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NEVADA TEST SITE ANNUAL SITE ENVIRONMENTAL REPORT - 1989

Volume I

Editors: Donald T. Wruble and Elizabeth M. McDowell

November 1990

Work Performed Under
Contract No. DE-AC08-89NV10630

prepared by:

Reynolds Electrical & Engineering Co., Inc.
Post Office Box 98521
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and

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Environmental Monitoring Systems Laboratory
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FOREWORD

Prior to 1989 annual reports of environmental monitoring and assessment results for the Nevada Test Site (NTS) were prepared in two separate parts. Onsite effluent monitoring and environmental monitoring results were reported in an onsite report prepared by the U.S. Department of Energy, Nevada Operations Office (DOE/NV). Results of the offsite radiological surveillance program conducted by the U.S. Environmental Protection Agency (EPA), Environmental Monitoring Systems Laboratory, Las Vegas, Nevada, were reported separately by that Agency.

Beginning with this 1989 annual Site environmental report for the NTS, these two documents are being combined into a single report to provide a more comprehensive annual documentation of the environmental protection program conducted for the nuclear testing program and other nuclear and non-nuclear activities at the Site. The two agencies have coordinated preparation of this combined onsite and offsite report through sharing of information on environmental releases and meteorological, hydrological, and other supporting data used in dose-estimate calculations.

ACKNOWLEDGEMENTS

The skill, dedication, and perseverance of Angela L. McCurdy in word processing and desktop publishing support were crucial to the production of this report. The statistical analyses and advice by Robert R. Kinnison and Lawrence E. Barker were valuable in presenting and interpreting the data. The computer graphics and general production assistance provided by Jeffery L. Kirkwood were also important contributions. Compilation and verification of data, as well as graphics support, were provided by Sheryl L. Pfeuffer and Frank R. Grossman.

The cooperative support of Charles F. Costa and Christopher A. Fontana of the EPA Environmental Monitoring Systems Laboratory, Las Vegas, in production of this combined onsite and offsite environmental report was appreciated.

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MEASUREMENT UNITS AND NOMENCLATURE

Radioactivity data in this report are expressed in curies, microcuries (one millionth of a curie) and picocuries (one millionth of a millionth). The curie (Ci) is the fundamental unit used to express the rate of radiations being produced from atomic nuclei transformations each second. A curie is 37 billion (37×10^9) nuclear transformations per second. The unit of becquerel is also used. A becquerel (Bq) is equal to one disintegration per second; therefore, it takes 3.7×10^{10} bequerels to make one curie.

The roentgen (R) is the fundamental unit used to describe the intensity of gamma radiation at a given measurement point (in air). The radiation exposure rate to external sources of penetrating radioactivity is expressed in milliroentgens per hour (mR/hr), or one-thousandth of a roentgen per hour. A typical radiation exposure rate from natural radioactivity of cosmic and terrestrial sources is 0.03 to 0.05 mR/hr.

The rem (for roentgen equivalent man) is a unit describing radiation dose, or the radiation energy imparted to human tissue when exposed to radiation. Dose is expressed in rem, millirem (mrem), or microrem (µrem). A typical annual dose rate from natural radioactivity (excluding exposure to radon in homes) is 100 to 130 mrem per year. The unit of sievert (Sv) is also used. One sievert is equivalent to 100 rem.

The radionuclides and corresponding symbols used in this report are:

Radionuclide	Symbol
Argon	Ar
Beryllium	Be
Bismuth	Bi
Cesium	Cs
Iodine	I
Krypton	Kr
Lead	Pb
Plutonium	Pu
Polonium	Po
Radon	Rn
Radium	Ra
Ruthenium	Ru
Strontium	Sr
Technetium	Tc
Tritium	^3H
Uranium	U
Xenon	Xe

LIST OF ACRONYMS

AAR	AIHA Asbestos Analysts Registry
AIHA	American Industrial Hygiene Association
AIRFA	American Indian Religious Freedom Act
ALARA	as low as reasonably achievable
ALI	Annual Limit of Intake
ASN	Air Surveillance Network
BECAMP	Basic Environmental Compliance and Monitoring Program
BNA	base/neutral/acid
BOD	biochemical oxygen demand
BWMF	Bulk Waste Management Facility
CAA	Clean Air Act
CAP	College of American Pathologists
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
CLP	Contract Laboratory Program
CRMP	Community Radiation Monitoring Program
COD	chemical oxygen demand
CP	Control Point
DAC	Derived Air Concentration
DCG	Derived Concentration Guide
DNA	Defense Nuclear Agency
DOE	U.S. Department of Energy
DOE/NV	DOE, Nevada Operations Office
DOI	U.S. Department of Interior
DOT	U.S. Department of Transportation
DRI	Desert Research Institute
EA	Environmental Assessment
EG&G	EG&G, Inc.
EMSL-LV	EPA Environmental Monitoring Systems Laboratory, Las Vegas
EOD	Explosive Ordinance Disposal
EPA	U.S. Environmental Protection Agency
ES&H	environment, safety, and health
ESAP	Environmental Survey Action Plan
FIFRA	Federal Insecticide, Fungicide, and Rodenticide Act
GCD	Greater Confinement Disposal
GI	gastrointestinal
GIS	geographical information system
GM	geometric mean
GOES	geostationary operational environmental satellite
HEPA	high-efficiency particulate aerosol
HTO	tritiated water
LANL	Los Alamos National Laboratory
LGFSTF	Liquified Gaseous Fuels Spill Test Facility
LLNL	Lawrence Livermore National Laboratory
LLW	low-level waste
LTHMP	Long-term Hydrological Monitoring Program
MCL	Maximum Contaminant Levels
MSL	mean sea level
MDC	Minimum Detectable Concentration

List of Acronyms, cont.

MSN	Milk Surveillance Network
MWMU	Mixed Waste Management Unit
NAEG	Nevada Applied Ecology Group
NCR	nonconformance report
NEPA	National Environmental Policy Act
NESHAP	National Emission Standards for Hazardous Air Pollutants
NGTSN	Noble Gas and Tritium Surveillance Network
NIOSH	National Institute of Occupational Safety and Health
NIST	National Institute of Standards and Technology
NPDES	National Pollution Discharge Elimination System
NPL	National Priority List
NRC	National Response Center
NTS	Nevada Test Site
NTSO	DOE Nevada Test Site Operations Office
NVLAP	National Voluntary Laboratory Accreditation Program
PAT	NIOSH Proficiency Analytical Testing Program
PCB	polychorinated biphenyl
PIC	pressurized ion chamber
ppb	parts per billion
O&M	Operations and Maintenance
QA	quality assurance
QAP	Quality Assessment Program
QC	quality control
RC	residual chlorine
RCRA	Resource Conservation and Recovery Act
REECo	Reynolds Electrical & Engineering Company, Inc.
RIDP	Radionuclide Inventory and Distribution Program
RPD	relative percent difference
RPT	Radiation Protection Technician
RWMS	Radioactive Waste Management Site
SARA	Superfund Amendments and Reauthorization Act
SDWA	Safe Drinking Water Act
SGZ	surface ground zero
SLB	shallow land burial
SMSN	Standby Milk Surveillance Network
SNL	Sandia National Laboratory
TLD	thermoluminescent dosimeter
TRU	transuranic
TSCA	Toxic Substances Control Act
TSD	Treatment, Storage, and Disposal
TSS	total suspended solids
UCLA	University of California, Los Angeles
UNLV	University of Nevada, Las Vegas
UOR	unusual occurrence report
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
UST	underground storage tank
VOC	volatile organic compound
WIPP	Waste Isolation Pilot Plant
WSC	waste storage cell

1.0 INTRODUCTION

Donald T. Wruble

The NTS, located in Southern Nevada, has been the primary location for testing of nuclear explosives in the continental U.S. since 1951. During 1989, 12 underground nuclear tests at the NTS were announced by the DOE. Historical testing has included atmospheric testing in the 1950s and early 1960s, earth-cratering experiments, and open-air nuclear reactor and engine testing. Limited non-nuclear testing has included spills of hazardous material at the Liquified Gaseous Fuels Spill Test Facility. Radioactive and mixed waste disposal facilities for U.S. defense waste are also operated on the NTS. The NTS environment is characterized by desert valley and Great Basin mountain terrain and topography, with a climate, flora, and fauna typical of the Great Basin deserts of the southwest. The restricted access provided by the remote location of the NTS and adjacent U.S. Air Force lands, coupled with a lack of surface water and great depths to slow-moving groundwaters, afford environmental protection of surrounding residents to potential radiation exposures from releases of radioactivity or other contaminants as a result of nuclear testing operations. Population density within 150 kilometers of the NTS is only 0.5 persons per square kilometer, versus approximately 29 persons per square kilometer in the 48 contiguous states. The predominant land use surrounding the NTS is open range used for livestock grazing, with scattered mining and recreational areas.

1.1 NEVADA TEST SITE DESCRIPTION

The NTS is operated by the DOE as the on-continent test site for nuclear weapons testing. The NTS is located in Nye County, Nevada, with the southeast corner lying about 90 kilometers (56 miles) northwest of the city of Las Vegas, Nevada, as shown in Figure 1.1[a]. The NTS encompasses about 3500 square kilometers (1350 square miles), an area larger than the state of Rhode Island, and varies from 46 to 56 kilometers (28 to 35 miles) in width (eastern to western border) and from 64 to 88 kilometers (40 to 55 miles) in length (northern to southern border).

The NTS is surrounded on the east, north, and west sides by public access exclusion areas consisting of the Nellis Air Force Base Bombing and Gunnery Range and the Tonopah Test Range. This area provides a buffer zone between the test areas and public lands. This buffer area varies from 24 to 104 kilometers (15 to 65 miles) between the test areas and public lands. The combination of the U.S. Air Force range complex and the NTS is one of the larger unpopulated land areas in the U.S., comprising some 14,200 square kilometers (5470 square miles).

Figure 1.2 shows the general layout of the NTS, with the location of major facilities and area numbers referred to in this report.

(a) This figure and other figures in this chapter were generated with a computer-based geographical information system (GIS). GIS-generated graphics in this report were prepared by EG&G Energy Measurements, Inc., Las Vegas, Nevada. (See the bibliographic data listing at the end of this volume for sources.)

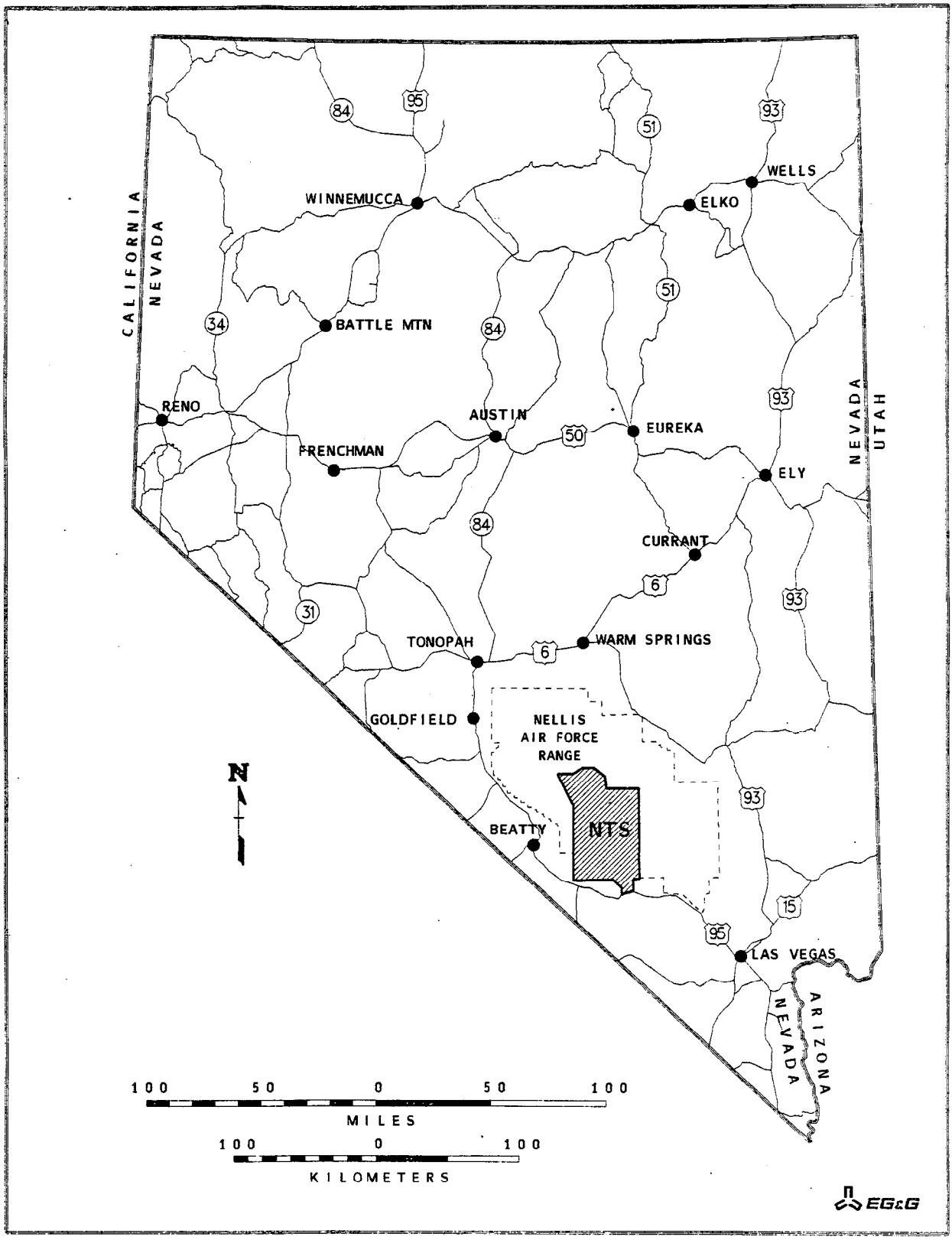

Figure 1.1 NTS Location

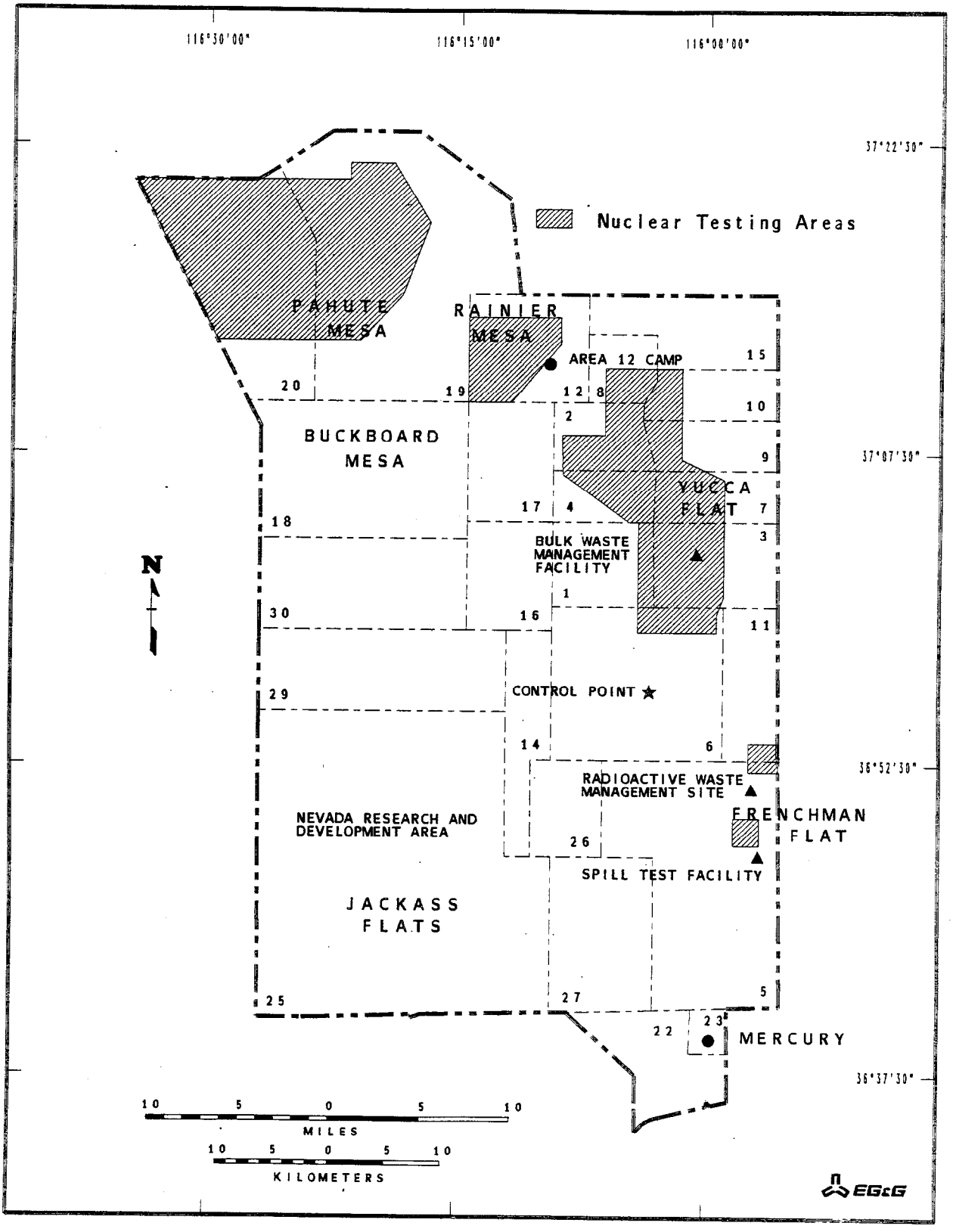

Figure 1.2 NTS Area Designations, Principal Facilities, and Testing Areas

The shaded areas indicate the principal geographical areas used for underground nuclear testing over the history of test site operations. Mercury, Nevada, at the southern end of the NTS, is the main base camp for worker housing and administrative operations for the Site. Area 12 Base Camp, at the northern end of the Site, is the other major worker housing and operations support facility on the Site.

1.2 MISSION AND NATURE OF OPERATIONS

The NTS has been the primary location for testing the nation's nuclear explosive devices since January 1951. Nuclear explosive tests conducted through the 1950s were predominantly atmospheric tests. These tests involved placing a nuclear explosive device on the ground surface or on a steel tower, suspending it from tethered balloons, or dropping it from aircraft.

Underground tests were first conducted in 1957. Testing was discontinued during a moratorium from October 1958 through September 1961. Four small atmospheric (surface) tests were conducted in 1961 and 1962 following the resumption of underground and atmospheric testing. Since late 1962 nearly all tests have been conducted in sealed vertical shafts drilled into the valley floor of Yucca Flat and the top of Pahute Mesa or in horizontal tunnels mined into the face of Rainier Mesa. Six earth-cratering (shallow burial) tests were conducted over the period of 1962 through 1968; five on or near Buckboard Mesa in Area 18 and the largest (SEDAN) at the northern end of Yucca Flat.

Other nuclear testing over the history of the NTS has included the Bare Reactor Experiment - Nevada series of experiments in the 1960s. This facility consisted of a 14-MeV neutron generator mounted on a 465-meter (1527-foot) steel tower to conduct neutron and gamma-ray interaction studies on shielding materials, electronic components, live organisms, and tissue-equivalent simulations for biomedical and environmental research. From 1959 through 1973, a series of open-air nuclear reactor, nuclear engine, and nuclear furnace tests were conducted in Area 25 at the Nuclear Rocket Development Station (now the Nevada Research and Development Area).

Limited non-nuclear testing has also occurred at the NTS, including spills of hazardous materials at the Liquified Gaseous Fuels Spill Test Facility in Area 5. These tests, conducted during the latter half of the 1980s, involved controlled spilling of liquid materials to study spill control and mitigation measures, and dispersion and transport of airborne clouds resulting from these spills. These tests are cooperative studies involving private industry, the Department of Transportation (DOT), and the DOE.

Waste disposal facilities for radioactive and mixed waste are also operated on the NTS for DOE defense waste disposal. Disposal sites are located in Area 5 and in Area 3. At the Area 5 Radioactive Waste Management Site (RWMS), low-level radioactive waste from DOE-affiliated onsite and offsite generators, and mixed waste from one offsite generator, are disposed of using standard shallow land disposal techniques. The Greater Confinement Disposal facility, consisting of a 10-foot diameter shaft 120 feet deep, is located at the Area 5 RWMS for experimental disposal of wastes not suited for shallow land burial because of high specific activity or potential for migration into biopathways.

Transuranic wastes are retrievably stored in surface containers at the Area 5 RWMS pending shipment to the Waste Isolation Pilot Plant facility in New Mexico. Nonradioactive hazardous wastes are also accumulated at the Area 5 RWMS before shipment to an offsite disposal facility. At the Area 3 Bulk Waste Management Site, only low-level radioactive waste in bulk form (such as debris collected from atmospheric nuclear test locations) is emplaced and buried in surface subsidence craters produced by underground nuclear tests.

1.3 1989 TEST ACTIVITIES

The underground nuclear tests conducted during 1989 (the period covered by this annual NTS environmental report) were designed and conducted by three national laboratories. The Lawrence Livermore National Laboratory (LLNL) of Livermore, California, and the Los Alamos National Laboratory (LANL) of Los Alamos, New Mexico, conducted tests in support of DOE nuclear testing program objectives. The Sandia National Laboratory of Albuquerque, New Mexico, supported tests conducted by the Defense Nuclear Agency (DNA), which uses the NTS as a nuclear testing facility under an agreement with the DOE.

The DOE announced 12 underground nuclear tests at the NTS during 1989. A list of these tests is provided in Table 1.1. A summary of the environmental monitoring observations for each of these tests is provided in Section 5.1.

Underground testing is carefully designed to ensure containment of the explosive energy and radioactivity resulting from each nuclear explosion. After the nuclear device and related diagnostic equipment are lowered into the prepared vertical shaft or emplaced in the excavated tunnel, the hole or tunnel is closed with a containment system. Vertical holes are backfilled with sand and gravel, including three to six solid plugs spaced throughout (referred to as "stemming"), to enhance containment capabilities. Stemming and plugs are used as seals against leakage of gases to the atmosphere.

The stemming material in tunnel tests normally consists of rock-matching grout (concrete) emplaced close to the device backed up by varying types, amounts, and combinations of grout and other stemming materials. Some tests may include a "line-of-sight" pipe with mechanical closure systems in the pipe to contain radioactivity. In addition, several large concrete and steel plugs block the tunnel between the experimental area and the portal to afford added protection against the possibility of gas escaping from the stemmed area.

During and following each test, both onsite and offsite monitoring are conducted to document radioactivity that might be released to the atmosphere. Releases might occur immediately following a test as a result of dynamic release of material through cracks, fissures, or the containment system (venting); during later hours, days, or weeks as a result of slow transfer of

Table 1.1 Announced Underground Nuclear Tests at the NTS - 1989

Test Name	Date	Test Organization
TEXARKANA	02/10	LANL
KAWICH	02/24	LLNL
INGOT	03/09	LLNL
PALISADE	05/15	LLNL
TULIA	05/26	LANL
CONTACT	06/22	LLNL
AMARILLO	06/27	LANL
DISKO ELM	09/14	DNA
HORNITOS	10/31	LLNL
MULESHOE	11/15	LANL
BARNWELL	12/08	LLNL
WHITEFACE	12/20	LANL

gases through the soil and rock overburden (seepage); or through controlled releases as part of post-test diagnostic and sampling operations. The onsite effluent detection and monitoring systems, the onsite and offsite environmental surveillance systems, and the 1989 results from these monitoring efforts are described in this report.

1.4 TOPOGRAPHY AND TERRAIN

The topography of the NTS is typical of much of the Basin and Range physiographic province of Nevada, Arizona, and Utah. North-south trending mountain ranges are separated by broad, flat-floored, and gently-sloped valleys. The topography is depicted in Figure 1.3. Elevations range from about 910 meters (3000 feet) above MSL in the south and east, rising to 2100 meters (6900 feet) in the mesa areas toward the northern and western boundaries. The slopes on the upland surfaces are steep and dissected, whereas the slopes on the lower surfaces are gentle and alluviated with rock debris from the adjacent highlands.

The principal effect upon the terrain from nuclear testing has been the creation of numerous dish-shaped surface subsidence craters, particularly in Yucca Flat. Most underground nuclear tests conducted in vertical shafts produced surface subsidence craters caused when the overburden above the nuclear cavity collapsed and formed a rubble "chimney" to the surface (Figure 1.4). A few craters have been caused from tests conducted on or near the surface during atmospheric testing, from shallow depth-of-burial cratering experiments, or from tunnel events.

There are no flowing streams on the NTS. Surface drainages for the Yucca Flat and Frenchman Flat are in closed-basin systems, draining onto the dry lake beds (playas) in each valley. The remaining area of the NTS drains via arroyos and dry stream beds that carry water only during unusually intense or persistent storms. Rainfall or snow melt typically infiltrates quickly into the moisture-deficient soil or runs off in normally dry channels, where it seeps into permeable sands and gravels. During extreme conditions, flash floods may occur. The surface drainage channel pattern for the NTS and its immediate vicinity is displayed in the GIS graphic shown in Figure 1.5.

The northern portions of the NTS have integrated channel systems which carry runoff beyond NTS boundaries onto the Nellis Air Force Base range complex and into the closed basins and playas in Kawich Valley and Gold Flat.

The western half and southernmost part of the NTS have channel systems which carry runoff from intense storms toward the normally dry Amargosa River channel. This channel ultimately drains into Death Valley, California.

1.5 GEOLOGY

The basic lithologic structure of the NTS is depicted in the GIS-generated graphic shown in Figure 1.6. Investigations of the geology of the NTS, including detailed studies of numerous drill holes and tunnels, have been in progress by the U.S. Geological Survey and other organizations since 1951. As a result the geology of the NTS is probably one of the better characterized large areas within the U.S. The distribution of drill holes is shown in Figure 1.7.

In general the geology consists of three major rock units. These are: (1) complexly folded and faulted sedimentary rocks of Paleozoic age overlain at many places by (2) volcanic tuffs and lavas of Tertiary age, which (in the valleys) are covered by (3) alluvium of late Tertiary and Quanternary age. The sedimentary rocks of Paleozoic age are many thousands of feet thick and are comprised mainly of carbonate rocks (dolomite and limestone) in the upper and lower parts, separated by a middle section of clastic rocks (shale and quartzite). The volcanic rocks in the valleys are down-dropped and tilted along steeply dipping normal faults of late Tertiary age. The alluvium is rarely faulted. Compared to the

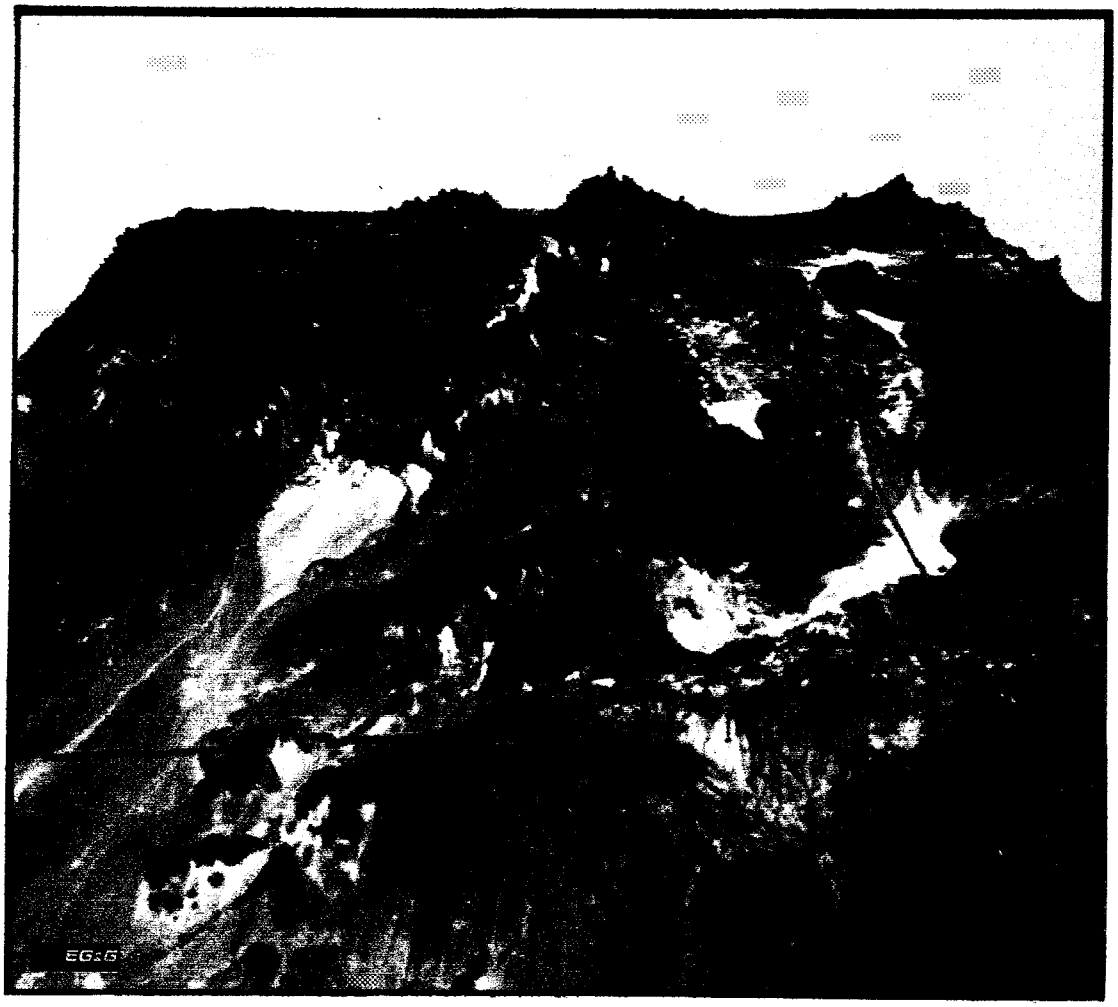

Figure 1.3 Topography of the NTS and Vicinity

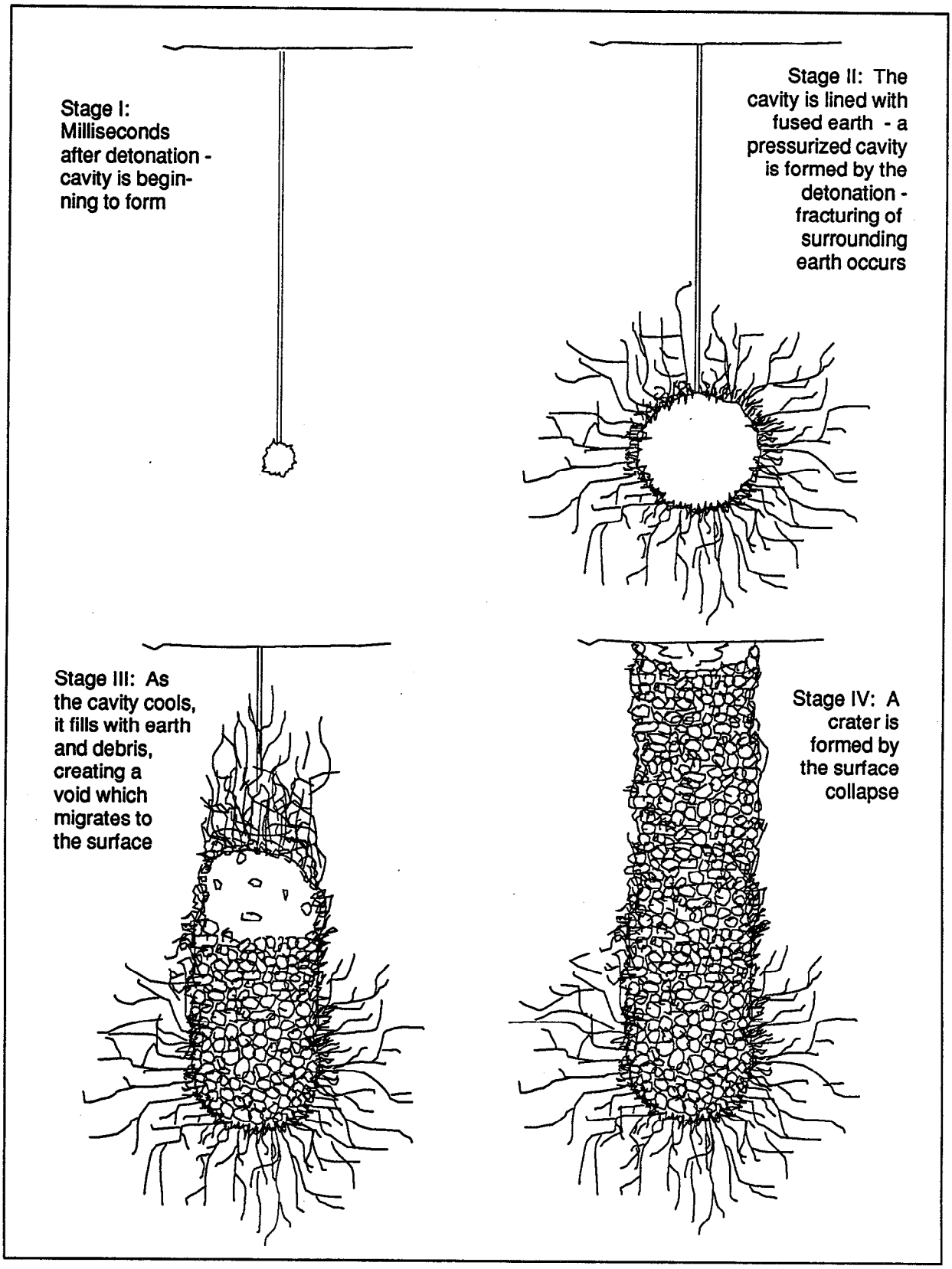

Figure 1.4 Formation of an Underground Nuclear Explosive Test Cavity, Rubble Chimney, and Surface Subsidence Crater

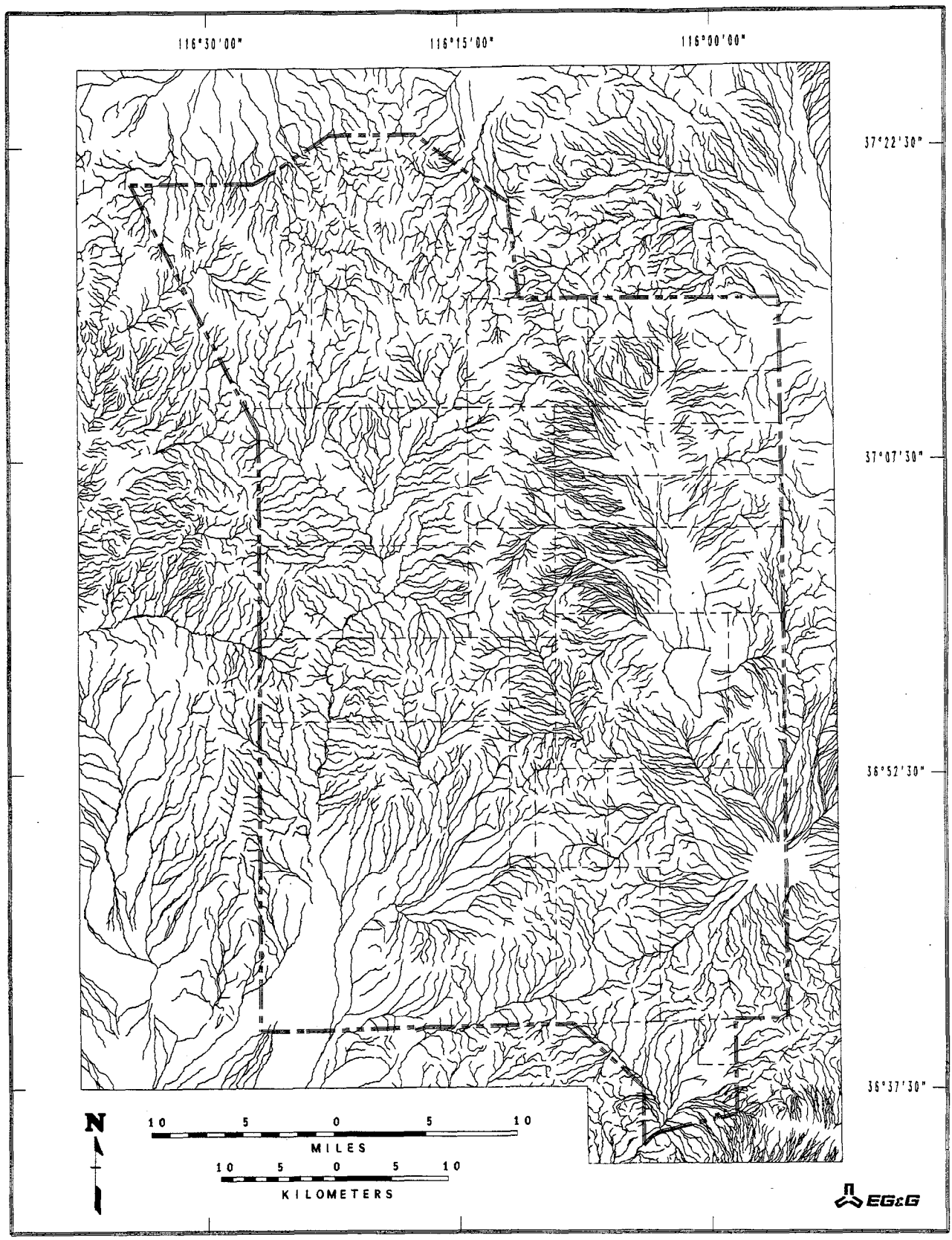

Figure 1.5 Surface Drainage Channel Pattern for the NTS

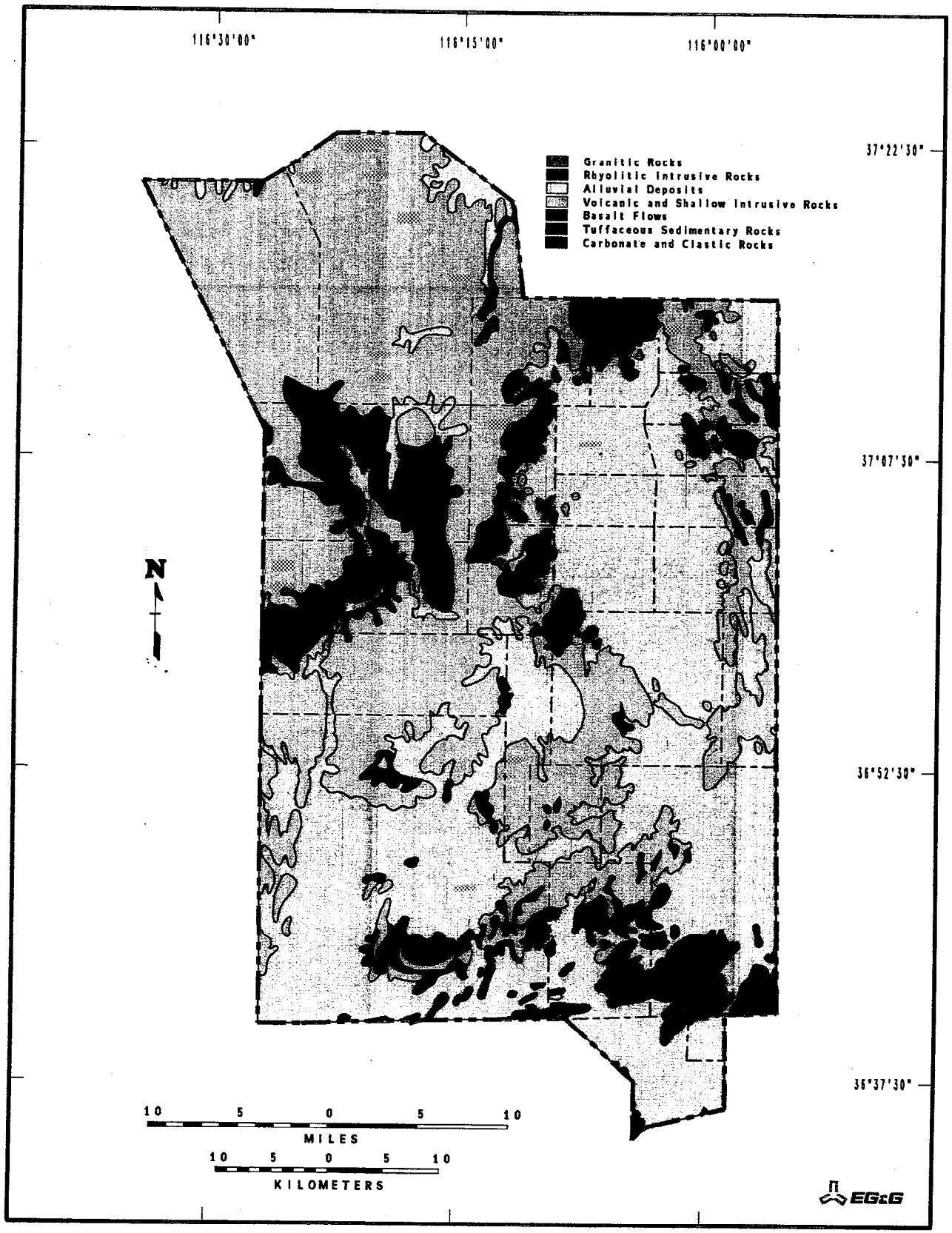

Figure 1.6 Basic Lithologic Structure of the NTS

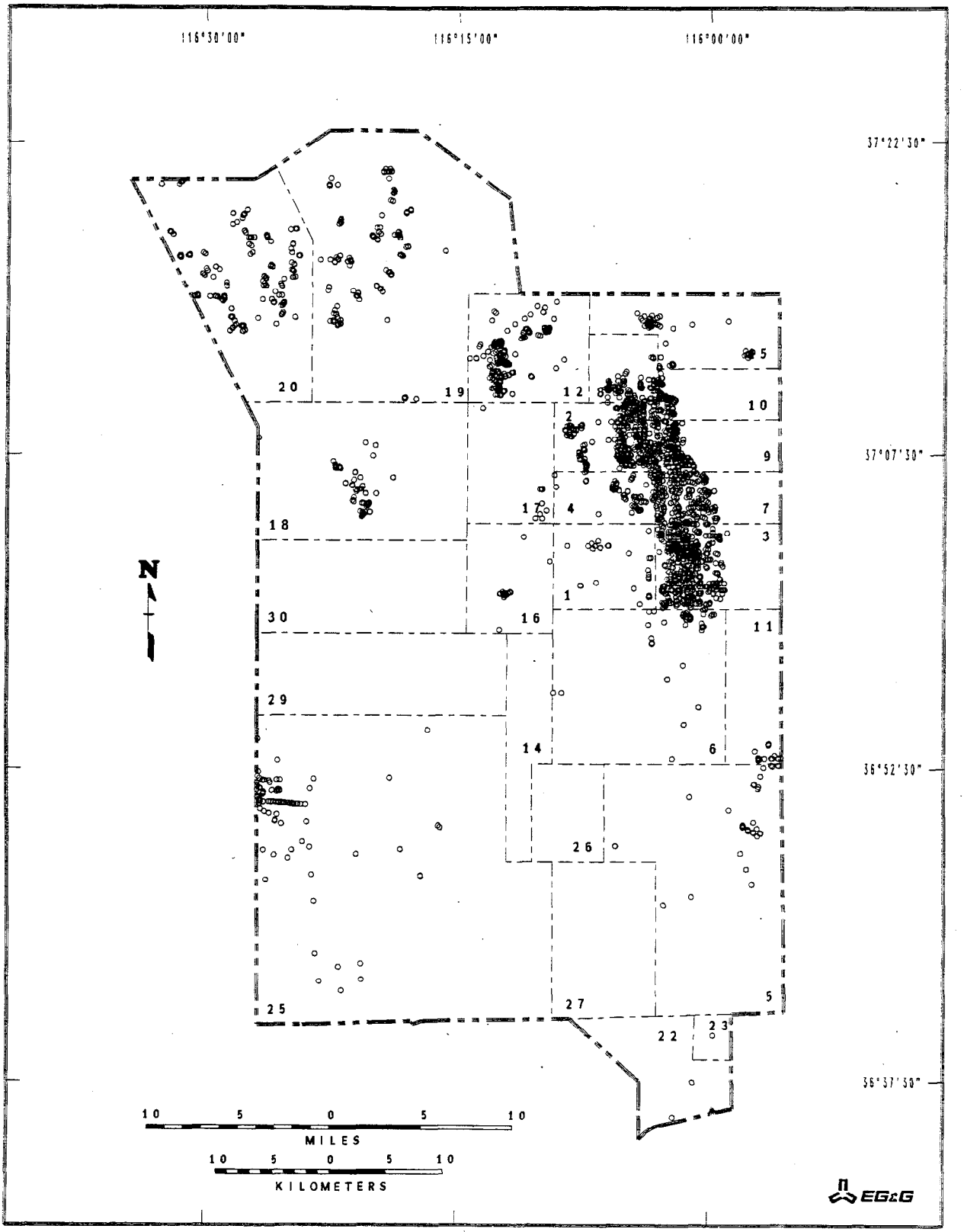

Figure 1.7 Drill Hole Locations on the NTS

Paleozoic rocks, the Tertiary rocks are relatively undeformed, and dips generally are gentle. The alluvium is derived from erosion of the nearby hills of Tertiary and Paleozoic rocks.

The volcanic rocks of Tertiary age are predominantly tuffs, which erupted from various volcanic centers, and lavas, mostly of rhyolitic composition. The aggregate thickness of the volcanic rocks is many thousands of feet, but in most places the total thickness of the section is far less because of erosion or nondeposition. These materials erupted before the collapse of large volcanic centers known as *calderas*. Alluvial materials fill the intermountain valleys and cover the adjacent slopes. They attain thickness of 600 to 900 meters (2000 to 3000 feet) in the central portions of the valleys. The alluvium in Yucca Flat is vertically offset along the prominent north-south-trending Yucca fault.

1.6 HYDROGEOLOGY

Some nuclear tests are conducted below the groundwater table; the others are at varying depths above the groundwater table. Great depths to the groundwater table and the slow velocity of water movement in the saturated and unsaturated zones beneath the NTS are of particular significance in terms of low potential for radioactivity transport from these tests or from shallow burial waste disposal sites to offsite areas. The deep aquifers, slow groundwater movement, and exceedingly slow downward movement of water in the overlying unsaturated zone serve as significant barriers to transport of radioactivity from underground sources via groundwater, preventing movement of radioactivity to offsite areas for thousands of years. Transport of radioactivity from surface sources have been estimated to take on the order of one to three million years (DOE 1989).

Depths to groundwater beneath NTS vary from about 200 meters (660 feet) beneath valleys in the southern part of the NTS to more than 625 meters (2050 feet) beneath part of Pahute Mesa. In the eastern portions of the NTS, the water table occurs generally in the alluvium and volcanic rocks above the regional carbonate aquifer. The flow in the shallower parts of the groundwater body is generally toward the major valleys (Yucca and Frenchman) where it deflects downward to join the regional drainage in the carbonate aquifer to the southwest. A GIS-generated depiction of the general NTS groundwater table is shown in Figure 1.8.

In the Pahute Mesa system, there is no deeply underlying aquifer similar to the carbonate aquifer. The strata beneath the mesa consist of a complex series of interbedded volcanic rocks with extreme contrast in hydraulic conductivity both laterally and vertically. Much of the water beneath Pahute Mesa is laterally-moving underflow from recharge regions to the north through interconnected zones of high hydraulic conductivity.

The estimated average velocity of groundwater flow through the lower carbonate aquifer in central Yucca Flat is from 2 to 180 meters (6 to 600 feet) per year (DOE 1989). Using the higher value as an average velocity, the transit time for water to reach Frenchman Flat is more than a century.

Vertical flow through the volcanic rocks beneath Yucca and Frenchman valleys is retarded by the bedded and zeolitized tuffs, which limit downward flow rates to less than 0.05 meters (0.2 feet) per year (DOE 1989). Assuming that the tuff aquitard beneath Yucca Flat has an average saturated thickness of 305 meters (1000 feet), the fastest time for water to move vertically from the top to the bottom of the tuff aquitard is about 6000 years.

Vertical flow in the near-surface portion of the unsaturated zone (vadose zone) of Frenchman Flat has been calculated to be upward because of evapotranspiration rates being higher than precipitation rates in the desert environment. Studies by the U.S. Geological Survey have shown potential annual evapotranspiration from standing water surfaces to range from 60 to 82

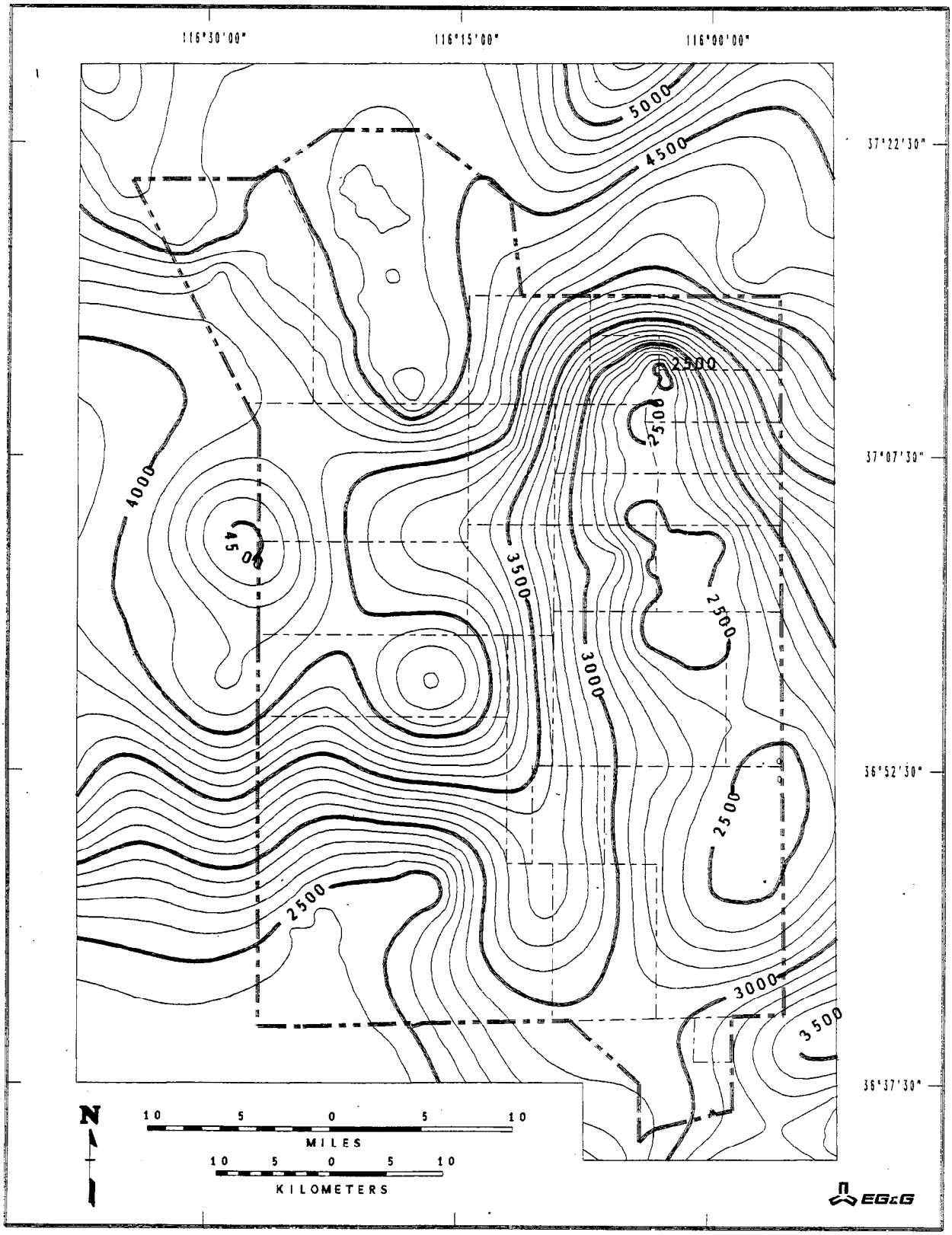

Figure 1.8 Groundwater Table Elevations at the NTS [measured in feet above mean sea level (MSL)]

inches, or roughly 15 times the annual precipitation (Winograd et al. 1971). Studies by the Desert Research Institute indicate a zone of no detectable vertical movement at a depth of approximately seven feet (Kearl 1982). Other studies have estimated the average downward travel time of water in the unsaturated zone from the surface to the water table in Yucca Flat to be on the order of two to three million years (Winograd and Thordarson 1975).

The hydrogeologic units at the NTS occur in three groundwater subbasins in the Death Valley groundwater basin. The actual subbasin boundaries are poorly defined, as shown in Figure 1.9. Groundwater beneath the eastern part of the NTS is in the Ash Meadows subbasin, defined by discharge through evapotranspiration along a spring line in Ash Meadows (south of the NTS). Most of the western NTS is in the Alkali Flat/ Furnace Creek Ranch subbasin, which discharges by evapotranspiration at Alkali Flat and by spring discharge near Furnace Creek Ranch. Groundwater beneath the far northwestern corner of the NTS may be in the Oasis Valley subbasin, discharging by evapotranspiration at Oasis Valley.

Some underflow past all of the subbasin discharge areas probably travels to springs in Death Valley. Recharge for all of the subbasins most likely occurs by precipitation at higher elevations and infiltration along stream courses and in playas. Regional groundwater flow is from the upland recharge areas in the north and east toward discharge areas at Ash Meadows and Death Valley, southwest of the Site. Due to the large topographic changes across the area and the importance of fractures to groundwater flow, local flow directions can be radically different from the regional trend.

Groundwater is the only local source of drinking water in the NTS area. Drinking and industrial water-supply wells for the NTS produce from the lower and upper carbonate aquifers, the volcanic aquifer, and the valley-fill aquifer. Though a few springs emerge from perched groundwater lenses at the NTS, discharge rates are low, and spring water is not currently used for DOE activities. South of the NTS, private and public supply wells are completed in the valley-fill aquifer.

1.7 CLIMATE AND METEOROLOGY

Precipitation and subsequent surface runoff have little to no role in transport of radionuclides to the offsite environment. Annual precipitation in Southern Nevada is very light and depends largely upon elevation. A characteristic of desert climates is the temporal and spatial variability of precipitation. Topography contributes to this variability. For example, on the NTS, the mesas receive an average annual precipitation of nine inches, which includes wintertime snow accumulations. The lower elevations receive approximately six inches of precipitation annually, with only occasional snow accumulations lasting a matter of days.

Precipitation usually falls in isolated showers, with large variations in precipitation amounts within a shower area. Summer precipitation occurs mainly in July and August, when intense heating of the ground below moist air masses transported northward from the tropical Pacific Ocean through the Gulf of California and into the desert southwest triggers thunderstorm development. On occasion a tropical storm will move northeastward from the west coast of Mexico, bringing widespread heavy precipitation to Southern Nevada during September and/or October.

Elevation also influences temperatures on the NTS. At an elevation of 6565 feet above MSL in Area 20 on Pahute Mesa, the average daily maximum/minimum temperatures are 40°/28°F in January and 80°/62°F in July. In Area 6 (Yucca Flat, 3924 feet MSL), the average daily maximum/minimum temperatures are 51°/21°F in January and 96°/57°F in July. The extreme temperatures at Mercury are 69°/12°F in January and 109°/59°F in July.

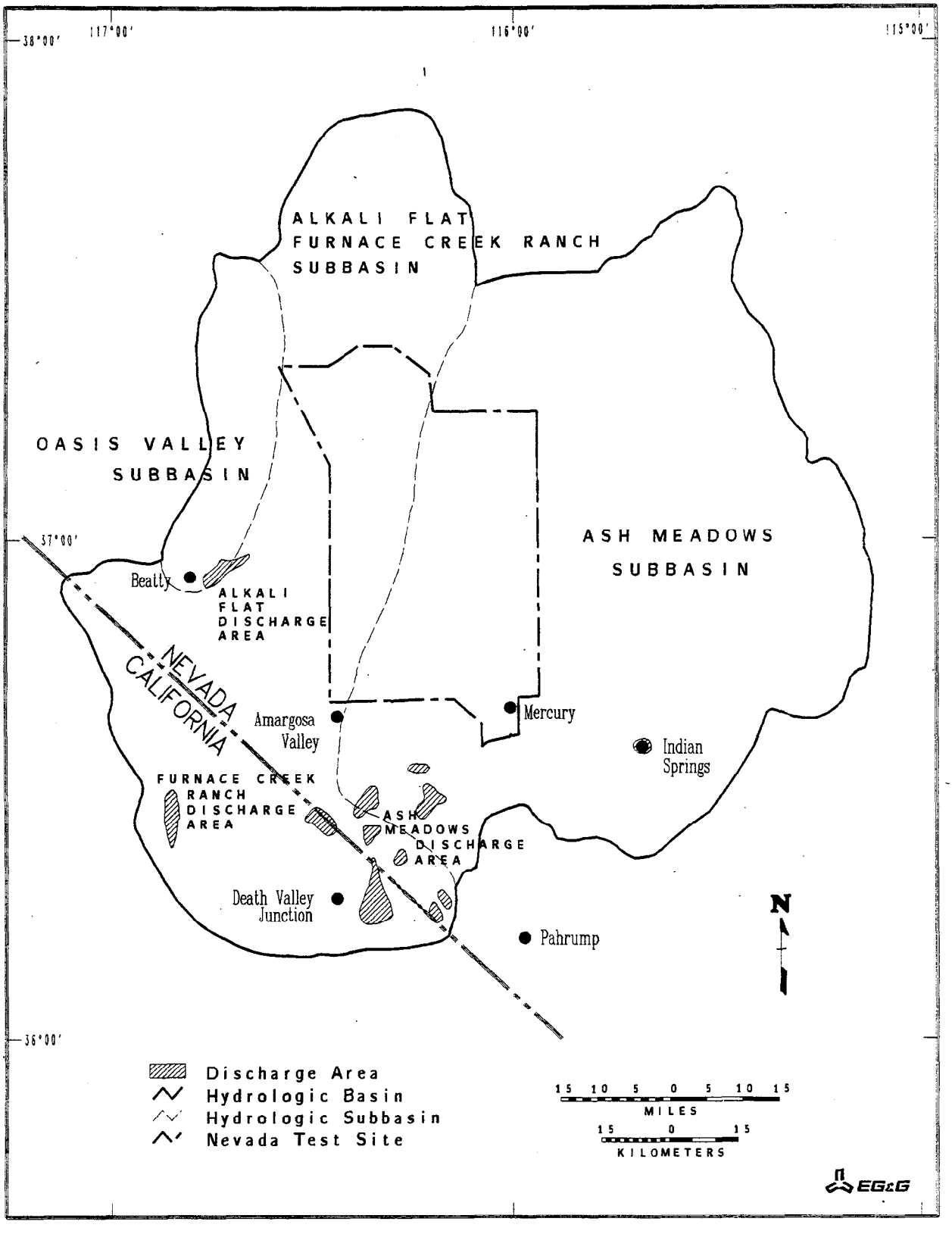

Figure 1.9 Groundwater Hydrologic Units of the NTS and Vicinity

Wind direction and wind speed is an important aspect of the environment at the NTS. These are major factors in planning and conducting nuclear tests, where atmospheric transport is the primary potential route of contamination transport to onsite workers and offsite populations.

The movements of large-scale pressure systems control the seasonal changes in the wind direction frequencies. Predominating winds are southerly during summer and northerly during winter. The general downward slope in the terrain from north to south results in an intermediate scenario that is reflected in the characteristic diurnal wind reversal from southerly winds during the day to northerly winds at night. This north/south reversal is strongest in the summer and, on occasion, becomes intense enough to override the wind regime associated with large-scale pressure systems. This scenario is very sensitive to the orientation of the mountain slopes and valleys.

At the higher elevations in Area 20, the average annual wind speed is 10.5 miles per hour (mph). The prevailing wind direction during winter months is from north-northeast, and, during summer months, winds prevail from the south. In Yucca Flat, the average annual wind speed is 7 mph. The prevailing wind direction during winter months is north-northwest and during summer months is south-southwest. At Mercury the average annual wind speed is 8 mph, with a prevailing wind direction of northwest during the winter months and southwest during the summer months. The 1989 ten-meter wind roses for the NTS are shown in Figure 1.10.

1.8 FLORA AND FAUNA

The greater part of the NTS is vegetated by various associations of desert shrubs typical of the Mojave or Great Basin Deserts, or the zone of transition desert between these. There are areas of desert woodland (pinyon-juniper) at higher elevations. Even there typical Great Basin shrubs, principally sagebrushes, are a conspicuous component of the vegetation. Although shrubs, or shrubs and small trees, are the dominant forms, herbaceous plants are well represented in the flora and play an important role in supporting animal life.

Extensive floral collection has yielded 711 taxas of vascular plants within or near the boundaries of the NTS (O'Farrell and Emery 1976) Associations of creosote bush, *Larrea tridentata*, which are characteristic of the Mojave Desert, dominate the vegetation mosaic on the bajadas of the southern NTS. Transitional associations between 4000 and 5000 feet in elevation in Yucca Flat are dominated by *Grayia spinosa-Lycium andersonii* (hopsage-desert thorn) associations, while the upper bajadas support *Coleogyne* types. Above 5000 feet the vegetation mosaic is dominated by sagebrush associations of *Artemisia tridentata* and *Artemisia arbuscula* ssp. *nova*. Above 6000 feet pinyon pine and juniper mix with the sagebrush associations where there is suitable moisture for these trees. No plant specie located on the NTS is currently on the federal endangered species list; however, the state of Nevada has placed *Astragalus beatleyae* on its critically endangered species list.

Most animals on the NTS are small and secretive (often nocturnal in habitat), hence not often seen by casual observers. Reptiles include four species of venomous snakes; bird species are mostly migrants or seasonal residents; and larger mammals include feral horses, burros, deer, mountain lions, bobcats, coyote, kit foxes, and rabbits. Rodents account for almost half the known species, and are, in terms of distribution and relative abundance, the most important group of mammals on the NTS. Most non-rodents have been placed in the "protected" classification by the state of Nevada. In 1989 the desert tortoise, *Gopherus agassizii*, was placed on the endangered species list by the U.S. Department of Interior. Tortoise habitats on the NTS are found in the southern third of the NTS, outside the current areas of nuclear test activities in Yucca Flat, Rainier Mesa, and Pahute Mesa.

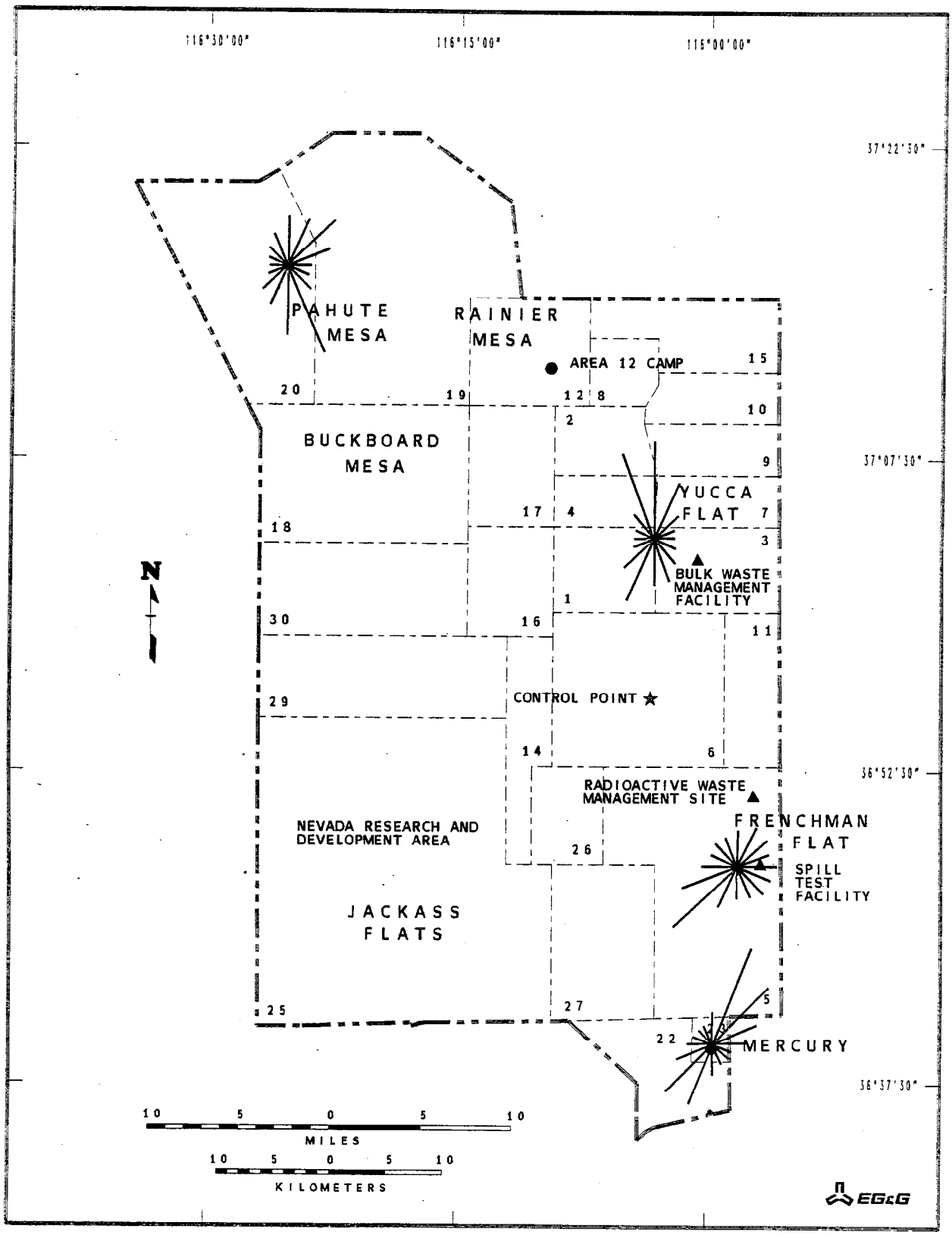

Figure 1.10 1989 Wind Rose Patterns for the NTS (Courtesy of Weather Services Nuclear Support Office, NOAA)

1.9 ARCHAEOLOGICAL AND HISTORICAL VALUES

Human habitation of the NTS area dates from as early as 10,000 B.C. to the present. Various aboriginal cultures occupied the NTS area over this extended period as evidenced by the presence of artifacts at many surface sites and more substantial deposits of cultural material in several rock shelters. The area was occupied by Paiute Indians at the time of the first known outside contact in 1849. This period of aboriginal occupation was sustained primarily by a hunting and gathering economy, based on using temporary campsites and shelters.

Because readily available surface water was the most important single determinant governing the location of human occupation, historic sites are often associated with prehistoric ones, both being situated near springs. As a consequence of this superposition of historic occupation, disturbance of certain aboriginal sites by modern man occurred long before use of the area as a nuclear testing facility began. The larger valleys show little or no evidence of occupation. Together these areas comprise almost the entire floors of Yucca, Frenchman, and Jackass Flats. Thus testing and associated operational activities have generally been most intense in those parts of the NTS where archaeological and historic sites are absent.

In addition to the archaeological sites, there are also some sites of historical interest on the NTS. The principal sites include: (1) the remains of primitive stone cabins with nearby corrals at three springs, (2) a natural cave containing prospector's paraphernalia in Area 30, and (3) crude remains of early mining and smelting activities. Even sites on the periphery of Yucca Flat, close to the area of repeated underground testing, seem to have been little affected by ground motion from tests. The stone cabin at Tippipah Spring, less than ten miles from numerous tests, has been found to be essentially unchanged compared to its condition shown in a photograph made eight years earlier (Norman 1969).

1.10 DEMOGRAPHY (EPA 1990)

Figure 1.11 shows the current population of counties surrounding the NTS, based on 1988 Bureau of Census estimates (DOC 1988). Excluding Clark County, the major population center (approximately 631,300 in 1988), the population density within a 150-kilometer radius of the NTS is about 0.5 persons per square kilometer. In comparison, the 48 contiguous states (1980 census) had a population density of approximately 29 persons per square kilometer. The estimated average population density for Nevada in 1980 was 2.8 persons per square kilometer.

The offsite area within 80 kilometers of the NTS Control Point (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 the Pahrump Valley. This growing rural community, with an estimated population of approximately 6000, is located 80 kilometers south of the Control Point. The Amargosa Farm area, which has a population of about 950, is located about 50 kilometers southwest of the Control Point. The largest town in the near offsite area is Beatty, which has a population of about 1500 and is located approximately 65 kilometers to the west of the Control Point.

