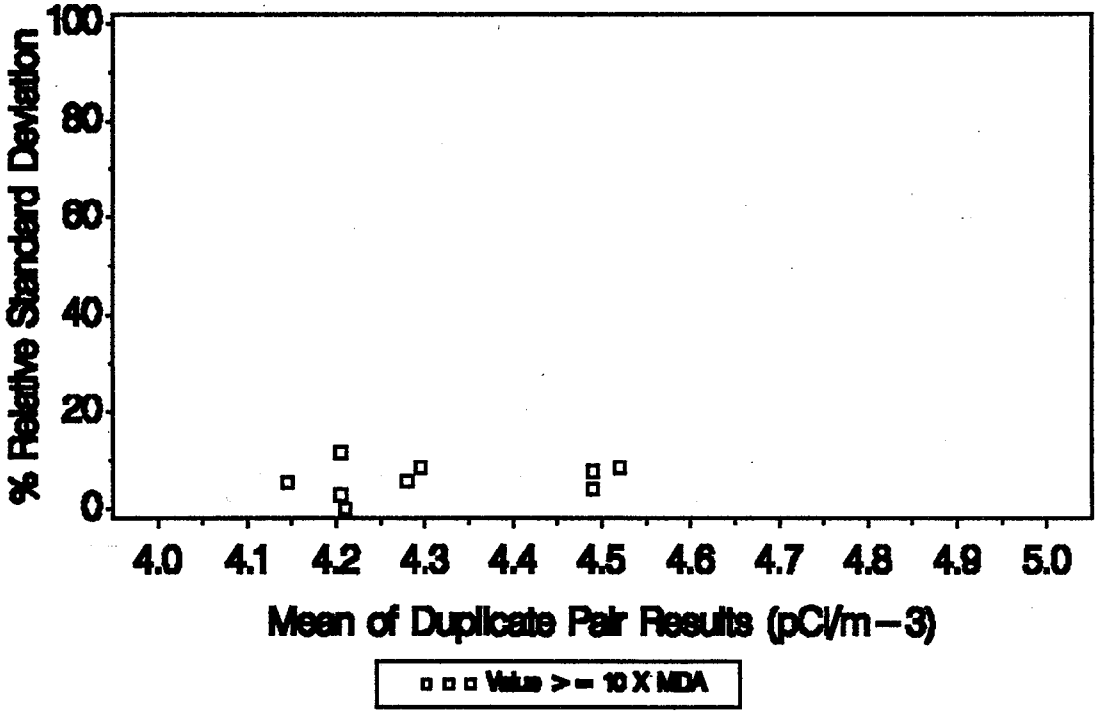

Figure 65. Precision results for $^{239+240}Pu$ in air.

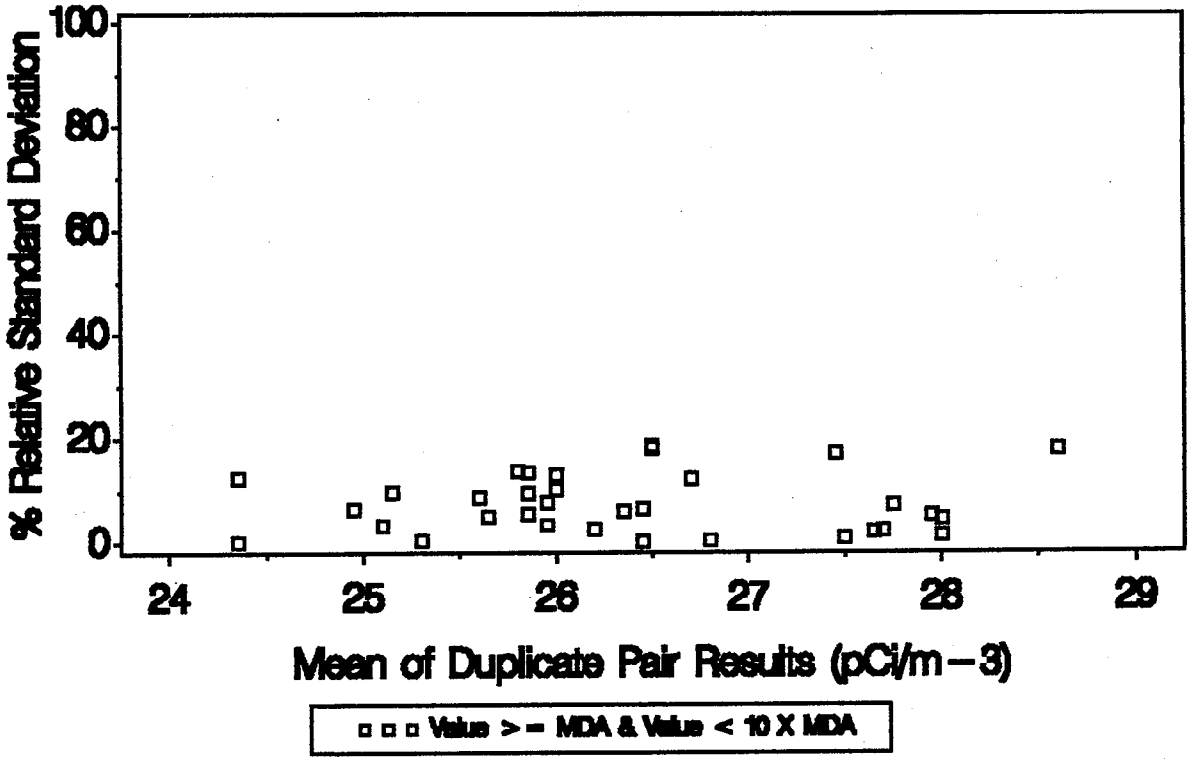

Figure 66. Precision results for ^{85}Kr in noble gas.

time. Although this method does not provide an independent assessment of precision (e.g., not derived from a second collocated PIC), it is a justifiable estimation of precision because background radiation levels at each station are relatively stable. Precision between the 4-hour averages transmitted from each PIC location are examined weekly and are used as a tool to identify equipment problems. The precision between weeks for 1991 is expressed as percent relative standard deviation (%RSD) or coefficient of variation. The %RSD can be calculated for each station by dividing the standard deviation of the weekly averages by the mean of the weekly averages (standard deviations and means of the PIC data are given in Section 3.2). The %RSD for each PIC station in 1991 was less than 5% except the Austin and Rachel stations. The Austin PIC had a between-week %RSD of 13% and the Rachel station had a between-week %RSD of 8%. The variability in the Austin PIC is probably due to seasonal differences. The variability in the PIC at Rachel is possibly due to seasonal differences but could also be partially due to equipment problems. The variability in the Rachel PIC is currently under investigation.

In addition to examination of %RSDs for individual duplicate pairs, an overall precision estimate was determined by calculating the pooled standard deviation. To convert to a unitless value, the pooled standard deviation was divided by the grand mean and multiplied by 100 to yield a %RSD. Table 17 presents the pooled data and estimates of overall precision. With the exception of gross alpha, the achieved precision is essentially equal to or better than the DQO for the analysis and activity range. The achieved precision for gross alpha is based on a limited number of duplicate pairs analyzed in the last quarter of 1991.

11.4.3 Accuracy

The accuracy of all analyses is controlled through the use of approved or NIST-traceable standards in instrument calibrations. Internal checks of instrument accuracy may be periodically performed, using spiked and blank matrix samples.

Table 17. Overall Precision of Analysis

Network	Analysis	Sample Type	Range	n	Pooled Std. Dev.	%RSD
LTHMP	Conv. Tritium	Spiked	≥MDC,<10 x MDC	47	226.62	5.6
	Enrich. Tritium	Spiked	≥MDC,<10 x MDC	8	11.21	14.1
	Enrich. Tritium	Spiked	≥10x MDC	20	6.97	7.0
	Enrich. Tritium	Field	≥10x MDC	18	9.98	5.6
Air Surveil-lance	Gross Alpha	Field	≥MDC,<10 x MDC	6	0.001	39.9
	Gross Beta	Field	≥MDC,<10 x MDC	113	0.003	22.4
	Gross Beta	Field	≥10x MDC	6	0.006	22.0
	$^{239+240}Pu$	Spiked	≥10x MDC	9	0.295	6.8
Noble Gas	^{85}Kr	Split	≥MDC,<10 x MDC	33	2.49	9.4
Tritium in Air	HTO	Split	≥MDC,<10 x MDC	4	0.83	10.7

These internal QC procedures are the only control of accuracy for whole body and lung counts, animal and vegetable samples, and PICs in 1991. The whole body counting facility participates in interlaboratory comparison studies when available through the DOE intercomparison committee. Spiked calibration phantoms are periodically exchanged throughout the DOE whole body counting facilities. No intercomparison phantoms were exchanged during 1991. For spectroscopic and radiochemical analyses, an independent measurement of accuracy is provided by participation in intercomparison studies using samples of known activities. The EPA EMSL-LV Radioanalysis Laboratory participates in two such intercomparison studies. An independent verification of the accuracy of the TLDs is achieved through participation in DOELAP.

In the EPA EMSL-LV Intercomparison Study program, samples of known activities of selected radionuclides are sent to participating laboratories on a set schedule throughout the year. Water, milk, and air filters are used as the matrices for these samples. Results from all participating laboratories are compiled and statistics computed comparing each laboratory's results to the known value and to the average of all laboratories. The comparison to the known value provides an independent assessment of accuracy for each participating laboratory. Comparison of results among all participating laboratories provides a measure of comparability, discussed in Section 11.4.4. Approximately 70 to 190 laboratories participate in any given intercomparison study. In Table 18, results for radionuclides commonly measured in the ORSP are given. Results for all intercomparison studies are provided in Appendix F. Accuracy, as percent difference or percent bias, is calculated by:

$$\%BIAS = \left(\frac{C_m - C_a}{C_a}\right) x\ 100$$

where:
$\%BIAS$ = *percent bias*
C_m = *measured concentration*
C_a = *known/theoretical concentration*

In most cases, the achieved accuracy was well within the established DQOs for the analysis. In general, these DQOs are ± 20 percent for values greater than ten times the MDC and ± 30 percent for results greater than the MDC but less than ten times the MDC. The DQO was exceeded for one alpha intercomparison sample in water and one in air, one beta intercomparison sample in air, one ^{137}Cs intercomparison sample in water, one ^{89}Sr intercomparison sample in water and one in milk, and one total potassium intercomparison sample in milk.

The other intercomparison study in which the EPA EMSL-LV Radioanalysis Laboratory participates is the semiannual DOE QA Program conducted by EML in New York, NY. Approximately 20 laboratories participate in this intercomparison study pro-

Table 18. Accuracy of Analysis from EPA Intercomparison Studies

Nuclide	Month	Known Value (pCi/L)[a]	Lab Average (pCi/L)[a]	Percent Bias
		Water Intercomparison Studies		
Alpha	April (PE)	54.0	67.33	24.7
Alpha	Sept	10.0	9.00	-10.0
Alpha	Oct (PE)	82.0	97.67	19.1
Beta	Sept	20.0	20.00	0.0
Beta	Oct (PE)	65.0	61.67	-5.1
^{137}Cs	Feb	8.0	8.33	4.1
^{137}Cs	April (PE)	25.0	20.00	-20.0
^{137}Cs	Oct	10.0	10.33	3.3
^{137}Cs	Oct (PE)	11.0	12.00	9.1
^{3}H	Feb	4418.0	4613.00	4.4
^{3}H	Oct	2452.0	2499.33	1.9
^{89}Sr	April (PE)	28.0	22.33	-20.2
^{89}Sr	May	39.0	34.33	-12.0
^{89}Sr	Sept	49.0	39.67	-19.0
^{89}Sr	Oct (PE)	10.0	8.33	-16.7
^{90}Sr	April (PE)	26.0	23.33	-10.3
^{90}Sr	May	24.0	24.00	0.0
^{90}Sr	Sept	25.0	23.67	-5.3
^{90}Sr	Oct (PE)	10.0	10.33	3.3
U (Nat)	Mar	7.6	7.67	0.9
U (Nat)	April (PE)	29.8	30.30	1.7
U (Nat)	July	14.2	14.43	1.6
U (Nat)	Oct (PE)	13.5	13.17	-2.4
U (Nat)	Nov	24.9	23.97	-3.7
$^{239+240}Pu$	Aug	19.4	18.23	-6.0
		Air Intercomparison Studies		
Alpha	Mar	5.0	6.00	20.0
Alpha	Aug	10.0	14.00	40.0
Beta	Mar	31.0	36.67	18.3
Beta	Aug	62.0	80.33	29.6
		Milk Intercomparison Studies		
^{89}Sr	Apr	32.0	29.67	-7.3
^{89}Sr	Apr	23.0	18.67	-18.8
^{89}Sr	Sept	25.0	22.33	-10.7
^{89}Sr	Sept	16.0	12.67	-20.8
^{90}Sr	Apr	32.0	32.00	0.0
^{90}Sr	Apr	23.0	19.67	-14.5
^{90}Sr	Sept	25.0	25.33	1.3
^{90}Sr	Sept	20.0	18.00	-10.0

Continued

Table 18. Continued.

Nuclide	Month	Known Value (pCi/L)[a]	Lab Average (pCi/L)[a]	Percent Bias
		Milk Intercomparison Studies		
K (tot)	Apr	1650.0	1212.67	-26.5
K (tot)	Apr	1550.0	1587.33	2.4
K (tot)	Sept	1740.0	1710.67	-1.7
K (tot)	Sept	1700.0	1754.67	3.2

[a] Values were obtained from the individual intercomparison study reports and are reported with the significant figures included in those reports.

PE = performance evaluation study

gram, although each laboratory receives only its own results and the EML value. The EML result is assumed to represent the known or true activity concentration. Results for radionuclides commonly analyzed in the ORSP are given in Table 19; results for all analyses are given in Appendix F. In all cases, the EPA results differed from the EML known activities by a percent bias of less than ± 10 percent. These results are well within the established DQO.

In addition to use of irradiated control samples in the processing of TLDs, DOELAP monitors accuracy, precision, and bias as part of the accreditation program. As with the intercomparison studies, dosimeters receiving a known type and level exposure are submitted as single blind samples. The designation "single blind" indicates the analyst recognizes the sample as being other than a routine sample, but does not know the radiation type or level to which the dosimeter has been exposed except that dosimeters are identified as having been exposed in either the "protection range" or the "accident range". Individual results are not provided to the participant laboratories by DOELAP until the conclusion of the third round of performance testing in each test cycle. Issuance of the accreditation certificate indicates acceptable accuracy, precision, and bias and successful completion of a comprehensive onsite review by independent DOELAP Site Assessors.

11.4.4 Comparability

The EPA Intercomparison Study reports (EPA, 1991) provide results for all laboratories participating in each intercomparison study. A grand average is computed for all values, excluding outliers. A normalized deviation statistic compares each laboratory's result (mean of three replicates) to the known value and to the grand average. If the value of this statistic (in multiples of standard normal deviate, unitless) lies between control limits of -3 and +3, the accuracy (deviation from known value) or comparability (deviation from grand average) is within normal statistical variation. Table 20 displays data from the 1991 intercomparison studies for the variables most commonly measured in the ORSP. The complete data set for all variables is presented in Appendix F. Of the commonly measured variables, there were three instances in which the Radioanalysis Laboratory results deviated from the grand average by more than three standard normal deviate units. These were the April intercomparison sample for total potassium in milk, the August sample for beta emitters on an air filter, and the September water intercomparison sample containing ^{89}Sr. The first two of these also exceeded the DQO for accuracy (see Section 11.4.3, above). The third sample, ^{89}Sr in water, was within the DQO for accuracy. Apart from these three, all of the normalized deviations from the grand average were within the statistical control limit range of -3 to +3. This indicates acceptable comparability of the Radioanalysis Laboratory with the 69 to 207 laboratories participating in the EPA Intercomparison Study Program.

Table 19. Accuracy of analysis from DOE Intercomparison Study

Nuclide	Month	EML (Known) Value (pCi/L)[a]	EPA Lab Average (pCi/L)[a]	Percent Bias
		Water Intercomparison Studies		
^{137}Cs	Mar	169	163	-3.5
^{137}Cs	Sept	46.0	48.3	5.0
^{3}H	Sept	100	102	2.0
^{90}Sr	Sept	10.1	9.93	-1.7
U (Nat)	Sept	0.940	0.949	1.0
$^{239+240}Pu$	Sept	0.510	0.480	-5.9
		Air Intercomparison Studies		
^{7}Be	Mar	53.0	47.8	-9.8
^{7}Be	Sept	53.8	56.4	4.8
$^{239+240}Pu$	Sept	0.084	0.087	3.6
		Vegetation Intercomparison Studies		
$^{239+240}Pu$	Sept	0.365	0.359	-1.6
		Soil Intercomparison Studies		
$^{239+240}Pu$	Sept	7.35	7.22	-1.8

[a] Values were obtained from the Environmental Measurements Laboratory (EML) and reported with the significant figures provided by EML.

11.4.5 Representativeness

Representativeness cannot be evaluated quantitatively. Rather, it is a qualitative assessment of the ability of the sample to model the objectives of the program. The primary objective of the ORSP is to protect the health and safety of the offsite residents. Therefore, the DQO of representativeness is met if the samples are representative of the radiation exposure of the resident population. Monitoring stations are located in resident population centers. Siteing criteria specific to radiation sensors are not available for many of the instruments used. Existing siteing criteria developed for other pollutants are applied to the ORSP sensors as available. For example, siteing criteria for the placement of air sampler inlets are contained in Prevention of Significant Deterioration guidance documents (EPA, 1976). Inlets for the air samplers at the ORSP stations have been evaluated against these criteria and, in most cases, meet the siteing requirements. Guidance or requirements for handling, shipping, and storage of radioactivity samples are followed in program operations and documented in SOPs. Standard analytical methodology is used and guidance on the holding times for samples, sample processing, and results calculations are followed and documented in SOPs.

In the LTHMP, the primary objectives are protection of drinking water supplies and monitoring of any potential cavity migration. Sampling locations are primary "targets of opportunity", i.e., the sampling locations are primarily wells developed for other purposes than radioactivity monitoring. Guidance or requirements developed for CERCLA and RCRA regarding the number and location of monitoring wells has not been applied to the LTHMP sampling sites. In spite of these limitations, the samples are representative of the first objective, protection of drinking water supplies. At all of the LTHMP monitoring areas, including on

Table 20. Comparability of Analysis from EPA Intercomparison Studies

Nuclide	Month	No. of Participating Laboratories	EPA Lab Average (pCi/L)	Grand Average (pCi/L)	Normalized Deviation from Grand Average	Ratio EPA Lab Average/ Grand Average
			Water Intercomparison Studies			
Alpha	April (PE)	179	67.33	49.71	2.18	1.35
Alpha	Sept	207	9.00	10.36	-0.47	0.87
Alpha	Oct (PE)	187	97.67	75.57	1.82	1.29
Beta	Sept	207	20.00	20.30	-0.10	0.99
Beta	Oct (PE)	187	61.67	55.53	1.06	1.11
^{137}Cs	Feb	151	8.33	9.06	-0.25	0.92
^{137}Cs	April (PE)	179	20.00	25.49	-1.90	0.78
^{137}Cs	Oct	162	10.33	10.86	-0.18	0.95
^{137}Cs	Oct (PE)	187	12.00	12.45	-0.15	0.96
^{3}H	Feb	150	4613.00	4437.60	0.69	1.04
^{3}H	Oct	166	2499.00	2532.00	-0.16	0.99
^{89}Sr	April (PE)	179	22.33	25.74	-1.18	0.87
^{89}Sr	May	104	34.33	37.43	-1.07	0.92
^{89}Sr	Sept	69	39.67	49.57	-3.43*	0.80
^{89}Sr	Oct (PE)	187	8.33	9.79	-0.51	0.85
^{90}Sr	April (PE)	179	23.33	23.61	-0.10	0.99
^{90}Sr	May	104	24.00	28.85	0.05	0.83
^{90}Sr	Sept	69	23.67	24.72	-0.46	0.96
^{90}Sr	Oct (PE)	187	10.33	10.09	0.08	1.02
U (Nat)	Mar	117	7.67	7.30	0.21	1.05
U (Nat)	April (PE)	179	30.30	28.88	0.82	1.05
U (Nat)	July	127	14.43	13.38	0.61	1.08
U (Nat)	Oct (PE)	187	13.17	13.25	-0.05	0.99
U (Nat)	Nov	90	23.97	23.76	0.12	1.01
$^{239+240}Pu$	Aug	61	18.23	19.22	-0.90	0.95
			Air Intercomparison Studies			
Alpha	Mar	185	6.00	6.25	-0.09	0.96
Alpha	Aug	179	14.00	12.21	0.62	1.15
Beta	Mar	185	36.67	32.19	1.55	1.14
Beta	Aug	179	80.33	64.66	5.43*	1.24
			Milk Intercomparison Studies			
^{89}Sr	Apr	96	29.67	27.07	0.90	1.10
^{89}Sr	Apr	104	18.67	23.14	-1.55	0.81
^{89}Sr	Sept	95	22.33	20.95	0.48	1.07
^{89}Sr	Sept	98	12.67	13.53	-0.30	0.94
^{90}Sr	Apr	96	32.00	28.02	1.38	1.14
^{90}Sr	Apr	104	19.67	22.33	-0.92	0.88

Continued

Table 20. Continued.

Nuclide	Month	No. of Participating Laboratories	EPA Lab Average (pCi/L)	Grand Average (pCi/L)	Normalized Deviation from Grand Average	Ratio EPA Lab Avg./ Grand Avg.
			Milk Intercomparison Studies			
^{90}Sr	Sept	95	25.33	21.09	1.47	1.20
^{90}Sr	Sept	98	18.00	17.57	0.15	1.02
K (tot)	Apr	96	1212.70	1653.00	-9.19*	0.73
K (tot)	Apr	104	1587.00	1548.00	0.86	1.03
K (tot)	Sept	95	1710.70	1667.00	0.86	1.03
K (tot)	Sept	98	1754.70	1713.60	0.84	1.02

[a] Values were obtained from the individual intercomparison study reports and are reported with the significant figures included in those reports.
PE = performance evaluation study.
(Nat) = natural.
* = outside control limits.

and around the NTS, all potentially impacted drinking water supplies are monitored, as are many supply sources with virtually no potential to be impacted by radioactivity resulting from past or present nuclear weapons testing. The sampling network at some locations is not optimal for achieving the second objective, monitoring of any migration of radionuclides from the test cavities. An evaluation conducted by DRI describes, in detail, the monitoring locations for each LTHMP location and the strengths and weaknesses of each monitoring network (Chapman and Hokett, 1991). This evaluation is cited in the discussion of the LTHMP data in Chapter 7.

12. Sample Analysis Procedures

The procedures for analyzing samples collected for this report are described in *Radiochemical and Analytical Procedures for Analysis of Environmental Samples* (Johns, 1979) and are summarized in Table 21. These include gamma analysis, gross beta on air filters, strontium, tritium, plutonium, and noble gas analyses. These procedures outline standard methods used to perform given analytical procedures.

Table 21. Summary of Analytical Procedures

Type of Analysis	Analytical Equipment	Counting Period (min)	Analytical Procedures	Sample Size	Approximate Detection Limit[a]
HpGe Gamma[b]	HpGe detector-calibrated at 0.5 keV/channel (0.04 to 2 meV range) individual detector efficiencies ranging from 15 to 35%.	Air charcoal cartridges and individual air filters, 30; 100 for milk, water, suspended solids.	Radionuclide concentration quantified from gamma spectral data by online computer program.	560 m^3 for air filters and charcoal cartridges; 3.5 L for milk and water.	For routine milk and water generally, 5 x 10^{-9} µCi/mL (1.85 x 10^{-1} Bq/L) for most common fallout radionuclides in a simple spectrum. Filters for LTHMP suspended solids, 6 x 10^{-9} µCi/mL (2.22 x 10^{-1} Bq/L). Air filters and charcoal cartridges, 0.04 x 10^{-12} µCi/mL (1.48 x 10^{-3} Bq/m^3).
Gross alpha and beta on air filters	Low-level end windows, gas flow proportional counter with a 5-cm diameter window.	30	Samples are counted after decay of naturally occurring radionuclides.	560 m^3	alpha: 8.0 x 10^{-16} µCi/mL (3.0 x 10^{-5} Bq/m^3) beta: 2.5 x 10^{-15} µCi/mL (9.25 x 10^{-5} Bq/m^3)
$^{89,90}Sr$	Low background thin-window, gas-flow, proportional counter.	50	Chemical separation by ion exchange. Separated sample counted successively; activity calculated by simultaneous solution of equations.	1.0 L for milk or water. 0.1 to 1 kg for tissue.	^{89}Sr=5 x 10^{-9} µCi/mL (1.85 x 10^{-1} Bq/L) ^{90}Sr=2 x 10^{-9} µCi/mL (7.4 x 10^{-2} Bq/L)
^{3}H	Automatic liquid scintillation counter with output printer.	300	Sample prepared by distillation.	5 to 10 mL for water.	300 to 700 x 10^{-9} µCi/mL (11-26 Bq/L)[c]

Continued

Table 21. Continued.

Type of Analysis	Analytical Equipment	Counting Period (min)	Analytical Procedures	Sample Size	Approximate Detection Limit[a]
^{3}H	Automatic liquid scintillation counter with output printer.	300	Sample prepared by distillation.	5 to 10 mL for water.	300 to 700 x 10^{-9} µCi/mL (11-26 Bq/L)[c]
^{3}H Enrichment (LTHMP samples)	Automatic liquid scintillation counter with output printer.	300	Sample concentrated by electrolysis followed by distillation.	250 mL for water.	10 x10^{-9} µCi/mL (3.7 x 10^{-1} Bq/L)
$^{238,239+240}Pu$	Alpha spectrometer with silicon surface barrier detectors operated in vacuum chambers.	1,000	Water sample or acid-digested filter or tissue samples separated by ion exchange, electroplated on stainless steel planchet.	1.0 L for water; 0.1 to 1 kg for tissue; 5,000 to 10,000 m^3 for air.	^{238}Pu=0.08 x 10^{-9} µCi/mL (2.9 x 10^{-3} Bq/L), $^{239+240}Pu$=0.04 x 10^{-9} µCi/mL (1.5 x 10^{-3} Bq/L) for water. For tissue samples, 0.04 pCi (1.5 x 10^{-3} Bq) per total sample for all isotopes; 5 x 10^{-17} to 10 x 10^{-17} µCi/mL (1.9 x 10^{-6} to 3.7 x 10^{-6} Bq/m^3) for plutonium on air filters.
^{85}Kr, ^{133}Xe, ^{135}Xe	Automatic liquid scintillation counter with output printer.	200	Separation by gas chromatography; dissolved in toluene "cocktail" for counting.	0.4 to 1.0m^3 for air.	^{85}Kr, ^{133}Xe, ^{135}Xe=4x 10^{-12} µCi/mL (1.5 x 10^{-1} Bq/m^3)

[a] The detection limit is defined as the smallest amount of radioactivity that can be reliably detected, i.e., probability of Type I and Type II error at 5 percent each (DOE81).

[b] Gamma spectrometry using a high purity intrinsic germanium (HpGe) detector.

[c] Depending on sample type.

13. Radiation Protection Standards For External and Internal Exposure

Design and operation of the ORSP are based on requirements and guidelines contained in applicable legislation and literature. A summary of applicable regulations and guidelines follows.

13.1 Dose Equivalent Commitment

For stochastic effects in members of the public, the following limits are used:

	Effective Dose mrem/yr	Dose Equivalent[a] mSv/yr
Occasional annual exposures[b]	500	5
Prolonged period of exposure	100	1

[a] Includes both effective dose equivalent from external radiation and committed effective dose equivalent from ingested and inhaled radionuclides.

[b] Occasional exposure implies exposure over a few years with the provision that over a lifetime the average exposure does not exceed 100 mrem (1 mSv) per year (ICRP, 1983).

13.2 Concentration Guides

ICRP-30 (ICRP, 1979) lists Derived Air Concentrations (DAC) and Annual Limit on Intake (ALI). The ALI is the secondary limit and can be used with assumed breathing rates and ingested volumes to calculate concentration guides. The concentration guides (CGs) in Table 22 were derived in this manner and yield the committed effective dose equivalent (50 year) of 100 mrem/yr for members of the public.

13.3 U.S. Environmental Protection Agency Drinking Water Guide

In 40 CFR 141 (CFR, 1988), the EPA set allowable concentrations for continuous controlled releases of radionuclides to drinking water sources. Any single or combination of beta and gamma emitters should not lead to exposures exceeding 4 mrem/yr. For tritium, this is 2.0×10^{-5} μCi/mL (740 Bq/L) and for ^{90}Sr is 8×10^{-9} μCi/mL (0.3 Bq/L).

Table 22. Routine Monitoring Guides

Nuclide	Sampling Frequency	Locations	Sample Size	Count Time	Concentrations Guide[a]		MDC	MDC (%CG)
Air Surveillance Network		(ASN)	m^3	Minutes	Bq/m^3	µCi/mL	mBq/m^3	
^{7}Be	1/wk	all	560	30	1700	4.7×10^{-8}	17	1×10^{-3}
^{95}Zr	1/wk	all	560	30	12	3×10^{-10}	4.1	4×10^{-2}
^{95}Nb	1/wk	all	560	30	110	3×10^{-9}	1.8	2×10^{-3}
^{99}Mo	1/wk	all	560	30	110	3×10^{-9}	1.5	2×10^{-3}
^{103}Ru	1/wk	all	560	30	58	1.5×10^{-9}	1.8	3×10^{-3}
^{131}I	1/wk	all	560	30	4	1×10^{-10}	1.8	4×10^{-2}
^{132}Te	1/wk	all	560	30	17	5×10^{-10}	1.8	1×10^{-2}
^{137}Cs	1/wk	all	560	30	12	3×10^{-10}	1.8	2×10^{-2}
^{140}Ba	1/wk	all	560	30	120	3×10^{-9}	4.8	4×10^{-3}
^{140}La	1/wk	all	560	30	120	3×10^{-9}	2.6	2×10^{-3}
^{141}Ce	1/wk	all	560	30	52	1.4×10^{-9}	3.0	6×10^{-3}
^{144}Ce	1/wk	all	560	30	1.2	3×10^{-11}	12	1.0
^{238}Pu	1/mo	all	2400	1000	5×10^{-4}	1×10^{-14}	1.5×10^{-3}	0.32
Gross Beta	1/wk	all	560	30	2×10^{-2}	5×10^{-13}	0.11	6×10^{-1}
^{3}H	1/wk	19	5	150	4.6×10^{3}	1.2×10^{-7}	148	3×10^{-3}
^{85}Kr	1/wk	16	0.4	200	2.2×10^{4}	6.2×10^{-7}	148	6×10^{-4}
^{133}Xe	1/wk	16	0.4	200	1.8×10^{4}	4.9×10^{-7}	370	2×10^{-3}
^{135}Xe	1/wk	16	0.4	200	2.3×10^{3}	6.2×10^{-8}	370	2×10^{2}
Water Surveillance Network (LTHMP)[b]		Liters	Minutes	Bq/L	µCi/mL		Bq/L	
^{3}H	1/mo	all	1	300	740	2×10^{-5}	12	1.6
^{3}H+ (enriched tritium)	1/mo	all	0.25	300	740	2×10^{-5}	0.37	5×10^{-2}
^{89}Sr	1st time	all	1	50	16	4.4×10^{-7}	0.18	1.1
^{90}Sr	1st time	all	1	50	0.8	2.2×10^{-8}	0.074	9.2
^{137}Cs	1/mo	all	1	100	3.3	8.8×10^{-8}	0.33	10
^{226}Ra	1st time	all	1	1000	1.4	3.9×10^{-8}	0.037	2.6
^{234}U	1st time	all	1	1000	8.2	2.2×10^{-7}	0.0035	0.04
^{235}U	1st time	all	1	1000	10	2.8×10^{-8}	0.0035	0.035
^{236}U	1st time	all	1	1000	10	2.8×10^{-8}	0.0035	0.035
^{238}Pu	1st time	all	1	1000	6.2	1.7×10^{-8}	0.003	0.05
$^{239+240}Pu$	1st time	all	1	1000	4.1	1.1×10^{-8}	0.002	0.05
Gamma	1/mo	all	3.5	30	--	--	0.18	<0.2
Milk Surveillance Network		(MSN)	Liters	Minutes	Bq/L	µCi/mL	Bq/L	
^{3}H	1/mo	all	3.5	300	12×10^{4}	3×10^{-3}	12	0.01
^{131}I	1/mo	all	3.5	100	41	1×10^{-6}	0.18	0.44
^{137}Cs	1/mo	all	3.5	100	160	4×10^{-6}	0.33	0.2
^{89}Sr	1/mo	all	3.5	50	820	2×10^{-5}	0.18	0.02
^{90}Sr	1/mo	all	3.5	50	40	1×10^{-6}	0.074	0.18

Dosimetry Networks		Locations	Number	Exposure Guide	MDC	MDC(%CG)
TLD (Personnel)	1/mo	72	1	100mR	3.01mrem	2
TLD (Station)	1/quarter	130	3 to 6	--	5.10mrem	--
PIC	weekly	29	Continuous	--	2µR/hr	--

[a] ALI and DAC values from ICRP-30 modified to 1 mSv annual effective dose equivalent for continuous exposure. Te and I data corrected to 2 g thyroid, greater milk intake, and smaller volume of air breathed annually (1 year-old infant).

[b] For tritium, Sr, and Cs the concentration guide is based on Drinking Water Regs, (4 mrem/yr) (CFR, 1988).

14 Summary and Conclusions

The primary functions of the ORSP are to conduct routine environmental monitoring for radioactive materials in areas potentially impacted by nuclear tests and, when necessary, to implement actions to protect the public from radiation exposure. Components of the ORSP include surveillance networks for air, noble gas, atmospheric tritium, and milk; biomonitoring of meat, game animals, and vegetables; exposure monitoring by thermoluminescent dosimetry, pressurized ion chambers, and whole body counting; and long-term hydrological monitoring of wells and surface waters. In 1991, data from all networks and monitoring activities indicated no radiation directly attributable to current activities conducted at the NTS. Therefore, there was no need for any protective actions to be taken. The following sections summarize the ORSP activities for 1991.

14.1 Thermoluminescent Dosimetry Program

In 1991, external exposure was monitored by a network of thermoluminescent dosimeters (TLDs) at 130 fixed locations surrounding the NTS and by TLDs worn by 72 offsite residents. No apparent net exposures were related to NTS activities. As discussed in Section 3.1, regulatory or ALARA investigation limits were not exceeded for any individual or cumulative exposure. The range of exposures was similar to those observed in other areas of the U.S.

14.2 Pressurized Ion Chamber Network

The Pressurized Ion Chamber (PIC) network measures ambient gamma radiation exposure rates. The 29 PICs deployed around the NTS in 1991 showed no unexplained deviations from background levels. The maximum annual exposure of 154 mR/yr was measured at Stone Cabin Ranch, Nevada; the minimum of 52 mR/yr was recorded at Las Vegas, Nevada. As discussed in Section 3.2 these values are within the U.S. background range and are consistent with previous years' trends.

14.3 Air Surveillance Network

In 1991, the Air Surveillance Network (ASN) consisted of 33 continuously operating sampling locations surrounding the NTS. These stations were complemented by 76 standby stations which were operated at least one week each quarter. At least one standby sampler is located in each state west of the Mississippi River.

In the majority of cases, no gamma emitting radionuclides were detected by gamma spectrometry (i.e., the results were gamma-spectrum negligible). Naturally occurring ^{7}Be was the only radionuclide occasionally detected. As in previous years, the majority of the gross beta results exceeded the MDC. The plutonium results from four of the composite samples exceeded the MDC in 1991. Two of these were very close to the MDC: ^{238}Pu results from Las Vegas, Nevada and ^{238}Pu results from Logan and Vernal, Utah. The other two values exceeding the MDC were the $^{239+240}Pu$ results from the high-volume air samples collected from Amargosa Valley and from Rachel, Nevada. Operation of the Air Sampling Network and the data results were discussed in Section 4.1.

14.4 Tritium In Atmospheric Moisture

At the beginning of 1991, the tritium network consisted of 20 continuously operating and two standby stations. Several changes were made to the network in 1991. These are discussed in Section 4.2.1. Of the 957 samples collected in 1991, 23 were of insufficient volume to permit analysis, and six of the results exceeded the MDC. Three of these six results, from Shoshone, Goldfield, and Rachel, Nevada were very close to the MDC. Of the other three values above MDC, one was from Salt Lake City, Utah and the other two were from Las Vegas, Nevada. The operation of the tritium samplers and the data results are discussed in Section 4.2.

14.5 Noble Gas Sampling Network

At the beginning of 1991, the Noble Gas Sampling Network (NGSN) consisted of 16 routinely operated and three standby stations. Several changes were made to the network in 1991. These are discussed in Section 4.3.1. Samples collected were analyzed for ^{85}Kr and ^{133}Xe. As in previous years, all of the results for ^{133}Xe were below the MDC. All of the ^{85}Kr were above the MDC and were within the range anticipated from sampling background levels.

14.6 Foodstuffs

Milk samples were collected from 23 Milk Surveillance Network (MSN) and 115 Standby Milk Surveillance Network (SMSN) stations in 1991. For both MSN and SMSN samples, only naturally occurring ^{40}K averaging 2.17 gm/L was detected by gamma spectroscopy. The majority of the ^{3}H, ^{89}Sr, and ^{90}Sr results were below the MDC. For the MSN, one sample result from the June Cox Ranch, Caliente, Nevada and one from the Harbecke Ranch, Shoshone, Nevada exceeded the MDC for ^{3}H. For both of these results, the MDC falls within or very close to one standard deviation of the analysis indicating the result is within expected statistical variation. For ^{89}Sr, one result from the David Hafen Ranch, Ivins, Utah was the only value which exceeded the MDC. The MDC for this result was also within one standard deviation of the analysis result. For ^{90}Sr results, two samples from the Harbecke Ranch, Shoshone, Nevada and two samples from the Karen Harper Ranch, Tonopah, Nevada exceeded the MDC. Values above MDC have been observed at the Harbecke Ranch in previous years. The higher values have generally occurred during the summer months, indicating those values may be associated with feeding patterns during those months. The Karen Harper Ranch has not been sampled in previous years so there is no historical record from that ranch. One ^{3}H result, three ^{89}Sr results, and 17 ^{90}Sr results were above the MDC for samples from the SMSN stations. This is consistent with the number of values exceeding the MDC in 1990.

Sampling under the animal investigation program in 1991 showed detectable concentrations of tritium in two mule deer collected from the NTS and detectable concentrations of $^{239+240}Pu$ were found in one or more tissues from each of the four mule deer collected. The mountain lion collected on the NTS also evidenced detectable concentrations of tritium, $^{239+240}Pu$, and ^{90}Sr. All but one of the cattle liver samples yielded detectable concentrations of $^{239+240}Pu$. Only one bighorn sheep bone yielded a concentration of $^{239+240}Pu$ greater than the MDC of the analysis. Strontium-90 was detected in all of the bone samples for each species. No gamma-emitting radionuclides other than naturally occurring ^{40}K were detected in any tissue sample. Medians and ranges of radionuclides in bighorn sheep tissues and all analyzed cattle tissues except liver were generally similar to those obtained in previous years. Cattle liver yielded higher concentrations of radionuclides than noted in previous years. While ranges of radionuclide concentrations in mule deer were similar to those obtained in previous years, the medians were higher. This is attributed to collection of two (out of four) animals with evidence of radioactive contamination. As the objective of the animal investigation program is to detect worst-case conditions, the results indicate that the component of possible radionuclide ingestion from meat is small (see Chapter 8, Dose Assessment).