The Mojave Desert of California, which includes Death Valley National Monument, lies along the southwestern border of Nevada. The National Park Service (NPS 1990) estimated that the population within the Monument boundaries ranges from a minimum of 200 permanent residents during the summer months, to as many as 5000 tourists and campers on any particular day during the major holiday periods in the winter months. As many as 30,000 are in the area during "Death Valley Days" in the month of November. The next largest town and contiguously populated area (about 40

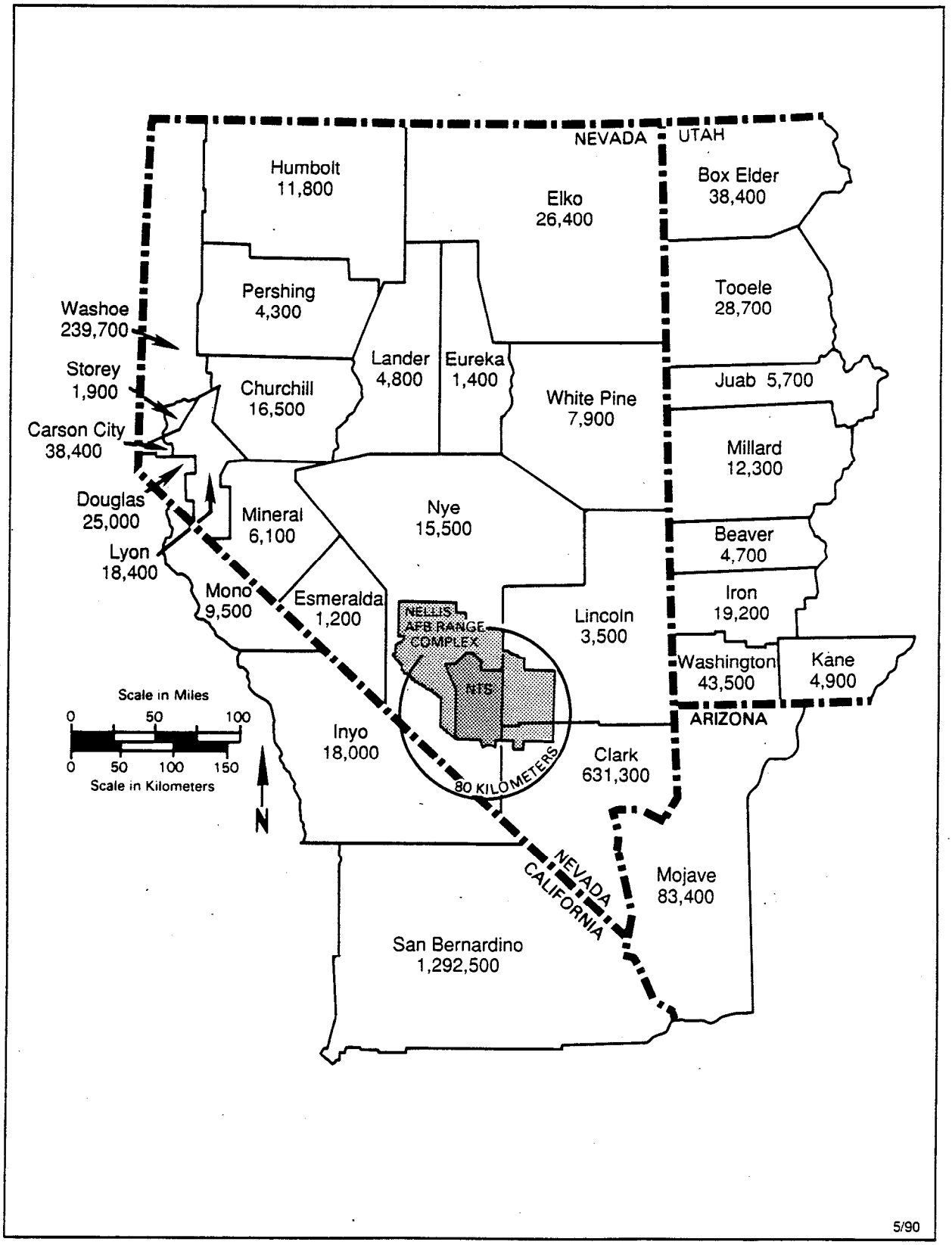

Figure 1.11 Population Distribution in Counties Surrounding the NTS [based on 1988 Census estimates (EPA 1990)]

square miles) in the Mojave Desert is Barstow, California, located 265 kilometers south-southwest of the NTS, with a 1988 population of about 20,990. The largest populated area is the Ridgecrest-China Lake area, which has a current population of 27,460 and is located 190 kilometers southwest of the NTS. The Owens Valley, where numerous small towns are located, lies 50 kilometers west of Death Valley. The largest town in the Owens Valley is Bishop, located 225 kilometers west-northwest of the NTS, with a population of 3570.

The extreme southwestern region of Utah is more developed than the adjacent portion of Nevada. The largest community is St. George, located 220 kilometers east of the NTS, with a 1988 population of 22,970. The next largest town, Cedar City, with a population of 12,020, is located 280 kilometers east-northeast of the NTS.

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, 165 kilometers south-southeast of the NTS, with a 1988 population estimate of 20,160, and Kingman, located 280 kilometers southeast of the NTS, with a population of about 11,510. Northwestern Arizona is not included in the EPA monitoring program, since nuclear tests are not conducted if the prevailing winds are in the southeast direction (i.e., toward northwestern Arizona).

1.11 SURROUNDING LAND USE (EPA 1990)

Figure 1.12 is a map of the offsite area showing a wide variety of land uses such as farming, mining, grazing, camping, fishing, and hunting within a 300-kilometer radius of the NTS Control Point. West of the NTS, elevations range from 85 meters below MSL in Death Valley to 4420 meters above MSL in the Sierra Nevada Range. Parts 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 Moapa Valley, supporting irrigation for small-scale but intensive farming of a variety of crops. Grazing is also common in this area, particularly towards 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 the state within 300 kilometers of the NTS Control Point. Many of the residents have access to locally-grown fruits and vegetables.

Recreational areas lie in all directions around the NTS 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 utilized throughout the year except for the winter months. Camping and fishing locations to the southeast, south, and southwest are utilized throughout the entire year. The peak hunting season is from September through January.

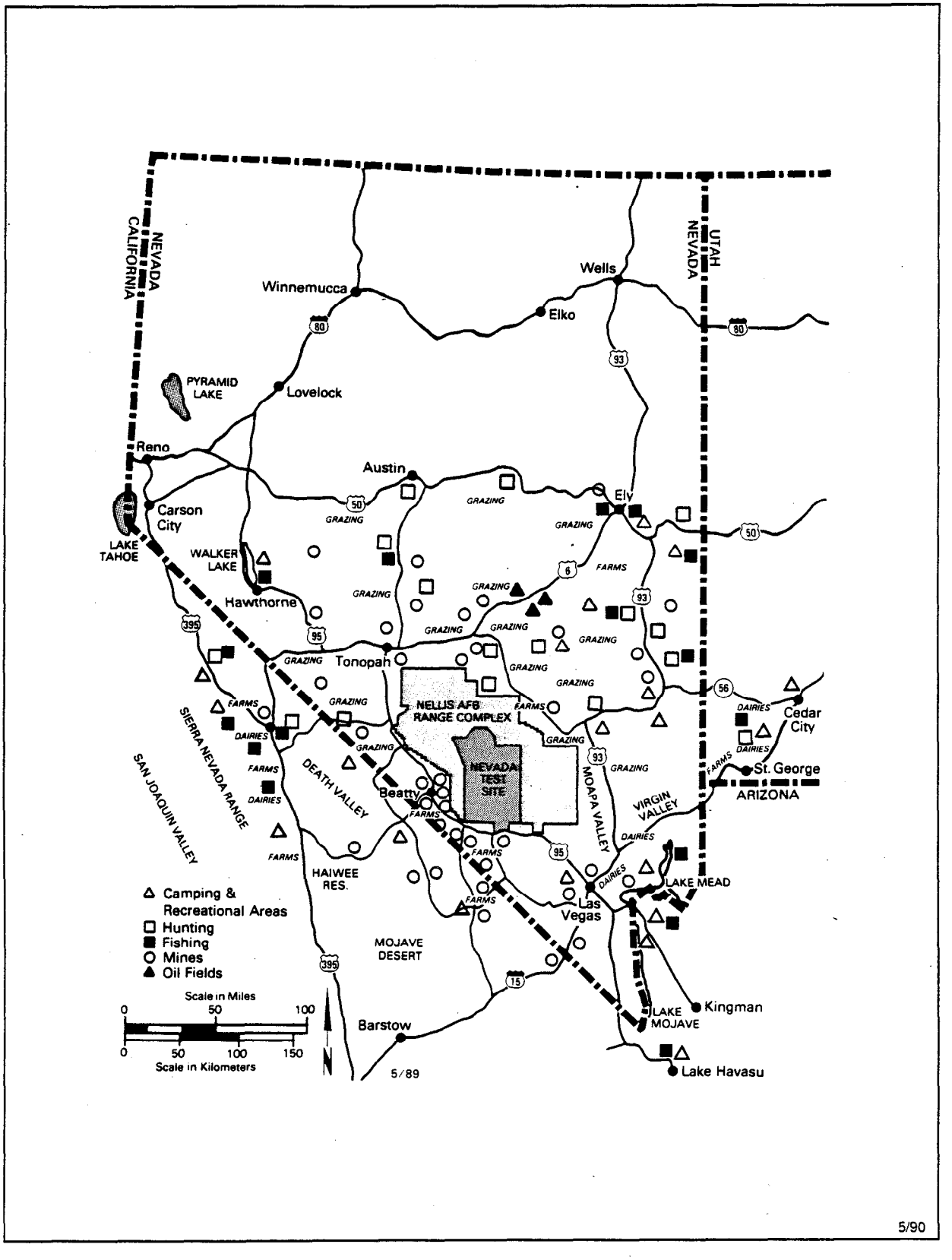

Figure 1.12 Land Use Around the NTS (EPA 1990)

2.0 SUMMARY

Donald T. Wruble

Onsite monitoring by DOE contractors and Site User organizations on the NTS during 1989 indicated that underground nuclear testing operations resulted in the release of approximately 157 curies of radioactivity to the onsite environment in the form of airborne radioactive gases. Approximately 2069 curies of tritium were released to onsite containment ponds. No liquid discharges were released to the offsite area, and there was no indication of potential migration of radioactivity to the offsite area through groundwater. Offsite monitoring by the EPA indicated that airborne radioactivity from test operations was not detectable offsite, and no measurable net exposure to members of the offsite population was detected through the offsite dosimetry program. Using the mathematical AIRDOS model and onsite radionuclide emissions data, the calculated highest individual radiation dose to an offsite resident was 1.5 x 10^{-4} mrem. The individual receiving the highest dose was also exposed to 67 mrem from natural background radiation. There were no nonradiological releases to the offsite area other than hazardous waste shipments to EPA-approved disposal facilities.

2.1 ENVIRONMENTAL MANAGEMENT

The commitment of the DOE Nevada Operations Office (NV) to accomplishments in management of NTS environmental resources can best be summarized by the results and observations of the NTS Tiger Team Compliance Assessment, conducted from October 30 to December 1, 1989. This assessment was part of a ten-point initiative by the Secretary of Energy, Admiral James D. Watkins, USN (Ret.), to conduct independent oversight compliance and management assessments of environmental, safety, and health programs at over 100 of the DOE operating facilities. In the December 1989 draft report of its NTS Compliance Assessment, the Tiger Team related that members of the Environmental Team who also participated in the NTS environmental survey in 1987 "stated that they were impressed with the visible environmental improvements at the NTS since their 1987 visit." They reported that "the progress made by the NTS in responding to the (1987) Survey findings and generally improving environmental conditions indicates that both NV and the principal contractors at the NTS have made a sincere commitment to protection of the environment."

These findings were further noted by the Secretary of Energy in his letter to the Manager/NV, stating, "I was recently briefed by the Tiger Team Leaders on the results of the NTS Assessment. While it is clear that some environment, safety, and health (ES&H) compliance deficiencies do exist, I was pleased to note that the results of the assessment indicate that the Nevada Operations Office and its contractor organizations are aggressively implementing an effective ES&H culture...

"Your organization has demonstrated that a well-managed operation can fulfill mission objectives and goals and at the same time meet environment, safety, and health responsibilities."

2.2 RADIOLOGICAL ENVIRONMENT

Radiological effluents in the form of air emissions and liquid discharges are released into the NTS environment as part of nuclear testing operations. Radioactivity in liquid discharges released to onsite waste treatment or disposal systems (containment ponds) is monitored to assess the efficacy of treatment and control and to provide a quantitative and qualitative annual summary of the radioactivity released onsite. Air emissions are monitored for source characterization and operational safety, as well as environmental monitoring purposes.

Air emissions in 1989 primarily consisted of radioactive xenons, krypton, argon, and tritium released to the atmosphere during:

- Post-test drilling, mining, and/or sampling operations for three 1989 and four 1988 underground nuclear tests.
- One 1989 test-related gas seepage to the surface (which varied with atmospheric pressure changes) following post-test sampling operations for an 1989 underground nuclear test.

None of the 12 announced underground nuclear tests resulted in a "prompt venting" (dynamic release of radioactivity within the first hour following a test) of radioactive effluents. Approximately 157 curies of radioactivity were released as a result of gaseous seepage to the surface or small releases during post-test operations for recovery of drilling cores and other samples from the underground detonation vicinity. Table 2.1 shows the quantities of radionuclides released. None of the radioactive material listed in this table was detected offsite.

Onsite liquid discharges to containment ponds included a total of 1500 curies of tritium. (An additional 569 curies were released to the Area 5 Radionuclide Migration Study ditch and pond - see Section 5.1.2 - for a total NTS release of 2069 curies to onsite ponds.) Evaporation could have contributed tritiated water vapor to the atmosphere, but the amounts were too small to be detected by the tritium monitors offsite. No known liquid effluents were discharged offsite.

2.2.1 OFFSITE MONITORING (EPA 1990)

The offsite radiological monitoring program conducted around the NTS by the EPA Environmental Monitoring Systems Laboratory in Las Vegas (EMSL-LV) consisted of several extensive environmental sampling networks and radiation detection and dosimetry networks.

In 1989 the Air Surveillance Network (ASN) consisted of 31 continuously-operating sampling locations surrounding the NTS and 78 standby stations (operated one or two weeks each quarter) in all states west of the Mississippi River. During 1989 no airborne radioactivity related to current nuclear testing at the NTS was detected on any sample from the ASN. Other than naturally-occurring ^{7}Be, the only activity detected by this network was ^{238}Pu on one composite air filter sample from Rachel, Nevada, in January 1989.

The Noble Gas and Tritium Surveillance Network (NGTSN) consisted of 20 offsite sampling stations (outside of the NTS and exclusion areas) in 1989. In addition to 18 Community Radiation Monitoring Program (CRMP) stations, there were stations at Lathrop Wells and Pioche, Nevada. At Pioche and at Salt Lake City, Utah, samples were collected for tritium analysis only. During 1989 no NTS-related radioactivity was detected at any network sampling station. As in previous years, results for xenon and tritium were typically below the minimum detectable concentration (MDC). The results for krypton, although exceeding the MDC, were within the range of worldwide values expected from sampling background levels.

Sampling of 29 Long-Term Hydrological Monitoring Program wells and surface waters around the NTS showed only background radionuclide concentrations.

Table 2.1 Radionuclide Emissions on the NTS during 1989 (EPA 1990)

Radionuclide	Half-life (years)	Quantity Released (Ci)
Airborne Releases		
^{3}H	12.35	73
^{37}Ar	0.096	15.1
^{39}Ar	269	0.0042
^{85}Kr	10.72	0.21
^{127}Xe	0.10	0.000038
^{129m}Xe	0.022	0.0022
^{131m}Xe	0.0326	0.33
^{133}Xe	0.0144	63
^{133m}Xe	.0071	1.1
^{135}Xe	0.001	3.9
^{137}Cs	30.17	0.0000073
Tunnel and Radionuclide Migration Ponds		
^{3}H	12.35	2069
^{238}Pu	87.743	0.000017
$^{239+240}Pu$	24065	0.00034
Gross Beta	------	0.20

The Milk Surveillance Network (MSN) consisted of 27 sampling locations within 300 kilometers of the NTS and 106 Standby Milk Surveillance Network (SMSN) locations throughout the western U.S., except Texas. Tritium was detected in two MSN and two SMSN samples. Radiostrontiums above the MDCs were found in eight samples at six different locations during the year from the MSN. Eleven samples from the SMSN contained detectable radiostrontiums attributed to worldwide fallout. SMSN sample ^{90}Sr levels from worldwide fallout caused by atmospheric testing have tended to decrease over time since peaking in the late 1960s.

Other foods were analyzed regularly, most of which were meat from domestic or game animals. The radionuclide most frequently found in the edible portion of the sampled animals was ^{137}Cs. However, the concentrations of ^{137}Cs have been near the MDC since 1968. The ^{90}Sr levels in samples of animal bone remained very low, as did $^{239+240}Pu$ in both bone and liver samples.

External exposure was monitored by a network of thermoluminescent dosimeters (TLDs) at 135 fixed locations surrounding the NTS and by TLDs worn by 65 offsite residents. No apparent net exposures were related to NTS activities. There were no apparent net exposures above natural background when tests for statistical significance of variation were applied. The range of exposures measured, varying with altitude and soil constituents, was similar to the range of such exposures found in other areas of the U.S.

Internal exposure was assessed by whole-body counting through use of a single germanium detector, lung counting with six semi-planar detectors, and bioassay through radiochemical procedures. In 1989 counts were made on 221 individuals from (1) offsite areas around the NTS, (2) the EMSL-LV, (3) EG&G facilities throughout the U.S., (4) five DOE

contractors, and (5) members of the general public concerned about possible radiation exposure. No internal exposures above applicable regulatory limits were found. In addition, physical examinations of offsite residents revealed a normal, healthy population consistent with the age and sex distribution of that population.

No radioactivity attributable to NTS operations was detectable by the monitoring networks. However, based on the NTS releases reported in Table 5.1 (see Section 5.1), atmospheric dispersion model calculations (AIRDOS-PC) indicated that the maximum individual dose would have been 1.5×10^{-4} mrem (1.5×10^{-6} mSv), and the dose to the population within 80 kilometers of the NTS Control Point would have been 1.1×10^{-3} person-rem (1.1×10^{-5} person-Sv). The person receiving the highest dose was also exposed to 67 mrem from natural background radiation. A summary of the effective dose equivalents due to operations at the NTS is presented in Table 2.2. In the unlikely event that a certain mule deer had been collected by a hunter rather than by EPA personnel, that hunter could have received a dose equivalent of 6×10^{-2} mrem (6×10^{-4} mSv) if the hunter ate all the liver and meat from the deer.

A network of CRMP stations are operated for the EPA, DOE, and the Desert Research Institute (DRI) by local residents. Each station is an integral part of the ASN, NGTSN, and the TLD network. In addition, they are equipped with a pressurized ion chamber connected to a gamma-rate recorder.

Table 2.2 Summary of Annual Effective Dose Equivalents Due to Operations at the NTS during 1989 (EPA 1990)

	Maximum Dose at NTS Boundary[a]	Maximum Dose to an Individual[b]	Collective Dose to Population within 80 km of NTS
Dose	$2.2 \times 10^{-4} \pm 0.2 \times 10^{-4}$ mrem (2.2×10^{-6} mSv)	$1.5 \times 10^{-4} \pm 0.2 \times 10^{-4}$ mrem (1.5×10^{-6} mSv)	1.1×10^{-3} person-rem (1.1×10^{-5} person-Sv)
Location	Boundary 43 km south of the NTS Control Point	Pahrump, NV, 80 km S of the NTS Control Point	8400 people within 80 km of the NTS Control Point
NESHAP Standard	-------	25 mrem (0.25 mSv)	-------
Percentage of NESHAP	-------	6×10^{-4}	-------
Background	80 mrem (0.80 mSv)	67 mrem (0.67 mSv)	784 person-rem (7.84 person-Sv)
Percentage of Background	2.8×10^{-4}	2.2×10^{-4}	1.4×10^{-4}

(a) The maximum boundary dose is the dose to a hypothetical individual at the NTS boundary where the highest dose rate occurs. It assumes that the person remains in the open continuously all year.

(b) The maximum individual dose is to an individual outside the NTS boundary at a residence where the highest dose rate occurs and also assumes that person remains outside at that location continuously all year long. This is calculated from the reported effluent (Table 2.1) using AIRDOS-PC, Version 3 (1989), software.

All the CRMP stations are equipped with satellite telemetry transmitting equipment. With this equipment gamma exposure measurements acquired by the pressurized ion chambers are transmitted via the geostationary operational environmental satellite directly to the NTS and from there to the EMSL-LV by dedicated telephone line. Samples and data from these stations are analyzed and reported by the EPA at the EMSL-LV. Data are also interpreted and reported by DRI.

Data from these stations are reported herein as a integral part of the environmental monitoring networks. All measurements for 1989 were within the normal background range for the U.S.

2.2.2 ONSITE MONITORING

The primary radioactive liquid discharge to the onsite environment was water seepage from the test tunnels in Rainier Mesa (Area 12). A total of 71 million liters of water was discharged, containing 1500 curies of tritium. Contaminated water discharges to the contaminated pond for the Area 6 Decontamination Facility (used for equipment decontamination) contributed 7 x 10^{-3} curies of tritium to the pond. Discharges from the Area 5 Radionuclide Migration Study well contributed 569 curies of tritium in the 1200 million liters of water pumped to the ditch and pond at the Frenchman Flat playa boundary.

In addition to onsite sampling for noble gases (7 stations) and tritiated water vapor (17 stations), monthly composites of air particulate samples were analyzed for ^{238}Pu and $^{239+240}Pu$. The maximum annual average $^{239+240}Pu$ concentration was found at the Area 3 ah/at West sampling location. Results from the samples taken at that location averaged 3.4 x 10^{-16} µCi/mL during 1989. This quantity was 0.017 percent of the derived air concentration (DAC) for radiation workers. This concentration was statistically different at the five percent significance level from the network average for all sampling locations, excluding those at the Area 3 ah/at Bulk Waste Management Facility. The network average for all locations (excluding the ah/at site) was 4.0 x 10^{-17} µCi/mL.

The maximum annual average ^{238}Pu concentration from the analysis of samples taken at the Area 3 ah/at site was not statistically different from the network annual average at the five percent significance level.

The presence of plutonium on the NTS is primarily due to tests conducted before 1960 in which nuclear devices were detonated with high explosives (called "safety shots") in the atmosphere or on the ground surface. These tests spread low-fired plutonium in the eastern and northeastern areas of the NTS. Two decades later, elevated levels of plutonium in the air are still detected in Areas 1, 2, 3, 7, 8, 9, 10, and 15. During the waste cleanup efforts of early atmospheric tower shot sites at the Area 3 Bulk Waste Management Facility, some of the plutonium became airborne. High road traffic has caused elevated levels of plutonium around the Area 3 waste management facility for the past few years. Large quantities of water are now used for dust abatement, and it is believed this will appreciably reduce the airborne plutonium concentrations.

Natural springs are found onsite but are few in number. The term *natural springs* was a label given to the spring-supplied pools located within the NTS. Although there was no known human consumption from these springs, the measured concentrations were also compared to the Derived Concentration Guides (DCGs) for ingested water. The network annual average ^{3}H from samples taken at seven natural springs was 1.2 x 10^{-7} µCi/mL, which equaled 0.6 percent of the DCG for ^{3}H in drinking water. As with the ^{3}H results from open reservoirs, most of the sampling results from natural springs were below the detection limit.

Radioactivity in onsite water derived from onsite drinking water wells and industrial-use distribution systems was sampled and analyzed monthly for gross beta, gross alpha, ^{3}H, ^{238}Pu, $^{239+240}Pu$, and

gamma-emitting radionuclides. The network average gross beta activity of 6.9×10^{-9} µCi/mL was 0.10 percent of the DCG for ^{40}K (for comparison purposes), ^{3}H was 1.1×10^{-7} µCi/mL or 0.6 percent of the DCG, $^{239+240}Pu$ was 2.3×10^{-13} µCi/mL or 0.02 percent of the DCG, and ^{238}Pu was -2.9×10^{-12} µCi/mL (reflecting individual sampling results which are below the estimated counter background radiation level).

External gamma radiation exposure data from the onsite TLD network indicated the gamma exposure rates recorded during 1989 were not statistically different from the data collected in 1988. Recorded exposure rates ranged from 64 mR/year in Mercury to 1581 mR/year in a contaminated area in Area 2. Average annual exposure rates at NTS boundary TLD stations ranged from 77 to 212 mR/year. The average exposure rate for onsite "control" stations (considered uncontaminated) was 106 mR/year.

Ecological studies related to environmental radioactivity on the NTS continued under the Basic Environmental Compliance and Monitoring Program (BECAMP). The studies included (1) investigating the movement of radionuclides on and around the NTS through horizontal movement, water-driven erosion, vertical migration, and wind-driven erosional resuspension; (2) development of a human dose-assessment model specific to the environmental and radiological conditions of the NTS; (3) preparation of a peer-reviewed publication analyzing transfer of aged radionuclides which had been ingested by cattle grazing upon vegetation within fenced enclosures on a site that had been contaminated by plutonium 16 years earlier by testing of a nuclear device; and (4) monitoring of flora and fauna on the NTS to assess changes over time in the ecological condition of the NTS.

BECAMP experiments were conducted at the NTS to evaluate the effectiveness of removing plutonium-contaminated soils with a large truck-mounted vacuum cleaner. Results showed that this method is effective, relatively easy, and safe for equipment operators. The ecological impact was, however, serious in terms of soil erosion and destruction of small animal habitats.

The fifth in a series of BECAMP reports from the Radionuclide Inventory and Distribution Program was completed and released in 1989. The report presents the results of *in situ* measurements of gamma-emitting radionuclides and provide additional information from aerial surveys and analysis of soil samples to estimate inventories and distributions of radionuclides of NTS origin in the surface soil.

Environmental monitoring at and around the Area 5 low-level Radioactive Waste Management Site and the Area 3 low-level radioactivity Bulk Waste Management Facility indicated no radioactivity levels in surface water samples collected following precipitation events or on facility swipe samples. Airborne ^{3}H samples indicated levels which were not different than those elsewhere on the NTS.

Groundwater samples are not collected from the 800-foot deep aquifer below the waste management facility since waste constituent migration times from the surface to the aquifer have been calculated on the order of thousands of years. An unsaturated zone (vadose zone) sampling system has been installed as a more timely and responsive method of detecting downward waste migration.

2.3 NONRADIOLOGICAL ENVIRONMENT

The primary environmental permit areas for the NTS involved air quality and the Resource Conservation and Recovery Act (RCRA). Air emissions sources common to the NTS included particulates from construction aggregate production, surface disturbances, fugitive dust from unpaved roads, fuel burning equipment, open burning, and fuel storage facilities. These emissions were covered by a series of 28 state of Nevada air quality permits. The only nonradiological air emission of regulatory concern under the Clean Air Act was asbestos removal during five building

renovation projects and from insulated piping at an open tank farm. These were reported to the EPA under National Emission Standards for Hazardous Air Pollutants (NESHAP) requirements.

The RCRA Part A Permit application for the NTS was revised in 1989 to include five additional RCRA units. These were (1) Area 3 and Area 2 subsidence crater waste disposal complexes for debris disposal and (2) three injection wells, two in Area 2 and one in Area 3. Closure plans for the Area 3 crater complex, the Area 6 Decontamination Facility contaminated evaporation pond, and the Building 650 (Mercury) leach field were submitted to the state. A revised closure plan was submitted to the state on May 31, 1989, for the Area 23 hazardous waste disposal trenches in response to a notice of deficiency from the state. A RCRA Part B Permit application was submitted to the state in 1988 for permanent disposal of mixed waste at the Area 5 Radioactive Waste Management Site and is still under state and EPA review. Until the necessary permit is issued, disposal operations are being conducted under interim status as retrievable storage.

As there are no liquid discharges to navigable waters, offsite surface water drainage systems, or publicly-owned treatment works, no Clean Water Act National Pollution Discharge Elimination System (NPDES) permits are required for NTS operations. Under the conditions of state of Nevada operating permits, liquid discharges to 14 onsite sewage lagoons are regularly tested for biochemical oxygen demand, pH, and total suspended solids. In addition to the state-required monitoring, these influents were also tested for RCRA-related constituents as an internal initiative to further protect the NTS environment. Low parts-per-billion levels of metals, volatile organic compounds, base/neutral/ acid compounds, and cyanide were found in some influents. These results were reported to the state, and action guidance is pending state consideration.

In compliance with the Safe Drinking Water Act and five state of Nevada drinking water supply system permits for onsite distribution systems supplied by onsite wells, the systems are sampled monthly for residual chlorine and bacteria. No permit compliance problems were encountered. In order to achieve compliance with state regulations, a discharge permit application for two shallow injection wells for wash water and steam-cleaning effluent (non-hazardous) was submitted to the state.

Toxic Substances Control Act (TSCA) compliance involved routine sampling of electrical transformer oils, soil, and waste oil for polychorinated biphenyls (PCBs). A January 26, 1989, inspection by the EPA resulted in six findings involving record keeping and reporting deficiencies, warning signs, and transformer storage over 30 days before disposal. Corrective actions were taken, although no written report has been received from the EPA. Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) activities involved routine application of pesticides, with no non-compliance conditions encountered.

National Environmental Policy Act (NEPA) activities included preparation of two Environmental Assessments related to the proposed move of the Area 3 construction yard facility to Area 6 and the Liquified Gaseous Fuels Spill Test Facility. Six other Environmental Assessments were initiated and are pending. Three DOE Memoranda to File were written, including retrieval of transuranic waste from the NTS waste disposal facility, replacement of the Area 23 Hazardous Waste Accumulation Site with one in Area 5, and plutonium hydro testing. Fifteen Categorical Exclusion documentations were also completed.

In August 1989, under the emergency provisions of the Endangered Species Act, the U.S. Fish and Wildlife Service listed the Mohave desert tortoise as an "endangered species" north and west of the Colorado River. Desert tortoise distribution on the Site is patchy, but tortoises are generally found on the southern one-third of the Site, outside any active nuclear testing areas. An active protection program, including NTS worker-awareness actions, was continued.

Two environmentally-related unusual occurrence reports were filed during 1989. One pertained to the dumping of a truckload of uncontaminated drilling mud into a subsidence crater disposal site previously closed to any dumping. The second involved spillage of 60 gallons of aircraft fuel during an aircraft refueling operation at the Desert Rock Airstrip near the Mercury base camp. There were also two unplanned releases of nonradiological contaminants. A transformer oil leak stained some soil in the Warehouse C Yard (no PCBs were found in the soil), and 40 gallons of fuel were spilled at the Area 25 heliport.

2.4 ISSUES AND ACCOMPLISHMENTS

A key environmental issue concerning the NTS is the potential listing of the Site on the National Priority List (NPL) of hazardous sites for cleanup under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). The Hazard Ranking Score of 22.55, submitted to the EPA in 1988, is scheduled for reassessment in 1990 using the new EPA scoring system. Listing on the NPL may carry extensive budget and operational ramifications in terms of environmental cleanup.

A second issue involves receipt of a RCRA permit for permanent disposal of mixed waste at the Site, as this governs the acceptance of such waste from other DOE facilities. As noted earlier, the RCRA Part B permit application for permanent disposal of mixed waste at the Area 5 RWMS was submitted to the state in October 1988 and is still under review. Until this application is approved by the state and the EPA and the necessary permit is issued, disposal operations are being conducted as retrievable disposal under interim status granted by the state.

A third issue is the potential designation of the plant, *Astragalus beatleyae*, as an endangered species on the NTS. During 1989 surveys showed significant habitat in at least four northwestern areas of the Site. An agreement between the DOE and the U.S. Fish and Wildlife Service for *A. beatleyae* conservation was signed in 1989 and is effective until 1991. The state of Nevada has listed *A. beatleyae* as a "critically endangered species" based on information gathered in the 1970s. Additional information has been gathered since the listing which shows the original range of the species was underestimated.

Accomplishments can best be summarized by repeating the Tiger Team report statement that "the progress made by the NTS in responding to the (1987) Survey findings and generally improving environmental conditions indicates that both NV and the principal contractors at the NTS have made a sincere commitment to protection of the environment." The DOE/NV believes it has made significant strides during 1989 in its endeavors to conduct NTS operations in full compliance with the letter and spirit of environmental protection standards, guidelines, and goals.

The environmental monitoring results presented in this report document the conduct of 1989 nuclear test operations with no detectable radiation exposure to the offsite public. Calculation of the highest individual dose that could have been received by an offsite resident (based on onsite measurement of radioactive releases to the atmosphere) was 0.00015 mrem, compared to that individual's dose of 67 mrem from natural background radiation.

There were no major incidents of nonradiological contaminant releases to the environment, and ever more intensive efforts to continue characterizing and protecting the NTS environment were implemented during 1989. These efforts were characterized at the management level by such actions as establishing the Effluent and Environmental Monitoring Work Group, consisting of representative of the various NTS support contractors and User organizations, to more thoroughly coordinate and conduct the NTS environmental protection program.

3.0 COMPLIANCE SUMMARY

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In addition to conducting the nuclear testing programs in compliance with radiation protection guides and standards, the predominant environmental compliance activities at the NTS during 1989 involved hazardous waste management associated with Resource Conservation and Recovery Act (RCRA) requirements. Clean Air Act compliance involved sampling and reporting of asbestos renovation projects and state of Nevada air quality permit renewals and reporting. Toxic Substances and Control Act compliance activities were in response to an EPA inspection of PCB-management practices on the NTS. Compliance actions also included pre-operational surveys to protect and preserve archaeological and cultural history sites on the NTS. Endangered Species Act compliance actions involved accommodating regulations related to the August 1989 listing of the Mohave desert tortoise, with a habitat over approximately one-third of the NTS, as an endangered species. During 1989 work continued on environmental compliance corrective actions identified in the 1987 NTS environmental survey conducted by the DOE, and a DOE "Tiger Team" assessment of environmental compliance and program management was conducted in October 1989. Throughout 1989 the NTS was subject to no formal compliance agreements with federal or state regulatory agencies, and no notices of violation were issued with regards to Site operations and procedures.

3.1 NATIONAL ENVIRONMENTAL POLICY ACT (NEPA)

NEPA-related activities included eight Environmental Assessments (EAs), three Memoranda to File, and 15 Categorical Exclusions. These are described below.

3.1.1 ENVIRONMENTAL ASSESSMENTS

During 1989 two EAs were completed and six others were initiated for NTS projects.

COMPLETED ENVIRONMENTAL ASSESSMENTS

Area 3 Construction Camp Relocation

During 1989 an EA was prepared on the proposed relocation of Area 3 Camp support facilities to Area 6. Subject to the findings of the EA, DOE determined that the proposed relocation action was not a major federal action significantly affecting the quality of the human environment within the intent of the NEPA, and continued support facility operations at the relocated site would not differ substantially in nature or degree from activities at the NTS addressed previously in the September 1977 environmental impact statement for the NTS. Therefore, a new environmental impact statement was not required.

The proposed action involved initial construction activities which would temporarily disturb some of the surface terrain of the dry, sparsely-vegetated NTS. Such features as roads, buildings, parking areas, sewage lagoons, and equipment yards would replace habitat formerly available to plants and animals in those localities. However, the impacts on the plants and animals were expected to be minimal, given the relatively small affected area of 0.4 square kilometers (0.16 square miles).

No threatened or endangered plant or animal species or critical habitat for such species were present in the area, and no site of historical or archaeological significance would be affected. No socioeconomic impacts were anticipated as a result of the support camp relocation, as the facility operations and employees would remain the same as in the Area 3 location.

The construction and operation of the Area 6 Camp met the state of Nevada and federal air quality standards for major pollutants and general ambient air-emission guidelines. Although some dust would be generated during construction, it would be of a temporary nature and would be stabilized by dust suppressants. Calculated annual average and maximum 24-hour increases in ambient particulate concentrations at the nearest point of potential public exposure from construction and operation activities were 0.00 and 0.04 mg/m^3 respectively, in comparison with annual average and 24-hour ambient air quality particulate standards of 50 and 150 mg/m^3 respectively, per 40 CFR 50.

Groundwater resources would not be affected by the proposal because the groundwater depth at the proposed location is more than 450 meters (1500 feet) below the surface (Fenske and Carnahan 1975; Rush 1970). The only surface water present in the Yucca Flat basin has been occasional surface water runoff into Yucca Lake caused by rainfall, which generally has evaporated within a few days to a few weeks. It is unlikely that the action would have any significant impact on the water resources of the Yucca Flat area. No significant adverse impact to the soils was anticipated as a result of the proposal, as erosion prevention culverts and swales would be installed at the construction site.

Liquified Gaseous Fuels Spill Test Facility (LGFSTF)

An EA was prepared for the LGFSTF at Frenchman Flat addressing the environmental consequences of spill testing the following eleven hazardous materials in the Frenchman Flat basin: chlorosulfonic acid ($HClSO_3$), fluorosulfonic acid ($HFSO_3$), hydrogen chloride (HCl), methyl trichlorosilane (CH_3Cl_3Si), nitrogen tetroxide ($NO_2N_2O_4$), oleum (H_2SO_4), silicon tetrachloride ($SiCl_4$), sulfur-trioxide (SO_3), titanium tetrachloride ($TiCl_4$), trichlorosilane (Cl_3SiH), and unsymmetrical dimethyl hydrazine [$(CH_3)_2N_2H_2$]. Combustion testing on three of these hazardous materials, methyl trichlorosilane, trichlorosilane, and the nitrogen tetroxide/dimazine mixture, would also be conducted and evaluated. From these assessments, better models for predicting the dispersion behavior of volatilized chemicals could be developed. As a result, mitigations could be made in order to establish spill-test criteria that would protect natural resources and reduce land-use impacts of areas adjacent to the spill-test facility.

Potential environmental impacts were based on maximum expected spill sizes. Spill-test series would begin with small spills. Spill size would be gradually increased after the impacts of the initial test were evaluated and test personnel concluded that larger tests would cause no significant impacts. In addition to LGFSTF operation procedures, the following assumptions were made in preparation of the EA: (1) no materials would be released into the environment that had cumulative, long-term persistence in the environment; (2) tests would be limited to spills of 100 gallons or less; (3) spill tests would consist of releases of 15 minutes or less; and (4) sufficient time would be allowed between tests for recovery of natural resources. These restrictions would ensure that environmental impacts from the proposed spill tests would not be significant.

All proposed testing at the spill site would meet the state of Nevada and federal air quality standards for major pollutants and general ambient air-emission guidelines. As the proposed area is about 80 kilometers northwest of the urban areas of Clark County and the proposed spill trajectory is to the northeast, it is unlikely that ambient concentrations of the major air pollutants resulting from the spills would have a significant impact on the region's air quality.

Groundwater resources would not be affected by the proposal because an

impervious layer underlies the playa, and the groundwater is 200 meters below the surface. The actual lake bed would not be exposed to any free liquid material. Test materials would be either aerosolized in a wind tunnel or vaporized from an evaporation pan. The only surface water that could be contacted by a released gas would be in an artificial marsh or on the playa itself during the rainy season. None of the gas is expected to leave any significant residual from combination with water or to have any impact on the water resources of the Frenchman Flat area.

Limited information is available on phytotoxicity for these chemicals. No significant impact on vegetation was anticipated because toxic concentrations would be confined to the barren playa. There are no threatened or endangered plant species in the vicinity of the proposed action.

In terms of biological resources, past tests at Frenchman Flat have shown that when the test criteria are met gas clouds move downwind at very nearly the wind speed and do not persist for much longer than the spill duration. Previous test spills have not produced any significant impact on the biological resources within the Frenchman Flat basin.

DOE determined that the proposed tests would not affect the endangered desert tortoise. The U.S. Fish and Wildlife Service responded to DOE's findings by a letter dated September 7, 1989, and concurred with DOE's "determination that the proposed activity will have no effect on the endangered desert tortoise."

An EA (DOE/EA-0150), issued by DOE in 1981, concluded that Frenchman Flat was the most suitable site on which to construct and operate a facility to test accidental releases of liquefied natural gas. The accompanying Finding of No Significant Impact issued in September 1981 determined that there were no significant impacts associated with this action.

Another EA (DOE/EA-0225) and Finding of No Significant Impact issued by DOE in October 1983 addressed a proposed series of spill tests for other gaseous fuels at the Frenchman Flat facility. A third EA (DOE/EA-0309) was issued by DOE in June 1986 and was accompanied by a Finding of No Significant Impact in July 1986. DOE/EA-0309 assessed the consequences of spill-testing 14 test materials at the LGFSTF and concluded that no significant impacts would occur. A fourth EA (DOE/EA-0360) with a Finding of No Significant Impact was issued in June 1988, adding four more chemicals for spill test at the facility. These four EAs and Findings of No Significant Impact are still considered valid. Based on these earlier EAs and the findings of this EA, a Finding of No Significant Impact was submitted to DOE Headquarters for approval in December 1989.

IN-PROCESS ENVIRONMENTAL ASSESSMENTS

Propellant Initiation Program

This Air Force Armament Laboratory program involves tests to determine the damage to reentry vehicle warheads on a missile if the post-boost vehicle's propellant section were impacted by a kinetic energy weapon. Four alternative test sites were considered, one of which was the LGFSTF on Frenchman Flat at the NTS.

The EA for this program was completed in April 1989. It indicated that the test would cause temporary degradation in air quality due to release of toxic vapors in the vicinity and downwind of the test site. Potential adverse environmental impacts at the LGFSTF would be expected to be less than those at the three other facilities under consideration, since it is virtually devoid of plant and animal life.

It is not anticipated that the U.S. Air Force will continue operation at this site, in which case an additional EA will not be necessary.

U.S. Army Depleted Uranium Tests

These U.S. Army tests are conducted in Area 25 and used to study ammunition's usefulness, application, safety, and hazard classification. Operations include burn tests, vehicle and heavy armor impacts with large-caliber depleted uranium penetrator rounds, and burning a vehicle filled with depleted uranium artillery.

No depleted uranium contamination has been found outside the immediate vicinity of the targets, and the depleted uranium near the targets has been easily removed. No significant depleted uranium aerosol has been detected in earlier tests. Almost 100 percent of the detectable oxidized depleted uranium has been recovered in the past. There has never been a hazardous level release of respirable depleted uranium from past research tests. The quantities of depleted uranium used in these experiments are minimal and no significant radiation exposure is expected.

Device Assembly Facility

The Device Assembly Facility is an ongoing construction project, 90 percent complete at the time of this writing, located in the southern end of Area 6. This facility will enable the consolidation of the Los Alamos and Lawrence Livermore National Laboratories' nuclear test device assembly operations. It will consist of 100,000 square feet and will include assembly cell structures, an assembly bay, radiography facilities, a processing laboratory, a storage bunker, connecting corridors, an administrative office, service support areas, shipping and receiving buildings, two guard towers, an entry guard complex, and 4000 linear feet of eight-foot high parallel chain-link perimeter fences.

When the facility becomes operational, there will be approximately 50 people employed at the site. Clearing of vegetation around the facility for security reasons is still under consideration at the time of this writing. If the area is cleared around the facility, vegetation more than six inches tall will be taken up routinely by small equipment on a plant by plant basis. At most, the amount of land to be cleared for security at the facility will be 750 acres.

SCYLIA Facility

The Los Alamos Explosive Pulsed Power (SCYLIA) Facility is located in Buildings 2203, 2204, and 2205 of Area 26. It will be used to perform research and development in the areas of explosive pulsed power, high-magnetic-field physics, and conventional pulsed power. Once the facility becomes operational, it will house 20 to 25 people on a noncontinuous basis. Research will be performed on specific projects as information is needed.

Two different types of operations will be conducted. The primary operations involve the fielding and firing of explosive generators both as developmental power supplies and as explosive power supplies for active loads. Secondary operations include conducting of conventional pulsed power experiments to develop and certify active loads being driven by the explosive power supplies. Also, this part of the facility may provide valuable support for some down-hole operations such as detector checks.

Mixed Waste Management Unit (MWMU), Area 5

To provide disposal capacity for mixed waste, the DOE Nevada Operations Office (NV) has obtained interim operating status for a MWMU at the Area 5 Radioactive Waste Management Site (RWMS). Under this interim status, DOE/NV is disposing of mixed waste in a retrievable manner. DOE/NV has applied for a permit from the state of Nevada for disposal of mixed waste.

An EA for the MWMU was prepared in fiscal year 1989. This document is being revised and should be completed in final form during fiscal year 1990. The draft Safety Analysis Report for the Area 5 RWMS is being updated to include hazardous waste management and is expected to be completed in June 1990.

Waste Examination Building, Area 5

The Waste Examination Building, including a real-time radiography unit for examination of waste packages and a container breaching room, is scheduled to be constructed. An EA is being prepared and is expected to be completed in 1990.

3.1.2 MEMORANDA TO FILE

Memoranda to file projects included:

WIPP TRANSURANIC (TRU) WASTE RETRIEVAL AT THE NTS

This memorandum covered retrieval of the TRU wastes stored at the Area 5 RWMS in preparation for transfer of the waste to the Waste Isolation Pilot Plant (WIPP) in New Mexico.

HAZARDOUS WASTE ACCUMULATION SITE, AREA 5

This addressed the replacement of the existing Hazardous Waste Accumulation Site in Area 23 with a facility in Area 5, adjacent to the RWMS.

PLUTONIUM HYDRO TEST

This was written to address tests on experimental devices studying the environmental consequences of an inadvertent release of plutonium from device testing at the NTS.

3.1.3 CATEGORICAL EXCLUSIONS

Fifteen Categorical Exclusion projects included an indoor pistol range modification, an electrical substation expansion, a steam cleaning pad modification, a water system upgrade in Area 25, water-line construction at the RWMS in Area 5, several building modifications or renovations, underground storage tank removal, and trenching in Area 5.

3.2 CLEAN AIR ACT

As there are no criteria pollutant or prevention of significant deterioration monitoring requirements for NTS operations, Clean Air Act compliance requirements were limited to asbestos and radionuclide monitoring and reporting under National Emissions Standards for Hazardous Air Pollutants (NESHAP). NTS air quality regulatory compliance activities for 1989 primarily involved state of Nevada air quality permit reporting and renewals (see Table 4.1, Section 4.3.1 for a listing of permit renewals). Air pollution sources common at the NTS include aggregate production, stemming activities, surface disturbances, fugitive dust from unpaved roads, fuel burning equipment, open burning, and fuel storage facilities.

The 1988 annual report for state of Nevada air quality permits was submitted to the state on March 19, 1990. This report included the production, operating hours, and a report of all surface disturbances of five acres or greater.

3.2.1 NATIONAL EMISSIONS STANDARDS FOR HAZARDOUS AIR POLLUTANTS (NESHAP)

During 1989 five NESHAP notifications were made to the EPA, Region IX. These notifications were for asbestos renovation projects in accordance with the requirements of 40 CFR 61.145-146. The Site operating contractor (REECo) collected and analyzed bulk, occupational, environmental, and clearance samples for these projects. The five areas are listed in Table 3.1.

A violation of 40 CFR 61.12(c) was reported by the Site operating contractor on May 5, 1989. These air quality regulations state that asbestos sources shall be maintained to minimize emissions through good air pollution control practices. The violation involved two outdoor tank farms in Area 26. The insulation on the piping at

Table 3.1 NESHAP Notifications for NTS Asbestos Renovation Projects in 1989

Area	Building	Friable Asbestos	Estimate of Start Date	Completion Date
23	300	550 sq ft kitchen fire proofing	10/16/89	10/20/89
26	2205	350 linear ft pipe insulation	09/05/89	09/08/89
26	2204	200 linear ft pipe insulation & 500 sq ft transite board	03/13/89	03/24/89
25	4015	75 linear ft pipe insulation & 18,000 sq ft vinyl asbestos floor tile	02/27/89	03/10/89
26	2203	500 linear ft pipe insulation	01/26/89	02/02/89

these farms was exposed, damaged, and scattered on the ground. This area was posted with asbestos warning signs, and cleanup will begin as funding becomes available.

NTS operations were conducted in full compliance with the radioactive air emissions standards of NESHAP.

3.3 CLEAN WATER ACT

There are no National Pollution Discharge Elimination System (NPDES) permits for the NTS, as there are no wastewater discharges to onsite or offsite surface waters. Water monitoring at the NTS is limited to sampling wastewater influents to lagoons and ponds under a series of state of Nevada permits, as summarized in Section 6.1.2.

3.4 RESOURCE CONSERVATION AND RECOVERY ACT (RCRA)

Significant activities involving RCRA for 1989 included: (1) a RCRA waste management inspection by the EPA, Region IX, (2) an NTS RCRA Part A permit application revision, (3) responses to a state of Nevada notice of deficiency for the Area 23 Hazardous Waste Landfill Trenches Closure Plan along with (4) other RCRA closure plan activities, (5) underground storage tank removals, and (6) initiation of a waste minimization plan for the NTS.

The Site operations contractor has been assigned EPA Generator Identification Number NV3890090001 as the operator for the NTS. The required hazardous waste generator annual report was sent to the state of Nevada on March 30, 1989. Due to a change in computer format by the EPA, the annual report was an abbreviated version which did not include the waste identification number, amounts, or disposal facilities receiving the waste. This information will be included in the report for 1990.

3.4.1 RCRA INSPECTION

On February 28, 1989, the EPA conducted a RCRA inspection of the NTS. Thirteen potential violations were identified in the

inspection report. The findings and corrective action responses are listed below.

FINDING - STORAGE OF INCOMPATIBLE ITEMS

Storage containers of incompatibles (acids and caustics) were stored within the same area in the Area 23 container storage area [40 CFR 265.177(c)].

Corrective Action

The acids and bases were separated and stored in different cells of the accumulation area immediately after the inspector commented on the situation.

FINDING - HAZARDOUS WASTE LABELS

Hazardous waste labels were missing on containers in the corrosive storage section of the Area 23 container storage area [40 CFR 262.34(a)(3)].

Corrective Action

All barrels were labelled properly. Those with unknown materials were labelled "Hazardous Waste" until sampling results identified the contents.

FINDING - ACCUMULATION DATES

Accumulation dates were not indicated on containers stored in the corrosive section of the Area 23 container storage area [40 CFR 262.34(a)(a)].

Corrective Action

Accumulation start dates were added to all waste labels where they had been omitted.

FINDING - WASTE SOLVENT AT MOTOR POOL

A drum of waste solvent in the Area 23 Motor Pool was being stored with an open bung [40 CFR 265.173(a)].

Corrective Action

The waste solvent container at the Area 23 Fleet Operations satellite accumulation area was capped, followed by written direction to the staff to keep the barrels capped between fillings.

FINDING - CONTAINERS IN IGNITABLE SECTION

Containers in the ignitable section of the Area 23 container storage area were not in good condition [40 CFR 265.171].

Corrective Action

All barrels in poor condition were placed in over-pack barrels.

FINDING - MIXED WASTE STORED OVER 90 DAYS

Containers containing "scintillation cocktail" mixed waste were being stored for greater than 90 days [40 CFR 262.34(a)].

Corrective Action

Mixed waste barrels cannot be disposed of in the NTS Mixed Waste Management Unit (MWMU) until that waste stream is approved by the state of Nevada for disposal. This approval is pending completion of an EA for the facility. These actions have been agreed to by the DOE and the state of Nevada. This particular mixed waste was sent in September 1989 to the Gainsville Florida U.S Ecology Quadrex HPS disposal site and incinerated.

FINDING - AISLE SPACE

Adequate aisle space was not maintained in the ignitable section of the Area 23 container storage area [40 CFR 265.35].

Corrective Action

Aisle space was increased between all rows of drums.

FINDING - INADEQUATE CONTINGENCY PLANS

Contingency plans for the MWMU in Area 5 and explosive ordinance disposal (EOD) facility in Area 11 did not include the home address of emergency coordinators [40 CFR 265.52(d)].

Corrective Action

Contingency plans for the MWMU and the EOD have been updated to include the home addresses of the emergency coordinators.

FINDING - INSPECTION OF EMERGENCY RESPONSE EQUIPMENT

The inspection schedules for the MWMU and Area 23 container storage area did not include provisions for inspecting emergency response equipment [40 CFR 265.15(b)(1)].

Corrective Action

The inspection report given to the RCRA inspector was an out-of-date form that should not have been used. A copy of the correct form, which included provision for verification of emergency response equipment inspections, was provided.

FINDING - INSPECTION TIME NOT ON LOG

The time of inspection was not indicated on the inspection log for the MWMU [40 CFR 265.15(d)].

Corrective Action

The current forms for inspection of facilities include a place for recording the time of inspection.

FINDING - 1987 ANNUAL REPORT DEFICIENCY

The 1987 annual report did not include a description of efforts to reduce the volume and toxicity of wastes or a description of actual changes in volume or toxicity [40 CFR 262.41 (a) (6 and 7)].

Corrective Action

The annual RCRA generator report for 1987 supplied all information that was requested in the report form supplied by the state of Nevada. No additional information on waste minimization was requested by the state. The current waste minimization plan for the NTS requires an annual report, which will provide the information needed for the 1989 RCRA report.

FINDING - NO TREATMENT, STORAGE, AND DISPOSAL (TSD) ANNUAL REPORT

No TSD annual report was prepared for the NTS [40 CFR 265.75].

Corrective Action

No 1987 mixed-waste disposal biennial TSD report was submitted because interim status for disposal was not granted by the state of Nevada until October 1988, and no disposal started until 1989.

Although thermal treatment (disposal) of explosives was conducted during 1987, the Part A modification to include that activity in the Part B permit application was not made until August 1988. Therefore, no report was sent for 1987.

A 1989 TSD biennial report for both facilities was submitted in February 1990 for 1989.

FINDING - PART B APPLICATION NOT AVAILABLE

The Part B application Volumes I and II were not available for review at the time of the inspection [40 CFR 265.74].

Corrective Action

The Site operating contractor's Environmental Compliance Office now has a full set of the RCRA Part B application and closure plans.

3.4.2 AREA 23 HAZARDOUS WASTE LANDFILL TRENCHES

Responses were made to the state of Nevada, Division of Environmental Protection notice of deficiency for the Area 23 hazardous waste trenches on April 20, 1989. State of Nevada comments concerned the applicability of the moisture gauges for vadose zone monitoring, assurances of moisture gauge installation according to manufacturer's specifications, quarterly reporting requirements for moisture monitoring, and a plan for remedial action response to suspected contaminant migration. Additionally, a certification, as specified in 40 CFR 270.11, was requested to accompany the revised closure plan.

The revised closure plan was resubmitted on May 31, 1989. Revisions to the narrative included descriptions of the installation and utilization of the moisture gauges, data reporting, and records location for monitoring information and the remedial action which will be implemented if data from any moisture gauge shows an increase in soil moisture content. A certification, as specified in 40 CFR 270.11, was prepared for signature by the Manager, DOE/Nevada Operations Office (NV).

The public comment/hearings period for this closure plan will occur in 1990. Final closure will commence following these periods.

3.4.3 UNDERGROUND STORAGE TANKS (USTs)

Sixteen USTs which contained petroleum products were removed from service and disposed of in NTS landfills, as listed in Table 3.2. In all cases the tanks were removed from the ground and 47 soil samples were collected to assure that the tanks had not leaked during their service life. Soil samples were analyzed for volatile organics by Sierra Technical Services Laboratory in Las Vegas, Nevada. In all cases no leaks of 100 ppm or greater were detected. At Building 115 soil samples showed elevated hydrocarbon levels. This led to the discovery of a previous leak of several thousands gallons from USTs which had been replaced in 1978 (see "Nonconformance Reports," Section 8.2.2).

Table 3.2 Underground Storage Tanks Removed in 1989

Area/Building	Size (Gallons)	Tank Number	Date Removed	Landfill
23/160	10,000	23-160-1	12-11-89	U10c
23/160	10,000	23-160-2	12-12-89	Area 23
23/160	10,000	23-160-3	12-11-89	Area 23
23/160	10,000	23-160-4	12-12-89	Area 23
23/160	10,000	23-160-5	12-11-89	U10c
23/116	15,000	23-116-1	12-19-89	U10c
23/116	15,000	23-116-2	12-19-89	U10c
23/116	15,000	23-116-3	12-19-89	U10c
23/115	10,000	23-115-1	12-14-89	U10c
23/115	10,000	23-115-2	12-15-89	U10c
23/115	10,000	23-115-3	12-15-89	U10c
23/109	5,000	23-109-1	01-19-90	Area 23
23/109	5,000	23-109-2	01-19-90	Area 23
25/3107	4,500	25-3107	12-19-89	Area 23
18/CAMP	10,000	18-1	12-18-89	U10c
18/CAMP	10,000	18-2	12-18-89	U10c

All tanks were emptied prior to excavation. If combustible/flammable vapors persisted, dry ice was added to the tank until lower explosive limit levels were below 15 percent. Stained soil which resulted from fuel contamination (due to overfills or from residual fuel in lines when cut) was cleaned up and disposed of in the Area 23 landfill.

3.4.4 WASTE MINIMIZATION

Waste minimization efforts at the NTS included material substitutions, oil-burning units for compressors, and the initiation of a formal waste-minimization program.

Several biodegradable solvents were tested at the NTS in 1989. The Fleet Operations, Drilling, and Health Physics Departments of the Site operating contractor were the major participants in these tests. In all cases petroleum-based and chlorinated solvents were successfully replaced with solvents such as Cit-Con™, Citri-Kleen™, and Simple Green™. A tracking system is being established to document total amounts of regulated solvent reduction.

An oil reburning unit for large air compressors and generators used on drill rigs was used in 1989 with success. The unit operates by drawing a small amount of oil from the crankcase into the fuel tank of the generator. (The percentage of the mixture can be manually controlled.) At the same time new oil is added to the crankcase at a compensating rate. This system eliminates the need for oil changes and provides a reduction in the amount of waste oil generated. Five oil samples were collected to assure the levels of metals in the oil do not exceed those recommended for oil/fuel mixtures. Sampling evaluation will continue on a quarterly basis. More units will be installed in 1990.

3.5 COMPREHENSIVE ENVIRONMENTAL RESPONSE, COMPENSATION, AND LIABILITY ACT (CERCLA)/SUPERFUND AMENDMENTS AND REAUTHORIZATION ACT (SARA)

In 1987 a DOE Headquarters task force determined that underground nuclear device testing areas are CERCLA sites. Under CERCLA all releases of hazardous or extremely hazardous substances that exceed reportable quantities must be reported to the National Response Center (NRC). Following further review of the issue and reporting procedures by the DOE and the EPA, the DOE/NV began reporting nuclear tests to the NRC in 1989. This reporting is in accordance with Section 103 of CERCLA and Section 304 of SARA. The NRC was provided with reports of typical underground nuclear tests, listing types and quantities of hazardous materials used in the tests. Following a test the NRC is notified of the test and of which typical test profile to reference. The DOE/NV also began reporting underground tests to the state of Nevada, Emergency Management Division, as part of this reporting procedure.

Preliminary Assessment/Site Investigation reports were prepared for the NTS and for formerly used sites and submitted to the EPA by the April 17, 1988, deadline. A revised Hazard Ranking Score of 22.55 was submitted in November 1988 to reflect changes in the NTS water production well system. These sites are scheduled to be reassessed and rescored using a new Hazard Ranking Score system in 1990. The EPA will use these reports to determine if the sites are to be included on the National Priority List (NPL).

The possibility of listing the NTS on the NPL of hazardous waste sites, under the auspices of CERCLA, carries potential for extensive budget and operational impacts. During 1989 environmental restoration planning for environmental contamination mitigation and environmental restoration actions were continued.

SARA toxic chemical reporting requirements were met with a "Tier II" report submitted to the state of Nevada on February 28, 1990.

The chemicals reported primarily consisted of industrial and construction-related acids, cleaning solvents, and fuels stored in warehouse facilities or in use in onsite construction yards.

3.6 TOXIC SUBSTANCES CONTROL ACT

On January 26, 1989, two inspectors from the EPA Region IX office conducted an inspection of the NTS for PCB compliance, including review of sampling procedures and associated analysis. The following items were identified as potential deficiencies. No formal report of this inspection was received by either the DOE/NV or onsite operating contractor during 1989.

FINDING - RECORDS ON OIL-FILLED ELECTRICAL APPARATUS

Records identifying oil-filled electrical apparatus containing over 50 ppm of PCB did not go back sufficient years as required by 40 CFR 761.180. REECo started its record keeping in approximately 1984.

Response

Government-owned facilities were not required to comply substantively with all federal regulations until 1983 (Executive Order 1154), thus no records were maintained.

FINDING - NOTIFICATION OF PCB IN ELECTRICAL APPARATUS

There was a lack of documentation notifying the onsite fire department of the location of electrical apparatus containing PCBs throughout the NTS prior to December 1985.

Response

In November 1985 a meeting was held between the onsite NTS fire protection personnel and the Occupational Safety, Industrial Hygiene, and Power and Communications Departments of the onsite operating contractor to discuss the requirements of 40 CFR 761. (This involved identification and marking of PCB transformers in or near buildings.) Minutes of the meeting and further correspondence from November were provided to DOE/NV as documentation that the appropriate measures had been taken.

FINDING - INCOMPLETE FORMAL PCB ANNUAL REPORTS TO EPA

Formal annual PCB reports to EPA did not go back as many years (to 1979) as required by 40 CFR 761.180. The onsite operating contractor began sending reports to EPA in approximately 1983.

Response

Government-owned facilities were not required to comply substantively with all federal regulations until 1983 (Executive Order 1154), thus no formal reports were generated.

FINDING - TRANSFORMERS STORED OUTSIDE OVER 30 DAYS

Electrical transformers (containing 50 ppm of PCB) that were taken out of service and identified for disposal had been in outside storage for more than 30 days.

Response

The transformers cited were scheduled for disposal. Subcontracting delays with the disposal company caused the PCB storage building to become overloaded, thus the transformers had to be stored outside. New subcontracts require more frequent and on-demand pickups to eliminate reoccurrence of the problem.

FINDING - INADEQUATE TRANSFORMER WARNING SIGNS

The electrical transformers, identified in the finding immediately above, did not have adequate warning signs.

Response

Signs were posted the next day on the fence facing the road and on the ropes in the yard surrounding the storage area.

FINDING - INADEQUATE PCB STORAGE BUILDING POSTING

The PCB storage building was not posted with signs identifying it as a PCB storage site.

Response

Proper signs were posted before the inspectors left the area.

The onsite operating contractor has a PCB Identification Number, NVG-PCB-006, issued by the state of Nevada. The 1988 annual PCB report was submitted by DOE/NV to the state to meet the requirements of 40 CFR 761.180. The report included the quantity and status of PCB and PCB-contaminated transformers and other equipment on the NTS. Also reported was the number of shipments of PCBs and PCB-contaminated items from the NTS to an EPA-approved disposal facility. Any transformer which had not yet been tested was reported as PCB-contaminated.

3.7 FEDERAL INSECTICIDE, FUNGICIDE, AND RODENTICIDE ACT (FIFRA)

The NTS operating contractor was responsible for the application of pesticides at the NTS. The program was operated under the supervision of a company sanitarian who was certified as a pesticide applicator with the state of Nevada. The program consisted of application, training, record maintenance, and scheduling.

Pesticides were stored in an approved storage facility located in Area 23. Pesticide usage included insecticides, herbicides, and rodenticides. Insecticides were applied twice a month at the food service and storage areas, herbicides were applied once or twice a year, and all other pesticide applications were applied on an as-requested basis. General-use pesticides were used for most applications. However, restricted-use herbicides and rodenticides were used only on occasion.

Records were maintained on all pesticides used, both general and restricted. These records will be held for at least three years. Training activities include at least two safety meetings covering pesticide use, and all applicators are provided the opportunity to receive state-sponsored training materials.

No unusual environmental activities occurred in 1989 relating to FIFRA.

3.8 ARCHAEOLOGICAL AND CULTURAL HISTORY PRESERVATION

The National Historic Preservation Act established the National Register of Historic Places and required federal agencies to take into account any impact their actions might have upon historic sites listed in the register. In compliance with the law, DOE/NV contracts pre-activity surveys and other studies to assess any impacts NTS operations may have on historical and archaeological sites found on the NTS. From the findings of the surveys, plans are written for the recovery of data to mitigate the effects of operations on these sites. When the plans are approved by DOE/NV, data recovery programs are initiated for the collection of archaeological data. The data recovery programs culminate in technical reports on the scientific findings of the programs. The responsibility for conducting these studies belongs to a group (Task 5 - Compliance with Environmental Regulations/Archaeology) within the DOE/NV-sponsored Basic Environmental Compliance and Monitoring Program (BECAMP).

In 1989, 17 pre-activity surveys were conducted for archaeological sites on the NTS, and reports on the findings at each

site were submitted to DOE/NV. Five data recovery plans were written, four data recovery programs were initiated, and six technical reports were completed. The pre-activity surveys conducted in 1989 identified 92 sites containing previously-unknown archaeological information.

Initiation of the American Indian Religious Freedom Act Compliance Program occurred in 1989. The program involves (1) a literature review of baseline documents about Native American concerns on the NTS, (2) development of a study plan on how DOE/NV is considering the effects of NTS operations on Native American concerns, (3) consultation with Native Americans who have concerns on the NTS, including field visits, (4) preparation of a draft report on the findings of the study plan and consultations, with recommendations, for mitigation of adverse effects on Native American concerns, and (5) completion of a final report which has been reviewed by appropriate state of Nevada and federal agencies. The program is scheduled for completion in 1992.

3.9 ENDANGERED SPECIES PROTECTION

The Endangered Species Act requires federal agencies to assure that their actions do not (1) jeopardize the continued existence of state of Nevada and federally listed endangered or threatened plant or animal species or (2) result in the destruction or adverse modification of critical habitat for these species. In compliance with this law, DOE/NV contracts pre-activity surveys and other studies to identify the locations and areas occupied by protected species.

There are currently eight species of concern found on the NTS; seven plant species that are being considered for listing as endangered or threatened and one reptile species that was listed as an endangered species in 1989. The responsibility for conducting these studies belongs to the Task 5 - Compliance with Environmental Regulations/Endangered Species group within the DOE/NV-sponsored BECAMP. Their efforts in 1989 included identifying locations of the plant *Astragalus beatleyae* and work associated with the *A. beatleyae* conservation agreement (see below). Another group (Task 3 - Monitoring of the Flora and Fauna on the NTS) in BECAMP annually monitors the flora and fauna on the NTS, including the desert tortoise, *Gopherus agassizii*, in its survey work.

During 1989, 28 pre-activity surveys were conducted to determine the presence of threatened or endangered species. Survey results and recommendations were documented in 17 reports. Significant survey findings included four locations of potential habitat of the plant *Astragalus beatleyae* in NTS Areas 19 and 20, and four new locations of the plant *Penstemon pahutensis* in NTS Areas 12, 17, and 19.

The conservation agreement for *A. beatleyae* between DOE/NV and the U.S. Fish and Wildlife Service (USFWS) was signed in 1989 and is effective until 1991. The agreement includes (1) the preparation of a species management plan; (2) pre-activity surveys to identify and protect populations from disturbance; (3) implementation of field surveys to document species' life history, assess the viability of known populations, and locate new populations; (4) documentation of known populations on maps filed with the DOE/NV; and (5) fencing of the species' type locality. A species management plan for *A. beatleyae* has been drafted for transmittal to the USFWS.

Pursuant to requirements of the conservation agreement and species management plan, a field study plan for monitoring *A. beatleyae* was prepared and implemented in 1989. Field work included the collection of life history data from 13 *A. beatleyae* populations and of habitat characterization data including site descriptions, plant species composition, and vegetative cover.

The state of Nevada has listed *A. beatleyae* as a "critically endangered species" based

on information gathered in the 1970s. Additional information has been gathered since the listing which shows the original range of the species was underestimated. A letter to the state of Nevada reported this information and provided the requested listing.

NTS herbarium species identified as *Astragalus lentiginosus* var. *micans* was sent to an expert on North American *Astragalus* taxonomy for verification. This variety is a Category 1 candidate species for federal listing under the Endangered Species Act. The re-identification was var. *variabilis*, which is not a candidate for federal protection.

In August 1989 under the emergency provisions of the Endangered Species Act, the USFWS listed the Mohave desert tortoise *(Gopherus agassizii)* as an "endangered species" north and west of the Colorado River. The primary reasons for listing were the continued loss of habitat and the rapid decline in desert tortoise numbers due to disease, habitat destruction, and other factors. Thus the Mojave desert tortoise population receives the full protection given to any species listed under the Endangered Species Act of 1973.

The desert tortoise distribution on the NTS coincides closely with the creosote bush community on the southern third of the NTS. Tortoises also occur in the transition zone between creosote bush and blackbrush in northern Jackass Flats and northwestern Frenchman Flat. Tortoise distribution on the NTS is patchy; a large area of Frenchman Flat (the playa bottom) is devoid of resident tortoises, and lower valley areas of Jackass Flats in very sandy habitats have few individuals. Larger numbers of tortoises appear to inhabit the bajadas surrounding Jackass Flats, Frenchman Flat, most of Rock Valley, and Mercury Valley. Densities of tortoises on the NTS are generally low and range from 0 to 45 individuals per square mile, with most habitats probably having densities of 0 to 20 individuals per square mile.

In 1989 prior to listing by the USFWS, five desert tortoises were captured and marked on the NTS, bringing the total free-roaming individuals marked since September 1987 to 48. In addition to the above, tortoises inhabiting the Rock Valley/UCLA study enclosures have been recaptured twice a year when possible, measured and released, providing 26 years of continuous records for a cohort of tortoises. In 1989, 14 tortoises were observed in Rock Valley; 16 individuals were known to exist in 1988.

To better inform the NTS operating contractor employees on the subject of the Mohave desert tortoise, a notice was included in all paycheck envelopes outlining required habitat protection measures and restrictions on contact with the species.

Federal and state permits have been issued to NTS entities for study of endangered species. These biological studies include ongoing research on the desert tortoise. Reports are filed, as stipulated by the permits, to the state of Nevada.

In order to continue desert tortoise studies at the NTS, the Site operating contractor applied for an endangered species permit from the USFWS on November 3, 1989. Issue of this permit is not expected until 1990.

3.10 DOE ENVIRONMENTAL SURVEY

In 1987 DOE Headquarters sent an environmental survey team to the NTS to identify potential environmental compliance situations. Based on this survey, an environmental survey action plan was developed in 1988. The environmental survey action plan was designed to list and describe specified environmental corrective actions, provide scheduling and financial estimates for corrections, and be used to track the corrective action process.

At the end of 1989, 73 of a total 105 action items have been certified as completed or closed. This information is presented in

Table 3.3 Environmental Survey Action Plan Items

	Closed 1988	Closed 1989	Remaining Items
Radiation Disposal Issues	6	7	2
Wastewater Disposal	3	23	22
Air Pollution Permitting	4	2	0
RCRA Permitting Actions	1	1	1
Storage	3	4	0
Solid Waste Disposal	5	9	5
Quality Assurance	3	2	2
Total(s)	25	48	32

Table 3.3, "Environmental Survey Action Plan Items."

3.11 "TIGER TEAM" COMPLIANCE ASSESSMENT

The NTS Tiger Team Compliance Assessment, conducted from October 30 to December 1, 1989, was part of a 10-point initiative by the Secretary of Energy, Admiral James D. Watkins, USN (Ret.), to conduct independent oversight compliance and management assessments of environmental, safety, and health programs at over one hundred of the DOE operating facilities. In the December 1989 draft report of its NTS compliance assessment, the Tiger Team related that members of the Environmental Team who also participated in the NTS environmental survey in 1987 "stated that they were impressed with the visible environmental improvements at the NTS since their 1987 visit." They reported that "the progress made by the NTS in responding to the (1987) Survey findings and generally improving environmental conditions indicates that both NV (DOE/NV) and the principal contractors at the NTS have made a sincere commitment to protection of the environment." These findings were further noted by the Secretary of Energy in his letter to the Manager/NV, stating, "I was recently briefed by the Tiger Team Leaders on the results of the NTS Assessment. While it is clear that some environment, safety and health (ES&H) compliance deficiencies do exist, I was pleased to note that the results of the assessment indicate that the Nevada Operations Office and its contractor organizations are aggressively implementing an effective ES&H culture...

"Your organization has demonstrated that a well-managed operation can fulfill mission objectives and goals and at the same time meet environment, safety, and health responsibilities."

The Tiger Team identified 45 environmental "findings" in its assessment of the NTS, none reflecting situations which presented an immediate risk to public health or the environment. Potential noncompliance findings included 35 irregularities with federal or state of Nevada environmental regulations and/or DOE orders. Ten findings represented conditions which were judged to not meet "best management practices," i.e., practices which could be improved through application of available or improved methods. The Team also identified three "noteworthy practices," i.e., "exceptional ways of accomplishing a Performance Objective or some aspect of it." Other DOE facilities are encouraged to adopt these practices when they are applicable to their operation.

In response the Tiger Team report, the DOE/NV has developed an action plan to address each of the findings. In many cases the planned actions are

straightforward and can be readily implemented. Others will require substantial funding and years to implement. A schedule for accomplishing all actions has been established, and, assuming funding is made available, all work is planned to be completed by the end of fiscal year 1996 (September 30, 1996).

The "most significant findings" identified by the environmental sub-team of the Tiger Team were:

- Incomplete waste characterization for wastes slated for onsite and offsite disposal.
- Radioactive wastes being accepted at the Area 3 and Area 5 radioactive waste disposal sites from generators which were not approved in accordance with DOE/NV procedures.
- Various wastes generated on the NTS were managed with insufficient knowledge of hazardous waste-related components in waste streams.

"Noteworthy practices" identified by the team included:

- DOE/NV's establishment of an effluent and environmental monitoring working group, with membership representing NTS contractors and User organizations (such as the national laboratories), as a formal chartered committee to coordinate the development of environmental protection planning and review for NTS environmental monitoring.
- Establishment of the Community Radiation Monitoring Program, which enlists residents of communities surrounding the NTS to assist in maintaining, managing, and reporting data from offsite monitoring stations.
- The Site operating contractor's practice of communicating significant environmental issues to Site personnel through informational cards included in paycheck envelopes.

3.12 RADIATION PROTECTION

Results of environmental monitoring on the NTS during 1989 showed full compliance with the radiation exposure guidelines of DOE Order 5480.11, "Radiation Protection for Occupational Workers," DOE Order 5400.5, "Radiation Protection of the Public and the Environment," and the National Primary Drinking Water Regulations. Onsite air monitoring results showed average annual concentrations ranging from 0.0009 percent of the DOE Order 5400.5 guidelines for ^{85}Kr to 1.7 percent of the guidelines for $^{239+240}Pu$ in air. The guideline concentrations in DOE Order 5480.11 for occupational workers are one hundred to one thousand times higher than those for the public. Drinking water supplies on the NTS contained 0.002 percent of the DOE Order 5400.5 guideline and 0.22 percent of the National Primary Drinking Water Regulation for ^{3}H. Supply wells contained 0.005 percent of the DOE Order 5400.5 guideline for $^{239+240}Pu$. (Comparisons are made to the guidelines for public consumption although the general public does not consume water from these supplies.)

The calculated maximum individual offsite dose from onsite air emissions was 0.00015 mrem, compared to the National Emissions Standard for Hazardous Air Pollutants of 25 mrem per year.

4.0 ENVIRONMENTAL PROGRAM INFORMATION

The environmental monitoring and compliance program for the NTS consists of (1) radiological monitoring, (2) nonradiological monitoring, and (3) environmental permit and operating compliance.

4.1 RADIOLOGICAL MONITORING

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There are two radiological monitoring programs at the NTS, the onsite and offsite programs. The onsite radiological monitoring program is conducted by several organizations. REECo, the operating contractor at the NTS, is responsible for environmental surveillance and effluent monitoring. Several other organizations, such as the Lawrence Livermore National Laboratory (LLNL), Los Alamos National Laboratory (LANL), Desert Research Institute (DRI), EPA, and participants in the Basic Environmental Compliance and Monitoring Program also make radiological measurements. The offsite radiological monitoring program is conducted by the EPA's Environmental Monitoring Systems Laboratory in Las Vegas, Nevada (EMSL-LV).

4.1.1 ONSITE MONITORING

At the NTS radiological effluents may originate from: (1) tunnels, (2) underground test event sites [at or near surface ground zeros (SGZs)], and (3) facilities where radioactive isotopes are either used, processed, stored, or discharged. All of these types of sites have the potential or are known to discharge radioactive effluents into the environment.

Air sampling was conducted for radioactive particulates, halogens, noble gases, and tritiated water vapor. Ambient gamma monitoring was conducted throughout the Site. Potable water (from groundwater wells), spring water, well reservoirs, and waste disposal ponds were sampled for radiological substances. These tasks made up the environmental surveillance program at the NTS.

CRITERIA

DOE Order 5400.1, "General Environmental Protection Program," published in November of 1988, established the onsite environmental protection program requirements, authorities, and responsibilities for DOE operations. These mandates assured compliance with applicable federal, state, and local environmental protection laws and regulations. Other orders applicable to environmental monitoring include DOE Order 5480.11, "Radiation Protection for Occupational Workers;" DOE Order 5480.1B, "Environment, Safety, and Health Program for Department of Energy Operations;" DOE Order 5484.1, "Environmental Protection, Safety, and Health Protection Information Reporting Requirements;" DOE Order 5400.5, "Radiation Protection of the Public and the Environment;" and DOE Draft Order 5400.6, "Radiological Effluent Monitoring and Environmental Surveillance."

EFFLUENT MONITORING

Effluent monitoring efforts at the NTS focused on monitoring nuclear test event sites, tunnel discharge waters, and the radiological Area 6 Decontamination Facility. During 1989 effluent monitoring was

conducted at 12 test event sites, 4 tunnel facilities, 1 decontamination facility, and 1 groundwater radionuclide migration research water well.

Liquid Effluent Monitoring

Radiologically-contaminated water was discharged from N, T, and E Tunnels in the Rainier Mesa (Area 12) range. Once each month a grab sample was taken from each tunnel's effluent discharge point and from each tunnel's contaminated water holding pond. The water from these tunnels was analyzed for tritium (^{3}H), gross beta, gamma emitters, $^{239+240}Pu$, and ^{238}Pu. Tritium was the main radionuclide detected at the tunnel sites. Other radionuclides were detected infrequently.

A conservative estimate of the flow rate discharged from each tunnel was made to quantify the total annual radiological effluent release. The average annual concentration (in Ci/gallon) of the isotope of interest in the effluent liquid was multiplied by the estimated total quantity of liquid discharged from the tunnel during a calendar year. This value was reported as the total liquid radiological effluent discharged from the facility.

A similar technique was employed at the Area 6 Decontamination Facility, where a flow to the Decontamination Facility holding pond was estimated, then the total quantity of water discharged was multiplied by the concentration of ^{3}H in the water. Aside from ^{3}H there were no other radionuclides detected in the pond influent during 1989.

At the radionuclide migration research well in Area 5, the flow of water was intentionally discharged to a collecting pond. This flow was maintained with a pump at 600 gallons per minute. The well water was contaminated with measurable amounts of ^{3}H. Therefore the total discharge of ^{3}H to the environment was determined fairly accurately.

Airborne Effluent Monitoring

Tritiated airborne water vapor was monitored on a continuing basis at the Area 12 G Tunnel complex to determine airborne emissions from tunnel ventilation.

Pahute Mesa events in Area 19 and 20 were monitored for ^{85}Kr and ^{133}Xe. For each event conducted in these areas during 1989, up to three portable noble gas samplers were placed in the vicinity of the SGZ. Noble gas samplers were deployed for any test conducted in an Area 12 tunnel. Portable noble gas samplers were used to detect any seeps of noble gases created from the fission process. The portable noble gas sampling unit used was similar in design to the permanent sampler used for environmental surveillance. The sampling system is described in "Environmental Surveillance," below.

ENVIRONMENTAL SURVEILLANCE

Environmental surveillance was conducted onsite throughout the NTS. Several fixed, continuous-sampling locations monitor for radioactive materials in the air, surface water, and groundwater.

Air Monitoring

The environmental surveillance program maintained samplers designed to detect airborne radioactive particles, radioactive gases (including halogens and noble gases), and radioactive hydrogen (^{3}H) as water vapor in the form $^{3}H^{3}HO$ or ^{3}HHO.

Air sampling units were located at 52 stations on the NTS to measure radionuclides in the form of particulates and halogens. All placements were chosen primarily to provide monitoring of radioactivity at sites with high worker population density. Geographical coverage, access, and availability of commercial power were also considered.

An air sampling unit consisted of a positive displacement pump drawing air through a nine-centimeter diameter Whatman GF/A filter for trapping particulates, followed by a charcoal cartridge collecting radioiodines. The filter and cartridge were mounted in a plastic, cone-shaped sample holder. The unit drew approximately 100 L/min of air. A dry-gas meter measures the volume of

air displaced over the sampling period (typically seven days). The unit sampled a total volume of approximately 1000 cubic meters.

The samples were held for no less than five days and no more than seven days prior to analysis to allow naturally-occurring radon and its daughter products to decay. Gross beta counting was performed with a gas-flow proportional counter for 20 minutes. The lower limit of detection for gross beta, assuming typical counting parameters, was 2×10^{-16} µCi/mL. Gamma spectroscopy was accomplished using germanium detectors with an input to a 2000-channel spectrometer, calibrated at 1 kiloelectronvolt (keV) per channel from 0.02 to 2 megaelectronvolts (MeV).

Weekly air samples for a given sampling station were prepared in batches on a monthly basis and radiochemically analyzed for $^{239+240}$Pu. This procedure incorporated an acid dissolution and an ion-exchange recovery on a resin bed. Plutonium was deposited by plating on a stainless steel disk. The chemical yield of the plutonium was determined with an internal ^{236}Pu or ^{241}Pu tracer. Alpha spectroscopy was performed utilizing a solid-state silicon surface barrier detector. The lower limit of detection for ^{238}Pu and $^{239+240}$Pu was approximately 1×10^{-17} µCi/mL.

The radioactive noble gases ^{85}Kr and ^{133}Xe were determined from continuous samples of air taken at seven permanent locations. The noble gas samplers maintained a steady sampling flow rate for one week. Noble gas sampling units were housed in a metal tool box and, with the exception of a few minor differences, were similar to the portable units used to monitor effluents. Three metal air bottles were attached to the sampling units with short hoses. A vacuum was maintained on the first bottle, which was then pumped into the other two bottles. The flow rate was approximately 0.5 mL/min. The two collection bottles were exchanged weekly and yielded a sample volume of about 300 liters.

The noble gases were separated and collected from the atmospheric sample by a series of cryogenic gas-distillation techniques. Water and carbon dioxide were removed at room temperature, and the krypton and xenon were collected on charcoal at liquid nitrogen temperatures. These gases were transferred to a molecular sieve where they were separated from any remaining gases and each other. The krypton and xenon were transferred to separate scintillation vials and counted on a liquid scintillation counter. The lower limits of detection for ^{85}Kr and ^{133}Xe were 4×10^{-12} and 10×10^{-12} µCi/mL, respectively.

Airborne tritiated water vapor was monitored at 17 permanent locations throughout the NTS. Constant airflow over moisture-collecting material was maintained for a two-week period, during which airborne moisture was extracted and, at the end of the sampling period, transferred to the onsite laboratory for analysis. The airborne tritium sampler was capable of unattended operation for up to two weeks in desert areas. A small electronic pump drew air into the apparatus at approximately 0.5 L/min, and the tritiated water vapor was removed from the air stream by two silica-gel drying columns. Appropriate aliquots of condensed moisture were obtained by heating the silica gel. Liquid scintillation counting determined the tritiated water vapor activity. The lower limit of detection for tritiated water vapor analysis was 3×10^{-13} µCi/mL.

Ambient Gamma Monitoring

Ambient gamma monitoring was conducted at 150 stations within the NTS through use of thermoluminescent dosimeters (TLDs). A TLD emits light when it is heated after having been exposed to radiation, hence the term "thermoluminescent." The total amount of light given off by the crystal is proportional to the amount of energy absorbed from the radiation. The intensity of light emitted from the TLD crystal is directly proportional to the radiation dose.

The dosimeters used were UD-814AS environmental dosimeters manufactured by Panasonic. One TLD badge consisted of four elements housed in an air-tight, water-tight, ultraviolet-light-protected case.

The first element, made of lithium borate, was only slightly shielded in order to capture low-energy radiation. The other three elements, made of calcium sulfate, were shielded by 1000 mg/cm^2 of lead to screen out low-energy radiation. These TLDs were deployed for a period of one calendar quarter.

Each TLD holder was placed about one meter above the ground at each monitoring location. Previous research has indicated that only about five to ten percent of the total exposure from natural background is from gamma emitters below 150 keV (Beck 1972).

Water Monitoring

Water samples were collected at various frequencies from selected potable water consumption points, supply wells, natural springs, open reservoirs, final effluent ponds, and contaminated ponds. The frequency of collection was determined on the basis of a preliminary radiological pathways analysis. Potable water was collected weekly; supply wells were sampled monthly. Samples were collected in one-liter glass containers. All samples were analyzed for gross beta, tritium, and gamma-emitting isotopes. Plutonium analyses were performed on a quarterly basis.

A 500-mL aliquot was taken from the water sample and counted in a Nalgene bottle for gamma activity with a germanium detector. A 5-mL aliquot was used for tritium analysis through liquid scintillation counting. The remainder of the original sample was evaporated to 15 mL, transferred to a stainless steel counting planchet, and evaporated to dryness after the addition of a wetting agent. Beta counting was accomplished as described above ("Air Monitoring") except that the water samples were counted for 100 minutes.

The lower limits of detection for water analyses were:

- Gamma spectroscopy, $\cong 1 \times 10^{-8}$ µCi/mL.
- Tritium, 9×10^{-7} µCi/mL.
- Gross beta, 1×10^{-9} µCi/mL.

For the quarterly plutonium analysis of water samples, an additional one-liter sample was collected. The radiochemical procedure was similar to that previously described in this chapter under "Air Monitoring." Alpha spectroscopy was used to measure any ^{238}Pu and $^{239+240}$Pu. The lower limit of detection for this procedure was 4×10^{-11} µCi/mL.

Waste Management Site Monitoring

Environmental surveillance was conducted at NTS Radioactive Waste Management Project sites. These sites were used for the disposal of radioactive waste materials as low-level waste (LLW) from the NTS and from other DOE facilities. Shallow disposal in trenches, pits, augured shafts, and subsidence craters was accomplished at the Area 5 Radioactive Waste Management Site (RWMS) and at the Area 3 Bulk Waste Management Facility (BWMF).

The Area 5 RWMS contains the LLW disposal unit, the transuranic waste storage cell, and the Greater Confinement Disposal Unit. The Area 3 BWMF accepted bulk LLW which could not be packaged. Much of the waste material buried there was contaminated soil and metal remaining from the atmospheric testing of nuclear weapons at the NTS. The materials were deposited in subsidence craters (craters which resulted from surface ground collapse after underground nuclear detonations, see Figure 1.4).

Nine permanent air particulate/halogen sampling stations and nine permanent tritiated water vapor sampling stations surrounded the RWMS in Area 5. Sixteen TLD stations also surrounded this site. Three tritiated water vapor sampling stations were located within the personnel facility at the RWMS. Two permanent air particulate/halogen samplers were located inside the actual disposal trenches.

The BWMF was surrounded by four air particulate/halogen sampling stations, and several TLD stations were located nearby.

Radionuclide Migration and Uptake Studies

A series of studies on the potential of subsurface radionuclide migration were continued on the NTS by the DRI, LANL, and LLNL. These studies included:

- Field research on enhancement of groundwater recharge by surface subsidence craters.
- Study of precipitation recharge of Pahute Mesa groundwater recharge.
- Unsaturated zone migration of radionuclides in the vicinity of the CAMBRIC event migration study site ditch (see Section 5.1.2).
- Geologic formation fluid pressure studies in Area 3 and Area 4.
- Area 2 hydrogeology characterization and test cavity vicinity plume migration in Area 20.
- Experiments on the role of colloidal transport of radionuclides in groundwater.

The Basic Environmental Compliance and Monitoring Program (BECAMP) was involved in special studies on the NTS that focused on (1) the movement of radionuclides through the environment and (2) the resultant dose to man. BECAMP used the past accomplishments of two former DOE/NV-sponsored programs at the NTS, the Nevada Applied Ecology Group (NAEG) and the Radionuclide Inventory and Distribution Program (RIDP), in ongoing efforts to design effective programs to assess changes over time in the radiological conditions on the NTS, update human dose-assessment models, and provide information to DOE/NV related to site-restoration projects and compliance with environmental regulations.

The main objective of one group in BECAMP (Task 1 - Movement of Radionuclides On and Around the NTS) has been to determine the rate of movement of surface-deposited radionuclides in four categories: horizontal movement, water-driven erosion, vertical migration, and wind-driven resuspension. Efforts in 1989 were concentrated in areas relevant to investigating the horizontal movement, vertical migration, and water-driven erosion of radionuclides in soil. Information from past studies on the NTS was sufficient to satisfy immediate needs, so resuspension studies were postponed. Studies in 1989 included developing field monitoring techniques to detect changes in radionuclide concentrations in soil, examining the natural variability in soil characteristics and its influence on the ability to detect changes in soil radionuclide concentrations, and investigating the influence of local vertical distribution of plutonium in soils on the precision of *in situ* measurements. The investigations described used radionuclide soil-concentration data published in works of the NAEG and RIDP and resulted in two draft publications. The only monitoring work conducted in 1989 was in Area 11 of the NTS in conjunction with the development of *in situ* detection systems.

A second task in the BECAMP program (Task 2 - Human Dose Assessment Models) has been updating the NAEG/NTS dose-assessment model. The NAEG/NTS model estimated the dose, via ingestion and inhalation, to man from $^{239+240}Pu$. The BECAMP dose-assessment model is an expanded version of the NAEG model that has been updated to include all significant radionuclides in the NTS environs and all exposure pathways, including external exposure from gamma-emitting radionuclides. In 1989 sensitivity and uncertainty analyses were performed on the NAEG model, and work was begun on the BECAMP model to include: (1) a more detailed, multi-compartment gut submodel for calculating dose, (2) the gamma-exposure pathway, and (3) other radionuclides that were found in measurable quantities on the NTS by RIDP.

Another group within BECAMP (Task 4 - Annual Peer-Reviewed Publications) has been assigned to prepare a major yearly thematic, peer-reviewed publication that addresses an important issue related to the potential environmental impacts of past,

present, and future activities at the NTS and its environs. In 1989 a paper was published dealing with the transfer of $^{239+240}Pu$, ^{238}Pu, ^{241}Am, and ^{137}Cs to cattle that had grazed in an arid environment contaminated 16 years earlier by testing of a nuclear device (Gilbert et al. 1989). This paper used the same experiment as an earlier 1988 publication dealing with the transfer of aged plutonium to cattle grazing on a contaminated desert environment (Gilbert et al. 1988a). A second publication was released in late 1988 dealing with the transport of radionuclides through the NTS environment (Gilbert et al. 1988b), and the fifth in a series of reports from the RIDP was also released in 1989 (McCarther and Mead 1989).

4.1.2 OFFSITE MONITORING (EPA 1990)

The EPA conducted the offsite radiological monitoring program around the NTS. The Agency's EMSL-LV was responsible for conducting the program. The radiological safety activities of the EMSL-LV were divided into two areas, both designed to detect environmental radiation; special test support and routine environmental surveillance.

Special test support involved fielding mobile monitoring teams around the NTS during all nuclear tests. Radiation protection technicians, equipped with a variety of radiation survey instruments, dosimeters, portable air samplers, and supplies for collecting environmental samples, were prepared to conduct a monitoring program as directed from the NTS Control Point via two-way radio communications. Radiation sampling and tracking aircraft operated by EG&G (a DOE support contractor) were flown over the NTS to gather meteorological data, obtain samples, and determine the total volume of the radioactive "cloud" should any airborne radioactive release have occurred. Information from these aircraft could be used in positioning the EPA mobile radiation protection technicians.

The routine surveillance program included pathways monitoring that consisted of air, water, and milk surveillance networks surrounding the NTS, and a limited animal and vegetable sampling program. In addition, external and internal exposures of offsite populations were assessed using state-of-the-art dosimetry equipment.

AIR MONITORING

The Air Sampling Network (ASN) was designed to monitor the areas within 350 kilometers of the NTS, with some concentration of stations in the prevailing downwind direction. Station location was dependent upon the availability of electrical power and, at stations distant from the NTS, on a resident willing to operate the equipment. This continuously-operating network was supplemented by a standby network which covered the contiguous states west of the Mississippi River.

During 1989 the ASN consisted of 31 continuously-operating sampling stations and 78 standby stations. The air sampler at each station was equipped to collect particulate radionuclides on filters and gaseous radioiodines in charcoal cartridges. The filters and charcoal cartridge samples from all active stations, and the filters from standby stations, received complete analyses. The charcoal cartridge samples from standby stations were analyzed only if there was some reason to expect the presence of radioiodines.

Samples of airborne particulates were collected at each active station on 5-cm diameter, glass-fiber filters at a flow rate of about 80 cubic meters per day. Filters were changed after sampler operation periods of one week (approximately 570 cubic meters). Activated charcoal cartridges placed directly behind the filters to collect gaseous radioiodine were changed at the same time as the filters. The standby network was activated for one week per quarter. The standby samplers were identical to those used at the active stations and were operated by state and municipal health department personnel or by other local residents. All analytical work was performed at the EMSL-LV.

A second part of the EPA offsite air network was the Noble Gas and Tritium

Surveillance Network (NGTSN). The sources of these radionuclides include noble gases and tritium emitted from nuclear reactors, reprocessing facilities (non-NTS facilities), and worldwide nuclear testing. Tritium is also produced naturally. The monitoring network detected radioactivity from these "background" sources, but the NGTSN was designed to detect an increase in these levels due to possible NTS emissions. Network samplers were typically located in populated areas surrounding the NTS with emphasis on night-time "drainage" winds leading from the test areas. Other samplers were located in communities at some distance from the NTS. In 1989 this network consisted of 20 sampling stations located in the states of Nevada, Utah, and California.

Noble gas samples were collected by compressing air into storage tanks. The equipment continuously sampled air over a seven-day period and stored approximately 0.6 cubic meters of air in the tanks. The tanks were exchanged weekly and returned to the EMSL-LV for analysis. Analysis started by condensing the samples at liquid nitrogen temperature and using gas chromatography to separate the gases. The separate fractions of xenon and krypton were dissolved in scintillation cocktails and counted in a liquid scintillation counter.

For ^{3}H sampling, a molecular sieve column was used to collect water from air. Up to 10 cubic meters of air were passed through the column over a seven-day sampling period. Water adsorbed on the molecular sieve was recovered, and the concentration of ^{3}H in the water was determined by liquid scintillation counting.

WATER MONITORING

As part of EPA's Long-Term Hydrological Monitoring Program, surface water and groundwater sampling and analysis have been performed for many years on water sources on and around the NTS. At nearly all locations, the standard operating procedure was to collect four samples. Two samples were collected in 500-mL glass bottles to be analyzed for ^{3}H. The results from analysis of one of these was reported while the other sample served as a backup in case of loss or as a duplicate sample. The remaining two samples were collected in 3.8-liter plastic containers (cubitainers). One of these was analyzed by gamma spectrometry and the other was stored as a backup or for duplicate analysis.

On wells with operating pumps, the samples were collected at the nearest convenient outlet. If the well had no pump, a winch-powered sampling canister was used. With this canister it was possible to collect 3-liter samples from wells as deep as 1800 meters. At a few locations, because of limited supply, only 500-mL samples for ^{3}H analysis were collected. At the normal sample collection sites, the pH, conductivity, and water temperature were measured when the sample was collected. Also, after the first time samples were collected from a well, ^{89}Sr, ^{90}Sr, ^{226}Ra, ^{238}Pu, $^{239+240}Pu$, and uranium isotopes were determined by radiochemistry as time permitted.

The samples were collected monthly, when possible, and analyzed by gamma spectrometry as well as for ^{3}H. For a few NTS wells and for all the water sources around the NTS, a sample was collected twice per year at about a six-month interval. One of the semi-annual samples was analyzed for ^{3}H by the conventional method, the other by enrichment.

MILK SURVEILLANCE NETWORK

In 1989 the Milk Surveillance Network (MSN) consisted of 27 locations within 300 kilometers of the NTS from which samples were scheduled for collection every month. The raw milk was collected in 4-liter cubitainers and preserved with formaldehyde. In addition, all major milksheds west of the Mississippi River, represented by 106 locations in 1989, were sampled on an annual basis as part of the Standby Milk Surveillance Network (SMSN). One exception was Texas, which sampled the milksheds in that state. SMSN samples were supplied by cooperating state Food and Drug Administration personnel upon the

request of the EPA regional offices. These samples, also preserved with formaldehyde, were mailed to the EPA. The annual activation of the SMSN helped maintain readiness and highlighted any trends of increasing radionuclide concentrations in western states.

All samples were analyzed by high-resolution gamma spectroscopy to detect gamma-emitting radionuclides. One sample per quarter for each location in the MSN and samples from two locations in each western state in the SMSN were subjected to radiochemical analytical evaluations. These samples were analyzed for ^{3}H by liquid scintillation counting, and for ^{89}Sr and ^{90}Sr by anion exchange method.

BIOMONITORING

Samples of muscle, lung, liver, kidney, blood, and bone were collected periodically from cattle purchased from private herds that graze areas adjacent to the NTS. Soft tissues were analyzed for gamma-emitting radionuclides. Bone and liver were analyzed for strontium and plutonium, and blood was analyzed for ^{3}H. Each November and December, bone and kidney samples from desert bighorn sheep killed and donated by licensed hunters in Southern Nevada have been analyzed for strontium, plutonium, and tritium. These kinds of samples have been collected and analyzed for up to 32 years to determine long-term trends. During 1989 four NTS mule deer were collected and were sampled in the same manner as the cattle.

During the Summer of 1989, samples of vegetable produce were collected from offsite farms in Utah and Nevada. Collections included: carrots and tomatoes from Virgin, Utah; beets and grapes from St. George, Utah; potatoes and zucchini squash from Rachel, Nevada; swiss chard and turnips from Rachel, Nevada; and squash and potatoes from Hiko, Nevada.

EXTERNAL GAMMA EXPOSURE MONITORING

The EPA's offsite TLD network was designed primarily to measure total ambient gamma exposures at fixed locations. A secondary function of the network was the measurement of exposures from past nuclear tests to offsite residents living within estimated fallout zones. Measurement of exposures to specific individuals involved the multiple variables associated with any personnel monitoring program. Measuring environmental ambient gamma exposures in fixed locations provided a reproducible index which could then be easily correlated to the maximum exposure an individual would have received were the person continuously present at that location. Monitoring of individuals made possible an estimate of individual exposures and helped to confirm the validity of correlating fixed-site ambient gamma measurements to projected individual exposures.

During 1989 a total of 135 offsite stations were monitored to determine background ambient gamma radiation levels. Each station had a custom-designed holder that could hold from one to four Panasonic TLDs. Normal operations involved packaging two TLDs in a heat-sealed bag to provide protection from the elements and placing the dosimeter packet into the fixed station holder. Fixed environmental monitoring TLDs were normally deployed for a period of approximately three months (one calendar quarter). The annual adjusted ambient gamma exposure (mR/year) was calculated by multiplying the average daily rate for each station by 365. A review of the measurement periods showed that few stations were monitored for exactly 365 days. However, when the results of a "nominal" 365-day year were compared with the results obtained by multiplying the average mR/day by the actual number of days, calculated differences were less than 1 mR/year. This is considered to be an insignificant discrepancy.

During 1989 a total of 65 individuals living in areas surrounding the NTS were provided with personnel TLD dosimeters. The TLDs used to monitor individuals were sensitive to beta, gamma, neutron, and low- and high-energy x-radiations. The TLDs used to monitor fixed reference background locations were designed to be

sensitive only to gamma and high-energy x-radiations. Because personnel dosimeters were cross-referenced to associated fixed reference background TLDs, all personnel exposure measurements present were presumed to be gamma or high-energy x-radiation. Exposures of this type were numerically equivalent to the absorbed dose.

TLDs used to monitor individuals were provided in holders which were 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 could be used to estimate not only ambient gamma radiation exposure but to characterize the absorbed radiation dose an individual wearing the dosimeter might have received. TLDs issued to individuals were normally deployed and collected on a monthly monitoring schedule.

Monitoring of offsite personnel was accomplished with the Panasonic UD-802 dosimeter. This dosimeter contained two elements of $Li_2B_4O_7$:Cu and two of $CaSO_4$:Tm phosphors. The four elements were behind 14-, 300-, 300-, and 1000-mg/cm^2 of Teflon, plastic, plastic, and plastic/lead filtration, respectively. These filtrations closely approximate the attenuation afforded by the dead layer of the skin, the cornea of the eye, and the "deep" tissues of the body. Monitoring of offsite environmental stations was accomplished with the Panasonic UD-814 dosimeter. This dosimeter contained a single element of $Li_2B_4O_7$:Cu and three replicate $CaSO_4$:Tm elements. The first element was filtered by 14 mg/cm^2 of plastic, and the remaining three were filtered by 1000 mg/cm^2 of plastic and lead. The three replicate phosphors were used to provide improved statistics and extended response range.

The EPA also used a pressurized ion chamber (PIC) network to monitor external gamma exposure rates. These rates varied with altitude (cosmic radiation) and natural radioactivity in the soil (terrestrial radiation). There were 27 PICs deployed around the NTS; of these, 18 were at Community Radiation Monitoring Program (CRMP) stations. Data were collected almost instantaneously via satellite telemetry. The data were also recorded on magnetic tapes and strip charts. In the event of an accidental release of radioactivity from the NTS, the PIC network could have signaled via satellite telemetry and provided instantaneous data from all PIC locations.

Data were displayed in μR/hr (0.001 mR/hr) on a digital readout display at each location for easy access by the public. Computer analysis of the data was accomplished on a weekly basis at the EMSL-LV. As part of routine quality assurance procedures, trends were noted and compared to previous years. Source checks were conducted weekly and data were plotted by the EMSL-LV resident expert for comparison to previous weeks.

POPULATION RADIONUCLIDE UPTAKE MONITORING

The EPA whole-body counting facility has been maintained at the EMSL-LV since 1966. The facility is equipped to determine the identity and quantity of gamma-emitting radionuclides which might have been inhaled or ingested by offsite residents and others exposed to 1989 NTS radiation releases. Routine "counting" of radionuclides in a person consisted of a 2000-second count with a sensitive radiation detector placed next to a person reclining in one of the two shielded counting rooms.

The Offsite Human Surveillance Program was initiated in December 1970 to determine levels of radionuclides in some of the families residing in communities and ranches surrounding the NTS. This program started with 34 families (142 individuals). In 1989, 15 of these families (36 individuals) were still active in the program in addition to six families added in recent years.

These persons travelled to the EMSL-LV for a biannual whole-body count. A urine sample was also collected for ^3H analysis. At 18-month intervals a physical exam, health history, and the following were performed: urinalysis, complete blood

count, serology, chest x-ray (three-year intervals), sight screening, audiogram, vital capacity, EKG (if over 40 years old), and thyroid panel. The individual was then examined by a physician.

Analysis for internally deposited radionuclides was also performed for EPA employees, DOE contractor employees, and other workers who might have been occupationally exposed, as well as for concerned members of the general public. Results of counts on individuals from Las Vegas and other cities were used for comparison.

COMMUNITY RADIATION MONITORING PROGRAM STATIONS

Beginning in 1981 the DOE and EPA established a network of CRMP stations in the offsite areas in order to increase public awareness of radiation monitoring activities. The DOE, through an interagency agreement with the EPA, sponsored the program and contracted with the DRI to manage the stations and with the University of Utah to train station managers. Each station was operated by a local resident, in most cases a science teacher, who was trained in radiation monitoring methods by the University of Utah. Samples were analyzed at the EMSL-LV. The DRI provided data interpretation to the communities involved.

During 1989 all of the 18 stations, except for Milford and Delta, Utah, had one of the samplers for the ASN, NGTSN, and dosimetry (TLD) network, plus a PIC and recorder for immediate readout of external gamma exposure and a recording barograph. The stations at Milford and Delta were complete except for noble gas samplers, which will be added when the equipment becomes available. All of the equipment was mounted on a stand at a prominent location in each community so the residents were aware of the surveillance and, if interested, could have ready access to the data.

Computer-generated reports for each station were issued weekly. These reports indicated the current weekly PIC average, the previous week's and year's averages, and the maximum and minimum backgrounds in the U.S. In addition to being posted at each station, copies were sent to newspapers in Nevada and Utah and provided to appropriate federal and state personnel in California, Nevada, and Utah.

All of the CRMP stations were equipped with satellite telemetry-transmitting equipment. With this equipment, gamma exposure measurements acquired by the PICs were transmitted via the geostationary operational environmental satellite (GOES) directly to the NTS and from there to the EMSL-LV by dedicated telephone line.

4.2 NONRADIOLOGICAL MONITORING

Charles W. Burhoe and Scott E. Patton

The 1989 nonradiological program for the NTS included onsite sampling of various environmental media and substances for compliance with federal and state regulations or permits, and ecological studies conducted as part of the BECAMP. These programs include wildlife surveys and vegetation trend studies in disturbed and undisturbed areas of the Site. No offsite nonradiological monitoring was conducted in 1989 as no tests were conducted at the Liquified Gaseous Fuels Spill Test Facility, resulting in no nonradiological environmental releases to the offsite area.

4.2.1 ONSITE MONITORING

As there were (and are) no industrial-type production facility operations on the NTS, there was no significant production of nonradiological air emissions or liquid discharges to the environment when compared to many other DOE nuclear facility operations. Sources of potential contaminants were limited to construction support and Site operation activities. This included motor pool facilities; large equipment and drilling rig maintenance areas; cleaning, warehousing and supply facilities; and general worker support facilities (including lodging and administrative offices) in the Mercury Base Camp, Area 12 Camp, and to a lesser extent in Area 20 and the NTS Control Point complex in Area 6. The Liquified Gaseous Fuels Spill Test Facility in Area 5 is a source of potential release of nonradiological contaminants to the environment, depending on the individual tests conducted, but no tests were conducted during 1989. Consequently, nonradiological environmental monitoring at the NTS in 1989 was limited to:

- Routine sampling of drinking water distribution systems for Safe Drinking Water Act and state of Nevada compliance.
- Sewage lagoon influent sampling for Resource Conservation Recovery Act (RCRA) constituents and compliance with state of Nevada operating permits.
- PCB sampling of electrical transformer oils, soils, and waste oil for Toxic Substance Control Act compliance.
- Asbestos sampling in conjunction with asbestos removal and renovation projects, and following occupational safety and National Emission Standards for Hazardous Air Pollutants (NESHAP) compliance.
- Sampling of soil, water sediment, waste oil, and other media for RCRA constituents.

ECOLOGICAL STUDIES

Ecological studies conducted under the BECAMP involved monitoring of the flora and fauna on the NTS to assess changes over time in the ecological condition of the NTS and to provide information needed for assessing NTS compliance with environmental laws, regulations, and orders. The monitoring effort (conducted by the BECAMP Task 3 group - Monitoring of the Flora and Fauna on the NTS) has been arranged into three interrelated phases of work: (1) a series of five non-disturbed control study plots in the test-impacted ecosystems that are monitored at 1-, 2-, 3-, 4-, or 5-year intervals to establish natural baseline conditions; (2) a series of study plots in representative disturbed areas that are monitored at 3- to 5-year intervals to determine the impact of disturbance, document site recovery, and investigate natural recovery processes; and

(3) a series of wildlife observation plots centered around natural-spring and man-made water-source habitats on the NTS.

The monitoring and survey work includes: (1) soil sampling to determine the fertility status of soil with respect to organic-matter content, available forms of nitrogen, and both macro- and micro-nutrient elements; (2) vegetation sampling for the purpose of determining the health status, recovery, and utilization of vegetation in disturbed and undisturbed areas; (3) trapping of rodents and reptiles to determine the condition of individual specimens and the continuity and stability of resident populations; (4) surveys to obtain information concerning resident populations of desert tortoises, kit foxes, rabbits, deer, and feral horses; and (5) the maintenance and preservation of herbarium and biological data archives.

In 1989 monitoring sites on which plants and animals were surveyed numbered: (1) 19 for Spring ephemeral plants, (2) 29 for perennial plants, (3) 19 for small mammals, and (4) 8 for lizards. Many of these sites contained paired disturbed/ undisturbed plots. Monitoring sites surveyed included the control baseline plot in Yucca Flat and three new plots in subsidence craters (with associated controls) that were established in Yucca Flat. An alpha-radiation-contaminated site (GMX) in Frenchman Flat was surveyed, as were a drill pad on Pahute Mesa, a bladed area in north Mid Valley, and an area burned in Red Rock Canyon in 1988. The area downwind of the Liquified Gaseous Fuels Spill Test Facility in Frenchman Flat was also surveyed.

Vegetation was sampled on 15 sites that had previously been established in 1963 by Dr. Janice Beatley, University of California. A new site was sampled in Gold Meadow (Area 12) to cover previously unsampled territory. Some of the Beatley plots included paired plots: (1) a burned and unburned pair in Mid Valley (Area 14), and (2) a pristine and denuded site in the Wahmonie ghost town (Area 20).

Survey work on horses, deer, and raptors was expanded in 1989. Horse counts were made through the Summer, one day a month, in regions around the springs and well reservoirs which resulted in a reasonable estimate of the feral horse population on the NTS. Estimates were made for deer in preliminary searches to find appropriate and cost-effective study methods. Records were kept of raptor sightings in 1989.

4.2.2 OFFSITE MONITORING

No offsite nonradiological monitoring was conducted in 1989, as no tests were conducted at the Liquified Gaseous Fuels Spill Test Facility. Hence there were no nonradiological environmental releases to the offsite area.

4.3 PERMITS

Carl S. Soong

NTS environmental permits included 27 state of Nevada air quality permits involving emissions from construction operation facilities, boilers, storage tanks, and open burning. Five permits for onsite drinking water systems and four for sewage discharges to onsite lagoons or septic tank fields have been issued by the state of Nevada. A permit application for two shallow injection wells used for nonhazardous waste water disposal was submitted to the state in 1989. The RCRA Part A permit application for disposal of LLW on the NTS was revised to include addition onsite units. The RCRA Part B permit application for mixed waste disposal, submitted in 1988, is still under review by the state of Nevada and the EPA.

4.3.1 AIR QUALITY PERMITS

Table 4.1 is a listing of state of Nevada air quality operating permits renewed in 1989. Pursuant to the requirements for boiler permits (OP-1035 and OP-1036) at the NTS, annual fuel analysis of diesel fuel No. 2 (DF #2) was submitted to the state of Nevada in November 1989. The data provided included the sulfur content and BTU content of the DF #2 delivered to the NTS.

Open burning permits (OP 89-19 and OP 89-5) have reporting requirements for each burn conducted. For OP 89-19, the Nevada Air Quality Officer must be notified of each burn no later than five days following the burn, either by telephone or written communication. During 1989 five open burns of explosives-contaminated debris in Area 27 were reported for this permit. These burns were conducted on April 10, May 25, July 21, August 29, and November 7, 1989.

In March 1989 the annual sand and gravel report was submitted to the U.S. Department of the Interior reporting the amount of sand and gravel produced at the Area 1 Shaker Plant during fiscal year 1989.

Table 4.1 Nevada Air Quality Operating Permits Renewed in 1989

Location	Permit	Replaces	Expiration Date
Area 1 Shaker Plant	OP 1972	OP 922	12/04/94
Area 1 rotary dryer	OP 1973	OP 923	12/04/94
Area 1 portable crusher	OP 1974	OP 1217	12/04/94
Area 2 Stemming Facility	OP 1975	OP 957	12/04/94
Area 2 Stemming Facility	OP 1976	OP 958	12/04/94
Area 12 Batch Plant	OP 1977	OP 928	12/04/94
Area 23 boiler	OP 1978	OP 925	12/04/94
Area 3 Aggregate Plant	OP 1979	OP 919	12/04/94
NTS open burning	OP 90-6	OP 89-5	09/30/90

For OP 89-5, the Air Quality Officer must be notified by telephone at least two working days in advance of each training exercise for Class A flammables. A written summary of each exercise must be submitted to the Air Quality Officer within 15 days following the exercise and must include the following: date, time, duration, exact location, and amount of flammables burned. An annual report was submitted to the state on September 21, 1989.

During 1989, 21 burns were conducted for radiological emergency response training and 12 training burns were conducted by onsite fire protection services. An air quality permit to construct (No. 2332) was issued by the state of Nevada on October 6, 1989, for an incinerator in Area 23. The incinerator will be used by Wackenhut Security, Inc., for the destruction of classified materials. Upon completion of construction, the state will conduct an onsite inspection and issue an operating permit. Table 4.2 is a listing of all permits active in 1989.

4.3.2 DRINKING WATER SYSTEM PERMITS

The NTS operates and maintains five drinking water supply systems. Permits for these systems are renewed on an annual

Table 4.2 Active Air Quality Permits, Nevada Test Site - 1989

Permit No.	Facility or Operation	Expiration Date
OP 89-19[a]	Open burning, Area 27	02/28/90
OP 90-6[a]	Open burning fire rescue	09/30/90
OP 1035	Superior boiler/portable	10/20/90
OP 1036	York-Shipley boiler	10/20/90
OP 1082	Rex LO-GO Concrete Batch Plant	01/30/91
OP 1085	Storage tank, DF #2	02/25/91
OP 1086	Storage tank, unleaded fuel	02/25/91
OP 1087	Storage tank, DF #2	02/25/91
OP 1089	Portable stemming facility, Area 3	02/25/91
OP 1090	Storage tank, unleaded fuel	02/25/91
OP 1287	Aggregate Plant	02/12/92
OP 1304	Portable cement bins, Area 6	03/06/92
OP 1366	Portable cement bins, Area 6	04/01/92
OP 1505	LGF Spill Test Facility	11/02/92
OP 1583	Cafeteria boiler, Ajax boiler	03/23/93
OP 1584	Cafeteria boiler, Ajax boiler	03/23/93
OP 1585	Area 12 Cafeteria boiler, Ajax boiler	03/23/93
OP 1591	Surface area disturbances	03/23/93
OP 1966[a]	Cement storage equipment, Area 6	11/21/94
OP 1972[a]	Shaker Plant	12/04/94
OP 1973[a]	CMI rotary dryer	12/04/94
OP 1974[a]	Cedarapids crusher	12/04/94
OP 1975[a]	Stemming Facility	12/04/94
OP 1976[a]	Stemming Facility	12/04/94
OP 1977[a]	Concrete Batch Plant	12/04/94
OP 1978[a]	Ajax boiler WOFD-6500	12/04/94
OP 1979[a]	Aggregate Mixing/Hopper Plant	12/04/94
PTC 2332[a]	Incinerator (permit to construct)	N/A

(a) New or reissued permits in 1989.

basis. The systems serving Area 2, 12, and 23 were community systems. The remaining systems were non-community systems. These systems were chlorinated by automatic equipment. New or repaired water lines were super-chlorinated before being placed into service in accordance with American Water Works Association standards and the Uniform Plumbing Code. Each system was tested monthly for pH, residual chlorine, and coliform bacteria content in accordance with the requirements of Nevada Administrative Code 445.141.21. Daily chlorine levels at the distribution points were logged by the Site Maintenance Department of the NTS operating contractor. The permits are listed in Table 4.3.

4.3.3 SEWAGE DISCHARGE PERMITS

New sewage discharge permits were issued for Area 2/Area 6, Area 22/Area 23, and Area 12. All previous permits were combined into four. These are listed in Table 4.4. Permit restrictions require quarterly discharge monitoring reports to be submitted to the state. There were no permit violations during 1989.

VARIANCE APPLICATION FOR SEWAGE DISCHARGE

A discharge variance was requested from the Nevada Department of Human Resources, Health Division, for the Tweezer Facility in Area 11. The request was made because of substandard percolation rates in the area for a septic tank field drain system. The field-measured rate average is 120 minutes/inch. The Ten States Standards, used by the state of Nevada, has the slowest allowable percolation rate, 60 minutes/inch.

The proposed variance alternative was an evapotranspiration bed. This system draws the effluent to the surface by capillary action for evaporation. A septic tank was used with this system, as with the standard drain field system. The benefit gained from this exemption was in operational reliability and reduced cost. State approval is not expected until 1990.

Table 4.3 NTS Drinking Water Supply System Permits, 1989

Permit No.	Area(s)	Expiration Date
NY-5024-12NC	Area 1	09/30/90
NY-4009-12C	Area 2 & 12	09/30/90
NY-360-12C	Area 23	09/30/90
NY-4098-12NC	Area 25	09/30/90
NY-5000-12NC	Area 6	09/30/90

Table 4.4 NTS Sewage Discharge Permits, 1989

Permit No./Area	Date Issued	Expiration Date
NEV87069/2&6	02/28/89	02/28/94
NEV87076/22&23	02/28/89	02/28/94
NEV87060/25&6	03/31/88	03/31/93
NEV87059/12	02/28/89	02/28/94

SEWAGE LAGOON OPERATIONS AND MAINTENANCE (O&M) MANUALS

Sewage lagoon O&M manuals were submitted to the state for eight sewage lagoon systems. The state returned review comments for only one O&M plan (the Area 23 system) in August. A revised O&M manual for Area 23 was resubmitted to the state within 30 days. No further state response was received during 1989. The remaining O&M manuals have been similarly revised and are ready for submission when the state approves the Area 23 manual.

4.3.4 INJECTION WELL PERMITS

In order to achieve compliance with state regulations, in October 1989 a discharge permit application for two shallow injection wells (approximately 60 feet deep) at the Area 1 Subdock was submitted to the state of Nevada, Division of Environmental Protection. These wells receive wash water and steam cleaning effluent from cleaning drill pipe which was contaminated with soil, dust, rust, and traces of grease. The waste water will be processed through an oil/water separator prior to entering the wells. No hazardous waste enters the injection wells. These wells have been in service for three years. The state had not responded to the permit application at the time of this report.

4.3.5 RCRA PERMITS

The RCRA Part A permit application for hazardous and mixed waste disposal at the NTS was revised in 1989 to include five additional RCRA units. These units include the U3axbl subsidence crater waste disposal complex in Area 3 (filled with onsite and offsite debris), the U2bu subsidence crater, the U3fi injection well, the Area 2 bit-cutter injection well, and the LLNL post-shot containment shop injection well. The U2bu and U3fi sites are mixed waste units. The Area 2 injection wells are suspected of receiving hazardous wastes in the form of waste water from steam cleaning.

A RCRA closure plan for the U3axbl complex was submitted to the state in February 1989. RCRA closure plans for the remaining units will be prepared in 1990. RCRA units listed on the original Part A application included the Building 650 leachfield (in Mercury), the Area 23 waste disposal trenches, the Area 6 Decontamination Pad, and the Area 11 Explosive Ordinance Disposal facility.

Closure plans for the Area 6 Decontamination Facility evaporation pond and the Building 650 leach field were submitted to the state in February 1989 for review and comment. These are mixed waste units. Because these units have little documented information available on waste disposal practices, the closure plans are designed to include an extensive site investigation. Revised site investigation plans were submitted in October 1989. While clean closure of these units is proposed, alternative closure methods will be considered based on the data obtained from the site investigation, which is scheduled to commence in 1990.

The RCRA Part B permit application for permanent disposal of mixed waste at the Area 5 RWMS was submitted to the state in October 1988 and is under review. Until this application is approved by the state and EPA and the necessary permit is issued, disposal operations are being conducted as retrievable disposal under interim status granted by the state.

A Part B application for the Area 11 Explosive Ordinance Disposal facility was submitted to the state in November 1988. Disposal at this facility continues under interim status.

4.4 GROUNDWATER PROTECTION

Lynn L. Ebeling

Natural hydrogeological barriers to groundwater contamination from NTS operations were enhanced by operational procedures and actions to limit potential sources of contamination. Waste control, treatment, and cleanup actions, coupled with underground test location restrictions, were used to minimize the likelihood of contamination. Onsite and offsite groundwater monitoring was used to document long-term water quality changes that might occur. In 1989 an extensive hydrogeology characterization project was initiated to further enhance the understanding of the NTS groundwater system and its movement toward offsite areas.

The NTS has several natural features that protect the groundwater from contamination. The arid climate (see Section 1.7) leaves very little water available to leach surface contaminates into the soil or transport them through the vadose zone toward the groundwater tables. The soils have very low infiltration rates, isolating much of this water near the surface. The net vertical water movement between the water table and the surface is so small that it has yet defied accurate measurement. The aquitards separating the aquifers provide additional barriers to vertical migration. In the event that contamination occurs from underground nuclear tests or other sources, the NTS and regional hydrogeology (see Section 1.6) involves extremely slow groundwater movement toward distant offsite areas where public use might occur.

The primary sources for NTS groundwater contamination are the underground cavities created by nuclear detonations. Cavities occur at the ends of mined tunnels or at the bottom of drilled holes. Some of the tests in drill holes have been detonated below the water table. However, most of the contaminants produced by the detonation are contained in the fused rock in the wall of the cavity which formed as the vaporized material condensed and solidified.

The potential for groundwater contamination resulting directly from nuclear device detonations is now being minimized in several ways. These include:

- Testing is limited to three main areas; Pahute Mesa, Rainier Mesa, and Yucca Flat. This localizes the contamination sources to a few sites.
- Tests are normally detonated in extremely dry formations, well above the regional carbonate aquifer, increasing the potential migration time to the water table and consequent possible horizontal migration in regional groundwater flow.
- Areas with high potential for flooding or infiltration, such as dry washes, are avoided.
- Exploratory holes below the depth at which the device is placed are grouted or stemmed to prevent open pathways to deeper formations.

In addition to the underground nuclear tests, the NTS has known potential groundwater pollution sources similar to most other municipal and industrial activities. These include liquid waste ponds, leach fields, sanitary landfills, underground storage tanks and two shallow injection wells. The NTS has additional potential pollution sources associated with the weapons testing program, including radioactive waste disposal sites and surface residues from earlier atmospheric nuclear detonations.

As part of DOE's groundwater protection program, potential sources of land contamination from conventional hazardous

waste are being reduced. Leach fields are being replaced with evaporation ponds, and ponds are being lined. Underground storage tanks are being removed or upgraded. Solvents are being replaced with biodegradable substitutes. Other chemical wastes are shipped offsite for commercial disposal. Use of injection wells and French drains is being discontinued.

The radioactive and mixed-waste disposal facilities are mainly shallow land burial areas. No free liquid wastes are accepted, extensive flood protection is provided, and closure designs strongly emphasize limiting deep soil infiltration. These sites will most likely remain too dry for significant migration and consequent groundwater contamination to occur.

As part of the 1989 groundwater protection program, monthly samples were collected from the 14 supply wells on the NTS. Those used for human consumption were sampled weekly. Monthly samples were also collected from springs when flow was sufficient to collect a sample.

Other agencies also monitored the groundwater at the NTS. The EPA, as part of its Long-term Hydrological Monitoring Program, sampled 33 wells on the NTS and a similar number of wells and springs in the surrounding area. The Nevada Division of Environmental Protection has also sampled various supply wells on the NTS. None of the sampling results have given an indication of movement of groundwater contaminants off the NTS.

In accordance with the RCRA permit application, typical up-gradient and down-gradient monitoring wells were not employed for monitoring groundwater in the vicinity of the mixed waste disposal facility in Area 5 because of the great depth and extremely long potential migration time from the shallow land burial pits to the groundwater. Instead, vadose zone monitoring was conducted to monitor the unsaturated zone under the pits to obtain much more timely information on any possible movement of waste constituents toward the groundwater table.

An extensive NTS geohydrology characterization program was initiated in 1989 to develop further information for use in enhancing the groundwater protection program. This preliminary plan included construction of over 90 wells to depths of over 1000 meters. Some of these wells will be placed in areas where there is presently only indirect information. Construction of these wells will better define the occurrence and thickness of the geologic formations, including aquifers and aquitards.

Formation samples taken during construction will be tested to determine physical and chemical properties. The wells will also be pumped to determine aquifer properties such as transmissivity, boundary locations, and leakage through aquitards. Water samples will be chemically analyzed to indicate flow paths and travel times. Water table elevations, together with the hydraulic information from laboratory testing of the media samples and the pumping test, will allow much more accurate predictions of vertical and areal migration velocities. Water samples from these wells will be taken and tested for radionuclides during the monitoring phase of the program.

5.0 RADIOLOGICAL MONITORING RESULTS

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Radiological environmental monitoring results from onsite environmental programs included (1) effluent sampling results for airborne emissions and liquid discharges to containment ponds and (2) environmental surveillance sampling and study results for onsite surveillance conducted by REECo and offsite surveillance conducted by the EPA. Onsite monitoring results indicated that environmental concentrations of radioactivity resulting from NTS air emissions were statistically no different than background except in the immediate onsite vicinity of the emissions. These short-term emissions over a period of hours or days, and radioactive liquid discharges to onsite containment ponds, produced concentrations that were only a small fraction of a percent above background in terms of potential exposure of onsite workers. Offsite monitoring indicated that environmental radiation concentrations and exposure rates were statistically no different than background, with no measurable exposure of offsite residents from NTS test operations.

5.1 RADIOLOGICAL EFFLUENT MONITORING

Monitoring efforts for potential airborne radioactive effluents at the NTS consisted primarily of intensive air sampling and radiation detection through instrumentation deployed in the vicinity of nuclear tests during and following conduct of the tests. These arrays showed no prompt release of radioactivity for any of the twelve announced tests in 1989. Subsequent gas seepage to the surface following post-test operations for one 1989 test, and during post-test operations for three 1989 tests and four late-1988 tests, resulted in releases of gaseous radioactivity totaling 157 curies. Air samples collected in and around the Area 5 Radioactive Waste Management Site (RWMS) indicated that the facility contributed no airborne concentrations that were statistically different from background. The primary liquid effluents were Rainier Mesa tunnel seepage water collected in containment ponds at the tunnel mouths. Influent to these ponds essentially contained only tritium (^3H), with a total tunnel seepage discharge of 1500 curies. Additionally, 569 curies were released in water discharged to a surface pond from a radionuclide migration study research well.

5.1.1 AIRBORNE EFFLUENTS

The majority of radiological air effluents at the NTS in 1989 originated from underground nuclear explosive tests conducted by NTS User organizations; the Lawrence Livermore National Laboratory (LLNL), the Los Alamos National Laboratory (LANL), and the Defense Nuclear Agency (DNA) of the Department of Defense (DOD). (See Table 5.1 for a listing of all onsite effluent releases.) Each responsible organization performed effluent monitoring at the time of detonation and continued until all research activities were completed. In support of any User request, the onsite operations contractor (REECo) performed radioactive noble gas monitoring at test

Table 5.1 NTS Radionuclide Emissions - 1989

Airborne Effluent Releases

Event or Facility Name (Airborne Releases)	Curies										
	^{3}H	^{37}Ar	^{39}Ar	^{85}Kr	^{127}Xe	^{129m}Xe	^{131m}Xe	^{133}Xe	^{133m}Xe	^{135}Xe	^{137}Cs
Area 12, G Tunnel	2.27×10^{1}										
Area 12, P Tunnel DISKO ELM		8.90×10^{0}	1.50×10^{-3}	3.34×10^{-2}	3.17×10^{-5}	2.10×10^{-3}	2.28×10^{-1}	3.76×10^{1}	7.90×10^{-1}	3.80×10^{-2}	
Area 12, N Tunnel MISTY ECHO	3.44×10^{-2}	6.17×10^{0}	2.66×10^{-3}	1.15×10^{-1}	5.80×10^{-6}	7.50×10^{-5}	3.40×10^{-2}	3.43×10^{-1}			
Area 2, KAWICH								7.05×10^{0}	2.90×10^{-1}	2.45×10^{0}	
Area 4, BULLFROG	2.70×10^{-2}			9.00×10^{-3}							
Area 20, COMSTOCK	4.00×10^{-3}			3.30×10^{-4}							
Area 4, PALISADE								1.00×10^{0}		1.40×10^{0}	
Area 2, SCHELLBOURNE	8.70×10^{-2}			1.80×10^{-2}							7.30×10^{-6}
Area 27, Assembly Ops.	5.00×10^{1}										
Area 20, BARNWELL				3.30×10^{-2}			7.10×10^{-2}	1.71×10^{1}	6.34×10^{-2}	6.00×10^{-5}	
TOTAL	7.29×10^{1}	1.51×10^{1}	4.16×10^{-3}	2.09×10^{-1}	3.75×10^{-5}	2.17×10^{-3}	3.33×10^{-1}	6.30×10^{1}	1.14×10^{0}	3.89×10^{0}	7.30×10^{-6}

Liquid Effluent Releases

Containment and Radionuclide Migration (RNM) Ponds	Curies			
	Gross Beta	^{3}H	^{238}Pu	$^{239+240}Pu$
Area 12, E Tunnel	1.38×10^{-3}	3.03×10^{0}	4.90×10^{-6}	3.97×10^{-5}
Area 12, T Tunnel	2.03×10^{-1}	1.48×10^{3}	1.10×10^{-5}	2.99×10^{-4}
Area 20, N Tunnel	1.58×10^{-3}	1.65×10^{1}	7.00×10^{-7}	1.47×10^{-6}
Area 6, Decontamination Pad Pond	7.95×10^{-4}	7.15×10^{-3}	2.10×10^{-8}	4.77×10^{-7}
Area 5, U5eRNM2S		5.69×10^{2}		
TOTAL	2.06×10^{-1}	2.07×10^{3}	1.66×10^{-5}	3.41×10^{-4}

sites conducted within Rainier Mesa and Pahute Mesa. This involved deployment of one or more noble gas samplers near surface ground zeros (SGZs) to monitor possible release of radioactive gases. Considering all radionuclides measured, approximately 157 curies were released as airborne effluents.

An increase in efforts to monitor radioactive air emissions at the NTS began in November 1988. Requirements for expanded effluent monitoring at NTS facilities have resulted from new DOE orders and draft orders such as DOE Order 5400.1, DOE Order 5400.5, and draft DOE Order 5400.6, as well as from EPA requirements in the National Emission Standards for Hazardous Air Pollutants (EPA 1989). Before November 1991 the Area 12 tunnels, Area 6 Decontamination Facility, nuclear test sites, RWMSs, and all other potential effluent sites throughout the NTS will be assessed for their potential to contribute to public dose and be considered in designing the Site Effluent Monitoring Program, part of the NTS environmental monitoring plan required by DOE Order 5400.1.

NUCLEAR EVENT MONITORING

This section is a summary of the specific nuclear event monitoring conducted at the NTS prior to and after each event, as well as routine effluent monitoring conducted at other sites. The various events, by name, and the results of measurements taken at each event site are presented. Also listed are other NTS facilities which are monitored for effluents on a routine basis.

Air emissions from nuclear testing operations consisted primarily of radioactive xenons, argons, ^{85}Kr, and ^{3}H released (1) during post-test drill-back, mine-back, or sampling operations following three 1989 underground nuclear tests, (2) through gas seepage after completion of post-test operations following one 1989 test, and (3) during gas sampling operations at four 1988 test event sites. None of the tests resulted in a prompt release or venting (i.e., a release of radioactive materials within 60 minutes of the nuclear test). Seepage rates have been found to vary depending on atmospheric pressure changes, reflecting the pressure differential between underground gases and the atmosphere. This pressure-related variation in surface seepage rates of radioactive gases diffusing from the underground nuclear test point is sometimes referred to as "atmospheric pumping." Air emissions were monitored for source characterization and operational safety as well as environmental monitoring purposes.

REECo provided onsite radiological safety support, including monitoring for effluents (air emissions), during the 12 announced nuclear tests conducted at the NTS in 1989 by the NTS User organizations: LANL, LLNL, and DNA. REECo, at the request of Sandia National Laboratory (SNL), conducted routine air emission sampling at the G Tunnel complex. The amount of tritiated water vapor emitted from G Tunnel was calculated by multiplying the total flow of air discharged by the concentration of tritium in the discharged air.

The test-associated services provided by REECo included detecting, recording, evaluating, and reporting of radiological conditions prior to, during, and for an extended period after each test, and provision of aerial monitoring teams during each test to detect airborne releases. Personnel equipped with specialized collection and measurement instruments were prepared to respond rapidly should an accidental release of airborne radioactive materials have occurred from the underground test.

Complete radiological safety coverage was also provided during post-event drill-back (for vertical shaft testing) and mining (tunnel testing) operations. These activities involved either drilling or mining into the vicinity of the nuclear detonation to acquire samples of test-associated material. These operations bore a potential for releasing radioactive gases to the atmosphere. Seepage of these gases to the surface might also have occurred. Methods of data accumulation included recording telemetered radiation measurements from the test area, air sampling, worker bioassays, and whole-body counting.

Telemetered data from the radiation detection array surrounding SGZ provided the first information following detonation of a nuclear device. A typical array for a vertical shaft event is shown in Figure 5.1. Each gamma-sensitive, ion-chamber detector was linked by microwave and hard-wire communications to a console in one of two buildings at the NTS Control Point and/or the Control and Data Acquisition Center. The console also displayed information from each of the permanent telemetered remote area monitor (RAM) arrays. The levels measured on each console and the time of the measurement, in minutes after zero time (detonation), were recorded and displayed. Release of radioactive material within the first 60 minutes following a test did not occur during 1989.

Following the test, when control of the test area is released by the DOE Test Controller, REECo personnel accompanied the Test Group Director's inspection party entering the potential radiological exclusion area to perform initial surveys. Radiation measurements, obtained using portable detection instruments, plus measurements of time and location were recorded on survey forms and the information reported by radio. Survey locations were determined from roadside numbered reference stakes. Maps showing the locations of these reference stakes in relation to roads and landmarks were provided to participating test groups. Radiation exposure rates obtained with portable instruments usually were made at waist-high level (approximately one meter above the ground).

During the post-event drill-back and mining activities, REECo personnel maintained continuous environmental surveillance in the work area. For drill-back coverage, radiation detector probes were placed in strategic locations in the work areas and connected to recorders and alarms to warn of increases in radiation levels. Radiation monitoring personnel, using portable instruments, periodically checked work area radiation levels and issued protective equipment or evacuated area personnel, when necessary.

For drill-back containment of radioactive material releases to the atmosphere, LANL utilized a pressurized recirculation system. LLNL used a ventline filter system designed to trap radioactive particulates released from the drill casing. In the ventline system, trapped radioactive material was allowed to decay under controlled conditions. For DNA tunnel operations, the effluent was passed through a charcoal/ high-efficiency particulate aerosol (HEPA) filter system before release. This trapped radioactive material was also allowed to decay under controlled conditions. When requested by the organization conducting the test, portable air sampling units were placed at predetermined locations. The sampler drew air at a calibrated rate through a particulate filter and charcoal cartridge. Gaseous radionuclides present (radioiodine, in particular) were trapped in the cartridges. The filters and cartridges were changed at specific times and analyzed by the REECo laboratory.

TEXARKANA Event Summary

The TEXARKANA event was conducted by LANL in hole U7ca in Area 7 (Yucca Flat) at 1206 hours on February 10, 1989. There was no detectable release of fission products within the first 60 minutes after detonation. Telemetry measurements began at 1206 hours on February 10, 1989, and ended at 1206 hours on February 11, 1989. The maximum exposure rate detected by the SGZ RAM array was background. The initial radiation survey into the test area began at 1221 hours on February 10, 1989, and ended at 1300 hours on February 10, 1989. The maximum gamma exposure rate detected was background. There was no radioactivity release detected during post-event operations.

KAWICH Event Summary

The KAWICH event was conducted by LLNL in hole U2cu in Area 2 (Yucca Flat) at 0815 hours on February 24, 1989. Telemetry measurements began at 0816 hours on February 24, 1989, and ended at 0900 hours on February 25, 1989. The maximum exposure rate detected was

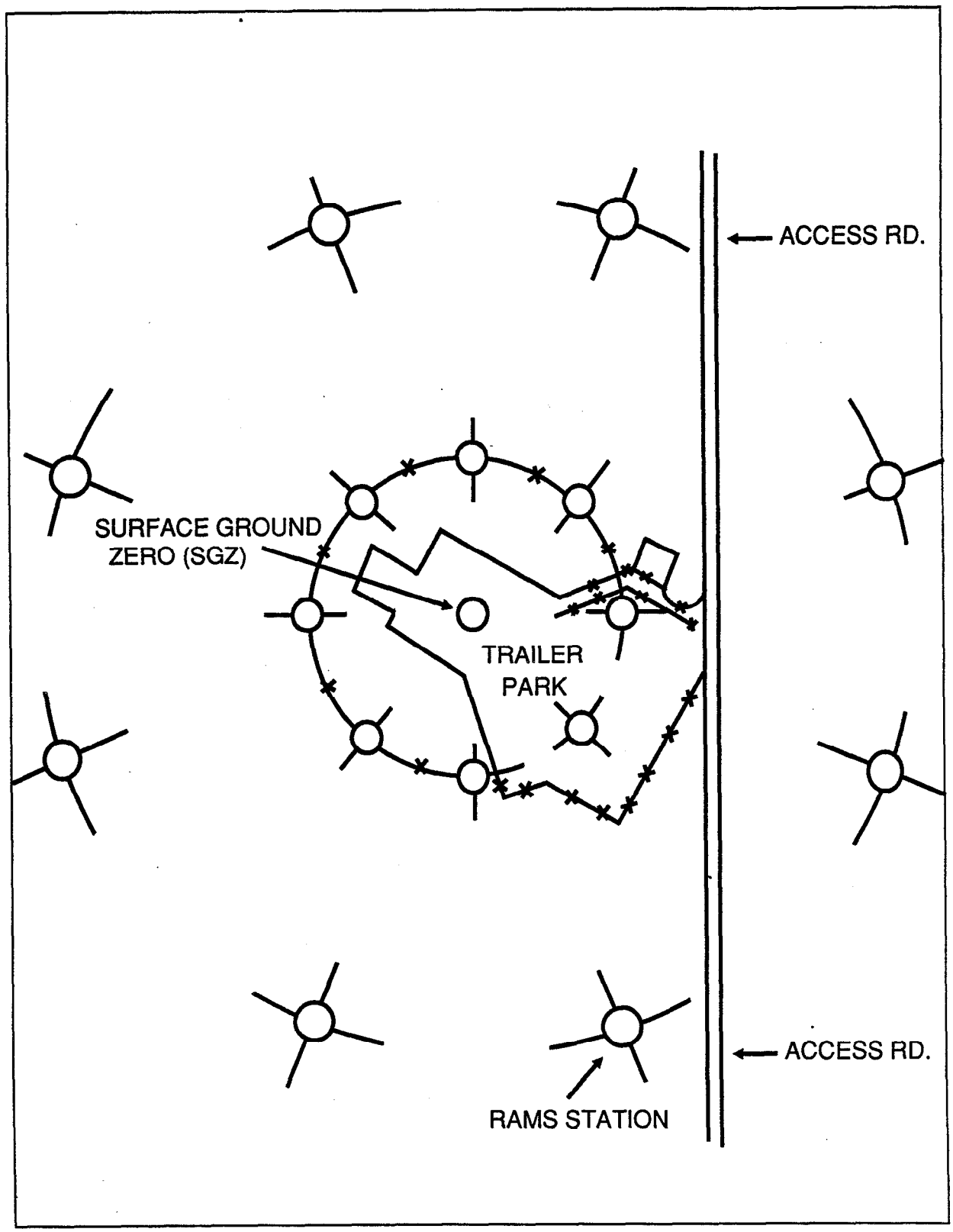


Figure 5.1 Typical RAM Array for a Nuclear Test. *The stations on the inner arc are at a radius of 320 feet from SGZ; the outer arc stations are at 1000 feet from SGZ*

background. There was no detectable release of fission products within the first 60 minutes after detonation. The initial radiation survey into the test area began at 0843 hours on February 24, 1989, and ended at 0930 hours on February 24, 1989. The maximum gamma exposure rate detected was 0.05 mR/hr (background). A total of 9.79 curies of radioactive xenons was released through the ventline filters during drilling and coring operations.