Fifteen samples of locally grown fruits and vegetables were collected in the fall of 1991. No gamma-emitting radionuclides were detected apart from naturally occurring ^{40}K. Two samples from the same location yielded detectable concentrations of ^{238}Pu and concentrations of $^{239+240}Pu$ greater than the analysis MDC were found in seven samples. No correlation between radionuclide concentration and mode of growth (i.e., surface crops as opposed to root crops) was evident. The observed plutonium may be contained in the fruit or vegetable material or may be contained in soil or dust adhering to the vegetable surface. In the latter case, residents could reduce the potential for radionuclide ingestion by thorough washing of vegetables prior to eating and peeling of potatoes and carrots. The worst-case dose that could potentially result from eating these fruits and vegetables is discussed in Chapter 8, Dose Assessment.

14.7 Internal Dosimetry

Internal deposition of radioactive material is assessed by whole body counting using a single intrinsic coaxial germanium detector, lung counting using six intrinsic germanium semiplanar detectors,

and bioassay using radiochemical procedures. During 1991, a total of 2,800 gamma spectra was obtained from whole-body counting of 350 persons (including those individuals who were counted twice). One hundred and six of the counts were on participants of the Offsite Internal Dosimetry Program. All spectra were representative of normal background and showed only naturally occurring ^{40}K. No transuranic radionuclides were detected in any lung-counting data. No internal exposure above applicable regulatory limits was detected in either occupationally exposed individuals or members of the general public who participated in the Internal Dosimetry Program at EMSL-LV.

Bioassay results for the Offsite Internal Dosimetry Program showed that the concentration of tritium in single urine samples collected at random periods of time (i.e., whenever the individual was able to come to EMSL-LV) varied from below the MDC average value of 2.7×10^{-7} μCi/mL (10 Bq/L) to 3.8×10^{-7} μCi/mL (14 Bq/L). Two values were slightly above the MDC. This can be accounted for by random statistical fluctuation. The highest value of 3.8×10^{-7} μCi/mL (14 Bq/L) is only 0.01 percent of the annual limit of intake for the general public. As no accidental or planned releases from NTS were reported in 1991, no additional bioassay sampling was performed. As reported in previous years, medical examinations of the offsite families revealed a generally healthy population. The blood examinations and thyroid profiles showed no symptoms which could be attributed to past or present NTS testing operations.

14.8 Long-Term Hydrological Monitoring Program

The Long-Term Hydrological Monitoring Program is discussed in detail in Chapter 7. None of the domestic water supplies monitored in the LTHMP in 1991 yielded tritium activities of any health concern. The greatest tritium activity measured in any water body which has potential to be a drinking water supply was less than one percent of the Interim Primary Drinking Water Regulation. In general, surface water and spring samples yielded tritium activities greater than those observed in shallow domestic wells in the same area. This is probably due to scavenging of atmospheric tritium by precipitation. There were no indications that migration from any test cavity is affecting any domestic water supply.

In most cases, monitoring wells also yielded no detectable radionuclide activity. Exceptions include wells into test cavities and wells monitoring known areas of contamination. Known areas of contamination exist at Project GNOME where USGS conducted a tracer study experiment, some areas onsite at Project DRIBBLE, and a few surface areas near Project LONG SHOT. The 1991 results for these monitoring wells are consistent with decreasing trends observed over time.

Monitoring well EPNG 10-36 at Project GASBUGGY was a notable exception to wells evidencing decreasing trends. This well is a former gas well located 435 feet northwest of SGZ. The sampling depth of this well is approximately 3600 ft in the Ojo Alamo Sandstone, a nonpotable aquifer. The tritium activity in 1991 was 484 ± 4 pCi/L, approximately 10 times the historic background activity. An increase in tritium activity was first observed in 1984, seventeen years after the test was conducted. In every year since then, with the exception of 1987, tritium activities have been between 100 and 560 pCi/L, with wide variability sometimes noted between consecutive years. The proximity of the well to the test cavity suggests the possibility that the increased activity may be indicative of migration from the test cavity.

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Glossary of Terms

Definitions of terms given here are modified from the U.S. Nuclear Regulatory Commission Glossary of terms (NRC81).

background radiation — The radiation in man's natural environment, including cosmic rays and radiation from the naturally radioactive elements, both outside and inside the bodies of humans and animals. It is also called natural radiation. The usually quoted average individual exposure from background radiation is 125 millirem per year in midlatitudes at sea level.

becquerel (Bq) — A unit, in the International System of Units, of measurement of radioactivity equal to one nuclear transformation per second.

beta particle (*B*) — A charged particle emitted from a nucleus during radioactive decay, with a mass equal to 1/837 that of a proton. A positively charged beta particle is called a positron. Large amounts of beta radiation may cause skin burns, and beta emitters are harmful if they enter the body. Beta particles are easily stopped by a thin sheet of metal or plastic.

blind samples — A spiked sample, the composition of which is unknown to the technician, which has been introduced into the laboratory as a separate sample. These samples are used for the verification of analytical accuracy. Approximately one percent of the sample load shall be blind samples.

cosmic radiation — Penetrating ionizing radiation, both particulate and electromagnetic, originating in space. Secondary cosmic rays, formed by interactions in the earth's atmosphere, account for about 45 to 50 millirem of the 125 millirem background radiation that an average individual receives in a year.

coulomb (C) — Unit of electrical charge in the MKSA system of units. A coulomb is a quantity of a charge equal to one ampere-second.

curie (Ci) — The basic unit used to describe the rate of radioactive disintegration. The curie is equal to 37 billion disintegrations per second, which is approximately the rate of decay of 1 gram of radium; named for Marie and Pierre Curie, who discovered radium in 1898.

dosimeter — A portable instrument for measuring and registering the total accumulated dose to ionizing radiation.

duplicate — A second aliquot of a sample which is approximately equal in mass or volume to the first aliquot and is analyzed for the sample parameters. The laboratory performs duplicate analyses to evaluate the precision of an analysis.

half-life — The time in which half the atoms of a particular radioactive substance disintegrate to another nuclear form. Measured half-lives vary from millionths of a second to billions of years. Also called physical half-life.

ionization — The process of creating ions (charged particles) by adding one or more electrons to, or removing one or more electrons from, atoms or molecules. High temperatures, electrical discharges, nuclear radiation, and x-rays can cause ionization.

ionization chamber — An instrument that detects and measures ionizing radiation by measuring the electrical current that flows when radiation ionizes gas in a chamber.

isotope — One of two or more atoms with the same number of protons, but different numbers of neutrons in their nuclei. Thus, ^{12}C, ^{13}C and ^{14}C are isotopes of the element carbon, the numbers denoting the approximate atomic weights. Isotopes have very nearly the same chemical properties, but often different physical properties (for example, ^{12}C and ^{14}C are radioactive).

matrix spike — An aliquot of a sample which is spiked with a known concentration of the analyte of interest. The purpose of analyzing this type of sample is to evaluate to the effect of the sample matrix upon the analytical methodology.

method blank — A method blank is a volume of demineralized water for liquid samples, or an appropriate solid matrix for soil/sediment samples, carried through the entire analytical procedure. The volume or weight of the blank must be approximately equal to the volume or weight of the sample processed. Analysis of the blank verifies that method interferences caused by contaminants in solvents, reagents, glassware, and other sample processing hardware are known and minimized.

minimum detectable (MDC) — The smallest amount of radioactivity that can be reliably detected with a probability of Type I and Type II error at five percent each (DOE81).

millirem (mrem) — A one-thousandth part of a rem. (See rem.)

milliroentgen (mR) — A one-thousandth part of a roentgen. (See roentgen.)

noble gas — A gaseous element that does not readily enter into chemical combination with other elements. An inert gas.

personnel monitoring — The determination of the degree of radioactive contamination on individuals using survey meters, or the determination of radiation dosage received by means of internal or external dosimetry methods.

picocurie (pCi) — One trillionth part of a curie.

quality factor — The factor by which the absorbed dose is to be multiplied to obtain a quantity that expresses, on a common scale for all ionizing radiations, the biological damage to exposed persons. It is used because some types of radiation, such as alpha particles, are more biologically damaging than other types.

rad — Acronym for radiation absorbed dose. The basic unit of absorbed dose of radiation. A dose of one rad means the absorption of 100 ergs (a small but measurable amount of energy) per gram of absorbing material.

radioisotope — An unstable isotope of an element that decays or disintegrates spontaneously, emitting radiation.

radionuclide — A radioisotope.

rem — Acronym of roentgen equivalent man. The unit of dose of any ionizing radiation that produces the same biological effect as a unit of absorbed dose of ordinary X-rays. (See quality factor.)

roentgen (R) — A unit of exposure to ionizing radiation. It is that amount of gamma or X-rays required to produce ions carrying one electrostatic unit of electrical charge in one cubic centimeter of dry air under standard conditions. Named after Wilhelm Roentgen, German scientist who discovered X-rays in 1895.

scintillation (dectector or counter) — The combination of phosphor, photomultiplier tube, and associated counter electronic circuits for counting light emissions produced in the phosphor by ionizing radiation.

Sievert (Sv)	A unit, in the International System of Units (SI), of dose equivalent which is equal to one joule per kilogram (1 Sv equals 100 rem).
terrestrial radiation	The portion of natural radiation (background) that is emitted by naturally occurring radioactive materials in the earth.
tritium	A radioactive isotope of hydrogen that decays by beta emission. It's half-life is about 12.5 years.
verification/ reference standard	A prepared sample of known concentration of a purchased standard reference material. These samples are analyzed in triplicate and the results are used to verify accuracy and precision of the procedure.
X-rays	Penetrating electromagnetic radiation (photon) having a wavelength that is much shorter than that of visible light. These rays are usually produced by excitation of the electron field around certain nuclei. In nuclear reactions, it is customary to refer to photons originating in the nucleus as gamma rays, and to those originating in the electron field of the atom as X-rays. These rays are sometimes called roentgen rays after their discoverer, Wilhelm K. Roentgen.

Appendix A

Table A-1. Offsite Station TLD Results, 1991

Station	Number	Start Date	End Date	# Days	Number of Data Points	Equiv. Exposure Rate (mR/day)[a] Min.	Max.	Ave.	Annual Equiv. Exp. (mR)[b]
Arizona									
Colorado City	008STA230	10/30/90	11/12/91	378	4	0.17	0.19	0.18	65
Jacob's Lake	008STA452	10/30/90	11/12/91	378	4	0.25	0.28	0.26	96
Page	008STA708	10/31/90	11/12/91	378	4	0.13	0.16	0.15	55
California									
Baker	005STA035	11/01/90	11/19/91	378	4	0.23	0.30	0.26	95
Barstow	005STA045	11/01/90	11/19/91	378	4	0.28	0.37	0.32	119
Bishop	005STA095	11/03/90	11/20/91	378	4	0.26	0.36	0.31	111
Death Valley Jct.	005STA290	01/09/91	07/03/91	378	2	0.12	0.21	0.16	60
Furnace Creek	005STA340	01/09/91	07/02/91	378	2	0.07	0.18	0.13	47
Independence	005STA445	11/02/90	11/20/91	378	4	0.23	0.32	0.28	101
Lone Pine	005STA545	11/02/90	11/20/91	378	4	0.23	0.33	0.28	103
Mammoth Geothermal	005STA576	11/03/90	11/20/91	378	4	0.26	0.38	0.32	117
Mammoth Lakes	005STA575	11/03/90	11/20/91	378	4	0.19	0.38	0.30	109
Olancha	005STA700	11/02/90	11/20/91	378	4	0.22	0.31	0.26	94
Ridgecrest	005STA765	11/02/90	11/20/91	378	4	0.23	0.33	0.27	98
Shoshone	005STA855	11/01/90	11/19/91	378	4	0.20	0.28	0.22	81
Valley Crest	005STA920	01/09/91	04/02/91	83	2	0.06	0.13	0.10	35
Nevada									
Alamo	002STA015	10/30/90	11/12/91	378	3	0.21	0.28	0.23	86
Amargosa Center	007STA825	01/14/91	07/03/91	378	2	0.15	0.30	0.22	82
Amargosa Valley	007STA490	01/14/91	07/01/91	378	2	0.16	0.26	0.21	75
American Borate	007STA910	01/14/91	07/02/91	378	2	0.16	0.31	0.24	87
Atlanta Mine	002STA023	12/04/90	08/28/91	378	2	0.27	0.28	0.27	99
Austin	006STA025	11/07/90	11/18/91	378	4	0.30	0.43	0.36	132
Battle Mountain	005STA055	11/28/90	12/10/91	378	4	0.15	0.28	0.22	80
Beatty	007STA065	01/09/91	07/01/91	378	2	0.17	0.29	0.23	83
Blue Eagle Ranch	003STA106	01/08/91	10/09/91	378	3	0.02	0.30	0.16	60
Blue Jay	004STA115	01/08/91	10/09/91	378	3	0.19	0.45	0.33	120
Cactus Springs	007STA140	11/01/90	11/18/91	378	4	0.14	0.21	0.17	61
Caliente	002STA155	10/29/90	11/12/91	378	3	0.19	0.26	0.22	82
Carp	002STA160	10/29/90	11/15/91	378	3	0.14	0.23	0.18	65
Cherry Creek	009STA210	12/05/90	08/28/91	378	2	0.32	0.34	0.33	120
Clark Station	004STA215	01/08/91	10/09/91	378	3	0.15	0.38	0.28	102
Coaldale	006STA220	11/06/90	11/13/91	378	4	0.19	0.31	0.27	98
Complex 1	003STA240	10/31/90	11/15/91	378	3	0.22	0.29	0.25	93
Corn Creek	001STA295	11/01/90	11/18/91	378	4	0.11	0.19	0.14	50
Cortez/Hwy 278	009STA298	03/12/91	12/10/91	378	3	0.27	0.49	0.41	149
Coyote Summit	004STA230	10/30/90	11/15/91	378	3	0.24	0.37	0.31	113
Crescent Valley	009STA233	11/28/90	12/10/91	378	4	0.14	0.35	0.22	81
Currant	003STA245	01/08/91	10/09/91	378	3	0.14	0.33	0.26	95
Currie	005STA275	12/05/90	08/28/91	378	2	0.33	0.34	0.34	122
Diablo Mtc. Sta.	004STA300	01/03/91	10/08/91	378	3	0.21	0.40	0.33	120
Duckwater	003STA305	01/08/91	10/09/91	378	3	0.13	0.29	0.23	84
Elgin	002STA315	10/29/90	11/15/91	378	3	0.27	0.34	0.29	107
Elko	005STA320	11/27/90	12/10/91	378	4	0.14	0.35	0.21	75
Ely	003STA326	12/05/90	08/27/91	378	2	0.23	0.25	0.24	86
Eureka	006STA333	01/15/91	10/09/91	378	2	0.22	0.31	0.27	97
Fallon	009STA335	11/29/90	12/12/91	378	4	0.13	0.31	0.19	70
Flying Diamond	003STA338	10/31/90	11/15/91	378	3	0.14	0.22	0.17	64
Gabbs	006STA350	11/06/90	11/13/91	378	4	0.11	0.22	0.18	65
Geyser Ranch	003STA370	12/04/90	08/27/91	378	3	0.11	0.30	0.22	82

Continued

Table A-1. Continued.

Station	Number	Start Date	End Date	# Days	Number of Data Points	Equiv. Exposure Rate (mR/day)[a] Min.	Max.	Ave.	Annual Equiv. Exp. (mR)[b]
Goldfield	006STA380	11/13/90	11/13/91	378	4	0.18	0.31	0.25	91
Groom Lake	004STA400	11/14/90	10/09/91	378	2	0.06	0.28	0.17	61
Hancock Summit	004STA420	11/01/90	11/15/91	378	3	0.33	0.45	0.37	136
Hiko	002STA430	10/30/90	11/16/91	378	3	0.14	0.19	0.17	61
Hot Creek Ranch	004STA440	01/08/91	10/09/91	378	3	0.13	0.25	0.21	75
Indian Springs	007STA450	11/01/90	11/18/91	378	4	0.14	0.25	0.19	70
Ione	011STA452	11/06/90	11/13/91	378	3	0.24	0.31	0.28	104
Kirkeby Ranch	003STA390	12/04/90	08/27/91	378	2	0.18	0.23	0.21	75
Koyne's Ranch	004STA460	11/01/90	11/15/91	378	3	0.18	0.31	0.24	89
Las Vegas Apts.	001STA472	01/02/91	07/02/91	378	2	0.15	0.17	0.16	58
Las Vegas UNLV	001STA485	01/02/91	07/02/91	378	2	0.08	0.13	0.10	37
Las Vegas USDI	001STA480	01/02/91	07/02/91	378	2	0.12	0.19	0.15	55
Lida	006STA500	11/13/90	11/13/91	378	4	0.18	0.31	0.26	95
Lovelock	009STA548	11/28/90	12/11/91	378	4	0.15	0.27	0.19	68
Lund	003STA555	12/06/90	08/29/91	378	2	0.21	0.26	0.23	85
Manhattan	006STA585	11/07/90	11/14/91	378	4	0.25	0.45	0.34	123
Medlin's Ranch	004STA943	11/01/90	11/15/91	378	3	0.23	0.35	0.28	104
Mesquite	001STA615	10/29/90	11/15/91	378	4	0.12	0.16	0.14	51
Mina	006STA620	11/06/90	11/13/91	378	4	0.16	0.29	0.24	86
Moapa	002STA757	10/29/90	11/12/91	378	4	0.17	0.21	0.20	72
Mtn Meadows Ranch	004STA185	01/03/91	10/09/91	378	3	0.13	0.19	0.16	58
Nash Ranch	003STA655	10/30/90	11/16/91	378	3	0.16	0.24	0.19	71
Nyala	004STA690	01/03/91	10/08/91	378	3	0.08	0.25	0.18	66
Overton	001STA705	10/29/90	11/20/91	378	4	0.13	0.15	0.15	54
Pahrump	007STA720	11/01/90	11/19/91	378	4	0.11	0.18	0.14	49
Penoyer Farms	004STA670	10/31/90	11/15/91	378	3	0.24	0.36	0.28	104
Pine Creek Ranch	004STA730	10/31/90	11/15/91	378	3	0.27	0.35	0.30	111
Pioche	002STA740	10/29/90	11/12/91	378	3	0.17	0.19	0.18	66
Queen City Summit	004STA750	01/03/91	10/08/91	378	3	0.24	0.41	0.33	121
Rachel	004STA773	10/31/90	11/15/91	378	3	0.24	0.29	0.26	95
Reed Ranch	004STA760	01/03/91	10/08/91	378	2	0.34	0.35	0.35	127
Reno	009STA757	11/29/90	12/11/91	378	4	0.14	0.33	0.20	71
Round Mountain	006STA775	11/07/90	11/14/91	378	4	0.21	0.35	0.30	108
Ruby Valley	009STA788	11/27/90	12/10/91	378	4	0.24	0.47	0.31	112
So. Desert Corr.	007STA860	11/01/90	11/18/91	378	4	0.12	0.20	0.14	53
Shurz	009STA805	11/29/90	12/12/91	378	4	0.22	0.47	0.29	107
Silver Peak	005STA857	11/13/90	08/22/91	378	4	0.18	0.20	0.19	70
Springdale	007STA885	01/10/91	04/03/91	83	2	0.17	0.31	0.24	88
Steward Ranch	003STA912	12/04/90	03/04/91	90	2	0.29	0.33	0.31	113
Stone Cabin Ranch	004STA915	01/03/91	04/02/91	89	3	0.14	0.33	0.26	94
Sunnyside	003STA930	12/06/90	03/06/91	90	2	0.13	0.16	0.14	53
Tempiute	004STA940	11/01/90	02/05/91	96	3	0.26	0.31	0.28	104
Tonopah Test Range	006STA947	01/02/91	04/10/91	98	3	0.24	0.50	0.36	130
Tonopah	006STA945	11/07/90	02/07/91	92	4	0.29	0.32	0.31	113
Twin Springs Ranch	004STA955	01/03/91	04/01/91	88	3	0.09	0.40	0.26	95
Uhalde's Ranch	004STA010	10/31/90	02/05/91	97	3	0.26	0.32	0.29	106
Warm Springs #1	004STA975	01/03/91	04/02/91	89	3	0.20	0.39	0.32	116
Warm Springs #2	004STA977	01/03/91	04/02/91	89	3	0.94	1.15	1.04	378
Wells	005STA985	11/27/90	03/12/91	105	4	0.17	0.36	0.23	84
Winnemucca	009STA998	11/28/90	03/13/91	105	4	0.12	0.37	0.21	78
Young's Ranch	006STA980	08/22/90	02/06/91	168	4	0.07	0.26	0.21	75

Continued

Table A-1. Continued.

Station	Number	Start Date	End Date	# Days	Number of Data Points	Equiv. Exposure Rate (mR/day)[a] Min.	Max.	Ave.	Annual Equiv. Exp. (mR)[b]
Utah									
Boulder	010STA116	12/05/90	12/11/91	378	4	0.18	0.29	0.23	85
Bryce Canyon	010STA118	12/05/90	12/11/91	378	4	0.18	0.24	0.21	77
Cedar City	001STA200	11/28/90	12/09/91	378	4	0.16	0.23	0.19	71
Delta	011STA295	01/30/91	01/09/92	378	3	0.15	0.34	0.22	81
Duchesne	011STA303	01/29/91	01/07/92	378	3	0.12	0.27	0.18	66
Enterprise	001STA325	11/27/90	12/09/91	378	4	0.26	0.39	0.32	116
Ferron	008STA337	01/29/91	01/07/92	378	3	0.12	0.30	0.18	67
Garrison	003STA360	12/05/90	08/28/91	378	2	0.22	0.22	0.22	80
Grantsville	011STA393	01/30/91	01/09/92	378	3	0.15	0.29	0.20	73
Green River	008STA395	08/07/90	11/12/91	378	4	0.04	0.21	0.15	54
Gunnison	008STA405	12/06/90	12/10/91	378	4	0.13	0.16	0.15	54
Ibapah	009STA443	12/05/90	08/28/91	378	2	0.24	0.34	0.29	106
Kanab	008STA453	10/30/90	11/12/91	378	4	0.11	0.17	0.14	52
Loa	010STA520	12/05/90	12/11/91	378	4	0.28	0.39	0.33	122
Logan	011STA530	01/10/91	07/05/91	378	2	0.15	0.24	0.20	72
Lund	010STA560	11/28/90	12/09/91	378	4	0.25	0.34	0.28	104
Milford	001STA620	12/04/90	12/10/91	378	4	0.28	0.37	0.32	118
Monticello	008STA650	10/31/90	11/13/91	378	4	0.22	0.23	0.23	83
Nephi	011STA660	12/06/90	12/10/91	378	4	0.13	0.18	0.16	58
Parowan	010STA725	12/04/90	12/12/91	378	4	0.18	0.20	0.19	70
Price	011STA743	01/29/91	01/07/92	378	3	0.15	0.30	0.20	74
Provo	011STA745	01/29/91	01/08/92	378	3	0.13	0.23	0.18	65
Salt Lake City	001STA800	01/30/91	01/08/92	378	3	0.12	0.21	0.17	61
St. George	001STA795	11/28/90	03/01/91	93	4	0.12	0.14	0.12	45
Trout Creek	009STA948	12/05/90	03/05/91	90	2	0.20	0.23	0.21	78
Vernal	011STA973	01/29/91	04/09/91	70	3	0.13	0.29	0.19	71
Vernon	011STA974	01/30/91	04/10/91	70	3	0.17	0.33	0.22	82
Wendover	005STA990	11/27/90	03/12/91	105	4	0.10	0.30	0.17	64
Willow Spr. Lodge	011STA997	01/30/91	04/10/91	70	3	0.13	0.26	0.18	66

UNLV - University of Nevada, Las Vegas
USDI - United States Department of Interior

[a] Daily exposure rates are obtained by dividing the total exposure from each TLD by the number of days in the measurement period.

[b] Annual exposures are calculated by multiplying average daily exposure rate by 365.25.

Table A-2. Offsite Personnel TLD Results, 1991

Person I.D.	Location	Background Station #	Start Date	End Date	# Days	Number of Data Points	Equiv. Deep Dose Rate (mrem/day)[a] Min.	Max.	Ave	Annual Equiv. Dose (mrem)[b]
	California									
304	Death Valley Jct.	005STA290	01/09/91	07/03/91	175	6	0.18	0.55	0.36	133
359	Death Valley Jct.	005STA290	01/10/91	07/11/91	182	6	0.06	0.43	0.21	76
60	Shoshone	005STA855	01/08/91	07/08/91	181	6	0.14	0.52	0.29	105
404	Shoshone	005STA855	01/08/91	07/08/91	181	6	0.10	0.68	0.34	123
	Nevada									
22	Alamo	002STA015	01/03/91	08/05/91	214	7	0.03	0.18	0.10	38
427	Alamo	002STA015	01/03/91	08/06/91	215	7	0.05	0.39	0.18	66
380	Amargosa Center	007STA825	01/03/91	07/02/91	180	6	0.18	0.57	0.30	114
426	Amargosa Valley	012YCA023	01/03/91	07/02/91	180	6	0.24	0.56	0.37	135
329	Austin	006STA025	01/16/91	07/09/91	174	6	0.19	0.57	0.30	111
21	Beatty	007STA065	01/10/91	07/02/91	173	6	0.09	0.44	0.29	105
38	Beatty	007STA065	01/09/91	07/01/91	173	6	0.21	0.41	0.28	102
358	Beatty	007STA065	01/11/91	07/02/91	172	6	0.15	0.42	0.30	111
429	Beatty	007STA065	02/12/91	07/02/91	140	5	0.03	0.35	0.21	78
9	Blue Eagle Ranch	003STA106	01/08/91	07/16/91	189	6	0.11	0.31	0.22	79
2	Caliente	002STA155	01/02/91	08/06/91	216	7	0.21	0.36	0.32	117
336	Caliente	002STA155	01/02/91	08/01/91	211	7	0.05	0.27	0.16	58
10	Complex 1	003STA240	01/03/91	08/06/91	215	7	0.11	0.50	0.30	110
11	Complex 1	003STA240	01/03/91	08/06/91	215	7	0.07	0.36	0.19	69
56	Corn Creek	001STA295	01/02/91	08/31/91	241	8	0.04	0.26	0.15	59
14	Coyote Summit	004STA230	01/04/91	08/13/91	221	7	0.12	0.36	0.22	81
15	Coyote Summit	004STA230	01/04/91	08/13/91	221	7	0.04	0.34	0.18	65
47	Ely	003STA326	01/02/91	07/12/91	191	6	0.06	0.30	0.18	67
44	Ely	003STA326	07/10/91	08/06/91	27	1	0.18	0.18	0.18	66
302	Gabbs	006STA350	01/15/91	07/10/91	176	6	0.04	0.39	0.22	79
7	Goldfield	006STA380	01/17/91	07/11/91	175	6	0.07	0.76	0.35	127
19	Goldfield	006STA380	01/17/91	07/11/91	175	6	0.04	0.39	0.21	76
40	Goldfield	006STA380	01/17/91	07/11/91	175	6	0.10	0.28	0.18	66
424	Terrell's Ranch	012YCA810	01/10/91	07/02/91	173	5	0.05	0.52	0.29	105
232	Hiko	002STA430	01/04/91	08/06/91	214	7	0.03	0.19	0.13	46
3	Hot Creek Ranch	004STA440	01/09/91	07/16/91	188	6	0.12	0.29	0.20	73
6	Indian Springs	007STA450	01/07/91	07/08/91	182	6	0.04	0.52	0.20	72
37	Indian Springs	007STA450	01/07/91	07/08/91	182	6	0.04	0.44	0.18	64
405	Indian Springs	007STA450	01/07/91	07/08/91	182	6	0.06	0.24	0.15	54
381	Ione	011STA452	01/15/91	07/10/91	176	6	0.10	0.50	0.28	102
300	Koyne's Ranch	004STA460	01/03/91	08/06/91	215	7	0.05	0.46	0.17	64
49	Las Vegas UNLV	001STA485	01/31/90	04/02/91	426	3	0.03	0.24	0.11	39
25	Las Vegas USDI	001STA480	01/02/91	08/31/91	241	8	0.02	0.19	0.09	34
297	Las Vegas USDI	001STA480	01/02/91	08/31/91	241	8	0.04	0.20	0.11	39
326	Las Vegas USDI	001STA480	01/02/91	05/02/91	120	4	0.11	0.19	0.14	50
376	Las Vegas USDI	001STA480	01/02/91	07/31/91	210	7	0.03	0.44	0.14	50
377	Las Vegas USDI	001STA480	01/02/91	08/31/91	241	8	0.03	0.22	0.10	36
398	Las Vegas USDI	001STA480	01/02/91	08/31/91	241	8	0.04	0.40	0.26	94
399	Las Vegas USDI	001STA480	01/02/91	08/31/91	241	8	0.00	0.35	0.20	72
402	Las Vegas USDI	001STA480	01/02/91	08/31/91	241	8	0.04	0.32	0.15	56
403	Las Vegas USDI	001STA480	01/02/91	08/31/91	241	8	0.04	0.27	0.15	56
423	Las Vegas USDI	001STA480	08/01/91	08/31/91	30	0	DOSIMETER NOT RETURNED			
428	Las Vegas USDI	001STA480	01/03/91	08/31/91	240	8	0.02	0.44	0.24	87
379	Manhattan	006STA585	01/16/91	07/09/91	174	6	0.09	0.46	0.32	116
307	Mina	006STA620	01/15/91	07/10/91	176	6	0.02	0.30	0.18	67
18	Nyala	004STA690	01/03/91	07/16/91	194	6	0.07	0.33	0.18	64

Continued

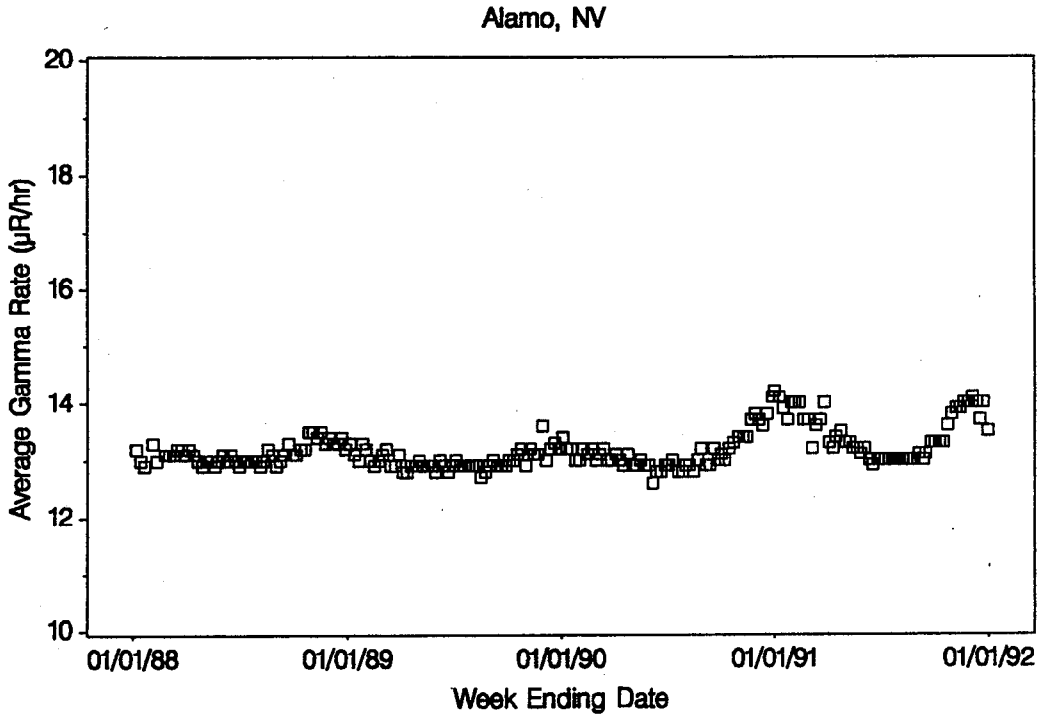
Table A-2. Continued.

Person I.D.	Location	Background Station #	Start Date	End Date	# Days	Number of Data Points	Equiv. Deep Dose Rate (mrem/day)[a] Min.	Max.	Ave	Annual Equiv. Dose (mrem)[b]
299	Round Mountain	006STA775	01/16/91	07/09/91	174	6	0.09	0.57	0.29	107
341	Silver Peak	005STA857	01/17/91	07/10/91	174	6	0.05	0.57	0.31	112
29	Stone Cabin Ranch	004STA915	01/03/91	07/16/91	194	6	0.24	0.68	0.46	167
42	Tonopah	006STA945	01/17/91	07/11/91	175	6	0.09	0.54	0.30	110
339	Tonopah	006STA945	01/17/91	07/10/91	174	6	0.16	0.50	0.31	113
348	Overton	001STA705	01/02/91	08/01/91	211	7	0.18	0.29	0.23	83
372	Pahrump	007STA720	01/03/91	07/01/91	179	6	0.05	0.22	0.15	55
410	Pahrump	007STA720	01/08/91	07/08/91	181	6	0.03	0.58	0.26	94
411	Pahrump	007STA720	01/08/91	07/08/91	181	6	0.03	0.44	0.26	96
248	Penoyer Farms	004STA670	01/03/91	08/06/91	215	7	0.16	0.38	0.22	82
293	Pioche	002STA740	01/02/91	08/05/91	215	7	0.03	0.39	0.15	56
264	Rachel	004STA773	01/04/91	08/06/91	214	7	0.13	0.31	0.25	92
334	Rachel	004STA773	01/03/91	08/06/91	215	7	0.16	0.26	0.20	75
443	Rachel	004STA773	07/10/91	08/06/91	27	1	0.09	0.09	0.09	32
370	Twin Springs Ranch	004STA955	01/03/91	07/16/91	194	6	0.21	0.39	0.32	118
	Utah									
44	Cedar City	001STA200	01/02/91	08/01/91	211	7	0.09	0.39	0.20	71
344	Delta	011STA295	01/02/91	08/06/91	216	7	0.08	0.19	0.15	54
345	Delta	011STA295	01/02/91	08/06/91	216	7	0.09	0.50	0.25	90
346	Milford	001STA620	01/02/91	08/05/91	215	7	0.15	0.34	0.24	89
347	Milford	001STA620	01/02/91	08/05/91	215	7	0.08	0.61	0.39	143
52	Salt Lake City	001STA800	01/02/91	08/06/91	216	7	0.06	0.26	0.17	63
45	St. George	001STA795	01/02/91	08/02/91	212	7	0.03	0.14	0.08	31

USDI - United States Department of Interior
UNLV - University of Nevada, Las Vegas

[a] Daily dose rates are obtained by dividing the total dose from each TLD by the number of days in the measurement period.

[b] Annual doses are calculated by multiplying average daily dose rate by 365.25.



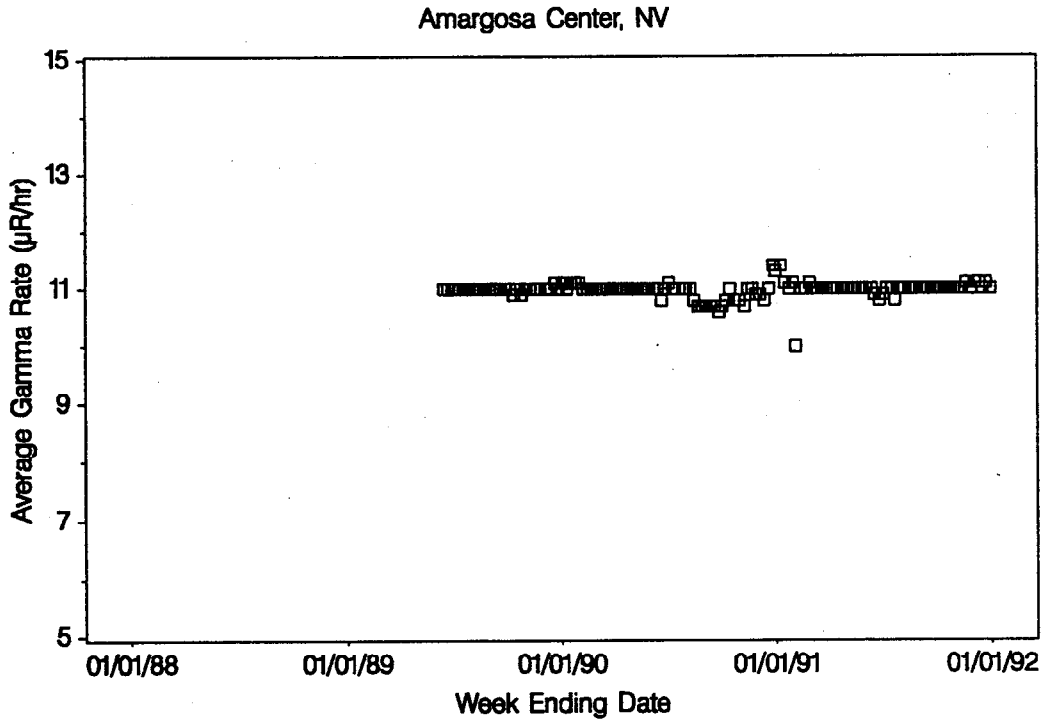
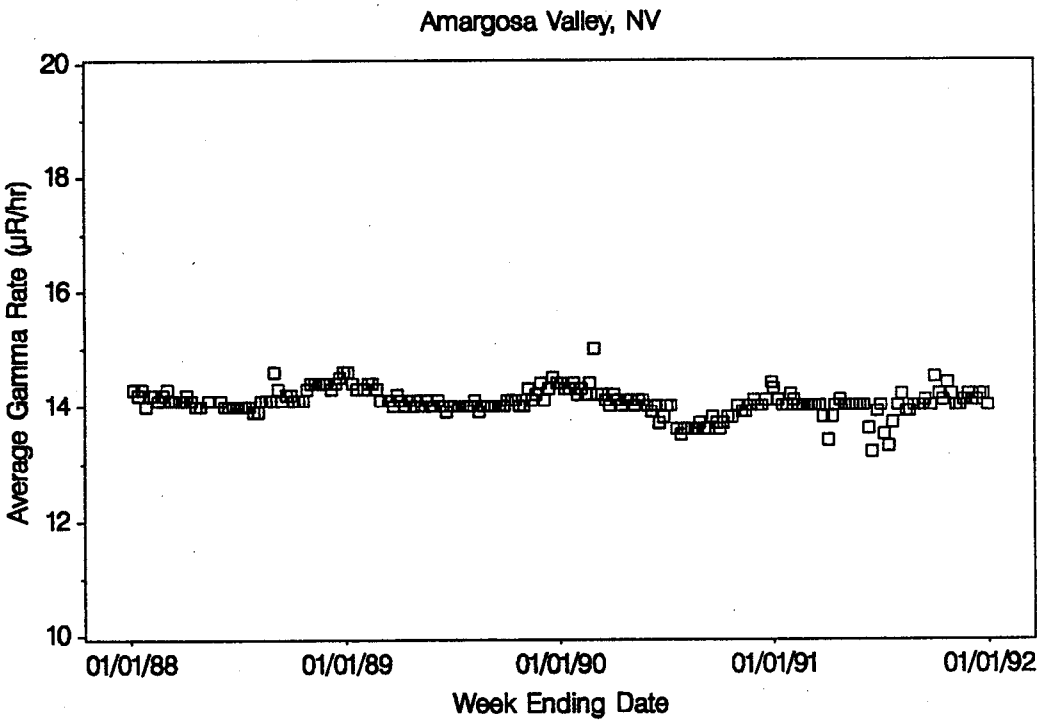


Figure A-1. Weekly averages of Pressurized Ion Chamber data, by station, January, 1988 to December, 1991.