INGOT Event Summary

The INGOT event was conducted by LLNL in hole U2gg in Area 2 (Yucca Flat) at 0605 hours on March 9, 1989. There was no detectable release of fission products within the first 60 minutes after detonation. Telemetry measurements began at 0606 hours on March 9, 1989, and ended at 0800 hours on March 10, 1989. The maximum exposure rate detected was background. The initial radiation survey into the test area began at 0630 hours on March 9, 1989, and ended at 0651 hours on March 9, 1989. The maximum gamma exposure rate detected was 0.05 mR/hr (background). There was no release of radioactivity during post-event operations.

PALISADE Event Summary

The PALISADE event was conducted by LLNL in hole U4at in Area 4 (Yucca Flat) at 0610 hours on May 15, 1989. There was no detectable release of fission products within the first 60 minutes after detonation. Telemetry measurements began at 0611 hours on May 15, 1989, and ended at 0755 hours on May 16, 1989. The initial radiation survey into the test area began at 0624 hours on May 15, 1989, and ended at 0711 hours on May 15, 1989. The maximum gamma exposure rate detected was 0.05 mR/hr (background). A total of 2.4 curies of radioactive xenons was released through the ventline filters.

TULIA Event Summary

The TULIA event was conducted by LANL in hole U4s in Area 4 (Yucca Flat) at 1107 hours on May 26, 1989. There was no detectable release of fission products within the first 60 minutes after detonation or during post-event operations. Telemetry measurements began at 1107 hours on May 26, 1989, and ended at 1107 hours on May 27, 1989. The maximum exposure rate detected was 0.05 mR/hr (background). The initial radiation survey into the test area began at 1208 hours on May 26, 1989, and ended at 1238 hours on May 26, 1989. The maximum gamma rate detected was 0.05 mR/hr (background). There was no release of radioactivity during post-event operations.

CONTACT Event Summary

The CONTACT event was conducted by LLNL in hole U20aw in Area 20 (Pahute Mesa) at 1415 hours on June 22, 1989. There was no detectable release of fission products within the first 60 minutes after detonation. Telemetry measurements began at 1416 hours on June 22, 1989, and ended at 1430 hours on June 23, 1989. The maximum exposure rate detected was background. The initial radiation survey into the test area began at 1438 hours on June 22, 1989, and ended at 1509 hours on June 22, 1989. The maximum gamma exposure rate detected was background. There were no drill-back operations. There was no release of radioactivity during post-event operations.

AMARILLO Event Summary

The AMARILLO event was conducted by LANL in hole U19ay in Area 19 (Pahute Mesa) at 0830 hours on June 27, 1989. There was no detectable release of fission products within the first 60 minutes after detonation. Telemetry measurements began at 0830 hours on June 27, 1989, and ended at 0835 hours on June 28, 1989. The maximum exposure rate detected was 0.05 mR/hr (background). The initial radiation survey into the test area began at 0944 hours on June 27, 1989, and was completed at 1014 hours on June 27, 1989. The maximum exposure rate detected was 0.05 mR/hr (background). There was no release of radioactivity during post-event operations.

DISKO ELM Event Summary

The DISKO ELM event was a tunnel test conducted by DNA in Area 12 (Rainier Mesa) in the U12p.03 drift of P Tunnel at

0800 hours on September 14, 1989. There was no detectable release of fission products within the first 60 minutes after detonation. Telemetry measurements began at 0800 hours on September 14, 1989, and ended at 0900 hours on September 21, 1989. The maximum exposure rate detected by the above-ground detector array was background. The initial surface radiation survey into the test area began at 0946 hours on September 14, 1989. The maximum gamma exposure rate detected during reentry from Gate 300 (near the Control Point) to the portal area was 0.04 mR/hr (background). Survey teams stood by at the P Tunnel portal during the initial gas sampling of the tunnel atmosphere. Initial reentry personnel departed the portal area by 1500 hours on September 14, 1989. Event radioactivity was contained within the tunnel until ventilation was established, when controlled effluent releases were conducted. The effluent was passed through a charcoal/HEPA filtration system before being released. A total of 38.5 curies of radioactive xenons were released during eight ventilation and gas diagnostic test periods, lasting from September through December, 1989.

HORNITOS Event Summary

The HORNITOS event was conducted by LLNL in hole U20bc in Area 20 (Pahute Mesa) at 0730 hours on October 31, 1989. There was no detectable release of fission products within the first 60 minutes after detonation. Telemetry measurements began at 0731 hours on October 31, 1989, and ended at 0740 hours on November 1, 1989. The maximum exposure rate detected was 0.05 mR/hr (background). The initial radiation survey into the test area began at 0804 hours on October 31, 1989, and was completed at 0843 hours on October 31, 1989. The maximum exposure rate detected was 0.05 mR/hr (background). There was no release of radioactivity during post-event operations.

MULESHOE Event Summary

The MULESHOE event was conducted by LANL in hole U7bk in Area 7 (Yucca Flat) at 1220 hours on November 15, 1989. There was no detectable release of fission products within the first 60 minutes after detonation. Telemetry measurements began at 1220 hours on November 15, 1989, and ended at 1220 hours on November 16, 1989. The maximum exposure rate detected was 0.05 mR/hr (background). The initial radiation survey into the test area began at 1300 hours on November 15, 1989, and ended at 1320 hours on November 15, 1989. The maximum gamma exposure detected was 0.05 mR/hr (background). There was no release of radioactivity during post-event activities.

BARNWELL Event Summary

The BARNWELL event was conducted by LLNL in hole U20az in Area 20 (Pahute Mesa) at 0700 hours on December 8, 1989. There was no detectable release of fission products during the first 60 minutes after detonation. Telemetry measurements began at 0701 hours on December 8, 1989, and ended at 0700 hours on December 9, 1989. The maximum exposure rate detected was 0.05 mR/hr (background). The initial radiation survey into the test area began at 0723 hours on December 8, 1989, and ended at 0910 hours on December 8, 1989. The maximum gamma exposure rate detected was 0.05 mR/hr (background). During post-event drilling operations, a total of 0.057 curies of radioactive xenons was released through the ventline filters. After post-event operations were completed, a fracture near the post-event pad began to release (seep) gaseous radioactive effluent. A total of 17.2 curies of radioactive krypton and xenons was released from this test during 1989. The seep continued intermittently into early 1990.

WHITEFACE Event Summary

The WHITEFACE event was conducted by LANL in hole U3lp in Area 3 (Yucca Flat) at 1400 hours on December 20, 1989. There was no release of fission products within the first 60 minutes after detonation. Telemetry measurements began at 1400 hours on December 20, 1989, and ended at 1400 hours on December 21, 1989. The maximum gamma exposure rate detected was 0.05 mR/hr (background). The initial

radiation survey into the test area began at 1416 hours on December 20, 1989, and ended at 1430 hours on December 20, 1989. The maximum gamma exposure rate detected was 0.05 mR/hr (background). There were no post-event drill-back operations.

Noble Gas Monitoring

Portable air samplers were set up surrounding or in the vicinity of the SGZ for the five events conducted in the Rainier Mesa/Pahute Mesa region during 1989. These air samplers were similar to the samplers used to monitor noble gases as part of the Site-wide environmental surveillance program (see Section 5.2.1). The only modification to the sampler was that those sampling units deployed at the event sites could operate for several weeks on battery power. Otherwise the samples were taken and analyzed using the same methods described for the environmental surveillance noble gas samplers.

Typically, two noble gas samplers were deployed near one of the RAM stations which surround the SGZ in a circular array. This deployment at RAM stations was performed to establish a common reference point with the surveyed RAM locations. Predominant wind direction and access were the two main factors used when choosing the appropriate RAM station.

Data results for the five events monitored are presented in Table 5.2, "Noble Gas Monitoring Results from Pahute Mesa/Rainier Mesa Events." A maximum ^{85}Kr concentration of 6.4×10^{4} pCi/m^3 was detected at the U20az site (BARNWELL). The maximum ^{85}Kr concentration was detected from a U20az sample taken over a one-week period. This concentration and the maximum concentration of ^{133}Xe detected of 1.1×10^{7} pCi/m^3 were both less than the Derived Air Concentrations (DACs) for these radionuclides.

Releases from Previous Years' Tests

A series of radioactive effluent releases through the Rainier Mesa N Tunnel ventilation system occurred from January 26, 1989, through April 19, 1989. These releases were part of the gas diagnostics program following the MISTY ECHO event. (This event was detonated December 12, 1988, at 1230 hours in the U12n.23 drift of N Tunnel.) Sampling and testing of gases in the chimney region were part of this study, and the planned releases were passed through a charcoal/HEPA filtration system before being released. Radioactive krypton, xenons, argon, and tritium were released, totaling 6.69 curies in 1989.

Post-test underground gas sampling operations for three 1988 tests resulted in releases of ^{3}H, ^{85}Kr, and ^{137}Cs during sampling. These data are shown on Table 5.1 for the SHELLBOURNE (conducted May 13, 1988), COMSTOCK (June 2, 1988), and BULLFROG (August 30, 1988) tests in Areas 2 and 4. A total of 0.145 curies was released from these sampling operations.

TUNNEL COMPLEX EFFLUENT

The G Tunnel complex ventilation system was routinely monitored during 1989 for ^{3}H in water vapor. Sampling was conducted weekly for four hours. A desiccant was used to extract the tritiated water vapor from the air. SNL calculated a total release of 22.7 curies of airborne ^{3}H from the G Tunnel complex for 1989.

RADIOACTIVE WASTE MANAGEMENT

Two permanent particulate/halogen samplers were located within the disposal pits at the RWMS in Area 5. The low-level waste disposal pits in Area 5 may be considered to be diffuse effluent sources. (Effluent sources can be considered as either "point" sources or "diffuse" sources. A point source is a single defined point, the origin, such as a vent or a stack. A diffuse source is an area source or several sources of radioactive contaminants released into the atmosphere.) The disposal site, along with other NTS sites, will be investigated and assessed according to the requirements of DOE Order 5400.1 by November 1991 to determine their ultimate classification as effluent sources.

Results of samples taken within Pit #3 in Area 5 displayed an annual average concentration of 1.9×10^{-14} µCi/mL of gross

Table 5.2 Noble Gas Monitoring Results from Pahute Mesa/Rainier Mesa Events - 1989

			pCi/m^3			
Location	Start	Stop	^{85}Kr	± 1s	^{133}Xe	± 1s[(a)]
P Tunnel East	09/15/89	09/21/89	49.4	1.25	43	-
P Tunnel East	09/21/89	09/27/89	-	-	-	-
P Tunnel South	09/15/89	09/21/89	-	-	4	-
P Tunnel South	09/21/89	09/27/89	27.1	0.90	40	-
P Tunnel Water tank	09/21/89	09/27/89	28.3	0.85	3250	80.00
P Tunnel Water tank	09/21/89	09/27/89	16.4	0.75	2360	71.50
P Tunnel West	09/15/89	09/21/89	20.0	0.85	8	-
P Tunnel West	09/21/89	09/27/89	10.4	0.85	48	-
U19ay Station 3	06/28/89	07/06/89	51.0	0.95	20	-
U19ay Station 5	07/06/89	07/12/89	22.7	1.80	36	-
U19ay Station 5	07/18/89	07/27/89	21.5	1.50	52	-
U19ay Station 5	07/27/89	08/01/89	23.2	1.45	11	-
U19ay Station 5	08/08/89	08/16/89	-	-	14	-
U19ay Station 5	08/16/89	08/22/89	25.4	0.85	9	-
U19ay Station 13	07/06/89	07/12/89	155.0	1.45	39	-
U19ay Station 13	07/06/89	07/12/89	171.0	1.50	56	-
U19ay Station 13	07/12/89	07/18/89	140.0	1.35	90	-
U19ay Station 13	07/16/89	07/18/89	103.0	1.20	-	-
U19ay Station 13	07/18/89	07/27/89	121.0	1.90	-	-
U19ay Station 13	07/27/89	08/01/89	69.3	1.15	-	-
U19ay Station 13	07/27/89	08/01/89	92.7	1.30	19	-
U19ay Station 13	08/01/89	08/08/89	79.0	1.30	30	-
U19ay Station 13	08/01/89	08/08/89	-	-	13	-
U19ay Station 13	08/08/89	08/16/89	28.0	0.80	13	-
U19ay Station 13	08/16/89	08/22/89	-	-	40	-
U19ay Station 13	08/22/89	08/31/89	100.0	1.10	15	-
U19ay Station 13	08/22/89	08/31/89	25.8	0.95	15	-
U20aw	07/18/89	07/27/89	21.2	1.05	29	-
U20aw	07/27/89	08/01/89	-	-	5	-
U20aw	08/01/89	08/08/89	15.0	0.75	4	-
U20aw	08/08/89	08/16/89	23.8	1.00	20	-
U20aw	08/16/89	08/22/89	27.9	2.45	22	-
U20aw	08/22/89	08/31/89	22.1	0.90	14	-
U20aw South	06/28/89	07/06/89	14.6	1.80	149	-
U20aw South	07/06/89	07/12/89	30.3	0.65	284	-
U20aw South	07/12/89	07/18/89	39.1	1.25	45	-
U20az RAM 2	12/18/89	12/27/89	2890.0	5.50	1,930,000	277.00
U20az RAM 2	12/18/89	12/27/89	714.0	3.00	1,240,000	169.00
U20az RAM 2	12/27/89	01/02/90	27,800.0	17.50	11,200,000	1385.00
U20az RAM 2	01/02/90	01/08/90	10,880.0	20.50	1,900,000	602.00
U20az RAM 7	12/19/89	12/28/89	24.1	0.80	883	5.50

Note: Missing values are marked by a dash; ^{133}Xe results with no error value denote a detection limit.

(a) s = Counting error or the sample standard deviation.

Table 5.2 (Noble Gas Monitoring, cont.)

			pCi/m^3			
Location	Start	Stop	^{85}Kr	± 1s	^{133}Xe	± 1s[a]
U20az RAM 7	12/19/89	12/28/89	21.5	1.65	552	5.00
U20az RAM 7	12/27/89	01/02/90	63,500.0	33.50	267,000	276.00
U20az RAM 7	01/02/90	01/08/90	702.0	6.00	3600	26.50
U20az Station 5	07/14/89	07/18/89	24.6	1.45	66	-
U20bc RAM 6 South	11/01/89	11/07/89	30.3	0.95	6	-
U20bc RAM 6 South	11/07/89	11/16/89	-	-	107	-

Note: Missing values are marked by a dash; ^{133}Xe results with no error value denote a detection limit.

(a) s = Counting error or the sample standard deviation.

beta activity. The NTS annual average gross beta concentration, not including the Area 5 samplers distributed around the disposal site, was 2.1 x 10^{-14} µCi/mL. There is no statistical difference between these averages at the five percent significance level. Similarly, the results from Pit #4 displayed no statistical difference at the five percent significance level between the annual average of 2.1 x 10^{-14} µCi/mL at Pit #4 and the average of 2.1 x 10^{-14} µCi/mL for similar samplers located throughout the NTS, excluding Area 5.

Analysis of samples taken within Pit #3 and #4 indicate that the operations in the RWMS in Area 5 are not contributing radiological effluents in concentrations statistically different at the five percent significance level from concentration levels present in the NTS environment. Radioactive effluents above the concentrations present in the NTS environment were not detected from Area 5 disposal operations. Gross beta and plutonium results from all the samplers located at the RWMS facility in Area 5 are displayed in Figure 5.2, "RWMS Air Sampling Analyses Results - 1989."

Nine water vapor samplers for tritium were located surrounding the Area 5 RWMS. These samplers are placed near the perimeter berm of the disposal site as seen in Figure 5.3. The annual average for the nine stations was 8.8 x 10^{-12} ± 8.7 x 10^{-12} µCi/mL. This average was not statistically different at the five percent significance level from the annual average of other sampling locations distributed throughout the NTS. Furthermore, none of the annual average ^{3}H concentrations from any one of the nine locations were statistically different from the annual average of the nine-station network. The results indicate the waste disposal operations at the Area 5 RWMS did not contribute measurable levels of tritiated water vapor to the NTS environment. The annual average ^{3}H concentrations from the samplers located surrounding the RWMS facility in Area 5 are displayed in Figure 5.3.

Thermoluminescent dosimeters (TLDs) deployed surrounding the RWMS facility in Area 5 indicated that the gamma exposure rates measured in 1989 were not statistically different from the levels measured in 1988. The exposure rates are in mR/day as shown in Figure 5.4, "RWMS Gamma Exposure Measurement Results - 1989." The gamma exposure rates detected at the RWMS perimeter were not determined to be atypical from the majority of gamma measurements taken at other NTS locations. This information is presented in Volume II, Appendix F, "Onsite Thermoluminescent Dosimeter Data."

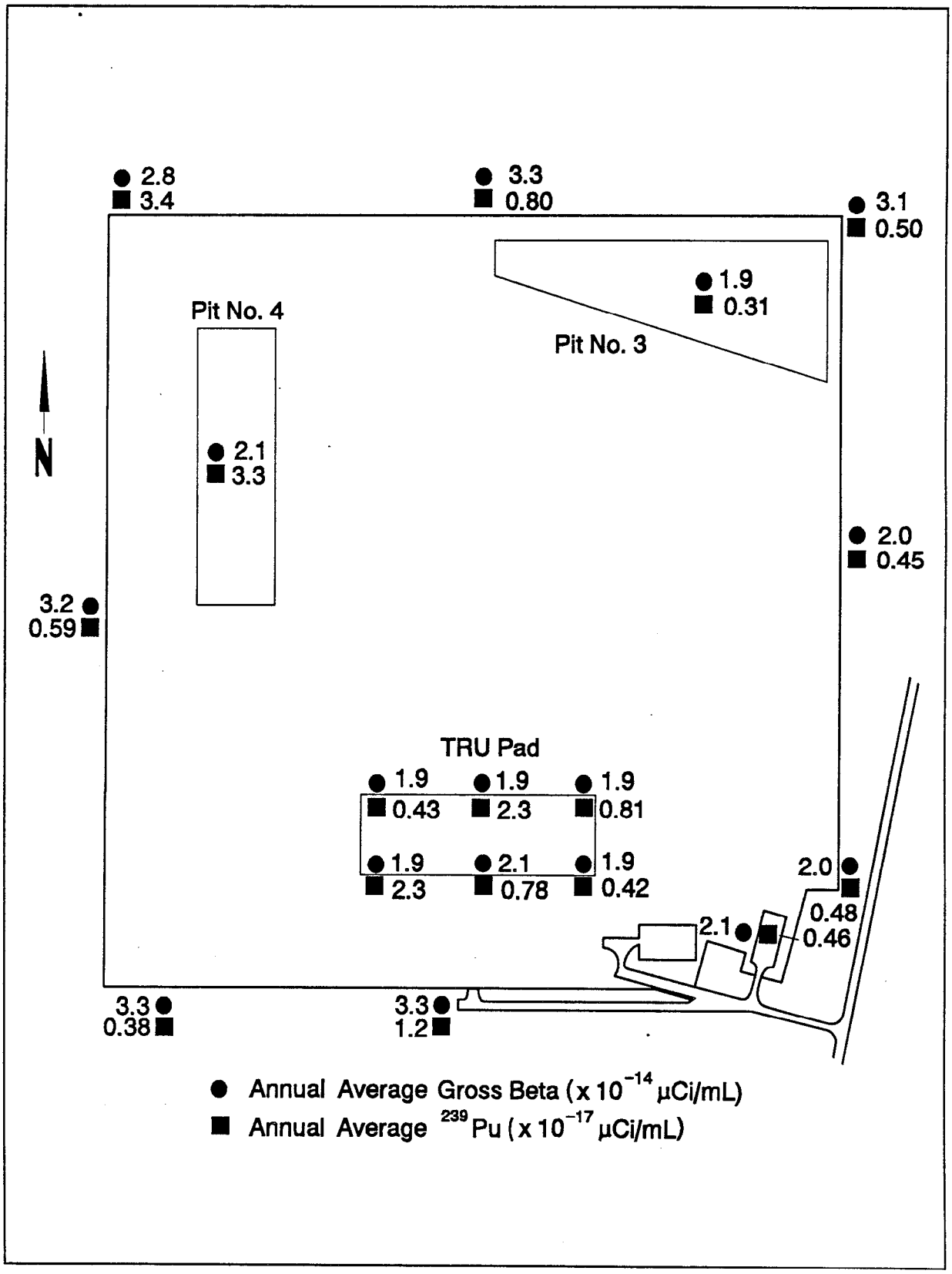


Figure 5.2 RWMS Air Sampling Annual Average Results - 1989

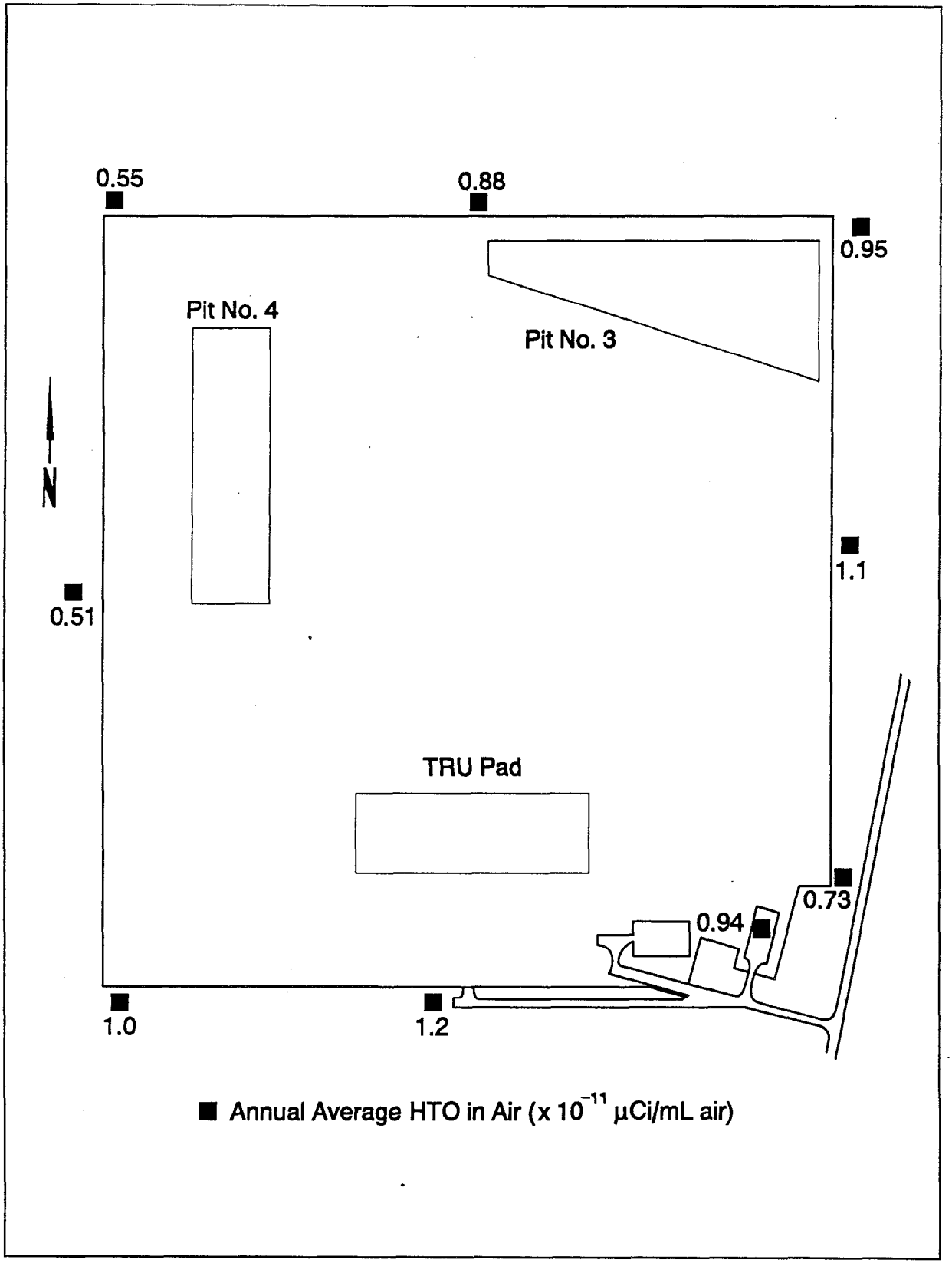


Figure 5.3 RWMS Tritiated Water Vapor Annual Average Results - 1989

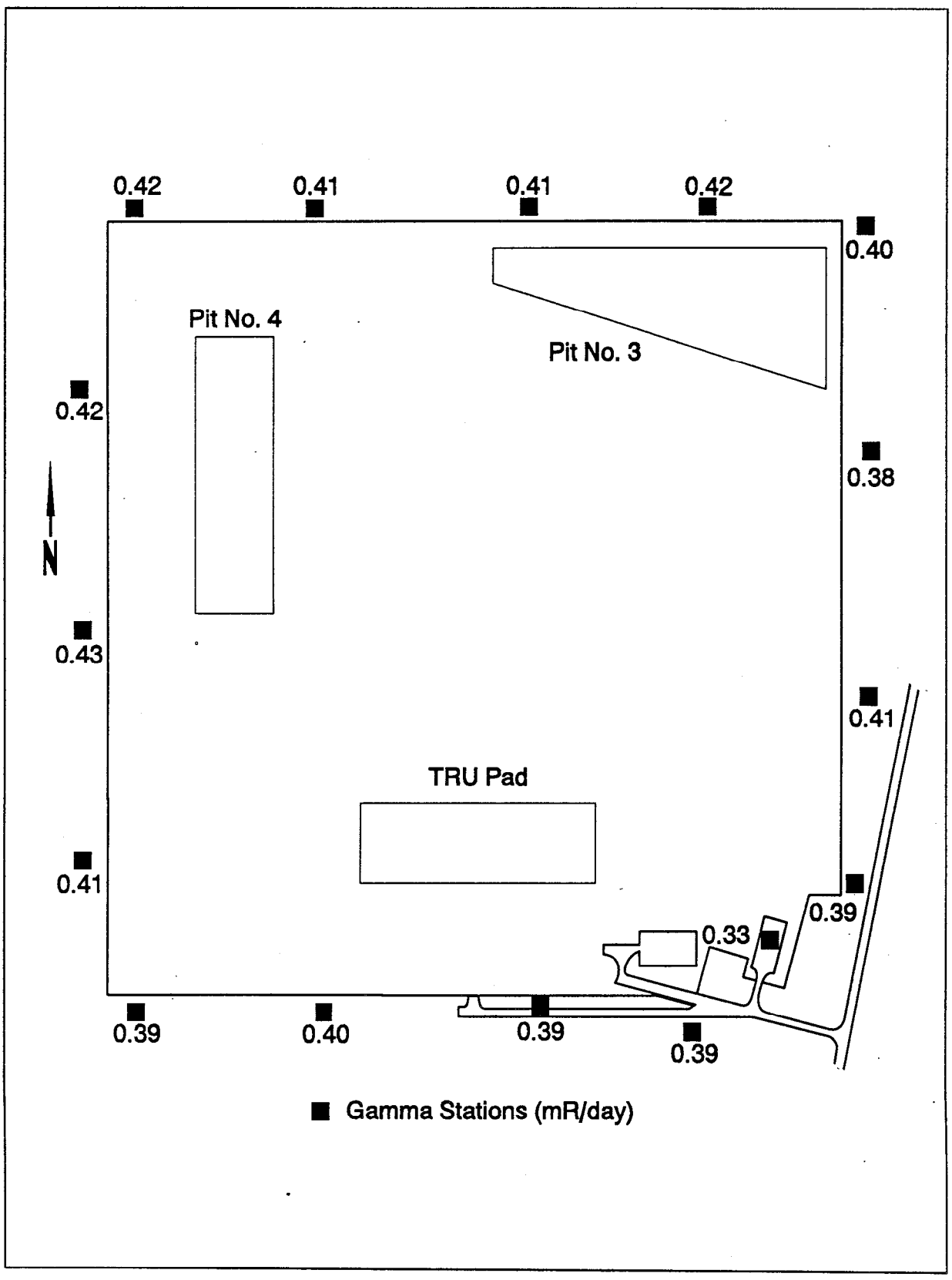


Figure 5.4 RWMS TLD Annual Average Results - 1989

5.1.2 LIQUID EFFLUENTS

Liquid effluents at the NTS originated from tunnels, research studies of radionuclide movement through groundwater, and from cleanup of radiologically-contaminated equipment. All liquid discharges contained within the NTS were typically held in containment ponds. Monthly grab samples were taken from each pond and, where possible, from the influent. Radioactive liquid effluents discharged to onsite ponds totaled approximately 2069 curies during 1989.

TUNNELS

The Rainier Mesa range, located in Area 12, is the location for nuclear tests conducted within tunnels by the DOD. As a result of drilling operations and seepage, water discharged from these tunnels was collected in ponds outside the tunnels. This water was usually contaminated with radionuclides, mainly ^{3}H, which were generated during nuclear tests.

Liquid effluents were discharged during 1989 from three tunnels: N, T, and E. A monthly grab sample was taken from each containment pond and from the tunnel discharge. Monitoring results indicated that the water discharged from the three tunnels listed contained measurable quantities of ^{3}H and fission products. Total quantities of ^{3}H, ^{238}Pu, $^{239+240}Pu$, and beta activity were reported for each liquid effluent source and are listed in Table 5.1.

The primary source of liquid discharges was from tunnel seepage to near-portal containment ponds. No liquid effluents were discharged offsite. Onsite discharges to evaporating ponds contained a total of 1500 curies of ^{3}H to these ponds. (An additional 569 curies was released to the Area 5 radionuclide migration study ditch - see "Radionuclide Migration Study" below - for a total NTS release of 2069 curies of ^{3}H to onsite ponds.) Discharges of other radionuclides totaled less than 1 curie.

Radioactivity in liquid discharges released to onsite waste treatment or disposal systems (containment ponds) was monitored to assess the efficacy of treatment and control and to provide a quantitative and qualitative annual summary of the radioactivity released onsite.

During 1989 an estimated 3.2×10^{7} liters of water were discharged into the T Tunnel containment ponds. Sampling results from the tunnel effluent pipe indicated an annual average of 4.6×10^{-2} µCi/mL of ^{3}H. Therefore, the total quantity of ^{3}H discharged out of the T Tunnel complex was calculated to be 1480 curies. Additional ^{3}H effluent data for T Tunnel and other sites discussed in Section 5.1.2 are found in Table 5.3.

At N Tunnel an estimated 3.7×10^{7} liters of water were discharged into the containment ponds. The average 1989 annual concentration of ^{3}H from samples taken at the N Tunnel effluent pipe was 4.5×10^{-4}

Table 5.3 Tritium in NTS Effluents - 1989

Location	Discharge Volume (L)	Average ^{3}H Concentration (µCi/mL)	Total ^{3}H Discharge (Ci)
T Tunnel	3.2×10^{7}	4.6×10^{-2}	1.48×10^{3}
N Tunnel	3.7×10^{7}	4.5×10^{-4}	1.65×10^{1}
E Tunnel	1.9×10^{6}	1.6×10^{-3}	3.03×10^{0}
U5eRNM2S	1.2×10^{9}	4.7×10^{-4}	5.69×10^{2}
Area 6 Decontamination Facility Pond	4.0×10^{6}	1.8×10^{-6}	7.15×10^{-3}

μCi/mL. The gamma emitters were for the most part undetected. The total ^{3}H discharge from N Tunnel activities for 1989 was calculated to be 16.5 curies.

The E Tunnel complex has been inoperative for several years. However, water continued to discharge from the tunnel. The total flow during 1989 was estimated to be 1.9×10^{6} liters. Samples taken from this liquid discharge displayed an annual average of 1.6×10^{-3} μCi/mL of ^{3}H. The containment ponds for this tunnel were dry during 1989. The total ^{3}H activity discharged into the environment from E Tunnel effluents was calculated to be 3.03 Curies.

RADIONUCLIDE MIGRATION STUDY

Pumping of the subsurface radionuclide migration study well in Area 5 continued through 1989. This well, located 90 meters (297 feet) from the CAMBRIC underground nuclear test location, has been pumped continuously since 1975 to force migration of radionuclides from the CAMBRIC cavity to the well through the subsurface geology in order to study migration potential and rates. The CAMBRIC test was conducted 73 meters (241 feet) below the water table in 1965. Water pumped to the surface is released to a man-made ditch, which drains to the edge of the Frenchman Flat playa, forming a small pond area. Tritium has been observed in the pumped water since 1978 (Burbey and Wheatcraft 1986).

The concentration of ^{3}H in the water discharged from the well averaged 4.7×10^{-4} μCi/mL during 1989. The flow from this well, measured at 600 gallons per minute, discharged a total volume of 1.2×10^{9} liters during 1989, for a total ^{3}H discharge into the NTS environment of 569 curies. The water is not used for drinking or industrial purposes.

DECONTAMINATION FACILITY

The Decontamination Facility, located in Area 6, discharges contaminated water generated during equipment decontamination processes into a containment pond. Grab samples are taken from this pond on a monthly basis and analyzed for ^{3}H, beta, ^{238}Pu, $^{239+240}Pu$, and gamma activity.

During 1989 sampling results from influent to the containment pond at the Decontamination Facility were consistently below detection limits for all radionuclides except ^{3}H. The annual average of ^{3}H at the Decontamination Facility containment pond was 1.8×10^{-6} μCi/mL. The total volume of liquid discharged to the containment pond during 1989 was estimated to be 4×10^{6} liters. Therefore, the total discharge of ^{3}H for 1989 was estimated to be 7.15×10^{-3} curies.

5.2 RADIOLOGICAL ENVIRONMENTAL SURVEILLANCE

Onsite surveillance of airborne particulates, noble gases, and tritiated water vapor indicated onsite concentrations that were generally not statistically different from background concentrations. Surface water samples collected from open reservoirs of natural springs and of industrial-purpose water reservoirs gave no indication of statistically significant contamination levels. Groundwater monitoring results also showed no levels different from background. External gamma exposure monitoring indicated that the gamma environment within the NTS remained consistent with previous years. All gamma monitoring stations displayed expected results, ranging from the background levels predominant throughout the NTS to the types of exposure rates associated with known contaminated zones and radiological material storage facilities. Special environmental studies included radionuclide transport studies and study of plutonium concentrations in soils, flora, and fauna. Results of offsite environmental surveillance by the EPA indicated no NTS-related radioactivity was detected at any air sampling station, and there were no apparent net exposures detectable by the offsite dosimetry network.

5.2.1 ONSITE ENVIRONMENTAL SURVEILLANCE

Onsite radiological surveillance consists of (1) a network of 52 air sampling stations, with samples analyzed for gross beta, plutonium, and radioactive gases; (2) 17 tritiated water vapor sampling stations; (3) surface water samples from 13 open water supply reservoirs, 7 springs, 9 waste-water containment ponds, and 3 sewage lagoons; (4) samples from 14 groundwater supply wells; (5) groundwater samples from 9 drinking water consumption points; and (6) 150 ambient gamma exposure measurements taken with TLDs. Additional radiological surveillance is conducted through the special Site studies of the Basic Environmental Compliance and Monitoring Program (BECAMP), including: (7) investigating the movement of radionuclides on and around the NTS through horizontal movement, water-driven erosion, vertical migration, and wind-driven erosional resuspension; (8) development of a human dose-assessment model specific to the environmental and radiological conditions of the NTS; (9) preparation of a peer-reviewed publication that addresses an important issue related to the potential environmental impacts of past, present, and future activities on the NTS; and (10) monitoring of the flora and fauna on the NTS to assess changes over time in the ecological condition of the NTS.

RADIOACTIVITY IN AIR

Fifty-two air sampling stations were operated continuously to collect particulate and halogen samples. At each of the locations, samples were collected weekly with glass fiber filters and charcoal cartridges. The filters were counted for gross beta and gamma activity each week, combined at the end of the month, and then analyzed for ^{238}Pu, $^{239+240}Pu$. The charcoal cartridge was counted for gamma activity each week. The individual gross beta, ^{238}Pu, $^{239+240}Pu$, and gamma sampling results are listed in Volume II, Appendix A, "Onsite ^{238}Pu, $^{239+240}Pu$, Gamma-Emitting Radionuclides, and Gross Beta in Air," Tables A.1 through A.4.

Air monitoring for the noble gases ^{85}Kr and ^{133}Xe was performed at seven permanent locations. These air samples were collected weekly. A distillation process separated the components of the air, and the radioactive krypton and xenon in the sample were measured.

Tritiated water vapor was monitored continuously at 17 locations. Samples were collected every two weeks and taken to the onsite laboratory for ^{3}H analysis.

For the purpose of comparing measured quantities of airborne radioactivity to the DAC found in DOE Order 5480.11, "Radiation Protection for Occupational Workers," and to Derived Concentration Guides (DCGs) found in DOE Order 5400.5, "Radiation Protection of the Public and the Environment," the following assumptions are taken:

- The chemical species of the radionuclides detected was unknown, so the most restrictive DAC or DCG was used (almost always Class Y compounds, which take on the order of years to clear from the respiratory system). All of the DCGs and DACs used are listed in Table 5.4, "Radionuclide Concentration Guides for Air and Water."
- For air sampling results, all of the gross beta activity detected was assumed to be ^{90}Sr.

Table 5.4 Radionuclide Concentration Guides for Air and Water

	µCi/mL			
Radionuclide	DAC (air)[a]	DCG (air)[b]	DCG (water)	MCL (water)[c]
^{3}H	2×10^{-5}	1×10^{-7}	2×10^{-3}	2×10^{-5}
^{40}K	2×10^{-7}	9×10^{-10}	7×10^{-6}	-
^{85}Kr (ns)	1×10^{-4}	3×10^{-6}	-	-
^{90}Sr	8×10^{-9}	9×10^{-12}	1×10^{-6}	8×10^{-9}
^{133}Xe (ns)	1×10^{-4}	5×10^{-7}	-	-
^{226}Ra	3×10^{-10}	1×10^{-12}	1×10^{-7}	5×10^{-9}
^{238}Pu	3×10^{-12}	3×10^{-14}	4×10^{-8}	-
$^{239+240}Pu$	2×10^{-12}	2×10^{-14}	3×10^{-8}	-

(ns) = nonstochastic value

(a) DAC - The Derived Air Concentration used for limiting radiation exposures through inhalation of radionuclides by workers. The values are based on either a stochastic (committed effective dose equivalent) dose of 5 rem or a nonstochastic (organ) dose of 50 rem, whichever is more limiting. In the table, the value shown is a stochastic limit unless followed by (ns).

(b) DCG - Derived Concentration Guides are reference values for conducting radiological environmental protection programs at operational DOE facilities and sites. The DCG values for internal exposure shown are based on a committed effective dose equivalent of 100 mrem for the radionuclide taken into the body by ingestion or inhalation during one year.

(c) MCL - The Maximum Contaminant Level is the maximum permissible level of a contaminant in water which is delivered to the free-flowing outlet of the ultimate user of a public water system. MCL values are reported in the EPA National Primary Drinking Water Standards (40 CFR 141). The values listed in the table are based on 4 mrem committed effective dose equivalent for the radionuclide taken into the body by ingestion of water during one year.

PARTICULATE SAMPLING RESULTS

Gross Beta

Figure 5.5 displays the average gross beta results for 1989 sampling. Sampling results from the Radioactive Waste Management Site (RWMS) in Area 5 were detailed previously in Figures 5.3 through 5.5. Air particulate samples were held for seven days prior to gross beta counting and gamma spectrum analysis to allow for the decay of radon and radon daughters. Samples collected at Gate 200 in Area 5 were counted for gross beta and gamma without allowing seven days for this decay. Although the beta activity results from the Gate 200 samples were higher and more variable than the results from samples held for seven days, they provided a rapid indication of unusual events such as fallout from foreign sources. As such the gross beta results from samples taken at the Area 5, Gate 200 station were not included in the annual averages nor were they considered during dose calculations. Dose calculations resulting from NTS operations are determined exclusive of naturally-occurring radionuclides such as ^{220}Rn and ^{222}Rn and their daughter products. Table 5.5 presents the network arithmetic averages, minimums, and maximums for 1989 airborne gross beta sampling results.

The network (all locations excluding Gate 200) annual average gross beta concentration was 2.2×10^{-14} µCi/mL. This concentration is 0.001 percent of the ^{90}Sr DAC for radiation workers listed in DOE Order 5480.11 and 0.24 percent of the DCG for members of the general public noted in DOE Order 5400.5. One sample standard deviation of this annual average was 0.50×10^{-14} µCi/mL. None of the annual averages from individual sampling locations (again, excluding Area 5 Gate 200) were statistically different at the five percent significance level from the network annual average.

Plutonium

Monthly composite samples from each particulate sampling location were analyzed for ^{238}Pu, and $^{239+240}Pu$. Sampling results averaged below 10^{-15} µCi/mL of $^{239+240}Pu$ and 10^{-17} µCi/mL of ^{238}Pu for all locations during 1989, with the majority of results for both isotopes being on the order of 10^{-18} µCi/mL.

The maximum annual average $^{239+240}Pu$ concentration was found at the Area 3 ah/at West sampling location. Results from the samples taken at that location averaged 3.4×10^{-16} µCi/mL during 1989. This quantity was 0.017 percent of the DAC for radiation workers and 1.7 percent of the DCG for members of the general public. This concentration was determined to be statistically different at the five percent significance level from the network average for all sampling locations, excluding those at the Area 3 ah/at Bulk Waste Management Facility. The network average for all location (excluding the ah/at site) was 4.0×10^{-17} µCi/mL.

The maximum annual average ^{238}Pu concentration from the analysis of samples taken at the Area 3 ah/at site was not statistically different from the network annual average ^{238}Pu concentration at the five percent significance level. No other locations displayed concentrations significantly different at the five percent significance level from the network average. Table 5.6 and 5.7 list the measured minimum, maximum, and average ^{238}Pu concentrations for the year, respectively. Figure 5.6 shows the airborne $^{239+240}Pu$ annual average results at their respective locations.

The presence of plutonium on the NTS is primarily due to tests conducted before 1960 in which nuclear devices were detonated with high explosives (called "safety shots"). These tests spread low-fired plutonium in the eastern and northeastern areas of the NTS. Two decades later, higher than normal levels of plutonium in the air are still detected in Areas 1, 2, 3, 7, 8, 9, 10, and 15. During cleanup efforts for these atmospheric safety shot sites at the Area 3 Bulk Waste Management Facility, some of the ^{238}Pu and $^{239+240}Pu$ becomes airborne. As such, higher than normal levels of plutonium have been detected around the Area 3 Bulk Waste Management Facility for the past few years.

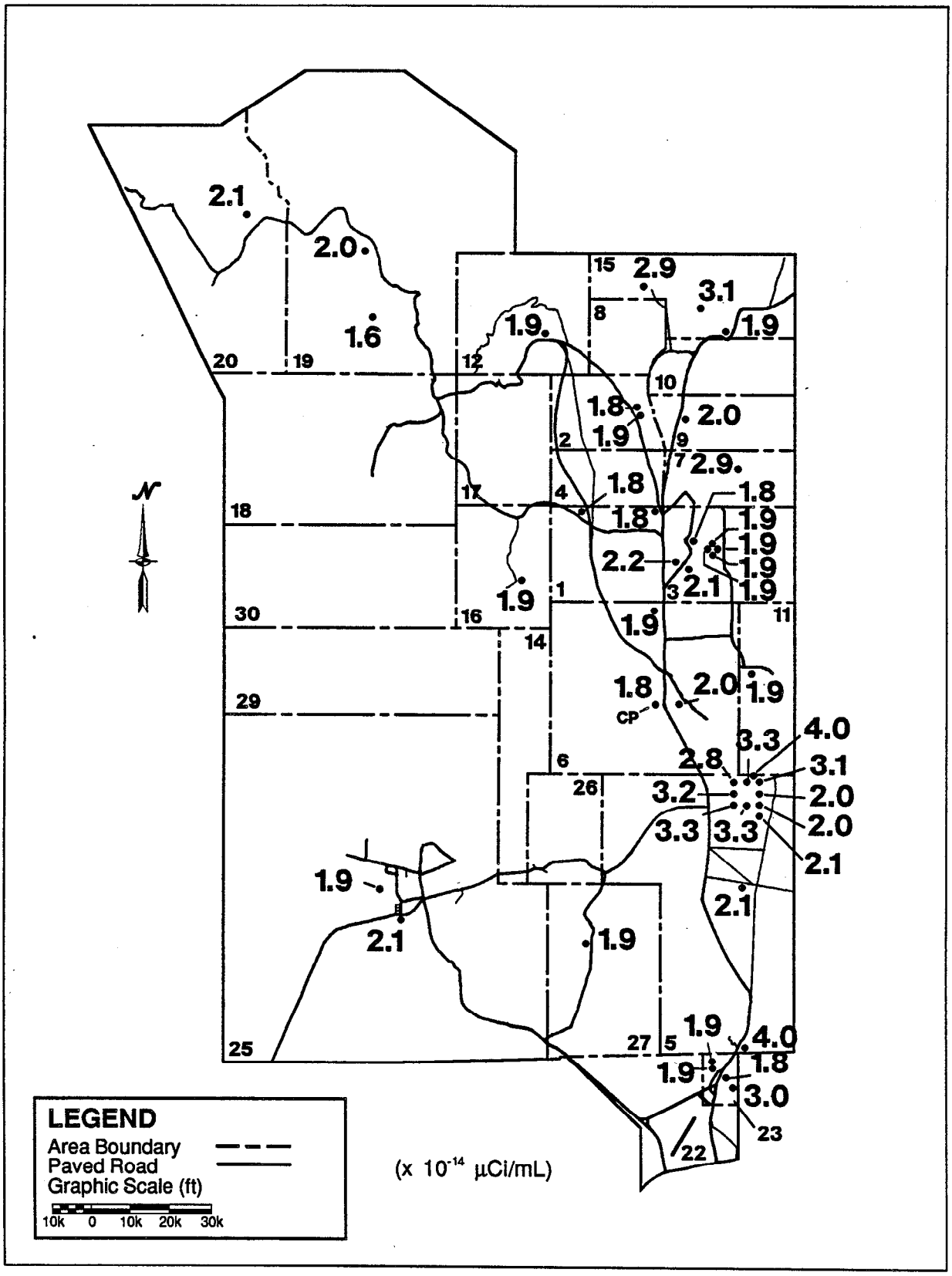


Figure 5.5 Airborne Gross Beta Annual Average Concentrations - 1989

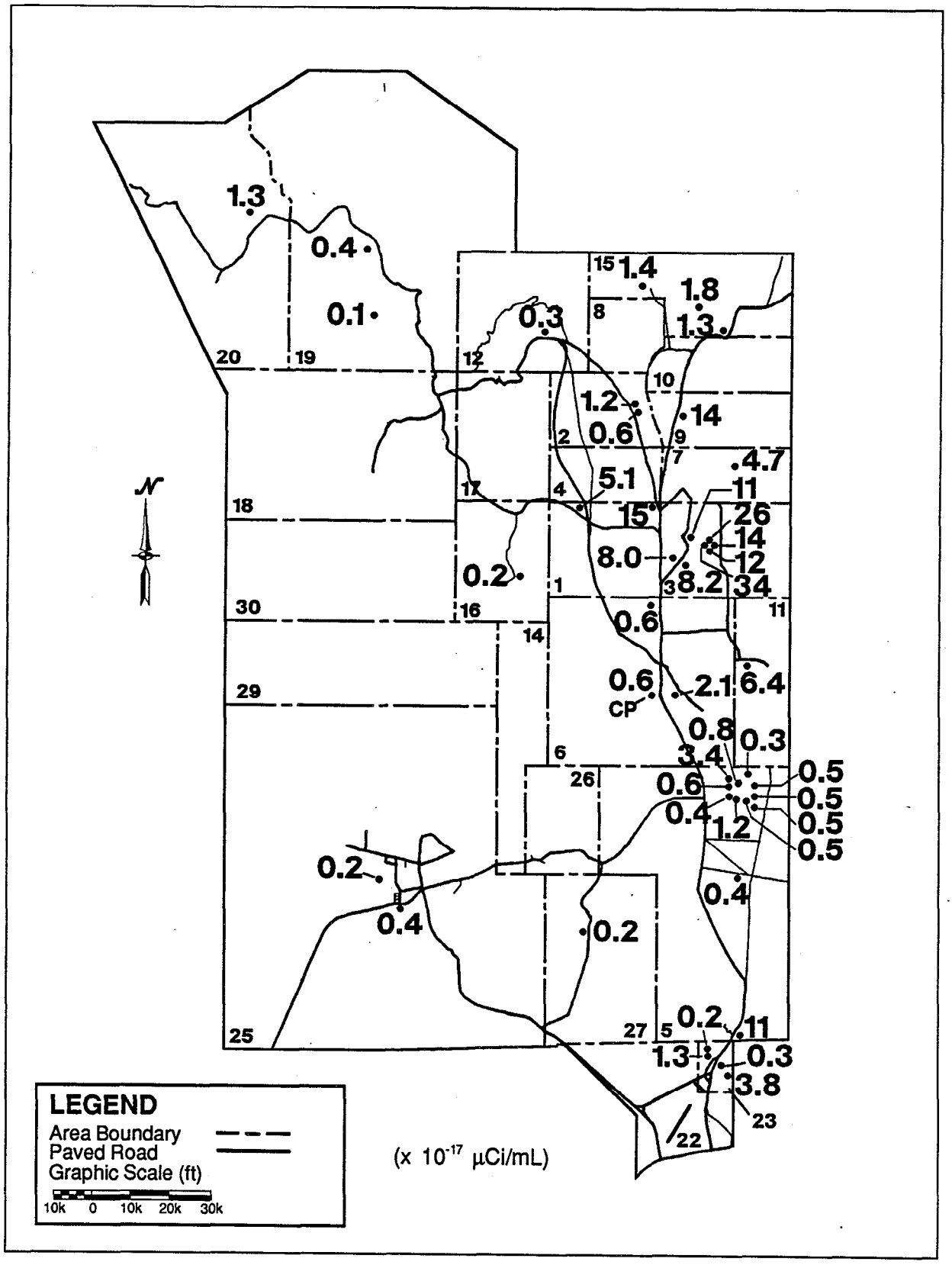


Figure 5.6 Airborne $^{239+240}$Pu Annual Average Results - 1989

Table 5.5 Airborne Gross Beta Concentrations - 1989

Location	µCi/mL Minimum	Maximum	Average
Area 1, BJY	7.6×10^{-15}	4.3×10^{-14}	1.8×10^{-14}
Area 1, Gravel Pit	4.3×10^{-15}	3.3×10^{-14}	1.8×10^{-14}
Area 2, 2-1 Substation	9.2×10^{-15}	3.1×10^{-14}	1.9×10^{-14}
Area 2, Complex	7.7×10^{-15}	5.8×10^{-14}	1.9×10^{-14}
Area 3, 3-300 Bunker	8.4×10^{-15}	3.3×10^{-14}	1.8×10^{-14}
Area 3, ah/at East	9.4×10^{-16}	3.6×10^{-14}	1.9×10^{-14}
Area 3, ah/at North	8.4×10^{-15}	3.0×10^{-14}	1.9×10^{-14}
Area 3, ah/at South	8.6×10^{-15}	3.1×10^{-14}	1.9×10^{-14}
Area 3, ah/at West	7.2×10^{-15}	3.4×10^{-14}	1.9×10^{-14}
Area 3, Complex No. 2	9.7×10^{-15}	3.4×10^{-14}	2.1×10^{-14}
Area 3, Compound	1.0×10^{-14}	5.4×10^{-14}	2.1×10^{-14}
Area 5, DOD Yard	9.7×10^{-15}	3.5×10^{-14}	1.9×10^{-14}
Area 5, Gate 200	8.6×10^{-15}	1.3×10^{-13}	4.0×10^{-14}
Area 5, RWMS No. 1	1.1×10^{-14}	4.3×10^{-14}	2.1×10^{-14}
Area 5, RWMS No. 2	9.7×10^{-15}	3.5×10^{-14}	2.0×10^{-14}
Area 5, RWMS No. 3	9.1×10^{-15}	3.6×10^{-14}	2.0×10^{-14}
Area 5, RWMS No. 4	8.5×10^{-15}	6.0×10^{-13}	3.1×10^{-14}
Area 5, RWMS No. 5	9.9×10^{-15}	7.1×10^{-13}	3.3×10^{-14}
Area 5, RWMS No. 6	1.1×10^{-15}	2.8×10^{-15}	2.8×10^{-14}
Area 5, RWMS No. 7	1.0×10^{-14}	6.4×10^{-13}	3.2×10^{-14}
Area 5, RWMS No. 8	1.0×10^{-14}	6.5×10^{-13}	3.3×10^{-14}
Area 5, RWMS No. 9	1.1×10^{-14}	6.8×10^{-13}	3.3×10^{-14}
Area 5, RWMS Pit No. 3	1.1×10^{-14}	3.6×10^{-14}	1.9×10^{-14}
Area 5, RWMS Pit No. 4	1.5×10^{-14}	3.2×10^{-14}	2.1×10^{-14}
Area 5, RWMS T.P. NE	9.7×10^{-15}	3.1×10^{-14}	1.9×10^{-14}
Area 5, RWMS T.P. North	1.1×10^{-14}	3.1×10^{-14}	1.9×10^{-14}
Area 5, RWMS T.P. NW	9.9×10^{-15}	3.2×10^{-14}	1.9×10^{-14}
Area 5, RWMS T.P. SE	9.7×10^{-15}	3.2×10^{-14}	1.9×10^{-14}
Area 5, RWMS T.P. South	1.2×10^{-14}	3.2×10^{-14}	2.1×10^{-14}
Area 5, RWMS T.P. SW	9.6×10^{-15}	3.2×10^{-14}	1.9×10^{-14}
Area 5, Well 5B	9.4×10^{-15}	3.6×10^{-14}	2.1×10^{-14}
Area 6, CP-6	8.6×10^{-16}	3.2×10^{-14}	1.8×10^{-14}
Area 6, Well 3	9.4×10^{-15}	3.1×10^{-14}	1.9×10^{-14}
Area 6, Yucca Complex	1.2×10^{-14}	3.3×10^{-14}	2.0×10^{-14}
Area 7, Ue7ns	9.2×10^{-15}	5.8×10^{-13}	2.9×10^{-14}
Area 9, 9-300 Bunker	6.8×10^{-16}	6.7×10^{-14}	2.0×10^{-14}
Area 11, Gate 293	8.6×10^{-15}	3.3×10^{-14}	1.9×10^{-14}
Area 12, Complex	8.0×10^{-15}	8.7×10^{-14}	1.9×10^{-14}
Area 15, EPA Farm	7.4×10^{-15}	6.8×10^{-13}	3.1×10^{-14}
Area 15, Gate 700 South	7.7×10^{-15}	5.8×10^{-14}	1.9×10^{-14}
Area 15, PILE DRIVER	8.1×10^{-15}	5.6×10^{-13}	2.9×10^{-14}
Area 16, Substation	9.1×10^{-16}	1.1×10^{-13}	1.9×10^{-14}
Area 19, Echo Peak	8.5×10^{-15}	3.9×10^{-14}	1.6×10^{-14}
Area 19, Substation	8.3×10^{-15}	2.0×10^{-13}	2.0×10^{-14}
Area 20, Dispensary	1.4×10^{-15}	1.4×10^{-13}	2.1×10^{-14}
Area 23, Building 790	7.9×10^{-15}	5.7×10^{-14}	1.9×10^{-14}

Table 5.5 (Gross Beta, cont.)

Location	µCi/mL Minimum	Maximum	Average
Area 23, Building 790 No. 2	6.8×10^{-16}	5.0×10^{-14}	1.9×10^{-14}
Area 23, East Boundary	0.0	6.1×10^{-13}	3.0×10^{-14}
Area 23, H & S Roof	1.1×10^{-15}	3.1×10^{-14}	1.8×10^{-14}
Area 25, EMAD North	9.0×10^{-15}	3.4×10^{-14}	1.9×10^{-14}
Area 25, NRDS Warehouse	8.1×10^{-15}	3.8×10^{-14}	2.1×10^{-14}
Area 27, Cafeteria	8.4×10^{-15}	3.4×10^{-14}	1.9×10^{-14}

Table 5.6 Airborne $^{239+240}$Pu Concentrations - 1989

Location	µCi/mL Minimum	Maximum	Average
Area 1, BJY	6.5×10^{-18}	1.2×10^{-15}	1.5×10^{-16}
Area 1, Gravel Pit	-5.6×10^{-19}	5.1×10^{-16}	5.1×10^{-17}
Area 2, 2-1 Substation	1.8×10^{-18}	1.6×10^{-17}	6.0×10^{-18}
Area 2, Complex	2.0×10^{-18}	5.8×10^{-17}	1.2×10^{-17}
Area 3, 3-300 Bunker	5.5×10^{-18}	2.4×10^{-16}	1.1×10^{-16}
Area 3, ah/at East	3.7×10^{-17}	8.3×10^{-16}	1.4×10^{-16}
Area 3, ah/at North	4.7×10^{-17}	5.3×10^{-16}	2.6×10^{-16}
Area 3, ah/at South	1.8×10^{-18}	2.6×10^{-16}	1.2×10^{-16}
Area 3, ah/at West	1.1×10^{-16}	9.4×10^{-16}	3.4×10^{-16}
Area 3, Complex No. 2	0.0×10^{0}	1.6×10^{-16}	8.2×10^{-17}
Area 3, Compound	1.8×10^{-17}	5.1×10^{-16}	8.0×10^{-17}
Area 5, DOD Yard	-6.4×10^{-19}	8.6×10^{-18}	2.5×10^{-18}
Area 5, Gate 200	-6.8×10^{-19}	7.9×10^{-16}	1.0×10^{-16}
Area 5, RWMS No. 1	-1.2×10^{-17}	1.6×10^{-17}	4.6×10^{-18}
Area 5, RWMS No. 2	-5.3×10^{-19}	1.4×10^{-17}	4.8×10^{-18}
Area 5, RWMS No. 3	-1.6×10^{-18}	1.3×10^{-17}	4.5×10^{-18}
Area 5, RWMS No. 4	-5.1×10^{-19}	1.5×10^{-17}	5.0×10^{-18}
Area 5, RWMS No. 5	0.0×10^{0}	6.1×10^{-17}	8.0×10^{-18}
Area 5, RWMS No. 6	1.4×10^{-18}	3.4×10^{-16}	3.4×10^{-17}
Area 5, RWMS No. 7	-6.0×10^{-19}	2.7×10^{-17}	5.9×10^{-18}
Area 5, RWMS No. 8	0.0×10^{0}	1.5×10^{-17}	3.8×10^{-18}
Area 5, RWMS No. 9	1.9×10^{-18}	3.1×10^{-17}	1.2×10^{-17}
Area 5, RWMS Pit No. 3	-6.5×10^{-19}	1.6×10^{-17}	3.1×10^{-18}
Area 5, RWMS Pit No. 4	-3.8×10^{-18}	2.7×10^{-16}	3.3×10^{-17}
Area 5, RWMS T.P. NE	0.0×10^{0}	4.7×10^{-17}	8.1×10^{-18}
Area 5, RWMS T.P. North	1.0×10^{-18}	1.5×10^{-16}	2.3×10^{-17}
Area 5, RWMS T.P. NW	-1.6×10^{-18}	1.8×10^{-17}	4.7×10^{-18}
Area 5, RWMS T.P. SE	-4.7×10^{-19}	1.7×10^{-17}	4.2×10^{-18}
Area 5, RWMS T.P. South	2.0×10^{-18}	1.3×10^{-17}	7.8×10^{-18}
Area 5, RWMS T.P. SW	-8.1×10^{-19}	1.4×10^{-16}	2.3×10^{-17}

Table 5.6 ($^{239+240}$Pu Concentrations, cont.)

Location	µCi/mL Minimum	Maximum	Average
Area 5, Well 5B	0.0×10^{0}	1.2×10^{-17}	3.7×10^{-18}
Area 6, CP-6	1.1×10^{-18}	1.4×10^{-17}	5.7×10^{-18}
Area 6, Well 3	2.3×10^{-18}	1.6×10^{-17}	6.2×10^{-18}
Area 6, Yucca Complex	1.2×10^{-17}	3.2×10^{-17}	2.1×10^{-17}
Area 7, Ue7ns	3.7×10^{-18}	2.7×10^{-16}	4.7×10^{-17}
Area 9, 9-300 Bunker	2.3×10^{-18}	3.5×10^{-16}	1.4×10^{-16}
Area 11, Gate 293	4.5×10^{-19}	5.4×10^{-16}	6.4×10^{-17}
Area 12, Complex	-5.5×10^{-19}	6.8×10^{-18}	2.6×10^{-18}
Area 15, EPA Farm	-1.3×10^{-18}	3.9×10^{-17}	1.8×10^{-17}
Area 15, Gate 700 South	1.7×10^{-18}	3.0×10^{-17}	1.3×10^{-17}
Area 15, PILEDRIVER	-6.8×10^{-19}	1.0×10^{-16}	1.4×10^{-17}
Area 16, Substation	-8.2×10^{-19}	1.1×10^{-17}	2.4×10^{-18}
Area 19, Echo Peak	-8.4×10^{-19}	3.7×10^{-18}	1.3×10^{-18}
Area 19, Substation	-7.1×10^{-19}	9.0×10^{-18}	3.5×10^{-18}
Area 20, Dispensary	8.9×10^{-19}	1.1×10^{-16}	1.3×10^{-17}
Area 23, Building 790	-9.0×10^{-19}	8.7×10^{-17}	1.3×10^{-17}
Area 23, Building 790 No. 2	0.0×10^{0}	8.6×10^{-18}	2.3×10^{-18}
Area 23, East Boundary	-6.4×10^{-19}	3.6×10^{-16}	3.8×10^{-17}
Area 23, H & S Roof	-6.2×10^{-19}	1.3×10^{-17}	3.3×10^{-18}
Area 25, EMAD North	-6.8×10^{-19}	6.9×10^{-18}	1.6×10^{-18}
Area 25, NRDS Warehouse	4.6×10^{-19}	1.2×10^{-17}	3.6×10^{-18}
Area 27, Cafeteria	-5.6×10^{-19}	4.8×10^{-18}	2.2×10^{-18}

Table 5.7 Airborne ^{238}Pu Concentrations - 1989

Location	µCi/mL Minimum	Maximum	Average
Area 1, BJY	-7.7×10^{-18}	3.1×10^{-17}	6.2×10^{-18}
Area 1, Gravel Pit	-1.3×10^{-17}	1.2×10^{-17}	1.7×10^{-18}
Area 2, 2-1 Substation	-5.8×10^{-18}	1.5×10^{-17}	2.7×10^{-18}
Area 2, Complex	-3.6×10^{-18}	1.7×10^{-17}	6.3×10^{-18}
Area 3, 3-300 Bunker	-7.2×10^{-18}	2.1×10^{-17}	5.2×10^{-18}
Area 3, ah/at East	-3.0×10^{-17}	1.4×10^{-17}	9.1×10^{-19}
Area 3, ah/at North	-1.0×10^{-17}	1.6×10^{-17}	3.1×10^{-18}
Area 3, ah/at South	-6.4×10^{-18}	1.1×10^{-17}	4.4×10^{-18}
Area 3, ah/at West	-1.3×10^{-17}	2.8×10^{-17}	5.4×10^{-18}
Area 3, Complex No. 2	-6.3×10^{-18}	2.3×10^{-17}	7.0×10^{-18}
Area 3, Compound	-6.6×10^{-18}	9.1×10^{-18}	1.3×10^{-18}
Area 5, DOD Yard	-1.2×10^{-18}	1.3×10^{-17}	4.6×10^{-18}
Area 5, Gate 200	-9.6×10^{-18}	2.3×10^{-17}	1.1×10^{-18}

Table 5.7 (^{238}Pu Concentrations, cont.)

Location	µCi/mL		
	Minimum	Maximum	Average
Area 5, RWMS No. 1	-7.1×10^{-18}	1.8×10^{-17}	1.9×10^{-18}
Area 5, RWMS No. 2	-1.4×10^{-17}	9.2×10^{-18}	-1.2×10^{-18}
Area 5, RWMS No. 3	-1.2×10^{-17}	2.1×10^{-17}	4.8×10^{-18}
Area 5, RWMS No. 4	-2.0×10^{-18}	2.2×10^{-17}	7.1×10^{-18}
Area 5, RWMS No. 5	-1.2×10^{-17}	2.2×10^{-17}	4.6×10^{-18}
Area 5, RWMS No. 6	-9.1×10^{-18}	1.6×10^{-17}	1.2×10^{-18}
Area 5, RWMS No. 7	-6.8×10^{-18}	7.4×10^{-18}	7.5×10^{-20}
Area 5, RWMS No. 8	-1.2×10^{-17}	1.5×10^{-17}	1.8×10^{-18}
Area 5, RWMS No. 9	-1.8×10^{-17}	1.3×10^{-17}	-5.7×10^{-19}
Area 5, RWMS Pit No. 3	-6.8×10^{-18}	2.1×10^{-17}	5.3×10^{-18}
Area 5, RWMS Pit No. 4	-3.3×10^{-17}	6.7×10^{-18}	-2.1×10^{-18}
Area 5, RWMS T.P. NE	-5.4×10^{-18}	8.7×10^{-18}	4.5×10^{-19}
Area 5, RWMS T.P. North	-1.3×10^{-17}	7.2×10^{-18}	-1.5×10^{-18}
Area 5, RWMS T.P. NW	-2.1×10^{-17}	1.0×10^{-17}	-3.5×10^{-18}
Area 5, RWMS T.P. SE	-6.2×10^{-18}	1.5×10^{-17}	2.6×10^{-18}
Area 5, RWMS T.P. South	-1.0×10^{-17}	7.8×10^{-18}	6.7×10^{-19}
Area 5, RWMS T.P. SW	-4.4×10^{-18}	1.5×10^{-17}	8.9×10^{-19}
Area 5, Well 5B	-3.9×10^{-18}	1.5×10^{-17}	2.6×10^{-18}
Area 6, CP-6	-3.8×10^{-18}	1.3×10^{-17}	3.4×10^{-18}
Area 6, Well 3	-6.7×10^{-18}	1.4×10^{-17}	5.1×10^{-18}
Area 6, Yucca Complex	-7.7×10^{-18}	9.4×10^{-18}	7.6×10^{-20}
Area 7, Ue7ns	-5.6×10^{-17}	2.6×10^{-17}	-2.6×10^{-19}
Area 9, 9-300 Bunker	-1.2×10^{-17}	1.6×10^{-17}	4.4×10^{-18}
Area 11, Gate 293	-1.2×10^{-17}	1.4×10^{-17}	2.0×10^{-18}
Area 12, Complex	-9.9×10^{-18}	2.0×10^{-17}	1.9×10^{-18}
Area 15, EPA Farm	-7.7×10^{-18}	2.0×10^{-17}	4.0×10^{-18}
Area 15, Gate 700 South	-7.4×10^{-18}	1.7×10^{-17}	4.7×10^{-18}
Area 15, PILEDRIVER	-9.8×10^{-18}	2.5×10^{-17}	3.1×10^{-18}
Area 16, Substation	-5.3×10^{-18}	3.9×10^{-17}	6.8×10^{-18}
Area 19, Echo Peak	-1.2×10^{-17}	1.4×10^{-17}	-6.1×10^{-20}
Area 19, Substation	-1.4×10^{-17}	2.1×10^{-17}	3.9×10^{-18}
Area 20, Dispensary	-8.6×10^{-18}	1.8×10^{-17}	3.3×10^{-18}
Area 23, Building 790	-6.1×10^{-18}	1.4×10^{-17}	2.6×10^{-18}
Area 23, Building 790 No. 2	-4.4×10^{-18}	1.7×10^{-17}	5.0×10^{-18}
Area 23, East Boundary	-2.9×10^{-18}	1.6×10^{-17}	4.7×10^{-18}
Area 23, H & S Roof	-7.5×10^{-18}	1.5×10^{-17}	1.6×10^{-18}
Area 25, EMAD North	-5.1×10^{-18}	4.3×10^{-17}	5.5×10^{-18}
Area 25, NRDS Warehouse	-1.1×10^{-17}	1.5×10^{-17}	2.0×10^{-18}
Area 27, Cafeteria	-1.0×10^{-17}	2.2×10^{-17}	4.8×10^{-18}

Gamma

The charcoal cartridges used to collect halogen gases and glass fiber filters used to collect particulate radiation were analyzed each week by gamma spectroscopy. The results from the gamma spectroscopy analyses are provided in

Appendix A, Table A.3. The gamma results above detection were few in number and did not display reoccurrence or trends. The most abundant isotope detected was ^{40}K, which is found naturally in the environment. Other isotopes were detected at levels below one percent of the DCG. Statistical discussions are provided in Appendix A.

NOBLE GAS SAMPLING RESULTS

Krypton-85

The locations of the ^{85}Kr sampling stations and the annual averages are shown in Figure 5.7. The annual average concentration and standard deviation of ^{85}Kr during 1989 for the network (seven continuous sampling stations with weekly sample collection) was 23 x 10^{-12} µCi/mL (or 23 pCi/m^3) ± 5.2 x 10^{-12} µCi/mL. This average did not include sampling results from the Area 20 Camp noble gas sampler. The results from the Area 20 Camp were determined to be statistically different from all other stations. The Area 20 Camp annual average concentration of 27 x 10^{-12} µCi/mL was 0.0009 percent of the DCG for members of the general public.

The sampler at Area 20 Camp is nearby several SGZs of tests conducted in the Pahute Mesa. The elevated ^{85}Kr concentrations at Area 20 Camp is attributed to a phenomenon called "atmospheric pumping." Both ^{133}Xe and ^{85}Kr are produced during the fission of nuclear material. These noble gases, being chemically inert, are able to travel through the geologic overburden of an underground test. During passage of deep, low-pressure weather systems, the emanation rate of radioactive noble gases from the soil increases as does naturally-occurring ^{220}Rn and ^{222}Rn. Consequently, higher-yield nuclear tests conducted in Pahute Mesa are likely to result in enhanced noble gas levels measured at the surface.

Although the ^{85}Kr annual average concentration of 26 x 10^{-12} µCi/mL observed by EPA in its offsite network was greater than the onsite average of 23 x 10^{-12} µCi/mL, this slight variation is deemed to be within normal variations and cannot be ascribed to NTS emissions. Table 5.8 lists the average ^{85}Kr concentrations at each location along with the minimum and maximum values detected.

Xenon-133

For the large majority of samples collected during 1989, ^{133}Xe results were below the detection limit. Unlike all of the other data presented in this report, only the detection limits from analysis of ^{133}Xe samples were reported. This practice was discontinued late 1989, and during 1990 all data will be reported regardless of its relationship to the detection limit. Further discussions are presented in Volume II, Appendix E, "Onsite Radioactive Noble Gases in Air." All ^{85}Kr and ^{133}Xe results are listed in Table E.1 of this appendix.

Table 5.8 Airborne ^{85}Kr Concentrations - 1989

	x 10^{-12} µCi/mL		
Location	Minimum	Maximum	Average
Area 1, BJY	10.8	34.2	24.1
Area 1, Gravel Pit	13.4	31.7	22.4
Area 5, Gate 200	7.8	31.7	22.7
Area 12, Camp 16.3	33.9	22.9	
Area 15, EPA Farm	13.3	38.5	22.3
Area 20, Dispensary	17.3	39.0	26.8
Area 25, EMAD	9.3	35.5	22.1

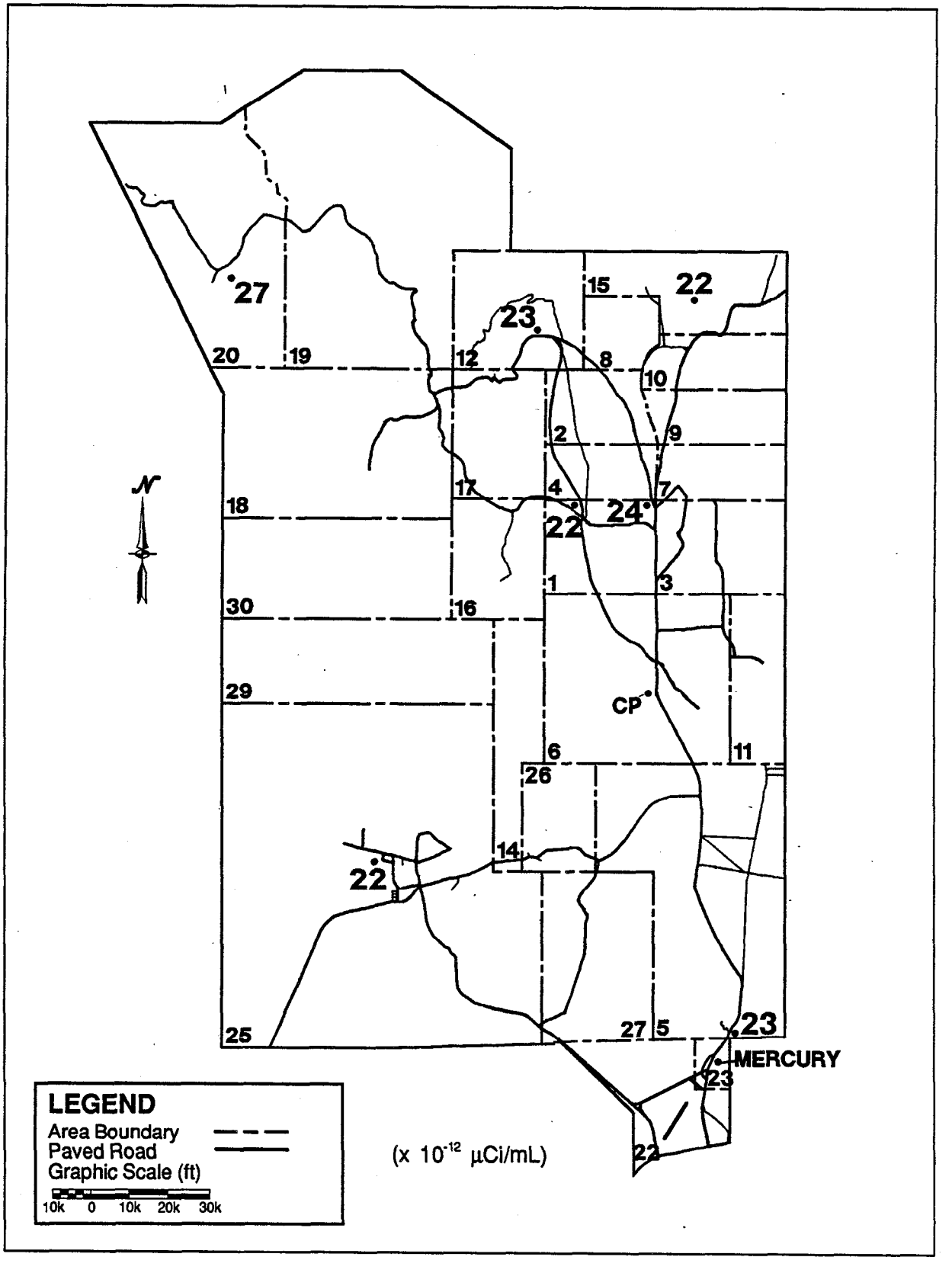


Figure 5.7 NTS ^{85}Kr Annual Average Concentrations - 1989

TRITIATED WATER VAPOR SAMPLING RESULTS

The annual average concentration of tritiated water vapor from sampling conducted at 17 permanent sampling locations was $8.5 \times 10^{-12} \pm 1.5 \times 10^{-11}$ µCi/mL. This concentration was 0.009 percent of the DCG. The individual averages of the stations are shown in Figure 5.8. None of the locations were statistically different at the five percent significance level from the network annual average. Each of these locations was sampled continuously for a two-week period. Table 5.9 lists the maximum, minimum, and annual average concentration for each tritiated water vapor sampling location. Volume II, Appendix B, "Onsite Tritium in Air," Table B.1, lists the measurement results for each location.

RADIOACTIVITY IN SURFACE WATER

Surface water sampling at the NTS was conducted at 13 open reservoirs, 7 natural springs, 9 containment ponds (previously referred to as contaminated ponds), and 3 sewage lagoons (previously referred to as effluent ponds). A grab sample was taken each month from each surface water location. The sample was analyzed for ^{3}H, gross beta, and gamma activity. Each quarter an additional sample was collected and submitted for ^{238}Pu and $^{239+240}Pu$ analysis. Gamma results for all sample locations did not identify any radionuclides consistently above the detection limit, with the exception of sample results from the containment ponds. The data from the containment ponds is shown in Volume II, Appendix C, "Onsite Radioactivity in Containment Ponds." Surface water at the NTS was scarce during 1989 because of the continuing drought. Sources of surface water were, for the most part, man-made, created for or by NTS operations.

Open reservoirs have been established at various locations on the NTS for industrial uses. There is no known human consumption of any surface water on the NTS. Comparisons of the annual averages

Table 5.9 Airborne Tritium Concentrations - 1989

	µCi/mL		
Location	Minimum	Maximum	Average
Area 1, BJY	7.2×10^{-14}	1.7×10^{-10}	1.5×10^{-11}
Area 5, RWMS Office	6.1×10^{-13}	5.6×10^{-11}	9.4×10^{-12}
Area 5, RWMS SE	2.2×10^{-13}	1.9×10^{-11}	7.3×10^{-12}
Area 5, RWMS East	1.1×10^{-12}	2.0×10^{-11}	1.1×10^{-11}
Area 5, RWMS NE	1.8×10^{-13}	2.1×10^{-11}	9.5×10^{-12}
Area 5, RWMS North	1.4×10^{-12}	2.9×10^{-11}	8.8×10^{-12}
Area 5, RWMS NW	2.7×10^{-13}	2.1×10^{-11}	5.5×10^{-12}
Area 5, RWMS West	1.3×10^{-12}	1.3×10^{-11}	5.1×10^{-12}
Area 5, RWMS SW	8.0×10^{-13}	8.0×10^{-11}	1.0×10^{-11}
Area 5, RWMS South	4.5×10^{-13}	2.5×10^{-11}	1.2×10^{-11}
Area 10, Gate 700s	1.1×10^{-14}	1.3×10^{-11}	3.2×10^{-12}
Area 12, Camp	8.6×10^{-14}	1.9×10^{-11}	5.9×10^{-12}
Area 15, EPA Farm	6.4×10^{-13}	8.2×10^{-11}	2.6×10^{-11}
Area 23, Building 790-2	1.7×10^{-14}	5.4×10^{-12}	2.4×10^{-12}
Area 23, Site Boundary	7.4×10^{-14}	3.7×10^{-12}	2.3×10^{-12}
Area 25, EMAD	-1.6×10^{-13}	1.6×10^{-11}	3.0×10^{-12}
Area 23, H & S Roof	2.5×10^{-13}	4.2×10^{-11}	5.7×10^{-12}
Network Statistics	-1.6×10^{-13}	1.7×10^{-10}	8.5×10^{-12}

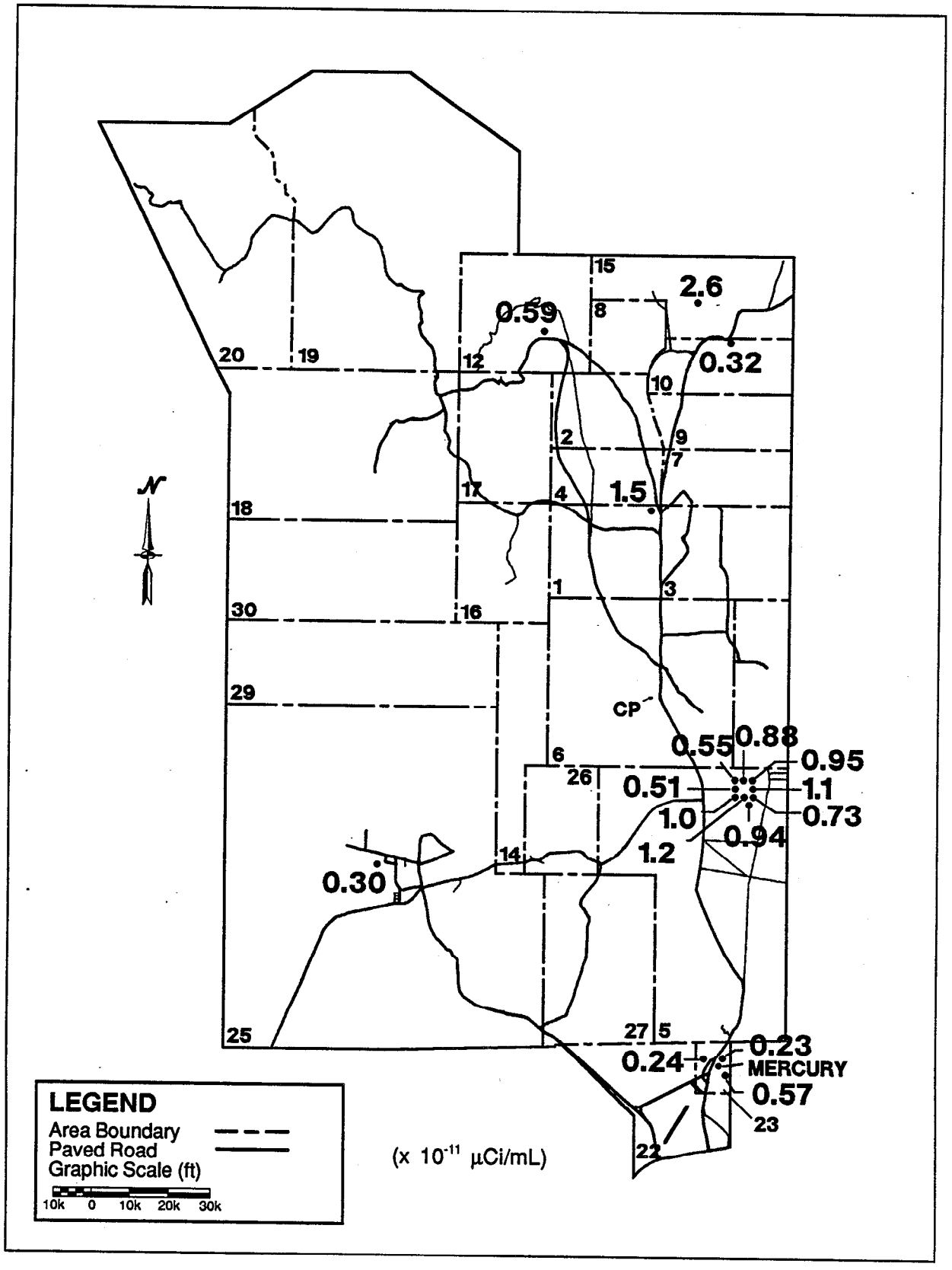


Figure 5.8 NTS Tritiated Water Vapor Annual Average Concentrations - 1989

were made to DCGs for ingested water listed in DOE Order 5400.5, even though there was no known consumption of these waters.

Natural springs are found onsite but are few in number. The term *natural springs* was a label given to the spring-supplied pools located within the NTS. Although there was no known human consumption from these springs, the measured concentrations were also compared to the DCGs for ingested water found in DOE Order 5400.5. Water from all of the springs was consumed by wild animals.

Nine contaminated water sources were sampled on a monthly basis. These ponds were impounded waters from tunnel test areas (including the effluent liquid as it is discharged from the tunnel) and a contaminated laundry release point. All containment ponds were fenced, restricted access areas posted with radiological warning signs.

Tritium, gross beta, and gamma analyses were performed for each monthly sample, and ^{238}Pu and $^{239+240}Pu$ analyses were performed quarterly.

The annual average for each isotope analyzed is presented and compared to the DCG for ingested water. The one exception is the containment ponds, which are not compared to ingested water permissible concentrations. All sampling results are presented in tabular form beginning with Appendix C, Table C.1. In each appendix, the result and corresponding one standard deviation (1s) counting error are presented. Any station which was determined to be statistically different is noted and discussed.

The individual sampling results and statistical analyses are listed in Appendix C, which contains all of the data for open reservoirs, natural springs, potable water, supply wells, containment ponds, and sewage lagoons. With the exception of containment ponds, no one annual average of any sampling location from this group was found to be statistically different from any other at the five percent significance level. Appendix C focuses on the data taken from containment ponds; Appendix D, "Onsite Radioactivity in Water other than Containment Ponds," discusses the data from sampling locations other than containment ponds. Analysis results from containment ponds showed measurable quantities of radioactivity and displayed identifiable trends. The following sections report minimum, maximum, and average data from gross beta analyses for all surface water sampling locations. Results from other analyses are presented in the appendices.

Open Reservoirs

Gross Beta

The location of each open reservoir sampled is shown in Figure 5.9 along with its annual average gross beta concentration level. The annual average beta concentration for all open reservoirs was 6.9×10^{-9} µCi/mL. This beta concentration is 0.69 percent of the ^{40}K DCG for ingested water. None of the reservoirs were found to be different from the annual average at the five percent significance level. Table 5.10, "Open Reservoir Gross Beta Analysis Results - 1989," includes a list of the 1989 annual averages for each monitored location. Appendix C, Table C.4, contains the individual data results. Statistical analyses from open reservoir sampling locations are presented in Appendix D.

Tritium

The annual average concentration of ^{3}H in open reservoirs during 1989 was 1.1×10^{-7} µCi/mL. This concentration was 0.006 percent of the DCG for ^{3}H. The majority of results were below the detection limit of the analytical equipment. No single sampling location displayed an annual average different at the five percent significance level from the network annual average for ^{3}H. The individual results are listed in Appendix C, Table C.5, and a statistical discussion is presented in Appendix D.

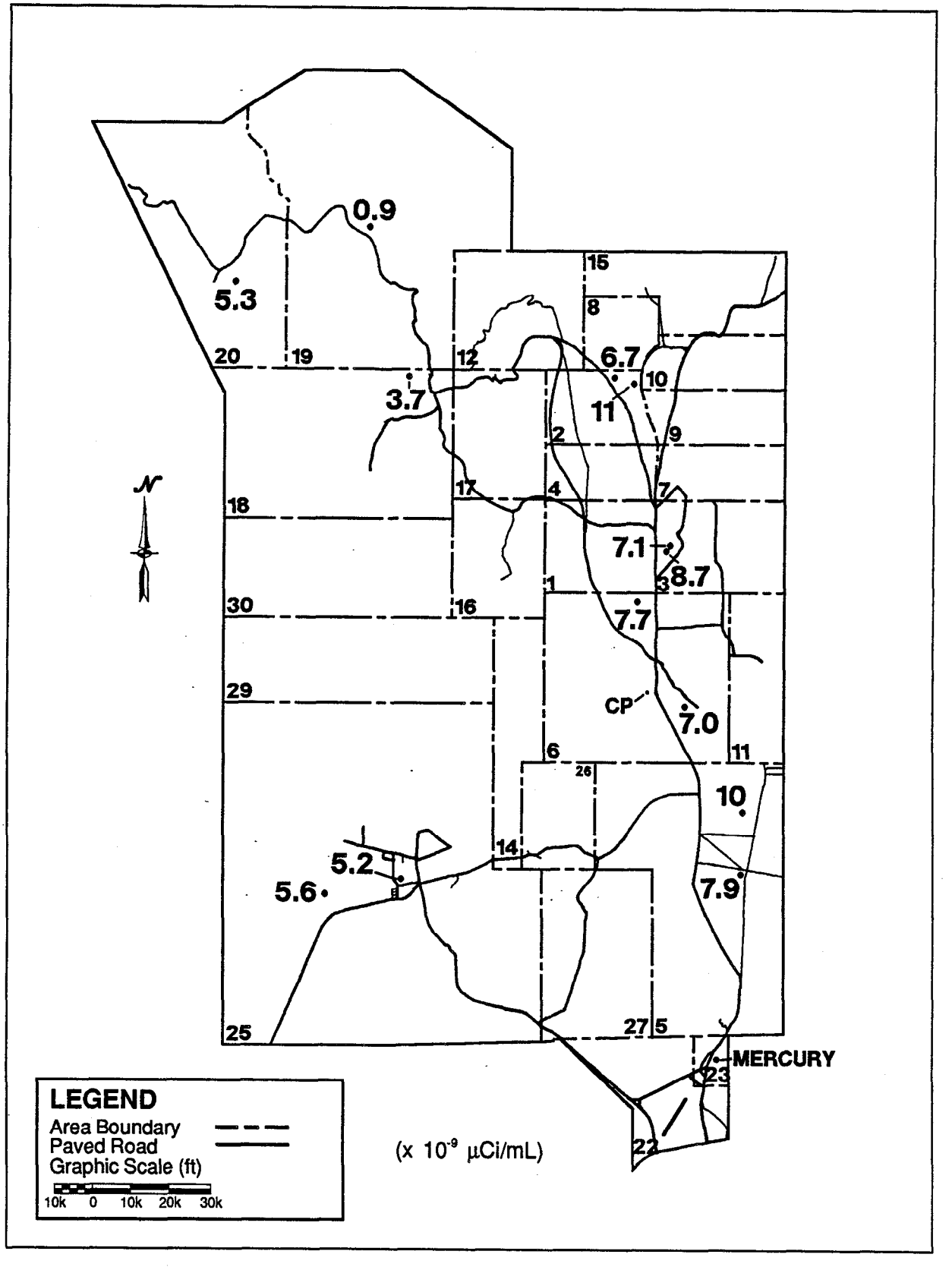


Figure 5.9 Open Reservoir Annual Average Gross Beta Concentrations - 1989

Table 5.10 Open Reservoir Gross Beta Analysis Results - 1989

Locations	µCi/mL Minimum	Maximum	Average
Area 2, Well 2 Reservoir	4.7×10^{-9}	9.5×10^{-9}	6.7×10^{-9}
Area 2, Mud Plant Reservoir	2.7×10^{-9}	6.2×10^{-8}	1.1×10^{-8}
Area 3, Well A Reservoir	3.5×10^{-9}	1.1×10^{-8}	7.1×10^{-9}
Area 3, Mud Plant Reservoir	5.7×10^{-9}	1.0×10^{-8}	8.7×10^{-9}
Area 5, Well 5B Reservoir	6.0×10^{-9}	1.1×10^{-8}	7.9×10^{-9}
Area 5, Ue5c Reservoir	6.9×10^{-9}	1.7×10^{-8}	1.0×10^{-8}
Area 6, Well 3 Reservoir	5.1×10^{-9}	1.1×10^{-8}	7.7×10^{-9}
Area 6, Well C1 Reservoir	5.0×10^{-9}	9.6×10^{-9}	7.0×10^{-9}
Area 18, Camp 17 Reservoir	2.6×10^{-9}	4.5×10^{-9}	3.7×10^{-9}
Area 19, Well U19c Reservoir	-4.4×10^{-11}	1.6×10^{-9}	9.0×10^{-10}
Area 20, Well 20a Reservoir	5.6×10^{-10}	1.9×10^{-8}	5.3×10^{-9}
Area 25, Well J12 Reservoir	1.7×10^{-9}	8.2×10^{-9}	5.6×10^{-9}
Area 25, Well J11 Reservoir	3.8×10^{-9}	7.3×10^{-9}	5.2×10^{-9}

Plutonium

The annual average concentration of $^{239+240}Pu$ for all open reservoirs was 3.0×10^{-11} µCi/mL. This annual average was 0.1 percent of the DCG for ingested water. None of the annual averages from any sampling location was different from the network average at the five percent significance level. All individual sampling results are tabulated in Appendix C, Table C.2.

The network annual average for ^{238}Pu was -2.4×10^{-10} µCi/mL. This concentration may be stated to be less than zero percent of the DCG for ^{238}Pu. When an analytical process is unable to detect the presence of activity in a sample above the background activity, the sample result given will be a negative number. This process is statistically probable when the activity of the radionuclide in the sample is less than the detection capability of the counting equipment. The annual average for several sample results can therefore be positive or negative.

None of the open reservoir sampling locations displayed an annual average below the detection limit. None of the sampling stations was statistically different from the network average at the five percent significance level. All individual results are presented in Appendix C, Table C.1. Appendix D presents statistical analyses results.

Natural Springs

Gross Beta

The locations of all natural springs sampled are shown in Figure 5.10 along with the annual average gross beta results. The annual average gross beta concentration for all samples collected from natural springs was 9.9×10^{-9} µCi/mL, which represents 0.14 percent of the ^{40}K DCG. None of the gross beta annual averages from natural springs were determined to be statistically different from the network average at the five percent significance level.

Table 5.11 presents a list of the gross beta averages at each natural spring sampling location. Appendix C, Table C.4, displays the individual sampling results. Statistical analyses are presented in Appendix D.

Tritium

The network annual average ^{3}H from samples taken at seven natural springs was

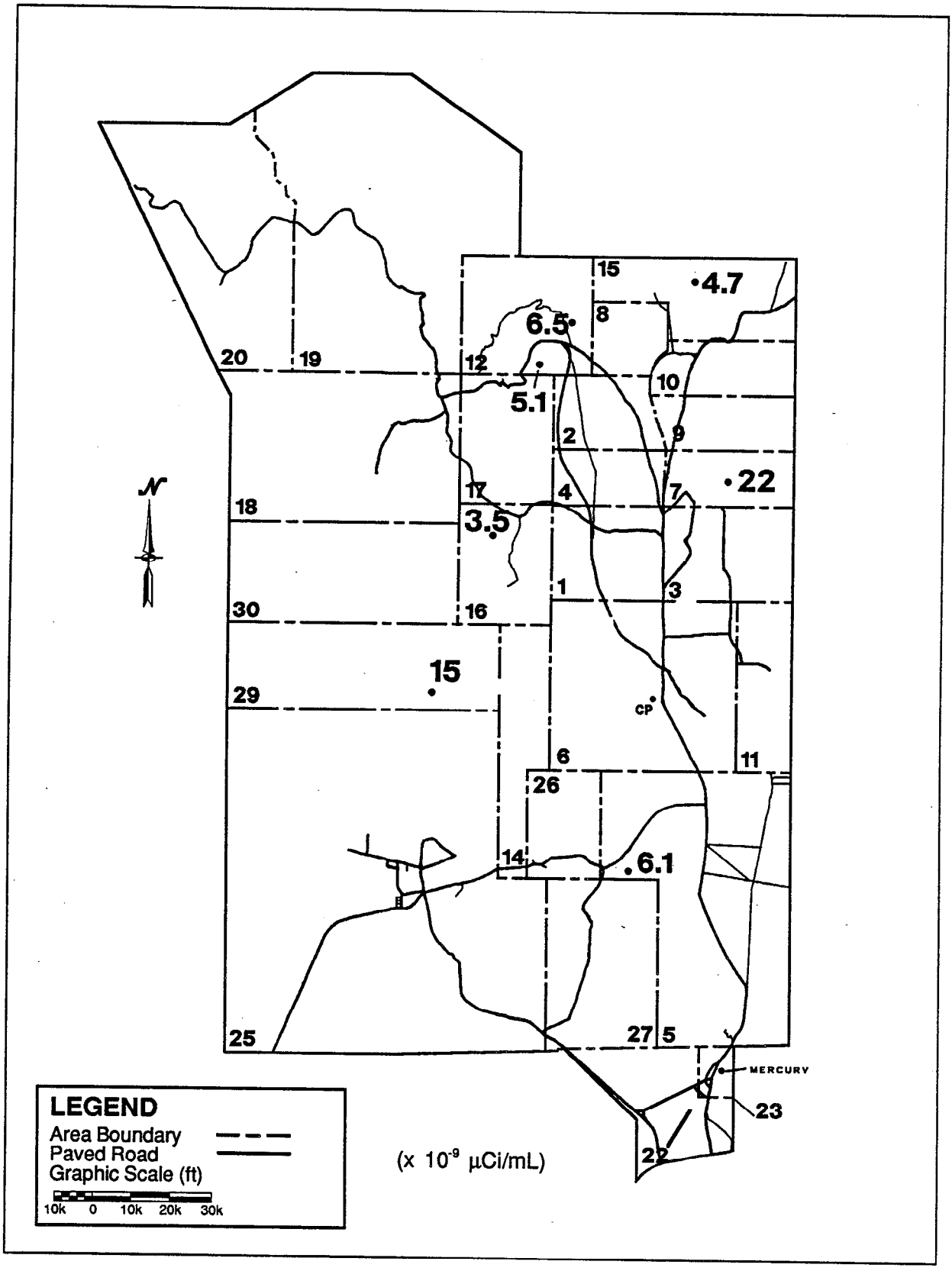


Figure 5.10 Natural Spring Annual Average Gross Beta Concentrations - 1989

Table 5.11 Natural Spring Gross Beta Analysis Results - 1989

Location	μCi/mL Minimum	Maximum	Average
Area 5, Cane Spring	2.1×10^{-9}	8.6×10^{-9}	6.1×10^{-9}
Area 7, Reitmann Seep	6.8×10^{-9}	4.2×10^{-8}	2.2×10^{-8}
Area 12, Captain Jack Spring	2.1×10^{-9}	7.1×10^{-9}	5.1×10^{-9}
Area 12, White Rock Spring	4.2×10^{-9}	1.3×10^{-8}	6.5×10^{-9}
Area 15, Tub Spring	3.6×10^{-9}	5.4×10^{-9}	4.7×10^{-9}
Area 16, Tippipah Spring	1.8×10^{-9}	6.8×10^{-9}	3.5×10^{-9}
Area 29, Topopah Spring	-8.3×10^{-9}	7.5×10^{-8}	1.5×10^{-8}

1.2×10^{-7} μCi/mL, which equaled 0.6 percent of the DCG for ^{3}H in drinking water.

As with the ^{3}H results from open reservoirs, most of the sampling results from natural springs were not significantly different from the network average at the five percent significance level. The individual results are listed in Appendix C, Table C.5. Appendix D contains the results of statistical analysis.

Containment Ponds

Radiologically-contaminated liquid was sampled at the NTS at three tunnel complexes, one decontamination facility, and one research well. The average gross beta concentration for each containment pond location is shown in Figure 5.11. At each tunnel complex, sampling was conducted at all active containment ponds and at the effluent discharge point. The Area 6 Decontamination Facility containment pond was grab sampled once per month. All samples taken from these sources were analyzed for ^{3}H, ^{238}Pu, $^{239+240}Pu$, gross beta, and gamma activity. The annual average of gross beta analyses from each sampling location is listed in Table 5.12, "Containment Pond Gross Beta Analysis Results - 1989." All data and statistical analyses are listed in Appendix C, Tables C.1 through C.5.

T Tunnel

The annual average ^{3}H concentration in samples taken from two sequential containment ponds at the Area 12 T Tunnel

Table 5.12 Containment Pond Gross Beta Analysis Results - 1989

Location	μCi/mL Minimum	Maximum	Average
Area 6, Decontamination Facility Pond	1.2×10^{-7}	2.7×10^{-7}	2.0×10^{-7}
Area 12, E Tunnel Effluent	7.3×10^{-8}	4.3×10^{-6}	7.3×10^{-7}
Area 12, N Tunnel Pond No. 1	7.2×10^{-9}	1.3×10^{-7}	5.3×10^{-8}
Area 12, N Tunnel Pond No. 2	2.2×10^{-8}	1.7×10^{-7}	5.6×10^{-8}
Area 12, N Tunnel Pond No. 3	4.2×10^{-9}	7.6×10^{-7}	1.2×10^{-7}
Area 12, N Tunnel Effluent	1.8×10^{-8}	1.3×10^{-7}	4.3×10^{-8}
Area 12, T Tunnel Pond No. 1	3.0×10^{-7}	1.5×10^{-5}	6.0×10^{-6}
Area 12, T Tunnel Pond No. 2	4.0×10^{-7}	1.6×10^{-5}	6.5×10^{-6}
Area 12, T Tunnel Effluent	1.5×10^{-7}	1.5×10^{-5}	6.3×10^{-6}

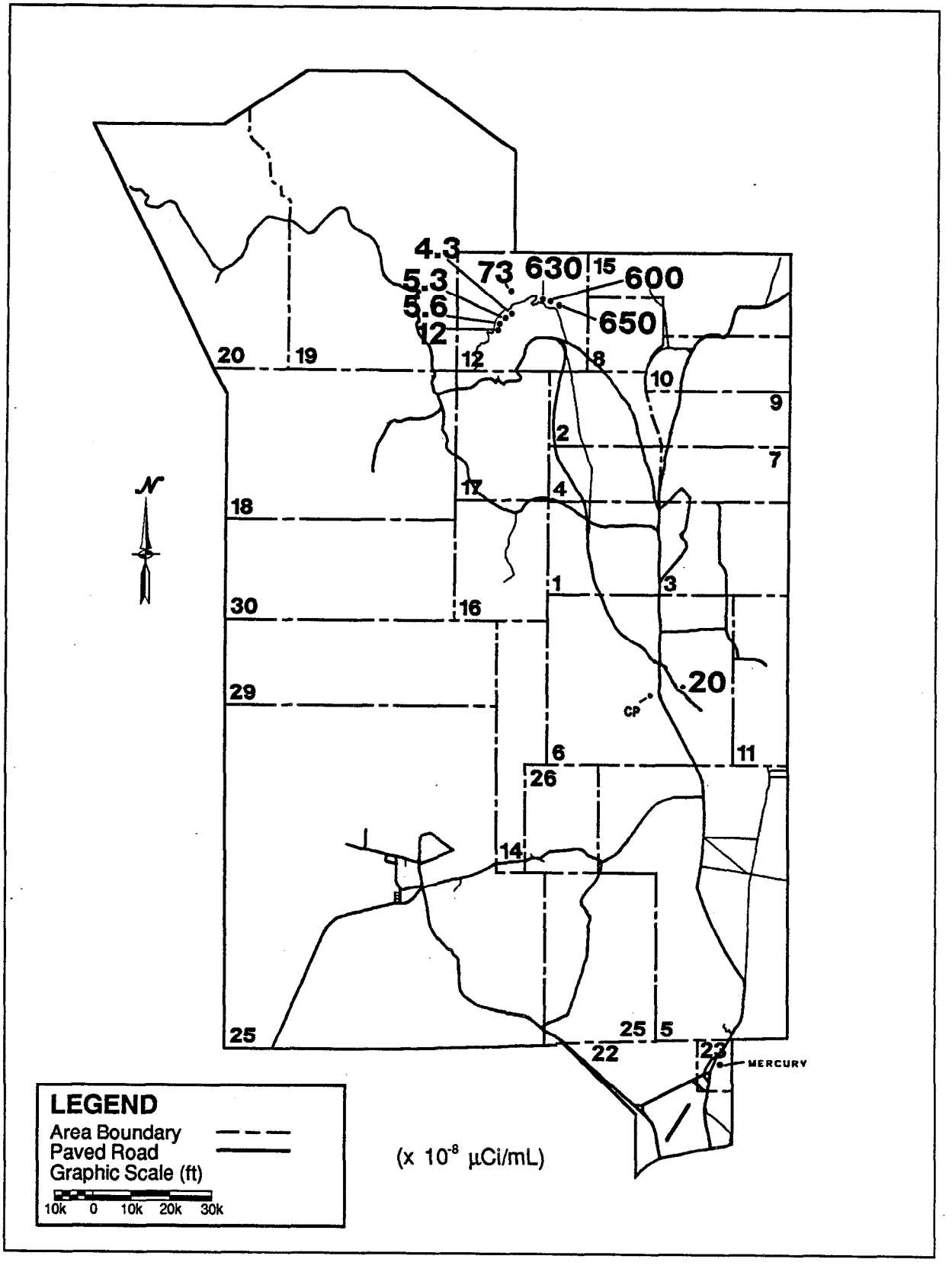


Figure 5.11 Containment Pond Annual Average Gross Beta Concentrations - 1989

complex was 4.9 x 10^{-2} µCi/mL. Gross beta activity from samples taken at the same locations averaged 6.3 x 10^{-6} µCi/mL during 1989, while annual concentrations of ^{238}Pu and $^{239+240}$Pu averaged 8.1 x 10^{-9} and 2.8 x 10^{-10} µCi/mL, respectively.

N Tunnel

The ^{3}H and gross beta annual average concentrations from samples taken from three containment ponds at the Area 12 N Tunnel complex were 5.1 x 10^{-4} and 6.7 x 10^{-8} µCi/mL, respectively. Concentrations of $^{239+240}$Pu and ^{238}Pu averaged 3.7 x 10^{-11} and 1.0 x 10^{-11} µCi/mL, respectively, during 1989.

E Tunnel

Because very little water discharged from the Area 12 E Tunnel complex, there was not enough water in the containment ponds to sample during 1989. Therefore, sampling was conducted at the tunnel effluent discharge to the pond. The ^{3}H annual average concentration from samples taken of the Area 12 E Tunnel effluent was 1.6 x 10^{-3} µCi/mL. The annual average beta activity from samples taken at this site was 7.3 x 10^{-7} µCi/mL. Concentrations of $^{239+240}$Pu and ^{238}Pu averaged 2.1 x 10^{-8} and 2.6 x 10^{-9} µCi/mL, respectively.

Area 6 Decontamination Facility Pond

During the decontamination of equipment at the Area 6 Decontamination Facility, the water used may become contaminated with various radionuclides. The water used during 1989 for decontamination was discharged into a nearby fenced and posted containment pond. A grab sample was taken and analyzed once per month. The annual average concentration of ^{3}H from these grab samples was 1.8 x 10^{-6} µCi/mL, while beta activity averaged 2.0 x 10^{-7} µCi/mL during 1989. Annual averages of ^{238}Pu and $^{239+240}$Pu from samples taken at this pond were 1.2 x 10^{-10} and 5.2 x 10^{-12} µCi/mL, respectively.

Radionuclide Migration Study Pond

At the Area 5 U5eRNM2S migration research well, a monthly grab sample was taken and analyzed for ^{3}H. The U5eRNM2S well was part of a radionuclide migration through groundwater study, which is discussed in Section 5.1.2 under "Radionuclide Migration Project."

Sewage Lagoons

Samples from three sewage lagoons were collected during 1989. These lagoons are part of a closed system used for evaporative treatment of sanitary waste. They are located in Areas 6, 12, and 23. There was no known contact by the working population.

The ^{3}H annual average of four quarterly samples taken at the lagoons was 1.4 x 10^{-7} µCi/mL. The annual average gross beta concentration was 2.3 x 10^{-8} µCi/mL. Annual averages of $^{239+240}$Pu and ^{238}Pu were 4.7 x 10^{-12} and 1.2 x 10^{-11} µCi/mL, respectively. No station was determined to be statistically different at the five percent significance level from the overall annual sewage lagoon average for any analyses result. All sampling results for sewage lagoons are presented in Appendix C, Tables C.1 through C.5. Statistical discussions of this data are provided in Appendix D.

RADIOACTIVITY IN GROUNDWATER

The principal water distribution system on the NTS is the potential critical pathway for the ingestion of waterborne radionuclides. Consequently, the water distribution system is sampled and evaluated frequently. The NTS water system consists of 14 supply wells, 9 of which supply potable water to onsite distribution systems. The drinking water is pumped from the wells to the points of consumption. The supply wells are sampled on a monthly basis. All drinking water is sampled weekly to provide a constant check of the end-use activity and to allow frequent comparisons to the radioactivity of the water in the supply wells. This section examines results from samples taken at the 14 supply wells, which furnished the water for consumption and industrial use at the NTS during 1989. Well C in Area 6 was shut down during the period February 6 through July 19, 1989,

and again from October 31, 1989, through January 31, 1990. All other wells functioned continuously during 1989.

Each monthly sample was analyzed for ^{3}H, gross beta, and gamma activity. An extra sample was taken each quarter and analyzed for ^{238}Pu, $^{239+240}Pu$, and gross alpha activity. Annual average results are presented for each analyses conducted on groundwater samples. (Statistical comparisons of the tritium data in this table and the EPA data in Table 5.24 are not considered valid or meaningful, as the laboratory analytical procedures used for the two data groups are different and produce different Miniumum Detectable Concentration levels.)

Supply Wells

Water from fourteen supply wells (shown in Figure 5.12) was used for a variety of purposes during 1989. Samples were collected from those wells which could potentially provide water for onsite human consumption. These data assisted in documenting the radiological characteristics of the NTS groundwater system. The sample results were maintained in a data base so that long-term trends and changes could be studied. Table 5.13, "Water Supply Well Averages - 1989," lists the supply wells and their respective sampling stations. Individual sampling results are presented in Appendix C, Tables C.1 through C.5, while Appendix D contains statistical discussions.

Gross Beta

The network average gross beta activity for supply wells was 6.9×10^{-9} µCi/mL, which was 0.10 percent of the DCG for ^{40}K and 0.69 percent of the DCG for ^{90}Sr. In previous reports (Scoggins 1983 and Scoggins 1984), it was shown that the majority of gross beta activity was attributable to naturally-occurring ^{40}K. The gross beta annual averages are shown at their respective supply well sampling locations in Figure 5.12.

Tritium

There were no supply well stations which displayed annual average concentrations different at the five percent significance

Table 5.13 Water Supply Well Averages - 1989

	µCi/mL			
Description	Beta	^{3}H	$^{239+240}Pu$	^{238}Pu
Area 2, Well 2	6.2×10^{-9}	1.4×10^{-7}	1.9×10^{-12}	6.6×10^{-12}
Area 5, Well 5C[a]	7.4×10^{-9}	9.0×10^{-8}	-7.3×10^{-14}	4.8×10^{-12}
Area 5, Well Ue5d	7.1×10^{-9}	2.1×10^{-8}	-3.8×10^{-12}	-2.2×10^{-11}
Area 6, Well C[a]	1.4×10^{-8}	2.0×10^{-7}	1.0×10^{-12}	-4.1×10^{-11}
Area 6, Well C1[a]	1.5×10^{-8}	6.7×10^{-8}	-3.0×10^{-12}	-1.1×10^{-11}
Area 15, Well Ue15d	1.7×10^{-8}	1.4×10^{-7}	2.9×10^{-12}	2.0×10^{-12}
Area 18, Well 8[a]	3.1×10^{-9}	1.8×10^{-7}	1.6×10^{-12}	7.3×10^{-12}
Area 22, Army Well #1[a]	5.4×10^{-9}	8.6×10^{-8}	-4.8×10^{-12}	-1.5×10^{-11}
Area 25, Well J-12[a]	4.4×10^{-9}	1.1×10^{-7}	4.5×10^{-12}	5.2×10^{-13}
Area 25, Well J-13[a]	4.2×10^{-9}	1.2×10^{-7}	-2.6×10^{-13}	-2.6×10^{-11}
Area 19, Well U19c	8.8×10^{-10}	6.2×10^{-8}	3.8×10^{-12}	-9.6×10^{-12}
Area 6, Well 4[a]	5.7×10^{-9}	1.1×10^{-7}	2.9×10^{-12}	1.6×10^{-11}
Area 16, Well 16d[a]	7.2×10^{-9}	1.1×10^{-7}	7.1×10^{-13}	1.6×10^{-11}
Area 20, Water Well	2.2×10^{-9}	5.9×10^{-8}	-5.4×10^{-12}	-1.3×10^{-11}

(a) Drinking water sources for onsite distribution systems.

level from the network annual average ^{3}H concentration of 1.1 x 10^{-7} µCi/mL. This annual average was 0.6 percent of the drinking water regulations for ^{3}H.

Plutonium

The annual average network $^{239+240}Pu$ concentration of 2.3 x 10^{-13} µCi/mL was 0.001 percent of the DCG for this radionuclide. The annual average ^{238}Pu concentration of -2.9 x 10^{-12} µCi/mL was less than zero percent of the DCG.

RADIOACTIVITY IN DRINKING WATER

As a check of any effect the water distribution system might have on end-use activity, ten consumption points were sampled during the reporting period. In order to be certain that all of the water available for consumption was being considered, each drinking water system had in previous years been identified and sampled. The NTS contained a total of five drinking water systems, each fed by a series of supply wells during most of 1989. The five systems were as seen in Table 5.14, "NTS Drinking Water Sources."

Table 5.14 NTS Drinking Water Sources

Supply Well	End-point
Well C, C1, 4	Area 3, Cafeteria
	Area 27, Cafeteria
	Area 6, Cafeteria
Well 8	Area 2, Cafeteria
	Area 12, Cafeteria
Well 16D	Area 1, Building 101
Well 5C, Army Well #1 (Mercury)	Area 23, Cafeteria
Well J-12, J-13	Area 25, Service Station
	Area 25, Building 4221

The potable water supply Well A in Area 3 was shut down in October 1988. The water now consumed in Area 3 is transported from the Area 6 supply well system. Table 5.15, "Radioactivity in NTS Drinking Water - 1989," displays results from sampling conducted at the potable water stations. This table lists annual averages from all analyses results for each station during 1989. Appendix C contains the individual sampling results, and Appendix D presents statistical evaluations.

Gross Beta

The annual average recorded from sampling conducted at ten potable water locations was 5.8 x 10^{-9} µCi/mL. This annual average was two percent of the EPA-equivalent DCG (this is a DCG concentration which gives 4 mrem committed effective dose equivalent in one year) for ^{40}K. The DCGs given in DOE Order 5400.5, "Radiation Protection of the Public and the Environment," were based on a committed effective dose equivalent of 100 mrem for the radionuclide taken into the body by ingestion during one year. The EPA Maximum Contaminant Levels (MCLs) are based on similar assumptions but with a more restrictive committed effective dose equivalent of 4 mrem when ingested during one year. Therefore, to calculate an EPA-equivalent DCG, the 100 mrem DCG is multiplied by 0.04. It is unduly conservative to assume that the beta activity in the drinking water originates from ^{90}Sr since, as was previously stated, most of the beta activity in the drinking water has been attributed to ^{40}K. Results of ^{90}Sr in drinking water have, for several years, reaffirmed this evaluation.

The annual average gross beta concentration from samples taken from Area 6 bottled water was determined to be statistically different from the network average. The annual average beta activity from samples taken from this bottled water was 8.6 x 10^{-11} µCi/mL, well below the averages of the remainder of the network. The locations of all potable water stations are shown in Figure 5.13, with their gross beta yearly averages.

Tritium

The annual average ^{3}H concentration in samples taken at ten potable water locations was 4.5 x 10^{-8} µCi/mL. This concentration was 0.002 of the DOE Order 5400.5 DCG value and 0.22 percent of the

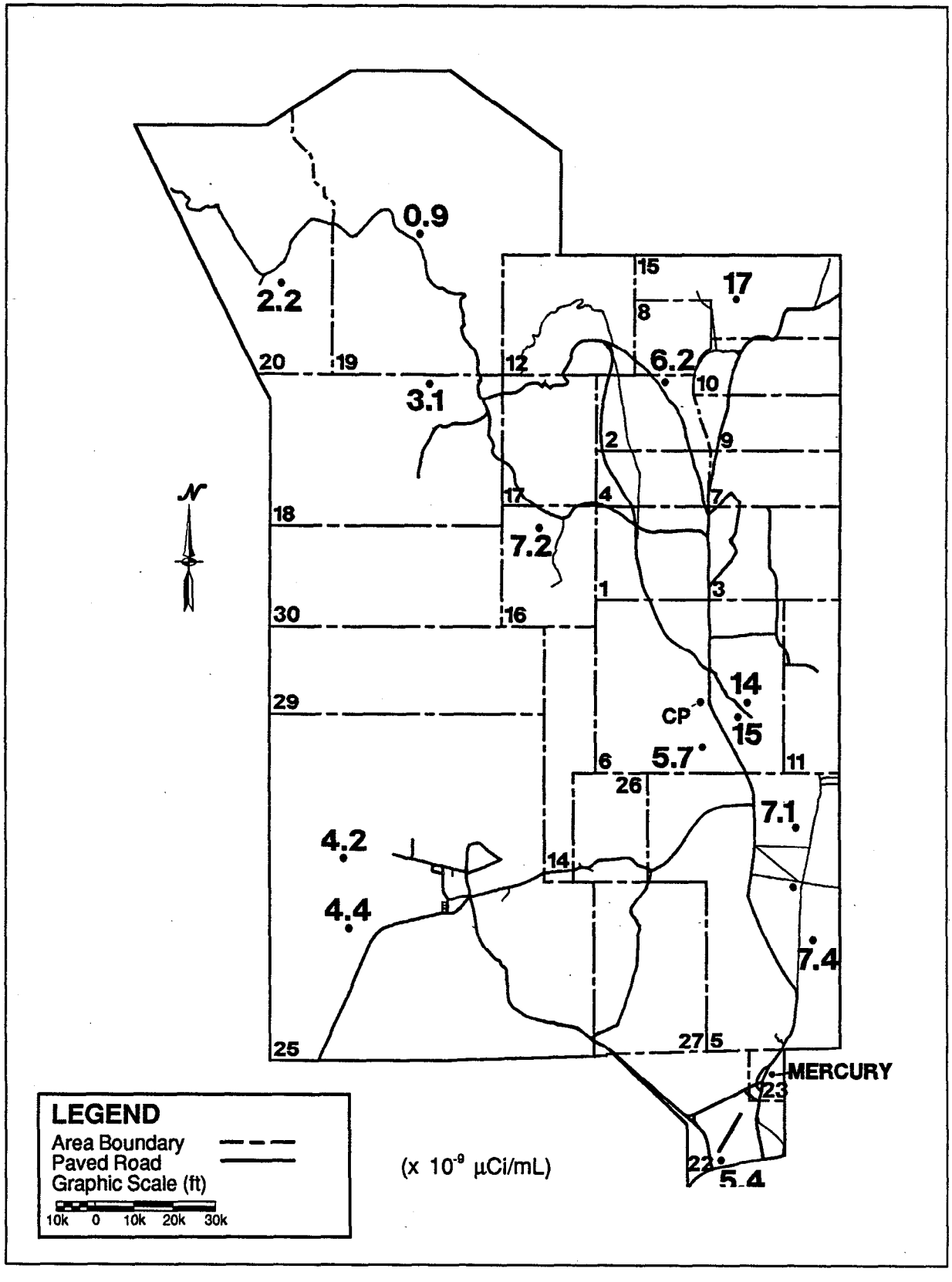


Figure 5.12 Supply Well Annual Average Gross Beta Concentrations - 1989

Table 5.15 Radioactivity in NTS Drinking Water - 1989

Description	μCi/mL Gross Beta	^{3}H	^{239}Pu	^{238}Pu	Gross Alpha
Area 3, Cafeteria	9.7×10^{-9}	4.9×10^{-8}	-2.3×10^{-12}	4.0×10^{-12}	1.2×10^{-8}
Area 2, Rest Room	3.2×10^{-9}	1.7×10^{-8}	-2.4×10^{-12}	1.2×10^{-11}	3.1×10^{-10}
Area 12, Cafeteria	2.9×10^{-9}	4.2×10^{-8}	-8.7×10^{-13}	-4.7×10^{-11}	6.0×10^{-10}
Area 23, Cafeteria	3.1×10^{-9}	7.5×10^{-8}	3.2×10^{-12}	-9.2×10^{-12}	4.9×10^{-9}
Area 27, Cafeteria	8.3×10^{-9}	6.5×10^{-8}	9.7×10^{-12}	-1.4×10^{-11}	5.7×10^{-9}
Bottled Water	8.6×10^{-11}	4.9×10^{-8}	3.5×10^{-12}	-1.3×10^{-11}	1.7×10^{-10}
Area 6, Cafeteria	9.5×10^{-9}	5.2×10^{-8}	2.9×10^{-12}	1.8×10^{-12}	8.7×10^{-9}
Area 25, Service Station	4.4×10^{-9}	2.4×10^{-8}	1.6×10^{-11}	1.1×10^{-11}	1.3×10^{-9}
Area 1, Building 101	5.9×10^{-9}	2.9×10^{-8}	-3.8×10^{-12}	2.3×10^{-12}	1.1×10^{-8}
Area 25, Building 4221	4.1×10^{-9}	2.8×10^{-8}	-4.7×10^{-12}	4.0×10^{-11}	5.7×10^{-10}

MCL for ^{3}H in drinking water. None of the annual averages from samples collected at the potable water stations were statistically different from the network average.

Plutonium

The annual averages of $^{239+240}Pu$ and ^{238}Pu from quarterly samples taken at ten potable water sampling locations were 9.8×10^{-13} and -3.0×10^{-12} μCi/mL, respectively. These averages, composed of results which were below the detection limits, were 0.003 and less than zero percent of the DCGs for $^{239+240}Pu$ and ^{238}Pu, respectively. None of the annual averages from individual locations were statistically different from the network averages.

Gross Alpha

In accordance with the National Primary Drinking Water Regulation, gross alpha measurements were conducted on the drinking water systems. The annual average and gross alpha results from sampling conducted quarterly at each location were presented in Table 5.15. Results from samples taken from four potable locations during 1989 averaged over 5×10^{-9} μCi/mL (5 pCi/L), which was the screening level for ^{226}Ra analysis. Water from the wells supplying the water to the locations which averaged over 5×10^{-9} μCi/mL was collected and analyzed for ^{226}Ra. The results are presented in Table 5.16, "Radium-226 Analysis Results for NTS Drinking Water - 1989." None of the ^{226}Ra results was above 3×10^{-9} μCi/mL; thus, onsite drinking water was in compliance with drinking water regulations.

EXTERNAL GAMMA EXPOSURES

Onsite Area

TLDs were deployed at 150 locations throughout the NTS to measure ambient gamma radiation levels. These dosimeters

Table 5.16 Radium-226 Analysis Results for NTS Drinking Water - 1989

Supply Well Consumption Point	Supply Well ^{226}Ra Results ($\times 10^{-9}$ μCi/mL ± 1s)
Area 3 Well A	< 0.1
Area 6 Well 4	< 0.1
Area 6 Well C	0.7 ± 0.05
Area 6 Well C1	0.5 ± 0.05
Area 16 Well 16D	1.1 ± 0.05

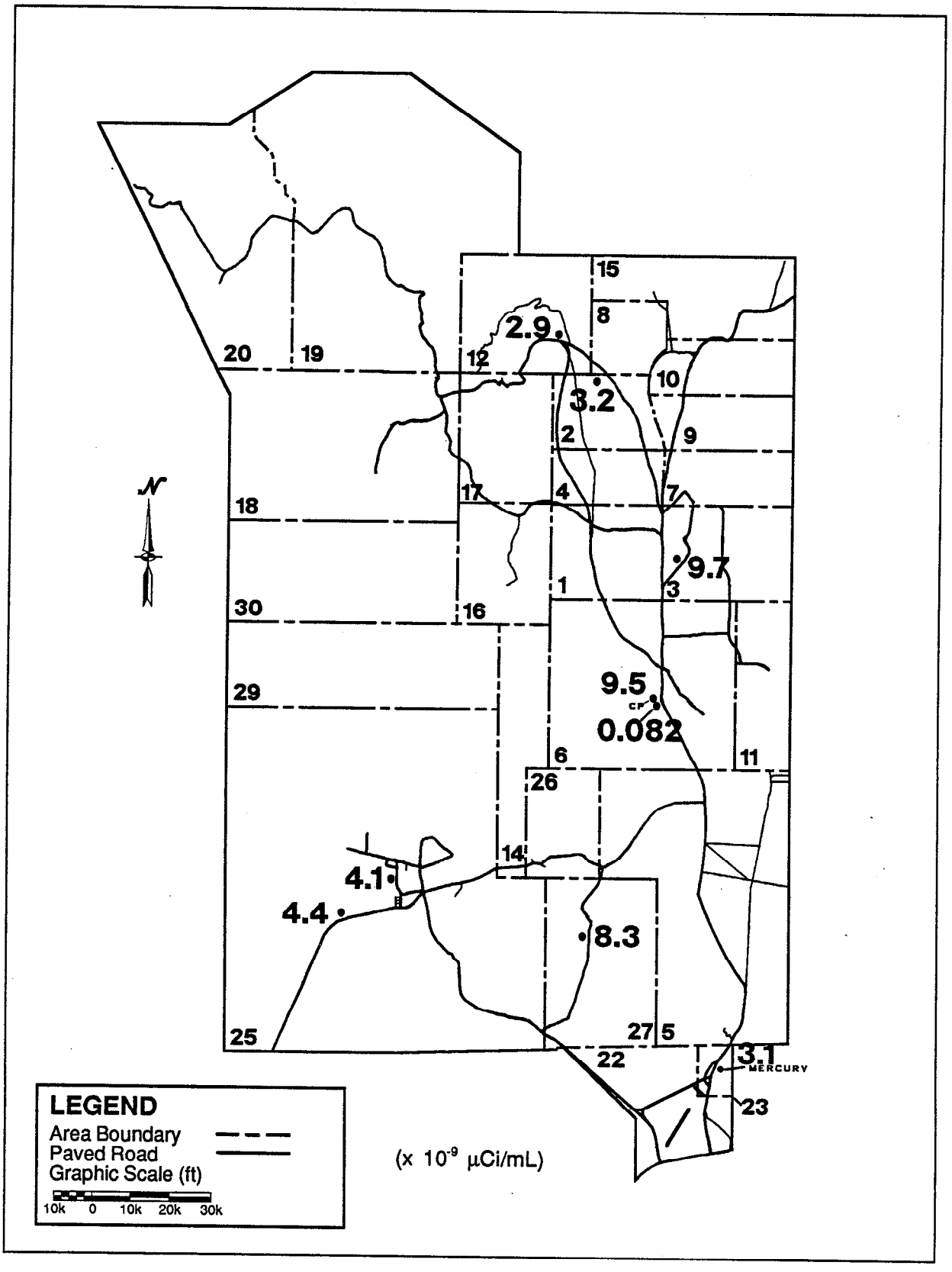


Figure 5.13 Potable Water Gross Beta Annual Averages - 1989

were manufactured by Panasonic and designed to measure the typical gamma conditions present in the environment. The TLDs were deployed on the NTS at locations with radiological conditions ranging from background levels to areas with known contamination. This report presents the data results from TLDs deployed during the second, third, and fourth quarter of 1989. The first quarter 1989 results have been reported in last year's onsite report (Gonzalez 1989) because of an overlap of 1988 TLD deployment into the first quarter of 1989.

The average gamma exposures recorded during 1989 were statistically not different from the averaged data collected in 1988. TLDs measured gamma exposures which ranged from 64 mR/year at Area 23, Building 650 Roof, to 1581 mR/year at Area 2, Stake 2N-8. The latter location has consistently been the site with the maximum exposure for several years.

A plot of the data shows that the TLD results were normally distributed about a mean of 148 mR/year when obvious outliers were not included. These data may be described to be the NTS gamma exposure rates which were not influenced by radiological areas. The second group of data range from 300 to 1581 mR/year. The TLDs collecting these data were deployed at locations with known contamination from, for example, weapons tests or radioactive material storage. Statistical analyses of the data are presented in Appendix F; Table F.1 lists a summary of the individual TLD data results.

Table 5.17 displays the results of gamma monitoring conducted at the NTS boundary. These locations were close to the physical boundary of the NTS and were reachable only via helicopter. The data collected at these locations were statistically not different from the data collected from the control locations.

A group of locations which were not, to the best of knowledge, influenced by radiological contamination, served as controls for the NTS. The data from these locations are presented in Table 5.18, "TLD Control Location Comparison." The overall network range of the control locations for 1989 was 0.18 to 0.38 mR/day. The average gamma exposure rate from the control locations was 0.29 mR/day or 106 mR/year.

Table 5.17 NTS Boundary Gamma Monitoring Result Summary - March 1989 to March 1990

Area	UTM Coordinate Location	2d Quarter (mR/day)	3d Quarter (mR/day)	4th Quarter (mR/day)	Average (mR/day)	1988 Annual Exposure (mR/yr)	1989 Annual Exposure (mR/yr)
3	N844,200 E704,900	0.23	0.33	0.17	0.24	84	88
5	N710,800 E720,000	0.21	0.30	0.15	0.22	82	80
9	N874,600 E691,500	0.23	0.34	0.18	0.25	93	91
11	N788,800 E709,500	0.40	0.65	0.35	0.47	175	172
12	N903,800 E635,500	0.34	0.52	0.24	0.37	135	135
15	N907,600 E686,200	0.45	0.68	0.35	0.49	178	179
18	N849,500 E545,000	0.45	0.68	0.35	0.49	184	179
19	N935,500 E639,750	0.43	0.69	-	0.56	252	204
19	N955,500 E614,200	0.45	0.70	-	0.58	181	212
20	N887,000 E558,000	0.52	0.79	0.41	0.57	201	208
20	N944,700 E563,300	0.25	0.42	0.21	0.29	193	106
20	N948,800 E527,800	0.41	0.72	-	0.57	60	208
22	N670,600 E667,300	0.20	0.29	0.15	0.21	84	77
25	N731,300 E638,700	0.31	-	0.23	0.27	117	99
25	N754,400 E557,800	0.41	0.63	0.32	0.45	146	164

Table 5.18 TLD Control Station Comparison

	Exposure Rate (mR/day)						
Station	1983	1984	1985	1986	1987	1988	1989
Bldg. 650 Dosimetry	0.21	0.15	0.13	0.31	0.14	0.26	0.19
Bldg. 650 Roof	0.18	0.14	0.12	0.13	0.17	0.24	0.18
Area 27 Cafeteria	0.39	0.32	0.29	0.27	0.38	0.49	0.32
CP-6	0.25	0.18	0.17	0.13	0.21	0.36	0.27
HENRE Site	0.36	0.30	0.28	0.27	0.34	0.47	0.38
NRDS Warehouse	0.36	0.32	0.28	0.28	0.39	0.46	0.38
Post Office	0.18	0.14	0.13	0.16	0.24	0.29	0.23
Well 5B	0.33	0.27	0.26	0.22	0.32	0.43	0.36
Yucca Oil Storage	0.28	0.23	0.21	0.22	0.30	0.29	0.32
Network Average	0.28	0.23	0.21	0.22	0.28	0.37	0.29

SPECIAL ENVIRONMENTAL STUDIES

The BECAMP conducts special environmental studies on the NTS that include (1) investigating the movement of radionuclides on and around the NTS through horizontal movement, water-driven erosion, vertical migration, and wind-driven erosional resuspension; (2) development of a human dose-assessment model specific to the environmental and radiological conditions of the NTS; (3) preparation of a peer-reviewed publication which addresses an important issue related to the potential environmental impacts of past, present, and future activities on the NTS; and (4) monitoring of the flora and fauna on the NTS to assess changes over time in the ecological condition of the NTS. The results of 1989 BECAMP investigations are summarized in the following sections.

Movement of Radionuclides On and Around the NTS

Investigations into the movement of radionuclides on and around the NTS were concentrated on the development of *in situ* field monitoring techniques, where it was found that the natural soil variability exerts a great influence on the precision of *in situ* germanium gamma-spectrometer (Ge-detector) system measurements of soil radionuclide concentrations. By using normalized soil plutonium-concentration data in many profiles from five widely separated sites at the NTS, variances in α (alpha), the inverse relaxation depth for $^{239+240}Pu$, and in the ratio $^{239+240}Pu/^{241}Am$ could be determined. These were shown to have equal magnitudes in the estimates for total variance of plutonium-concentration measurements and were large when compared to the variances in either soil bulk density or instrument performance.

Data were obtained from files of the Nevada Applied Ecology Group (NAEG), which were collected during 1973 to 1974 from five widely separated sites at the NTS where plutonium had been dispersed about twenty years earlier by explosion. The plutonium-concentration data were normalized to the total plutonium concentration in the soil profile down to a 25-cm depth and compared between data sets. The normalized plutonium concentrations in soil were found to be log-normally distributed at each depth. Furthermore, the estimation of the parameter α was best accomplished by combining all normalized concentration profiles within a site. The estimates of α for each site were found to be approximately log-normally distributed with a geometric standard deviation between 1.26 and 3.35. The variation within a site was just as large as between sites. For that reason, the geometric mean and geometric standard deviation of the combined data were taken as the best estimate for all sites (Figure 5.14), with a geometric standard deviation of 1.55.

The $^{239+240}Pu/^{241}Am$ ratio is also necessary to estimate plutonium concentrations from Ge-detector-measured americium concentrations in soil. From the same data set, distributions of $^{239+240}Pu/^{241}Am$ were obtained. These fit a log-normal distribution for each site. The typical geometric standard deviation of plutonium/americium, taking all sites together, was 1.41.

The imprecision of *in situ* Ge-detector measurements for plutonium is thus due to the combined variances of the parameter α and of the plutonium/americium ratio. The approximate geometric standard deviation for determination of plutonium concentration by field spectrometry with a Ge detector was determined to be 1.53, which is perhaps a larger uncertainty than one would accept for laboratory plutonium measurements. Because of the variations in both the vertical plutonium distribution and the plutonium/americium ratio, we can be 95 percent confident that estimates of plutonium are within a factor of two. But the variance of the normalized soil plutonium concentrations in the top soil was much greater. That is, the geometric standard deviation was 5.84 for 65 values in the top 0 to 2.5 cm and 5.39 for 60 values in the next 2.5 to 5.0 cm. This means that normalized plutonium concentrations at the same depth were log-normally distributed such that 10 percent of the concentrations were greater than 10 times the median concentration. Thus, the Ge-detector system was not more variable than the soil plutonium concentration it characterized.

A paper was published in 1989 on the results of a cleanup and treatment test at the NTS (Shinn et al. 1989). Experiments were conducted at the NTS to evaluate the effectiveness of removing plutonium-contaminated soils with a large, truck-mounted vacuum cleaner. The results showed that this method is effective, relatively easy, and safe for equipment operators. The ecological impact was, however, serious in terms of soil erosion and destruction of small animal habitats.

Human Dose-Assessment Models

The NAEG/NTS dose-assessment model (Martin and Bloom 1980) is used to estimate the dose to man from $^{239+240}Pu$. It is designed with the assumption that a "Reference Man" is living in a contaminated environment, eating only plants and animals living in the same environment. Figure 5.15 shows a schematic diagram of the NAEG model.

Work was begun in 1988 to modify the model to include other radionuclides found at the NTS and to include the external dose pathway for gamma-emitting radionuclides in addition to the ingestion and inhalation pathway for all radionuclides (Ng et al. 1988). In 1989 a sensitivity and uncertainty analysis was performed on the NAEG model, and work continued on modifying the model to include (1) a multi-compartment gut model for calculating the dose to the gut, (2) the gamma-exposure pathway, and (3) the radionuclides ^{60}Co, ^{90}Sr, ^{137}Cs, ^{152}Eu, ^{155}Eu, ^{238}Pu, and ^{241}Am that were found in measurable quantities on the NTS during the Radionuclide Inventory and Distribution Program (RIDP). The results of the sensitivity and uncertainty analysis performed on the NAEG model are described below and are found in a paper submitted for publication (Kercher and Anspaugh 1989).