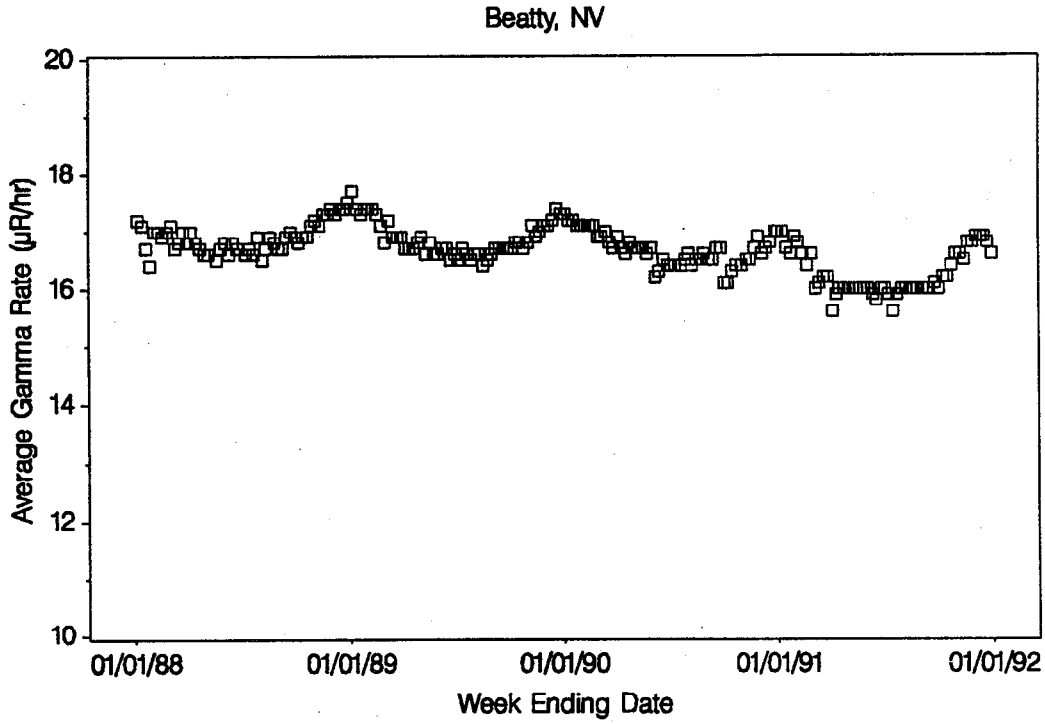
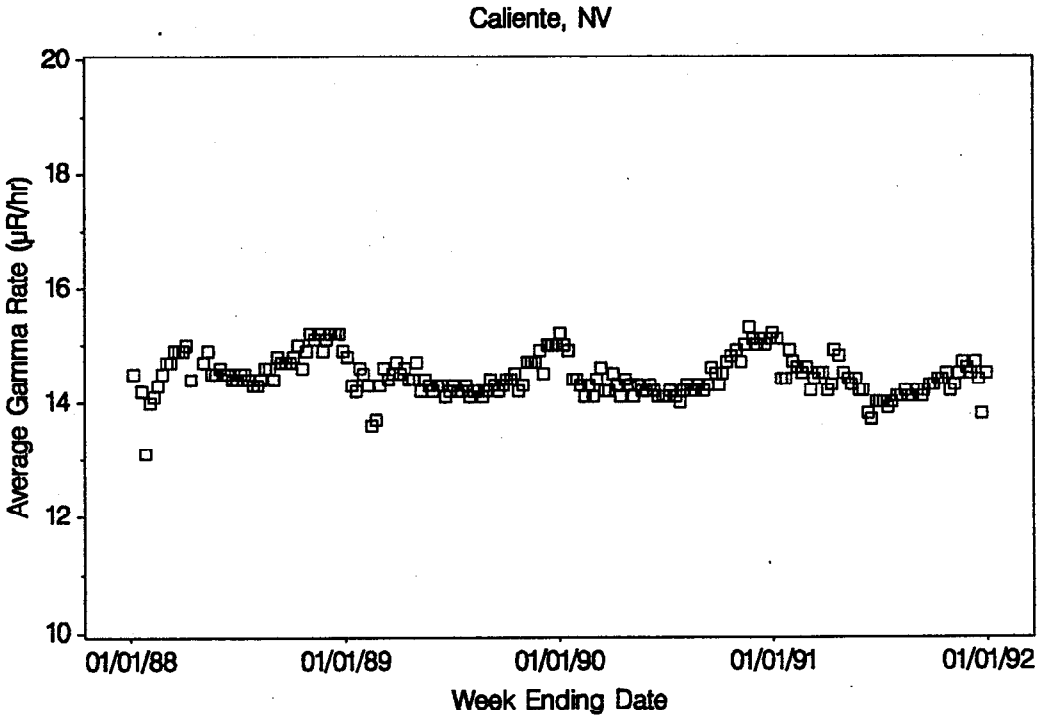
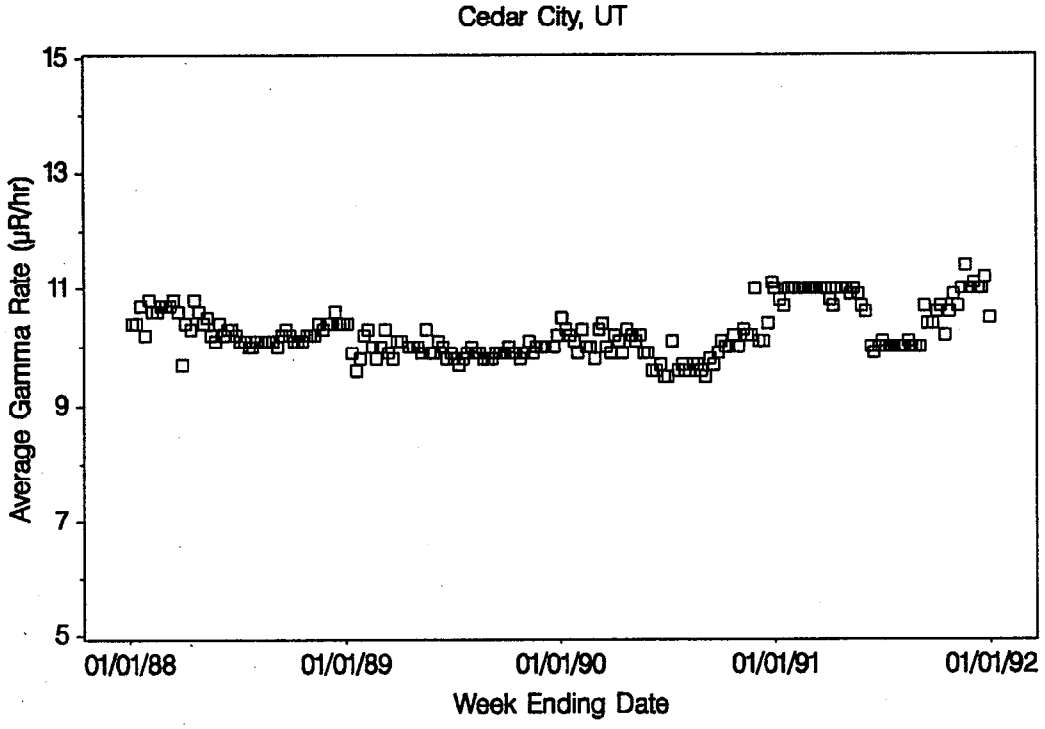


Figure A-1. Continued.





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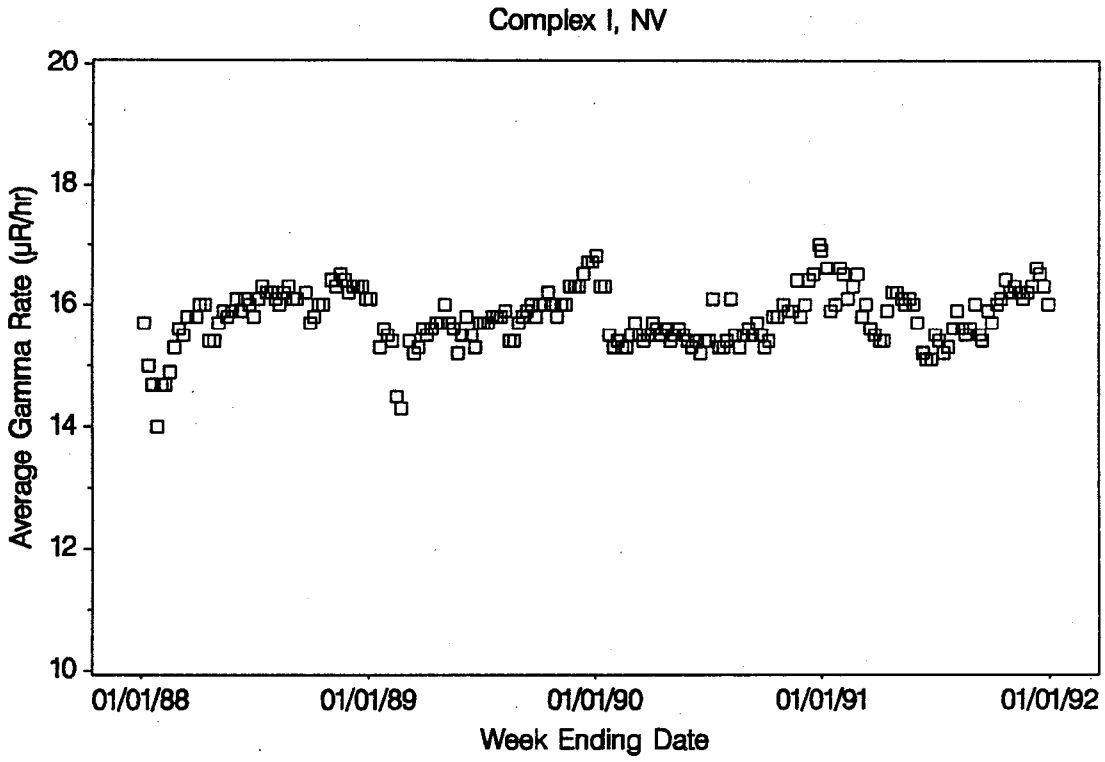

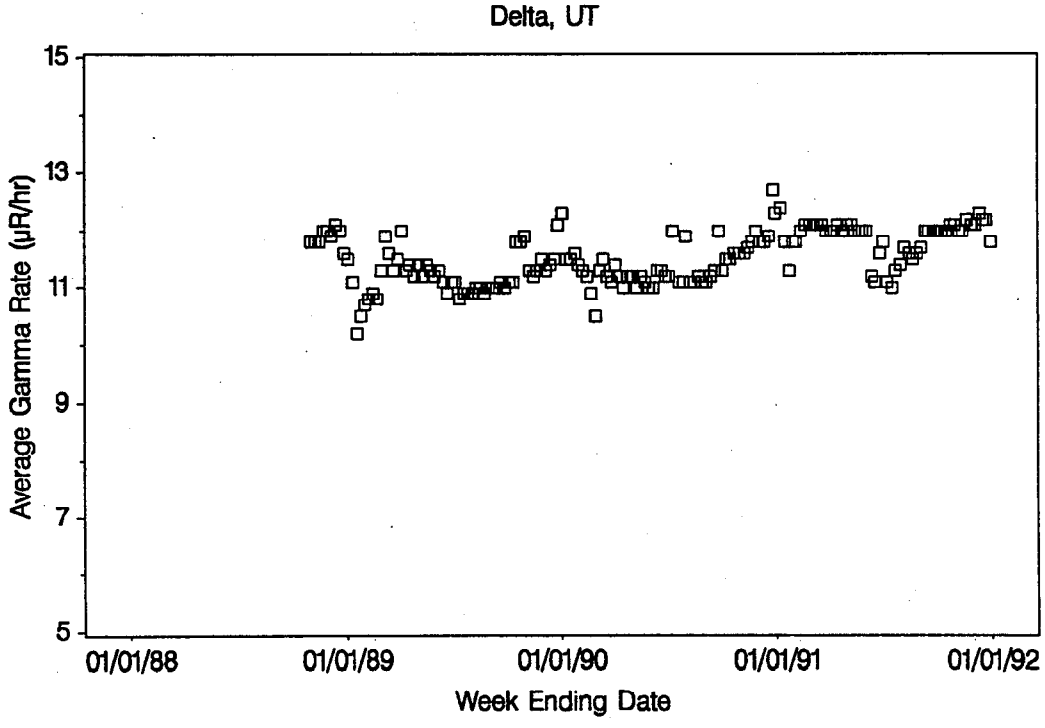

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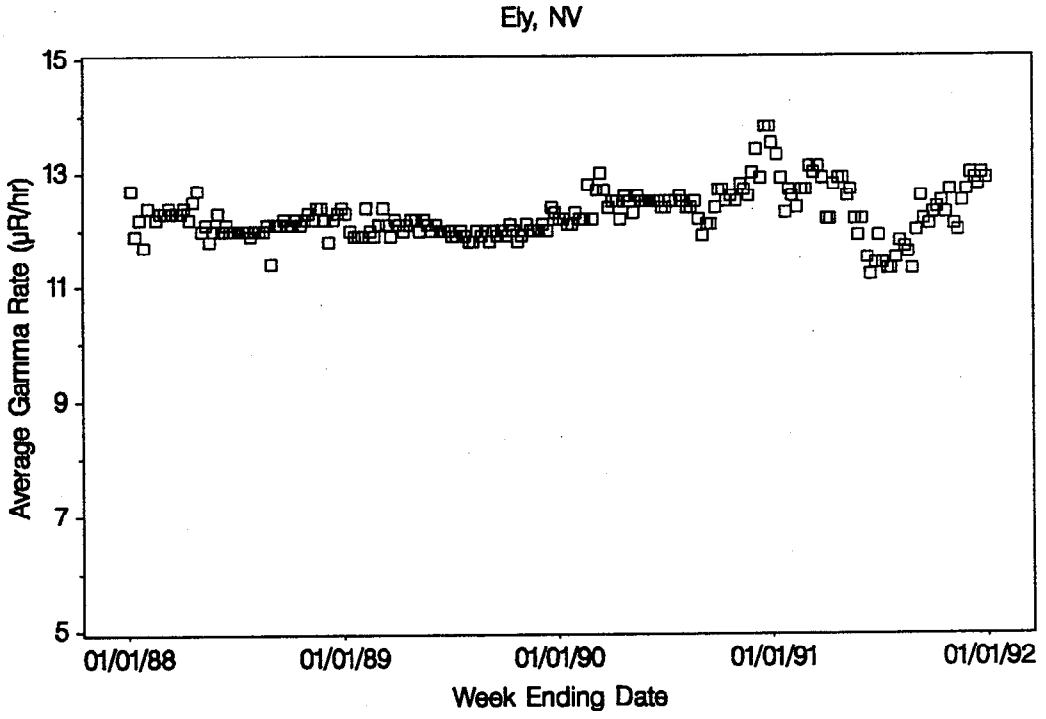


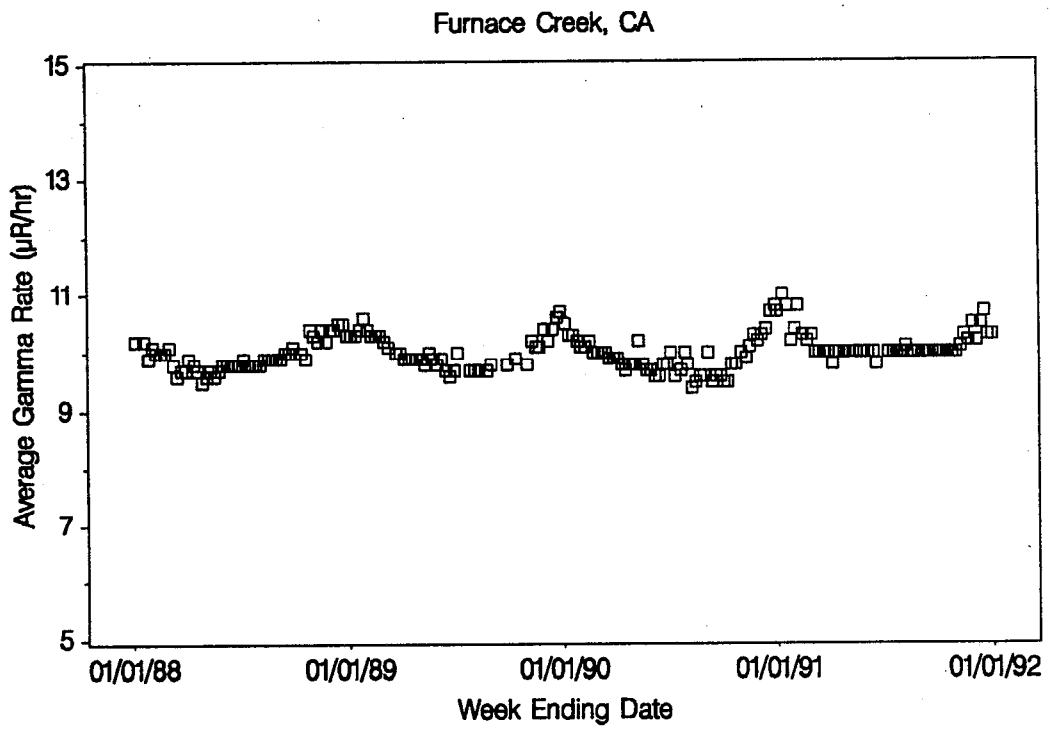
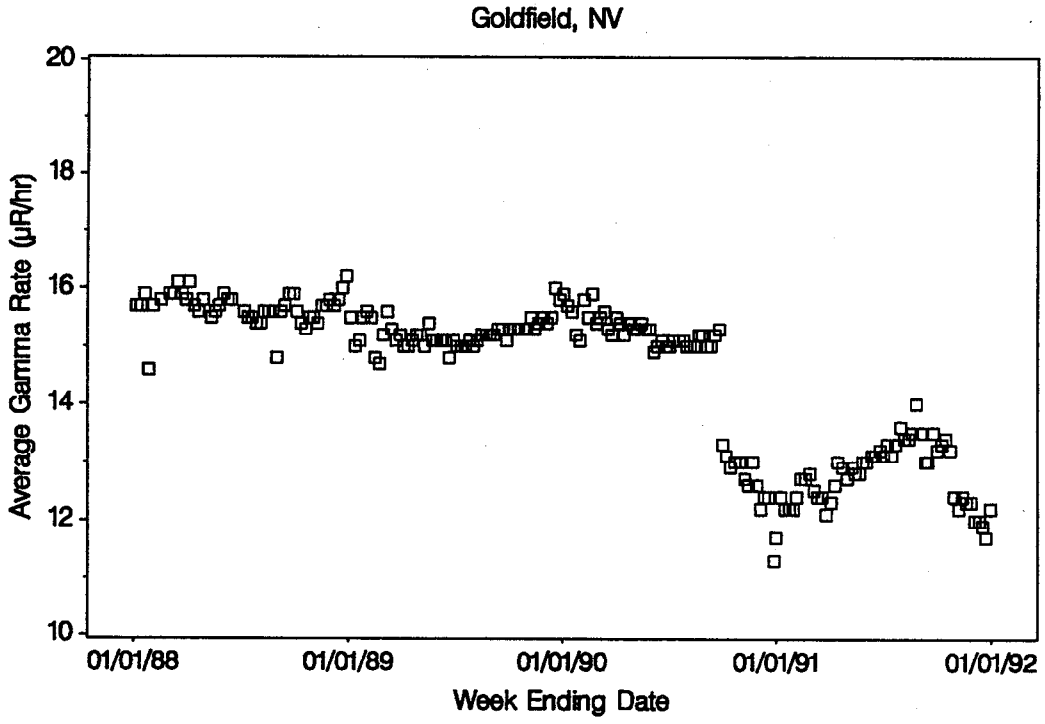
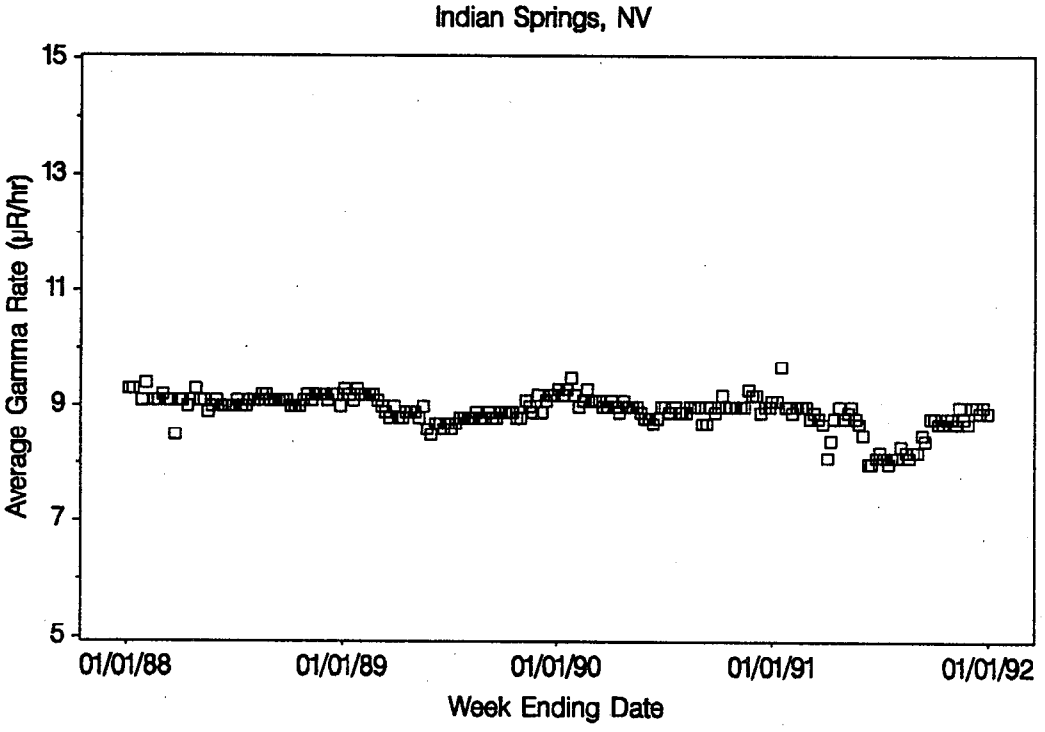


Figure A-1. Continued.





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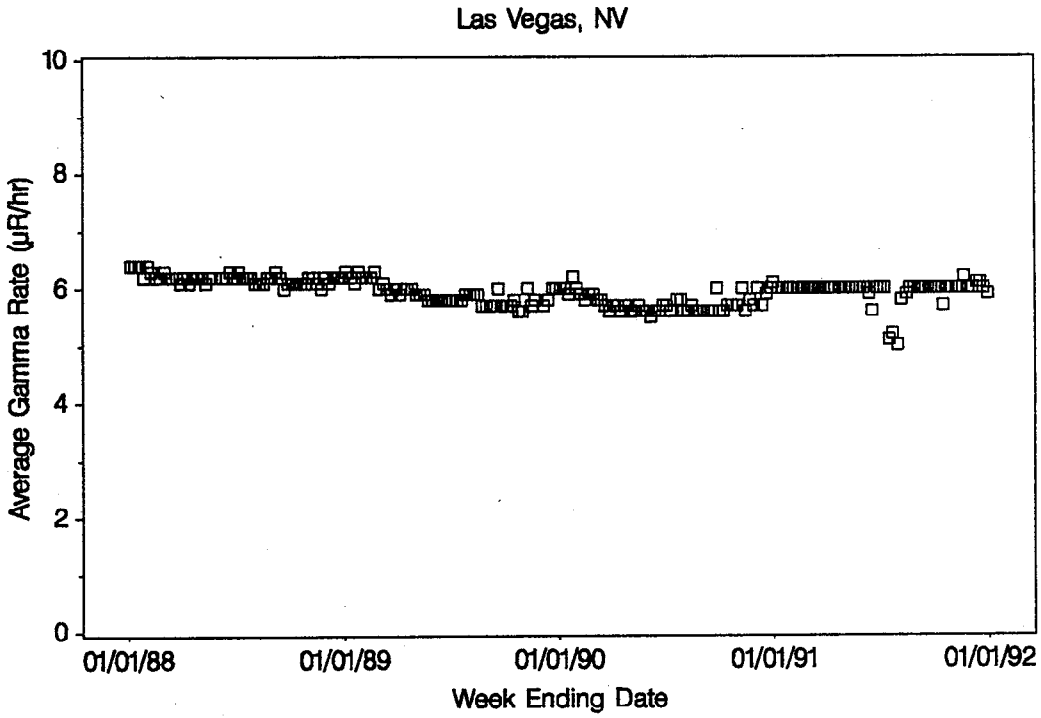


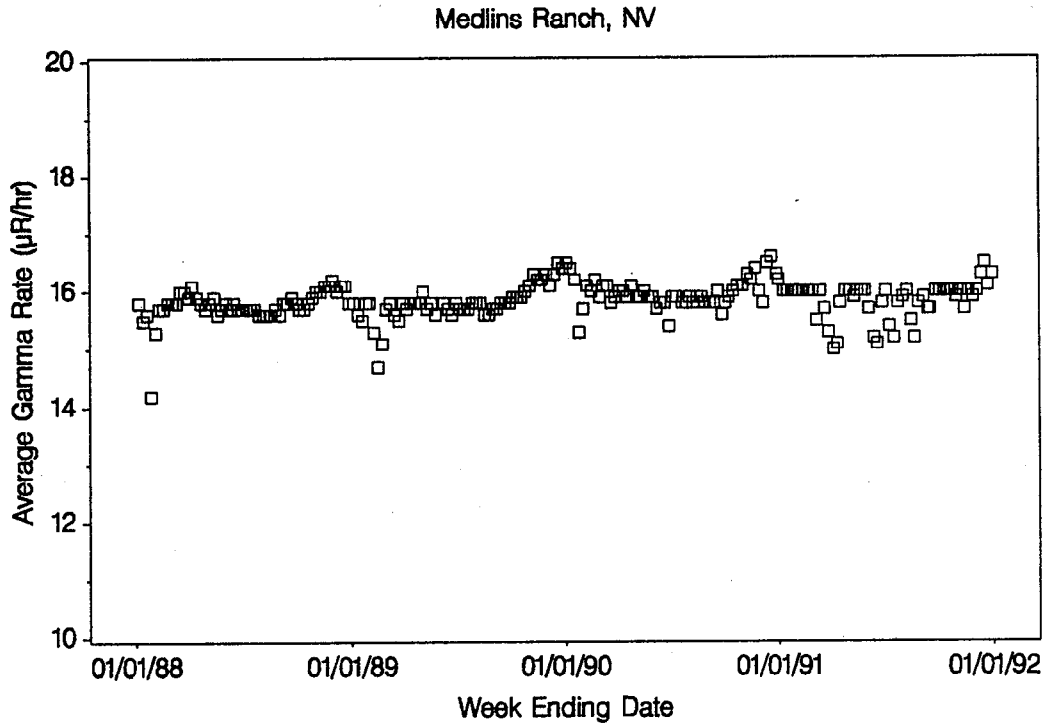
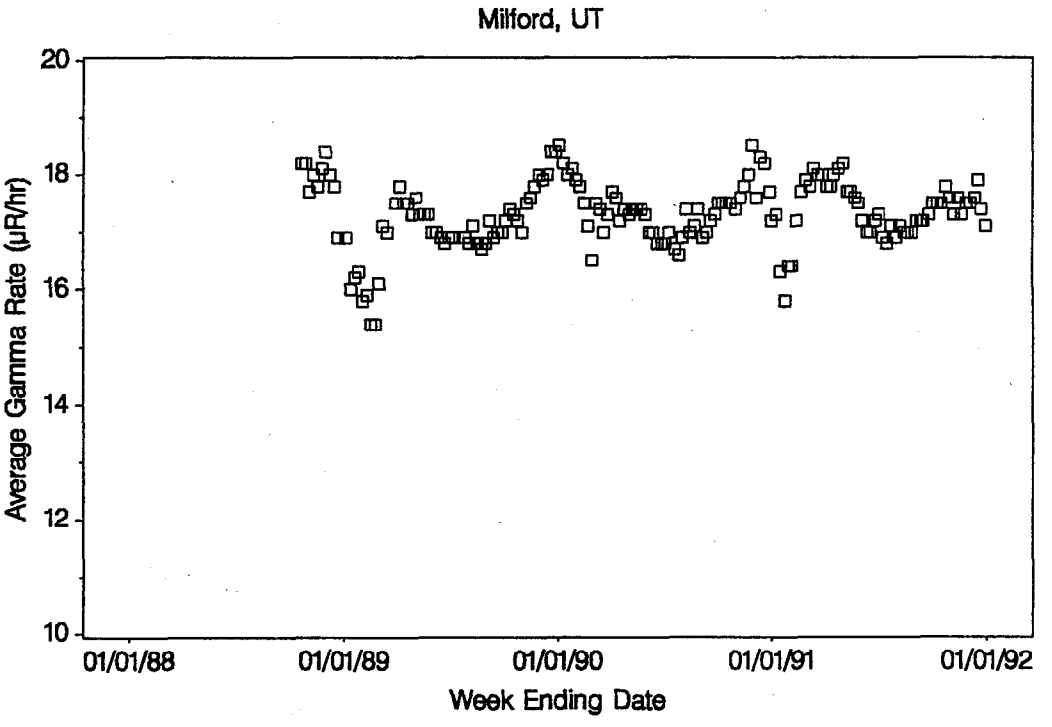


Figure A-1. Continued.



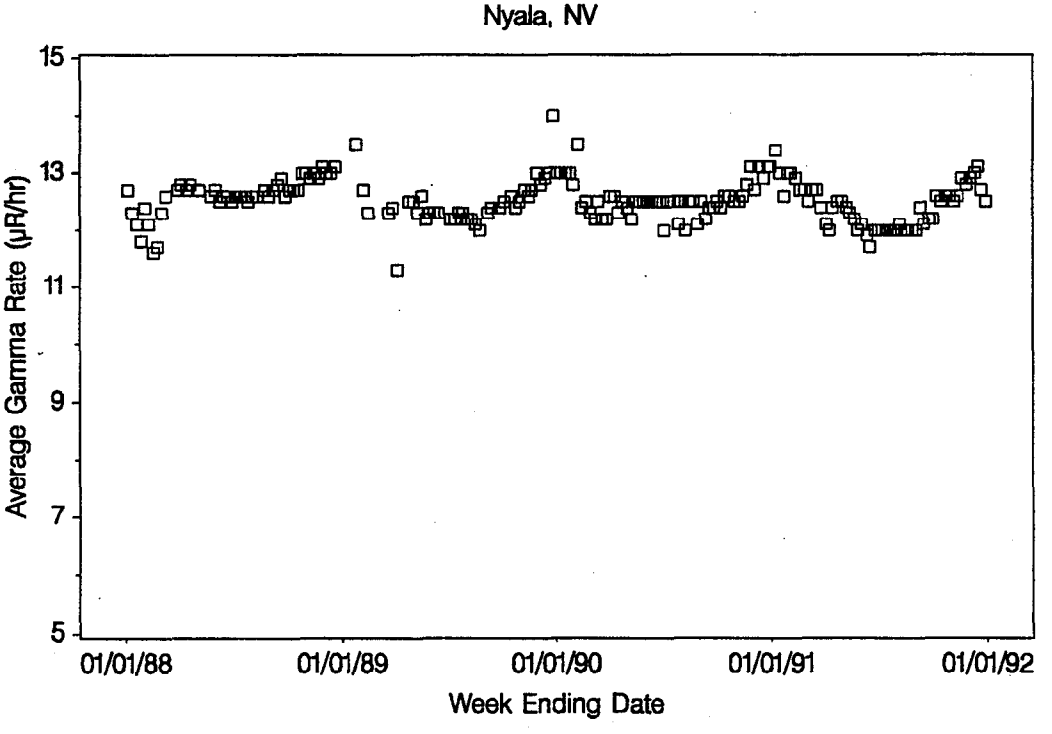
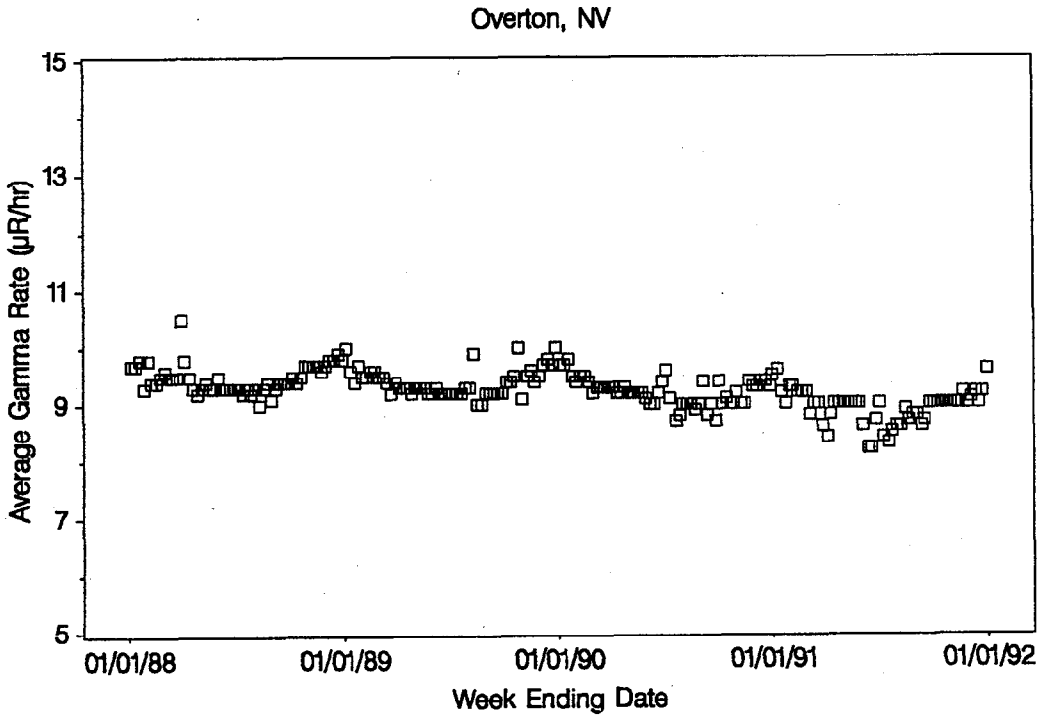
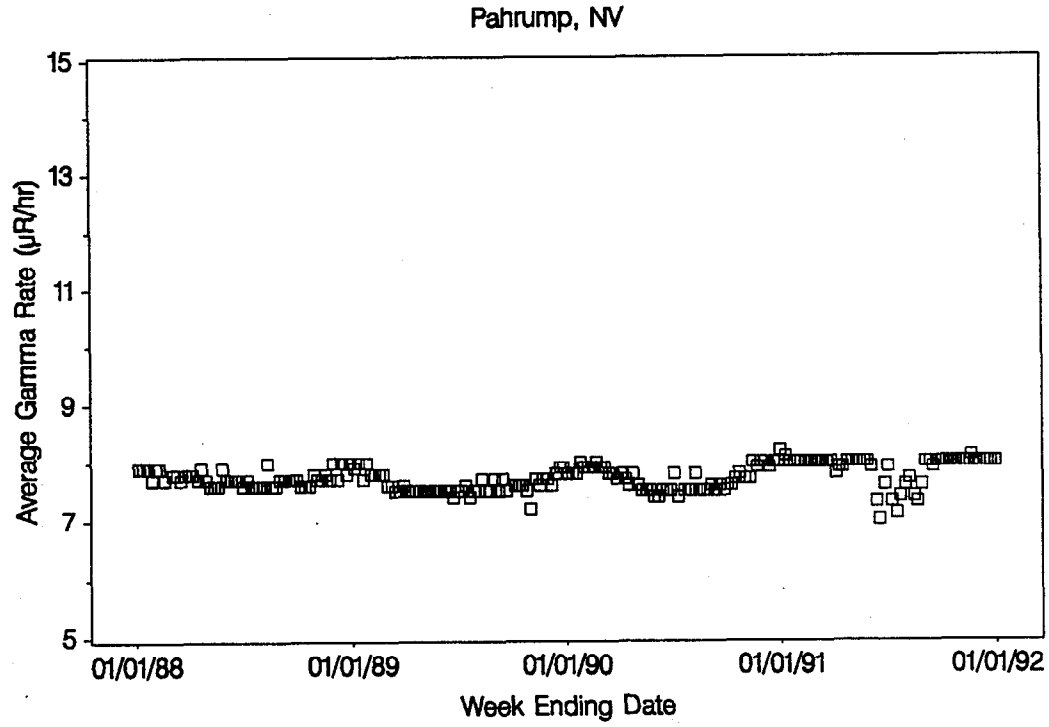


Figure A-1. Continued.