The sensitivity analysis indicated that the inhalation pathway is the critical pathway for receiving the highest dose from plutonium. The soil plutonium concentration and the factors controlling air concentration are the most important environmental parameters. The inhalation pathway accounts for 100 percent of the dose to the lung, upper respiratory tract, and thoracic lymph nodes and 95 percent of the dose to liver, bone, kidney, and total body. The only organ that was dose sensitive to parameters in the ingestion pathway was the gastrointestinal (GI) tract. The GI tract received 99 percent of its dose via ingestion. It was found that only a few of the model parameters control the dose for any one organ. The number

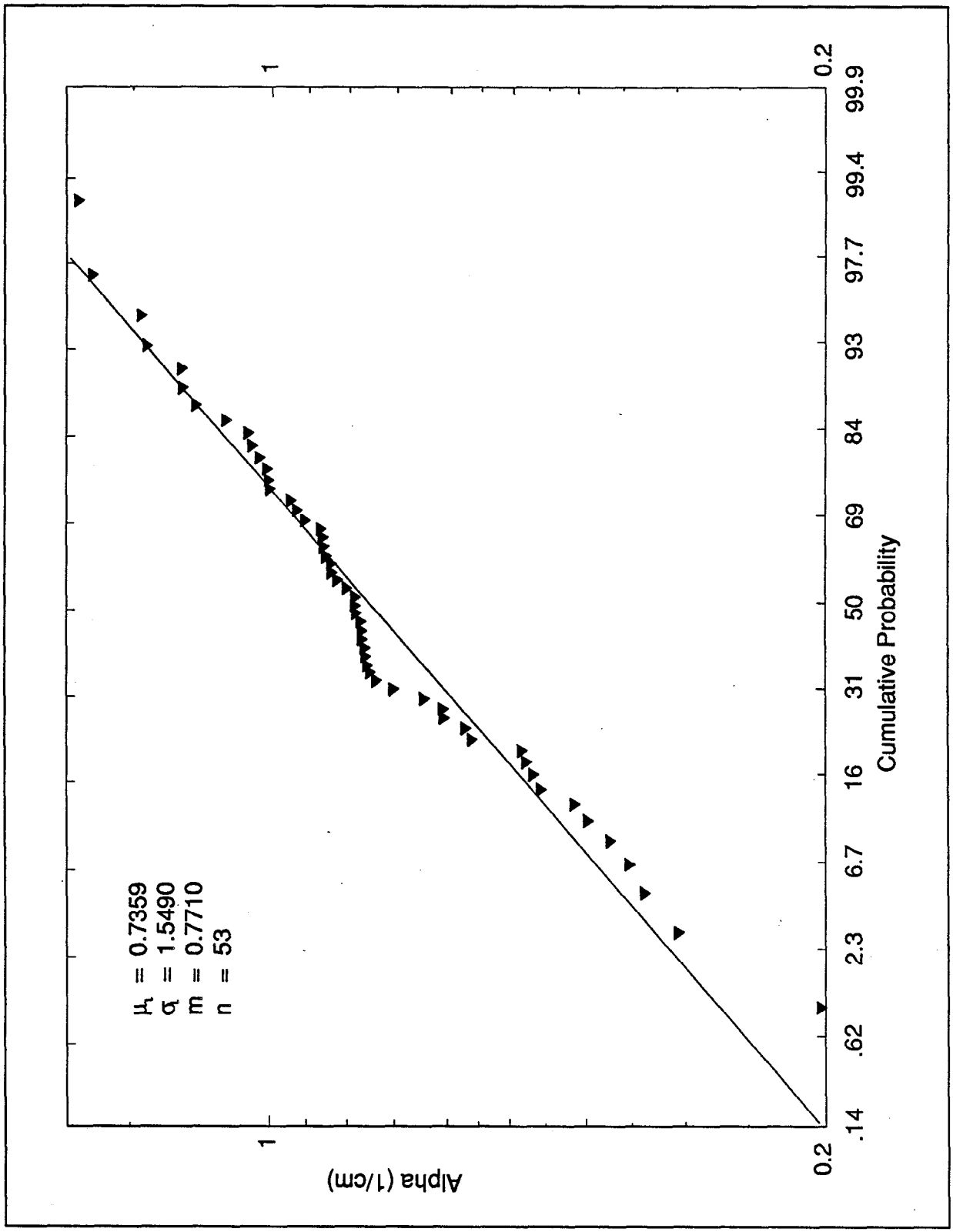


Figure 5.14 Cumulative Logarithmic Distribution of Inverse Relaxation Depth α for Plutonium Obtained from 53 Soil Profiles in Five Areas of NTS. *The geometric mean, geometric standard deviation, and median (m) are shown*

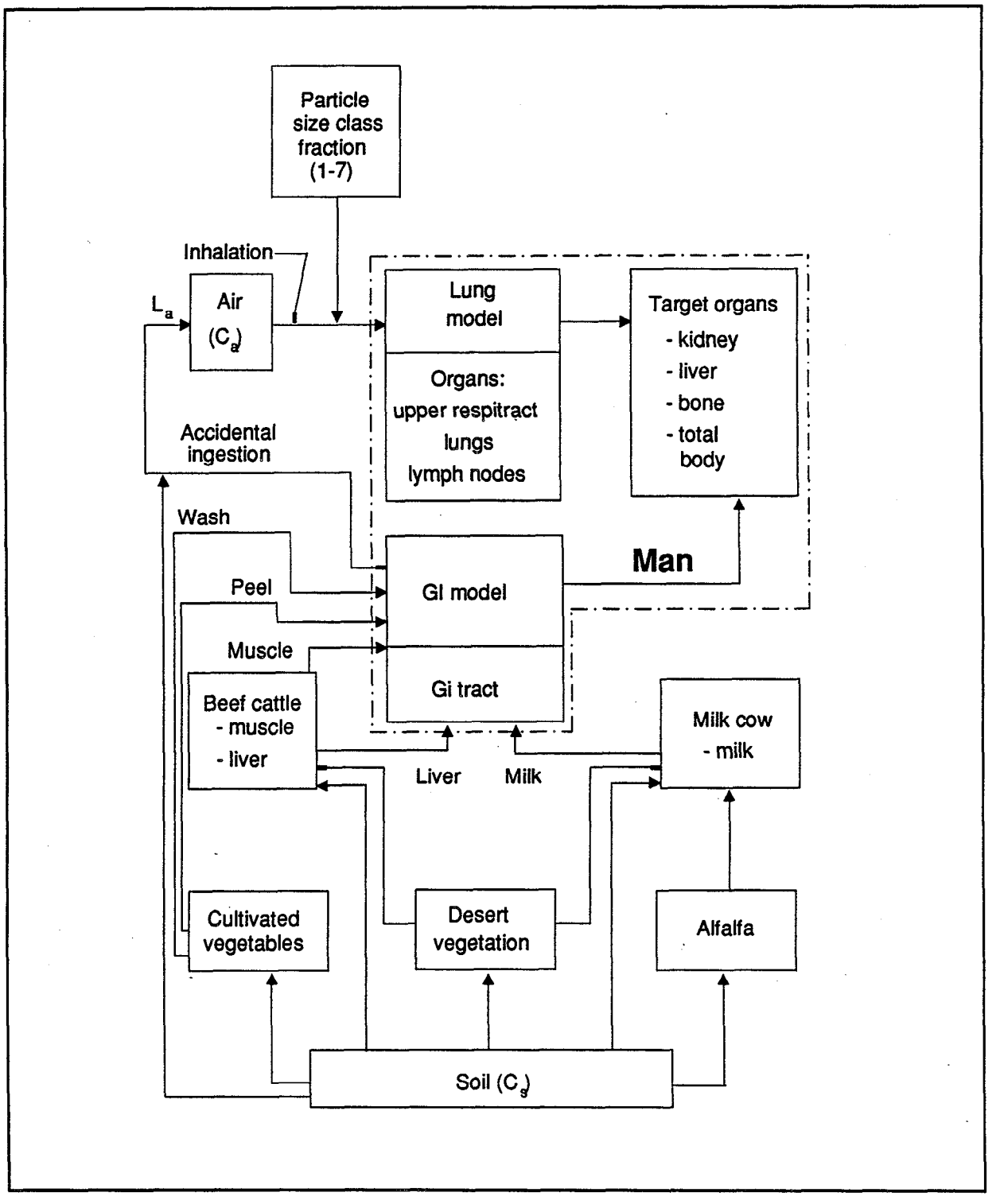


Figure 5.15 Schematic Diagram Showing Compartments of Major Submodels of the NAEG Model for Estimating $^{239+240}Pu$ Dose to Man. *Transfers of plutonium between compartments are shown by solid arrows. The man submodel is surrounded by a dashed line, L_a is the mass-loading factor of soil particles in air (g soil/m^3 air), C_s is the concentration of plutonium in soil (pCi/g soil), and C_a is the concentration of plutonium in air (pCi/m^3)* (Martin and Bloom 1980)

of important parameters was usually less than ten.

Uncertainty analysis indicated that choosing a uniform distribution for the input parameters produced a log-normal distribution of the dose. It was found that only a few parameters control the dose for each organ, and all organs have similar distributions of dose except for the lymph nodes.

Results from the sensitivity and uncertainty analysis suggested that future efforts should be in the improvement of the air-pathway submodel. Incorporation of realistic distributions of environmental parameters based on experimental data will be useful in future uncertainty analyses.

Thematic, Peer-Reviewed Publications

The thematic, peer-reviewed publication produced in 1989 addressed the transfer of aged radionuclides to cattle which grazed within fenced enclosures in a plutonium-contaminated site on the Nellis Air Force Base range complex (Gilbert et al. 1989). The paper dealt with two issues: the difference in average transfers of radionuclides to tissues of cattle and how these estimates of radionuclide transfers in cattle compare to transfers recommended for humans for radiological protection purposes. During the 1970s, 17 cattle grazed on an area which had been contaminated with plutonium in 1957. Data from this experiment were analyzed for the fraction of radionuclides which crossed the GI tract and transferred to individual tissues. The native vegetation grazed by the cattle was contaminated primarily from resuspension and deposition on the vegetation, not by soil-root uptake. Estimates were obtained of the fraction of ingested $^{239+240}$Pu, ^{238}Pu, ^{241}Pu, and ^{137}Cs that was transferred to blood, muscle, liver, kidney, femur, vertebra, and gonads of the cattle.

The findings of the investigation showed the estimated geometric mean (GM) GI-to-blood fractional transfer of ^{238}Pu (1×10^{-4}) was 20 times larger than the estimated transfer of $^{239+240}$Pu (5×10^{-6}), while the estimated transfer of ^{241}Am (1×10^{-5}) was about two times larger than that of $^{239+240}$Pu. These GM GI-to-blood transfers were smaller than the GI-to-blood transfer value of 1×10^{-3} recommended by the International Commission on Radiological Protection for humans exposed via food chains or occupationally from unknown mixtures or compounds of plutonium and americium. The estimated GM fractional transfers of ^{137}Cs from GI to muscle and liver were 3×10^{-2} (n=8) and 1×10^{-3} (n=3), respectively.

Two papers were published in 1988 that also investigated radionuclide dynamics in the desert environment. The first (Gilbert et al. 1988a), a predecessor to the paper described above, dealt with the derivation of the fractional transfer of $^{239+240}$Pu from soil and vegetation via ingestion and inhalation to blood and tissues of beef cattle which grazed within two fenced enclosures (the inner enclosure containing soil and native vegetation with higher concentrations) in a plutonium-contaminated site on the Nellis Bombing and Gunnery Range. The contamination was generated from a nuclear device which was explosively destroyed at ground zero 16 years prior to initiation of cattle grazing. Figure 5.16 shows the estimates of plutonium concentrations for soil, vegetation, rumen vegetation, and cattle tissues.

The second paper, published late in 1988, which dealt with radionuclide transport in a desert ecosystem (Gilbert et al. 1988b), reviewed NAEG studies conducted between 1970 and 1976 at two nuclear (fission) sites and two nonnuclear (nonfission) sites. Data from these studies were synthesized and compared regarding (1) soil particle-size distribution and the physical-chemical characteristics of $^{239+240}$Pu-bearing radioactive particles, (2) $^{239+240}$Pu resuspension rates, and (3) transuranic and fission-product radionuclide transfers from soil to native vegetation, kangaroo rats, and grazing cattle. Of particular interest, the data indicated that the transuranic contamination in soil at the nonnuclear site (Area 13) may be transferred more readily to plants and animals than the transuranic radionuclide soil contamination at the nuclear sites. Compared to these nuclear sites, Area 13

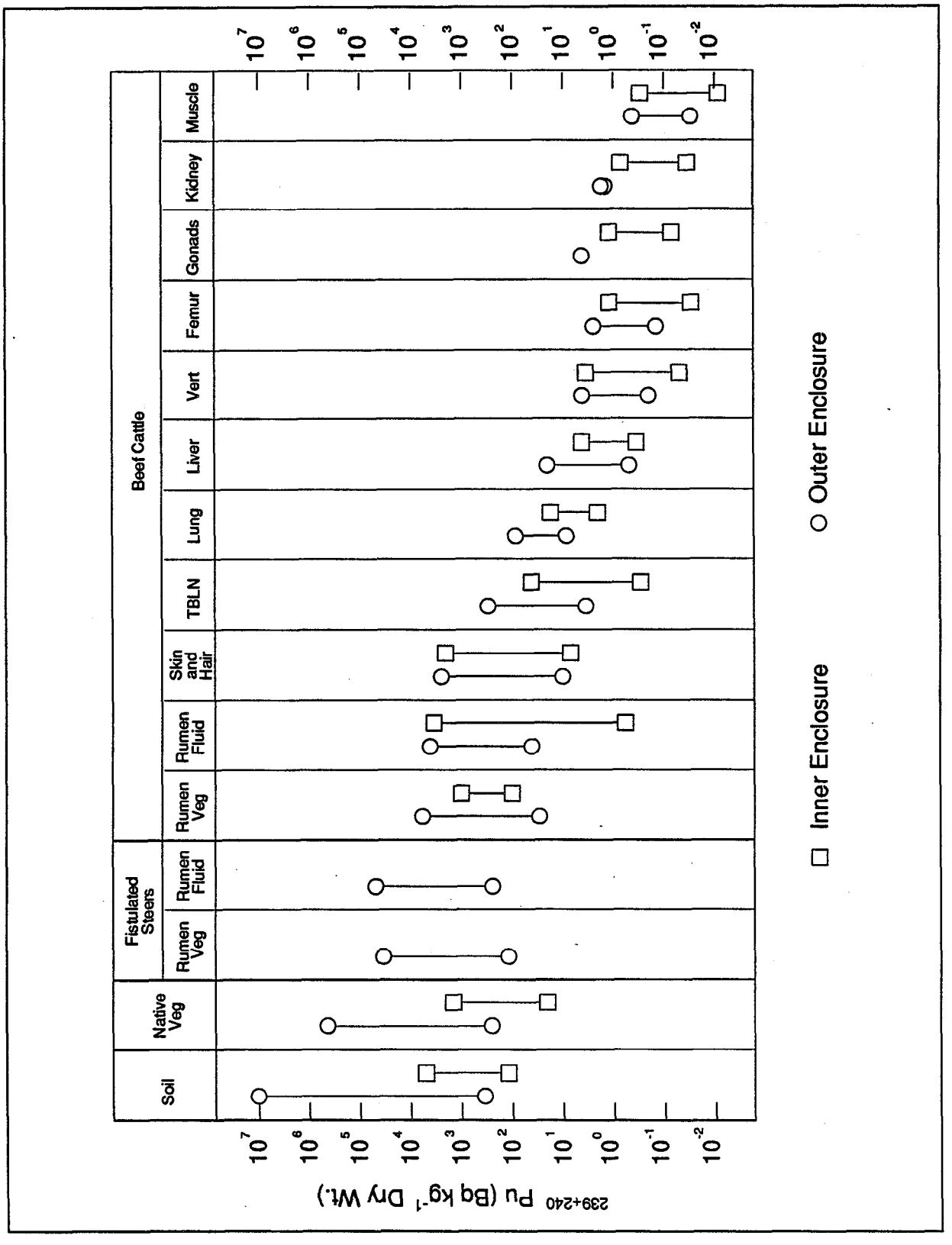


Figure 5.16 Estimates of Plutonium Concentrations for Soil, Vegetation, Rumen Vegetation and Fluid, and Cattle Tissues. *Cattle tissues are given on a dry weight basis* (Gilbert et al. 1988a)

has orders-of-magnitude higher resuspension factors; a higher percentage of radioactivity in smaller soil particle-size fractions; and GM carcass-over-soil, GI-over-soil, and pelt-over-soil $^{239+240}$Pu ratios that are ten times larger than at the nuclear sites. Also, the vegetation-over-soil ratios of $^{239+240}$Pu concentrations (an indirect measurement of resuspension factors) at Area 13 tend to exceed those at the nuclear sites.

The fifth in a series of reports from the RIDP was completed and released in 1989. The report (McArthur and Mead 1989) presents the results of *in situ* measurements of gamma-emitting radionuclides and additional information from aerial surveys and analysis of soil samples to estimate inventories and distributions of radionuclides of NTS origin in the surface soil. RIDP Report #5 includes the results from Plutonium Valley (Area 11), Frenchman Flat (Area 5), the BUGGY event site, test facilities in Areas 25 and 26, and Areas 17 and 18. It also gives the results of measurements in several relatively uncontaminated regions in Areas 12, 15, and 19.

5.2.2 OFFSITE ENVIRONMENTAL SURVEILLANCE (EPA 1990)

Offsite radiological surveillance by the EPA consists of (1) an Air Surveillance Network (ASN) of 31 continuously-operating stations and 78 standby stations for air particulates and reactive gases; (2) a 20-station Noble Gas and Tritium Surveillance Network (NGTSN); (3) a groundwater and surface water surveillance network at approximately 60 stations on and off the Site (33 at NTS wells); (4) a 27-station Milk Surveillance Network (MSN) around the NTS, with 106 additional stations in major milksheds west of the Mississippi River; (5) sampling of livestock and wildlife tissue and vegetables around the NTS; (6) a 135-station TLD network and 65-person offsite resident dosimetry program; (7) a 27-station external gamma exposure rate monitoring network; and (8) an offsite resident radionuclide uptake monitoring program.

AIR MONITORING NETWORK

During 1989 no airborne radioactivity related to current nuclear testing at the NTS was detected on any sample from the ASN or the Standby Air Surveillance Network (SASN), shown in Figures 5.17 and 5.18. Throughout the network, ^{7}Be was the only nuclide detected by gamma spectroscopy. The principal means of ^{7}Be production is from spallation of ^{16}O and ^{14}N by cosmic rays in the atmosphere.

The monthly average gross beta level in air samples from the Las Vegas, Nevada, station since 1981 is plotted in Figure 5.19. Data from other stations were similar and suggest little significant difference among stations. Summaries of the 1989 ASN data are shown in Table 5.19 and for 73 of the SASN stations in Table 5.20.

The filters from the stations at Las Vegas, Lathrop Wells, and Rachel, Nevada, and Salt Lake City, Utah, were composited as monthly samples and submitted quarterly for plutonium analysis. The other samples for plutonium analysis consisted of composited filters from two stations in each state in which standby stations were located.

The results of the ^{238}Pu and $^{239+240}$Pu analyses from 14 states are shown in Table 5.21. The only sample which showed a detectable amount of ^{238}Pu was the January composite from Rachel, Nevada. It was borderline detectable and could have been a statistical anomaly. Statistically, about five percent of the time a sample which does not contain plutonium will yield a false positive result. No $^{239+240}$Pu was detected. The plutonium results from the last two quarters of 1989 were not available for inclusion in the 1989 EPA data and will be reported in the Agency's offsite report for 1990.

Figure 5.20 shows the 20 stations of the NGTSN. NGTSN sample results are summarized in Tables 5.22 and 5.23 for all sampling locations. This summary consists of the maximum, minimum, and average concentration for each station. The number of samples analyzed is typically less than

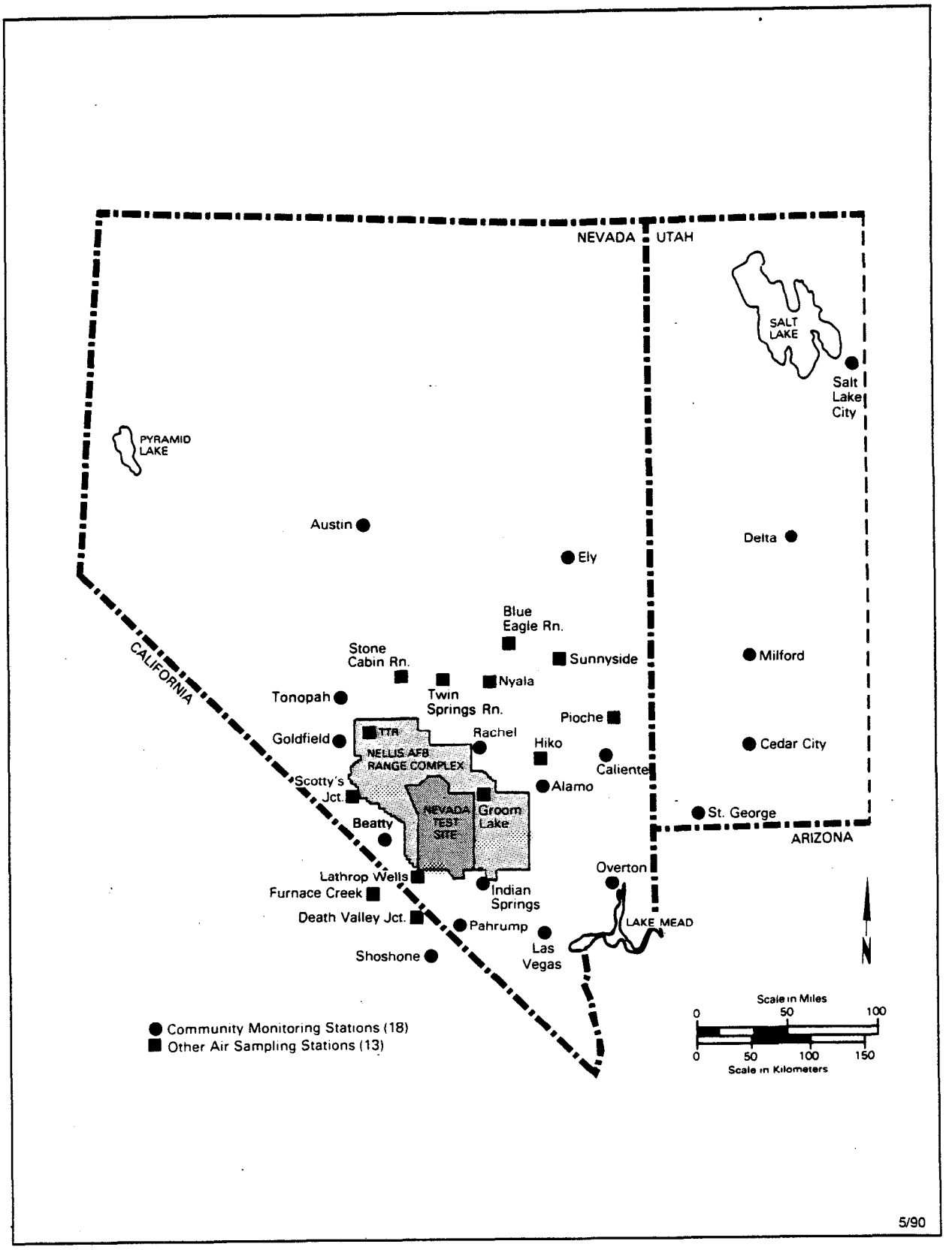


Figure 5.17 Air Surveillance Network Stations - 1989

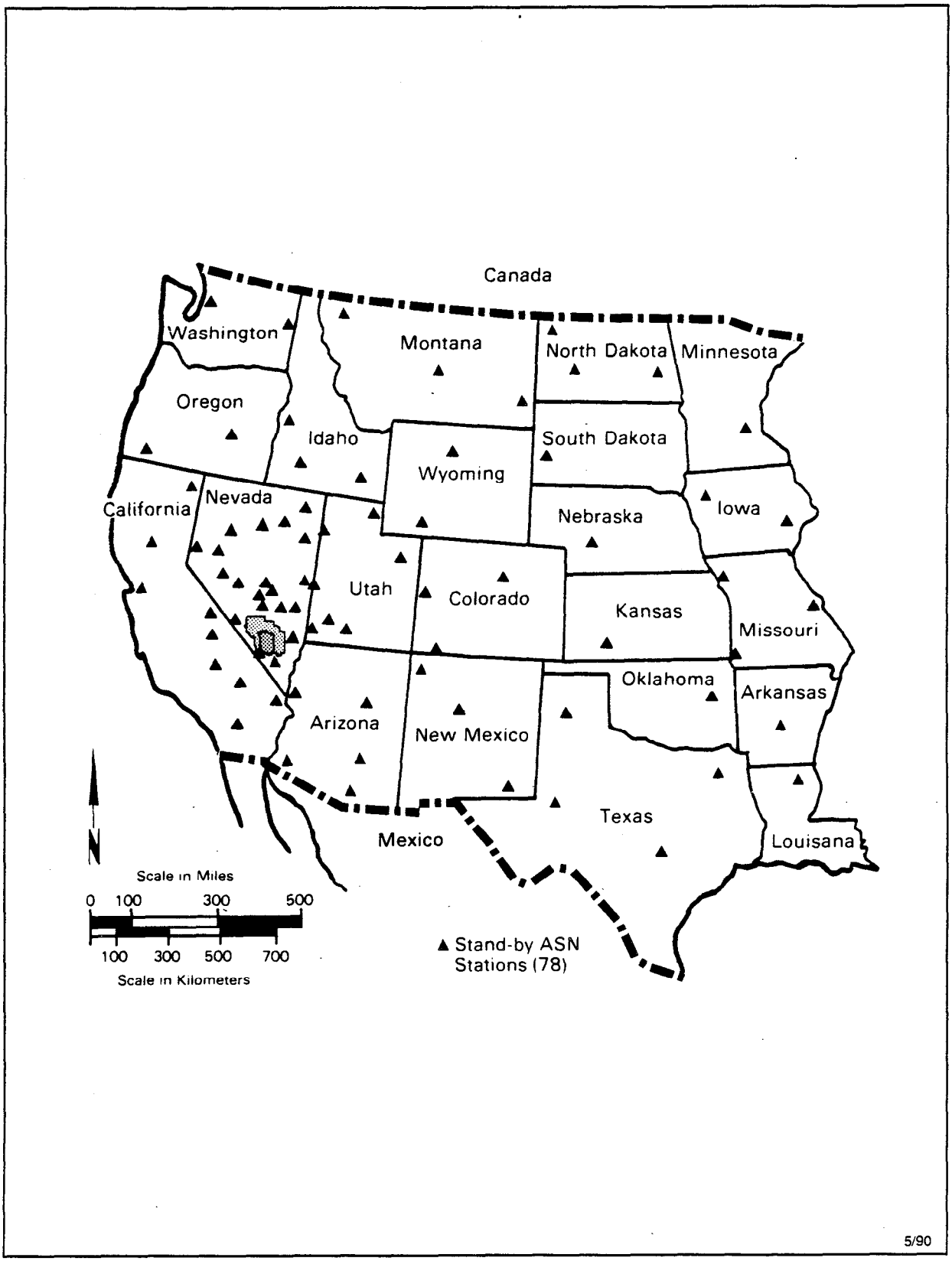
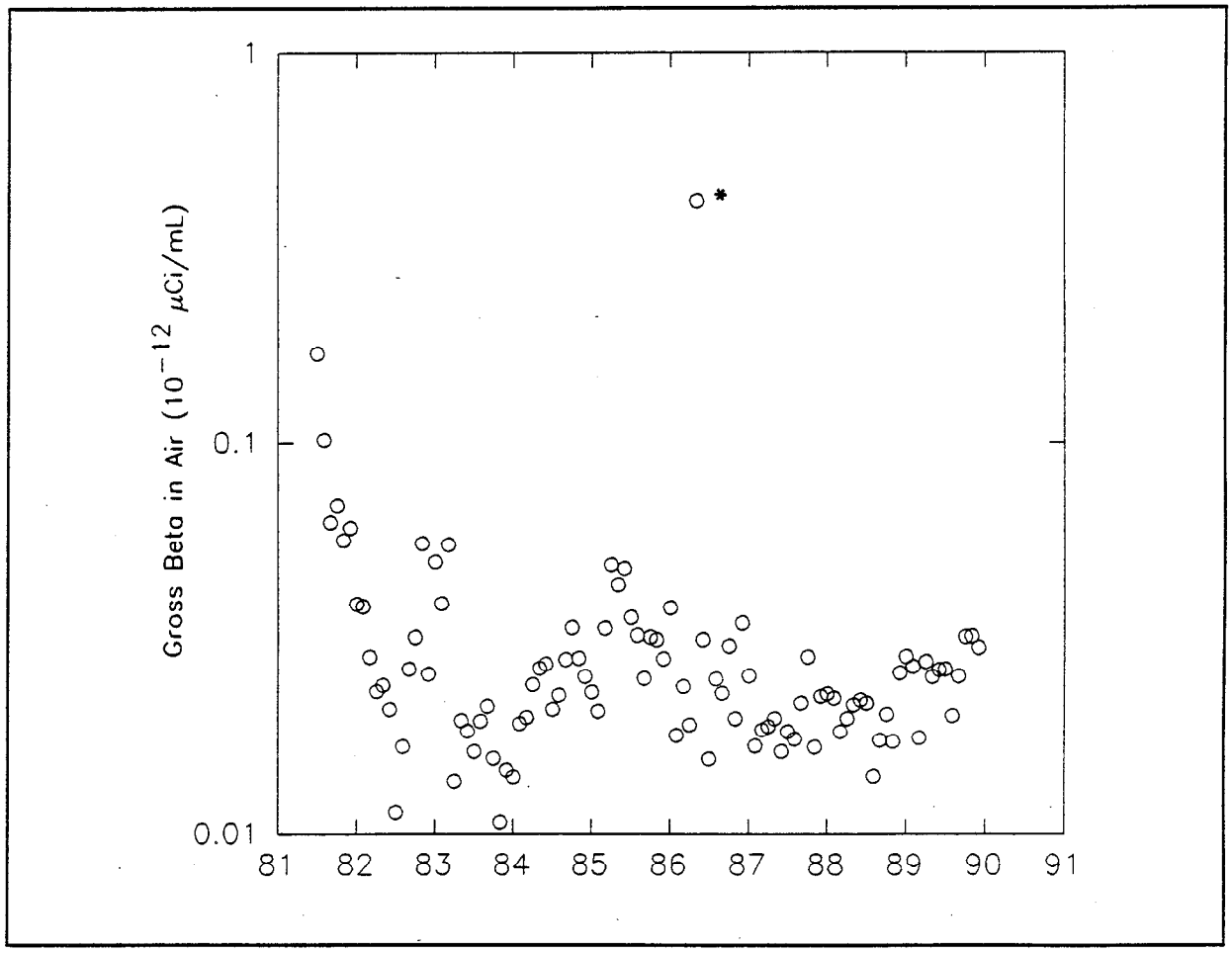


Figure 5.18 Standby Air Surveillance Network Stations - 1989



* Elevated concentration attributable to the April 1986 nuclear reactor accident at Chernobyl, USSR

Figure 5.19 Monthly Average Gross Beta in Air Samples, Las Vegas, Nevada - 1981-89

Table 5.19 Gross Beta Results at Air Surveillance Network Stations - 1989

Sampling Location	Number of Days Sampled[a]	Gross Beta Concentration (10^{-12} µCi/mL) Maximum	Minimum	Average
Death Valley Junction, CA	326	0.054	-0.004	0.030
Furnace Creek, CA	326	0.160	0.000	0.033
Shoshone, CA	357	0.051	-0.006	0.027
Alamo, NV	334	0.059	0.010	0.026
Austin, NV	330	0.056	-0.004	0.024
Beatty, NV	324	0.049	0.010	0.024
Blue Eagle Ranch, NV	318	0.210	0.008	0.026
Caliente, NV	319	0.240	0.002	0.035
Ely, NV	322	0.420	0.006	0.036
Fallini's Twin Springs Ranch, NV	325	0.040	0.010	0.022
Goldfield, NV	328	0.036	0.009	0.023
Groom Lake, NV	329	0.043	0.002	0.025
Hiko, NV	326	0.047	0.009	0.025
Indian Springs, NV	330	0.050	0.002	0.025
Las Vegas, NV	359	0.080	0.003	0.027
Lathrop Wells, NV	334	0.048	0.004	0.023
Nyala, NV	326	0.044	0.000	0.010
Overton, NV	329	0.046	0.012	0.027
Pahrump, NV	329	0.038	-0.005	0.023
Pioche, NV	313	0.150	0.003	0.025
Rachel, NV	322	0.086	0.009	0.022
Scotty's Junction, NV	354	0.051	0.006	0.027
Stone Cabin Ranch, NV	324	0.220	0.000	0.025
Sunnyside, NV	317	0.036	0.010	0.022
Tonopah, NV	319	0.056	0.009	0.024
Tonopah Test Range, NV	332	0.037	0.000	0.021
Cedar City, UT	332	0.044	0.011	0.025
Delta, UT	353	0.180	0.009	0.033
Milford, UT	351	0.098	0.006	0.028
Salt Lake City, UT	315	0.160	0.000	0.026
St. George, UT	360	0.260	0.003	0.033

(a) Analysis for gross beta on air filters from all continuously-operating stations was initiated (at different times for different stations) during the first quarter of 1989. This analysis previously was done on filters from five continuously-operating stations.

Table 5.20 Gross Beta Results at Standby Air Surveillance Network Stations - 1989

Sampling Location	Number of Days Sampled[a]	Gross Beta Concentration (10^{-12} µCi/mL) Maximum	Minimum	Average
Globe, AZ	14	0.048	0.038	0.043
Kingman, AZ	23	0.054	0.005	0.027
Tucson, AZ	21	0.041	0.024	0.033
Winslow, AZ	24	0.088	0.017	0.036
Yuma, AZ	28	0.047	0.030	0.038
Little Rock, AR	21	0.041	0.023	0.033
Alturas, CA	28	0.021	0.011	0.014
Baker, CA	35	0.048	0.025	0.040
Bishop, CA	22	0.048	0.027	0.039
Chico, CA	32	0.025	0.015	0.019
Indio, CA	25	0.057	0.018	0.034
Lone Pine, CA	24	0.037	0.004	0.021
Needles, CA	21	0.020	0.014	0.017
Ridgecrest, CA	20	0.029	0.003	0.014
Santa Rosa, CA	28	0.032	0.009	0.019
Cortez, CO	14	0.019	0.011	0.016
Denver, CO	37	0.044	0.013	0.024
Grand Junction, CO	29	0.098	0.030	0.059
Mountain Home, ID	23	0.029	0.003	0.018
Nampa, ID	21	0.032	0.017	0.023
Pocatello, ID	22	0.024	0.017	0.021
Fort Dodge, IA	29	0.040	0.028	0.033
Iowa City, IA	22	0.033	0.025	0.030
Dodge City, KS	35	0.032	0.014	0.025
Monroe, LA	28	0.035	0.018	0.027
Minneapolis, MN	30	0.024	0.012	0.018
Clayton, MO	14	0.029	0.022	0.025
Joplin, MO	21	0.043	0.016	0.027
St. Joseph, MO	22	0.038	0.024	0.030
Great Falls, MT	21	0.032	0.018	0.025
Kalispell, MT	28	0.040	0.018	0.025
Miles City, MT	21	0.029	0.023	0.025
North Platte, NE	25	0.048	0.024	0.036
Adaven, NV	45	0.031	0.006	0.019
Battle Mountain, NV	28	0.023	0.019	0.020
Currant NV				
Angle Worm Ranch	21	0.042	0.022	0.031
Currie, NV				
Currie Maintenance Station	13	0.036	0.025	0.028
Duckwater, NV	7	0.029	0.013	0.018

(a) Analysis for gross beta on air filters from all standby stations was initiated during the first quarter of 1989. This analysis was not performed on filters from standby stations prior to that time.

Table 5.20 (Gross Beta - SASN, cont.)

Sampling Location	Number of Days Sampled[a]	Gross Beta Concentration (10^{-12} µCi/mL) Maximum	Minimum	Average
Elko, NV				
Phillips 66 Truck Stop	14	0.011	0.005	0.008
Eureka, NV	24	0.031	0.019	0.026
Fallon, NV	21	0.060	0.022	0.035
Lovelock, NV	30	0.065	0.015	0.031
Lund, NV	36	0.023	0.010	0.017
Mesquite, NV	21	0.042	0.007	0.016
Reno, NV	23	0.032	0.013	0.022
Round Mountain, NV	21	0.028	0.018	0.022
Wells, NV	28	0.023	0.009	0.017
Winnemucca, NV	36	0.049	0.006	0.028
Albuquerque, NM	24	0.052	0.023	0.035
Carlsbad, NM	24	0.051	0.031	0.043
Shiprock, NM	38	0.049	0.029	0.039
Bismark, ND	24	0.028	0.021	0.026
Fargo, ND	21	0.056	0.019	0.036
Williston, ND	28	0.056	0.028	0.040
Muskogee, OK	21	0.048	0.005	0.030
Burns, OR	21	0.017	0.010	0.013
Medford, OR	22	0.023	0.003	0.012
Rapid City, SD	21	0.029	0.020	0.023
Amarillo, TX	35	0.040	0.031	0.035
Austin, TX	34	0.035	0.004	0.014
Midland, TX	14	0.021	0.013	0.017
Tyler, TX	26	0.038	0.008	0.022
Bryce Canyon, UT	35	0.033	0.011	0.023
Enterprise, UT	42	0.055	0.017	0.027
Garrison, UT	16	0.042	0.002	0.007
Logan, UT	24	0.071	0.022	0.032
Parowan, UT	44	0.042	0.006	0.021
Vernal, UT	20	0.039	0.016	0.031
Wendover, UT	23	0.026	0.007	0.020
Seattle, WA	18	0.016	0.004	0.013
Spokane, WA	21	0.039	0.021	0.029
Rock Springs, WY	21	0.035	0.013	0.024
Worland, WY	21	0.044	0.026	0.035

(a) Analysis for gross beta on air filters from all standby stations was initiated during the first quarter of 1989. This analysis was not performed on filters from standby stations prior to that time.

Table 5.21 Concentrations of ^{238}Pu and $^{239+240}Pu$ (Composited Air Samples) - 1989

Composite Sampling Location	Collection Date in 1989	Concentration ± 2s (MDC) ^{238}Pu (10^{-18} µCi/mL)	Concentration ± 2s (MDC) $^{239+240}Pu$ (10^{-18} µCi/mL)
Arizona (Winslow & Tucson)	01/25	-7 ± 27 (48)	0 ± 18 (30)
	04/17	9 ± 13 (16)	0 ± 9 (16)
California (Bishop & Ridgecrest)	02/14	7 ± 18 (24)	-4 ± 12 (24)
	04/24	0 ± 34 (55)	-5 ± 10 (23)
Colorado (Denver & Cortez)	02/22	2 ± 8 (12)	0 ± 5 (8)
	04/19	0 ± 31 (50)	5 ± 19 (25)
Idaho (Boise & Mountain Home)	01/25	-17 ± 50 (85)	-27 ± 24 (50)
	04/22	11 ± 17 (21)	-3 ± 5 (12)
Missouri (Clayton & Joplin)	01/25	-15 ± 57 (101)	-8 ± 34 (62)
	04/19	13 ± 13 (12)	-4 ± 5 (12)
Montana (Great Falls & Miles City)	01/25	54 ± 139 (204)	18 ± 62 (83)
	04/19	0 ± 13 (22)	6 ± 9 (9)
Nevada (Las Vegas)	01/30	0 ± 50 (82)	-13 ± 25 (51)
	02/27	-29 ± 22 (44)	2 ± 6 (8)
	03/27	8 ± 19 (27)	3 ± 13 (19)
	04/24	3 ± 5 (6)	-2 ± 2 (6)
	05/29	0 ± 6 (10)	1 ± 3 (4)
	06/26	1 ± 8 (12)	0 ± 4 (6)
Nevada (Lathrop Wells)	01/31	-137 ± 65 (133)	-26 ± 41 (78)
	02/28	2 ± 18 (29)	-4 ± 8 (18)
	03/27	-46 ± 29 (58)	12 ± 13 (11)
	04/30	1 ± 8 (12)	3 ± 6 (7)
	05/28	1 ± 5 (8)	-2 ± 3 (8)
	06/26	0 ± 6 (10)	-1 ± 2 (4)
Nevada (Rachel)	01/30	15 ± 11 (11)[a]	5 ± 7 (8)
	02/27	-9 ± 19 (33)	-9 ± 9 (19)
	03/27	-6 ± 11 (20)	3 ± 9 (13)
	04/24	4 ± 7 (9)	5 ± 5 (5)
	05/29	9 ± 17 (23)	3 ± 10 (13)
	06/26	2 ± 4 (6)	-1 ± 3 (6)

Note: All concentrations are below the MDC unless denoted by (a). A two standard deviation (2s) error is reported, versus the 1s for onsite data, because of the different procedures used by the two laboratories involved.

Table 5.21 (^{238}Pu and $^{239+240}Pu$ in Air, cont.)

Composite Sampling Location	Collection Date in 1989	Concentration ± 2s (MDC) ^{238}Pu (10^{-18} µCi/mL)	Concentration ± 2s (MDC) $^{239+240}Pu$ (10^{-18} µCi/mL)
New Mexico (Albuquerque & Carlsbad)	01/27	0 ± 36 (59)	-6 ± 22 (41)
	04/23	0 ± 7 (12)	0 ± 4 (6)
North Dakota (Bismarck & Fargo)	01/30	-95 ± 119 (217)	-35 ± 69 (13)
	04/19	7 ± 11 (12)	2 ± 8 (12)
Oregon (Burns & Medford)	01/27	-16 ± 24 (50)	5 ± 19 (25)
	05/02	10 ± 14 (16)	-5 ± 7 (16)
Texas (Austin & Amarillo)	01/30	-117 ± 107 (203)	8 ± 29 (39)
	05/22	-1 ± 5 (8)	-1 ± 1 (3)
Utah (Logan & Vernal)	02/09	73 ± 126 (169)	-18 ± 63 (120)
	04/24	8 ± 14 (19)	6 ± 9 (9)
Utah (Salt Lake City)	01/30	-17 ± 25 (45)	4 ± 7 (9)
	02/27	1 ± 7 (11)	0 ± 5 (8)
	03/27	-4 ± 62 (103)	-25 ± 31 (60)
	04/25	-2 ± 5 (10)	-1 ± 2 (4)
	05/29	5 ± 6 (8)	1 ± 3 (4)
	06/26	4 ± 6 (7)	1 ± 3 (4)
Washington (Seattle & Spokane)	01/25	26 ± 392 (641)	-153 ± 193 (376)
	04/19	8 ± 12 (16)	0 ± 5 (9)
Wyoming (Worland & Rock Springs)	01/25	Sample lost	Sample lost
	04/19	-2 ± 6 (11)	3 ± 8 (11)

Note: All concentrations are below the MDC unless denoted by (a).

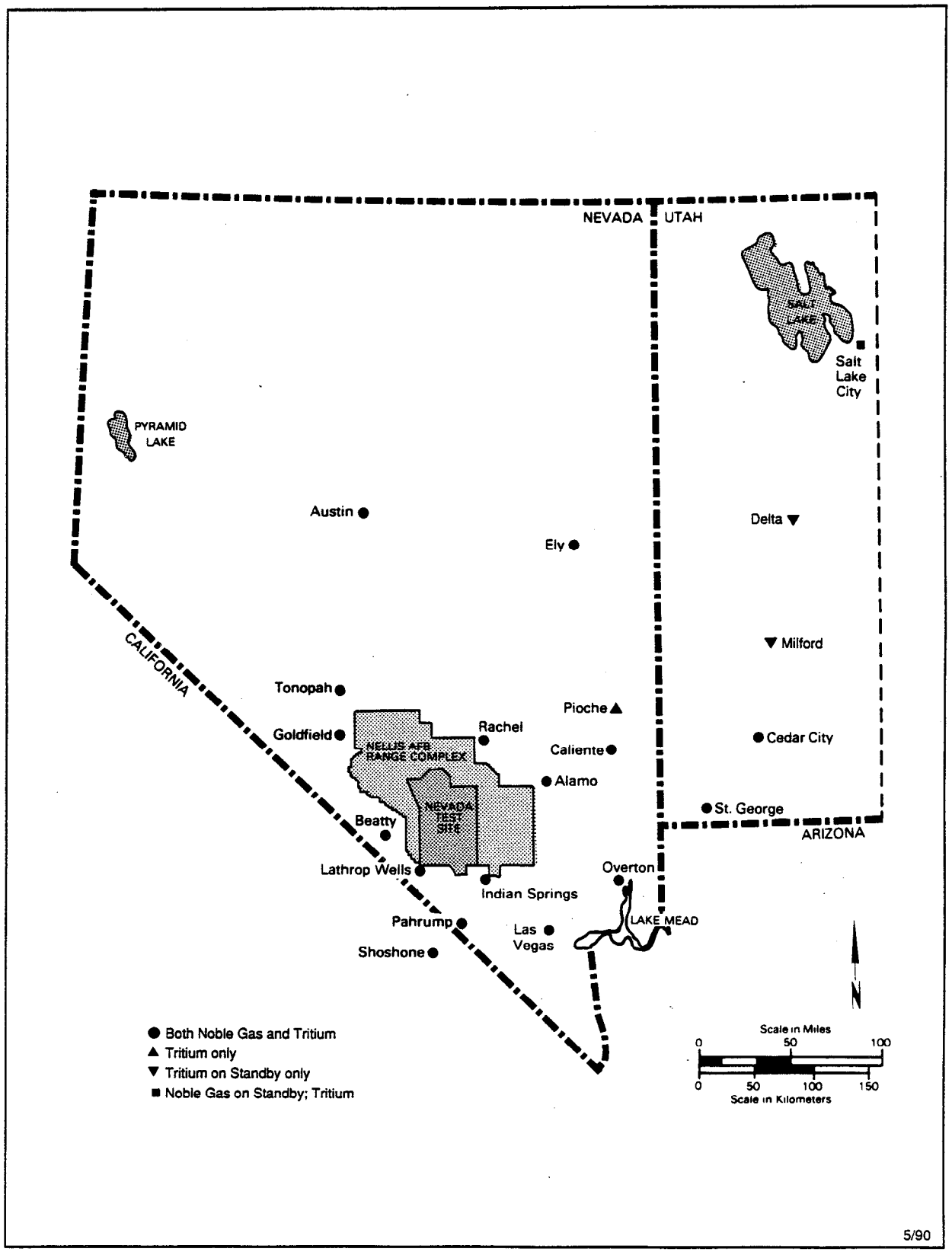


Figure 5.20 Noble Gas and Tritium Surveillance Network - 1989

Table 5.22 Offsite Noble Gas Surveillance Results - 1989

Sampling Location	Number of Samples Analyzed	Radio-nuclide	Radioactivity Concentration (10^{-12} µCi/mL)[a] Maximum	Minimum	Average	Percent of the Concentration Guide[b]
Shoshone, CA	48	^{85}Kr	31	21	27	0.02
	48	^{133}Xe	7.7	-6.7	1.1	<0.01
Alamo, NV	45	^{85}Kr	32	22	27	0.02
	47	^{133}Xe	8.1	-16	-0.018	<0.01
Austin, NV	45	^{85}Kr	31	21	27	0.02
	45	^{133}Xe	11	-18	-0.55	<0.01
Beatty, NV	50	^{85}Kr	32	20	27	0.02
	51	^{133}Xe	11	-10	1.8	<0.01
Caliente, NV	18	^{85}Kr	29	25	27	0.02
	18	^{133}Xe	5.7	-17	-1.4	<0.01
Ely, NV	43	^{85}Kr	30	22	26	0.02
	43	^{133}Xe	10	-16	0.42	<0.01
Goldfield,NV	51	^{85}Kr	32	21	26	0.02
	51	^{133}Xe	12	-14	0.82	<0.01
Indian Springs, NV	49	^{85}Kr	32	21	26	0.02
	49	^{133}Xe	13	-5.5	0.75	<0.01
Las Vegas, NV	49	^{85}Kr	31	21	26	0.02
	49	^{133}Xe	12	-12	1.1	<0.01
Lathrop Wells, NV	43	^{85}Kr	30	21	26	0.02
	44	^{133}Xe	9.4	-7.5	0.16	<0.01
Overton, NV	49	^{85}Kr	31	21	26	0.02
	49	^{133}Xe	10	-13	0.41	<0.01
Pahrump, NV	47	^{85}Kr	31	20	26	0.02
	48	^{133}Xe	4.5	-8.0	0.23	<0.01

(a) The units used in this table (10^{-12} µCi/mL) are equal to, and the values in the table may be read as, pCi/m^3.

(b) The concentration guides referenced are calculated from the Annual Limit of Intake (ALI), listed in ICRP-30, and (where applicable) are based on the respiration rate of Standard Man, with the resulting guide being equal to the nonoccupational exposure guide of 25 mrem for exposure from radionuclides in air.

Table 5.22 (Analytical Results - NGSN, cont.)

Sampling Location	Number of Samples Analyzed	Radio-nuclide	Radioactivity Concentration (10^{-12} µCi/mL)[a] Maximum	Minimum	Average	Percent of the Concentration Guide[b]
Rachel, NV	48	^{85}Kr	32	21	27	0.02
	48	^{133}Xe	9.0	-10	0.47	<0.01
Tonopah, NV	49	^{85}Kr	33	22	27	0.02
	51	^{133}Xe	11	-13	-0.15	<0.01
Cedar City, UT	48	^{85}Kr	30	20	26	0.02
	48	^{133}Xe	11	-8.8	0.52	<0.01
St. George, UT	47	^{85}Kr	30	20	26	0.02
	48	^{133}Xe	8.3	-14	0.085	<0.01

(a) The units used in this table (10^{-12} µCi/mL) are equal to, and the values in the table may be read as, pCi/m^3.

(b) The concentration guides referenced are calculated from the ALI, listed in ICRP-30, and (where applicable) are based on the respiration rate of Standard Man, with the resulting guide being equal to the nonoccupational exposure guide of 25 mrem for exposure from radionuclides in air.

Table 5.23 Offsite Tritium Surveillance Results - 1989

Sampling Location	Number of Samples Analyzed	Radio-nuclide	Radioactivity Concentration (10^{-12} µCi/mL)[a] Maximum	Minimum	Average	Percent of the Concentration Guide[b]
Shoshone, CA	52	^{3}H in atm. m.[a]	0.81	-0.53	0.079	-
	52	^{3}H as HTO in air	3.6	-2.1	0.44	<0.01
Alamo, NV	51	^{3}H in atm. m.[a]	0.42	-1.3	0.0061	-
	51	^{3}H as HTO in air	6.6	-24	-0.087	<0.01

(a) Concentrations of tritiated water vapor (HTO) in air are given in units of 10^{-12} µCi/mL (pCi/m^3) of water, while the activity of ^{3}H in atmospheric moisture is given in units of 10^{-6} µCi/mL (pCi/mL) of water.

(b) The concentration guides referenced are calculated from the ALI, listed in ICRP-30, and (where applicable) are based on the respiration rate of Standard Man, with the resulting guide being equal to the nonoccupational exposure guide of 25 mrem for exposure from radionuclides in air.

Table 5.23 (Offsite Tritium Results, cont.)

Sampling Location	Number of Samples Analyzed	Radionuclide	Radioactivity Concentration (10^{-12} µCi/mL)[a] Maximum	Minimum	Average	Percent of the Concentration Guide[b]
Austin, NV	52	^{3}H in atm. m.[a]	0.59	-1.4	-0.039	-
	52	^{3}H as HTO in air	3.2	-9.3	-0.16	<0.01
Beatty, NV	51	^{3}H in atm. m.[a]	0.74	-1.1	0.064	-
	51	^{3}H as HTO in air	11	-11	0.52	<0.01
Caliente, NV	52	^{3}H in atm. m.[a]	0.74	-0.50	0.061	-
	52	^{3}H as HTO in air	4.1	-2.9	0.30	<0.01
Ely, NV	52	^{3}H in atm. m.[a]	0.68	-1.3	0.00098	-
	52	^{3}H as HTO in air	3.9	-11	0.045	<0.01
Goldfield, NV	52	^{3}H in atm. m.[a]	0.58	-1.2	0.047	-
	52	^{3}H as HTO in air	4.3	-11	0.23	<0.01
Indian Springs, NV	50	^{3}H in atm. m.[a]	0.87	-0.67	0.066	-
	50	^{3}H as HTO in air	4.9	-1.8	0.37	<0.01
Las Vegas, NV	52	^{3}H in atm. m.[a]	0.71	-0.29	0.076	-
	52	^{3}H as HTO in air	2.6	-1.7	0.40	<0.01
Lathrop Wells, NV	50	^{3}H in atm. m.[a]	0.79	-0.41	0.056	-
	50	^{3}H as HTO in air	4.7	-2.4	0.28	<0.01
Overton, NV	52	^{3}H in atm. m.[a]	0.63	-0.52	0.036	-
	52	^{3}H as HTO in air	4.5	-3.1	0.17	<0.01
Pahrump, NV	51	^{3}H in atm. m.[a]	0.57	-0.33	0.068	-
	51	^{3}H as HTO in air	4.3-2.0	0.29	<0.01	
Pioche, NV	52	^{3}H in atm. m.[a]	0.39	-0.45	0.033	-
	52	^{3}H as HTO in air	3.5	-2.6	0.22	<0.01

(a) Concentrations of tritiated water vapor (HTO) in air are given in units of 10^{-12} µCi/mL (pCi/m^3) of water, while the activity of ^{3}H in atmospheric moisture is given in units of 10^{-6} µCi/mL (pCi/mL) of water.

(b) The concentration guides referenced are calculated from the ALI, listed in ICRP-30, and (where applicable) are based on the respiration rate of Standard Man, with the resulting guide being equal to the nonoccupational exposure guide of 25 mrem for exposure from radionuclides in air.

Table 5.23 (Offsite Tritium Results, cont.)

Sampling Location	Number of Samples Analyzed	Radio-nuclide	Radioactivity Concentration (10^{-12} µCi/mL)[a] Maximum	Minimum	Average	Percent of the Concentration Guide[b]
Rachel, NV	52	^{3}H in atm. m.[a]	0.62	-1.3	0.019	-
	52	^{3}H as HTO in air	4.2	-15	0.016	<0.01
Tonopah, NV	51	^{3}H in atm. m.[a]	0.59	-1.0	-0.017	-
	48	^{3}H as HTO in air	3.9	-7.1	-0.14	<0.01
Cedar City, UT	52	^{3}H in atm. m.[a]	0.60	-0.30	0.081	-
	52	^{3}H as HTO in air	4.9	-1.8	0.44	<0.01
St. George, UT	52	^{3}H in atm. m.[a]	0.50	-0.66	0.036	-
	52	^{3}H as HTO in air	7.8	-3.5	0.51	<0.01
Salt Lake City, UT	51	^{3}H in atm. m.[a]	0.72	-0.66	0.063	-
	51	^{3}H as HTO in air	4.2	-3.5	0.40	<0.01

(a) Concentrations of HTO in air are given in units of 10^{-12} µCi/mL (pCi/m^3) of water while the activity of ^{3}H in atmospheric moisture is given in units of 10^{-6} µCi/mL (pCi/mL) of water.

(b) The concentration guides referenced are calculated from the ALI, listed in ICRP-30, and (where applicable) are based on the respiration rate of Standard Man, with the resulting guide being equal to the nonoccupational exposure guide of 25 mrem for exposure from radionuclides in air.

the expected number (52) since samples are occasionally lost in the analysis process, an insufficient sample volume is collected for analysis, or a sample is lost or not collected due to equipment failure. Caliente, Nevada, has a low count for the number of samples processed because the noble gas sampler was not operational until mid-July. The measured ^{85}Kr concentrations ranged from 2.0 to 3.3 x 10^{-11} µCi/mL (0.74 to 1.2 Bq/m^3). Weekly network averages for ^{85}Kr concentrations (with two standard deviation error bars) measured in 1989 are shown in Figure 5.21.

The 1989 average concentration for the network was 2.65 x 10^{-11} µCi/mL (0.98 Bq/m^3). This network average concentration, as shown in Figure 5.22, has gradually increased from the time sampling began in 1972 to the present. This increase, observed at all stations, reflects the worldwide increase in ambient concentrations resulting from the increased use of nuclear technology. There is no evidence in the ^{85}Kr results to indicate that the radioactivity detected was from activities conducted at the NTS.

The analysis results for the 737 xenon samples counted were all below the Minimum Detectable Concentration (MDC), which varied, but was generally about 4.0 x 10^{-11} µCi/mL (1.48 Bq/m^3).

As in the past, ^{3}H concentrations in atmospheric moisture samples from the sampling stations were generally below the MDC of about 7.0 x 10^{-7} µCi/mL (0.026 Bq/mL) in water (Table 5.23). Of the 924

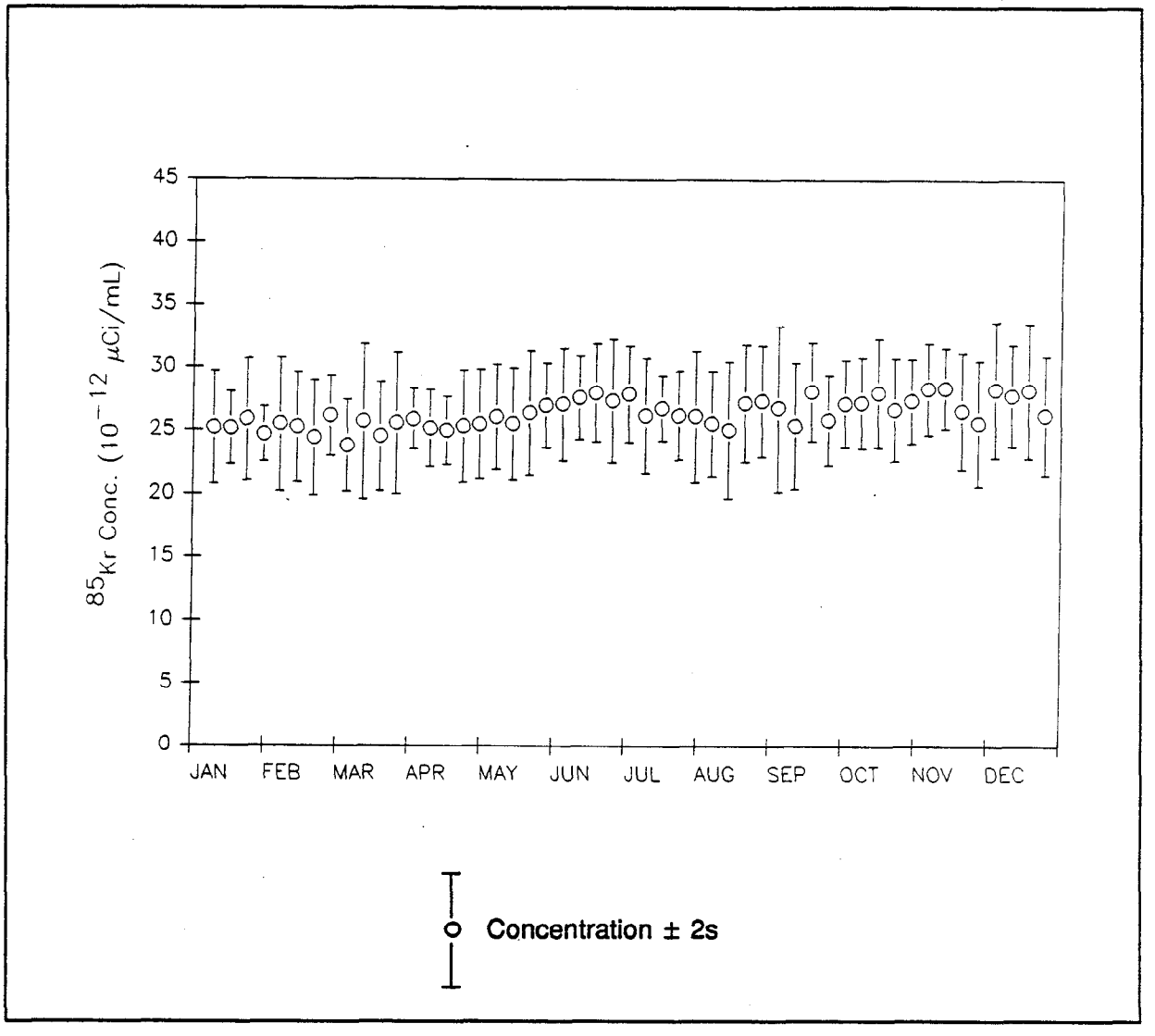


Figure 5.21 Network Weekly Average ^{85}Kr Concentrations in Air - 1989

network samples analyzed in 1989, only three slightly exceeded the MDC. Due to the statistical variations associated with counting radioactive samples, some samples may yield negative results, results between zero and the MDC, or some small percentage of the time even exceed the MDC, yielding a false positive indication. Results between zero and the MDC are not necessarily real but are below the sensitivity of the method. Results that slightly exceed the MDC may be true indicators of some slight elevation in activity levels or, as previously indicated, could be a result of statistical counting variations only. The range of ^{3}H concentrations observed at sampling stations was considered to be representative of statistical variations in counting background samples and not indicative of the presence of increased ^{3}H levels in the environment.

In conclusion, the sampling network found no detectable increase in noble gas or ^{3}H levels which could be attributed to activities at the NTS.

WATER MONITORING

The 33 wells on the NTS and a similar number of wells in areas near the NTS are part of the EPA's Long-Term Hydrological

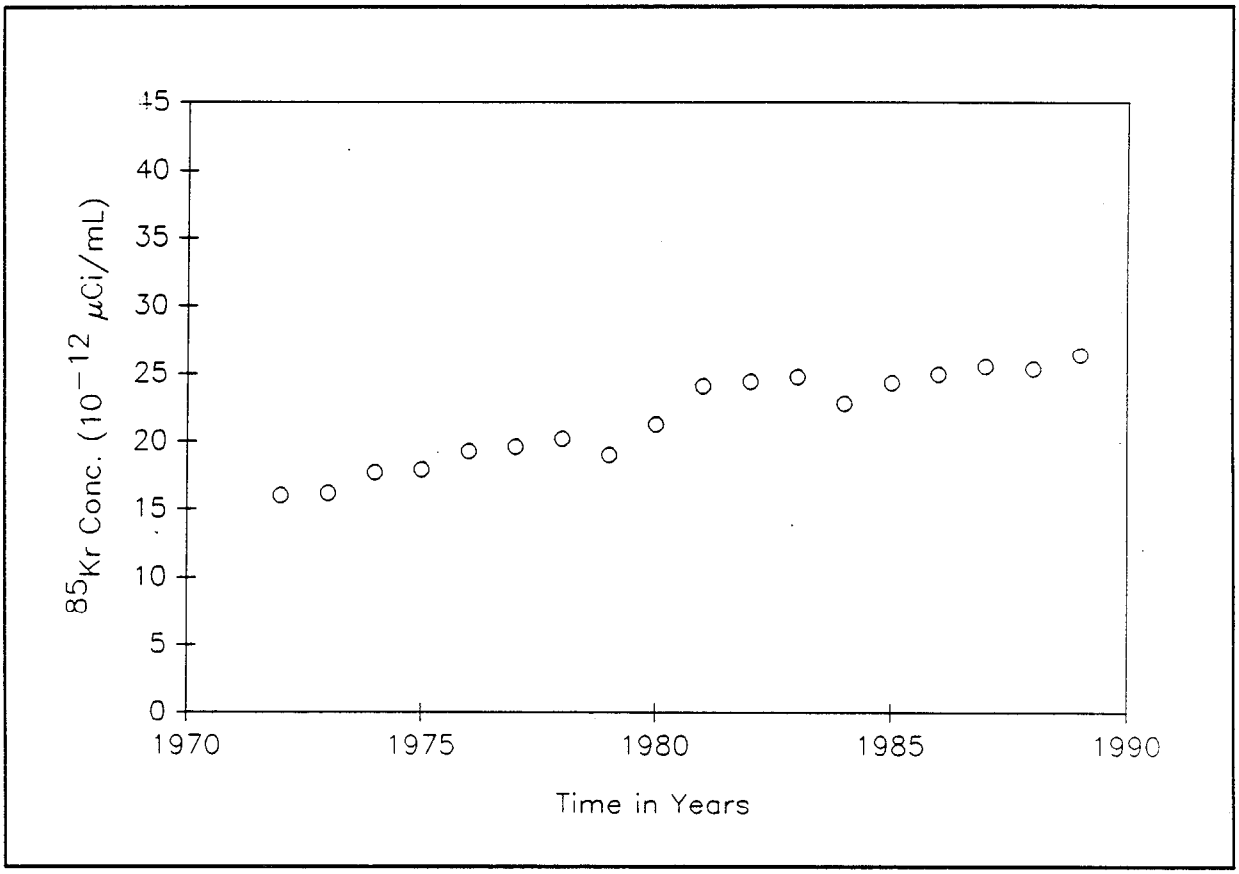


Figure 5.22 Annual Network Average ^{85}Kr Concentration - 1970-90

Monitoring Program (LTHMP) which is used to monitor surface water and groundwater on and off the NTS. These wells are shown in Figures 5.23 (onsite) and 5.24 (offsite).

Table 5.24 shows the maximum, minimum, and average ^{3}H concentrations found in the NTS wells that are sampled monthly. Table 5.25 contains the ^{3}H concentration in water samples collected from onsite and offsite water sources analyzed semi-annually.

Graphs of long-term ^{3}H trends for NTS wells are shown in Figures 5.25 and 5.26. The results for samples from Well UE-19c are typical of most deep water sources, i.e., no trend with time. The running average data show pulses that may represent surface water infiltration on about a 20-month cycle. Data from natural springs are similar, but the average concentration will be higher because of relatively rapid surface water recharge. For those water sources that had above-background levels of ^{3}H at earlier times, graphs such as those for Test Well B show a general downward trend with time. Other locations that follow this trend are Wells C and C-1 on the NTS. Only one 1989 sample, from Well UE-5n on the NTS, carried a ^{3}H concentration greater than one percent of the national drinking water regulation, i.e., greater than 2×10^{-7} µCi/mL. This well is not used as a drinking water supply well.