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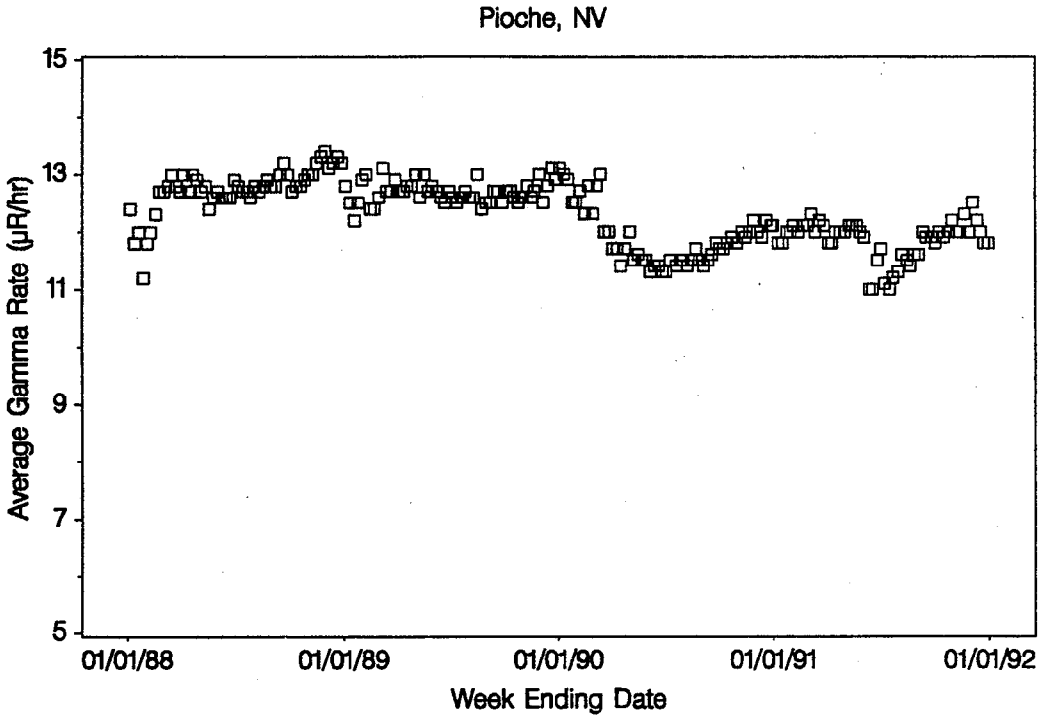

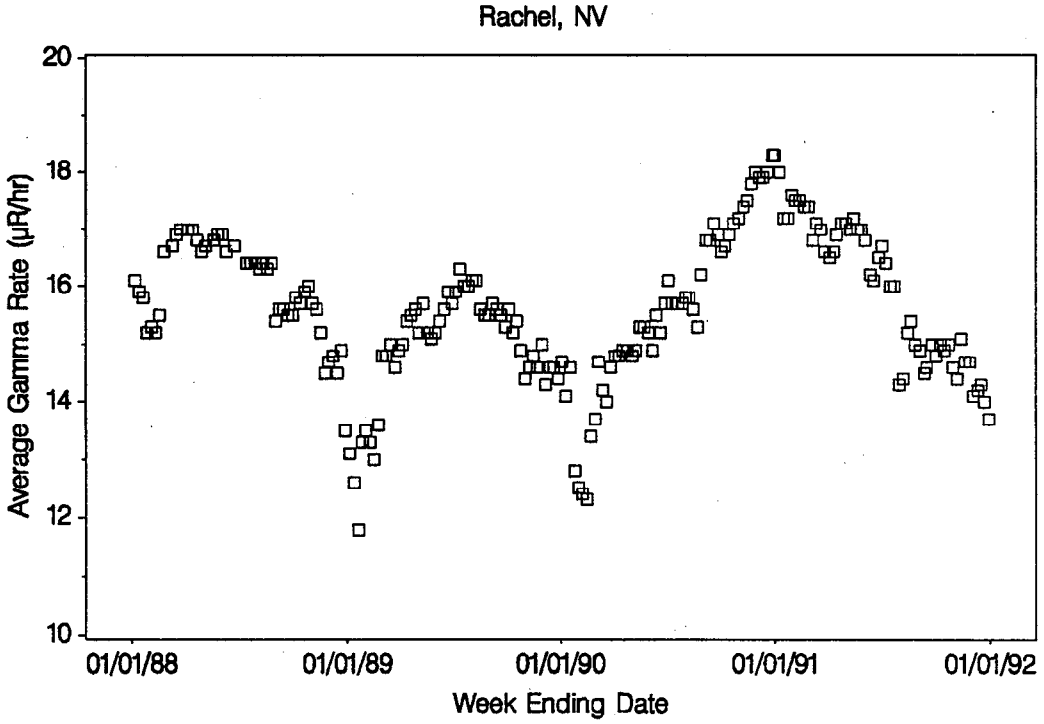

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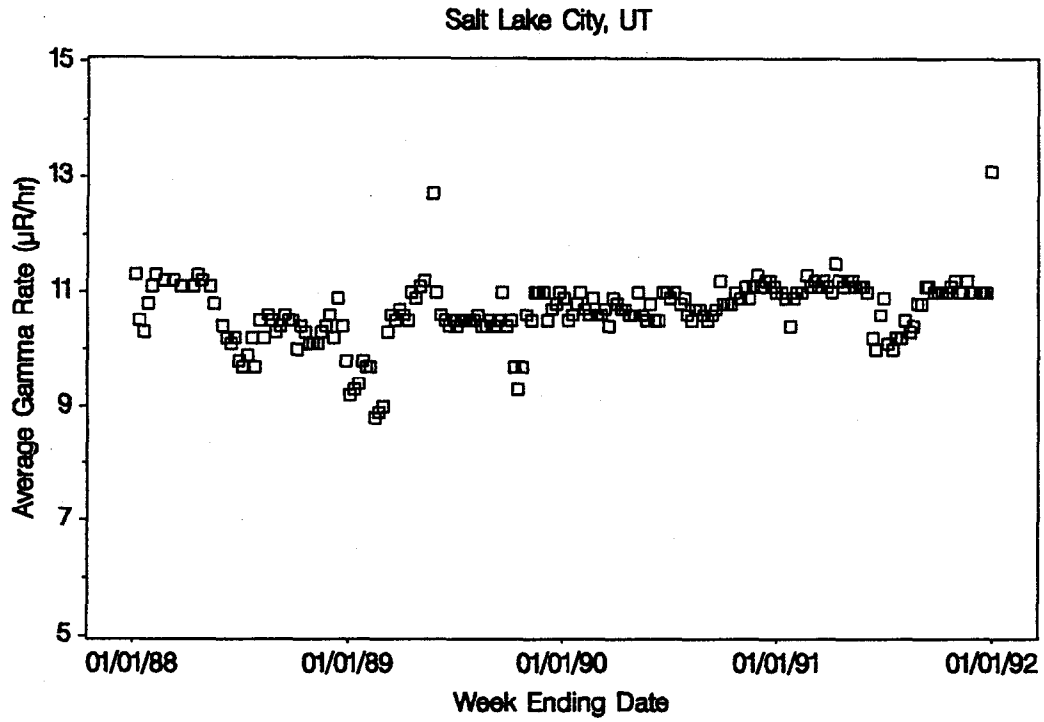


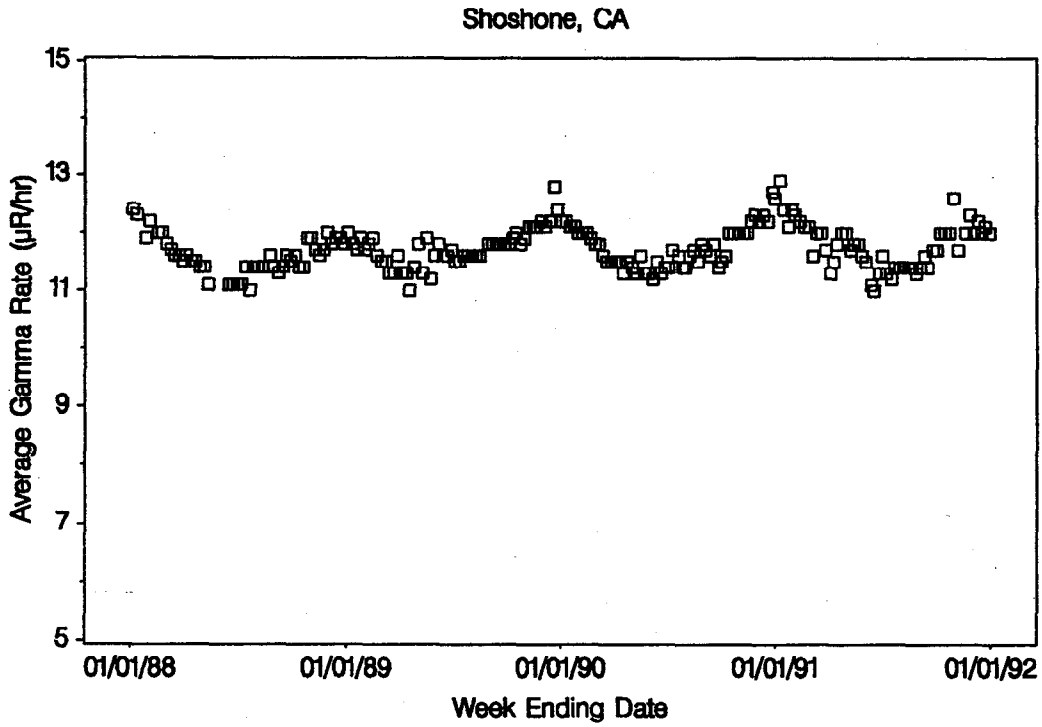
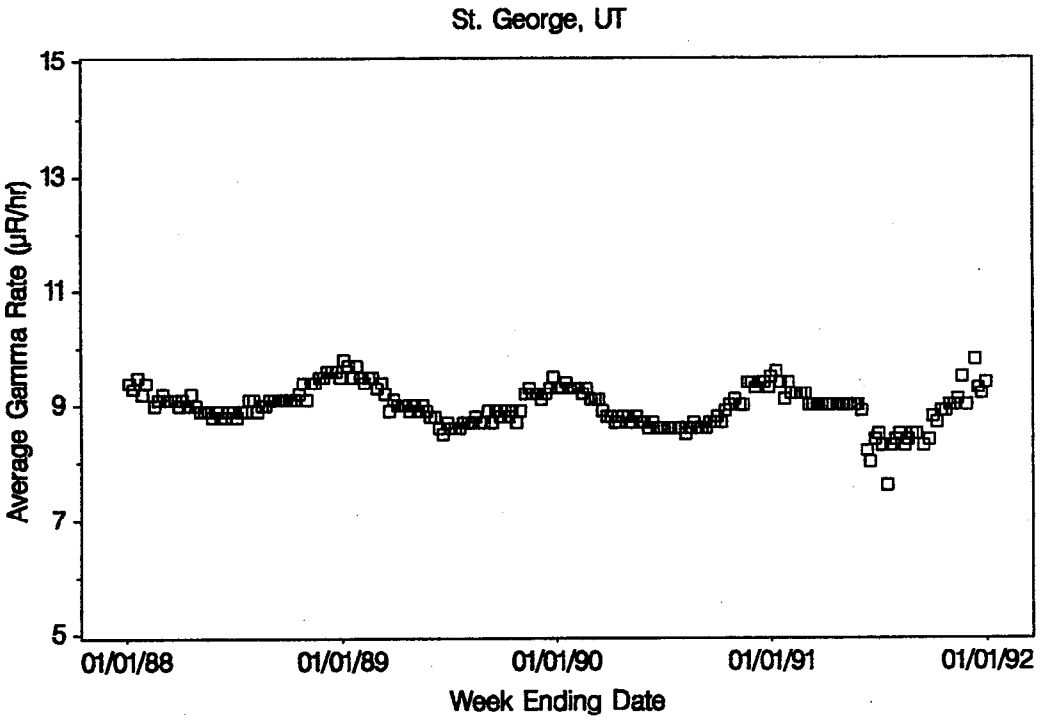


Figure A-1. Continued.



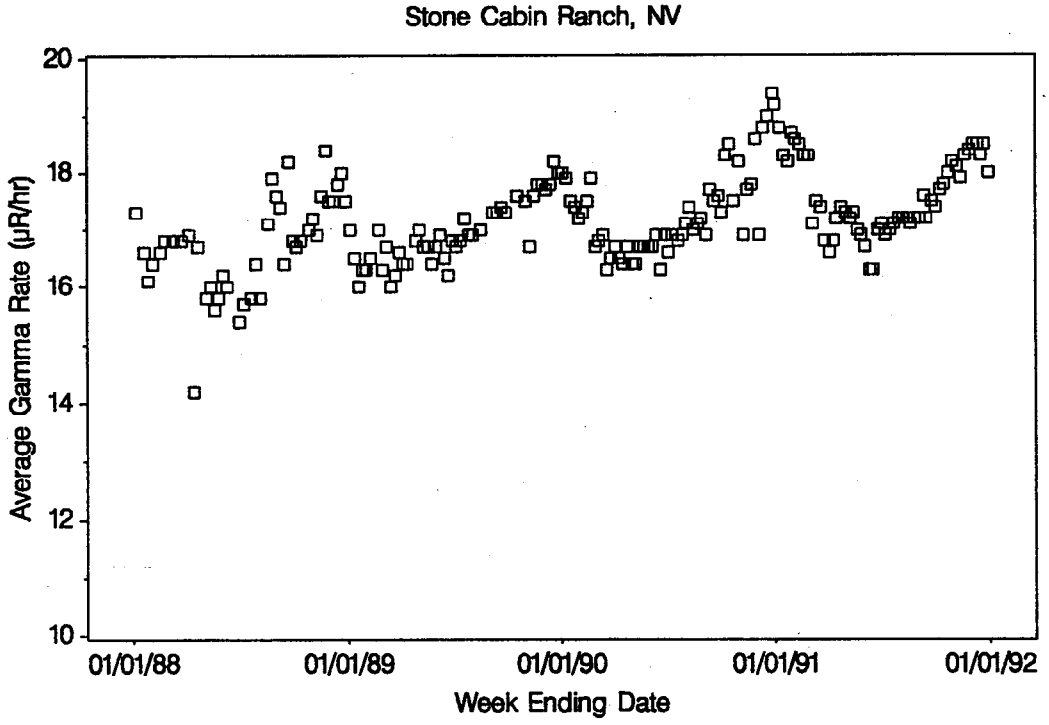
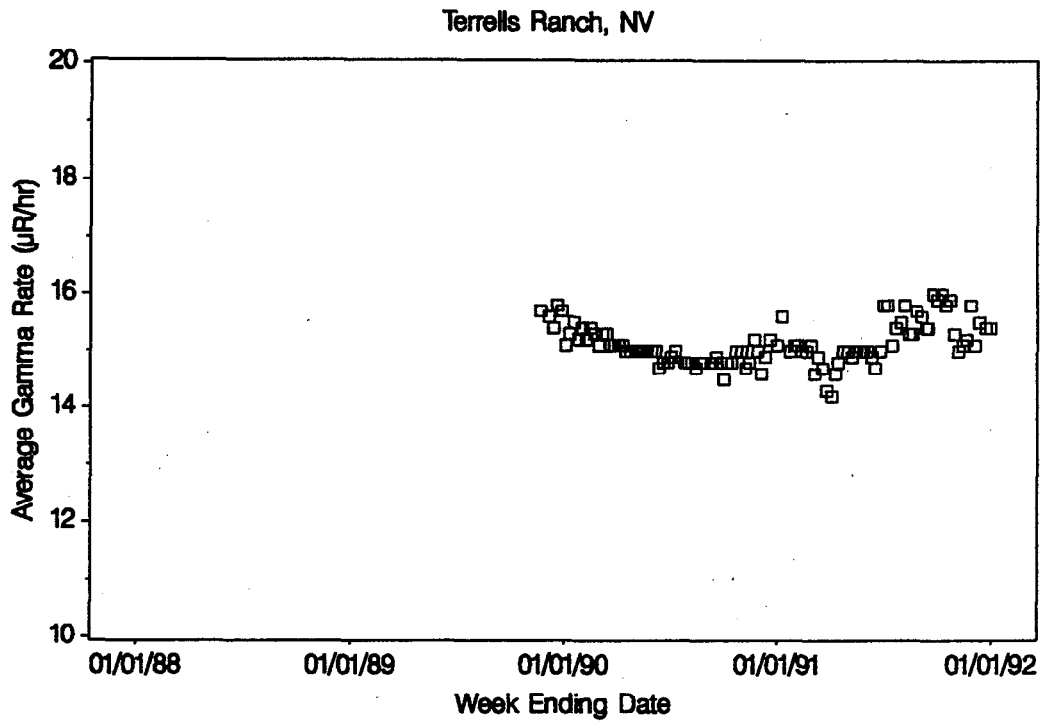


Figure A-1. Continued.



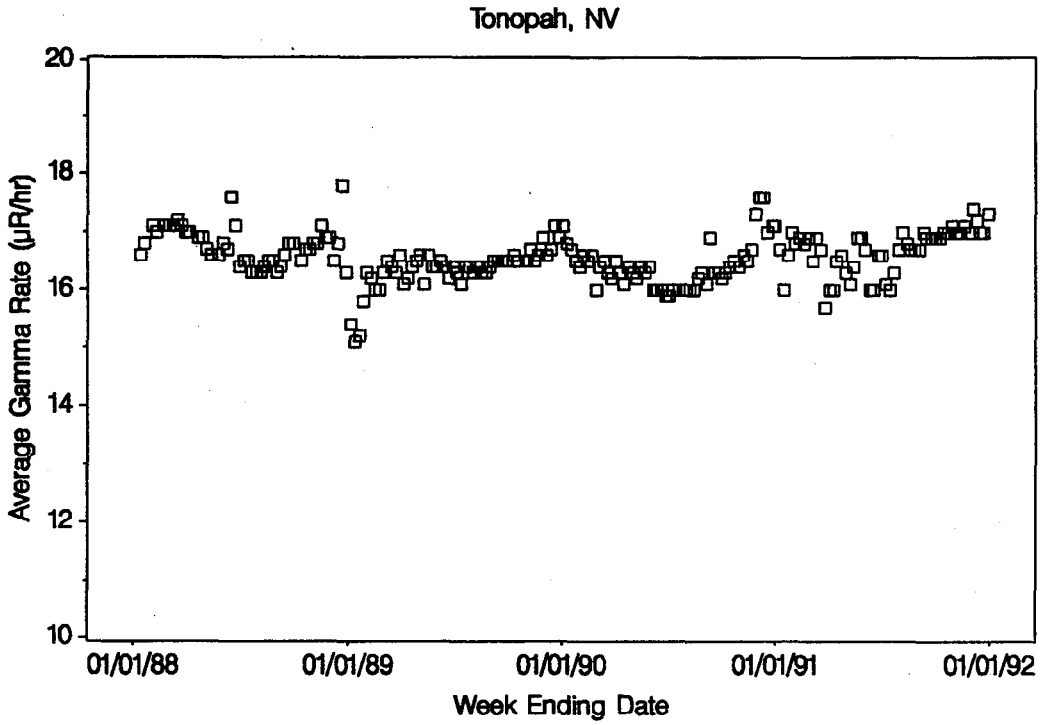


Figure A-1. Continued.

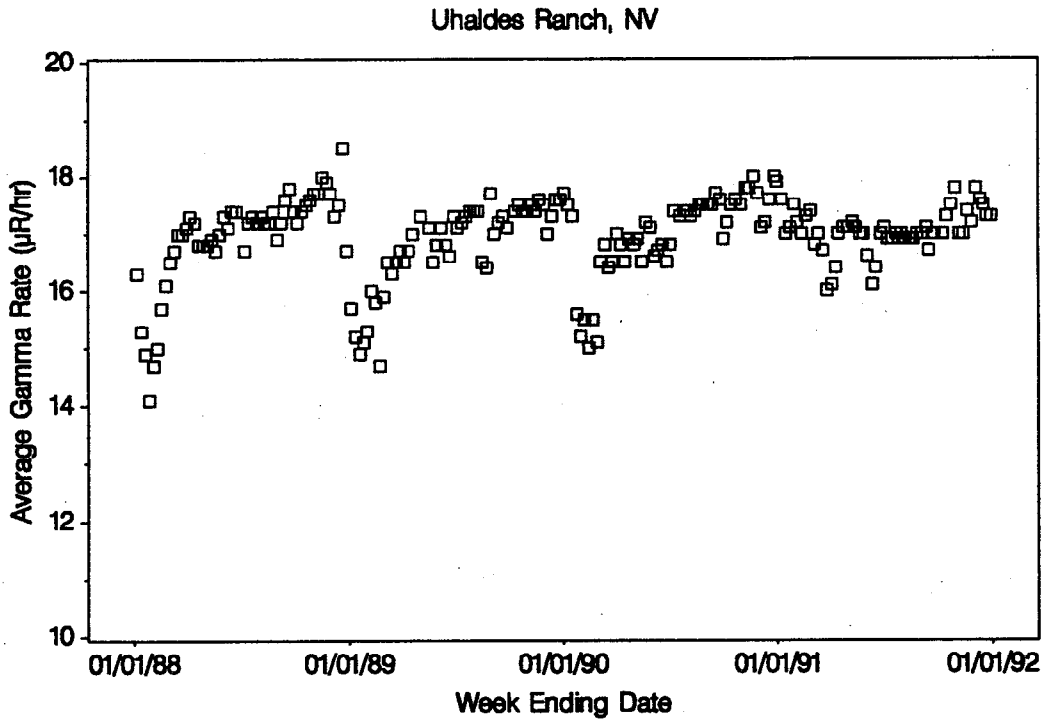


Figure A-1. Continued.

Appendix B

Atmospheric Monitoring Tables And Figures

Table B-1. Gross Beta Results for the Standby Air Surveillance Network, 1991

Sampling Location	Number of days Sampled[b]	Gross Beta Concentration x 10^{-12} µCi/mL[a]			
		Maximum	Minimum	Mean	Std. Dev.
Globe, AZ	30	0.025	0.013	0.017	0.006
Kingman, AZ	28	0.033	0.006	0.019	0.011
Tuscon, AZ	29	0.029	0.022	0.026	0.004
Winslow, AZ	28	0.039	0.009	0.024	0.013
Yuma, AZ	37	0.028	0.006	0.016	0.008
Little Rock, AR	33	0.018	0.008	0.013	0.004
Alturas, CA	21	0.018	0.005	0.010	0.007
Baker, CA	31	0.048	0.019	0.031	0.013
Bishop, CA	36	0.045	0.014	0.013	0.013
Chico, CA	27	0.018	0.010	0.014	0.004
Indio, CA	21	0.039	0.020	0.027	0.010
Lone Pine, CA	8	0.011	0.011	0.011	0.000
Needles, CA	21	0.011	0.006	0.008	0.002
Ridgecrest, CA	27	0.041	0.005	0.024	0.015
Santa Rosa, CA	28	0.017	0.005	0.009	0.006
Cortez, CO	35	0.025	0.017	0.022	0.004
Denver, CO	27	0.037	0.015	0.025	0.010
Grand Junction, CO	34	0.088	0.012	0.033	0.037
Mountain Home, ID	27	0.031	0.003	0.014	0.013
Nampa, ID	28	0.010	0.000	0.007	0.005
Pocatello, ID	21	0.012	0.009	0.010	0.001
Fort Dodge, IA	28	0.034	0.016	0.023	0.008
Iowa City, IA	21	0.031	0.014	0.024	0.009
Dodge City, KS	28	0.022	0.011	0.016	0.006
Monroe, LA	28	0.024	0.018	0.021	0.003
Minneapolis, MN	20	0.026	0.017	0.022	0.004
Clayton, MO	29	0.021	0.008	0.016	0.006
Joplin, MO	28	0.018	0.008	0.014	0.005
St. Joseph, MO	28	0.020	0.016	0.018	0.002
Great Falls, MT	35	0.019	0.007	0.013	0.005
Kalispell, MT	28	0.029	0.009	0.017	0.009
Miles City, MT	21	0.029	0.015	0.020	0.008
North Platte, NE	14	0.024	0.021	0.022	0.002
Battle Mountain, NV	26	0.050	0.012	0.027	0.017
Blue Jay, NV	29	0.033	0.015	0.023	0.008
Clark Station, NV	29	0.034	0.003	0.018	0.013
Angle Worm Ranch, NV	29	0.036	0.014	0.024	0.010
Currie Maint. Station, NV	30	0.028	0.006	0.018	0.011
Duckwater, NV	29	0.024	0.010	0.019	0.007
Elko, NV	29	0.029	0.008	0.018	0.009

Continued

Table B-1. Continued

Sampling Location	Number of days Sampled[b]	Gross Beta Concentration x 10^{-12} µCi/mL[a] Maximum	Minimum	Mean	Std. Dev.
Eureka, NV	20	0.016	0.001	0.007	0.009
Fallon, NV	35	0.068	0.011	0.028	0.023
Geyser Ranch, NV	26	0.017	0.010	0.014	0.003
Lovelock, NV	29	0.060	0.001	0.021	0.027
Lund, NV	21	0.018	0.007	0.013	0.006
Mesquite, NV	20	0.010	0.006	0.008	0.002
Reno, NV	28	0.043	0.004	0.021	0.017
Round Mountain, NV	29	0.019	0.012	0.016	0.003
Uhalde Ranch, NV	56	0.040	0.007	0.016	0.010
Wells, NV	23	0.038	0.010	0.020	0.015
Winnemucca, NV	29	0.050	0.012	0.025	0.017
Albuquerque, NM	35	0.025	0.010	0.016	0.006
Carlsbad, NM	27	0.012	0.004	0.008	0.003
Shiprock, NM	36	0.039	0.006	0.019	0.012
Bismarck, ND	28	0.024	0.015	0.019	0.004
Fargo, ND	27	0.026	0.013	0.020	0.006
Williston, ND	21	0.029	0.023	0.026	0.003
Muskogee, OK	21	0.019	0.014	0.016	0.003
Burns, OR	21	0.011	0.009	0.010	0.001
Medford, OR	20	0.035	0.008	0.019	0.014
Rapid City, SD	21	0.012	0.010	0.011	0.001
Amarillo, TX	37	0.022	0.013	0.018	0.004
Austin, TX	29	0.027	0.011	0.019	0.008
Midland, TX	28	0.010	0.003	0.006	0.003
Tyler, TX	31	0.022	0.013	0.017	0.004
Bryce Canyon, UT	46	0.016	0.000	0.009	0.007
Enterprise, UT	35	0.029	0.015	0.019	0.006
Garrison, UT	28	0.040	0.014	0.022	0.012
Logan, UT	29	0.017	0.007	0.013	0.005
Parowan, UT	21	0.018	0.009	0.014	0.005
Vernal, UT	35	0.050	0.011	0.021	0.016
Wendover, UT	28	0.029	0.006	0.018	0.011
Seattle, WA	37	0.007	0.003	0.005	0.017
Spokane, WA	31	0.036	0.004	0.016	0.014
Rock Springs, WY	41	0.021	0.012	0.016	0.003
Worland, WY	29	0.018	0.009	0.014	0.004

[a] 10^{-12} µCi/mL = pCi/m^3; multiply µCi/mL result by 0.037 to obtain Bq/m^3.
[b] Number of days sampled is determined by filter change dates.

Table B-2. Plutonium Results for the Air and Standby Air Surveillance Networks, 1991

Composite Sampling Location	Collection Date[b]	Concentration ± 1s (MDC)[a] ^{238}Pu x 10^{-18} µCi/mL	Concentration ± 1s (MDC)[a] $^{239+240}Pu$ x 10^{-18} µCi/mL
Arizona			
(Winslow & Tucson)	02/05/91	-23 ± 14 (62)	0 ± 11 (36)
	05/06/91	-35 ± 20 (95)	-12 ± 20 (77)
	08/30/91	-18 ± 13 (61)	-9.2 ± 9.2 (43)
	10/18/91	0 ± 3.7 (12)	7.8 ± 5.8 (12)
California			
(Bishop & Ridgecrest)	02/13/91	-12 ± 15 (55)	12 ± 12 (28)
	05/15/91	0 ± 8.2 (27)	0 ± 8.2 (27)
	09/11/91	-7 ± 5 (23)	11 ± 7.9 (16)
	12/26/91	6.6 ± 6.6 (18)	0 ± 3.1 (10)
Colorado			
(Denver & Cortez)	01/25/91	-11 ± 11 (50)	11 ± 19 (50)
	05/24/91	14 ± 11 (22)	-9.6 ± 9.6 (39)
	09/16/91	7.3 ± 15 (48)	0 ± 5.2 (17)
	10/24/91	-11 ± 11 (43)	3.8 ± 8.5 (25)
Idaho			
(Nampa & Mountain Home)	01/27/91	-9.4 ± 9.4 (44)	-9.4 ± 9.4 (44)
	04/24/91	-5.1 ± 8.8 (33)	-5.1 ± 5.1 (24)
	07/22/91	14 ± 17 (47)	7.1 ± 12 (33)
	10/20/91	0 ± 8.6 (28)	0 ± 6.1 (20)
Missouri			
(Clayton & Joplin)	01/30/91	7.1 ± 19 (57)	14 ± 14 (33)
	05/31/91	-4.5 ± 10 (36)	9 ± 11 (30)
	09/16/91	-6.5 ± 7.9 (30)	-3.2 ± 3.2 (15)
	10/31/91	4.4 ± 7.6 (20)	13 ± 9.8 (20)
Montana			
(Great Falls & Miles City)	01/31/91	-17 ± 21 (79)	-8.4 ± 8.4 (39)
	05/24/91	5.4 ± 9.3 (25)	-5.4 ± 5.3 (25)
	09/06/91	0 ± 11 (35)	4.3 ± 7.5 (20)
	10/31/91	-6.5 ± 4.6 (21)	6.5 ± 6.5 (15)
Alamo, Nevada	01/28/91	1.5 ± 3.5 (10)	1.5 ± 2.7 (7.2)
	02/25/91	-1.5 ± 2.1 (7.7)	2.2 ± 2 (4.9)
	03/25/91	-5.2 ± 2.6 (12)	0 ± 1.8 (6.1)
	04/29/91	-0.8 ± 0.8 (3.9)	-0.8 ± 1.4 (5.5)
	05/27/91	-0.8 ± 0.8 (3.9)	0.8 ± 1.4 (3.9)
	06/24/91	0 ± 1.8 (5.8)	-1.3 ± 1.3 (5.8)
	07/29/91	0 ± 2.3 (7.4)	1.6 ± 2.8 (7.4)

Continued

Table B-2. Continued

Composite Sampling Location	Collection Date[b]	Concentration ± 1s (MDC)[a] ^{238}Pu x 10^{-18} µCi/mL	Concentration ± 1s (MDC)[a] $^{239+240}Pu$ x 10^{-18} µCi/mL
	08/26/91	-1.5 ± 2.6 (9.9)	0 ± 2.1 (7.0)
	09/30/91	-2.3 ± 1.6 (7.4)	1.1 ± 1.9 (5.2)
	10/28/91	0 ± 5.2 (1.7)	0 ± 3.0 (9.9)
	11/25/91	0 ± 9.0 (29)	0 ± 5.2 (17)
	12/30/91	-1.7 ± 3.0 (11)	0 ± 2.4 (8)
Amargosa Valley, Nevada	01/27/91	-3.1 ± 3.1 (14)	0 ± 4.4 (14)
	02/24/91	2.6 ± 5.8 (17)	0 ± 3.7 (12)
	03/31/91	-25 ± 19 (78)	0 ± 12 (39)
	04/28/91	3.9 ± 4.7 (13)	1.9 ± 3.4 (9)
	05/26/91	-3.4 ± 7.6 (27)	3.4 ± 5.9 (22)
	05/28/91(Hi Vol)	-0.1 ± 0.1 (0.4)	*1.1 ± 0.3 (0.4)
	06/30/91	0 ± 3.3 (11)	7.1 ± 5.3 (11)
	07/29/91	-3.9 ± 6.7 (26)	0 ± 5.5 (18)
	08/25/91	-3.0 ± 5.3 (20)	-3.0 ± 3.1 (14)
	09/29/91	-1.8 ± 3.2 (12)	-1.8 ± 1.8 (8.5)
	10/27/91	SAMPLE LOST	
	11/24/91	9.9 ± 6.1 (12)	0 ± 3.5 (12)
	12/30/91	-1.2 ± 2.8 (10)	-1.2 ± 1.2 (5.8)
Las Vegas, Nevada	01/28/91	0 ± 9.2 (30)	3.3 ± 5.7 (15)
	02/25/91	*17 ± 8.1 (16)	0 ± 3.4 (11)
	03/25/91	4.2 ± 4.2 (9.8)	0 ± 3 (9.8)
	04/29/91	-1.8 ± 4.1 (15)	1.8 ± 4.1 (12)
	05/27/91	-2.5 ± 2.5 (12)	-2.5 ± 2.5 (12)
	06/24/91	10 ± 6.2 (12)	-2.5 ± 5.6 (20)
	07/29/91	-4.6 ± 5.6 (20)	4.6 ± 3.5 (7.2)
	08/26/91	0 ± 14 (46)	-4.9 ± 5.0 (25)
	09/30/91	-1.9 ± 1.9 (7.6)	-0.9 ± 0.9 (4.4)
	10/28/91	-2.3 ± 2.3 (11)	0 ± 3.3 (11)
	11/25/91	-2.3 ± 3.9 (15)	-2.3 ± 2.3 (11)
	12/30/91	-1.6 ± 1.6 (7.4)	0 ± 2.2 (7.4)
Rachel, Nevada	01/28/91	-2.6 ± 2.6 (12)	0 ± 3.6 (12)
	02/25/91	7.8 ± 6.2 (16)	-2 ± 2 (9.1)
	03/25/91	-3 ± 2.3 (9.4)	1 ± 1.7 (4.7)
	04/29/91	4.3 ± 3.2 (6.6)	-4.3 ± 2.5 (11)
	05/28/91	0 ± 4.1 (13)	4.1 ± 4.1 (9.5)
	06/24/91	-3 ± 6.8 (25)	0 ± 6.1 (20)
	07/08/91(Hi Vol)	0.3 ± 0.3 (0.6)	*7.4 ± 1.1 (0.6)
	07/29/91	-2.1 ± 5.7 (20)	-2.1 ± 2.1 (9.9)
	08/26/91	-11 ± 6.5 (30)	0 ± 5.3 (17)
	09/30/91	1.9 ± 3.3 (8.9)	0 ± 2.7 (8.9)

Continued

Table B-2. Continued

Composite Sampling Location	Collection Date[b]	Concentration ± 1s (MDC)[a] ^{238}Pu x 10^{-18} µCi/mL	$^{239+240}Pu$ x 10^{-18} µCi/mL
	10/28/91	0 ± 3.9 (13)	-2.0 ± 2.0 (9.2)
	11/24/91	1.7 ± 2.9 (7.7)	-1.7 ± 1.7 (7.7)
	12/30/91	-3.8 ± 4.6 (17)	2.5 ± 3.1 (8.4)
New Mexico (Albuquerque & Carlsbad)	03/22/91	-8.4 ± 6.3 (26)	0 ± 3.9 (13)
	06/28/91	35 ± 22 (41)	-27 ± 15 (71)
	09/03/91	-3.2 ± 7.2 (26)	-3.2 ± 3.2 (15)
	10/30/91	-4.2 ± 4.2 (19)	0 ± 5.9 (19)
North Dakota (Bismarck & Fargo)	03/12/91	5.9 ± 13 (39)	12 ± 12 (28)
	06/27/91	0 ± 7.7 (26)	7.8 ± 7.8 (18)
	09/22/91	-3.5 ± 3.5 (16)	-3.5 ± 3.5 (16)
	10/31/91	-15 ± 10 (40)	3.0 ± 6.8 (20)
Oregon (Burns & Medford)	02/11/91	-12 ± 8.4 (39)	0 ± 8.4 (28)
	09/16/91	-3.8 ± 2.7 (12)	0 ± 2.7 (8.8)
	10/16/91	33 ± 25 (52)	11 ± 19 (52)
Texas (Austin & Amarillo)	03/15/91	-3.2 ± 5.5 (21)	-3.2 ± 3.2 (15)
	06/28/91	10 ± 17 (47)	0 ± 14 (47)
	09/07/91	-6.0 ± 4.3 (20)	-3.0 ± 3 (14)
	10/18/91	-14 ± 10 (40)	-7.0 ± 5.0 (23)
Utah (Logan & Vernal)	03/11/91	-15 ± 12 (48)	-5.1 ± 5.2 (24)
	06/27/91	*21 ± 11 (19)	-8.3 ± 8.3 (34)
	09/09/91	-22 ± 26 (96)	0 ± 10 (34)
	10/24/91	-14 ± 9.8 (45)	-6.9 ± 6.9 (32)
Salt Lake City, Utah	01/28/91	3.7 ± 5.2 (15)	0 ± 2.6 (8.6)
	02/25/91	-1.1 ± 2.8 (9.9)	0 ± 1.5 (5)
	03/25/91	-2 ± 2 (9.1)	0 ± 2.8 (9.1)
	04/29/91	0 ± 2.5 (8.1)	0 ± 2.5 (8.1)
	05/31/91	2.9 ± 5 (13)	-5.7 ± 5.8 (23)
	06/28/91	0 ± 4.1 (14)	2.1 ± 3.6 (9.6)
	07/26/91	-13 ± 8.4 (33)	2.5 ± 4.4 (12)
	08/30/91	8.4 ± 7.5 (18)	0 ± 4.0 (13)
	09/27/91	-13 ± 6.6 (31)	3.3 ± 5.7 (15)
	10/25/91	-5.2 ± 5.2 (20)	-1.7 ± 3.0 (11)

Continued

Table B-2. Continued

Composite Sampling Location	Collection Date[b]	Concentration ± 1s (MDC)[a] ^{238}Pu x 10^{-18} µCi/mL	Concentration ± 1s (MDC)[a] $^{239+240}Pu$ x 10^{-18} µCi/mL
	11/29/91	-6.6 ± 4.7 (22)	0 ± 4.7 (15)
	12/27/91	-2.2 ± 2.2 (10)	-2.2 ± 2.2 (10)
Washington (Seattle & Spokane)	03/22/91	-5.5 ± 9.5 (36)	-5.5 ± 5.5 (26)
	06/29/91	70 ± 44 (82)	0 ± 41 (142)
	08/26/91	0 ± 6.8 (22)	3.4 ± 5.9 (16)
	11/15/91	0 ± 6.7 (22)	0 ± 6.7 (22)
Wyoming (Worland & Rock Springs)	03/30/91	8.7 ± 20 (57)	8.7 ± 15 (41)
	05/13/91	8.1 ± 18 (53)	8.1 ± 14 (38)
	09/14/91	-5.0 ± 6.1 (23)	0 ± 3.5 (12)
	10/31/91	-5.4 ± 9.3 (35)	-5.4 ± 5.4 (25)

[a] MDC = minimum detectable concentration.
[b] Collection date of the last (most recent) sample included in the composite.
* Concentration is greater than the MDC.

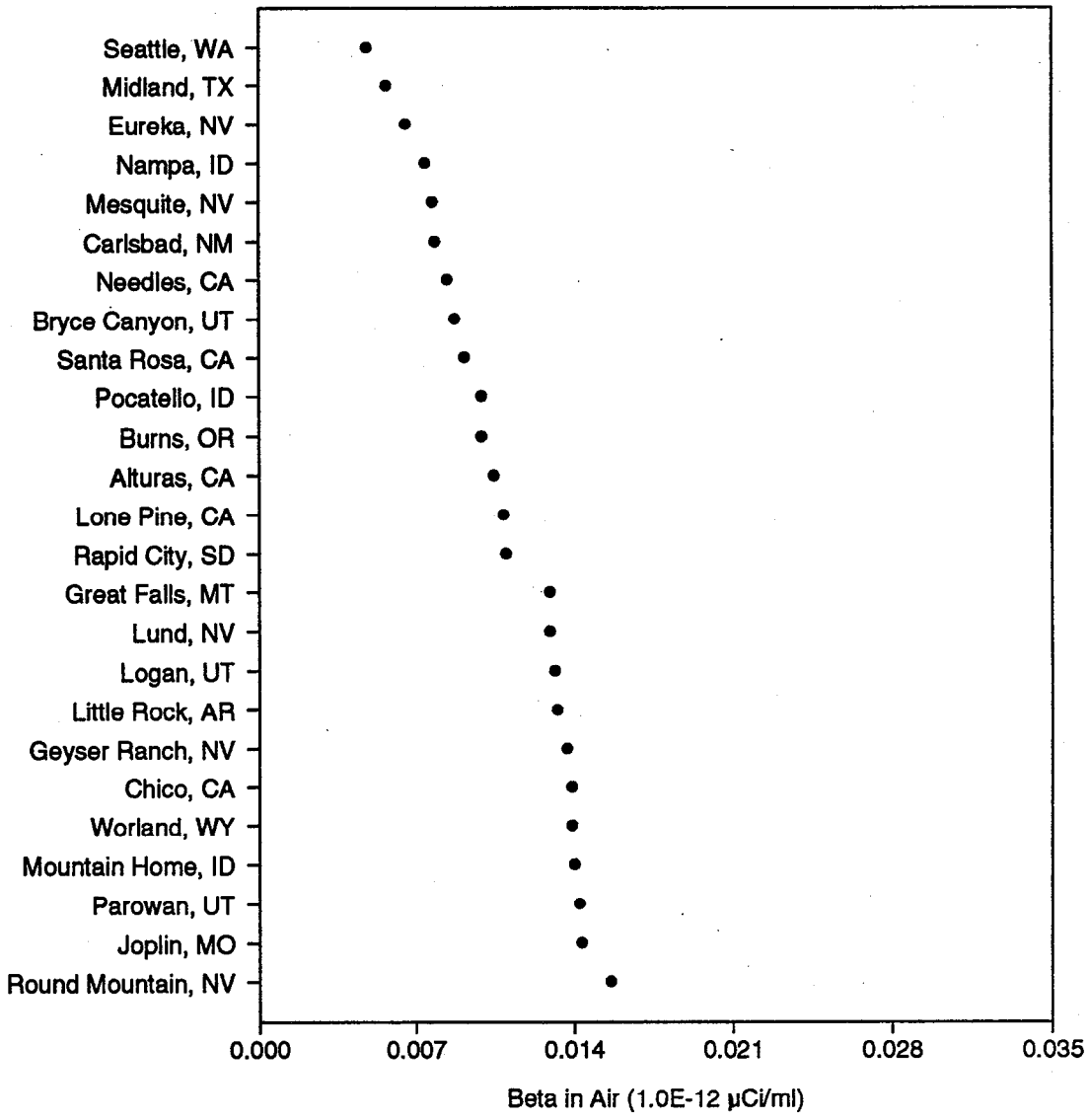


Figure B-1. Distribution of gross beta values from standby air surveillance network stations - 1991.

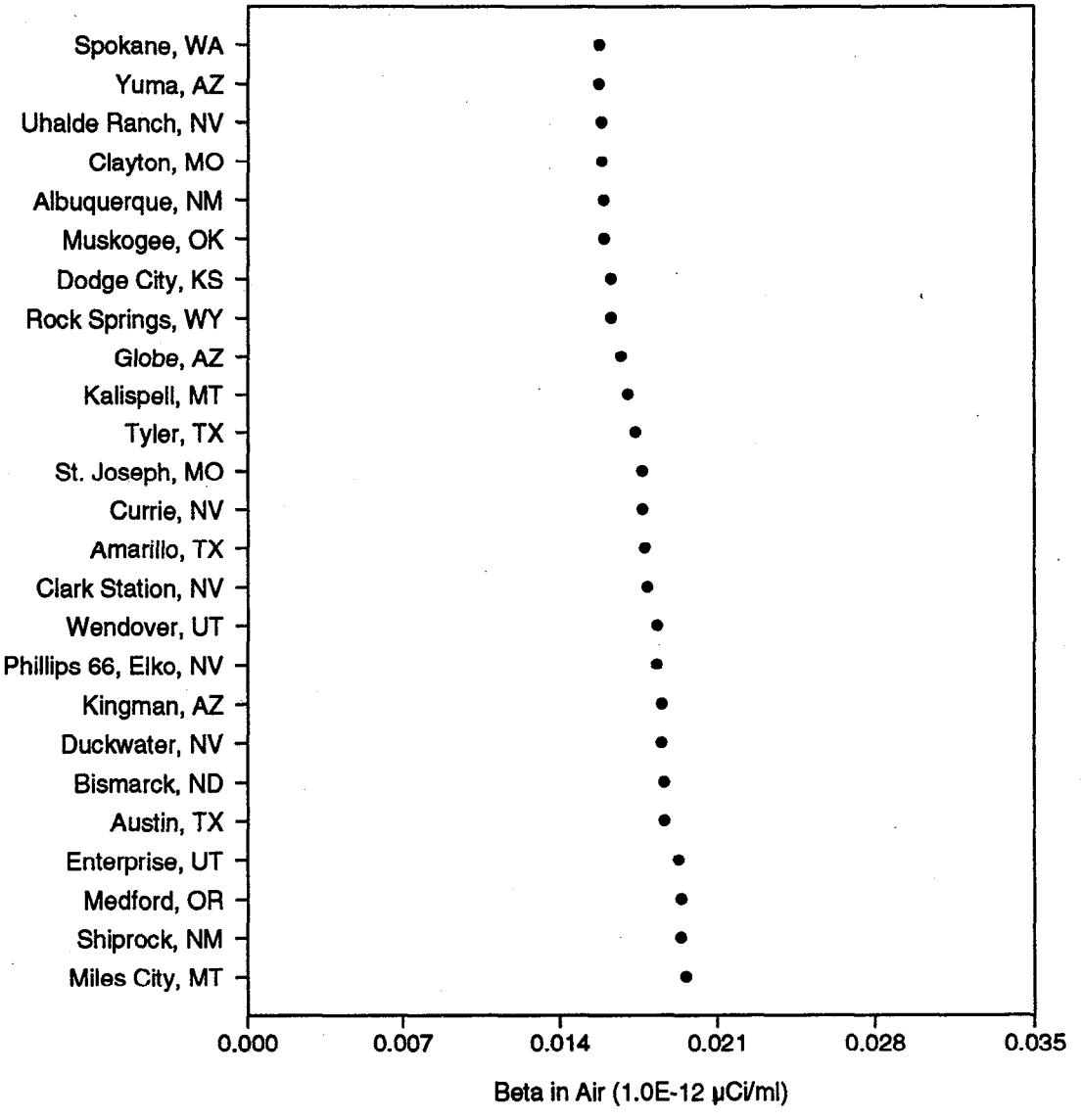


Figure B-1. Continued.

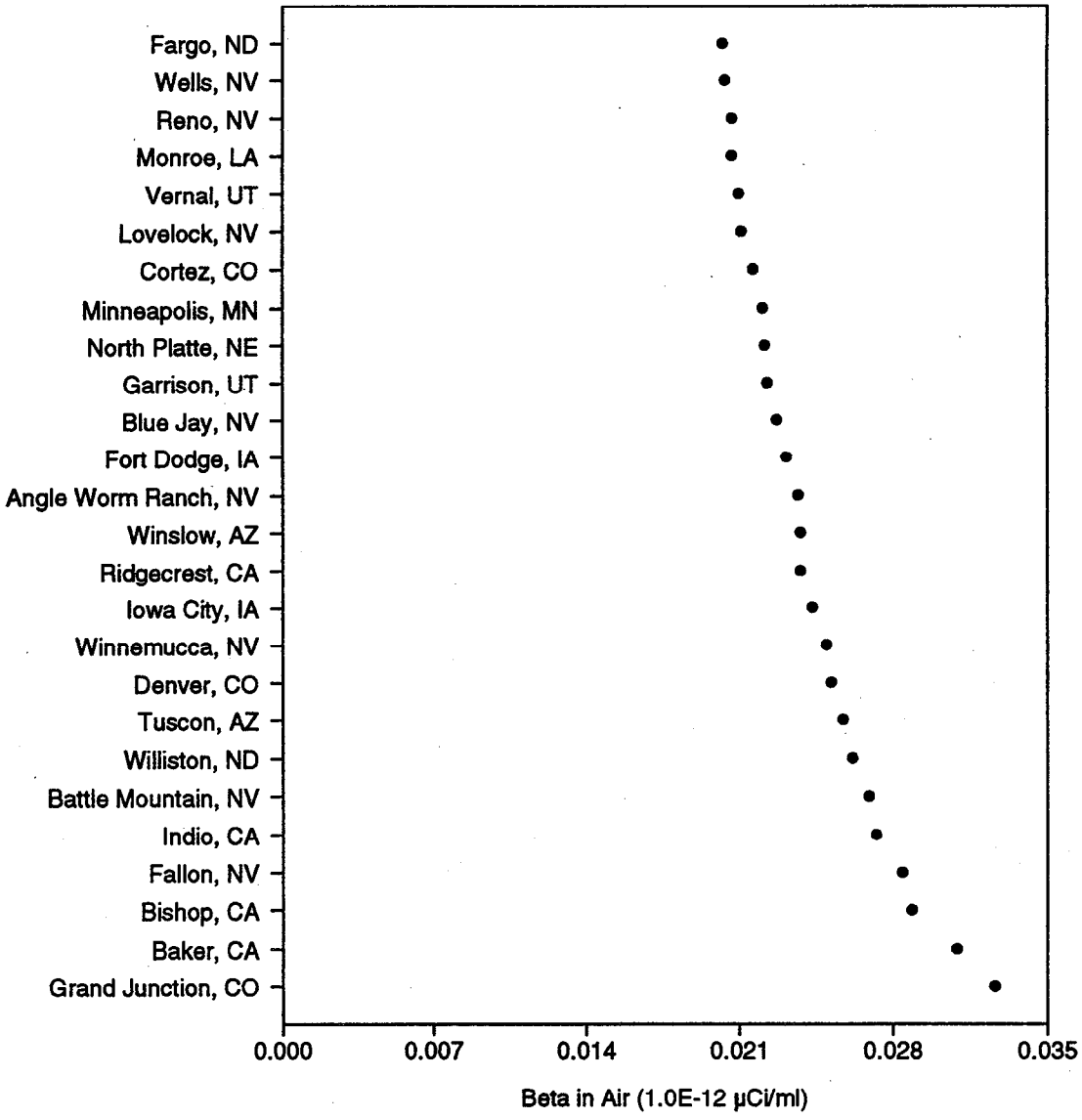


Figure B-1. Continued.

Appendix C

Note: The mid-west region referred to in Figures C-3 and C-6 includes Louisiana, Texas, Arkansas, Illinois, Oklahoma, Missouri, Kansas, Iowa, Nebraska, Minnesota, and South and North Dakota. The mountain region referred to in Figures C-4 and C-7 includes New Mexico, Arizona, Colorado, Utah, Wyoming, Idaho, and Montana. The western region referred to in Figures C-5 and C-8 includes California, Nevada, Washington and Oregon.

Table C-1. Milk Surveillance Network Results, 1991

Sampling Location	Collection Date	Concentration ± 1s (MDC)[a] ^{3}H (10^{-9}µCi/mL)[b]	^{89}Sr (10^{-9}µCi/mL)[b]	^{90}Sr (10^{-9}µCi/mL)[b]
Benton, CA	01/03	188 ± 116 (379)	N/A	2.4 ± 0.94 (2.6)
Irene Brown Ranch	04/24	44 ± 90 (297)	N/A	0.59 ± 0.35 (1.4)
	07/10	180 ± 95 (308)	0.050 ± 0.85 (1.2)	0.16 ± 0.34 (1.4)
	10/24	88 ± 111 (363)	N/A	0.25 ± 0.33 (1.4)
Hinkley, CA				
Desert View Dairy	01/03	170 ± 114 (372)	N/A	0.76 ± 0.49 (1.6)
	04/24	86 ± 92 (301)	N/A	0.39 ± 0.33 (1.4)
	07/10	0 ± 93 (306)	N/A	-0.62 ± 0.32 (1.4)
	10/23	178 ± 110 (358)	N/A	0.11 ± 0.32 (1.4)
Inyokern, CA	01/03	81 ± 113 (370)	N/A	0.32 ± 0.42 (1.5)
Cedarsage Farm	04/24	197 ± 94 (304)	N/A	0.19 ± 0.33 (1.4)
	07/10	207 ± 94 (303)	N/A	0.081 ± 0.34 (1.4)
	10/23	173 ± 114 (372)	N/A	-0.080 ± 0.32 (1.4)
Alamo, NV	02/06	183 ± 116 (379)	N/A	-0.57 ± 0.35 (1.4)
Cortney Dahl Ranch	08/06	152 ± 119 (389)	N/A	-0.14 ± 0.52 (1.9)
	11/01	352 ± 116 (372)	N/A	0.29 ± 0.34 (1.5)
Amargosa Valley, NV	08/05	190 ± 117 (383)	N/A	0.067 ± 0.39 (1.6)
Bar-B-Cue Ranch	11/15	213 ± 111 (360)	-0.78 ± 0.95 (1.5)	0.37 ± 0.39 (1.6)
Amargosa Valley, NV	03/06	236 ± 113 (367)	0.15 ± 2.50 (3.3)	0.77 ± 0.72 (2.4)
John Deer Ranch	06/13	-40 ± 90 (299)	N/A	0.88 ± 0.42 (1.6)
	09/12	120 ± 111 (364)	N/A	0.26 ± 0.30 (1.3)
Austin, NV	06/05	8.5 ± 90 (298)	N/A	0.61 ± 0.32 (1.3)
Young's Ranch	09/17	113 ± 108 (352)	N/A	0.16 ± 0.32 (1.3)
	12/10	230 ± 84 (270)	0.066 ± 0.60 (0.9)	0.63 ± 0.34 (1.4)
Blue Jay, NV	05/15	153 ± 94 (306)	N/A	0.18 ± 0.34 (1.4)
Blue Jay Springs	06/05	177 ± 93 (300)	N/A	0.58 ± 0.35 (1.4)
Jim Bias Ranch	09/04	-20 ± 111 (367)	N/A	0.64 ± 0.32 (1.3)
Caliente, NV	02/07	217 ± 120 (390)	N/A	0.27 ± 0.36 (1.5)
June Cox Ranch	05/01	100 ± 93 (306)	N/A	-0.77 ± 0.96 (3.2)
	08/07	208 ± 121 (392)	N/A	0.42 ± 0.31 (1.3)
	11/01	*409 ± 115 (368)	N/A	0.22 ± 0.40 (1.6)
Currant, NV	06/05	113 ± 94 (306)	N/A	0.51 ± 0.39 (1.4)
Blue Eagle Ranch	09/18	-31 ± 108 (355)	N/A	0.78 ± 0.31 (1.3)
Currant, NV	06/12	154 ± 87 (282)	0.92 ± 0.86 (1.2)	0.86 ± 0.36 (1.3)
Manzonie Ranch	09/09	103 ± 112 (366)	N/A	1.2 ± 0.36 (1.3)
	12/10	143 ± 83 (270)	N/A	1.1 ± 0.36 (1.3)
Duckwater, NV	11/20	114 ± 109 (355)	0.13 ± 0.84 (1.1)	0.66 ± 0.38 (1.4)
Bradshaw's Ranch				
Dyer, NV	03/13	21 ± 113 (371)	0.66 ± 1.03 (1.4)	0.55 ± 0.38 (1.4)
Ozel Lemon	06/04	219 ± 97 (314)	N/A	0.52 ± 0.31 (1.3)
	09/10	201 ± 110 (356)	N/A	0.19 ± 0.34 (1.4)

Continued

Table C-1. Continued

Sampling Location	Collection Date	Concentration ± 1s (MDC)[a] ^{3}H (10^{-9}µCi/mL)[b]	^{89}Sr (10^{-9}µCi/mL)[b]	^{90}Sr (10^{-9}µCi/mL)[b]
Logandale, NV	02/04	241 ± 112 (363)	N/A	0.072 ± 0.51 (1.8)
Leonard Marshall	05/01	-88 ± 89 (295)	N/A	-0.31 ± 0.42 (1.6)
	08/01	192 ± 92 (299)	N/A	0.091 ± 0.37 (1.5)
	11/01	301 ± 113 (365)	N/A	0.54 ± 0.35 (1.4)
Lund, NV	02/06	205 ± 115 (372)	N/A	0.29 ± 0.43 (1.5)
Ronald Horsley Ranch	05/07	179 ± 94 (306)	N/A	0.047 ± 0.60 (2.2)
	08/06	-6 ± 95 (314)	N/A	0.37 ± 0.33 (1.3)
	11/01	233 ± 112 (363)	N/A	0.65 ± 0.37 (1.5)
Mesquite, NV	01/04	62 ± 115 (376)	N/A	1.2 ± 0.56 (1.9)
Hafen Dairy	04/05	120 ± 115 (377)	-0.054 ± 0.60 (0.98)	0.23 ± 0.32 (1.4)
	07/01	256 ± 94 (302)	-0.035 ± 0.87 (1.3)	0.30 ± 0.32 (1.4)
	10/01	80 ± 114 (374)	N/A	0.66 ± 0.37 (1.4)
Moapa, NV	01/04	323 ± 119 (384)	N/A	1.3 ± 0.99 (3)
Rockview Dairies,Inc	04/05	-37 ± 113 (374)	-0.33 ± 0.77 (1.2)	0.87 ± 0.40 (1.5)
	07/01	-28 ± 92 (303)	0.21 ± 0.89 (1.3)	0.46 ± 0.33 (1.4)
	10/01	153 ± 111 (362)	N/A	0.11 ± 0.34 (1.5)
Nyala, NV	03/05	103 ± 116 (379)	0.85 ± 1.20 (1.6)	0.74 ± 0.41 (1.5)
Sharp's Ranch	06/04	-4.3 ± 91 (301)	N/A	1.1 ± 0.38 (1.4)
	09/10	294 ± 115 (371)	N/A	0.38 ± 0.34 (1.4)
	12/03	199 ± 85 (275)	-0.14 ± 0.68 (0.97)	0.79 ± 0.34 (1.3)
Pahrump, NV	01/02	182 ± 114 (371)	N/A	0.71 ± 0.39 (1.4)
Pahrump Dairy	04/23	70 ± 91 (299)	N/A	0.31 ± 0.41 (1.5)
	07/09	36 ± 89 (293)	N/A	0.44 ± 0.31 (1.4)
	10/21	93 ± 106 (347)	N/A	0.59 ± 0.37 (1.5)
Shoshone, NV	02/06	246 ± 117 (379)	N/A	1.1 ± 0.55 (1.6)
Harbecke Ranch	05/01	77 ± 94 (308)	N/A	1.2 ± 0.51 (1.6)
	08/06	297 ± 95 (305)	N/A	*2.6 ± 0.43 (1.3)
	11/01	*475 ± 112 (358)	N/A	*2.0 ± 0.48 (1.5)
Tonopah, NV	10/24	340 ± 126 (406)	N/A	*2.5 ± 0.43 (1.3)
Karen Harper Ranch	12/10	241 ± 86 (277)	0.62 ± 0.71 (0.85)	*1.6 ± 0.40 (1.3)
Cedar City, UT	01/03	144 ± 117 (381)	N/A	1.0 ± 0.47 (1.7)
Brent Jones Dairy	04/05	97 ± 112 (367)	0.19 ± 0.73 (1.0)	0.72 ± 0.37 (1.4)
	07/01	46 ± 93 (305)	N/A	0.71 ± 0.35 (1.4)
	10/02	165 ± 114 (372)	N/A	0.56 ± 0.32 (1.3)
Ivins, UT	01/03	237 ± 112 (364)	N/A	0.24 ± 0.48 (1.6)
David Hafen Ranch	04/05	344 ± 131 (422)	0.69 ± 0.63 (0.97)	0.20 ± 0.33 (1.4)
	07/01	-40 ± 91 (299)	*2.0 ± 1.0 (1.4)	-0.23 ± 0.36 (1.4)
	10/02	239 ± 113 (366)	N/A	-0.056 ± 0.31 (1.4)

[a] MDC = minimum detectable concentration.
[b] Multiply µCi/mL by 3.7×10^{7} to obtain Bq/L.
N/A = Sample not analyzed.
* = Concentration is greater than the

Table C-2. Standby Milk Surveillance Network Results, 1991

Sampling Location	Collection Date	Concentration ± 1s (MDC)[a] ^{3}H (10^{-9}µCi/mL)[b]	^{89}Sr (10^{-9}µCi/mL)[b]	^{90}Sr (10^{-9}µCi/mL)[b]
Taylor, AZ Sunrise Dairy	07/17	228 ± 114 (369)	0.69 ± 0.81 (1.2)	0.049 ± 0.37 (1.5)
Tucson, AZ Univ Of Arizona	07/25	232 ± 115 (375)	-0.42 ± 0.68 (1.1)	0.33 ± 0.30 (1.3)
Little Rock, AR Borden's	06/04	62 ± 92 (302)	N/A	*2.3 ± 0.42 (1.4)
Russellville, AR Arkansas Tech Univ	06/25	72 ± 91 (299)	N/A	*2.0 ± 0.43 (1.3)
Bakersfield, CA Favorite Foods, Inc	07/15	179 ± 89 (289)	0.21 ± 0.69 (1.2)	-0.21 ± 0.31 (1.4)
Orland, CA Meadow Glen Cheese	08/21	124 ± 115 (377)	N/A	-0.011 ± 0.31 (1.3)
Redding, CA McColl's Dairy Prod	08/12	67 ± 113 (371)	N/A	0.53 ± 0.33 (1.3)
Willows, CA Glenn Milk Producers	08/21	227 ± 113 (367)	N/A	1.1 ± 0.33 (1.3)
Delta, CO Meadow Gold Dairy	08/07	131 ± 119 (389)	N/A	0.089 ± 0.34 (1.4)
Denver, CO Safeway Dairy Plant	05/20	293 ± 96 (307)	N/A	0.22 ± 0.38 (1.4)
Quincy, IL Prairie Farms Dairy	06/05	94 ± 96 (316)	0.42 ± 1.0 (1.3)	*1.4 ± 0.39 (1.3)
Boise, ID Meadow Gold Dairies	08/05	134 ± 116 (377)	0.081 ± 0.79 (1.1)	0.78 ± 0.38 (1.4)
Idaho Falls, ID Reed's Dairy	08/29	130 ± 109 (357)	N/A	1.1 ± 0.34 (1.3)
Dubuque, IA Swiss Valley Farms	06/05	19 ± 92 (303)	*2.67 ± 1.2 (1.3)	*1.34 ± 0.43 (1.3)
Ellis, KS Mid-America Dairymen	06/05	2.8 ± 92 (303)	0.063 ± 1.1 (1.3)	1.3 ± 0.38 (1.3)
Sabetha, KS Mid-America Dairymen	06/11	228 ± 94 (306)	N/A	*1.8 ± 0.41 (1.4)
Baton Rouge, LA Borden's	08/19	209 ± 114 (371)	N/A	*3.1 ± 0.48 (1.3)
Monroe, LA Borden's Dairy	09/17	101 ± 109 (357)	N/A	*1.7 ± 0.42 (1.5)

Continued

Table C-2. Continued

Sampling Location	Collection Date	Concentration ± 1s (MDC)[a] ^{3}H (10^{-9}µCi/mL)[b]	^{89}Sr (10^{-9}µCi/mL)[b]	^{90}Sr (10^{-9}µCi/mL)[b]
New Orleans, LA Brown's Velvet Dry	12/11	190 ± 86 (277)	N/A	1.3 ± 0.40 (1.4)
Fosston, MN Land O' Lakes Inc	06/19	234 ± 97 (313)	N/A	*2.7 ± 0.51 (1.3)
Rochester, MN Assoc Milk Prod Inc	06/06	174 ± 94 (306)	0.56 ± 1.1 (1.3)	1.1 ± 0.38 (1.3)
Aurora, MO Mid-America Dairy Inc	07/31	200 ± 117 (381)	*1.14 ± 0.97 (1.1)	*2.3 ± 0.46 (1.4)
Chillicothe, MO Mid-America Dairymen	06/20	113 ± 95 (310)	N/A	*2.4 ± 0.44 (1.3)
Billings, MT Meadow Gold Dairy	11/15	*404 ± 114 (366)	-1.6 ± 0.95 (1.1)	*2.6 ± 0.39 (1.3)
Great Falls, MT Meadow Gold Dairy	08/26	149 ± 110 (357)	N/A	1.1 ± 0.37 (1.3)
Norfolk, NE Gillette Dairy	06/17	60 ± 92 (302)	N/A	*1.5 ± 0.43 (1.4)
North Platte, NE Mid-America Dairymen	06/27	147 ± 95 (308)	N/A	0.94 ± 0.42 (1.3)
Albuqerque, NM Borden's Valley Gold	08/08	211 ± 112 (365)	0.35 ± 0.74 (0.97)	0.64 ± 0.37 (1.4)
La Plata, NM River Edge Dairy	08/16	345 ± 116 (372)	N/A	0.55 ± 0.33 (1.4)
Bismarck, ND Bridgeman Creamery	07/31	42 ± 111 (364)	0.13 ± 0.95 (1.1)	*2.3 ± 0.44 (1.4)
Grand Forks, ND Minnesota Dairy	08/14	89 ± 112 (367)	N/A	0.33 ± 0.37 (1.4)
Enid, OK AMPI Goldspot Div	06/12	167 ± 96 (314)	N/A	*2.0 ± 0.43 (1.4)
McAlester, OK Jackie Brannon Corp	06/20	151 ± 97 (317)	N/A	*1.5 ± 0.43 (1.3)
Medford, OR Dairygold Farms	08/07	165 ± 111 (361)	0.36 ± 0.73 (1.0)	0.36 ± 0.36 (1.4)
Salem, OR Curly's Dairy	08/20	204 ± 118 (384)	N/A	0.95 ± 0.33 (1.3)
Tillamook, OR Tillamook Creamery	08/19	165 ± 111 (361)	N/A	1.1 ± 0.36 (1.3)

Continued

Table C-2. Continued

Sampling Location	Collection Date	Concentration ± 1s (MDC)[a] ^{3}H (10^{-9}µCi/mL)[b]	^{89}Sr (10^{-9}µCi/mL)[b]	^{90}Sr (10^{-9}µCi/mL)[b]
Rapid City, SD Gillette Dairy	08/08	269 ± 115 (371)	N/A	1.3 ± 0.39 (1.4)
Sioux Falls, SD Lakeside Dairy	12/31	116 ± 88 (288)	N/A	0.92 ± 0.39 (1.4)
Glen Rose, TX Daffan Family Dairy	06/13	-4.5 ± 92 (304)	N/A	1.0 ± 0.36 (1.4)
Sulphur Springs, TX Tommy Potts Dairy	08/05	109 ± 113 (370)	*1.2 ± 1.0 (1.0)	*2.8 ± 0.51 (1.4)
Windthorst, TX Lloyd Wolf Dairy	06/07	23 ± 90 (296)	N/A	0.91 ± 0.33 (1.3)
Beaver, UT Cache Valley Dairy	05/22	96 ± 96 (314)	N/A	1.2 ± 0.36 (1.4)
Provo, UT BYU Dairy Products	05/20	144 ± 94 (306)	N/A	0.80 ± 0.35 (1.3)
Seattle, WA Darigold Inc	09/16	60 ± 109 (356)	N/A	0.24 ± 0.35 (1.4)
Spokane, WA Darigold Inc	11/12	223 ± 112 (363)	N/A	*1.7 ± 0.39 (1.3)
Cheyenne, WY Dairy Gold Foods	06/11	110 ± 91 (297)	N/A	1.4 ± 0.38 (1.4)
Sheridan, WY Mydland Dairy	05/10	292 ± 97 (313)	N/A	1.2 ± 0.35 (1.3)

[a] MDC = minimum detectable concentration.
[b] Multiply µCi/mL by 3.7×10^{7} to obtain Bq/L.
N/A = Sample not analyzed.
* = Concentration is greater than the MDC.

Table C-3. Sampling Location and Collection Date for Standby Milk Surveillance Network Samples Receiving Gamma Spectroscopy Analysis Only.

Sampling Location	Collection Date	Sampling Location	Collection Date
Duncan, AZ		Ruston, LA	
Lunt Dairy	07/24	LA Tech Univ Dairy	09/19
Tempe, AZ		Shreveport, LA	
United Dairymen of AZ	07/24	Foremost Dairy	12/18
Batesville, AR		Fergus Falls, MN	
Hills Valley Foods	06/25	Mid-America Dairymen	06/25
Fayetteville, AR		Browerville, MN	
University of Arkansas	06/20	Land O' Lakes, Inc.	06/17
Helendale, CA		Nicollet, MN	
Osterkamp Dairy No. 2	07/16	Doug Schultz Farm	06/27
Chino, CA		Jackson, MO	
CA Inst. for Men	07/23	Mid-America Dairymen Inc	06/06
Fernbridge, CA		Jefferson City, MO	
Humboldt Creamery Assn	07/19	Central Dairy Co	06/11
Fresno, CA		Bozeman, MT	
CA State Univ Creamery	07/15	Country Classic-DBA-Darig	09/11
Holtville, CA		Kalispell, MT	
Schaffner & Son Dairy	07/23	Equity Supply Co	09/11
Manteca, CA		Omaha, NE	
A & J Foods, Inc	07/23	Roberts Dairy	06/19
Modesto, CA		Marshall Green	07/31
Foster Farms, Jersey Dairy	07/22	Chappell, NE	
Petaluma, CA		Leprino Foods	11/20
Point Reyes Seashore Dairy	07/17	Superior, NE	
San Jose, CA		Mid-America Dairymen	06/11
Marquez Bros Mexican Cheese	07/17	Logandale, NV	
San Luis Obispo, CA		Nevada Dairy	09/17
Cal Poly Univ Dairy	07/19	Reno, NV	
Saugus, CA		Model Dairy	07/10
Wayside Honor Ranch	07/26	Yerington, NV	
Cresent City, CA		Valley Dairy	07/24
Rumiano Cheese Co	07/17	Fargo, ND	
Soledad, CA		Cass Clay Creamery	07/30
Correction Training Nds.	07/12	Minot, ND	
Tracy, CA		Bridgemen Creamery	08/15
Deuel Voc Inst	07/10	Claremore, OK	
Manchester, CA		Swan Bros Dairy	07/10
Point Arema Dairies	07/17	Stillwater, OK	
Colorado Springs, CO		OK State Univ Dairy	06/05
Sinton Dairy CO	05/13	Grants Pass, OR	
Greeley, CO		Valley Of Rouge Dairy	12/03
Meadow Gold Dairy	05/28	Junction City, OR	
		Lockmead Farms Inc	09/16

Continued

Table C-3. Continued

Sampling Location	Collection Date	Sampling Location	Collection Date
Ft Collins, CO			
Poudre Valley Creamery	05/22	Klamath Falls, OR	
Caldwell, ID		Klamath Dairy Product	08/08
Dairymens Creamery	08/08	North Powder, OR	
Association		Elmer Hill Dairy	08/05
Pocatello, ID		Myrtle Point, OR	
Rowland's Meadowgold	08/19	Safeway Stores Inc	08/05
Dairy		Portland, OR	
Twin Falls, ID		Darigold Farms	12/24
Triangle Young's Dairy	08/30	Redmond, OR	
Kimballton, IA		Eberhard's Creamery Inc	08/27
Assoc. Milk Pro.Inc(AMPI)	06/05	Ethan, SD	
Lake Mills, IA		Ethan Dairy Products	11/04
Lake Mills Co-op Creamery	06/24	Volga, SD	
Lemars, IA		Land O'Lakes Inc	08/08
Wells Dairy	06/12	Canyon, TX	
Manhattan, KS		West Texas State Dairy	06/17
Kansas State University	06/17	Corpus Christi, TX	
Lafayette, LA		Peoples Baptist Church	06/05
Borden's	08/20	Fabens, TX	
New Orleans, LA		Island Dairy-El Paso Ct	06/07
Walker Roemer Dairy	12/11	Richfield, UT	
Riverton, WY		Ideal Dairy	05/22
Western Dairymen's Co-op	05/10	Smithfield, UT	
Thayne, WY		Cache Valley Dairy	05/28
Western Dairymen's Co-op	05/13	Moses Lake, WA	
		Safeway Stores Inc	11/12

Table C-4. Radionuclide results for Mule Deer

Animal	Tissue	% Ash	Radionuclide	Result ± 1s (MDC)	Units
Mule Deer #1a	blood		^{3}H	*4.2E+5 ± 1.1E+3 (5.6E+2)	pCi/L
	lung	1.0	^{238}Pu	*1.7E-3 ± 9.0E-4 (1.6E-3)	pCi/g ash
			$^{239+240}Pu$	*1.7E-2 ± 2.6E-3 (1.6E-3)	
	muscle	1.1	^{238}Pu	1.3E-2 ± 7.0E-3 (1.7E-2)	pCi/g ash
			$^{239+240}Pu$	*1.2E+0 ± 9.5E-2 (7.0E-3)	
	liver	1.4	^{238}Pu	2.4E-3 ± 2.7E-3 (7.4E-3)	pCi/g ash
			$^{239+240}Pu$	*8.0E-3 ± 2.8E-3 (3.7E-3)	
	bone	30	^{238}Pu	2.1E-3 ± 1.3E-3 (2.8E-3)	pCi/g ash
			$^{239+240}Pu$	*5.9E-3 ± 1.8E-3 (2.8E-3)	
			^{90}Sr	*8.8E-1 ± 1.7E-1 (3.9E-1)	
	rumen content	21	^{238}Pu	*6.9E-3 ± 1.6E-3 (1.5E-3)	pCi/g ash
			$^{239+240}Pu$	*5.7E-2 ± 4.7E-3 (1.5E-3)	
Mule Deer #2	blood		^{3}H	-2.8E+1 ± 1.4E+2 (4.6E+2)	pCi/L
	lung	0.9	^{238}Pu	*1.0E-2 ± 2.2E-3 (2.0E-3)	pCi/g ash
			$^{239+240}Pu$	*3.5E-1 ± 1.7E-2 (2.0E-3)	
	muscle	1.0	^{238}Pu	1.8E-2 ± 1.1E-2 (2.3E-2)	pCi/g ash
			$^{239+240}Pu$	*8.0E-1 ± 7.5E-2 (2.3E-2)	
	liver	0.9	^{238}Pu	*6.0E-3 ± 1.7E-3 (1.9E-3)	pCi/g ash
			$^{239+240}Pu$	*1.7E-1 ± 1.1E-2 (1.9E-3)	
	bone	34	^{238}Pu	9.2E-4 ± 2.1E-3 (6.0E-3)	pCi/g ash
			$^{239+240}Pu$	-1.8E-7 ± 1.9E-3 (6.0E-3)	
			^{90}Sr	*4.8E-1 ± 5.5E-2 (1.3E-1)	
	rumen content	1.7	^{238}Pu	2.0E-3 ± 1.4E-3 (3.8E-3)	pCi/g ash
			$^{239+240}Pu$	*8.8E-2 ± 6.5E-3 (1.6E-3)	
Mule Deer #3	blood		^{3}H	*1.0E+3 ± 1.5E+2 (4.6E+2)	pCi/L
	lung	1.0	^{238}Pu	-1.7E-2 ± 1.4E-2 (5.3E-2)	pCi/g ash
			$^{239+240}Pu$	4.3E-3 ± 7.5E-3 (2.0E-2)	
	muscle	1.0	^{238}Pu	-1.1E-3 ± 1.1E-3 (4.9E-3)	pCi/g ash
			$^{239+240}Pu$	3.2E-3 ± 2.4E-3 (4.9E-3)	
	liver	1.3	^{238}Pu	7.3E-4 ± 1.3E-3 (3.4E-3)	pCi/g ash
			$^{239+240}Pu$	2.2E-3 ± 1.7E-3 (3.4E-3)	

Continued

Table C-4. Continued.

Animal	Tissue	% Ash	Radionuclide	Result ± 1s (MDC)	Units
	bone	31	^{238}Pu	-1.4E-7 ± 1.4E-3 (4.7E-3)	pCi/g ash
			$^{239+240}Pu$	7.1E-4 ± 1.3E-3 (3.3E-3)	
			^{90}Sr	5.2E-1 ± 4.7E-1 (1.5E+0)	
	rumen content	1.7	^{238}Pu	3.1E-3 ± 2.4E-3 (4.9E-3)	pCi/g ash
			$^{239+240}Pu$	*1.7E-2 ± 4.6E-3 (4.9E-3)	
Mule Deer #4	blood		^{3}H	1.3E+1 ± 1.4E+2 (4.6E+2)	pCi/L
	lung	1.0	^{238}Pu	8.3E-4 ± 2.5E-3 (7.8E-3)	pCi/g ash
			$^{239+240}Pu$	-8.3E-4 ± 8.5E-4 (3.9E-3)	
	muscle	1.0	^{238}Pu	1.4E-3 ± 1.9E-3 (5.4E-3)	pCi/g ash
			$^{239+240}Pu$	-6.7E-4 ± 7.0E-4 (3.1E-3)	
	liver	1.3	^{238}Pu	2.3E-3 ± 2.6E-3 (7.3E-3)	pCi/g ash
			$^{239+240}Pu$	2.3E-3 ± 1.8E-3 (3.6E-3)	
	bone	35	^{238}Pu	-6.9E-4 ± 1.6E-3 (5.6E-3)	pCi/g ash
			^{238}Pu	6.9E-4 ± 1.2E-3 (3.2E-3)	
			^{90}Sr	9.5E-1 ± 4.2E-1 (1.4E+0)	
	rumen content	6.1	^{238}Pu	*1.2E-2 ± 2.2E-3 (2.3E-3)	pCi/g ash
			$^{239+240}Pu$	*1.1E-1 ± 7.0E-3 (1.7E-3)	

a Contaminated animal.
* Result is greater than MDC.