MILK SURVEILLANCE NETWORK

Although all samples collected for the MSN (Figure 5.27) and SMSN (Figure 5.28) were analyzed for gamma-emitting radionuclides, only naturally-occurring ^{40}K was detected for either network in any sample. Tritium was measured above the minimum detectable concentration in two samples from locations on the MSN (Inyokern, California, and Currant, Nevada) and from two locations on the SMSN (Delta, Colorado, and Fosston,

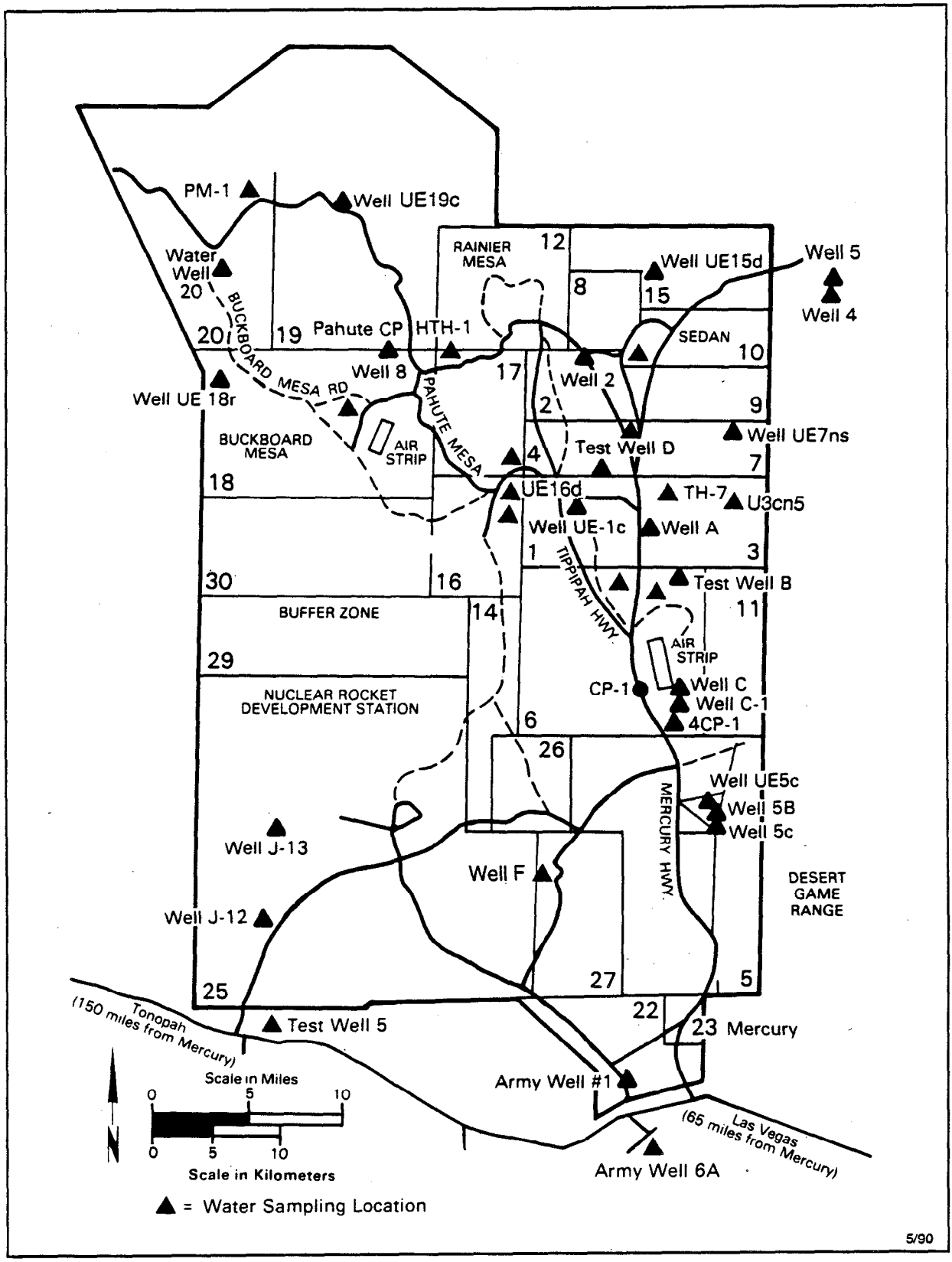


Figure 5.23 LTHMP Sampling Locations on the NTS - 1989

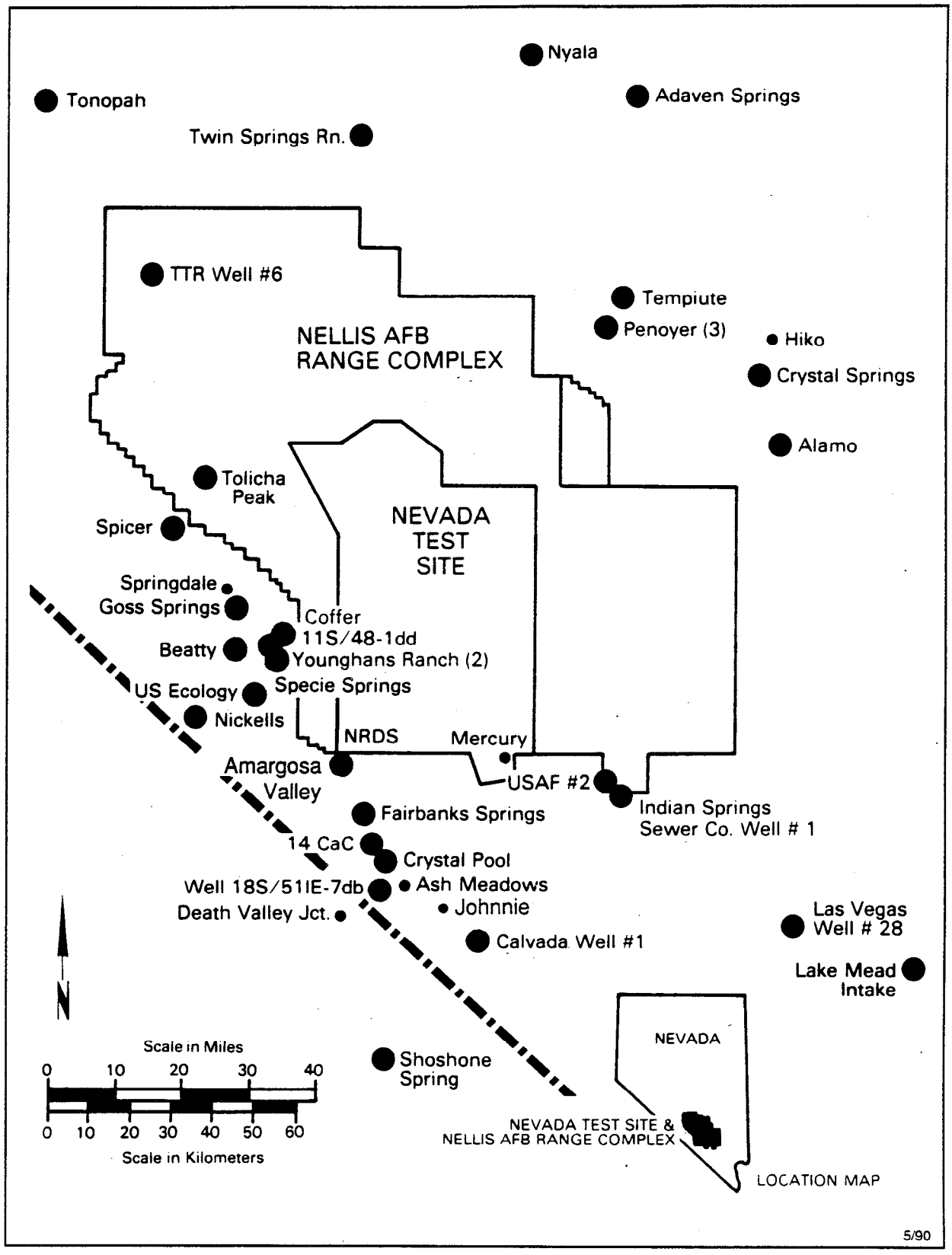


Figure 5.24 LTHMP Sampling Locations Near the NTS - 1989

Table 5.24 LTHMP Tritium Results for NTS Monthly Network - 1989

Sampling Location	Number of Samples Analyzed	Tritium Concentration (10^{-9} µCi/mL) Maximum	Minimum	Average	Percent of the Concentration Guide
Well 1 Army	13	5.9	-33	-4.7	<0.01
Well 2	12	5.0	-4.7	0.82	<0.01
Well 3[a]	2[a]	5.1	-4.4	0.36	<0.01
Well 4	12	4.7	-28	-2.2	<0.01
Well 4 CP-1	12	1.1	-26	-4.2	<0.01
Well 5	11	34	-11	2.9	0.01
Well 5C	12	2.9	-13	-2.3	<0.01
Well 8	12	3.3	-3.9	-0.33	<0.01
Well 20[b]	9[b]	3.6	-5.7	-1.3	<0.01
Well B Test	12	150	67	120	0.61
Well C	11	43	0.0	20	0.10
Well J-12	12	7.8	-25	-2.3	<0.01
Well J-13	12	27	-29	-0.25	<0.01
Well Ue19c	12	28	-5.0	2.8	0.01

(a) Replaced by Well 5.
(b) Samples not collected while pump inoperative.

Table 5.25 Tritium Results for the LTHMP NTS Semi-annual Network - 1989

Sampling Location	Collection Date	Tritium Concentration (10^{-9} µCi/mL) ± 2s	Percent of Concentration Guide
Shoshone, CA			
Shoshone Spring	01/04	17 ± 6	0.08
	07/11	200 ± 280[a]	-[b]
Adaven, NV			
Adaven Spring	07/06	83 ± 270[a]	-
Alamo, NV			
City Well 4	06/05	2 ± 6[a]	<0.01
	07/07	26 ± 7	0.13
Amargosa Valley, NV			
Crystal Pool	02/01	3.9 ± 6.6[a]	0.02
	09/07	38 ± 290	-

(a) Indicates results that are less than the MDC.

(b) The percent of the concentration guide is indeterminate for conventional analysis that is less than the MDC.

Table 5.25 (Tritium - LTHMP, cont.)

Sampling Location	Collection Date	Tritium Concentration (10^{-9} µCi/mL) ± 2s	Percent of Concentration Guide
Fairbanks Spring	02/17	-10 ± 6[a]	<0.01
	03/01	-5 ± 6[a]	<0.01
	09/07	0 ± 300[a]	- [b]
M. Nickell's Well	02/01	-1.1 ± 7.1[a]	<0.01
	06/08	-4 ± 7[a]	<0.01
15S-50E-18CDC	01/04	-1.8 ± 6.8[a]	<0.01
	06/06	-2.1 ± 6.8[a]	<0.01
17S-50E-14CAC	02/01	-1.1 ± 6.3[a]	<0.01
	09/07	-75 ± 290[a]	-
18S-51E-7DB	02/01	0 ± 6.7[a]	<0.01
	06/01	22 ± 290	-
Beatty, NV			
LLW Site	01/04	-0.9 ± 6.8[a]	<0.01
	09/07	NA	
Spicers Road D	02/01	-9 ± 6[a]	<0.01
	09/14	-130 ± 290[a]	-
Specie Springs	03/08	48 ± 7	0.24
	09/07	22 ± 290[a]	-
Tolicha Peak	02/01	7 ± 7[a]	<0.01
	09/26	140 ± 290[a]	---
Younghan's Ranch	01/05	-0.9 ± 7.6[a]	<0.01
	02/01	-3.9 ± 6.5[a]	<0.01
	03/09	-7 ± 7[a]	<0.01
11S-48-1DD Coffers	02/01	-5 ± 6.4[a]	<0.01
	08/02	-140 ± 290[a]	---
12S-47E-7DBD	04/06	-5.9 ± 6.4[a]	<0.01
	10/04	49 ± 290[a]	---
Boulder City, NV			
Lake Mead Intake	02/07	75 ± 7	0.38
	03/10	79 ± 7	0.39
	04/07	78 ± 7	0.39

(a) Indicates results that are less than the MDC.

(b) The percent of the concentration guide is indeterminate for conventional analysis that is less than the MDC.

Table 5.25 (Tritium - LTHMP, cont.)

Sampling Location	Collection Date	Tritium Concentration (10^{-9} µCi/mL) ± 2s	Percent of Concentration Guide
Clark's Station, NV	04/05	-2.1 ± 7.1[a]	<0.01
TTR Well 6	10/04	-53 ± 290[a]	-
Hiko, NV			
Crystal Springs	05/02	23 ± 7	0.12
	11/08	240 ± 290[a]	-
Indian Springs, NV			
Well 2, Air Force	01/05	4.4 ± 7.2[a]	<0.01
	11/06	75 ± 290[a]	-
Sewer Co. Well 1	01/03	-0.9 ± 6.9[a]	<0.01
	05/01	2 ± 6[a]	<0.01
	11/06	58 ± 290[a]	-
Johnnie, NV			
Johnnie Mine	08/01	2.9 ± 6.3[a]	<0.01
Las Vegas, NV			
Water Well 28	05/31	3 ± 6.6[a]	<0.01
	11/07	210 ± 290[a]	-
Nyala, NV			
Sharp's Ranch	06/06	-2.3 ± 6.8[a]	<0.01
Oasis Valley, NV			
Goss Springs	06/07	NA	
Pahrump, NV			
Calvada Well	06/01	3.6 ± 6.7[a]	<0.01
	07/11	32 ± 7	0.16
Rachel, NV			
Wells 7 & 8, Penoyer	02/01	112 ± 290[a]	-
	07/06	27 ± 6	0.14
Well 13, Penoyer	08/16	4.8 ± 6.3[a]	<0.01
Penoyer Culinary	07/06	27 ± 7	0.14
Tempiute, NV			
Union Carbide Well	08/09	-2 ± 6[a]	<0.01
Tonopah, NV			
City Well	08/02	2 ± 6[a]	<0.01

(a) Indicates results that are less than the MDC.

(b) The percent of the concentration guide is indeterminate for conventional analysis that is less than the MDC.

Table 5.25 (Tritium - LTHMP, cont.)

Sampling Location	Collection Date	Tritium Concentration (10^{-9} µCi/mL) ± 2s	Percent of Concentration Guide
Warm Springs, NV			
Twin Springs Ranch	08/01	2.2 ± 6.2[a]	<0.01
NTS (area)			
Well UE-1c (1)	02/14	-0.8 ± 6.3[a]	<0.01
	06/29	8 ± 300[a]	-
Well UE-1L (1)	01/19	12 ± 6	0.06
	06/29	Caved In	
Test Well 7 (3)	08/21	-180 ± 290[a]	-
Test Well D (4)	03/21	8 ± 6.3[a]	0.04
	09/06	9 ± 6.6[a]	0.04
Well UE-5c (5)	02/15	-3 ± 7[a]	<0.01
Well UE-5n	03/01	460 ± 9	2.3
Well UE-6e (6)	04/20	48 ± 7	0.24
Well C-1 (6)	02/15	2.5 ± 6.5[a]	0.01
	09/05	8.5 ± 6.3[a]	0.04
UE-10ITS #3 (10)	03/30	45 ± 230[a]	-
Well UE-15d (15)	01/10	100 ± 7	0.50
	02/15	83 ± 7	0.42
	08/09	79 ± 7	0.40
	11/02	58 ± 290[a]	-
Well UE-16d (16)	05/16	120 ± 280[a]	-
	08/09	-90 ± 290[a]	-
Well UE-16f (16)	01/25	9.2 ± 6.4[a]	0.05
	02/22	8.8 ± 6.6[a]	0.04
	11/08	89 ± 290[a]	-
Well UE-17a (17)	01/18	-2.6 ± 6.5[a]	<0.01
Well HTH #1 (17)	08/08	140 ± 8	0.70

(a) Indicates results that are less than the MDC.

(b) The percent of the concentration guide is indeterminate for conventional analysis that is less than the MDC.

Table 5.25 (Tritium - LTHMP, cont.)

Sampling Location	Collection Date	Tritium Concentration (10^{-9} µCi/mL) ± 2s	Percent of Concentration Guide
NTS, cont.			
Well UE-18r (18)	01/12	-5.9 ± 6.6[a]	<0.01
	05/17	4 ± 6.5[a]	0.02
Well UE-18t (18)	08/10	11 ± 6[a]	0.06
Army 6a (offsite)	07/12	26 ± 6	0.13

(a) Indicates results that are less than the MDC.

(b) The percent of the concentration guide is indeterminate for conventional analysis that is less than the MDC.

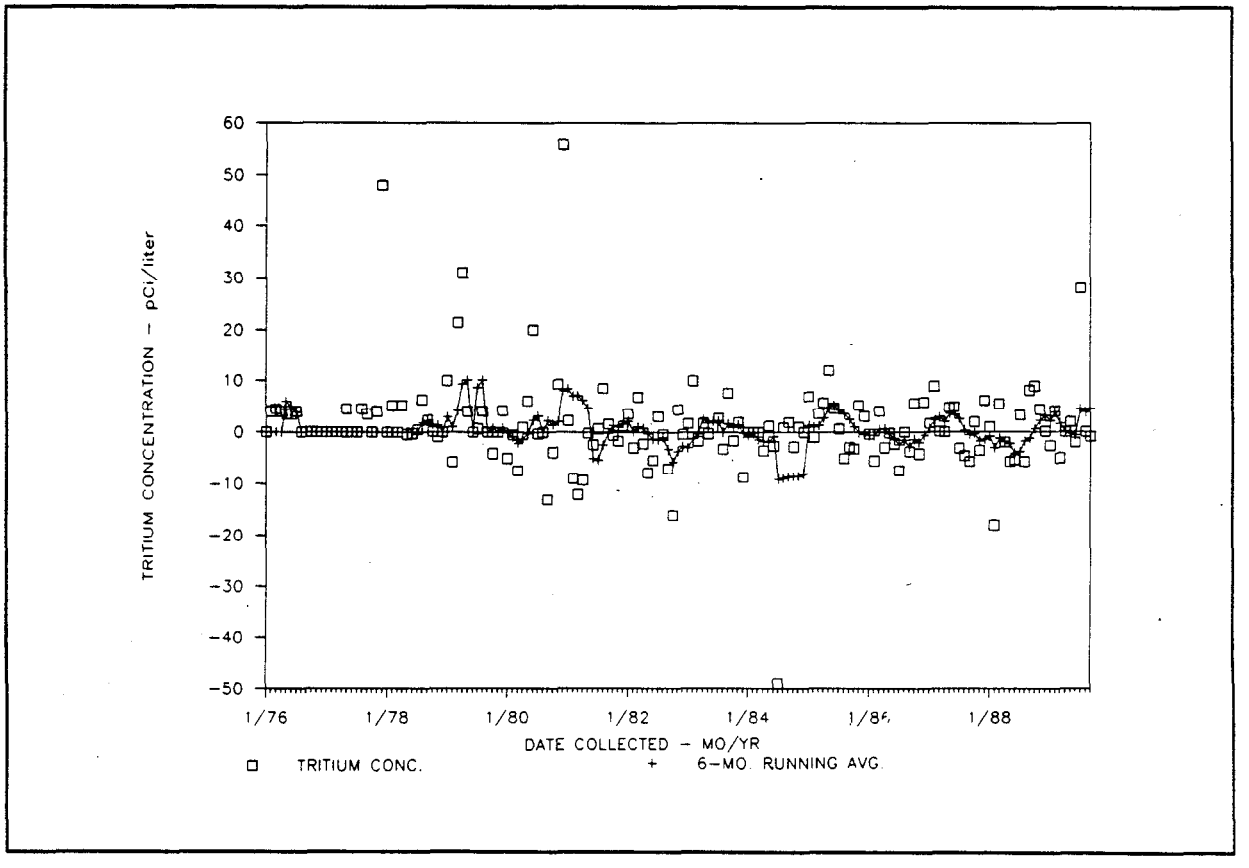


Figure 5.25 Typical Tritium Concentration in Deep Water Wells - 1989. *Tritium concentrations in Well UE-19c, Area 19, NTS*

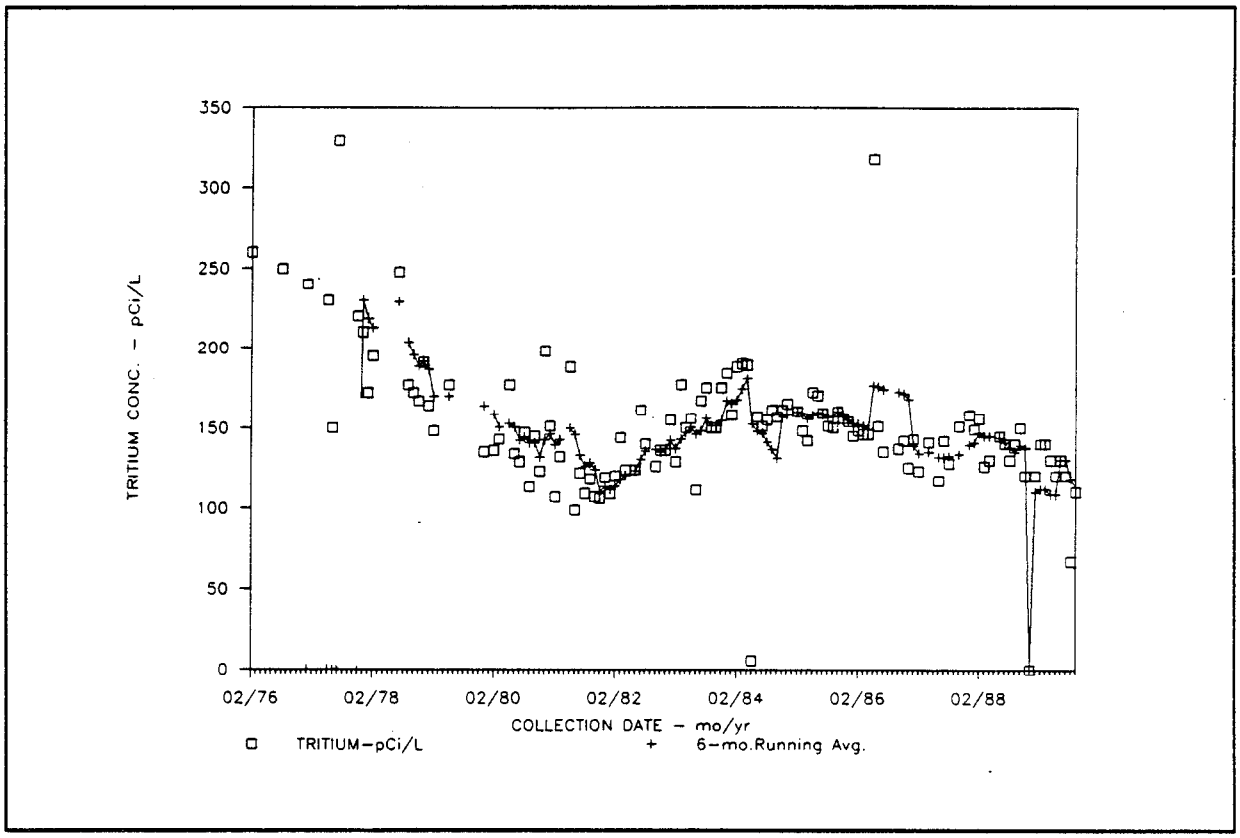


Figure 5.26 Wells with Higher Levels Early. *Tritium concentrations from Test Well B samples*

Minnesota). Radiostrontiums above the minimum detectable concentrations were measured in seven samples from six different locations during the year on the MSN. Eleven samples from the SMSN contained detectable radiostrontiums. Sampling results are in the 1990 EPA report for 1989 monitoring. (EPA 1990)

Analytical results from the monitoring of milk networks have been collected over many years, allowing for results to be compared over time. Figure 5.29 shows how levels of radioactive strontium (^{90}Sr) in Las Vegas, Salt Lake City, and New Orleans have decreased since the 1960s, when atmospheric weapons testing was conducted in locations worldwide. These analyses were performed on the Pasteurized Milk Network operated by the EPA's Eastern Environmental Radiation Facility in Montgomery, Alabama. No results for 1988 or 1989 were available for Salt Lake City. Results from the New Orleans samples have been consistently higher over the years and reflect a greater soil inventory of radiostrontiums from atmospheric testing as a result of weather patterns and precipitation.

BIOMONITORING

Collection sites for animal tissue sampled in late 1988 and 1989 are shown in Figure 5.30. The results obtained from analysis of the animal tissues are shown in Tables 5.26 and 5.27. Other than naturally-occurring ^{40}K, only one of the 107 samples had a detectable gamma emitter; the concentration of ^{137}Cs in a cow liver sample, which was 0.028 ± 0.016 pCi/g.

The results of radiochemical analyses are reported as the median and range of concentrations detected in ashed samples. All of the ^{90}Sr levels in the 24 bone samples were above the MDC, but only one of the ^{238}Pu results was above the

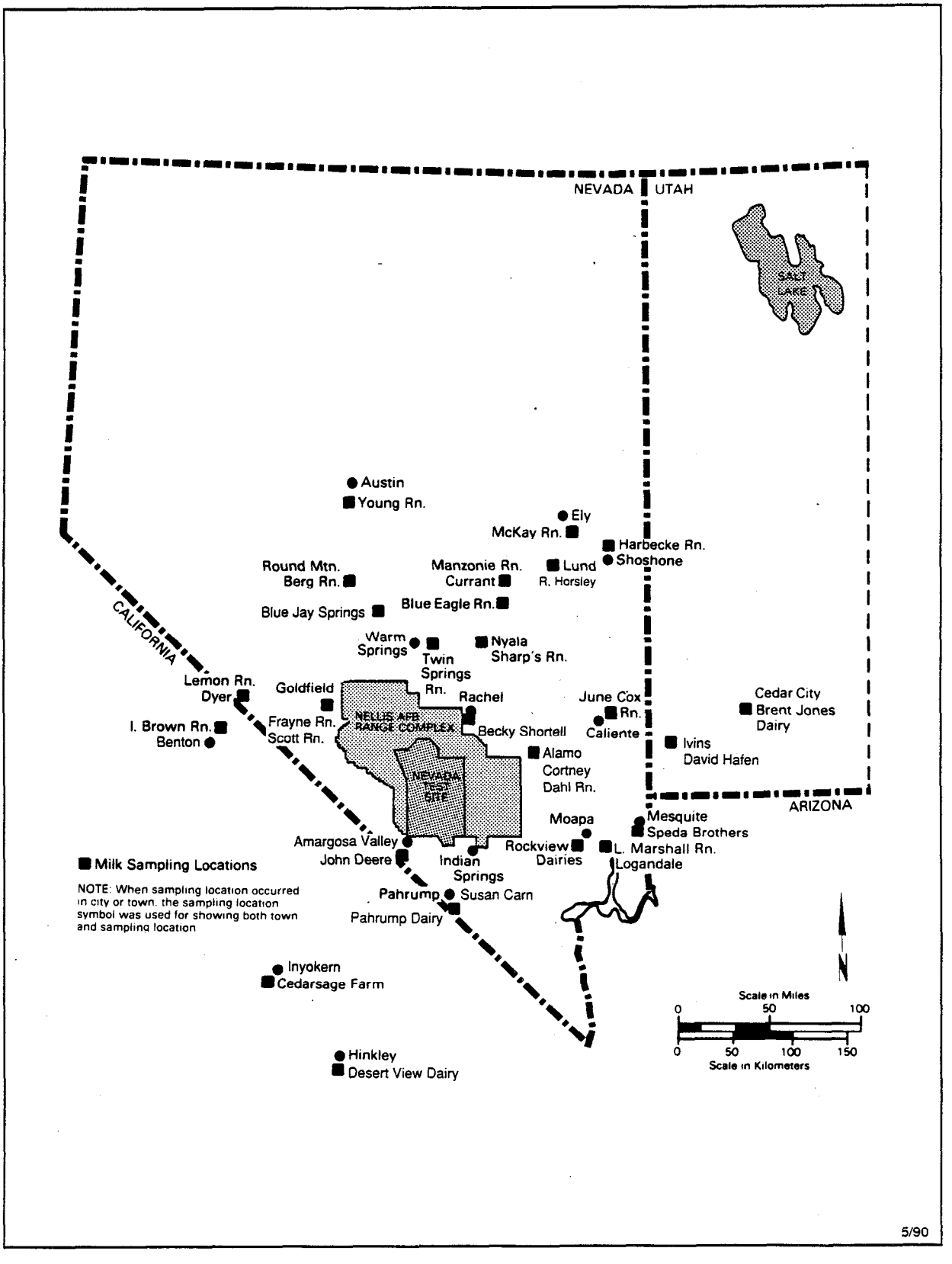


Figure 5.27 Milk Sampling Locations within 300 Kilometers of the NTS Control Point

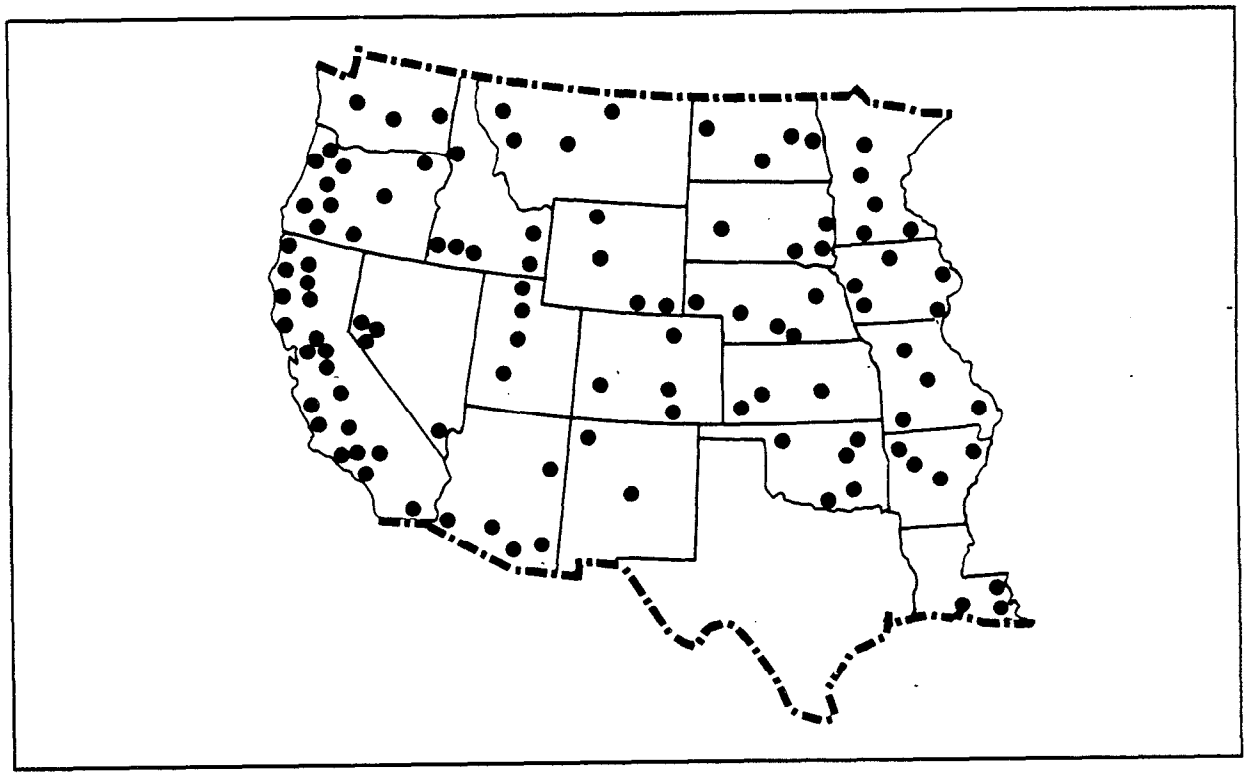


Figure 5.28 Standby Milk Surveillance Network Stations

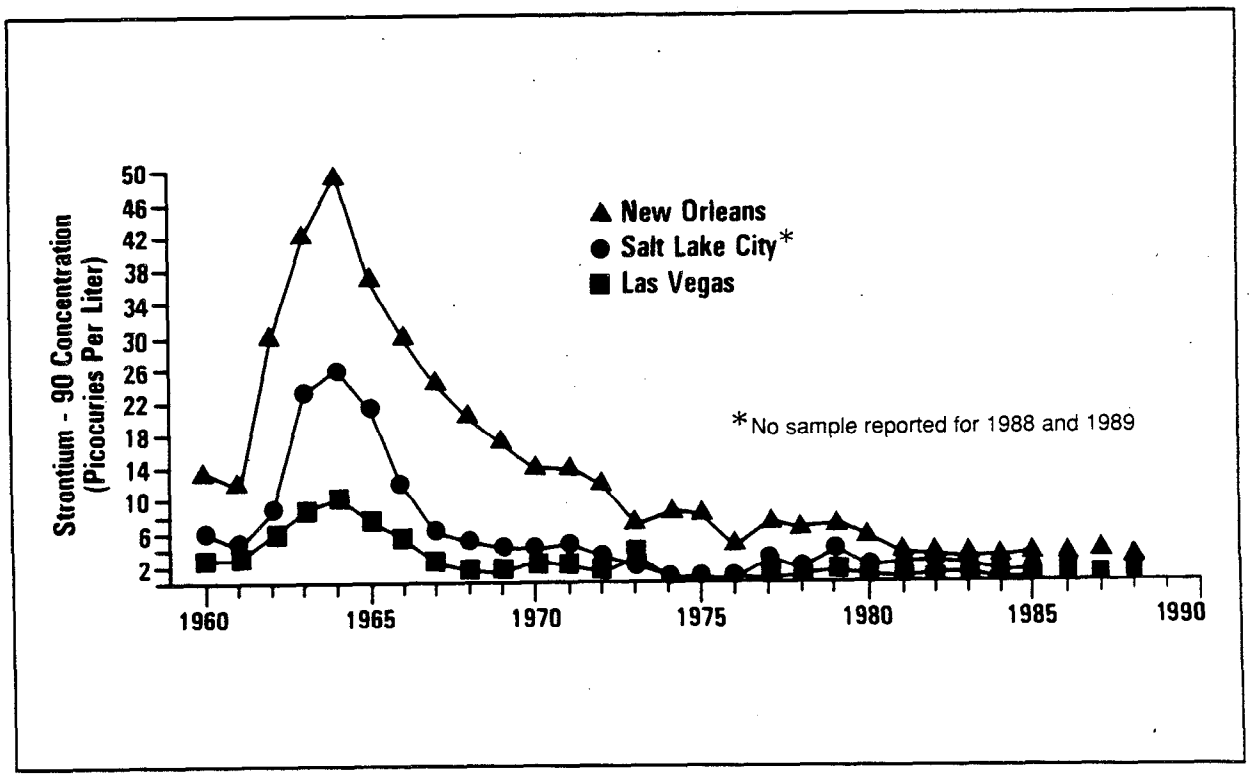


Figure 5.29 Concentrations of ^{90}Sr in Pasteurized Milk Network Samples - 1960-89

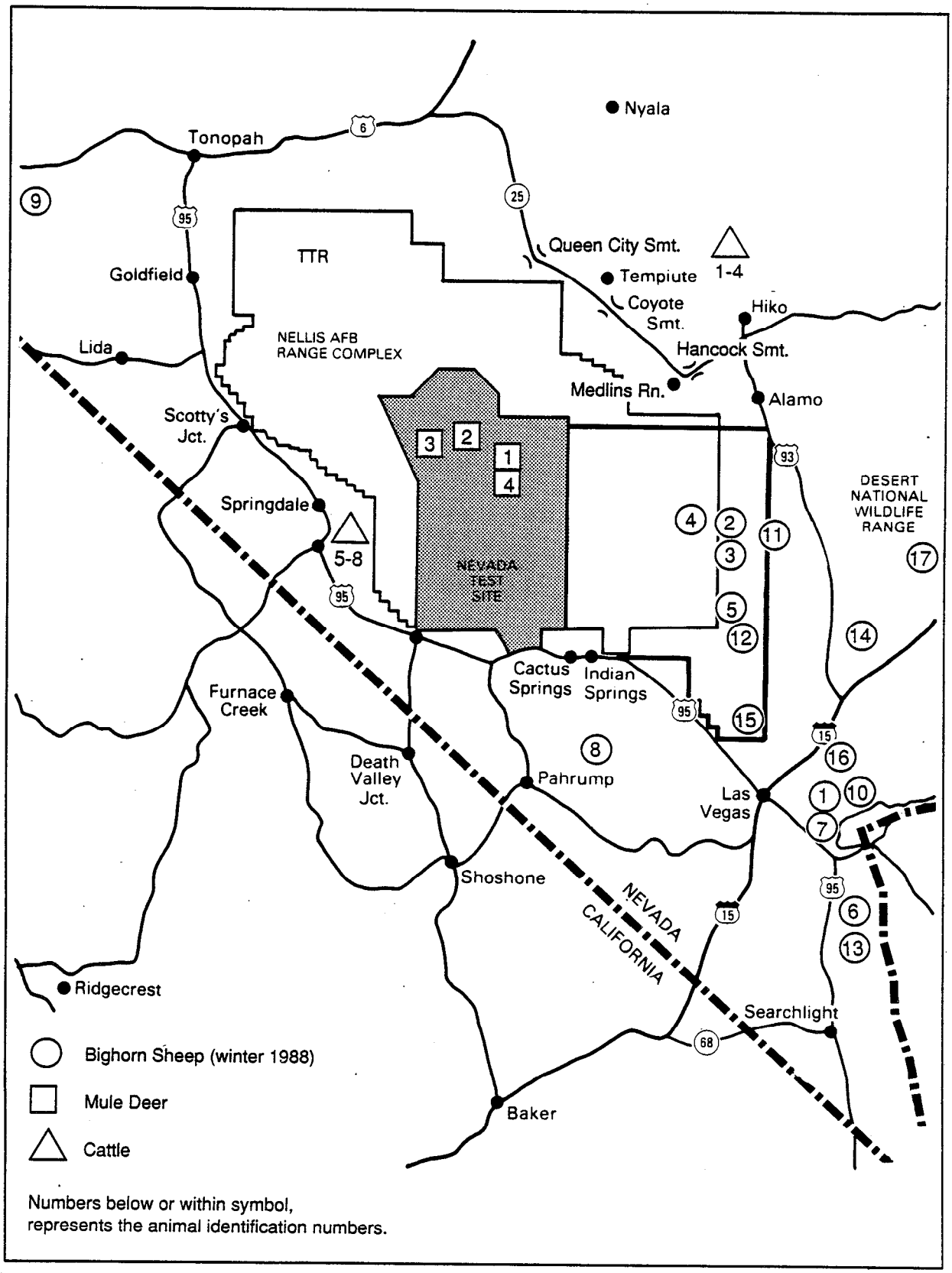


Figure 5.30 Collection Sites for Animals Sampled

Table 5.26 Radionuclide Concentrations in Desert Bighorn Sheep Samples - 1988

Bighorn Sheep (Collected in the Winter of 1988)	Percent Ash	Bone ^{90}Sr Concentration ± 2s (pCi/g Ash)	Bone ^{238}Pu Concentration ± 2s (10^{-3} pCi/g Ash)	Bone $^{239+240}Pu$ Concentration ± 2s (10^{-3} pCi/g Ash)	Kidney ^{3}H Concentration ± 2s (10^{-6} µCi/mL)[a]
1	21	0.06 ± 0.02	2.4 ± 5.5[b]	0.6 ± 1.3[b]	160 ± 350[b]
2	32	0.1 ± 0.03	7.9 ± 9.8[b]	1.1 ± 1.5[b]	-240 ± 350[b]
3	25	1.8 ± 0.09	4.8 ± 6.1[b]	0.4 ± 1.3[b]	1 ± 340[b]
4	28	1.3 ± 0.08	1.8 ± 5.7[b]	5.3 ± 3.1	150 ± 340
5	33	1.4 ± 0.08	0.6 ± 5.7[b]	0.8 ± 1.6[b]	NC
6	29	0.1 ± 0.04	5.0 ± 6.0[b]	0.7 ± 1.4[b]	180 ± 340[b]
7	28	0.3 ± 0.02	5.0 ± 6.1[b]	0.7 ± 1.4[b]	520 ± 350
8	NC	NC	NC	NC	540 ± 350
9	39	1.4 ± 0.1	5.6 ± 6.0[b]	3.1 ± 2.3	NC
10	NC	NC	NC	NC	1 ± 300[b]
11	37	1.8 ± 0.1	1.7 ± 5.4[b]	1.3 ± 1.7[b]	-380 ± 340[b]
12	37	1.4 ± 0.08	2.4 ± 5.2[b]	2.4 ± 2.0	400 ± 350
13	26	0.2 ± 0.08	5.1 ± 6.5[b]	2.1 ± 2.2[b]	1 ± 300[b]
14	21	1.2 ± 0.08	3.6 ± 6.9[b]	7.6 ± 4.2[b]	330 ± 350[b]
15	26	0.1 ± 0.	-0.5 ± 5.1[b]	2.8 ± 2.2	590 ± 350
16	35	0.6 ± 0.1	3.1 ± 5.5[b]	0.9 ± 1.5[b]	580 ± 350
17	NC	NC	NC	NC	400 ± 350
Median	28.5	0.9	3.35	1.2	180
Range	21 - 39	0.06 - 1.8	-0.5 - 7.9	0.4 - 7.6	-380 - 590

NC = Not collected

(a) Aqueous portion of kidney tissue.
(b) Counting error exceeds reported activity.

Table 5.27 Radiochemical Results For Animal Samples

Sample Type (Number)	Ash/fresh Wt. Ratio	^{90}Sr pCi/g Median (Range)	^{238}Pu pCi/g Median (Range)	$^{239+240}Pu$ pCi/g Median (Range)	^{3}H pCi/L Median (Range)
Cattle Blood (8)					420 (100;600)
Cattle Liver (8)	0.011		0.0023 (-0.0034;0.0096)	0.0081 (-0.046;0.025)	
Deer Muscle (3)	0.010		0.0017 (0.001;0.0042)	0.0024 (0.0001;0.0053)	
Deer Lung (3)	0.012		0.0087 (0.0004;0.016)	0.010 (0.0044;0.012)	
Deer Liver (3)	0.012		0.0018 (0.0001;0.0067)	0.0068 (0.0056;0.018)	

Table 5.27 (Animal Samples, cont.)

Sample Type (Number)	Ash/fresh Wt. Ratio	^{90}Sr pCi/g Median (Range)	^{238}Pu pCi/g Median (Range)	$^{239+240}$Pu pCi/g Median (Range)	^{3}H pCi/L Median (Range)
Deer Rumen Cont (3)	0.019		0.010 (0.005;0.013)	0.040 (0.040;0.040)	
Deer Blood (4)			-	-	15,000 (1;580,000)
Deer Bone (3)	0.327	1.2 (1.0,1.4)	0.002 (-0.0001;0.012)	0.0017 (0.0013;0.0020)	
Cattle Bone (7)[a]	0.195	0.8 (0.4,1.0)	0.0009 (-0.0001;0.0048)	0.0016 (0.0007;0.0033)	
Sheep Bone (14)	0.285	0.9 (0.06,1.8)	0.0034 (-0.0005;0.0079)	0.0012 (0.0004;0.0076)	
Sheep Kidney (15)					180 (-380;590)

(a) One cattle sample was lost.

MDC. There were 10 detectable $^{239+240}$Pu results; one in a cow bone sample and five in cow liver samples, although the maximum concentration was only 0.025 pCi/g ash. There were also two detectable concentrations in deer lung samples and three in deer rumen content samples as might be expected for animals that graze on the NTS. A graph of the average ^{90}Sr in bone from 1955 to date is shown in Figure 5.31. The 1989 data fit the pattern.

The ^{3}H analysis of cow blood samples and bighorn sheep kidney samples showed only background levels, median values were <400 pCi/L, as is found in surface waters in this area. The blood samples from the deer, however, contained elevated levels of ^{3}H (a maximum of 580,000 pCi/L) due to the deer having access to the tunnel drainage ponds on the NTS. The unfenced NTS tunnel drainage ponds of Area 12 continue to be a potential source of exposure to the offsite population, which may consume meat from mule deer or migratory fowl that may have drunk from those ponds.

During the Summer of 1989, samples of produce were collected from farms in Utah and Nevada. Carrots and tomatoes were collected from Virgin, Utah; beets and grapes from St. George, Utah; potatoes, zucchini squash, swiss chard, and turnips from Rachel, Nevada; and squash and potatoes from Hiko, Nevada. Other than naturally-occurring ^{40}K, there were no detectable gamma emitters, and none of the samples had a ^{3}H, ^{90}Sr, or ^{238}Pu concentration that exceeded the MDC. There was only one sample, the swiss chard from Rachel, Nevada, that had a detectable $^{239+240}$Pu concentration (0.017 ± 0.013 pCi/g ash). This may have been due to incomplete washing of the soil from the sample.

EXTERNAL GAMMA EXPOSURE MONITORING

Annual exposures measured at fixed environmental stations (Figure 5.32) ranged from 17 to 316 mR, with a mean of 66 ± 32 mR. The extremes occurred at the University of Nevada, Las Vegas (UNLV), and Warm Springs, Nevada, fixed monitoring locations, respectively.

The maximum net annual exposure of 316 mR at Warm Springs #2, Nevada, was

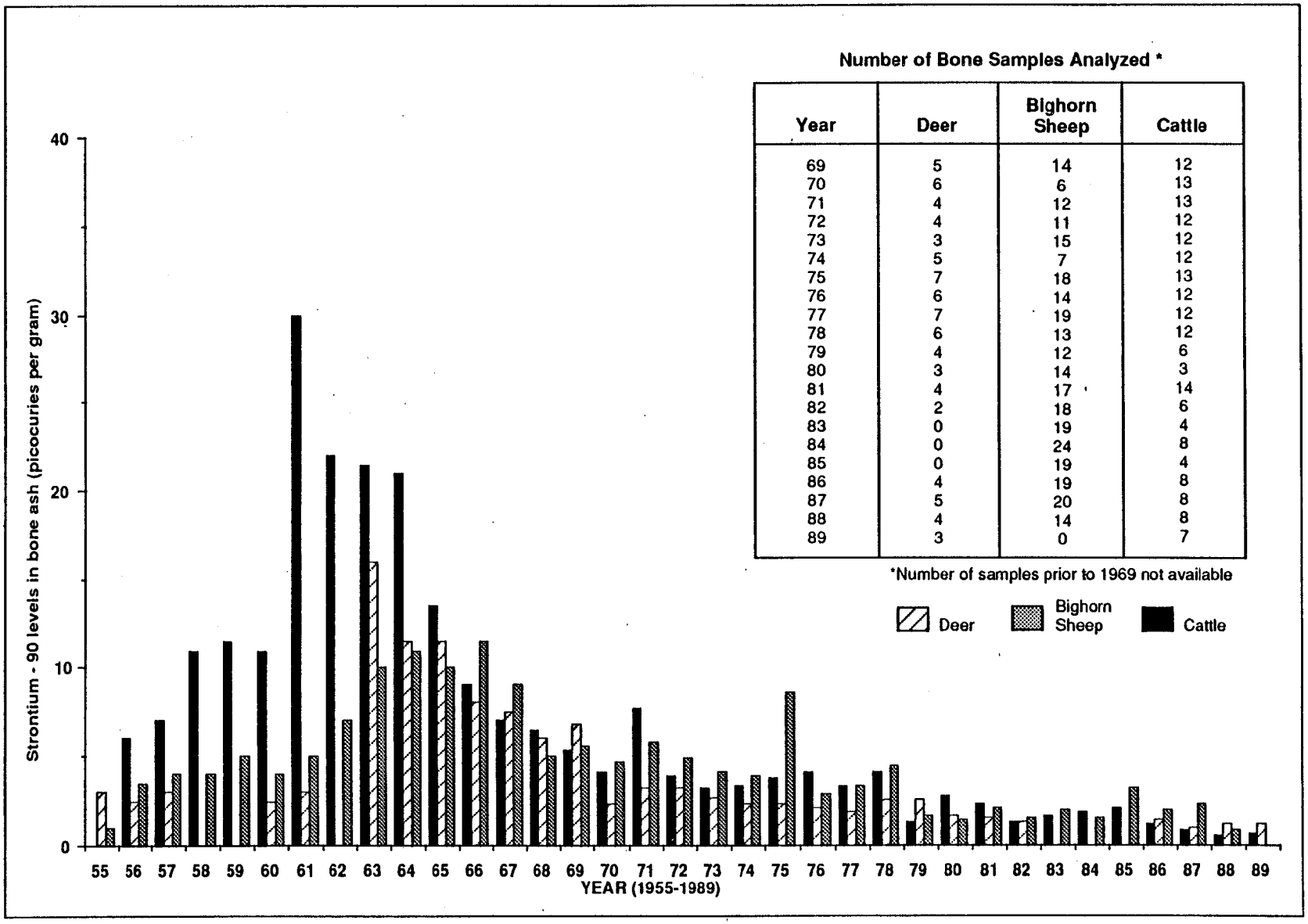


Figure 5.31 Average ^{90}Sr Concentrations in Animal Bone Ash - 1955-89

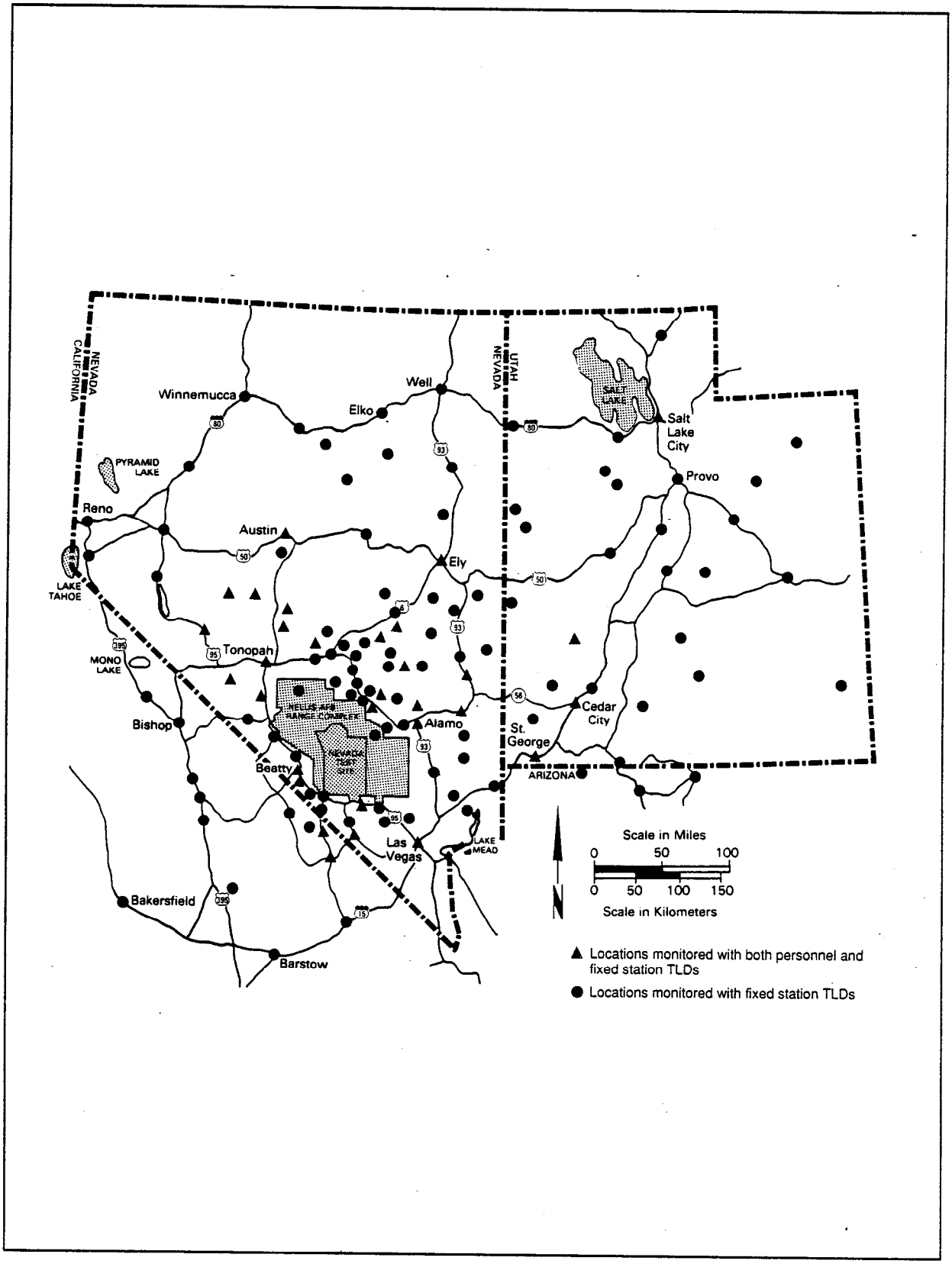


Figure 5.32 Locations Monitored with TLDs

determined to be due to high levels of naturally-occurring radioactive material in spring water at that location (EPA 1990). A second TLD, Warm Springs #1, Nevada, is located in a parking lot approximately 100 feet from the spring. This TLD showed results consistent with historical data from this site. Table 5.28 details the results obtained at each of the fixed environmental stations monitored by TLDs during 1989.

Table 5.29 and Figure 5.33 summarize the range of ambient gamma radiation levels at fixed environmental station locations. These data illustrate that, when the result from Warm Springs #2 is excluded so that the overall network data are more representative of potential NTS-related radioactivity, the means and ranges of measured ambient gamma exposures are very similar throughout the geographic area covered by this network.

Annual exposures at fixed environmental stations were evaluated to determine historical trends. Data for past years were taken from previous annual reports of the offsite monitoring program. Data for 1989 showed no statistically significant variation in annual ambient gamma exposure levels from those reported in previous years dating back to 1973. No statistically significant variation based on state or other location criterion was noted in the historic data. Figure 5.34 illustrates the average ± 2s annual exposures obtained at all fixed monitoring stations in each year since 1971.

A noticeable decrease in annual exposure levels occurred in 1974. Based on the best available information, this apparent decrease is most likely due primarily to a combination of switching from bulb-type dosimeters to the Harshaw TLD system in 1974 and to a general decline in global fallout as also noted by other monitoring networks. Overlaid upon the data in Figure 5.34 is a shaded box illustrating the range of natural background exposures in the U.S. due to cosmic and terrestrial radiations (Oakley 1972). This overlay illustrates that the ambient gamma exposures measured by TLDs at fixed environmental stations as part of this network were within the range of exposures anticipated throughout the U.S. due to "natural background."

Of 65 offsite residents monitored with personal TLDs, 60 showed zero detectable exposure above that measured at the associated reference background location.

The apparent individual exposures were slightly greater than the associated reference background. These ranged from 16 to 48 mrem absorbed dose equivalent for the year. Each of these represented total exposures obtained from several dosimeters worn during the year. Apparent exposures to an individual dosimeter of less than three times the associated reference background are considered to be within the range of normal variation for the TLD system. Therefore, none of the apparent net individual exposures are considered to represent an abnormal occurrence. Table 5.30 lists the results of offsite personnel TLD monitoring for 1989, and Table 5.31 provides a statistical summary of those data. Figure 5.35 summarizes the TLD monitoring results for offsite residents living in California, Nevada, and Utah. There was no statistically significant difference between the states in the recorded minima, maxima, or means.

The stations of the external gamma exposure rate monitoring network, or Pressurized Ion Chamber (PIC) network, are shown in Figure 5.36. Data for 1989 are displayed in Table 5.32 as the average μR/hr and annual mR/year from each station. Figure 5.37 shows annual averages for each location in mR/year as compared to the maximum and minimum U.S. background (BEIR 1980). The averages of the 27 PICs varied from 51.7 mR/year at Las Vegas, Nevada, to 164.7 mR/year at Austin, Nevada. The U.S. background maximum and minimum values shown represent the highest and lowest values, respectively, of the combined terrestrial and cosmic components of environmental gamma radiation exposure.

The 1989 PIC data is consistent with previous year trends. No prolonged unexplained deviations from background levels occurred during 1989. When calculated TLD exposures were compared with results obtained from collocated PICs, a uniform under-response of TLD versus

Table 5.28 Offsite Station TLD Results - 1989

Station Location	Measurement Period: Issue Date	Measurement Period: Collect Date	Elapsed Time (days)	Measured Daily Exp. Equivalent (mR/day): Max.	Min.	Avg.	Gamma Exposure (mR/yr ± 2s)[a]
Arizona							
Colorado City	11/01/88	11/06/89	370	0.16	0.10	0.12	44 ± 9
Jacob's Lake	11/01/88	11/06/89	370	0.22	0.15	0.19	68 ± 11
Page	11/01/88	11/07/89	371	0.13	0.09	0.11	40 ± 6
California							
Baker	11/02/88	11/07/89	370	0.20	0.12	0.17	64 ± 12
Barstow	11/02/88	11/07/89	370	0.29	0.18	0.24	88 ± 17
Bishop	11/02/88	11/14/89	377	0.27	0.18	0.23	83 ± 14
Death Valley Junction	01/06/89	01/05/90	364	0.22	0.16	0.18	65 ± 9
Furnace Creek	01/06/89	01/05/90	364	0.15	0.12	0.13	48 ± 5
Independence	11/02/88	11/08/89	371	0.20	0.17	0.19	69 ± 5
Lone Pine	11/02/88	11/08/89	371	0.21	0.15	0.18	67 ± 9
Mammoth Geothermal	11/02/88	11/14/89	377	0.25	0.18	0.23	83 ± 11
Mammoth Lakes	11/02/88	11/14/89	377	0.25	0.16	0.21	78 ± 14
Olancha	11/02/88	11/08/89	371	0.22	0.15	0.19	68 ± 11
Ridgecrest	11/02/88	11/08/89	371	0.19	0.14	0.17	61 ± 8
Shoshone	11/01/88	11/07/89	371	0.15	0.11	0.14	50 ± 6
Valley Crest	01/06/89	01/05/90	364	0.10	0.08	0.08	30 ± 3
Nevada							
Alamo	11/03/88	11/01/89	363	0.22	0.14	0.18	66 ± 12
American Borate	01/04/89	01/02/90	363	0.23	0.20	0.22	79 ± 5
Atlanta Mine	12/01/88	12/01/89	365	0.17	0.13	0.15	56 ± 6
Austin	11/22/88	11/08/89	351	0.31	0.21	0.27	100 ± 14
Battle Mountain	11/29/88	12/13/89	379	0.17	0.14	0.16	58 ± 5
Beatty	01/04/89	01/04/90	365	0.29	0.22	0.24	89 ± 11
Blue Eagle Ranch	01/04/89	01/03/90	364	0.14	0.10	0.12	43 ± 6
Blue Jay	01/05/89	01/04/90	364	0.32	0.23	0.26	96 ± 14
Caliente	11/01/88	11/01/89	365	0.22	0.15	0.19	68 ± 10
Carp	11/03/88	11/01/89	363	0.19	0.12	0.16	59 ± 10
Cactus Springs	11/01/88	11/06/89	370	0.11	0.07	0.10	35 ± 6
Cherry Creek	12/01/88	11/29/89	363	0.22	0.19	0.21	77 ± 5
Clark Station	01/04/89	01/03/90	364	0.28	0.21	0.23	86 ± 11
Coaldale	11/08/88	11/07/89	364	0.27	0.21	0.23	83 ± 9
Complex 1	11/02/88	11/01/89	364	0.27	0.17	0.23	83 ± 15
Corn Creek	11/01/88	11/06/89	370	0.07	0.06	0.07	24 ± 2
Cortez Rd/Hwy 278	11/29/88	12/12/89	378	0.26	0.20	0.23	85 ± 9
Coyote Summit	11/03/88	11/01/89	363	0.27	0.20	0.24	87 ± 10
Crescent Valley	11/29/88	12/12/89	378	0.17	0.14	0.16	59 ± 5
Crystal	11/01/88	01/30/89	90	0.09	0.09	0.09	34 ± 0
Currant	01/05/89	01/04/90	364	0.24	0.18	0.21	75 ± 9
Currie	12/01/88	11/29/89	363	0.23	0.20	0.21	77 ± 5

(a) mR/yr = Average mR/day x 365 days

Table 5.28 (Offsite TLDs, cont.)

Station Location	Measurement Period: Issue Date	Measurement Period: Collect Date	Elapsed Time (days)	Measured Daily Exp. Equivalent (mR/day): Max.	Min.	Avg.	Gamma Exposure (mR/yr ± 2s)[a]
Nevada, cont.							
Diablo Maintenance Station	01/06/89	01/05/90	364	0.31	0.21	0.26	94 ± 15
Duckwater	01/05/89	01/04/90	364	0.22	0.17	0.19	71 ± 7
Elgin	11/03/88	11/01/89	363	0.71	0.24	0.39	143 ± 71
Elko	11/29/88	12/12/89	378	0.15	0.13	0.14	52 ± 3
Ely	12/01/88	11/29/89	363	0.19	0.15	0.16	58 ± 6
Eureka	01/05/89	01/04/90	364	0.39	0.19	0.25	93 ± 31
Fallon	12/01/88	12/14/89	378	0.16	0.13	0.15	54 ± 5
Flying Diamond Camp	11/02/88	11/01/89	364	0.16	0.13	0.14	52 ± 5
Gabbs	11/16/88	11/07/89	356	0.17	0.11	0.13	49 ± 9
Geyser Ranch	12/01/88	12/01/89	365	0.22	0.17	0.20	73 ± 8
Goldfield	11/07/88	11/09/89	367	0.22	0.07	0.16	60 ± 23
Groom Lake	11/08/88	11/13/89	370	0.18	0.13	0.17	61 ± 8
Halloway Ranch	01/05/89	03/03/89	57	0.08	0.08	0.08	30 ± 0
Hancock Summit	11/03/88	11/01/89	363	0.66	0.31	0.43	156 ± 53
Hiko	11/03/88	11/01/89	363	0.29	0.11	0.18	64 ± 27
Hot Creek Ranch	01/05/89	01/04/90	364	0.20	0.15	0.18	64 ± 7
Indian Springs	11/01/88	11/06/89	370	0.09	0.07	0.08	29 ± 3
Ione	11/16/88	11/07/89	356	0.22	0.19	0.20	74 ± 4
Kirkeby Ranch	12/01/88	12/01/89	365	0.17	0.11	0.14	52 ± 9
Koyne's Ranch	11/03/88	11/01/89	363	0.21	0.15	0.18	66 ± 9
Las Vegas Airport	01/03/89	01/02/90	364	0.09	0.03	0.07	24 ± 9
Las Vegas (UNLV)	01/03/89	01/02/90	364	0.06	0.01	0.05	17 ± 8
Las Vegas (USDI)	01/03/89	01/02/90	364	0.12	0.07	0.10	37 ± 7
Lathrop Wells	01/04/89	01/02/90	363	0.21	0.17	0.19	69 ± 6
Lavada's Market	01/04/89	01/04/90	365	0.21	0.16	0.18	66 ± 8
Lida	11/08/88	11/01/89	358	0.21	0.17	0.19	71 ± 6
Lovelock	11/30/88	12/13/89	378	0.15	0.13	0.14	52 ± 3
Lund	12/01/88	11/30/89	364	0.17	0.15	0.16	60 ± 3
Manhattan	11/17/88	11/08/89	356	0.29	0.24	0.26	95 ± 7
Medlin's Ranch	11/01/88	11/01/89	365	0.26	0.17	0.22	82 ± 13
Mesquite	11/01/88	11/02/89	366	0.12	0.08	0.10	37 ± 6
Mina	11/16/88	11/07/89	356	0.22	0.17	0.19	69 ± 7
Moapa	11/01/88	11/02/89	366	0.20	0.08	0.15	54 ± 18
Mountain Meadows Ranch	01/04/89	01/03/90	364	0.15	0.11	0.12	45 ± 6
Nash Ranch	11/03/88	11/01/89	363	0.18	0.09	0.14	52 ± 13
Nevada LLW Site	03/22/89	01/04/90	288	0.60	0.23	0.34	123 ± 45
Nyala	01/04/89	01/03/90	364	0.18	0.15	0.16	59 ± 5
Overton	11/01/88	11/02/89	366	0.13	0.10	0.12	43 ± 5
Pahrump	11/01/88	11/06/89	370	0.09	0.06	0.08	27 ± 5
Penoyer Farms	11/02/88	11/01/89	364	0.29	0.20	0.25	90 ± 13
Pine Creek Ranch	11/03/88	11/01/89	363	0.30	0.21	0.26	95 ± 13
Pioche	11/01/88	11/01/89	365	0.19	0.14	0.16	60 ± 8

(a) mR/yr = Average mR/day x 365 days

Table 5.28 (Offsite TLDs, cont.)

Station Location	Measurement Period: Issue Date	Measurement Period: Collect Date	Elapsed Time (days)	Measured Daily Exp. Equivalent (mR/day): Max.	Min.	Avg.	Gamma Exposure (mR/yr ± 2s)[a]
Nevada, cont.							
Queen City Summit	01/06/89	01/05/90	364	0.30	0.26	0.28	101 ± 6
Rachel	11/03/88	11/01/89	363	0.27	0.19	0.23	85 ± 12
Reed Ranch	01/06/89	01/05/90	364	0.29	0.22	0.24	89 ± 11
Reno	11/30/88	12/14/89	379	0.15	0.13	0.14	52 ± 3
Round Mountain	11/14/88	11/08/89	359	0.25	0.14	0.22	79 ± 17
Ruby Valley	11/29/88	12/12/89	378	0.25	0.18	0.22	81 ± 11
South Desert Correctional Center	11/01/88	11/06/89	370	0.09	0.05	0.07	25 ± 6
Shurz	12/01/88	12/14/89	378	0.24	0.19	0.22	79 ± 8
Silver Peak	11/16/88	11/07/89	356	0.22	0.15	0.19	69 ± 10
Springdale	01/05/89	01/04/90	364	0.27	0.21	0.24	87 ± 9
Steward Ranch	12/01/88	12/01/89	365	0.26	0.21	0.23	85 ± 8
Stone Cabin Ranch	01/04/89	01/03/90	364	0.29	0.20	0.24	87 ± 13
Sunnyside	12/01/88	11/30/89	364	0.11	0.07	0.09	34 ± 6
Tempiute	11/02/88	11/01/89	364	0.30	0.21	0.25	90 ± 13
Tonopah Test Range	11/15/88	01/04/90	415	0.28	0.21	0.25	93 ± 12
Tonopah	11/08/88	11/08/89	365	0.25	0.21	0.24	86 ± 6
Twin Springs Ranch	01/04/89	01/03/90	364	0.27	0.21	0.24	86 ± 9
Uhalde's Ranch	11/02/88	11/01/89	364	0.27	0.19	0.24	86 ± 12
U.S. Ecology	01/04/89	01/04/90	365	0.28	0.22	0.24	89 ± 9
Warm Springs #1	01/04/89	01/03/90	364	0.29	0.24	0.26	96 ± 7
Warm Springs #2	04/05/89	01/03/90	273	0.93	0.80	0.86	316 ± 15
Wells	11/29/88	12/12/89	378	0.18	0.15	0.17	61 ± 5
Winnemucca	11/29/88	12/13/89	379	0.18	0.15	0.17	62 ± 5
Young's Ranch	11/17/88	11/08/89	356	0.20	0.16	0.19	68 ± 6
Utah							
Boulder	12/01/88	12/01/89	365	0.17	0.14	0.16	57 ± 5
Bryce Canyon	12/01/88	12/01/89	365	0.16	0.13	0.14	52 ± 5
Cedar City	12/01/88	12/04/89	368	0.13	0.11	0.12	43 ± 3
Delta	01/06/89	01/08/90	367	0.16	0.12	0.15	53 ± 6
Duchesne	01/04/89	01/10/90	371	0.13	0.11	0.12	43 ± 3
Enterprise	12/01/88	12/01/89	365	0.27	0.24	0.25	91 ± 5
Ferron	01/04/89	01/10/90	371	0.12	0.11	0.12	42 ± 2
Garrison	12/01/88	11/29/89	363	0.13	0.10	0.12	45 ± 5
Grantsville	01/05/89	01/09/90	369	0.13	0.11	0.12	45 ± 3
Green River	11/02/88	11/07/89	370	0.17	0.10	0.13	49 ± 11
Gunnison	12/01/88	12/01/89	365	0.12	0.09	0.11	40 ± 5
Ibapah	12/01/88	11/29/89	363	0.24	0.21	0.23	83 ± 5
Kanab	11/01/88	11/06/89	370	0.14	0.08	0.11	40 ± 9
Loa	12/01/88	12/01/89	365	0.27	0.24	0.26	95 ± 5
Logan	01/03/89	01/03/90	365	0.12	0.10	0.11	41 ± 3
Lund	12/01/88	12/01/89	365	0.23	0.20	0.22	79 ± 5

(a) mR/yr = Average mR/day x 365 days

Table 5.28 (Offsite TLDs, cont.)