Table C-5. Radionuclide results for Cattle

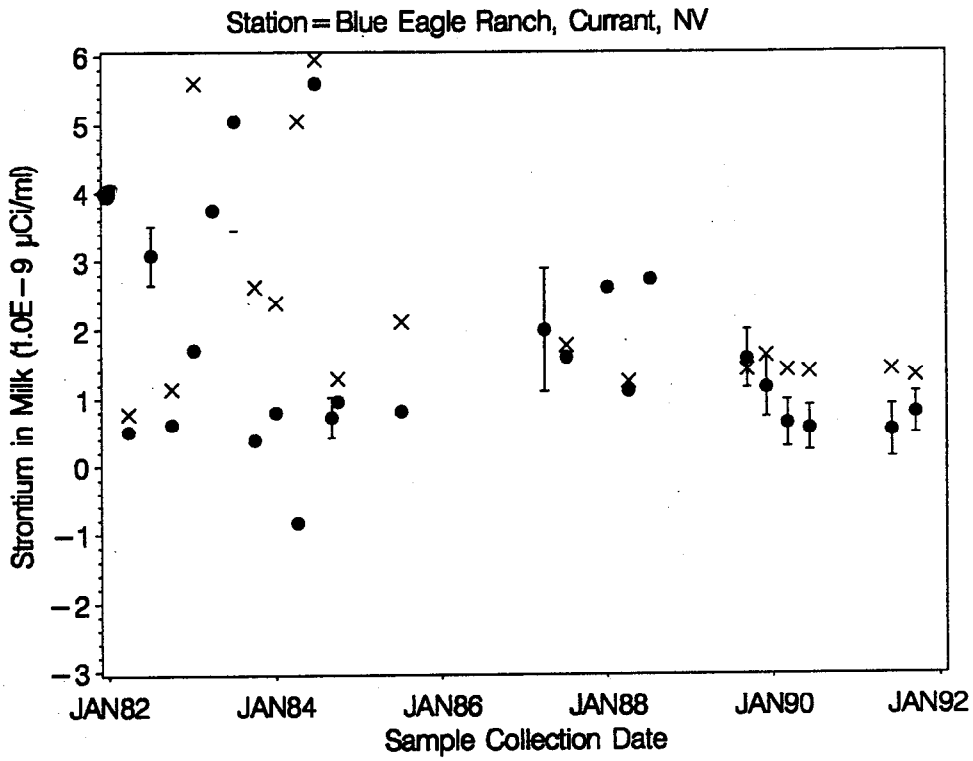
Animal	Tissue	% Ash	Radionuclide	Result ± 1s (MDC)	Units
Bovine #1	blood		^{3}H	1.2E+2 ± 1.1E+2 (3.6E+2)	pCi/L
	liver	1.3	^{238}Pu	9.4E-4 ± 1.1E-3 (2.9E-3)	pCi/g ash
			$^{239+240}Pu$	*3.1E-2 ± 3.4E-3 (1.5E-3)	
	bone	35	^{238}Pu	-3.1E-3 ± 4.5E-3 (1.6E-2)	pCi/g ash
			$^{239+240}Pu$	-3.1E-7 ± 3.2E-3 (1.0E-2)	
			^{90}Sr	*9.9E-1 ± 7.0E-2 (1.3E-1)	
Bovine #2	blood		^{3}H	2.2E+2 ± 1.1E+2 (3.4E+2)	pCi/L
	liver	1.3	^{238}Pu	*5.9E-2 ± 6.5E-3 (6.2E-3)	pCi/g ash
			$^{239+240}Pu$	*3.4E+0 ± 1.5E-1 (2.5E-3)	
	bone	41	^{238}Pu	7.3E-4 ± 1.7E-3 (4.8E-3)	pCi/g ash
			$^{239+240}Pu$	-7.3E-4 ± 1.3E-3 (4.8E-3)	
			^{90}Sr	*2.9E-1 ± 4.3E-2 (1.2E-1)	
Bovine #3	blood		^{3}H	3.6E+2 ± 1.2E+2 (3.9E+2)	pCi/L
	liver	1.3	^{238}Pu	2.4E-3 ± 1.8E-3 (3.7E-3)	pCi/g ash
			$^{239+240}Pu$	*1.3E-1 ± 1.2E-2 (3.7E-3)	
	hock	32	^{238}Pu	-5.3E-4 ± 5.5E-4 (2.5E-3)	pCi/g ash
			$^{239+240}Pu$	5.3E-4 ± 9.0E-4 (2.5E-3)	
			^{90}Sr	*7.1E-1 ± 5.5E-2 (1.2E-1)	
Bovine #4	blood		^{3}H	2.8E+2 ± 1.1E+2 (3.4E+2)	pCi/L
	liver	1.2	^{238}Pu	-1.0E-7 ± 1.5E-3 (4.8E-3)	pCi/g ash
			$^{239+240}Pu$	-1.0E-7 ± 1.5E-3 (4.8E-3)	
	bone	19	^{238}Pu	-8.3E-8 ± 8.5E-4 (2.7E-3)	pCi/g ash
			$^{239+240}Pu$	-8.3E-8 ± 8.5E-4 (2.7E-3)	
			^{90}Sr	*3.8E-1 ± 5.5E-2 (1.4E-1)	
Bovine #5	blood		^{3}H	2.4E+2 ± 1.2E+2 (3.7E+2)	pCi/L
	liver	1.3	^{238}Pu	3.6E-3 ± 2.5E-3 (5.8E-3)	pCi/g ash
			$^{239+240}Pu$	*2.0E-2 ± 4.5E-3 (4.1E-3)	
	bone	45	^{238}Pu	-1.1E-3 ± 1.9E-3 (6.7E-3)	pCi/g ash
			$^{239+240}Pu$	-5.4E-4 ± 5.5E-4 (2.5E-3)	
			^{90}Sr	1.3E+0 ± 4.8E-1 (1.6E+0)	

Continued

Table C-5. Continued.

Animal	Tissue	% Ash	Radionuclide	Result ± 1s (MDC)	Units
Bovine #6	blood		^{3}H	1.6E+2 ± 1.1E+2 (3.6E+2)	pCi/L
	liver	1.4	^{238}Pu	2.4E-3 ± 4.3E-3 (1.1E-2)	pCi/g ash
			$^{239+240}Pu$	*1.5E-2 ± 7.0E-3 (1.1E-2)	
	bone	26	^{238}Pu	-4.0E-4 ± 4.0E-4 (1.8E-3)	pCi/g ash
			$^{239+240}Pu$	*5.1E-3 ± 1.6E-3 (1.8E-3)	
			^{90}Sr	9.7E-1 ± 3.1E-1 (1.2E+0)	
Bovine #7	blood		^{3}H	2.5E+2 ± 1.2E+2 (3.8E+2)	pCi/L
	liver	1.0	^{238}Pu	3.4E-3 ± 3.2E-3 (9.0E-3)	pCi/g ash
			$^{239+240}Pu$	*4.7E-2 ± 7.0E-3 (5.7E-3)	
	bone	26	^{238}Pu	4.8E-4 ± 1.1E-3 (3.2E-3)	pCi/g ash
			$^{239+240}Pu$	1.9E-3 ± 1.2E-3 (2.2E-3)	
			^{90}Sr	8.0E-1 ± 4.2E-1 (1.6E+0)	
Bovine #8	blood		^{3}H	2.5E+2 ± 1.2E+2 (3.7E+2)	pCi/L
	liver	1.4	^{238}Pu	1.9E-3 ± 1.9E-3 (4.3E-3)	pCi/g ash
			$^{239+240}Pu$	*3.9E-2 ± 6.5E-3 (6.1E-3)	
	bone	47	^{238}Pu	-1.2E-3 ± 1.5E-3 (5.6E-3)	pCi/g ash
			$^{239+240}Pu$	-6.0E-4 ± 6.0E-4 (2.8E-3)	
			^{90}Sr	4.3E-1 ± 3.6E-1 (1.5E+0)	

* Result is greater than MDC.



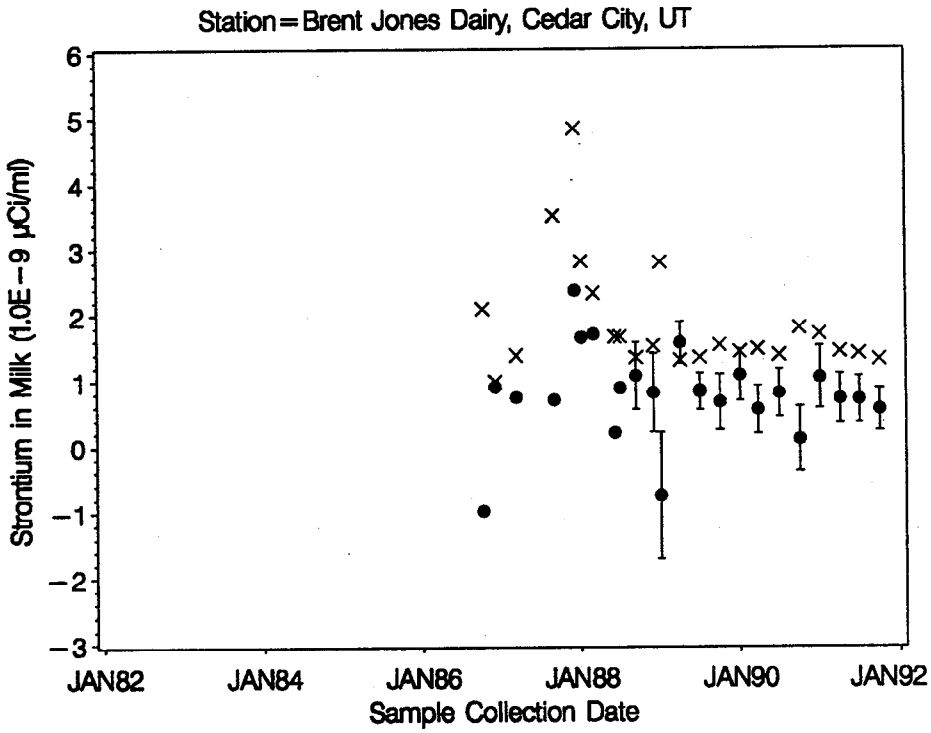
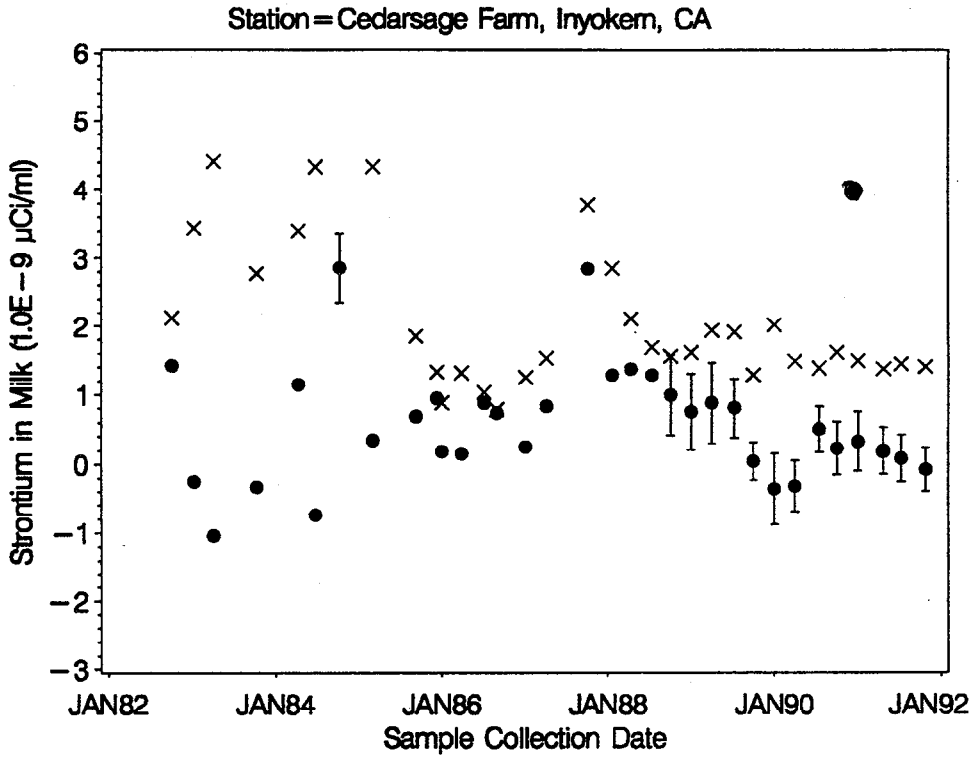


Figure C-1. Time series of strontium results for Milk Surveillance Network stations.



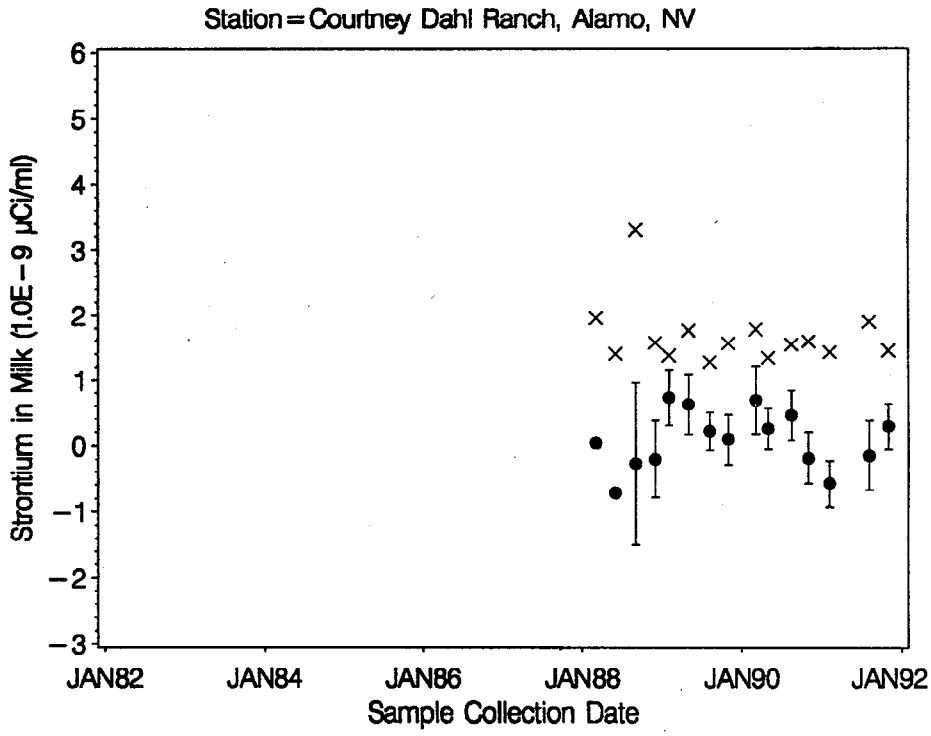
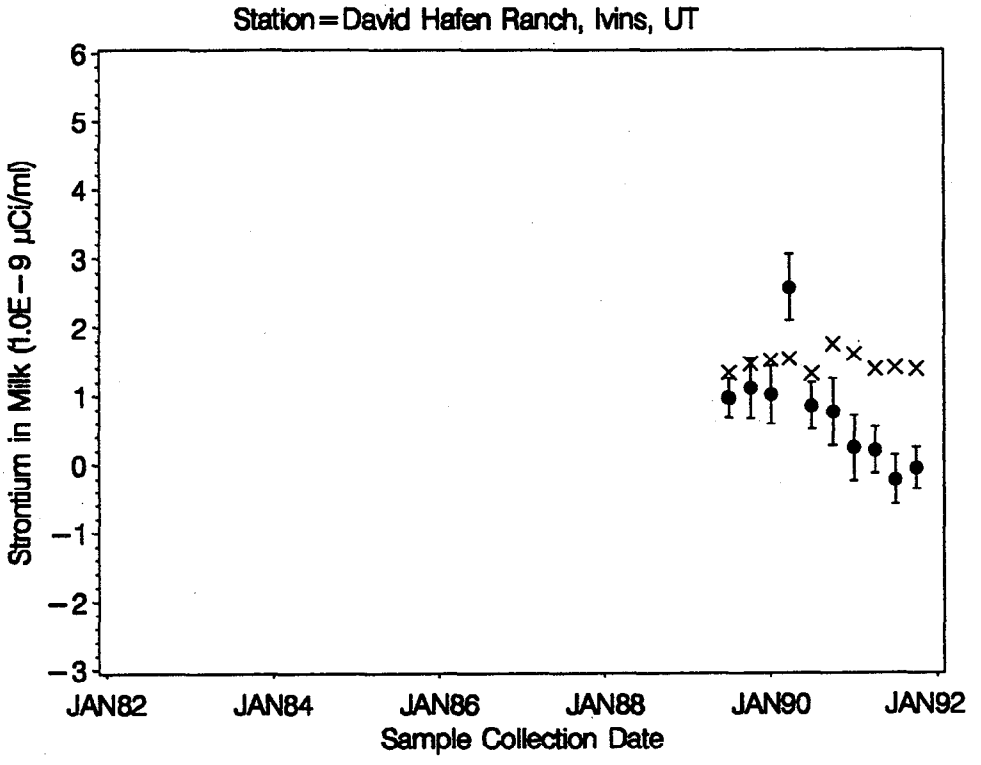


Figure C-1. Continued.



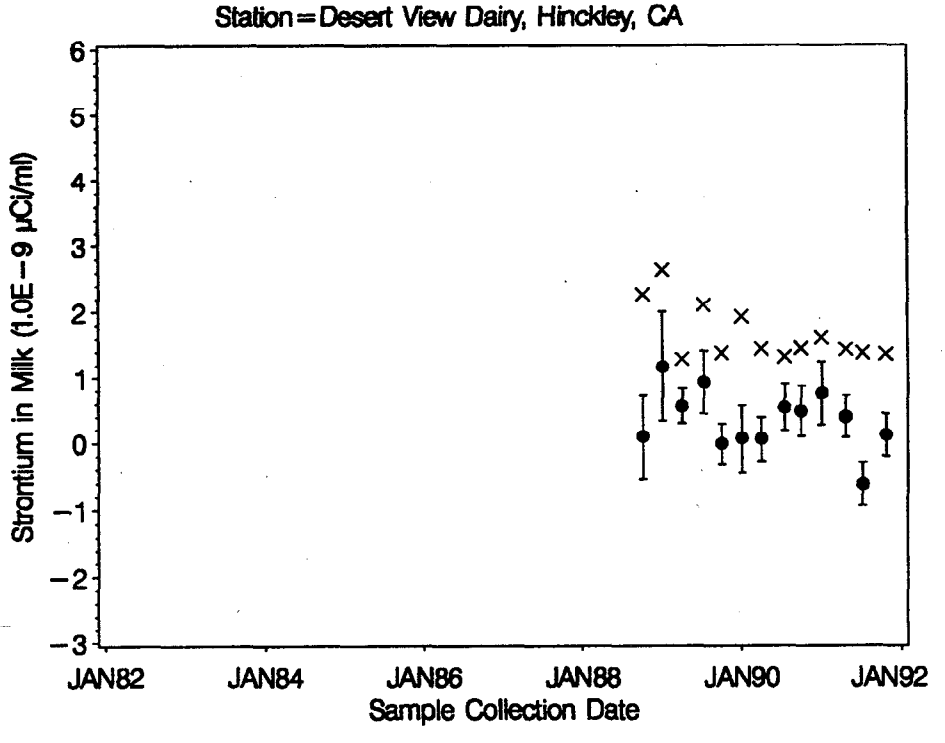
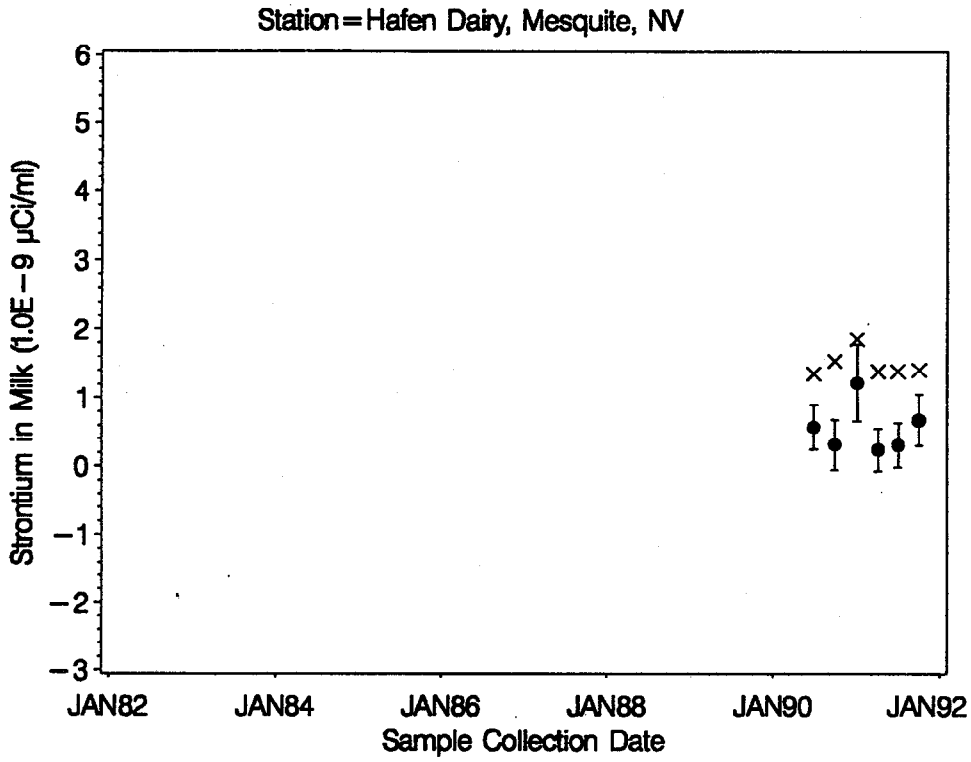


Figure C-1. Continued.



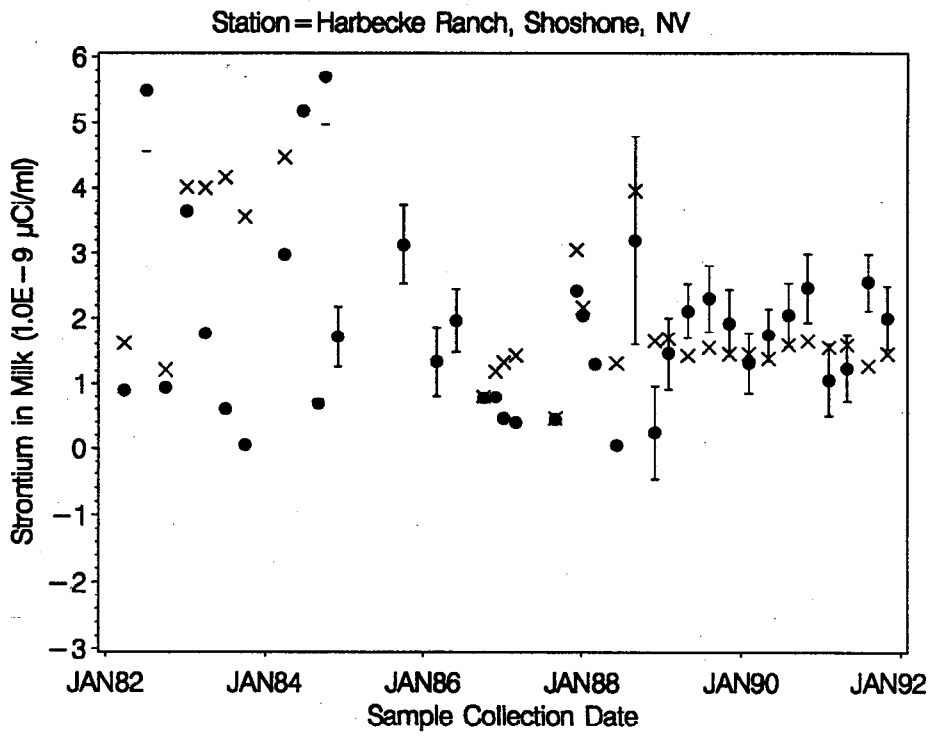
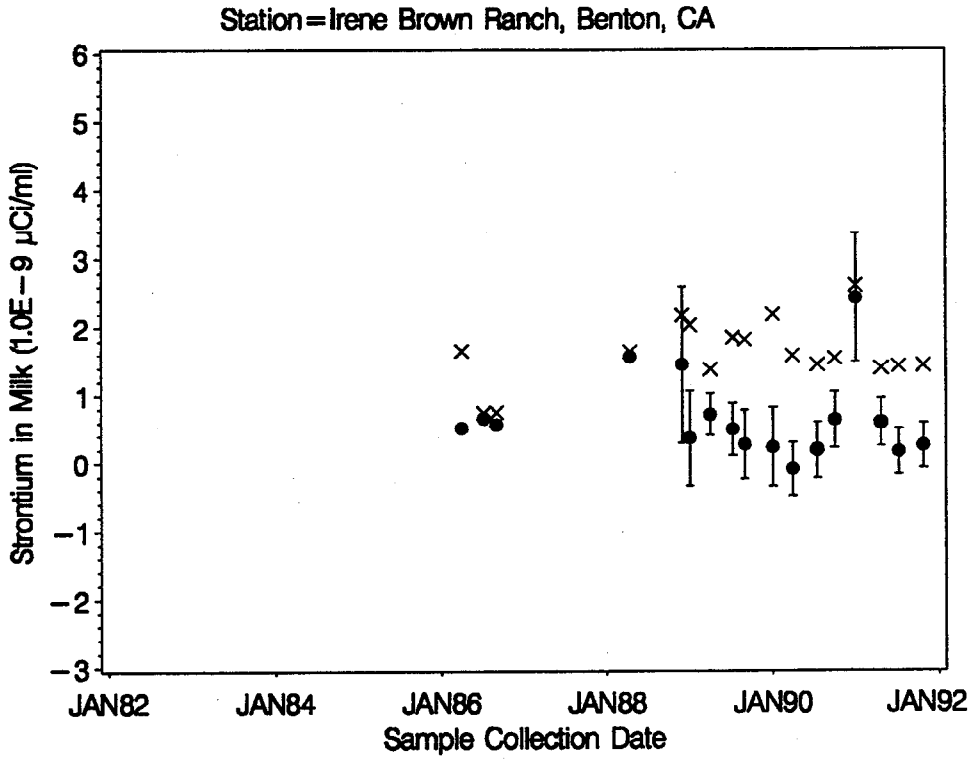


Figure C-1. Continued.



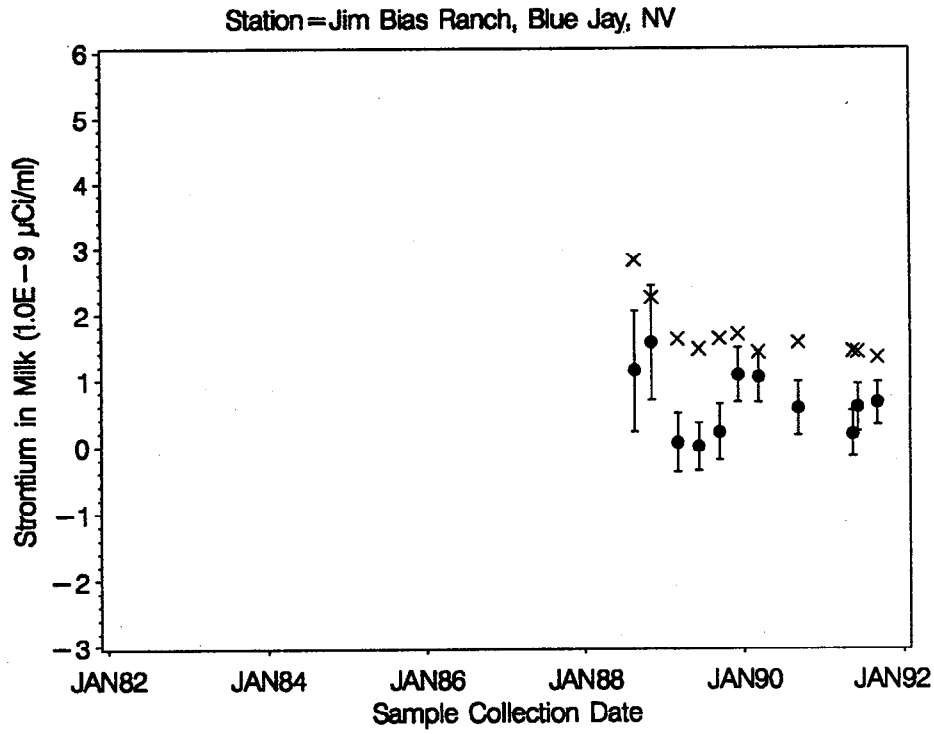
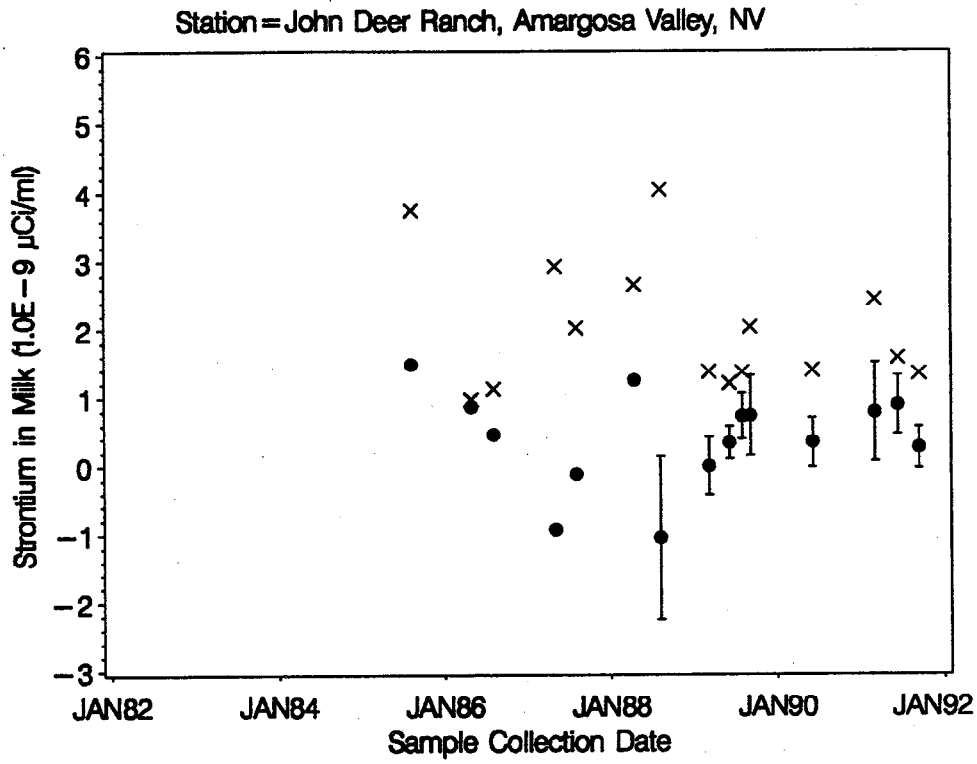


Figure C-1. Continued.



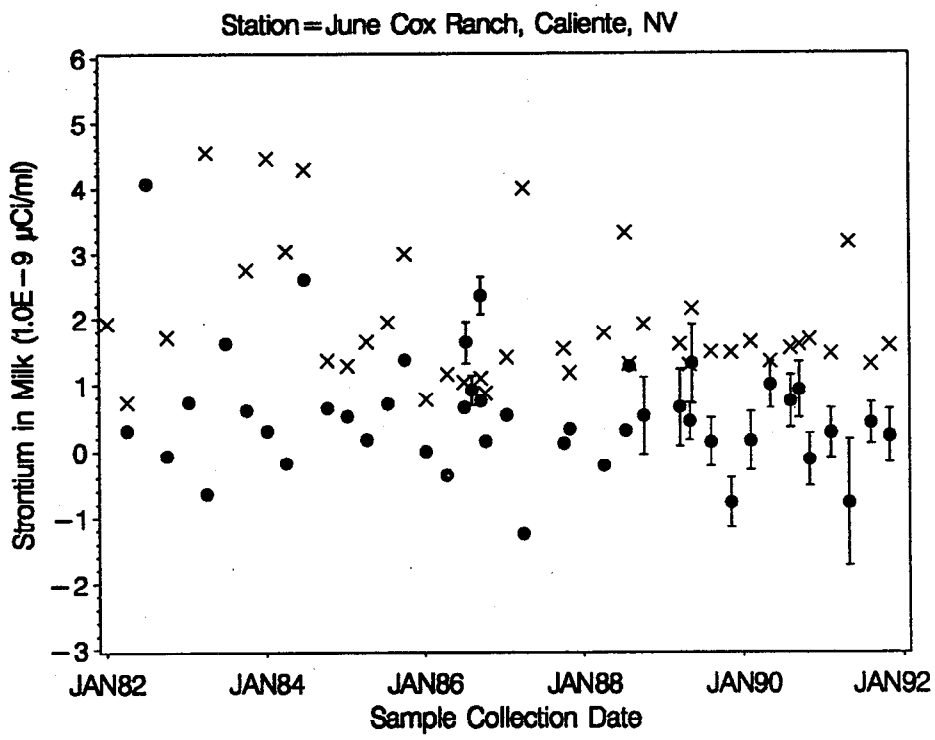
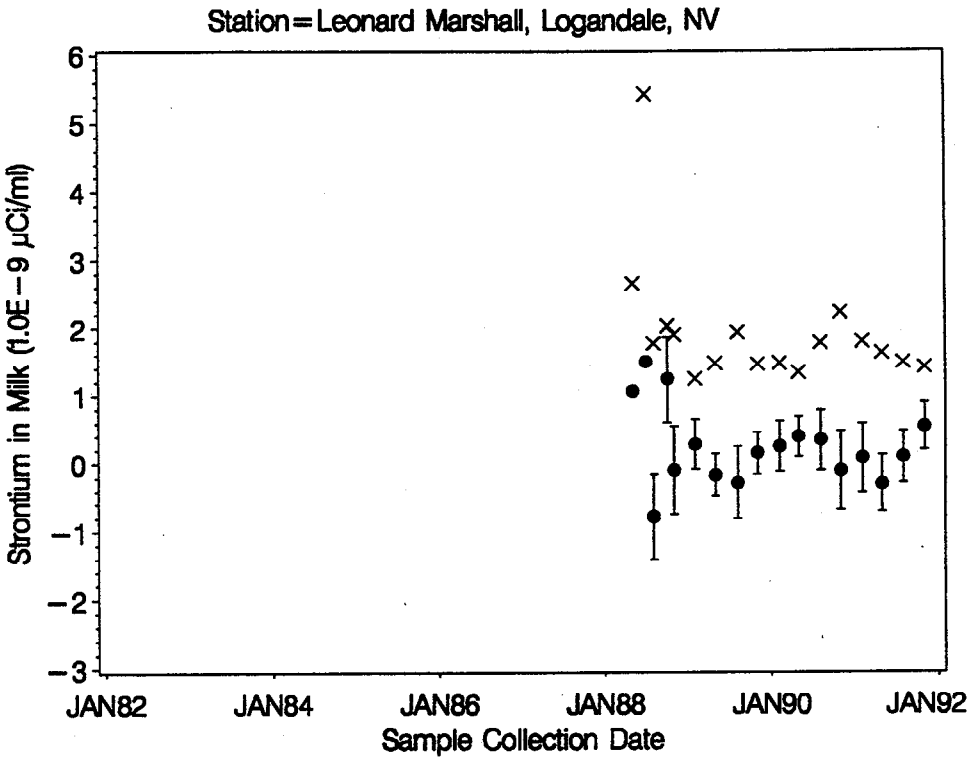


Figure C-1. Continued.



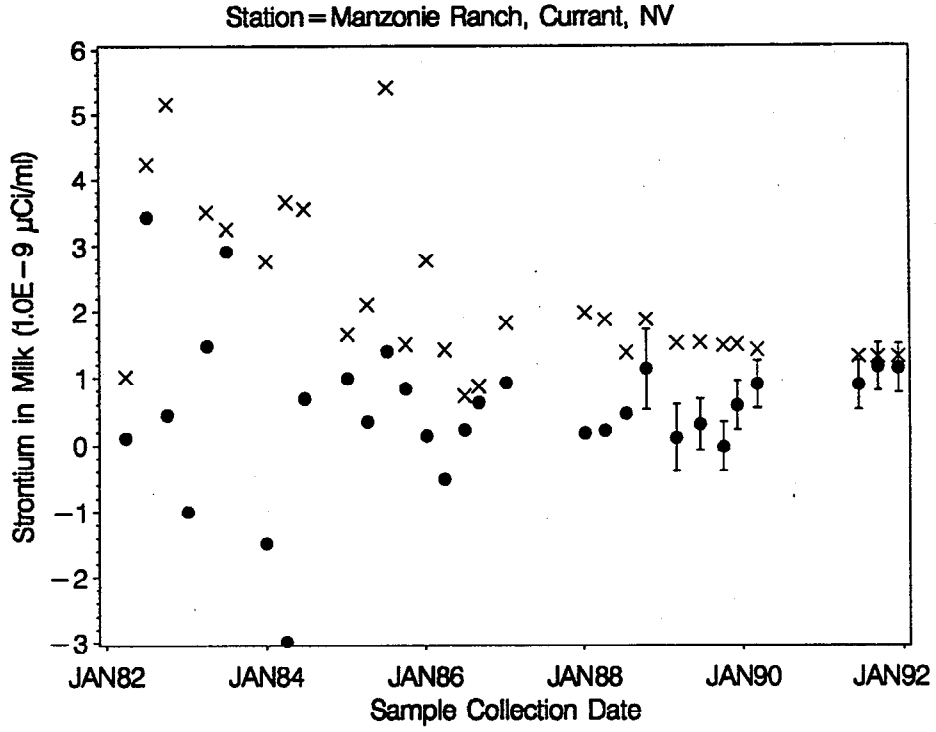
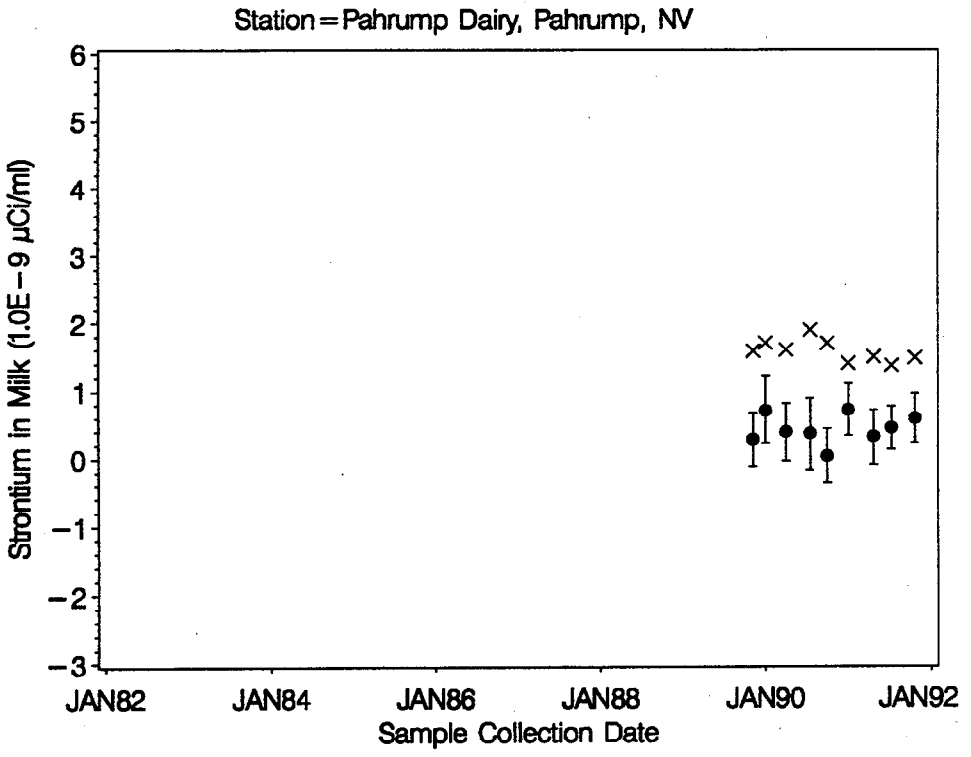


Figure C-1. Continued.



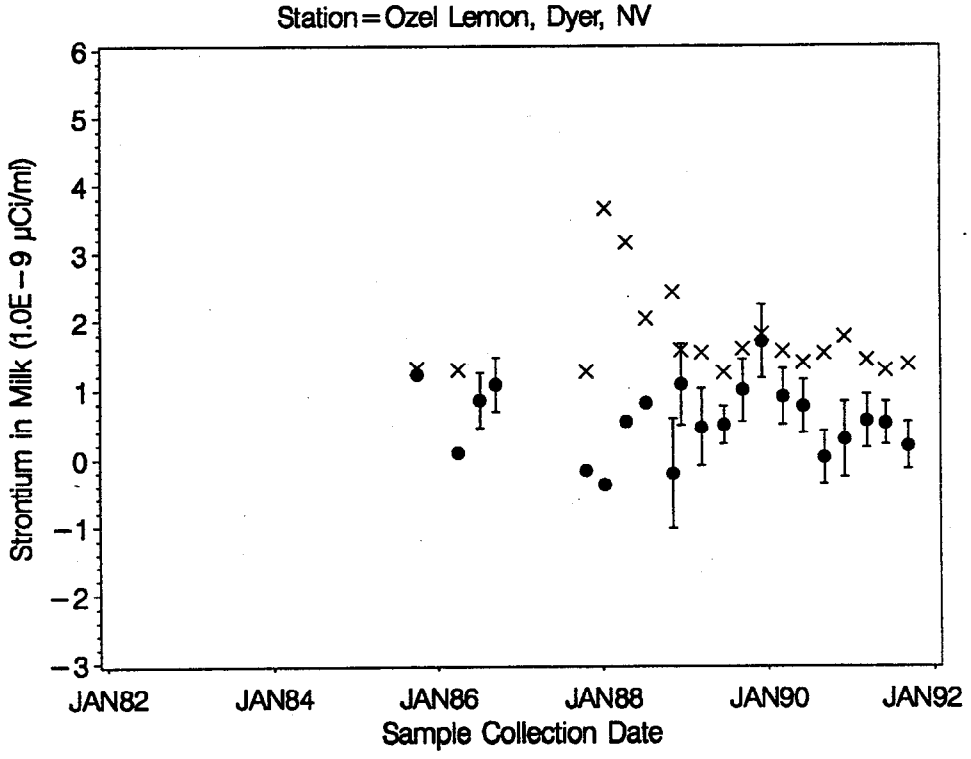
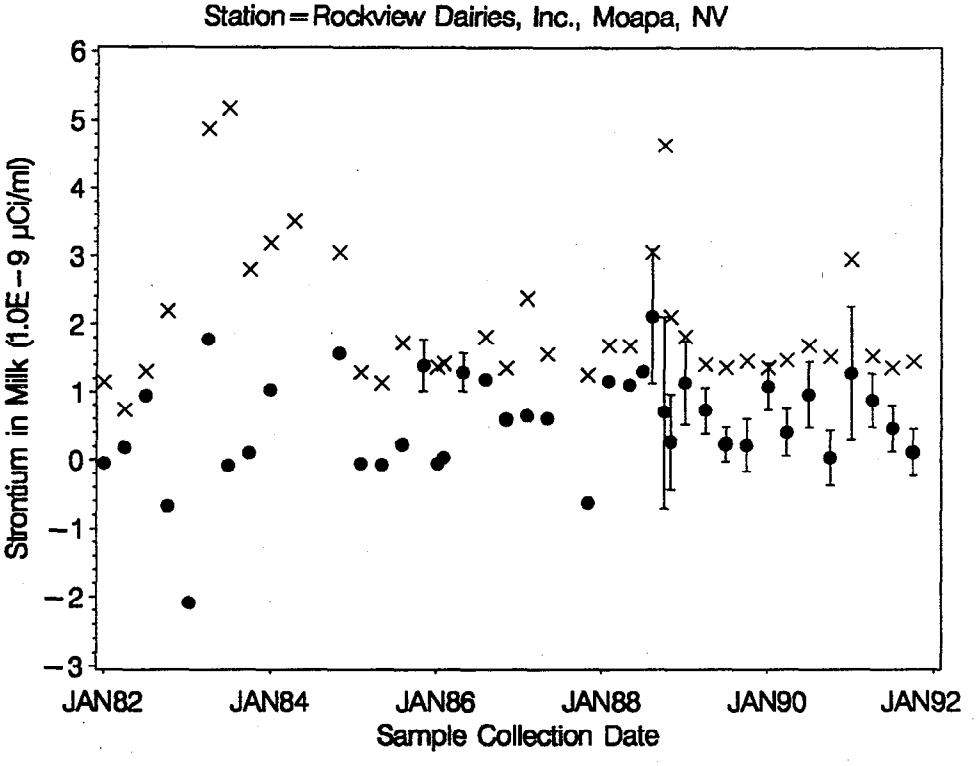


Figure C-1. Continued.



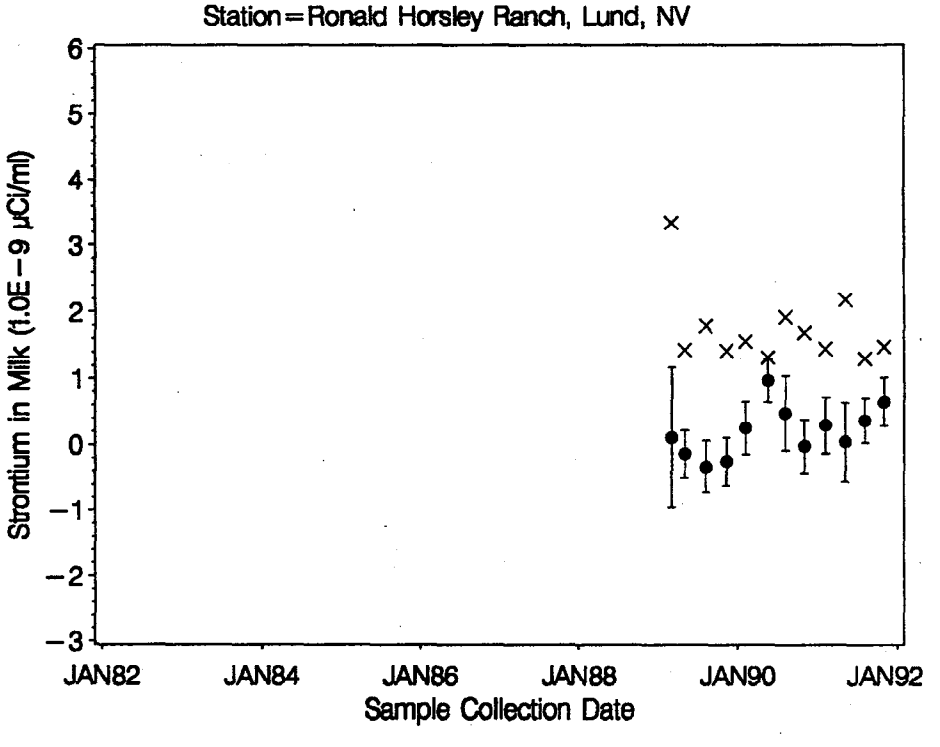
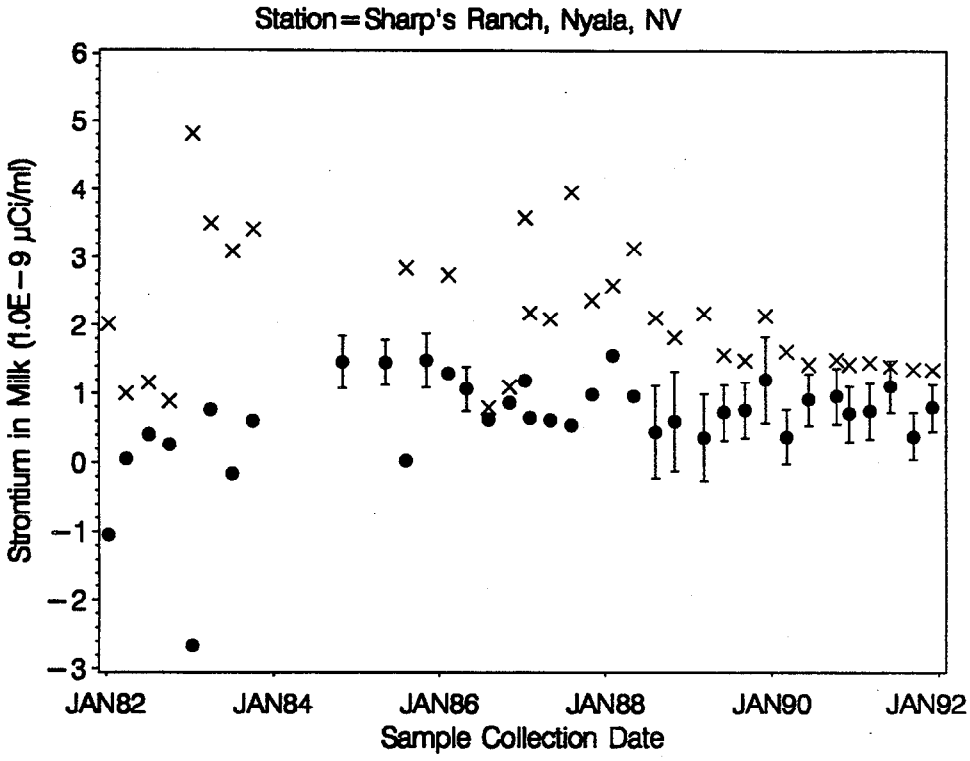


Figure C-1. Continued.



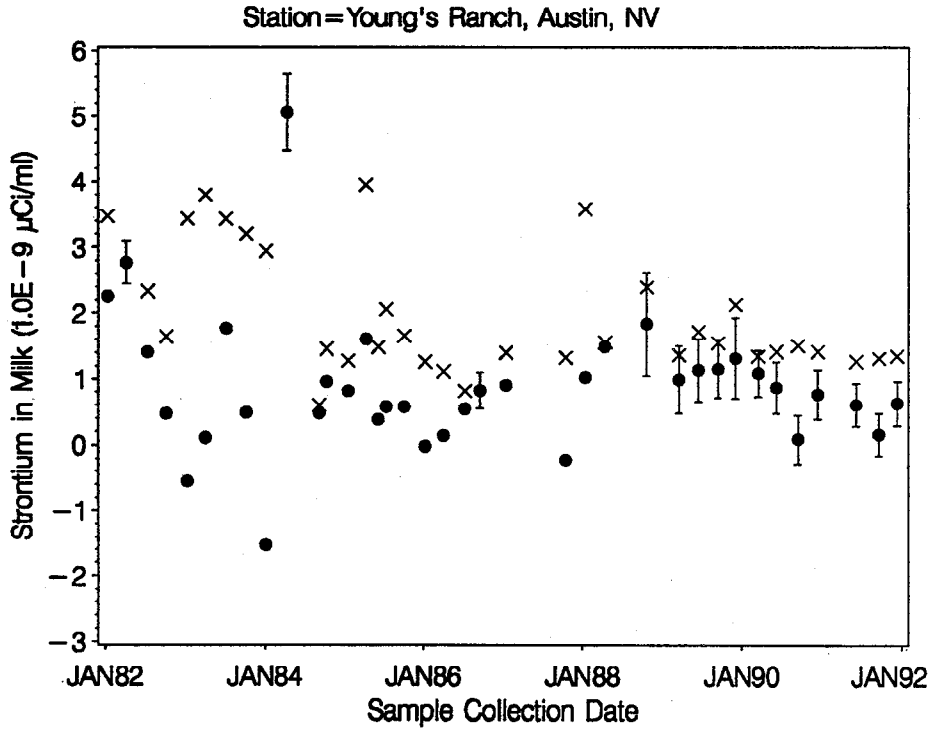


Figure C-1. Continued.

Appendix D

Table D-1. Tritium in Urine, Offsite Internal Dosimetry Network, 1991

Sampling Location	Collection Date	Concentration ± 1s (10^{-9} pCi/mL) [a]			(MDC)
Alamo, NV	12/11/90	111	±	64	(209)
	12/11/90	99	±	64	(208)
	12/16/90	82	±	63	(206)
	12/16/90	8	±	63	(206)
	12/16/90	24	±	62	(205)
	12/16/90	88	±	63	(206)
	12/16/90	103	±	63	(204)
Amargosa Farm Area, NV	07/23/91	-14	±	91	(301)
Beatty, NV	02/07/91	225	±	96	(311)
	02/07/91	246	±	96	(311)
	03/15/91	-56	±	90	(298)
	03/15/91	175	±	91	(295)
	03/19/91	77	±	92	(302)
	03/19/91	-50	±	90	(298)
	03/28/91	218	±	91	(294)
	03/28/91	144	±	92	(299)
	03/28/91	111	±	91	(296)
	03/29/91	28	±	89	(294)
	03/29/91	115	±	91	(297)
	03/29/91	208	±	93	(302)
	03/29/91	168	±	92	(298)
	08/13/91	69	±	76	(249)
	08/13/91	26	±	75	(247)
	08/13/91	-90	±	75	(248)
	12/17/91	60	±	63	(206)
	12/17/91	24	±	62	(204)
	12/23/91	39	±	62	(204)
	12/23/91	23	±	62	(205)
	12/23/91	26	±	62	(202)
	12/23/91	48	±	62	(204)
	12/23/91	20	±	63	(207)
	12/23/91	23	±	62	(205)
Currant, NV					
Blue Eagle Ranch	02/15/91	153	±	96	(313)
	02/15/91	-23	±	94	(311)
Ely, NV	06/05/91	136	±	88	(287)
	06/05/91	47	±	88	(289)
	12/12/91	131	±	64	(206)
	12/12/91	144	±	64	(206)

Continued

Table D-1. Continued

Sampling Location	Collection Date	Concentration ± 1s (10^{-9} pCi/mL) [a] (MDC)
Goldfield, NV	04/10/91	95 ± 90 (295)
	04/10/91	-69 ± 88 (291)
	04/10/91	88 ± 88 (288)
Henderson, NV	03/13/91	127 ± 97 (315)
	03/13/91	77 ± 96 (316)
Indian Springs, NV	06/25/91	-14 ± 90 (297)
	06/25/91	74 ± 97 (319)
	08/28/91	-19 ± 75 (248)
	08/28/91	-57 ± 74 (245)
	08/28/91	19 ± 76 (250)
Nyala, NV	01/11/91	126 ± 103 (337)
	01/11/91	-30 ± 103 (339)
	01/18/91	55 ± 88 (290)
	07/18/91	105 ± 95 (310)
	07/18/91	-36 ± 92 (305)
	07/18/91	42 ± 92 (302)
Overton, NV	01/04/91	161 ± 104 (340)
	01/04/91	83 ± 102 (333)
	01/04/91	166 ± 103 (335)
	01/04/91	187 ± 102 (330)
	01/04/91	81 ± 102 (335)
	01/04/91	232 ± 102 (332)
	05/08/91	86 ± 88 (286)
	05/08/91	*375 ± 97 (311)
	05/08/91	134 ± 88 (287)
	05/08/91	28 ± 88 (289)
	05/08/91	152 ± 90 (293)
	12/18/91	56 ± 63 (207)
	12/18/91	-78 ± 62 (205)
	12/18/91	10 ± 62 (205)
	12/18/91	114 ± 63 (206)
	12/18/91	32 ± 62 (205)
Pahrump, NV	03/13/91	166 ± 97 (315)
	08/02/91	-88 ± 90 (297)
	08/02/91	-93 ± 90 (300)
	08/02/91	-66 ± 91 (301)
	08/02/91	79 ± 92 (300)
Pioche, NV	04/05/91	81 ± 91 (289)
	04/05/91	4 ± 88 (289)

Continued

Table D-1. Continued

Sampling Location	Collection Date	Concentration ± 1s (10^{-9} pCi/mL) [a] (MDC)
	04/05/91	12 ± 89 (294)
	04/05/91	-45 ± 87 (289)
	05/04/91	112 ± 90 (293)
	09/26/91	109 ± 85 (279)
	09/26/91	21 ± 84 (278)
	09/26/91	181 ± 87 (282)
	09/26/91	121 ± 86 (218)
	09/26/91	116 ± 85 (278)
	10/15/91	58 ± 87 (284)
	10/15/91	164 ± 92 (300)
Rachel, NV	04/22/91	78 ± 88 (288)
	04/22/91	*357 ± 91 (293)
	04/22/91	201 ± 88 (285)
	04/22/91	289 ± 90 (289)
	04/22/91	260 ± 89 (285)
	09/10/91	11 ± 76 (249)
Cedar City, UT	12/13/91	108 ± 63 (204)
	12/13/91	148 ± 64 (206)
	12/13/91	79 ± 68 (222)
	12/13/91	92 ± 64 (208)
	12/13/91	93 ± 63 (206)

[a] Multiply by 0.037 to obtain Bq/L.

* Concentration is greater than the minimum detectable activity (MDC).

Table D-2. Tritium in Urine, Radiological Safety Program 1991

Sampling Location	Collection Date	Concentration ± 1s (10^{-9} pCi/mL) [a] (MDC)	Organization List
Riverside, Ca	06/18/91	-12 ± 83 (274)	DRI
Boulder City, NV	07/03/91	241 ± 84 (272)	EPA
Beatty, NV	04/19/91	128 ± 90 (294)	ARCATA
Carson City, NV	07/30/91	58 ± 76 (248)	NDEP
Hawthorne, NV	12/06/91	30 ± 63 (208)	DRI
Henderson, NV	06/28/91	-121 ± 81 (270)	EPA
	07/17/91	152 ± 73 (236)	NDEP
	09/13/91	119 ± 77 (252)	DRI
	09/18/91	-26 ± 76 (250)	EPA
Indian Springs, NV	07/11/91	25 ± 80 (263)	USGS
Las Vegas, NV	01/09/91	69 ± 90 (294)	EPA
	01/09/91	227 ± 92 (299)	EPA
	01/09/91	36 ± 90 (294)	EPA
	01/09/91	71 ± 90 (294)	EPA
	01/10/91	98 ± 86 (282)	EPA
	01/10/91	84 ± 87 (286)	REECo
	01/10/91	75 ± 90 (294)	EPA
	01/10/91	32 ± 90 (296)	EPA
	01/14/91	84 ± 95 (310)	EPA
	01/14/91	40 ± 92 (301)	EPA
	01/15/91	-0.98 ± 88 (291)	EPA
	01/15/91	94 ± 89 (291)	EPA
	01/16/91	3.9 ± 88 (290)	EPA
	01/16/91	177 ± 103 (334)	ERC
	01/17/91	63 ± 89 (291)	EPA
	01/17/91	*305 ± 91 (291)	EPA
	02/04/91	41 ± 94 (308)	EPA
	02/05/91	287 ± 97 (313)	DRI
	02/06/91	273 ± 96 (309)	EPA
	02/06/91	285 ± 96 (311)	EPA
	02/14/91	*359 ± 92 (295)	RSN
	02/22/91	88 ± 92 (300)	EPA
	02/27/91	20 ± 90 (297)	DRI
	02/27/91	112 ± 92 (300)	DRI
	03/27/91	67 ± 90 (296)	EPA
	04/09/91	138 ± 88 (286)	SAIC
	04/09/91	18 ± 88 (288)	WEC
	04/09/91	175 ± 89 (289)	SAIC

Continued

Table D-2. Continued

Sampling Location	Collection Date	Concentration ± 1s (10^{-9} pCi/mL) [a] (MDC)	Organization List
	04/10/91	59 ± 87 (286)	WEC
	04/10/91	63 ± 88 (287)	SAIC
	04/12/91	-4 ± 88 (290)	EPA
	04/15/91	-14 ± 88 (291)	DRI
	04/29/91	-46 ± 89 (295)	DRI
	06/11/91	254 ± 89 (288)	EG&G
	06/17/91	303 ± 98 (316)	DRI
	06/17/91	-42 ± 92 (303)	DRI
	06/17/91	101 ± 93 (304)	DRI
	06/18/91	*311 ± 94 (301)	DRI
	07/02/91	-31 ± 84 (276)	DRI
	07/02/91	-59 ± 84 (278)	DRI
	07/02/91	208 ± 82 (263)	DRI
	07/02/91	183 ± 84 (271)	DRI
	07/03/91	73 ± 81 (266)	EPA
	07/11/91	97 ± 80 (261)	USGS
	07/11/91	148 ± 82 (268)	USGS
	07/11/91	109 ± 76 (249)	USGS
	07/16/91	109 ± 81 (263)	NDEP
	07/16/91	192 ± 83 (267)	NDEP
	07/17/91	185 ± 80 (260)	NDEP
	08/07/91	227 ± 93 (301)	EG&G
	08/07/91	24 ± 91 (299)	SAIC
	08/08/91	43 ± 74 (244)	NSHD
	08/16/91	*267 ± 77 (248)	DRI
	08/19/91	-75 ± 74 (246)	DRI
	08/19/91	83 ± 75 (246)	DRI
	08/19/91	200 ± 76 (246)	DRI
	08/21/91	-12 ± 82 (270)	KAFB
	08/30/91	-23 ± 75 (248)	DRI
	09/06/91	55 ± 77 (253)	DRI
	09/06/91	-102 ± 74 (248)	DRI
	09/09/91	265 ± 83 (266)	DRI
	09/09/91	-48 ± 76 (252)	DRI
	09/23/91	-79 ± 75 (249)	DRI
	09/27/91	87 ± 88 (289)	DRI
	10/01/91	143 ± 86 (279)	EPA
	10/01/91	-65 ± 82 (271)	DRI
	10/03/91	554 ± 89 (279)	EG&G
	11/05/91	245 ± 87 (279)	EPA
	11/08/91	*337 ± 87 (279)	DRI
	12/05/91	21 ± 63 (209)	EPA
	12/09/91	52 ± 63 (205)	DRI
	12/09/91	83 ± 63 (206)	DRI
	12/18/91	11 ± 63 (206)	DRI

Continued

Table D-2. Continued

Sampling Location	Collection Date	Concentration ± 1s (10^{-9} pCi/mL) [a] (MDC)	Organization List
Mercury, NV	08/28/91	-12 ± 77 (253)	DRI
	09/16/91	-134 ± 78 (261)	DRI
NTS, NV			
Camp Mercury	08/19/91	87 ± 75 (246)	NTS
Reno, NV	06/25/91	203 ± 85 (274)	DRI

* Concentration is greater than the minimum detectable concentration (MDC).

[a] Mutiply by 0.037 to obtain Bq/L.

Appendix E

Table E-1. Long-Term Hydrological Monitoring Program 1991 Analytical Results for Nevada Test Site Locations Sampled Monthly

Sampling Location	Collection Date	Concentration ± 1s Tritium (pCi/L)	MDC (pCi/L)	Percent of Concentration Guide	Remarks
Well 1 Army	01/03	0.40 ± 3.26*	10.7	NA	
	02/05	0.82 ± 2.63*	8.65	NA	
	03/13	−2.2 ± 3.6*	11.9	NA	
	04/08	−1.9 ± 3.3*	11.0	NA	
	05/08	1.4 ± 2.9*	9.5	NA	
	06/03	4.3 ± 3.4*	11.2	NA	
	07/09	-2.6 ± 1.9*	6.4	NA	
	08/06	−2.9 ± 1.7*	5.7	NA	
	09/04	−0.25 ± 2.32*	7.66	NA	
	10/07	−2.9 ± 1.6*	5.3	NA	
	11/13	−2.1 ± 1.8*	6.0	NA	
	12/09	0.94 ± 1.63*	5.33	NA	
Well 2 - Well Shut Down Throughout 1991. Last sampled December 1990.					
Well 3	01/22	1.7 ± 2.7*	9.0	NA	
	02/13	3.8 ± 3.0*	9.9	NA	
	03/08	−2.6 ± 3.9*	12.8	NA	
	04/03	2.5 ± 3.0*	9.8	NA	
	05/02	7.6 ± 2.7*	8.7	NA	
	06/05	−2.1 ± 3.0*	10.0	NA	
	07/08	−0.37 ± 1.68*	5.53	NA	
	08/14	0.0 ± 1.8*	5.9	NA	
	09/10	3.3 ± 2.6*	8.4	NA	
	10/17	0.99 ± 1.67*	5.47	NA	
	11/21	1.5 ± 1.3*	4.2	NA	
	12/12	2.2 ± 1.9*	6.2	NA	
Well 4	01/22	5.8 ± 3.3*	10.6	NA	
	02/13	4.8 ± 2.9*	9.4	NA	
	03/08	−2.1 ± 2.9*	9.5	NA	
	04/03	−2.5 ± 2.9*	9.6	NA	
	05/02	3.4 ± 2.6*	8.5	NA	
	06/05	−0.45 ± 3.17*	10.5	NA	
	07/08	Not Sampled - Well Down			
	08/14	−3.8 ± 1.7*	5.6	NA	
	09/10	0.0 ± 2.4*	7.9	NA	
	10/17	1.0 ± 2.4*	8.0	NA	
	11/21	−2.1 ± 1.8*	5.9	NA	
	12/12	2.5 ± 2.1*	6.9	NA	

Continued

Table E-1. Continued

Sampling Location	Collection Date	Concentration ± 1s Tritium (pCi/L)	MDC (pCi/L)	Percent of Concentration Guide	Remarks
Well 4 CP-1	01/03	−1.4 ± 2.8*	9.1	NA	
	02/05	4.9 ± 2.4*	8.0	NA	
	03/13	−3.9 ± 3.1*	10.4	NA	
	04/08	3.0 ± 2.4*	8.0	NA	
	05/08	1.4 ± 2.5*	8.1	NA	
	06/03	−3.6 ± 2.3*	7.7	NA	
	07/09	0.56 ± 1.68*	5.51	NA	
	08/06	−4.6 ± 1.6*	5.5	NA	
	09/04	−0.88 ± 2.28*	7.54	NA	
	10/07	−2.5 ± 2.1*	6.9	NA	
	11/13	−2.0 ± 1.7*	5.7	NA	
	12/09	−1.1 ± 1.9*	6.1	NA	
Well 5	01/22	−5.6 ± 2.9*	9.6	NA	
	02/13	1.0 ± 3.0*	9.7	NA	
	03/08	−1.3 ± 3.1*	10.4	NA	
	04/03	−1.8 ± 3.1*	10.2	NA	
	05/02	4.2 ± 2.9*	9.6	NA	
	06/05	2.9 ± 2.9*	9.6	NA	
	07/08	−0.92 ± 1.72*	5.70	NA	
	08/14	−1.6 ± 1.4*	4.7	NA	
	09/10	0.81 ± 2.57*	8.46	NA	
	10/18	4.0 ± 2.7*	8.9	NA	
	11/21	2.2 ± 1.8*	6.0	NA	
	12/12	1.8 ± 1.5*	5.0	NA	
Well 5C	01/03	2.1 ± 3.0*	9.8	NA	
	02/05	2.6 ± 2.3*	7.5	NA	
	03/13	2.0 ± 3.2*	10.6	NA	
	04/08	3.7 ± 2.9*	9.6	NA	
	05/08	3.4 ± 2.0*	6.6	NA	
	06/03	−2.1 ± 2.3*	7.6	NA	
	07/09	0.58 ± 1.74*	5.70	NA	
	08/06	0.0 ± 1.6*	5.2	NA	
	09/04	−1.2 ± 2.0*	6.6	NA	
	10/07	−0.94 ± 1.56*	5.16	NA	
	11/13	−2.7 ± 1.5*	5.2	NA	
	12/09	0.0 ± 1.9*	6.2	NA	
Well 6	09/10	−1.9 ± 1.7*	5.6	NA	(a), New Sampling Location
	10/17	−0.68 ± 2.72*	8.98	NA	
	11/21	1.9 ± 1.6*	5.1	NA	
	12/12	−2.2 ± 1.8*	6.1	NA	

Continued

Table E-1. Continued

Sampling Location	Collection Date	Concentration ± 1s Tritium (pCi/L)	MDC (pCi/L)	Percent of Concentration Guide	Remarks
Well 8	01/03	−0.61 ± 2.46*	8.11	NA	
	02/05	3.5 ± 2.6*	8.5	NA	
	03/13	−8.7 ± 3.5*	11.7	NA	
	04/08	−2.2 ± 3.3*	10.8	NA	
	05/08	−0.73 ± 1.93*	6.37	NA	
	06/03	3.1 ± 2.3*	7.5	NA	
	07/09	2.8 ± 1.8*	5.8	NA	
	08/06	−2.3 ± 1.4*	4.6	NA	
	09/03	1.1 ± 2.0*	6.5	NA	
	10/07	0.0 ± 1.5*	5.0	NA	
	11/13	−0.36 ± 2.52*	8.29	NA	
	12/09	1.4 ± 2.4*	7.7	NA	
Well 20	01/03	−0.71 ± 2.29*	7.55	NA	
	02/05	0.94 ± 1.90*	6.22	NA	
	03/13	1.5 ± 2.6*	8.5	NA	
	04/08	2.3 ± 2.9*	9.6	NA	
		Well Shut Down Remainder of 1991			
Well A - Well Shut Down Throughout 1991. Last Sampled October 1988.					
Well B Test	01/02	128 ± 4	10	0.6	
	02/06	106 ± 3	8	0.5	
	03/13	Not Collected - Pump Locked			
	04/08	121 ± 3	9	0.6	
	05/09	120 ± 3	8	0.6	
	06/04	99 ± 3	7	0.5	
	07/10	110 ± 3	6	0.5	
	08/07	124 ± 3	6	0.6	
	09/17	120 ± 3	9	0.0	
	10/08	Not Sampled - Road Closed			
	11/12	115 ± 2	5	0.6	
	12/10	106 ± 3	6	0.5	
Well C	01/03	11 ± 3	9	0.1	
	02/05	20 ± 2	8	0.1	
	03/13	34 ± 4	11	0.2	
	04/08	62 ± 3	8	0.3	
	05/08	47 ± 3	9	0.2	
	06/03	15 ± 3	9	0.1	
	07/09	17 ± 3	8	0.1	
	08/06	15 ± 2	6	0.1	
	09/03	12 ± 2	7	0.1	
	10/07	8.7 ± 1.9	6.0	<0.1	
	11/13	16 ± 2	6	0.1	
	12/09	19 ± 2	6	0.1	

Continued

Table E-1. Continued

Sampling Location	Collection Date	Concentration ± 1s Tritium (pCi/L)	MDC (pCi/L)	Percent of Concentration Guide	Remarks
Well J-12	01/03	0.20 ± 3.27*	10.8	NA	
	02/05	−0.08 ± 2.41*	7.94	NA	
	03/13	−3.1 ± 3.3*	11.0	NA	
	04/08	2.4 ± 2.8*	9.1	NA	
	05/08	3.9 ± 3.5*	11.6	NA	
	06/03	−4.3 ± 3.4*	11.2	NA	
	07/09	1.9 ± 2.2*	7.1	NA	
	08/06	0.0 ± 1.7*	5.5	NA	
	09/04	−1.0 ± 1.8*	5.9	NA	
	10/07	−2.0 ± 1.6*	5.4	NA	
	11/13	0.0 ± 1.5*	5.0	NA	
	12/09	1.3 ± 2.2*	7.2	NA	
Well J-13	01/03	−3.4 ± 3.0*	9.8	NA	
	02/05	2.1 ± 3.3*	10.8	NA	
	03/13	−1.9 ± 3.1*	10.4	NA	
	04/08	2.3 ± 3.1*	10.1	NA	
	05/08	Not Sampled - Well Down			
	06/03	−2.1 ± 3.0*	9.9	NA	
	07/09	−0.38 ± 1.72*	5.67	NA	
	08/06	−3.5 ± 1.6*	5.3	NA	
	09/04	1.2 ± 2.9*	9.6	NA	
	10/07	3.4 ± 2.5*	8.1	NA	
	11/13	0.0 ± 1.4*	4.5	NA	
	12/09	0.0 ± 1.7*	5.6	NA	
Well UE19C	01/03	3.5 ± 2.6*	8.6	NA	
	02/05	2.9 ± 2.8*	9.3	NA	
	03/13	0.42 ± 2.70*	8.89	NA	
	04/08	2.8 ± 3.5*	11.5	NA	
	05/08	−0.99 ± 2.87*	9.47	NA	
	06/03	−1.8 ± 2.8*	9.2	NA	
	07/09	−1.7 ± 1.6*	5.2	NA	
	08/06	0.0 ± 1.5*	5.0	NA	
	09/03	−0.31 ± 2.24*	7.38	NA	
	10/07	1.7 ± 2.7*	8.8	NA	
	11/13	1.1 ± 1.9*	6.3	NA	
	12/09	0.0 ± 1.5*	5.0	NA	

* = Concentration is less than the minimum detectable concentration (MDC).

NA = Not applicable. Percent of concentration guide is not applicable either because the tritium result is less than the MDC or because the water is know to be nonpotable.

(a) = Additional analyses greater than MDC:

Analysis	Result	1 sigma	MDC	Units
Alpha	8.7	1.8	3.7	pCi/L
Beta	19	2	5	pCi/L
^{234}U	1.6	0.2	0.1	pCi/L
^{235}U	0.063	0.027	0.042	pCi/L
^{238}U	0.51	0.08	0.08	pCi/L

Table E-2. Long-Term Hydrological Monitoring Program 1991 Analytical Results for Nevada Test Site Locations Sampled Semiannually

Sampling Location	Collection Date	Concentration ± 1s Tritium (pCi/L)	MDC (pCi/L)	Percent of Concentration Guide	Remarks
Well 5B - Well Shut Down, Last Sampled July 1988.					
Well 6A Army	04/09	Not Sampled - Generator Down			
	07/11	1.8 ± 1.7*	5.7	NA	Hit Bottom at 1062'
Well 7 Test	01/02	Not Sampled - Road Blocked			
	07/11	−109 ± 125*	414	NA	
Well C-1	04/08	22 ± 4	11	0.1	
	10/07	108 ± 94*	309	NA	
Well D Test	01/02	7.6 ± 2.3	7.4	NA	
	07/10	0 ± 126*	414	NA	
Well HTH-1	06/04	0.88 ± 2.23*	7.32	NA	
	12/16	35 ± 2	6	NA	
Well U3CN-5 - Well Shut Down Throughout 1991. Last sampled December 1981.					
Well UE1C	01/02	0.94 ± 2.34*	7.67	NA	
	07/10	146 ± 126*	414	NA	
Well UE-4T	02/13	Not Sampled - Road Closed			
	09/17	423 ± 132*	430	NA	
Well UE5C	03/13	6.7 ± 3.0*	9.7	NA	
	09/04	256 ± 132*	430	NA	
	10/07	−98 ± 93*	309	NA	
Well UE-6D	03/13	Not Sampled - Instruments in Hole			
	09/10	Not Sampled - Insufficient Water			
Well UE6E	03/13	Not Sampled - No Access			
	09/17	303 ± 132*	430	NA	
Well UE7NS - Well shut down throughout 1991. Last sampled September 1987.					
Well UE15D	04/08	76 ± 3	10	0.4	
	10/07	Not Sampled - Well Down			
Well UE16D	05/08	31 ± 3	9	0.2	
	11/13	0.0 ± 1.6*	5.4	NA	

Continued

Table E-2. Continued

Sampling Location	Collection Date	Concentration ± 1s Tritium (pCi/L)	MDC (pCi/L)	Percent of Concentration Guide	Remarks
Well UE-16F	05/09	11 ± 3	9	0.1	
	11/14	9.9 ± 1.7	5.4	<0.1	
Well UE-17A	05/09	–4.3 ± 2.7*	9.1	NA	
	11/14	2.8 ± 1.6*	5.1	NA	
Well UE18R	06/04	–3.2 ± 2.6*	8.6	NA	
	12/16	–1.2 ± 2.1*	6.8	NA	
Well UE-18T	09/17	156 ± 3	7	0.8	
	12/16	Not Sampled- Road Out			

* = Concentration is less than the minimum detectable concentration (MDC).

NA = Not applicable. Percent of concentration guide is not applicable either because the tritium result is less than the MDC or because the water is know to be nonpotable.

Table E-3. Long-Term Hydrological Monitoring Program 1991 Analytical Results for Locations in the Vicinity of the Nevada Test Site

Sampling Location	Collection Date	Concentration ± 1s Tritium (pCi/L)	MDC (pCi/L)	Percent of Concentration Guide
Amargosa Valley, NV				
Well Mary Nickell's	02/04	0.67 ± 2.40*	7.91	NA
	06/11	0.97 ± 2.42*	7.97	NA
	08/12	206 ± 131*	430	NA
Shoshone, CA				
Shoshone Spring	02/05	33 ± 3	9	0.2
	08/05	314 ± 132*	430	NA
Adaven, NV				
Adaven Spring	01/03	27 ± 4	13	0.1
	07/02	0 ± 126*	414	NA
	08/06	339 ± 132*	430	NA
Alamo, NV				
City Well 4	01/28	5.0 ± 2.4*	7.9	NA
	07/03	109 ± 126*	414	NA
Ash Meadows, NV				
Crystal Pool	05/10	−2.8 ± 2.8*	9.3	NA
	11/19	80 ± 73*	239	NA
Fairbanks Springs	05/10	0.39 ± 2.80*	9.23	NA
	11/14	0 ± 73*	239	NA
Spring-17S-50E-14CAC	06/11	−0.91 ± 2.28*	7.54	NA
	12/02	218 ± 126*	413	NA
Well 18S-51E-7DB	05/10	2.9 ± 2.9*	9.6	NA
	11/19	40 ± 73*	239	NA
Beatty, NV				
Specie Springs	01/10	−445 ± 145*	487	NA
	07/12	1.8 ± 1.7*	5.5	NA
Tolicha Peak	03/05	0 ± 137*	451	NA
	08/07	0.90 ± 1.64*	5.36	NA
Well 11S-48-1DD Coffers	01/10	−145 ± 147*	487	NA
	07/11	0.93 ± 1.76*	5.78	NA
Well 12S-47E-7DBD City	07/02	0.98 ± 1.84*	6.04	NA

Continued

Table E-3. Continued

Sampling Location	Collection Date	Concentration ± 1s Tritium (pCi/L)	MDC (pCi/L)	Percent of Concentration Guide
Beatty, NV (continued)				
Well Road D Spicers	02/19	7.7 ± 3.2*	10.3	NA
	08/07	0.0 ± 1.7*	5.7	NA
Younghans Ranch (House)	06/12	4.2 ± 2.6*	8.4	NA
	12/04	146 ± 126*	413	NA
Boulder City, NV				
Lake Mead Intake	03/11	39 ± 137*	451	NA
	09/05	69 ± 3	10	0.3
	10/08	65 ± 2	6	0.3
Clark Station, NV				
Well 6 TTR	02/12	−47 ± 138*	456	NA
	08/08	0.0 ± 1.6*	5.4	NA
Hiko, NV				
Crystal Springs	07/01	36 ± 126*	414	NA
	08/07	267 ± 132*	430	NA
Indian Springs, NV				
Well 1 Sewer Company	03/04	156 ± 138*	451	NA
	09/03	−2.5 ± 3.0*	9.9	NA
Well 2 US Air Force	03/04	12 ± 137*	451	NA
	09/03	−3.3 ± 2.9*	9.5	NA
Johnnie, NV				
Johnnie Mine Well	03/19	−66 ± 137*	451	NA
	09/03	1.7 ± 1.5*	4.9	NA
Las Vegas, NV				
Well 28 Water District	03/11	39 ± 137*	451	NA
	09/06	0.89 ± 1.58*	5.17	NA
Lathrop Wells, NV				
City 15S-50E-18CDC	04/05	2.6 ± 3.0*	9.9	NA
	10/01	134 ± 94*	309	NA
Nyala, NV				
Sharp's Ranch	02/05	−231 ± 137*	456	NA
	08/08	2.7 ± 1.6*	5.3	NA
Oasis Valley, NV				
Goss Springs	08/07	0.84 ± 1.58*	5.18	NA

Continued

Table E-3. Continued

Sampling Location	Collection Date	Concentration ± 1s Tritium (pCi/L)	MDC (pCi/L)	Percent of Concentration Guide
Pahrump, NV				
Calvada Well	08/05	267 ± 132*	430	NA
Rachel, NV				
Wells 7 & 8 Penoyer	05/07	−127 ± 132*	437	NA
	10/02	0.62 ± 2.47*	8.14	NA
Well 13 Penoyer	04/23	85 ± 135*	442	NA
	05/07	85 ± 133*	6.9	NA
Well Penoyer Culinary	04/01	−72 ± 134*	442	NA
	10/02	−3.8 ± 2.1*	6.9	NA
	10/02	1.0 ± 2.8*	9.3	NA
Tempiute, NV				
Union Carbide Well	02/06	20 ± 138*	456	NA
	09/11	0.89 ± 1.58*	5.20	NA
Tonopah, NV				
City Well	03/05	−90 ± 137*	451	NA
	09/04	−0.91 ± 3.19*	10.5	NA
Warm Springs, NV				
Twin Springs Ranch	04/03	No Sample Collected		
	10/01	-5.0 ± 2.0*	6.8	NA

* = Concentration is less than the minimum detectable concentration (MDC).
NA = Not applicable. Percent of concentration guide is not applicable either because the tritium result is less than the MDC or because the water is know to be nonpotable.

Table E-4. Long-Term Hydrological Monitoring Program 1991 Analytical Results for Project FAULTLESS

Sampling Location	Collection Date	Concentration ± 1s Tritium (pCi/L)	MDC (pCi/L)	Percent of Concentration Guide
Blue Jay, NV				
Hot Creek Ranch Spring	03/19	5.0 ± 3.0*	9.7	NA
Maintenance Station	03/19	-2.4 ± 3.0*	9.8	NA
Well Bias	03/19	0.8 ± 2.6*	8.7	NA
Well HTH-1	03/19	-6.2 ± 3.4*	11.3	NA
Well HTH-2	03/19	-6.7 ± 3.3*	10.9	NA
Well Six Mile	03/19	-6.1 ± 3.5*	11.7	NA

* = Concentration is less than the minimum detectable concentration (MDC).
NA = Not applicable. Percent of concentration guide is not applicable either because the tritium result is less than the MDC or because the water is know to be nonpotable.

Table E-5. Long-Term Hydrological Monitoring Program 1991 Analytical Results for Project SHOAL

Sampling Location	Collection Date	Concentration ± 1s Tritium (pCi/L)	MDC (pCi/L)	Percent of Concentration Guide
Frenchmen Station, NV				
Hunt's Station	02/12	−2.3 ± 2.7*	8.8	NA
Smith/James Sprgs	02/13	67 ± 3	10	0.3
Spring Windmill	02/12	0.0 ± 3.3*	10.9	NA
Well Flowing	02/12	−1.7 ± 3.0*	9.8	NA
Well H-3	02/13	Not Sampled - Pump Inoperative		
Well HS-1	02/13	−1.4 ± 2.5*	8.3	NA

* = Concentration is less than the minimum detectable concentration (MDC).

NA = Not applicable. Percent of concentration guide is not applicable either because the tritium result is less than the MDC or because the water is known to be nonpotable.

Table E-6. Long-Term Hydrological Monitoring Program 1991 Analytical Results for Project RULISON

Sampling Location	Collection Date	Concentration ± 1s Tritium (pCi/L)	MDC (pCi/L)	Percent of Concentration Guide
Rulison, CO				
Lee Hayward Ranch	06/11	187 ± 4	10	0.9
Potter Ranch	06/11	119 ± 4	11	0.6
Robert Searcy Ranch	06/11	63 ± 4	11	0.3
Felix Sefcovic Ranch	06/11	133 ± 4	10	0.7
Grand Valley, CO				
Battlement Creek	06/11	56 ± 3	9	0.3
City Springs	06/11	0.78 ± 3.12*	10.3	NA
Albert Gardner Ranch	06/11	113 ± 4	10	0.6
Spring 300 Yd. N of GZ	06/11	57 ± 3	7	0.3
Well CER Test	06/11	57 ± 2.1	6	0.3

* = Concentration is less than the minimum detectable concentration (MDC).

NA = Not applicable. Percent of concentration guide is not applicable either because the tritium result is less than the MDC or because the water is know to be nonpotable.

Table E-7. Long-Term Hydrological Monitoring Program 1991 Analytical Results for Project RIO BLANCO

Sampling Location	Collection Date	Concentration ± 1s Tritium (pCi/L)	MDC (pCi/L)	Percent of Concentration Guide
Rio Blanco, CO				
B-1 Equity Camp	06/13	60 ± 3	9	0.3
Brennan Windmill	06/12	Not Sampled - Windmill Inoperative		
CER No.1 Black Sulfur	06/13	60 ± 3	9	0.3
CER No.4 Black Sulfur	06/13	62 ± 3	9	0.3
Fawn Creek 1	06/12	27 ± 2	6	0.1
Fawn Creek 3	06/12	30 ± 3	9	0.1
Fawn Creek 500 Ft Upstream	06/12	29 ± 2	6	0.1
Fawn Creek 500 Ft Downstream	06/12	34 ± 2	7	0.2
Fawn Creek 6800 Ft Upsteam	06/12	34 ± 2	7	0.2
Fawn Creek 8400 Ft Downstream	06/12	30 ± 2	7	0.1
Johnson Artesian Well	06/12	−0.94 ± 2.08*	6.88	NA
Well RB-D-01	06/13	−0.30 ± 3.01*	9.92	NA
Well RB-D-03	06/13	0.93 ± 3.12*	10.3	NA
Well RB-S-03	06/13	2.9 ± 2.8*	9.2	NA

* = Concentration is less than the minimum detectable concentration (MDC).

NA = Not applicable. Percent of concentration guide is not applicable either because the tritium result is less than the MDC or because the water is know to be nonpotable.

Table E-8. Long-Term Hydrological Monitoring Program 1991 Analytical Results for Project GNOME

Sampling Location	Collection Date	Concentration ± 1s Tritium (pCi/L)	MDC (pCi/L)	Percent of Concentration Guide	Remarks
Malaga, NM					
Well 1 Pecos Pumping Station	06/24	Not Sampled - No Access			
Well DD-1	06/25	8.8E+07 ± 3.5E+05	4.1E05	NA	(a)
Well LRL-7	06/25	9329 ± 165	414	NA	(b)
Well PHS 6	06/22	41 ± 4	11	0.2	
Well PHS 8	06/22	13 ± 3	10	0.1	Windmill Down - From Stock Tank
Well PHS 9	06/22	−1.1 ± 2.9*	9.6	NA	Windmill Down - From Stock Tank
Well PHS 10	06/22	2.0 ± 3.5*	11.6	NA	
Well USGS 1	06/25	−1.3 ± 3.5*	11.5	NA	
Well USGS 4	06/25	148,300 ± 443	414	NA	(c)
Well USGS 8	06/25	98,580 ± 368	414	NA	(d)
Carlsbad, NM					
Well 7 City	06/24	3.1 ± 3.6*	11.7	NA	
Loving, NM					
Well 2 City	06/22	4.8 ± 3.2*	10.6	NA	

* = Concentration is less than the minimum detectable concentration (MDC).

NA = Not applicable. Percent of concentration guide is not applicable either because the tritium result is less than the MDC or because the water is know to be nonpotable.

(a,b,c,d) = Additional analyses greater than MDC:

	Analysis	Result	1 sigma	MDC	Units
(a)	^{137}Cs	778,000	6050	NA	pCi/L
	^{90}Sr	15300	1265	2720	pCi/L
(b)	^{137}Cs	243	9	NA	pCi/L
	^{90}Sr	5.9	4.3	1.3	pCi/L
(c)	^{137}Cs	15	3	NA	pCi/L
	^{90}Sr	6080	49	13	pCi/L
(d)	^{137}Cs	52	5	NA	pCi/L
	^{90}Sr	4470	43	13	pCi/L

Table E-9. Long-Term Hydrological Monitoring Program 1991 Analytical Results for Project GASBUGGY

Sampling Location	Collection Date	Concentration ± 1s Tritium (pCi/L)	MDC (pCi/L)	Percent of Concentration Guide	Remarks
Gobernador, NM					
Arnold Ranch	06/18	7.1 ± 1.7	5.5	<0.1	
Bixler Ranch	06/18	13 ± 2	6	0.1	Sample from house
Bubbling Springs	06/18	48 ± 2	7	0.2	
Cave Springs	06/16	56 ± 2	5	0.3	
Cedar Springs	06/16	71 ± 2	6	0.4	
La Jara Creek	06/19	40 ± 2	6	0.2	
Lower Burro Canyon	06/19	42 ± 2	5	0.2	
Old School House Well	06/17	4.9 ± 1.9*	6.0	NA	(a), New Sampling Location
Pond N of Well 30.3.32.343	06/18	46 ± 2	6	0.2	
Well EPNG 10-36	06/16	484 ± 4	5	NA	
Well Jicarilla 1	06/19	25 ± 2	5	0.1	Sample from stock tank
Well 28.3.33.233 (South)	06/19	50 ± 2	6	0.2	
Well 30.3.32.343 (North)	06/18	Well Removed			
Windmill 2	06/19	0.94± 1.78*	5.83	NA	

* = Concentration is less than the minimum detectable concentration (MDC).

NA = Not applicable. Percent of concentration guide is not applicable either because the tritium result is less than the MDC or because the water is know to be nonpotable.

(a) = Additional analyses greater than MDC:

Analysis	Result	1 sigma	MDC	Units
^{234}U	1.12	0.08	0.05	pCi/L
^{238}U	0.39	0.04	0.04	pCi/L

Table E-10. Long-Term Hydrological Monitoring Program 1991 Analytical Results for Project DRIBBLE

Sampling Location	Collection Date	Concentration ± 1s Tritium (pCi/L)	MDC (pCi/L)	Percent of Concentration Guide	Remarks
		ONSITE SAMPLING LOCATIONS			
Baxterville, MS					
Half Moon Creek	04/21	19 ± 3	8	0.1	Pre Sample
	04/22	31 ± 3	10	0.1	Post Sample
Half Moon Creek Overflow	04/21	118 ± 3	9	0.6	Pre Sample
	04/22	280 ± 4	10	1.4	Post Sample
Pond West Of GZ	04/21	8.9 ± 2.9*	9.4	NA	Pre Sample
	04/22	9.9 ± 3.8*	12.4	NA	Post Sample
REECO Pit Drainage-A	04/24	20 ± 3	10	0.1	
REECO Pit Drainage-B	04/24	242 ± 5	15	1.2	
REECO Pit Drainage-C	04/24	288 ± 4	10	1.4	
Well E-7	04/23	8.5 ± 3.0*	9.7	NA	
Well HM-1	04/22	1.9 ± 2.7*	8.9	NA	Pre Sample
	04/22	0.0 ± 2.5*	8.3	NA	Post Sample
Well HM-2A	04/22	−2.9 ± 2.6*	8.6	NA	Pre Sample
	04/22	−0.63± 3.33*	11.0	NA	Post Sample
Well HM-2B	04/22	−1.2 ± 2.5*	8.3	NA	Pre Sample
	04/22	−0.19± 2.97*	9.77	NA	Post Sample
Well HM-3	04/22	−4.1 ± 2.7*	8.9	NA	Pre Sample
	04/22	−2.5 ± 3.5*	11.5	NA	Post Sample
Well HM-L	04/22	1282 ±141	442	NA	Pre Sample
	04/22	848 ± 7	12	NA	Post Sample
Well HM-L2	04/22	0.91± 2.88*	9.47	NA	Pre Sample
	04/22	−3.4 ± 3.6*	12.0	NA	Post Sample
Well HM-S	04/21	7530 ±169	442	NA	Pre Sample
	04/23	7644 ±170	442	NA	Post Sample
Well HMH-1	04/21	4962 ±158	442	NA	Pre Sample
	04/22	13,740 ±193	442	NA	Post Sample
Well HMH-2	04/21	7246 ±168	442	NA	Pre Sample
	04/22	14,380 ±196	442	NA	Post Sample
Well HMH-3	04/21	41 ± 3	11	NA	Pre Sample
	04/22	44 ± 3	8	NA	Post Sample
Well HMH-4	04/21	14 ± 3	9	NA	Post Sample
	04/21	18 ± 3	10	NA	Pre Sample
Well HMH-5	04/21	2229 ±145	442	NA	Pre Sample
	04/22	2737 ±148	442	NA	Post Sample
Well HMH-6	04/21	213 ± 4	10	NA	Pre Sample
	04/22	166 ± 3	9	NA	Post Sample
Well HMH-7	04/21	Not Sampled - Well Under Water			
	04/22	Not Sampled - Well Under Water			

Continued

Table E-10. Continued

Sampling Location	Collection Date	Concentration ± 1s Tritium (pCi/L)	MDC (pCi/L)	Percent of Concentration Guide	Remarks
		ONSITE SAMPLING LOCATIONS (Continued)			
Baxterville, MS (Continued)					
Well HMH-8	04/21	16 ± 3	10	NA	Pre Sample
	04/22	22 ± 3	8	NA	Post Sample
Well HMH-9	04/21	128 ± 4	11	NA	Pre Sample
	04/22	147 ± 4	9	NA	Post Sample
Well HMH-10	04/21	91 ± 4	11	NA	Pre Sample
	04/22	35 ± 3	10	NA	Post Sample
Well HMH-11	04/21	22 ± 2	7	NA	Pre Sample
	04/22	21 ± 3	11	NA	Post Sample
Well HMH-12	04/21	16 ± 3	10	NA	Pre Sample
	04/22	17 ± 3	8	NA	Post Sample
Well HMH-13	04/21	18 ± 3	10	NA	Pre Sample
	04/22	19 ± 3	11	NA	Post Sample
Well HMH-14	04/21	16 ± 3	9	NA	Pre Sample
	04/22	11 ± 3	10	NA	Post Sample
Well HMH-15	04/21	18 ± 3	10	NA	Pre Sample
	04/22	8.9 ± 2.5	8.2	NA	Post Sample
Well HMH-16	04/21	31 ± 3	9	NA	Pre Sample
	04/22	38 ± 3	9	NA	Post Sample
Well HT-2C	04/23	18 ± 4	12	NA	
Well HT-4	04/23	7.6 ± 3.0*	9.8	NA	
Well HT-5	04/23	4.2 ± 3.3*	10.7	NA	
		OFFSITE SAMPLING LOCATIONS			
Baxterville, MS					
Little Creek #1	04/23	21 ± 4	12	0.1	
Lower Little Creek #2	04/23	20 ± 3	10	0.1	
Salt Dome Hunting Club	04/24	33 ± 4	13	0.2	
Salt Dome Timber Co.	04/22	26 ± 3	9	0.1	
Anderson Pond	04/22	13 ± 3	10	0.1	
Anderson, Billy Ray	04/22	19 ± 2	8	0.1	
Anderson, Regina	04/22	18 ± 3	10	0.1	
Anderson, Robert Harvey	04/22	16 ± 2	7	0.1	
Anderson, Robert Lowell	04/22	14 ± 2	7	0.1	
	04/22	26 ± 3	10	0.1	
Burge, Joe	04/22	18 ± 3	11	0.1	
Chambliss, B.	04/23	–4.0 ± 2.7*	9.1	NA	
Daniels, Ray	04/22	27 ± 2	8	0.1	

Continued

Table E-10. Continued

Sampling Location	Collection Date	Concentration ± 1s Tritium (pCi/L)	MDC (pCi/L)	Percent of Concentration Guide	Remarks
		OFFSITE SAMPLING LOCATIONS (Continued)			
Baxterville, MS (Continued)					
Daniels, Webster Jr.	04/22	14 ± 3	10	0.1	
Daniels Fish Pond Well #2	04/22	24 ± 2	7	0.1	
Kelly Gertrude	04/22	−3.6 ± 2.2*	7.3	NA	
King, Rhonda	04/22	20 ± 3	10	0.1	
Lee, P. T.	04/22	44 ± 3	9	0.2	
Lowe, M.	04/23	Not Sampled - Now On Rural Water			
Mills, A. C.	04/22	0.50± 2.30*	7.55	NA	
Mills, Roy	04/22	20 ± 2	7	0.1	
Nobles Pond	04/22	21 ± 3	11	0.1	
Noble's Quail House	04/23	48 ± 4	12	0.2	
Noble, W. H., Jr.	04/22	36 ± 3	11	0.2	
Ready, R. C.	04/22	37 ± 2	7	0.2	
Saucier, Dennis	04/22	40 ± 3	10	0.2	
Saucier, Talmadge S.	04/23	28 ± 3	9	0.1	
Saucier, Wilma/Yancy	04/23	1.1 ± 3.3*	11.0	NA	
Smith, Rita	04/22	Not Sampled - Moved, Well Down			
Well Ascot 2	04/23	Not Sampled - Well In Water			
City Well	04/23	33 ± 3	10	0.2	
Columbia, MS					
Dennis, Buddy	04/23	14 ± 2	7	0.1	
Dennis, Marvin	04/23	26 ± 3	9	0.1	(a)
City Well 64B	04/23	17 ± 3	10	0.1	
Lumberton, MS					
Anderson, G. W.	04/22	27 ± 3	8	0.1	
Anderson, Lee L.	04/22	26 ± 3	11	0.1	
Bond, Bradley K.	04/22	28 ± 3	9	0.1	
Cox, Eddie	04/24	36 ± 3	11	0.2	(b)
Gil Ray's Crawfish Pond	04/23	13 ± 3	9	0.1	
Gipson, Herman	04/22	21 ± 2	7	0.1	
Graham, Sylvester	04/23	−2.6 ± 3.3*	11.0	NA	
Moree, Rita-House Well	04/23	4.8 ± 2.3*	7.4	NA	
Beach, Donald	04/22	Not Sampled - Moved, Well Down			
Powers, Sharon	04/22	18 ± 3	9	0.1	
Rushing, Debra	04/24	34 ± 3	10	0.2	
Saul, Lee L.	04/23	−1.3 ± 3.3*	10.8	NA	
Smith, Howard	04/23	0.07± 2.30*	7.57	NA	
Smith, Howard-Pond	04/23	18 ± 2	8	0.1	(c)
Well 2 City	04/23	4.7 ± 2.9*	9.6	NA	

Continued

Table E-10. Continued

Sampling Location	Collection Date	Concentration ± 1s Tritium (pCi/L)	MDC (pCi/L)	Percent of Concentration Guide	Remarks
		OFFSITE SAMPLING LOCATIONS (Continued)			
Purvis, MS					
Burge Willie Ray and Grace	04/22	15 ± 2	8	0.1	
City Supply	04/22	6.4 ± 2.9*	9.4	NA	
Gil, Ray-House Well	04/22	2.6 ± 3.1*	10.1	NA	

* = Concentration is less than the minimum detectable concentration (MDC).

NA = Not applicable. Percent of concentration guide is not applicable either because the tritium result is less than the MDC or because the water is known to be nonpotable.

(a,b,c) = Additional analyses greater than MDC:

	Analysis	Result	1 sigma	MDC	Units
(a)	^{238}U	0.035	0.019	0.033	pCi/L
(b)	^{238}U	0.022	0.011	0.017	pCi/L
(c)	^{234}U	0.054	0.019	0.044	pCi/L
	^{238}U	0.071	0.016	0.016	pCi/L

Table E-11. Long-Term Hydrological Monitoring Program 1991 Analytical Results for Amchitka Island, Alaska

Sampling Location	Collection Date	Concentration ± 1s Tritium (pCi/L)	MDC (pCi/L)	Percent of Concentration Guide	Remarks
BACKGROUND SITES					
Clevenger Lake	09/21	25 ± 3	9	0.1	
Constantine Spring	09/21	42 ± 3	8	0.2	(a)
Constantine Spring-Pump House	09/21	39 ± 2	5	0.2	(b)
RX-Site Pump House	09/24	18 ± 2	5	0.1	(c)
TX-Site Springs	09/24	24 ± 2	6	0.1	(d)
TX-Site Water Tank House	09/24	23 ± 2	6	0.1	(e)
Duck Cove Creek	09/23	19 ± 3	8	0.1	
Jones Lake	09/21	18 ± 2	6	0.1	
Site D Hydro Exploratory Hole	09/23	Not Sampled - Hole Plugged			
Site E Hydro Exploratory Hole	09/23	Not Sampled - Oil in Hole			
Well 1 Army	09/21	28 ± 2	6	0.1	
Well 2 Army	09/23	16 ± 2	5	0.1	
Well 3 Army	09/22	Not Sampled - Hole Plugged			
Well 4 Army	09/23	35 ± 2	6	0.2	
PROJECT CANNIKIN					
Cannikin Lake (North End)	09/21	20 ± 2	6	0.1	
Cannikin Lake (South End)	09/21	24 ± 2	6	0.1	
DK-45 Lake	09/23	23 ± 3	9	0.1	
Ice Box Lake	09/21	22 ± 2	6	0.1	
Pit South of Cannikin GZ	09/21	19 ± 2	6	0.1	
Well HTH-3	09/21	28 ± 2	5	0.1	
White Alice Creek	09/21	18 ± 2	8	0.1	
PROJECT LONG SHOT					
Long Shot Pond 1	09/22	14 ± 3	9	0.1	
Long Shot Pond 2	09/22	21 ± 3	9	0.1	
Long Shot Pond 3	09/22	27 ± 3	9	0.1	
Mud Pit No.1	09/22	192 ± 3	5	NA	
Mud Pit No.2	09/22	243 ± 3	5	NA	
Mud Pit No.3	09/22	282 ± 3	5	NA	
Reed Pond	09/22	23 ± 2	6	0.1	
Stream East-Longshot	09/23	190 ± 3	6	1.0	
Well EPA-1	09/22	17 ± 3	9	0.1	
Well GZ No.1	09/23	1128 ±99	309	NA	
Well GZ No.2	09/23	65 ± 2	6	0.3	
Well WL-1	09/22	17 ± 2	6	0.1	
Well WL-2	09/22	78 ± 2	5	0.4	

Continued

Table E-11. Continued

Sampling Location	Collection Date	Concentration ± 1s Tritium (pCi/L)	MDC (pCi/L)	Percent of Concentration Guide	Remarks
		PROJECT MILROW			
Clevenger Creek	09/22	22 ± 2	7	0.1	
Heart Lake	09/22	15 ± 2	6	0.1	
Well W-2	09/22	18 ± 2	7	0.1	
Well W-3	09/22	16 ± 3	9	0.1	
Well W-4	09/22	Not Sampled - Well Dry			
Well W-5	09/22	15 ± 2	7	0.1	
Well W-6	09/22	17 ± 2	8	0.1	
Well W-7	09/22	19 ± 3	9	0.1	
Well W-8	09/22	20 ± 2	6	0.1	
Well W-9	09/22	Not Sampled - Well In Water			
Well W-10	09/22	22 ± 2	6	0.1	
Well W-11	09/22	44 ± 3	9	0.2	
Well W-12	09/22	Not Sampled - Well In Stream			
Well W-13	09/22	29 ± 2	6	0.1	
Well W-14	09/22	19 ± 2	6	0.1	
Well W-15	09/22	18 ± 2	5	0.1	
Well W-16	09/22	Not Sampled - Well In Water			
Well W-17	09/22	Not Sampled - Well In Water			
Well W-18	09/22	27 ± 2	6	0.1	
Well W-19	09/22	Not Sampled - Well In Water			

* = Concentration is less than the minimum detectable concentration (MDC).

NA = Not applicable. Percent of concentration guide is not applicable either because the tritium result is less than the MDC or because the water is know to be nonpotable.

(a,b,c,d,e) = Additional analyses greater than MDC:

	Analysis	Result	1 sigma	MDC	Units
(a)	Beta	7.0	0.74	1.9	pCi/L
(b)	Alpha	2.9	0.70	1.5	pCi/L
	Beta	7.3	0.75	1.9	pCi/L
(c)	Alpha	1.3	0.34	0.8	pCi/L
	Beta	2.6	0.36	1.0	pCi/L
(d)	Alpha	1.7	0.37	0.7	pCi/L
	Beta	3	0.34	0.8	pCi/L
(e)	Alpha	1.4	0.36	0.8	pCi/L
	Beta	7.2	0.45	0.9	pCi/L

Appendix F

Table F-1. Accuracy of Analysis from EPA Intercomparison Studies

Nuclide	Month	Known Value (pCi/L)[a]	Lab Average (pCi/L)[a]	Percent Bias
		Water Intercomparison Studies		
Alpha	Jan	5.0	ND	
Alpha	April (PE)	54.0	67.33	24.7
Alpha	May	24.0	ND	
Alpha	Sept	10.0	9.00	-10.0
Alpha	Oct (PE)	82.0	97.67	19.1
Beta	Jan	5.0	ND	
Beta	April (PE)	115.0	ND	
Beta	May	46.0	ND	
Beta	Sept	20.0	20.00	0.0
Beta	Oct (PE)	65.0	61.67	-5.1
^{60}Co	Feb	40.0	36.67	-8.3
^{60}Co	June	10.0	ND	
^{60}Co	Oct	29.0	28.67	-1.1
^{60}Co	Oct (PE)	20.0	19.67	-1.6
^{65}Zn	Feb	149.0	141.33	-5.1
^{65}Zn	June	108.0	ND	
^{65}Zn	Oct	73.0	75.67	3.7
^{106}Ru	Feb	186.0	174.33	-6.3
^{106}Ru	June	149.0	ND	
^{106}Ru	Oct	199.0	180.67	-9.2
^{134}Cs	Feb	8.0	7.33	-8.4
^{134}Cs	April (PE)	24.0	18.67	-22.2
^{134}Cs	June	15.0	ND	
^{134}Cs	Oct	10.0	10.0	0.0
^{134}Cs	Oct (PE)	10.0	9.33	-6.7
^{137}Cs	Feb	8.0	8.33	4.1
^{137}Cs	April (PE)	25.0	20.00	-20.0
^{137}Cs	June	14.0	ND	
^{137}Cs	Oct	10.0	10.33	3.3
^{137}Cs	Oct (PE)	11.0	12.00	9.1
^{133}Ba	Feb	75.0	74.67	-0.4
^{133}Ba	June	62.0	ND	
^{133}Ba	Oct	98.0	90.33	-7.8
^{3}H	Feb	4418.0	4613.00	4.4
^{3}H	Oct	2452.0	2499.33	1.9
^{131}I	Feb	75.0	81.67	8.9
^{131}I	Aug	20.0	21.33	6.6
^{226}Ra	Mar	31.8	31.60	-0.6
^{226}Ra	April (PE)	8.0	8.10	1.2
^{226}Ra	July	15.9	ND	
^{226}Ra	Oct (PE)	22.0	ND	

Continued

Table F-1. Continued.

Nuclide	Month	Known Value (pCi/L)[a]	Lab Average (pCi/L)[a]	Percent Bias
		Water Intercomparison Studies		
^{226}Ra	Nov	6.5	ND	
^{228}Ra	Mar	21.1	ND	
^{228}Ra	April (PE)	15.2	11.33	-25.5
^{228}Ra	July	16.7	ND	
^{228}Ra	Oct (PE)	22.2	ND	
^{228}Ra	Nov	8.1	ND	
^{89}Sr	April (PE)	28.0	22.33	-20.2
^{89}Sr	May	39.0	34.33	-12.0
^{89}Sr	Sept	49.0	39.67	-19.0
^{89}Sr	Oct (PE)	10.0	8.33	-16.7
^{90}Sr	April (PE)	26.0	23.33	-10.3
^{90}Sr	May	24.0	24.00	0.0
^{90}Sr	Sept	25.0	23.67	-5.3
^{90}Sr	Oct (PE)	10.0	10.33	3.3
U (Nat)	Mar	7.6	7.67	0.9
U (Nat)	April (PE)	29.8	30.30	1.7
U (Nat)	July	14.2	14.43	1.6
U (Nat)	Oct (PE)	13.5	13.17	-2.4
U (Nat)	Nov	24.9	23.97	-3.7
^{239}Pu	Aug	19.4	18.23	-6.0
		Air Intercomparison Studies		
Alpha	Mar	25.0	ND	
Alpha	Mar	5.0	6.00	20.0
Alpha	Aug	25.0	ND	
Alpha	Aug	10.0	14.00	40.0
Beta	Mar	124.0	ND	
Beta	Mar	31.0	36.67	18.3
Beta	Aug	92.0	ND	
Beta	Aug	62.0	80.33	29.6
^{90}Sr	Mar	40.0	ND	
^{90}Sr	Mar	10.0	11.0	10.0
^{90}Sr	Aug	30.0	29.33	-2.2
^{90}Sr	Aug	20.0	18.67	-6.6
^{137}Cs	Mar	40.0	42.33	5.8
^{137}Cs	Mar	10.0	10.67	6.7
^{137}Cs	Aug	30.0	31.33	4.4
^{137}Cs	Aug	20.0	22.33	11.6
		Milk Intercomparison Studies		
^{89}Sr	Apr	32.0	29.67	-7.3
^{89}Sr	Apr	23.0	18.67	-18.8

Continued

Table F-1. Continued

Nuclide	Month	Known Value (pCi/L)[a]	Lab Average (pCi/L)[a]	Percent Bias
		Milk Intercomparison Studies		
^{89}Sr	Sept	25.0	22.33	-10.7
^{89}Sr	Sept	16.0	12.67	-20.8
^{90}Sr	Apr	32.0	32.00	0.0
^{90}Sr	Apr	23.0	19.67	-14.5
^{90}Sr	Sept	25.0	25.33	1.3
^{90}Sr	Sept	20.0	18.00	-10.0
^{131}I	Apr	60.0	59.33	-1.1
^{131}I	Apr	99.0	98.00	-1.0
^{131}I	Sept	108.0	108.33	0.3
^{131}I	Sept	58.0	63.33	9.2
^{137}Cs	Apr	49.0	45.33	-7.5
^{137}Cs	Apr	24.0	25.33	5.5
^{137}Cs	Sept	30.0	31.67	5.6
^{137}Cs	Sept	20.0	20.33	1.6
K (tot)	Apr	1650.0	1212.67	-26.5
K (tot)	Apr	1550.0	1587.33	2.4
K (tot)	Sept	1740.0	1710.67	-1.7
K (tot)	Sept	1700.0	1754.67	3.2

[a] Values were obtained from the individual intercomparison study reports and are reported with the significant figures included in those reports.

PE = performance evaluation study.

ND = not detected.

Table F-2. Accuracy of Analysis from DOE Intercomparison Studies

Nuclide	Month	EML Value (pCi/L)[a]	EPA Value (pCi/L)[a]	Percent Bias
		Water Intercomparison Studies		
^{144}Ce	Mar	35.1	39.2	11.7
^{144}Ce	Sept	226	214	-5.3
^{57}Co	Mar	230	214	-7.0
^{57}Co	Sept	166	174	4.8
^{60}Co	Mar	201	191	-5.0
^{60}Co	Sept	291	294	1.0
^{137}Cs	Mar	169	163	-3.5
^{137}Cs	Sept	46.0	48.3	5.0
^{3}H	Sept	100	102	2.0
^{54}Mn	Mar	213	206	-3.3
^{54}Mn	Sept	103	104	1.0
^{90}Sr	Sept	10.1	9.93	-1.7
U (Nat)	Sept	0.940	0.949	1.0
^{239}Pu	Sept	0.510	0.480	-5.9
		Air Intercomparison Studies		
^{7}Be	Mar	53.0	47.8	-9.8
^{7}Be	Sept	53.8	56.4	4.8
^{144}Ce	Mar	52.2	52.9	1.3
^{144}Ce	Sept	50.8	56.0	10.2
^{57}Co	Mar	5.82	5.44	-6.5
^{57}Co	Sept	16.6	19.3	16.3
^{60}Co	Mar	5.14	4.92	-4.3
^{60}Co	Sept	23.0	24.5	6.5
^{137}Cs	Mar	4.53	4.70	3.7
^{137}Cs	Sept	28.0	30.1	7.5
^{54}Mn	Mar	4.80	4.85	1.0
^{54}Mn	Sept	24.3	26.4	8.6
^{239}Pu	Sept	0.084	0.087	3.6
		Vegetation Intercomparison Studies		
^{239}Pu	Sept	0.365	0.359	-1.6
		Soil Intercomparison Studies		
^{239}Pu	Sept	7.35	7.22	-1.8

[a] Values were obtained from the Environmental Measurements Laboratory (EML) and reported with the significant figures provided by EML.

Nat = natural.

Table F-3. Comparability of Analysis from Intercomparison Studies[a]

Nuclide	Month	No. of Participating Laboratories	EPA Lab Average (pCi/L)	Grand Average (pCi/L)	Normalized Deviation from Grand Average	Ratio EPA Lab Average/ Grand Average
			Water Intercomparison Studies			
Alpha	Jan	198	ND	5.69	NA	
Alpha	April (PE)	179	67.33	49.71	2.18	1.35
Alpha	May	209	ND	20.94	NA	
Alpha	Sept	207	9.00	10.36	-0.47	0.87
Alpha	Oct (PE)	187	97.67	75.57	1.82	1.29
Beta	Jan	198	ND	6.60	NA	
Beta	April (PE)	179	ND	108.60	NA	
Beta	May	209	ND	44.73	NA	
Beta	Sept	207	20.00	20.30	-0.10	0.99
Beta	Oct (PE)	187	61.67	55.53	1.06	1.11
^{60}Co	Feb	151	36.67	40.04	-1.17	0.92
^{60}Co	June	159	ND	10.69	NA	
^{60}Co	Oct	162	28.67	29.83	-0.40	0.96
^{60}Co	Oct (PE)	187	19.67	20.22	-0.19	0.97
^{65}Zn	Feb	151	141.33	149.71	-0.97	0.94
^{65}Zn	June	159	ND	109.54	NA	
^{65}Zn	Oct	162	75.67	74.57	0.27	1.01
^{106}Ru	Feb	151	174.33	191.83	-1.60	0.91
^{106}Ru	June	159	ND	141.48	NA	
^{106}Ru	Oct	162	180.67	194.21	-1.17	0.93
^{134}Cs	Feb	151	7.33	8.09	-0.26	0.91
^{134}Cs	April (PE)	179	18.67	22.96	-1.49	0.81
^{134}Cs	June	159	ND	14.2	NA	
^{134}Cs	Oct	162	10.0	9.93	0.02	1.01
^{134}Cs	Oct (PE)	187	9.33	9.58	-0.08	0.97
^{137}Cs	Feb	151	8.33	9.06	-0.25	0.92
^{137}Cs	April (PE)	179	20.00	25.49	-1.90	0.78
^{137}Cs	June	159	ND	15.37	NA	
^{137}Cs	Oct	162	10.33	10.86	-0.18	0.95
^{137}Cs	Oct (PE)	187	12.00	12.45	-0.15	0.96
^{133}Ba	Feb	151	74.67	74.14	0.11	1.01
^{133}Ba	June	159	ND	61.37	NA	
^{133}Ba	Oct	162	90.33	95.56	-0.91	0.95
^{3}H	Feb	150	4613.00	4437.54	0.69	1.04
^{3}H	Oct	166	2499.33	2531.91	-0.16	0.99
^{131}I	Feb	120	81.67	77.00	1.01	1.06
^{131}I	Aug	113	21.33	20.96	0.11	1.02
^{226}Ra	Mar	115	31.60	29.45	0.77	1.07
^{226}Ra	April (PE)	179	8.10	7.72	0.55	1.05
^{226}Ra	July	120	ND	15.34	NA	
^{226}Ra	Oct (PE)	187	ND	21.57	NA	
^{226}Ra	Nov	121	ND	6.38	NA	
^{228}Ra	Mar	115	ND	19.14	NA	
^{228}Ra	April (PE)	179	11.33	14.01	-1.22	0.81

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Table F-3. Continued[a]

Nuclide	Month	No. of Participating Laboratories	EPA Lab Average (pCi/L)	Grand Average (pCi/L)	Normalized Deviation from Grand Average	Ratio EPA Lab Average/ Grand Average
			Water Intercomparison Studies (Continued)			
^{228}Ra	July	120	ND	15.63	NA	
^{228}Ra	Oct (PE)	187	ND	21.12	NA	
^{228}Ra	Nov	121	ND	8.19	NA	
^{89}Sr	April (PE)	179	22.33	25.74	-1.18	0.87
^{89}Sr	May	104	34.33	37.43	-1.07	0.92
^{89}Sr	Sept	69	39.67	49.57	-3.43*	0.80
^{89}Sr	Oct (PE)	187	8.33	9.79	-0.51	0.85
^{90}Sr	April (PE)	179	23.33	23.61	-0.10	0.99
^{90}Sr	May	104	24.00	28.85	0.05	0.83
^{90}Sr	Sept	69	23.67	24.72	-0.46	0.96
^{90}Sr	Oct (PE)	187	10.33	10.09	0.08	1.02
U (Nat)	Mar	117	7.67	7.30	0.21	1.05
U (Nat)	April (PE)	179	30.30	28.88	0.82	1.05
U (Nat)	July	127	14.43	13.38	0.61	1.08
U (Nat)	Oct (PE)	187	13.17	13.25	-0.05	0.99
U (Nat)	Nov	90	23.97	23.76	0.12	1.01
^{239}Pu	Aug	61	18.23	19.22	-0.90	0.95
			Air Intercomparison Studies			
Alpha	Mar	165	ND	29.73	NA	
Alpha	Mar	185	6.00	6.25	-0.09	0.96
Alpha	Aug	172	ND	28.33	NA	
Alpha	Aug	179	14.00	12.21	0.62	1.15
Beta	Mar	165	ND	130.11	NA	
Beta	Mar	185	36.67	32.19	1.55	1.14
Beta	Aug	172	ND	95.54	NA	
Beta	Aug	179	80.33	64.66	5.43*	1.24
^{90}Sr	Mar	165	ND	39.3	NA	
^{90}Sr	Mar	185	11.0	9.69	1.51	1.14
^{90}Sr	Aug	172	29.33	29.11	0.08	1.01
^{90}Sr	Aug	179	18.67	19.45	-0.27	0.96
^{137}Cs	Mar	165	42.33	44.61	-0.79	0.95
^{137}Cs	Mar	185	10.67	11.56	-0.31	0.92
^{137}Cs	Aug	172	31.33	32.48	-0.40	0.96
^{137}Cs	Aug	179	22.33	22.70	-0.13	0.98
			Milk Intercomparison Studies			
^{89}Sr	Apr	96	29.67	27.07	0.90	1.10
^{89}Sr	Apr	104	18.67	23.14	-1.55	0.81
^{89}Sr	Sept	95	22.33	20.95	0.48	1.07
^{89}Sr	Sept	98	12.67	13.53	-0.30	0.94
^{90}Sr	Apr	96	32.00	28.02	1.38	1.14

Continued

Table F-3. Continued[a]

Nuclide	Month	No. of Participating Laboratories	EPA Lab Average (pCi/L)	Grand Average (pCi/L)	Normalized Deviation from Grand Average	Ratio EPA Lab Average/ Grand Average
			Milk Intercomparison Studies (Continued)			
^{90}Sr	Apr	104	19.67	22.33	-0.92	0.88
^{90}Sr	Sept	95	25.33	21.09	1.47	1.20
^{90}Sr	Sept	98	18.00	17.57	0.15	1.02
^{131}I	Apr	96	59.33	61.17	-0.53	0.97
^{131}I	Apr	104	98.00	98.49	-0.09	1.00
^{131}I	Sept	95	108.33	108.56	-0.04	1.00
^{131}I	Sept	98	63.33	58.88	1.29	1.08
^{137}Cs	Apr	96	45.33	51.35	-2.08	0.88
^{137}Cs	Apr	104	25.33	24.65	0.24	1.03
^{137}Cs	Sept	95	31.67	31.35	0.11	1.01
^{137}Cs	Sept	98	20.33	21.47	-0.39	0.95
K (tot)	Apr	96	1212.67	1653.09	-9.19*	0.73
K (tot)	Apr	104	1587.33	1548.38	0.86	1.03
K (tot)	Sept	95	1710.67	1667.46	0.86	1.03
K (tot)	Sept	98	1754.67	1713.52	0.84	1.02

[a] Values were obtained from the individual intercomparison study reports and are reported with the significant figures included in those reports.

PE = performance evaluation study.
(Nat) = natural.
ND = not detected.
NA = not applicable.
* = outside control limits.