Station Location	Measurement Period: Issue Date	Measurement Period: Collect Date	Elapsed Time (days)	Measured Daily Exp. Equivalent (mR/day): Max.	Min.	Avg.	Gamma Exposure (mR/yr ± 2s)[a]
Utah, cont.							
Milford	12/01/88	12/01/89	365	0.25	0.23	0.24	89 ± 3
Monticello	11/02/88	11/07/89	370	0.20	0.14	0.17	63 ± 9
Nephi	01/06/89	01/09/90	368	0.12	0.08	0.11	39 ± 6
Parowan	12/01/88	12/01/89	365	0.14	0.13	0.14	50 ± 2
Price	01/04/89	01/10/90	371	0.13	0.11	0.12	44 ± 3
Provo	01/05/89	01/09/90	369	0.10	0.08	0.09	34 ± 3
Salt Lake City	01/04/89	01/03/90	364	0.15	0.10	0.12	45 ± 7
St. George	12/01/88	12/04/89	368	0.12	0.08	0.09	34 ± 6
Trout Creek	12/01/88	11/29/89	363	0.17	0.13	0.15	54 ± 6
Vernal	01/04/89	01/10/90	371	0.14	0.11	0.13	48 ± 5
Vernon	01/05/89	01/08/90	368	0.15	0.13	0.14	51 ± 3
Wendover	11/28/88	12/11/89	378	0.15	0.13	0.13	49 ± 4
Willow Springs Lodge	01/05/89	01/09/90	369	0.11	0.08	0.10	36 ± 5

Table 5.29 Fixed Environmental Station TLD Statistics - 1989

	Arizona	California	Nevada Stations: Including WS-2	Nevada Stations: Excluding WS-2	Utah	Entire TLD Network: Including WS-2	Entire TLD Network: Excluding WS-2	U.S. Average
Number of Fixed Stations Monitored:	3	13	88	87	29	133	132	
Number of Days Each Station Monitored:								
Minimum	370	364	57	57	363	57	57	
Maximum	371	8	415	415	378	415	415	
Average	370.3	370.6	357.5	358.5	367.4	361.2	361.9	
Standard Deviation	0.5	4.4	45.9	45.3	3.3	37.8	37.1	
Calculated CV	0.1%	1.2%	12.8%	12.6%	0.9%	11.9%	10.3%	
Equivalent Daily Exposures (mR/day):								
Minimum	0.09	0.08	0.01	0.01	0.08	0.01	0.01	
Maximum	0.22	0.29	0.93	0.71	0.27	0.93	0.71	
Average	0.140	0.180	0.197	0.189	0.145	0.177	0.177	
Standard Deviation	0.036	0.043	0.098	0.068	0.047	0.087	0.064	
Calculated CV	25.4%	0.4%	49.8%	35.9%	32.7%	1.0%	36.1%	
Calculated Gross Annual Exposures (mR/year):								
Minimum	40	30	17	17	34	17	17	43
Maximum	68	88	316	156	95	316	156	168
Average	50.7	65.7	71.9	69.1	52.9	66.7	64.8	68
Standard Deviation	12.4	15.5	36.0	24.8	17.2	31.8	23.4	8
Calculated CV	24.4%	23.6%	50.0%	36.0%	32.5%	47.7%	36.1%	

CV = Coefficient of variation

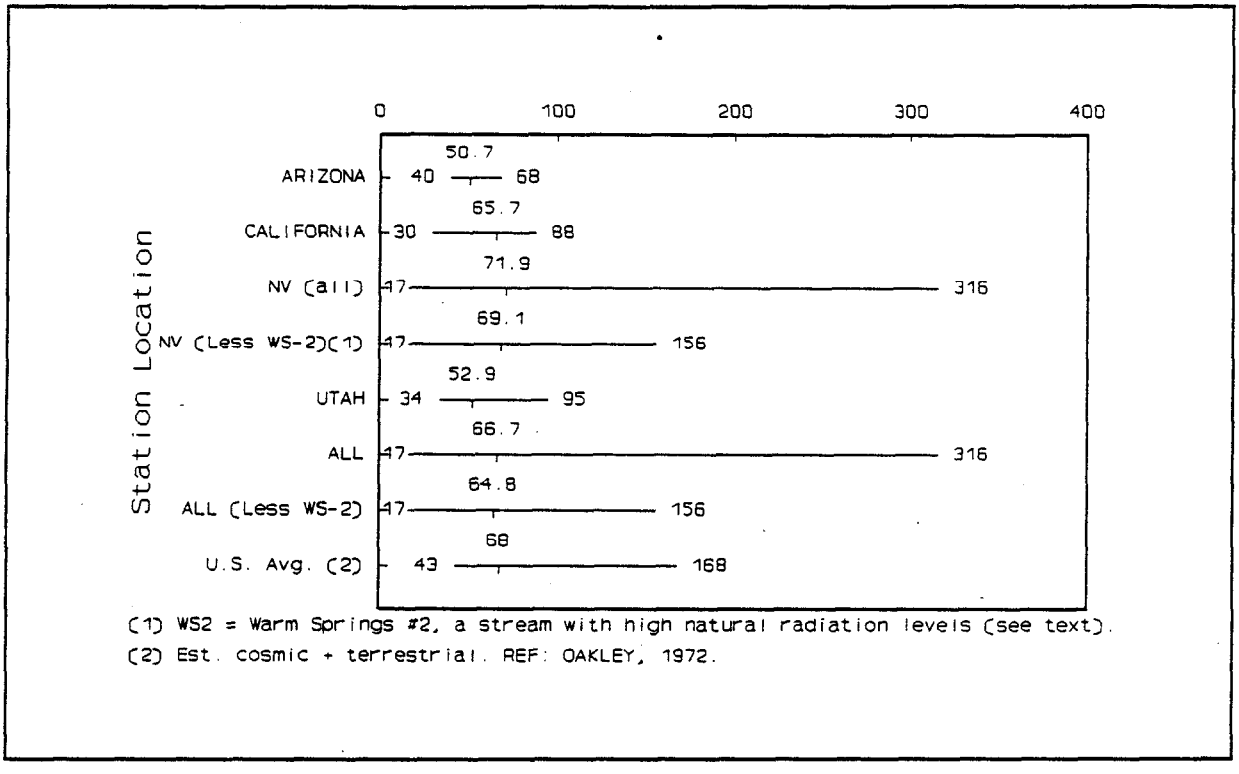


Figure 5.33 Range of Ambient Gamma Exposures at Fixed Environmental Stations by State - 1989

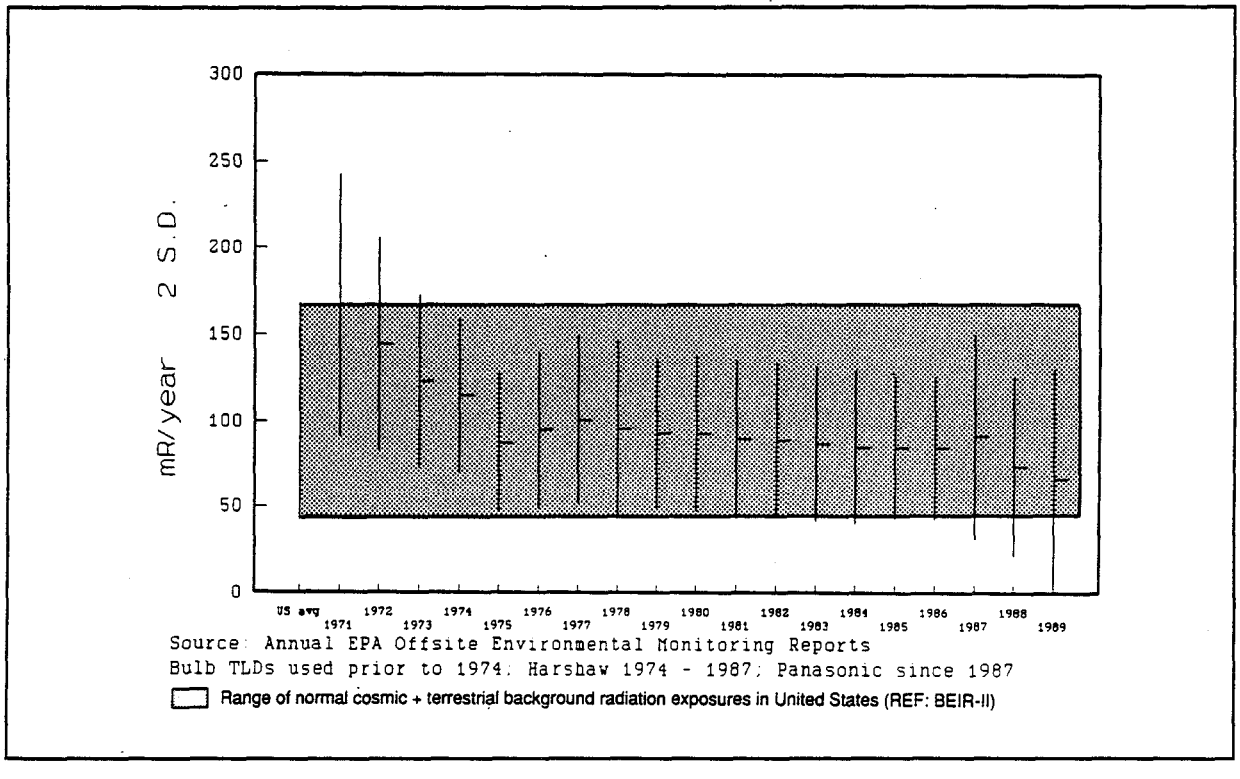


Figure 5.34 Historical Trends - TLD Exposures at Fixed Environmental Stations - 1971-89

Table 5.30 Offsite Resident TLD Results - 1989

Resident Identification Number	Associated Reference Background Location	Measurement Period		Elapsed Time (days)	Equivalent Dose Rate (mrem/day)			Annual Measured Dose (mrem/yr)[a]	Associated Reference Background Exposure ± 2s (mR/yr)
		Issue Date	Collect Date		Max.	Min.	Avg.		
Arizona									
No individuals residing in Arizona were monitored during the period covered by this report.									
California									
359	Death Valley Junction	04/04/89	01/04/90	275	0.28	0.06	0.21	58	50 ±2
304	Death Valley Junction	01/06/89	01/05/90	364	0.45	0.16	0.32	116	66 ±3
331	Death Valley Junction	01/05/89	04/04/89	89	0.15	0.03	0.10	9	16 ±1
60	Shoshone	01/04/89	01/02/90	363	0.35	0.01	0.15	54	51 ±2
Nevada									
22	Alamo	01/04/89	01/10/90	371	0.22	0.06	0.11	41	67 ±3
29	Austin	01/12/89	01/10/90	363	0.40	0.07	0.20	73	98 ±5
38	Beatty	01/06/89	01/04/90	363	0.52	0.19	0.28	102	87 ±4
21	Beatty	01/06/89	01/04/90	363	0.38	0.07	0.20	73	87 ±4
9	Blue Eagle Ranch	01/04/89	01/03/90	364	0.37	0.03	0.13	4	44 ±2
2	Caliente	01/04/89	01/08/90	369	0.33	0.11	0.22	81	70 ±3
336	Caliente	01/04/89	01/08/90	369	0.27	0.03	0.14	52	70 ±3
11	Complex 1	01/05/89	01/09/90	369	0.34	0.10	0.22	81	85 ±4
10	Complex 1	01/05/89	01/09/90	369	0.34	0.08	0.22	81	85 ±4
56	Corn Creek	01/03/89	01/02/90	364	0.23	0.02	0.09	33	25 ±1
25	Corn Creek	01/03/89	01/02/90	364	0.18	0.03	0.08	29	25 ±1
15	Coyote Summit	01/04/89	01/09/90	370	0.23	0.04	0.15	56	89 ±4
14	Coyote Summit	01/04/89	01/09/90	370	0.21	0.06	0.15	56	89 ±1
233	Ely	01/11/80	01/08/90	362	0.19	0.05	0.11	40	58 ±3
47	Ely	01/11/80	01/08/90	362	0.32	0.05	0.14	51	58 ±3
302	Gabbs	01/10/89	01/09/90	364	0.19	0.07	0.13	47	47 ±2
343	Gabbs	01/10/89	11/07/89	301	0.25	0.04	0.15	45	39 ±2
7	Goldfield	01/11/89	01/16/90	370	0.23	0.08	0.15	56	59 ±3
19	Goldfield	01/11/89	01/17/90	371	0.27	0.03	0.15	56	59 ±3
40	Goldfield	01/11/89	01/12/90	366	0.83	0.09	0.23	84	59 ±3
232	Hiko	01/04/89	01/09/90	370	0.20	0.02	0.12	44	67 ±3
3	Hot Creek Ranch	01/05/89	01/04/90	364	0.44	0.09	0.21	76	66 ±3
37	Indian Springs	01/03/89	01/02/90	364	0.20	0.03	0.10	36	29 ±1
6	Indian Springs	01/03/89	01/02/90	364	0.23	0.03	0.12	44	29 ±1
381	Ione	11/07/89	01/09/90	63	0.27	0.08	0.17	11	13 ±1
300	Koyne's Ranch	01/12/89	01/09/90	362	0.24	0.09	0.15	54	65 ±3
49	Las Vegas (UNLV)	01/03/89	01/02/90	364	0.22	0.02	0.09	33	18 ±1
377	Las Vegas (USDI)	07/31/89	01/02/90	155	0.27	0.02	0.12	19	16 ±1
349	Las Vegas (USDI)	01/03/89	04/03/89	90	0.06	0.04	0.05	5	9 ± 0.4
376	Las Vegas (USDI)	07/31/89	01/02/90	155	0.20	0.05	0.11	17	16 ±1
297	Las Vegas (USDI)	01/03/89	01/02/90	364	0.13	0.01	0.05	18	36 ±2
326	Las Vegas (USDI)	01/03/89	01/02/90	364	0.23	0.03	0.09	33	36 ±2
342	Lavada's Market	01/04/89	01/04/90	365	0.36	0.07	0.16	58	66 ±3
380	Lavada's Market	09/05/89	01/04/90	121	0.38	0.15	0.25	30	22 ±1
379	Manhattan	09/13/89	01/10/90	119	0.29	0.17	0.23	27	31 ±1
307	Mina	01/10/89	01/09/90	364	0.25	0.08	0.17	62	69 ±3

(a) mrem/yr = Average mrem/day multiplied by the number of days.

Table 5.30 (Offsite Resident TLDs, cont.)

Resident Identification Number	Associated Reference Background Location	Measurement Period: Issue Date	Measurement Period: Collect Date	Elapsed Time (days)	Equivalent Dose Rate (mrem/day): Max.	Min.	Avg.	Annual Measured Dose (mrem/yr)[a]	Associated Reference Background Exposure ± 2s (mR/yr)
Nevada, cont.									
18	Nyala	01/04/89	01/03/90	364	0.29	0.03	0.15	55	58 ±3
348	Overton	01/10/89	01/04/90	359	0.21	0.02	0.09	32	43 ±2
372	Pahrump	07/06/89	01/02/90	180	0.14	0.02	0.08	14	14 ±1
354	Pahrump	01/04/89	07/06/89	183	0.22	0.02	0.14	26	15 ±1
36	Pahrump	01/04/89	01/02/90	363	0.16	0.03	0.09	33	29 ±1
248	Penoyer Farms	01/05/89	01/09/90	369	0.29	0.03	0.16	59	92 ±4
293	Pioche	01/04/89	01/08/90	369	0.23	0.06	0.14	52	59 ±3
264	Rachel	01/05/89	01/09/90	369	0.30	0.10	0.20	74	85 ±4
54	Rachel	01/03/89	03/27/89	83	0.12	0.01	0.05	4	19 ±1
334	Rachel	01/05/89	01/09/90	369	0.27	0.04	0.16	59	85 ±4
299	Round Mountain	01/12/89	01/10/90	363	0.33	0.10	0.23	83	80 ±4
341	Silver Peak	01/11/89	01/17/90	371	0.31	0.07	0.18	67	70 ±3
29	Stone Cabin Ranch	01/04/89	01/03/90	364	0.31	0.03	0.21	76	87 ±4
42	Tonopah	01/13/89	01/19/90	371	0.35	0.10	0.20	74	89 ±4
339	Tonopah	01/11/89	01/11/90	365	0.27	0.15	0.21	77	88 ±4
8	Twin Springs Ranch	01/04/89	05/02/89	118	0.29	0.20	0.25	30	28 ±1
370	Twin Springs Ranch	06/06/89	01/03/90	211	0.24	0.03	0.16	34	51 ±2
358	U.S. Ecology	03/09/89	01/04/90	301	0.43	0.15	0.26	78	72 ±3
Utah									
44	Cedar City	01/04/89	01/04/90	365	0.21	0.04	0.14	51	44 ±2
345	Delta	01/06/89	01/08/90	367	0.81	0.05	0.22	81	55 ±3
344	Delta	01/06/89	01/08/90	367	0.22	0.03	0.13	48	55 ±3
347	Milford	01/06/89	01/08/90	367	0.29	0.04	0.17	62	88 ±4
346	Milford	01/06/89	01/08/90	367	0.28	0.07	0.17	62	88 ±4
52	Salt Lake City	01/04/89	01/03/90	364	0.31	0.09	0.17	62	44 ±2
45	St. George	01/06/89	01/04/90	363	0.20	0.03	0.10	36	33 ±2

(a) mrem/yr = Average mrem/day multiplied by the number of days.

PIC was noted. The TLDs consistently recorded calculated exposures of approximately one-half those recorded by PICs, as shown by the correlation graph in Figure 5.38. This difference may be attributed to several factors:

- The PIC measures ionization in air (the Roentgen) while the TLD measures energy deposited in matter (the rad). Results of the two methods are not adjusted to account for this difference.
- 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 loss due to normal fading (studies by Panasonic have shown this loss to be minimal over the sampling period used).
- 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 almost linear above approximately 80 keV and above approximately 150 keV, respectively.

Table 5.31 Offsite Resident TLD Statistics - 1989

	Arizona	California	Nevada	Utah	All Three States	U.S. Average
Number of Individuals Monitored:	0	4	54	7	65	
Number of Days Each Station was Monitored:						
Minimum		89	63	363	63	
Maximum		364	371	367	371	
Average		272.8	316.4	365.7	319.0	
Standard Deviation		112.1	95.0	1.6	93.0	
Calculated CV		41.1%	30.0%	0.4%	29.2%	
Equivalent Daily Ambient Gamma Exposures (mR/day)						
Minimum		0.01	0.01	0.03	0.01	
Maximum		0.45	0.83	0.81	0.83	
Average		0.195	0.156	0.157	0.158	
Standard Deviation		0.082	0.057	0.035	0.057	
Calculated CV		42.1%	36.4%	22.5%	36.3%	
Calculated Annual Ambient Gamma Exposures (mR/year) (reference background NOT subtracted):						
Minimum		9	4	36	4	43
Maximum		116	102	81	116	168
Average		59.4	49.5	57.5	51.0	68
Standard Deviation		38.2	22.9	13.1	23.6	
Calculated CV		64.3%	46.3%	22.7%	46.2%	

CV = Coefficient of variation.

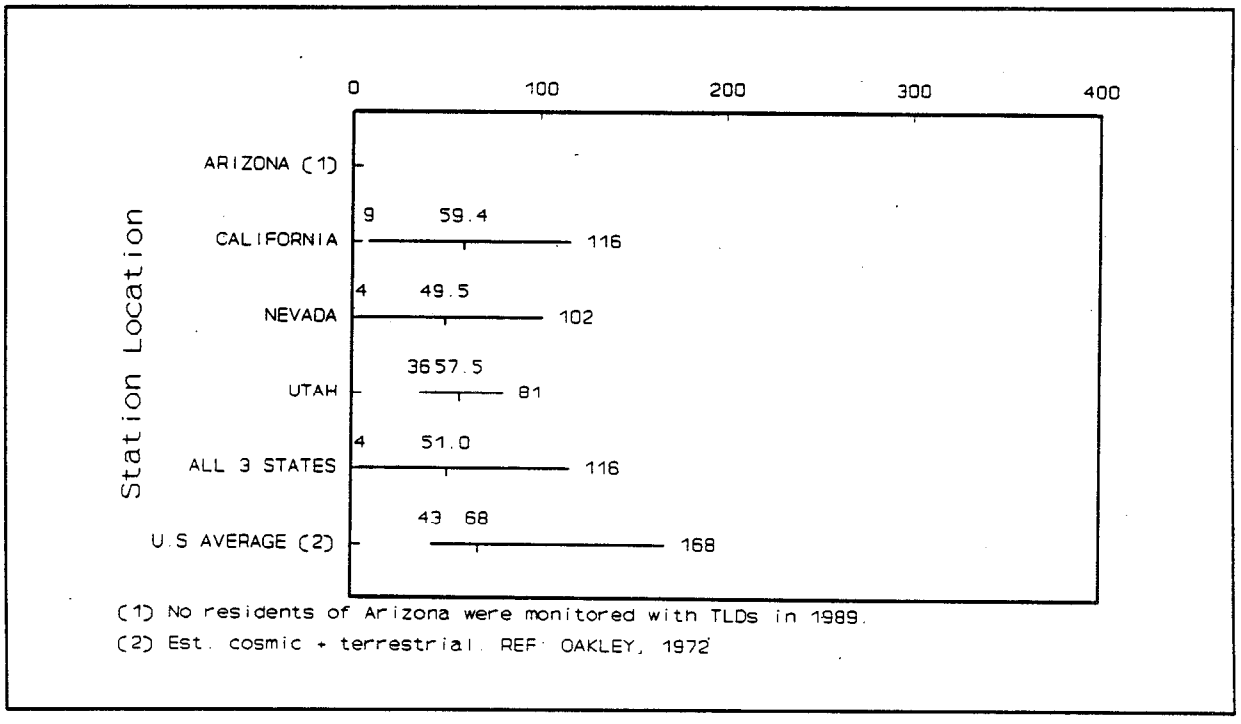


Figure 5.35 Range of Ambient Gamma Exposures of Offsite Residents by State - 1989

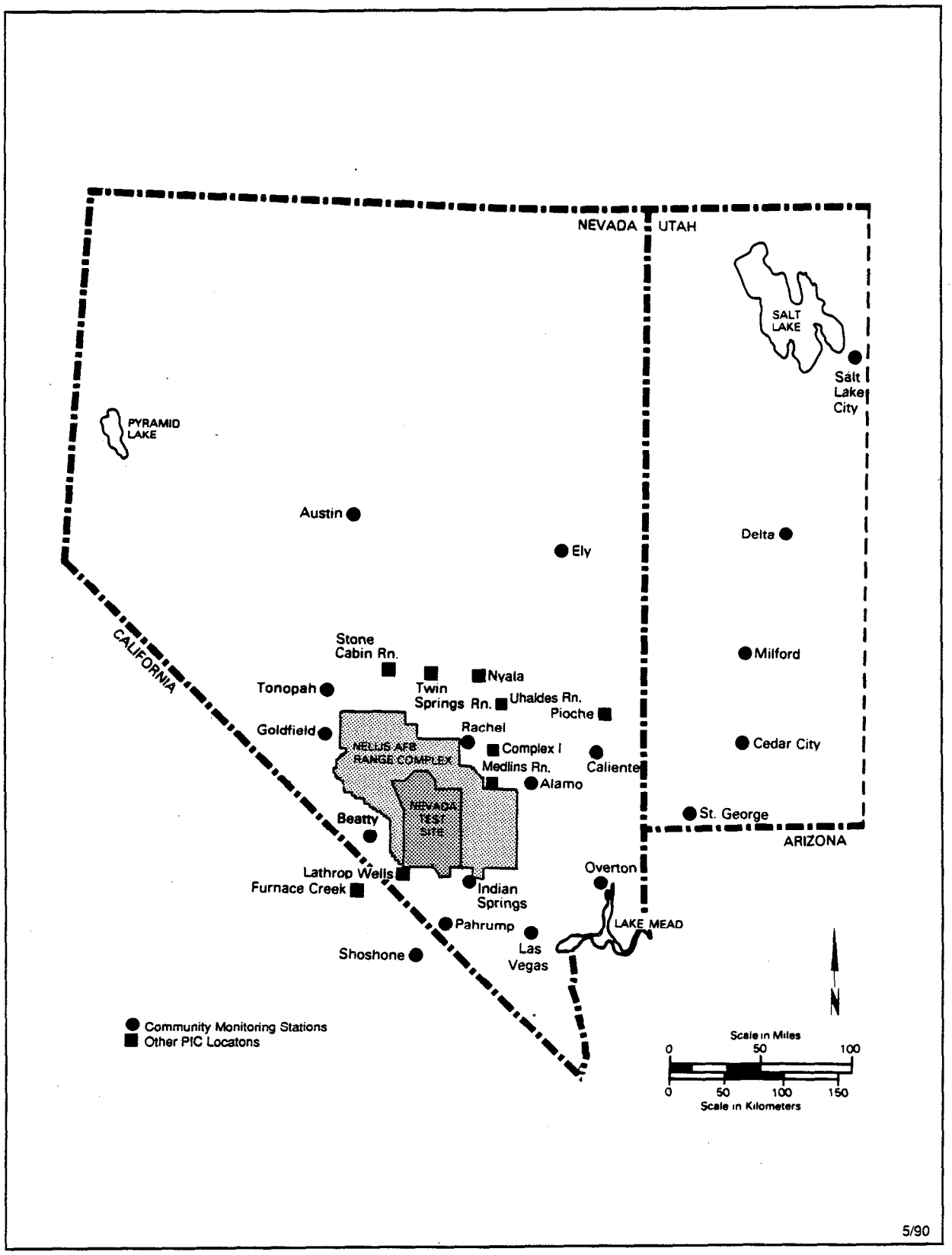


Figure 5.36 Community Monitoring PIC Stations and Other PIC Station Locations - 1989

Table 5.32 Pressurized Ion Chamber Readings - 1989

Station Location	Number of Weekly Values	Exposure Rate, (μR/hr)[a] Maximum	Minimum	Avg. ± 2s	mR/yr ± 2s
Alamo, NV	52	13.6	12.7	13.0 ± 0.3	113.9 ± 2.9
Austin, NV	47	20.0	15.4	18.8 ± 2.1	164.7 ±18.6
Beatty, NV	52	17.7	16.4	16.9 ± 0.6	147.8 ± 5.3
Caliente, NV	52	15.0	13.6	14.4 ± 0.6	126.1 ± 4.9
Cedar City, UT	50	10.4	9.6	10.0 ± 0.3	87.2 ± 2.8
Complex I, NV	50	16.7	14.3	15.7 ± 0.9	137.8 ± 7.8
Delta, UT	52	12.1	10.2	11.2 ± 0.7	98.2 ± 6.4
Ely, NV	52	12.4	11.8	12.0 ± 0.3	105.4 ± 2.6
Furnace Creek, CA	42	10.7	9.6	10.0 ± 0.6	88.0 ± 4.9
Goldfield, NV	51	16.0	14.7	15.2 ± 0.5	133.4 ± 4.3
Indian Springs, NV	52	9.3	8.5	8.9 ± 0.4	78.1 ± 3.4
Las Vegas, NV	51	6.3	5.6	5.9 ± 0.4	51.7 ± 3.2
Lathrop Wells, NV	50	14.6	13.9	14.1 ± 0.3	123.4 ± 2.9
Medlin's Ranch, NV	51	16.5	14.7	15.8 ± 0.6	138.4 ± 5.3
Milford, UT	49	18.4	15.4	17.1 ± 1.3	149.4 ±11.6
Nyala, NV	37	14.0	11.3	12.5 ± 0.9	109.3 ± 7.5
Overton, NV	52	10.0	9.0	9.4 ± 0.5	82.4 ± 4.3
Pahrump, NV	51	8.0	7.2	7.6 ± 0.3	66.6 ± 2.8
Pioche, NV	52	13.1	12.2	12.7 ± 0.4	111.1 ± 3.4
Rachel, NV	52	16.3	11.8	14.9 ± 1.9	130.8 ±16.9
St. George, UT	52	9.8	8.5	9.0 ± 0.7	79.0 ± 5.7
Salt Lake City, UT	51	12.7	8.8	10.4 ± 1.4	91.0 ±12.0
Shoshone, CA	51	12.8	11.0	11.7 ± 0.6	102.8 ± 5.6
Stone Cabin Ranch, NV	44	18.2	16.0	16.9 ± 1.1	148.2 ± 9.7
Tonopah, NV	51	17.1	15.1	16.4 ± 0.7	143.3 ± 6.4
Twin Springs Ranch, NV	40	18.3	15.5	16.9 ± 1.2	148.3 ±10.8
Uhalde's Ranch, NV	49	17.7	14.7	16.8 ± 1.5	147.0 ±13.5

(a) Weekly averages.

- 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. Studies are planned for 1990 to determine the extent to which this factor influences PIC response.

- The use of TLDs for environmental monitoring requires several approximations, each of which contributes to the noted difference between the two systems.

(1) Environmental TLDs do not have a "flat" response at the low (<100 keV) energies characteristic of many noble gases and of beta radiations. The $CaSO_4$ used in environmental TLDs is known to over-respond at low energies.

(2) Environmental TLDs, while calibrated in a fixed geometry with a parallel beam incident upon the dosimeter, are deployed in an immersion cloud geometry. This results in a portion of the exposure occurring behind the filter. Because of this, development of an appropriate

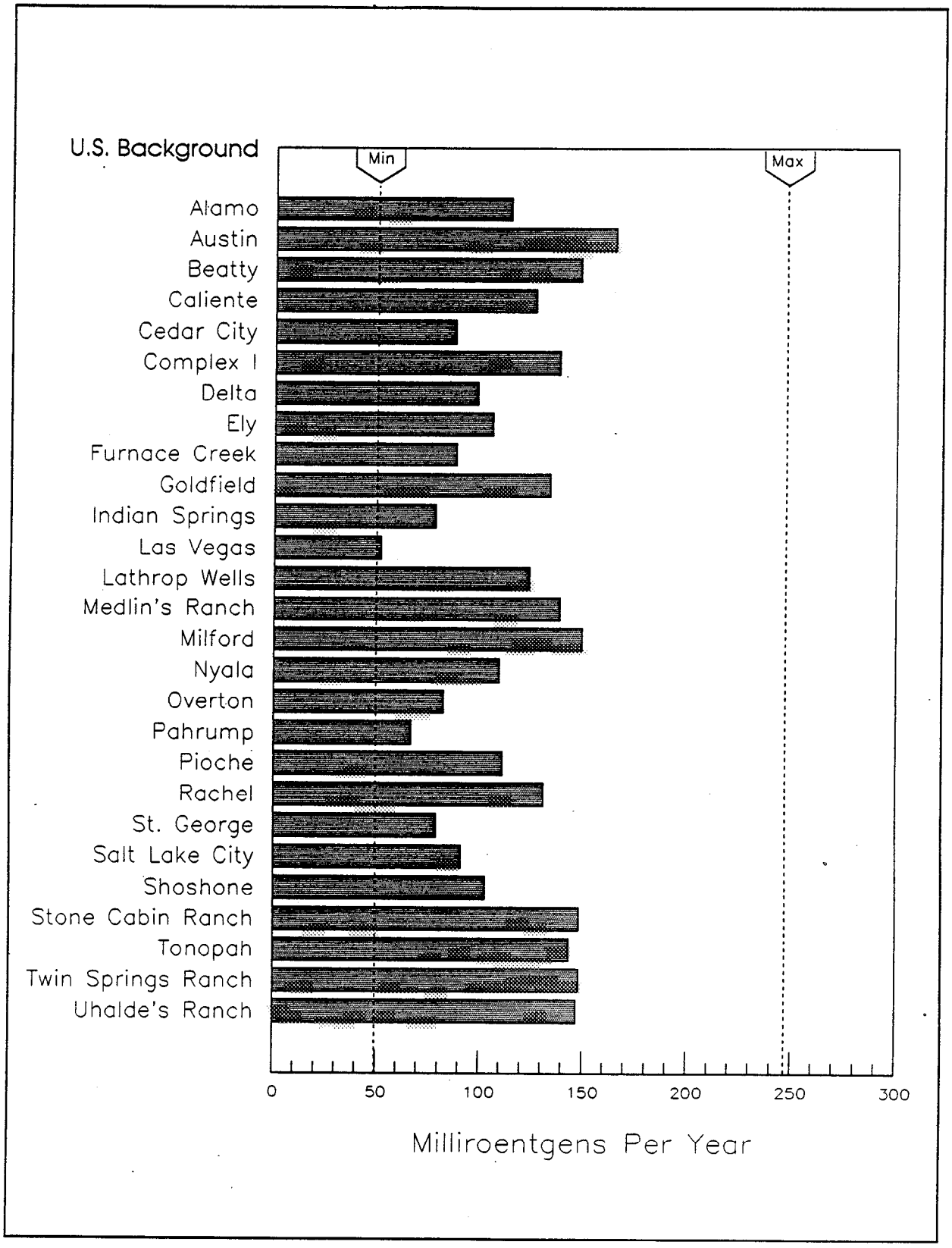


Figure 5.37 Annual PIC Averages by Station In Milliroentgens per Year - 1989

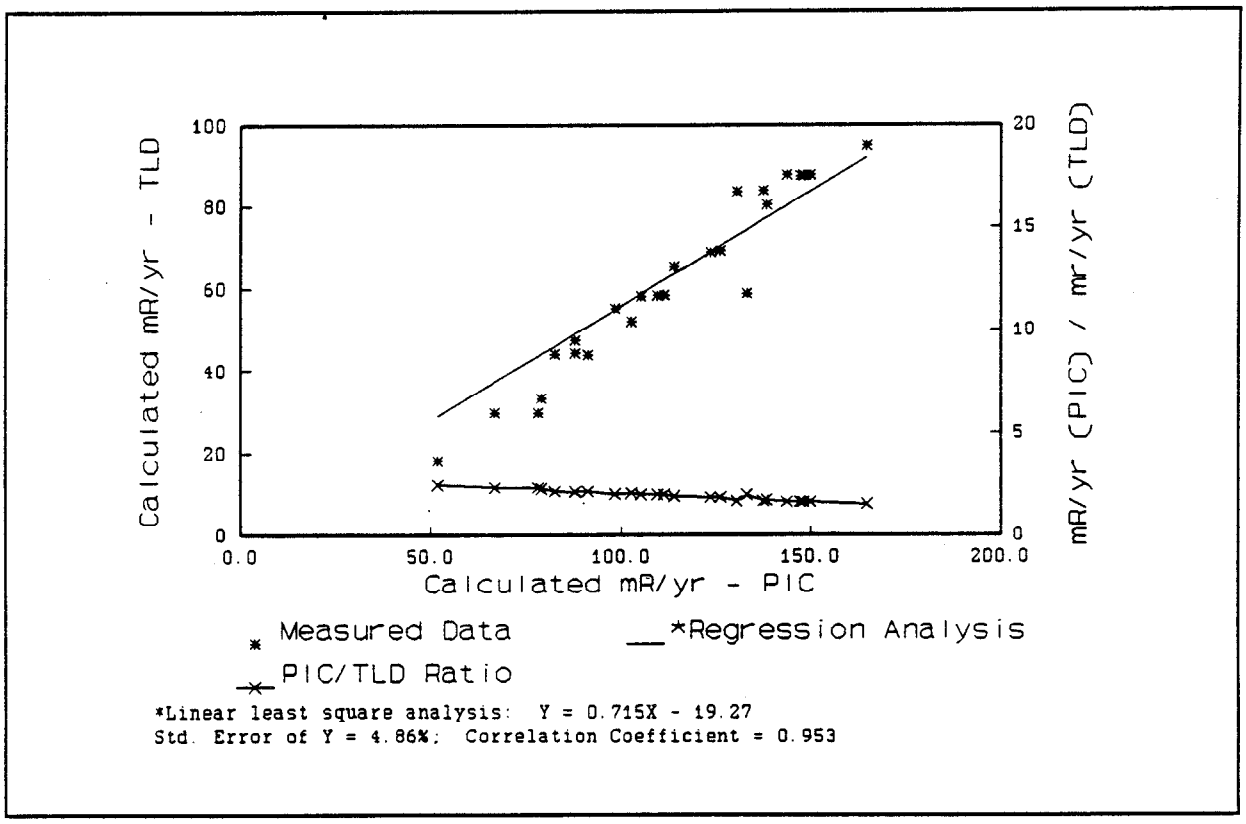


Figure 5.38 Correlating TLD and PIC Results - 1989

algorithm to correct environmental TLDs for differences in radiation type and energy is normally not attempted.

(3) By their design, environmental TLDs are effectively incapable of discerning beta radiations.

For these reasons, it is important that neither the TLD nor the PIC be considered as "definitive" devices, but as two complementary components of a comprehensive environmental monitoring system.

POPULATION RADIONUCLIDE UPTAKE

During 1989 EPA obtained a total of 904 gamma spectra from whole-body counting of 221 individuals of whom 101 were participants in the Offsite Human Surveillance Program (Figure 5.39). Cesium-137 is generally the only fission product detected. As a result of worldwide fallout following the Chernobyl accident, a trace amount of ^{137}Cs was detected in a limited number of individuals visiting or residing in Europe. In general the spectra were representative of normal background and showed only naturally-occurring ^{40}K. No transuranic radionuclides were detected in any lung counting data.

Bioassay results for the Offsite Human Surveillance Program showed that the concentration of tritium in single urine samples collected at random periods of time varied from below the MDC (average 3.65×10^{-7} µCi/mL, 13.5 Bq/L) to 4.66×10^{-6} µCi/mL (172 Bq/L) (see Table 5.33). The average value for tritium in urine was 3.9×10^{-7} µCi/mL (14.5 Bq/L). Nearly half of the concentrations were below the MDC. None of the values above the MDC were over applicable limits. The highest value, 4.66×10^{-6} µCi/mL, was 2.5 percent of the annual limit of intake for the general public.

The higher than MDC tritium values seen in the offsite population occur routinely. There appears to be no correlation with ^{3}H found

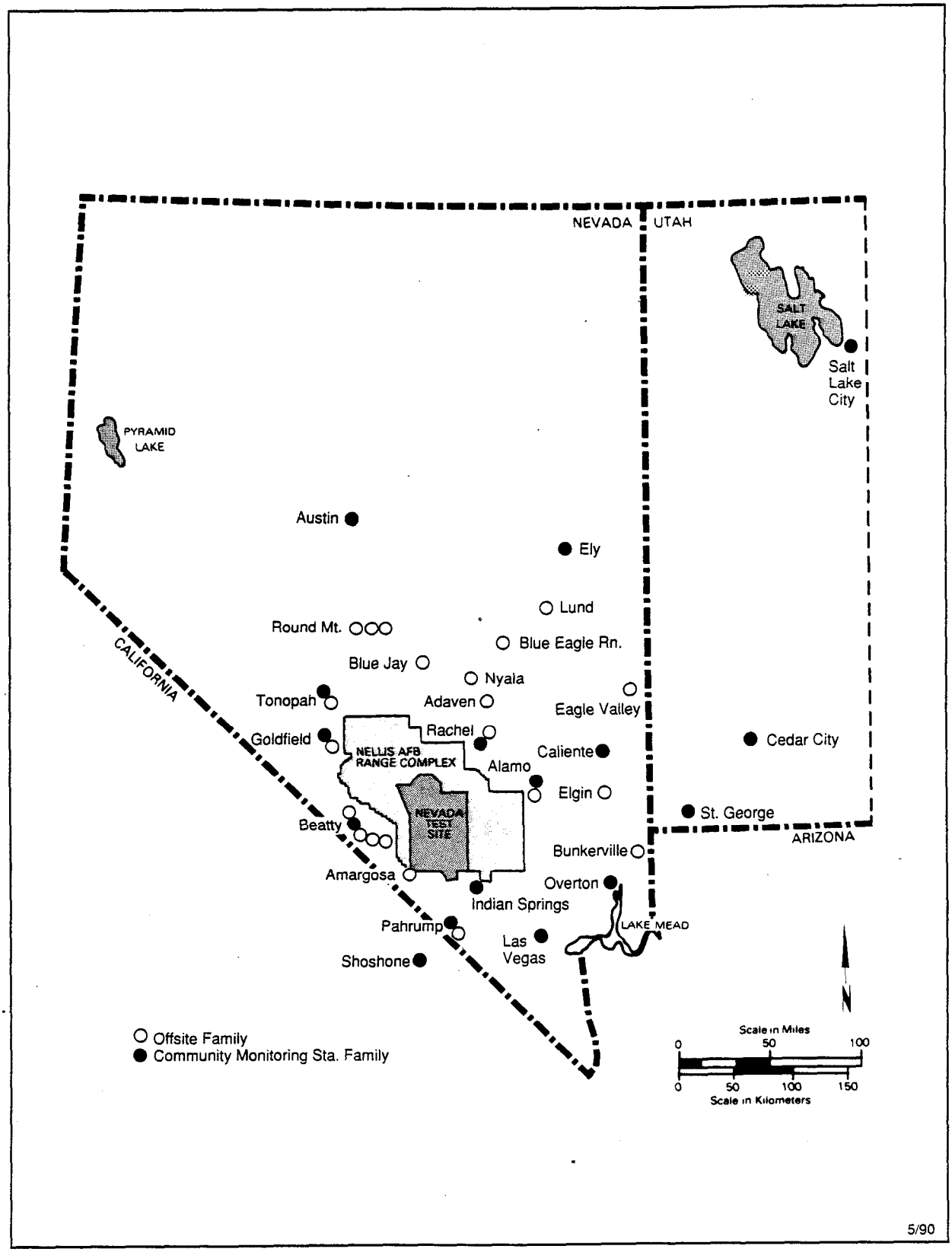


Figure 5.39 Location of Families in the Offsite Human Surveillance Program

Table 5.33 Tritium in Urine Offsite Human Surveillance Program

Sampling Location	Collection Date 1989	Concentration ± 2s of MDC) (10^{-9} µCi/mL)
Shoshone, CA	05/12	44 ± 212 (348)
	05/12	156 ± 218 (356)
Alamo, NV	03/17	138 ± 220 (360)
	03/17	-58 ± 218 (360)
Beatty, NV	03/13	-26 ± 216 (356)
	03/13	81 ± 216 (354)
	03/13	146 ± 182 (297)
	03/23	136 ± 221 (361)
	03/23	403 ± 233 (375)[a]
	04/25	110 ± 216 (354)
	04/25	244 ± 216 (351)
	04/25	354 ± 226 (364)
	04/25	-119 ± 214 (355)
	07/01	319 ± 194 (313)[a]
	07/12	373 ± 191 (306)[a]
	07/12	460 ± 192 (307)[a]
	12/13	107 ± 184 (300)
	12/13	135 ± 187 (305)
	12/13	99 ± 185 (303)
Caliente, NV	07/14	473 ± 195 (311)[a]
	07/14	269 ± 194 (314)
	07/14	930 ± 205 (319)[a]
	07/14	397 ± 195 (312)[a]
	07/14	425 ± 195 (312)[a]
Currant, NV Blue Eagle Ranch	08/04	515 ± 199 (316)[a]
	08/04	755 ± 203 (318)[a]
Ely, NV	03/20	125 ± 228 (373)
	03/20	17 ± 215 (354)
	04/07	38 ± 214 (351)
	04/07	730 ± 232 (366)[a]
	10/11	144 ± 204 (334)
	10/11	62 ± 203 (334)
Goldfield, NV	08/17	423 ± 193 (309)[a]
	08/17	445 ± 192 (307)[a]
	08/17	798 ± 214 (336)[a]
	08/17	346 ± 194 (312)[a]
Indian Springs, NV	08/11	136 ± 203 (331)
	08/11	691 ± 198 (311)[a]
	09/06	268 ± 202 (327)
	09/06	207 ± 204 (331)
	09/06	218 ± 206 (335)
Las Vegas, NV	07/14	937 ± 196 (303)[a]
Stateline, NV	03/15	50 ± 195 (321)
	03/15	167 ± 219 (357)
Amargosa Farm Area, NV	07/13	523 ± 195 (310)[a]
	07/13	445 ± 192 (306)[a]
	07/19	768 ± 200 (313)[a]
	07/21	361 ± 193 (310)[a]
Nyala, NV	03/14	-68 ± 153 (253)
	03/14	271 ± 158 (254)[a]
	03/14	104 ± 221 (361)
	03/24	208 ± 219 (357)
	11/02	225 ± 194 (315)
	11/02	101 ± 185 (302)
	11/16	191 ± 187 (304)
	11/16	100 ± 186 (305)
Overton, NV	06/27	1192 ± 219 (336)[a]
	06/27	521 ± 195 (310)[a]
	06/27	397 ± 194 (310)[a]
	06/27	377 ± 195 (313)[a]
	06/27	270 ± 192 (310)
	08/16	268 ± 191 (308)
	08/16	389 ± 198 (318)[a]
	08/16	290 ± 193 (312)
	08/16	377 ± 194 (311)[a]
	08/16	538 ± 196 (312)[a]
Pahrump, NV	05/12	40 ± 212 (349)
	06/16	-123 ± 192 (319)
	06/16	69 ± 194 (318)
	06/16	77 ± 194 (318)
	08/11	291 ± 192 (310)
	08/11	Insufficient sample

(a) Concentration is greater than the MDC.

Table 5.33 (Tritium in Urine, cont.)

Sampling Location	Collection Date 1989	Concentration ± 2s of MDC (10^{-9} µCi/mL)
Rachel, NV	03/31	604 ± 225 (357)[a]
	03/31	423 ± 220 (354)[a]
	08/08	480 ± 196 (314)[a]
	08/08	656 ± 198 (313)[a]
	08/21	331 ± 194 (312)[a]
Tonopah, NV	03/24	-195 ± 212 (354)
	06/23	7.5 ± 187 (309)
	06/23	96 ± 187 (306)
	06/23	471 ± 194 (310)[a]
	06/23	487 ± 194 (310)[a]
	08/18	3743 ± 232 (309)[a]
	08/18	483 ± 195 (310)[a]
	08/18	376 ± 192 (309)[a]
	08/18	4662 ± 240 (307)[a]
	11/16	123 ± 185 (301)
Cedar City, UT	02/03	417 ± 255 (412)[a]
	02/03	652 ± 264 (421)[a]
	02/03	157 ± 249 (406)
	02/03	315 ± 254 (412)
	07/24	386 ± 194 (312)[a]
	07/24	607 ± 204 (323)[a]
	07/24	387 ± 193 (309)[a]
	07/24	258 ± 192 (310)
	07/24	537 ± 195 (309)[a]
St. George, UT	05/12	238 ± 220 (357)

(a) Concentration is greater than the MDC.

in air samples at a statistically acceptable confidence level. Biological indicators of exposure have been shown to be much more sensitive than instruments as they concentrate the activity over time. The samples cannot be used as other than an indicator of exposure as they are a single random sample.

As reported in previous years, medical examinations of the offsite families revealed a generally healthy population. The blood examinations and thyroid profiles showed no abnormal results which could be attributed to past or present NTS testing operations.

The plot of the average tritium in urine from the offsite Human Surveillance Program, Figure 5.40, shows the values from 1979 through 1990. Additional sampling, during planned releases (if any) from NTS, will be performed in 1990.

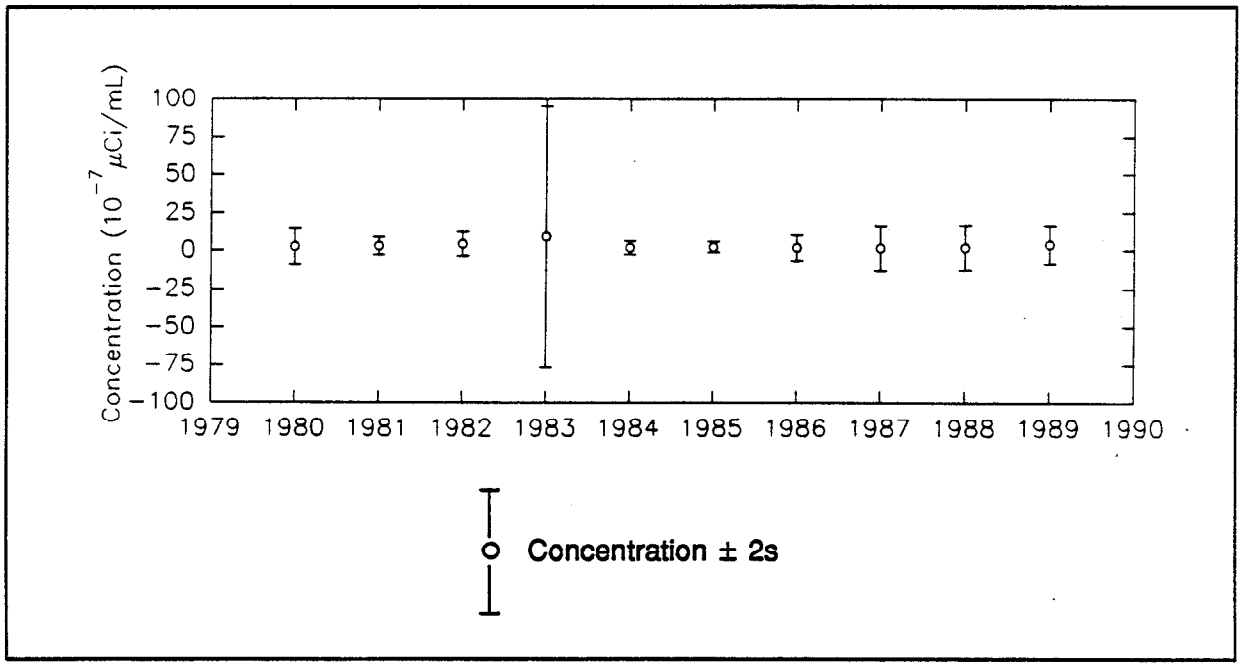


Figure 5.40 Mean and Standard Deviation for the Concentration of Tritium in the Urine of Offsite Residents - 1979-89

6.0 NONRADIOLOGICAL MONITORING

Charles W. Burhoe, Richard B. Hunter, and Glen A. Clark

Environmental nonradiological monitoring of NTS operations involves onsite monitoring only, as there are no nonradiological discharges to the offsite environment. Onsite drinking water distribution systems are monitored for Safe Drinking Water Act compliance; sewage influents to onsite lagoons are monitored for Clean Water Act compliance; polychlorinated biphenyl (PCB) monitoring is conducted for Toxic Substance Control Act compliance; asbestos monitoring is conducted for asbestos removal and renovation projects; and environmental media are sampled for hazardous characteristics and constituents in the vicinity of hazardous waste management sites on the NTS. Flora, fauna, and special environmental conditions are also monitored for trends and impacts.

6.1 ENVIRONMENTAL SAMPLES

6.1.1 SAFE DRINKING WATER ACT

All drinking water distribution systems on the NTS are sampled by the onsite contractor (REECo) monthly for coliform bacteria. Common sampling points are rest room and cafeteria sinks. Prior to September 31, 1989, the samples were submitted to a state of Nevada laboratory for analysis. On October 1, 1989, the Associated Pathologists Laboratories, located at 4230 Burnham Avenue, Suite 250, Las Vegas, Nevada 89119, began analyzing the samples for the State.

Residual chlorine (RC) and pH levels are determined at the collection point by using colorimetric methods approved by the state. The results are recorded in the onsite contractor's laboratory drinking water sample logbook, and the chlorine residual level is recorded on an analysis form. Using the "most probable number" technique, if the coliform bacteria colony count exceeds 2.2 colonies per 100-mL sample, the system is declared unsafe and closed. In order to reopen the system, samples collected for three consecutive days must have a coliform count that is in line with state requirements. Sample results for 1989 distribution systems are listed in Table 6.1, along with applicable state of Nevada permit numbers. RC results [0.1 to 1.0 parts per million (ppm)] and pH results (6.8 to 8.2) were all within permit criteria. No coliform counts greater than zero were detected.

Starting on April 1, 1989, sampling of trucks hauling potable water from NTS wells to work areas began for all loads. A total of 1010 water truck samples were collected during 1989. Of these, 991 contained 0 coliform colonies per 100-mL sample. Nineteen were invalid coliform bacteria samples; 17 were eliminated due to overgrowth by other bacteria, and 2 were not used due to their rusty color. Follow-up samples taken at these sources indicated that the water was safe for drinking. The invalid samples were most likely caused by sampling or analysis error.

In 1990, in addition to continuing the sampling described above, chemical analysis for inorganic and organic compounds of EPA and state regulatory interest will be conducted for all water distribution systems.

Table 6.1 Monthly Monitoring Results for NTS Potable Water Systems - 1989
[RC - residual chlorine, parts per million (ppm); coliform colony count, #/100 mL]

Area, Building	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
PERMIT 360-12C												
Area 22	Desert Rock Weather Station											
RC	0.5	0.2	0.5	0.4	0.3	0.4	0.2	0.4	0.2	0.3	0.4	0.2
pH	8.1	7.9	7.7	8.2	7.6	7.6	7.0	6.9	6.8	7.8	8.2	7.2
Coliform	0	0	0	0	0	0	0	0	0	0	0	0
Area 23	Building 652, Mercury											
RC	0.4	0.3	0.4	0.6	0.5	0.5	0.5	0.5	0.2	0.5	0.4	0.5
pH	8.0	8.1	7.6	7.8	7.6	7.2	7.2	7.4	7.1	6.8	7.5	7.5
Coliform	0	0	0	0	0	0	0	0	0	0	0	0
Area 23	Cafeteria, Mercury											
RC	0.5	0.4	1.0	0.5	0.4	0.5	0.3	0.5	0.5	0.5	0.6	0.8
pH	8.1	8.0	7.8	7.8	8.0	7.4	7.2	7.2	7.2	7.0	7.4	7.4
Coliform	0	0	0	0	0	0	0	0	0	0	0	0
Area 23	Bowling Alley, Mercury											
RC	0.6	0.2	1.0	0.5	0.2	0.5	0.3	0.4	0.4	0.6	0.6	0.9
pH	8.0	8.0	7.6	7.4	7.8	7.4	7.2	7.5	7.2	7.0	7.4	7.5
Coliform	0	0	0	0	0	0	0	0	0	0	0	0
PERMIT NY-4098 12NC												
Area 25	Site Maintenance											
RC	0.2	0.6	0.3	0.3	0.8	0.6	0.4	0.3	0.6	0.5	0.3	0.1
pH	8.1	7.9	8.1	8.1	7.4	7.4	7.0	7.0	7.6	7.2	7.1	7.3
Coliform	0	0	0	0	0	0	0	0	0	0	0	0
PERMIT NY-4099 12NC												
Area 2	Field Operations											
RC	0.3	0.4	0.5	0.4	0.4	0.4	0.2	0.4	0.4	0.3	0.4	0.4
pH	7.8	7.8	7.4	7.5	7.6	7.2	7.2	7.2	7.0	6.9	7.2	7.4
Coliform	0	0	0	0	0	0	0	0	0	0	0	0
Area 12	Building 12-909											
RC	0.3	0.5	0.5	0.6	0.5	0.4	0.2	0.4	0.4	0.5	0.5	0.3
pH	7.8	7.9	7.4	7.5	7.6	7.2	7.2	7.0	7.2	7.1	7.2	7.1
Coliform	0	0	0	0	0	0	0	0	0	0	0	0
Area 12	Cafeteria											
RC	0.4	0.4	0.6	0.5	0.5	0.5	0.2	0.3	0.4	0.5	0.5	0.5
pH	7.7	7.9	7.6	7.8	7.6	7.2	7.2	7.2	7.2	7.0	7.2	7.2
Coliform	0	0	0	0	0	0	0	0	0	0	0	0
PERMIT NY 5000-12NC												
Area 6	Building 6-625											
RC	0.4	0.5	0.4	0.4	---	---	---	---	---	---	---	---
pH	7.9	7.6	7.7	7.8	---	---	---	---	---	---	---	---
Coliform	0	0	0	0	---	---	---	---	---	---	---	---
Area 6	Well 3 Yard, Facility Housing											
RC	0.3	0.5	0.5	0.5	---	---	---	---	---	---	---	---
pH	7.8	7.6	7.6	7.6	---	---	---	---	---	---	---	---
Coliform	0	0	0	0	---	---	---	---	---	---	---	---

Table 6.1 (Potable Water, cont.)

Area, Building	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Area 6	Control Point Cafeteria											
RC	0.3	0.6	0.6	0.4	---	---	---	---	---	---	---	---
pH	7.6	7.4	7.4	7.5	---	---	---	---	---	---	---	---
Coliform	0	0	0	0	---	---	---	---	---	---	---	---
Area 6	Building 6 - Control Point 65											
RC	---	---	---	---	0.4	0.4	0.3	---	0.4	0.6	0.6	0.6
pH	---	---	---	---	7.2	7.4	7.2	---	7.0	7.0	7.0	7.0
Coliform	---	---	---	---	0	0	0	---	0	0	0	0
Area 6	Fire Station											
RC	---	---	---	---	0.2	0.4	---	---	---	---	0.6	0.6
pH	---	---	---	---	7.6	7.4	---	---	---	---	7.4	7.4
Coliform	---	---	---	---	0	0	---	---	---	---	0	0
Area 6	Building 6 - Control Point 160											
RC	---	---	---	---	0.4	0.3	---	0.3	0.4	0.5	0.6	0.6
pH	---	---	---	---	7.4	7.4	---	6.8	7.0	6.8	7.3	7.4
Coliform	---	---	---	---	0	0	---	0	0	0	0	0
Area 6	Building 70											
RC	---	---	---	---	---	---	0.3	0.4	0.3	0.5	---	---
pH	---	---	---	---	---	---	7.0	7.6	7.4	7.0	---	---
Coliform	---	---	---	---	---	---	0	0	0	0	---	---
Area 6	Building 162											
RC	---	---	---	---	---	---	---	0.3	---	---	---	---
pH	---	---	---	---	---	---	---	7.0	---	---	---	---
Coliform	---	---	---	---	---	---	---	0	---	---	---	---
Area 6	Building 165											
RC	---	---	---	---	---	---	0.3	---	---	---	---	---
pH	---	---	---	---	---	---	7.0	---	---	---	---	---
Coliform	---	---	---	---	---	---	0	---	---	---	---	---
Area 27												
RC	1.0	0.4	0.4	0.4	0.2	1.0	0.4	0.6	0.1	0.1	0.1	0.1
pH	8.0	8.1	7.7	7.6	7.9	7.6	7.8	7.6	7.2	7.2	7.1	7.3
Coliform	0	0	0	0	0	0	0	0	0	0	0	
	PERMIT NY-5084-12NC											
Area 1	Building 1-101											
RC	0.3	0.4	0.6	0.2	0.4	0.5	0.4	0.3	0.5	0.5	0.4	0.3
pH	7.9	7.8	7.7	7.5	7.4	7.5	7.4	7.6	7.4	7.8	7.0	7.1
Coliform	0	0	0	0	0	0	0	0	0	0	0	0

6.1.2 CLEAN WATER ACT

In accordance with the Nevada operating permits for the sewage lagoon systems on the NTS, regular influent sampling schedules have been set up according to permit specifications. Fourteen sewage lagoons were in operation at the end of 1989, with two new lagoons, Area 12 and Area 6 Yucca Lake[a], opened. Three existing lagoons, old Area 12, old Area 6 Yucca Lake, and Area 6 LANL, were closed. In addition, three lagoons did not have a sufficient inflow to monitor (Area 2, Area 25 Engine Test Stand, and Area 25 Test Cell "C").

(a) Yucca Lake is a dry lake bed (playa) on Yucca Flat.

Reporting of sampling results for all lagoon influents except Area 25 started in the second quarter of 1989. Quarterly averages were reported for the second and third quarters for all lagoons. Monthly sampling results for the Area 23 lagoon for total suspended solids (TSS), biochemical oxygen demand (BOD), and flow rate were reported for the fourth quarter.

State-required monitoring is conducted for flow rate, pH, BOD, and TSS. The flow rate and pH were estimated or measured at the time of sampling, while the BOD and TSS were determined by the City of Henderson Laboratory, 243 Water Street, Henderson, Nevada 89105. (See Table 6.2.)

Continuous monitoring of flow rates was conducted only on the Area 23 lagoon until the new Area 12 and Area 6 Yucca Lake facilities were completed. Until that time, flow rates were determined from periodic measurements at the Area 6 Yucca Lake, Area 12, and Area 25 Reactor Control sewage lagoons. ISCO flow meter numbers 2870 and 3210 were used for

Table 6.2 pH, BOD, and TSS in NTS Sewage Lagoon Influents - 1989

	Quarterly Average			Monthly		
	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter		
				Oct	Nov	Dec
pH						
Yucca Lake (Old)	N/S	9.5	7.7	---	Closed	---
Yucca Lake (New)	---	---	---	8.5		
Area 6 LANL	N/S	N/S	9.0	---	Closed	---
Area 6 Control Point 6	N/S	N/S	8.3	8.0		
Area 6 Control Point 72	N/S	N/S	9.5	6.5		
Area 12 Camp	N/S	7.0	6.8	7.3		
Area 22 Gate	N/S	9.8	7.0	7.1	7.4	7.7
Area 23	N/S	7.9	7.7	7.2	7.2	6.9
Area 25 Reactor Control	7.4	7.4	7.7	7.4		7.0
Area 25 Central Support	N/S	N/S	N/S	6.5		
FLOW RATE (in millions of gallons per day)						
Yucca Lake (Old)	N/S	N/S	.0038	---	Closed	---
Yucca Lake (New)	---	---	---	.0032	.0021	.0036
Area 6 LANL	N/S	.0045	.0045	---	Closed	---
Area 6 Control Point 6	N/S	.0078	.0044	.0047		
Area 6 Control Point 72	N/S	.0059	.0036	.0004		
Area 12 Camp	N/S	.0466	.0450	.0630		
Area 22 Gate	N/S	.0019	.0015	.0015		
Area 23	N/S	.0183	.1697	.1652	.0181	.0941
Area 25 Reactor Control	.0072	.0078	.0033	.0021		
Area 25 Central Support	N/S	N/S	.0007	.0006		
BOD (mg/L)						
Yucca Lake (Old)	N/S	N/S	N/S	154		
Yucca Lake (New)	---	---	---	N/S		
Area 12 Camp	N/S	>162	465	320		
Area 23	N/S	156	272	335	60	145
Area 25 Reactor Control	N/S	<40	N/S	N/S		
TSS (mg/L)						
Yucca Lake (Old)	N/S	N/S	N/S	244		
Yucca Lake (New)	---	---	---	---		
Area 12 CAMP	N/S	164	N/S	192		
Area 23	N/S	108	272	680	224	124
Area 25 Reactor Control	12	12	N/S	68		

N/S = No sample.

monitoring these flows. All other lagoons require an estimated flow rate.

The pH is determined by either a pH meter or colorimetric test strips when the BOD and TSS samples are collected. The sewage lagoon system permits require biannual sampling on the Area 6 Yucca Lake, Area 12, and Area 25 Reactor Control lagoon systems, and monthly sampling on the Area 23 lagoon systems for BOD and TSS. The samples at the old Yucca Lake and Area 12 sites were taken before the completion of the two new lagoon systems.

In addition to state-required monitoring, lagoon influent samples were collected for constituents relating to the Resource Conservation and Recovery Act (RCRA). The samples were submitted to Datachem Laboratory, 960 West LaVoy Drive, Salt Lake City, Utah 84123. Analysis was conducted for volatile organic compounds (VOCs), metals, and base/neutral/acid (BNA) compounds. Cyanide analyses were performed by the onsite contractor's industrial hygiene laboratory. Results of first- and second-quarter samples are provided in Table 6.3. These results were reported to the state of Nevada, and action guidance is pending state consideration. In 1990, in addition to continuing the above-mentioned sampling, RCRA samples will be taken to complete the closing of the old Yucca Lake, Area 6 LANL, and old Area 12 facilities.

Eight additional waste water discharges were sampled for the presence or absence of hazardous constituents. These are summarized below.

Table 6.3 RCRA Constituents in NTS Sewage Lagoons - 1989

	Results	
Analysis	April	August
Area 23 - North Central Primary Lagoon		
Cyanide	ND	
BNA	2.5 part per billion (ppb), Phenol	
VOC	ND	
Metals	80 ppb, Chromium 30 ppb, Silver	
Area 23 - East Secondary Lagoon		
Cyanide	ND	ND
BNA	ND	ND
VOC	ND	ND
Metals	10.0 ppb, Chromium (LD)	0.7 mg/L, Barium
Area 23 - Central Secondary Lagoon		
Cyanide	ND	8.0 ppb
BNA	ND	ND
VOC	ND	ND
Metals	ND	0.7 mg/L, Barium
Area 23 - West Secondary Lagoon		
Cyanide	ND	11.0 ppb
BNA	(a)	ND
VOC	ND	ND
Metals	ND	0.6 mg/L, Barium

Note: BNA and VOC are analyses for base/neutral/acid and volatile organic chemicals, respectively. BNA, VOC, and metal analyses were performed by Datachem Laboratory in Salt Lake City, Utah. Cyanide analyses were performed by REECo.

(a) Samples broken in shipment to laboratory. ND = None detected. LD = Limit of detection.

Table 6.3 (RCRA Constituents, cont.)

Analysis	Results: April	Results: August
Area 23 - South Central Primary Lagoon		
Cyanide		ND
BNA		3.4 ppb, Bis (2-Ethylhexyl) Phthalate
		4.5 ppb, Bis (2-Ethylhexyl) Phthalate
VOC		ND
Metals		0.6 mg/L, Barium
Gate 100 - Primary Lagoon		
Cyanide	ND	
BNA	[a]	
VOC	ND	
Metals	ND	
Area 6 CP - Primary Lagoon		
Cyanide	100 ppb	
BNA	ND	
VOC	ND	
Metals	10.0 ppb, Chromium (LD)	
Area 6 CP - Secondary Lagoon		
Cyanide	ND	
BNA	1.7 ppb, Phenol	
VOC	ND	
Metals	20 ppb, Chromium	
	50.0 ppb, Silver	
Area 6 H&N (CP-72) - Primary Lagoon		
Cyanide	ND	
BNA	25.0 ppb, Phenol	
	4.4 ppb, 1,4 Dichlorobenzene	
VOC	14.0 ppb, 1,2 & 1,4 Dichlorobenzene	
Metals	ND	
Area 6 Yucca Lake (Northwest System) - Primary Lagoon		
Cyanide	160 ppb	ND
BNA	13.0 ppb, Pyrene	ND
VOC	21.0 ppb, 1,2 & 1,4 Dicholorobenzene	3.8 ppb, 1,2 & 1,4 Dichlorobenzene
		5.5 ppb, 1,2 & 1,4 Dichlorobenzene
Metals	10.0 ppb, Chromium (LD)	ND
Area 6 Yucca Lake (Southeast System) - Northwest Primary Lagoon		
Cyanide	ND	
BNA	ND	
VOC	14.0 ppb, 1,2 & 1,4 Dichlorobenzene	
Metals	ND	
Area 6 Yucca Lake (Southeast System) - Southwest Primary Lagoon		
Cyanide	ND	
BNA	ND	
VOC	ND	
Metals	ND	
Area 2 - Primary Lagoon		
Cyanide	ND	
BNA	ND	
VOC	ND	
Metals	ND	

(a) Samples broken in shipment to laboratory. ND = None detected. LD = Limit of detection.

Table 6.3 (RCRA Constituents, cont.)

	Results	
Analysis	April	August
Area 12 - Fleet Operations (single pond)		
Cyanide	ND	
BNA	2.6 ppb Pyrene	
VOC	12.0 ppb, 1,2 & 1,4 Dichlorobenzene	
Metals	ND	
Area 12 Maintenance Camp - Southeast Primary Lagoon		
Cyanide	ND	
BNA	ND	
VOC	ND	
Metals	110 ppb, Lead	
Area 12 Maintenance Camp - Northeast Primary Lagoon		
Cyanide		ND
BNA		ND
VOC		ND
Metals		ND
Area 12 Maintenance Camp - Northwest Secondary Lagoon		
Cyanide	ND	
BNA	ND	
VOC	ND	
Metals	320 ppb, Lead	
Area 12 Maintenance Camp - Northeast Secondary Lagoon		
Cyanide	ND	
BNA	ND	
VOC	ND	
Metals	ND	
Area 12 Maintenance Camp - East Evaporation Lagoon		
Cyanide	ND	
BNA	ND	
VOC	ND	
Metals	70 ppb, Lead	
Area 12 Maintenance Camp - West Evaporation Lagoon		
Cyanide	ND	ND
BNA	ND	ND
VOC	ND	ND
Metals	ND	ND
Area 25 Reactor Control Point - Primary Lagoon		
Cyanide	ND	
BNA	ND	
VOC	ND	
Metals	ND	
Area 25 Central Support - Primary Lagoon		
Cyanide	ND	
BNA	ND	
VOC	3.1 ppb, trans-Dichlorethene 16.0 ppb, tetrachlorethane	
Metals	ND	

(a) Samples broken in shipment to laboratory. ND = None detected. LD = Limit of detection.

U4s DOWNHOLE WATER

Ice was used to cool the grout annulus on a drill hole. The melted water was sampled (one sample) prior to discharge into an unlined sump for evaporation. No hazardous constituents were detected.

AREA 12 N TUNNEL BYPASS DISCHARGE FROM AIR COMPRESSORS

Soil was stained with water discharged from the compressed air holding tank at the tunnel compressor pad. Other stained soils from maintenance operations areas at the tunnel were also sampled. Soils which contained no hazardous constituents were disposed of in the Class I landfill in Area 9. Contaminated soils will be consolidated with soils from other tunnel pads for RCRA disposal in a permitted disposal facility. (A total of 18 samples were taken.)

AREA 23, BUILDING 710 PAINT BOOTH WATER

The waste water from the paint booth was sampled (one sample) prior to discharge into the sanitary sewer system. No hazardous constituents were detected.

U12N TUNNEL DRAINAGE DISCHARGE

Groundwater seepage which discharges from the tunnel work stations was sampled (one sample) to assess potential contamination to the tunnel liquid discharge ponds. No hazardous constituents were detected.

AREA 2, BIT-CUTTER SHOP PARTS CLEANING EFFLUENT

The waste water used for bit and roller cooling was sampled (one sample) for hazardous constituents. No hazardous constituents were detected. The effluent was discharged to the sewage lagoon system.

AREA 12, BUILDING 12-16 STEAM CLEANING EFFLUENT

Soil in the area of the discharge from the steam cleaning pad was sampled (six samples) for hazardous constituents. No hazardous constituents were detected. This discharge will be routed to the sewage lagoon system in the future.

AREA 12 PAINT YARD

Stained soil areas were sampled (four samples). No hazardous constituents were detected. The stained areas were cleaned and the soil disposed of in the U10c Class I landfill.

6.1.3 TOXIC SUBSTANCES CONTROL ACT

During 1989, 927 transformer oil samples were analyzed to determine PCB concentrations. PCB analyses were also done on 3 soil samples, 4 waste oil samples, and 17 swipe samples.

Transformer oil results are as follows: 793 samples were less than 8 ppm of PCB (limit of detection), 123 samples were between 8 and 500 ppm, and 16 samples had concentrations in excess of 500 ppm. All three soil samples analyzed were less than the detection limit of 8 ppm. Of the four waste oil samples analyzed, one was less than the detection limit of 8 ppm, while the other three samples were in excess of 500 ppm. The 17 swipe samples ranged from less than 1 $\mu g/100\ cm^2$ to 3790 $\mu g/100\ cm^2$.

6.1.4 NATIONAL EMISSION STANDARDS FOR HAZARDOUS AIR POLLUTANTS

During 1989, 341 bulk and air samples were collected and analyzed in conjunction with asbestos removal and renovation projects at the NTS. Of the 195 bulk samples collected, 87 were positive for asbestos and 108 were negative. Fifty-three (27.2 percent) bulk quality assurance samples were also analyzed. A total of 146 general area air samples were collected and analyzed, along with 76 (52.1 percent) quality assurance samples.

Table 6.4 Number of RCRA Samples Analyzed - 1989

Sample Type / Analysis	Soil	Water	Sediment	Waste Oil	Other
Volatile Organics	53	139			2
Semi-volatile Organics	18	139			
ICP Metals	12	85			
EPTox Metals	14	54	1	9	5
EPTox Lead	16				
pH	6	17			6
Flashpoint	6	17		5	15
Other	3	59		7	14
Total	128	510	1	21	42

6.1.5 RESOURCE CONSERVATION AND RECOVERY ACT

Table 6.4 provides the number of samples analyzed in 1989 to satisfy RCRA requirements for the waste management and environmental compliance activities. All of the volatile and semi-volatile organics, ICP[a] metals, and EPTox[b] metals analyses were performed by outside commercial laboratories.

A minimum of 10 percent of quality control samples were analyzed for EPTox lead, pH, flashpoint, and other analyses, in addition to the analyses reported in the table.

6.2 ENVIRONMENTAL CONDITIONS

6.2.1 FLORA

The weather in 1989 was very dry, with precipitation at the NTS lower than any year since recording of precipitation data began in 1962. Precipitation measured at Yucca Flat in 1989 totaled 55.4 mm (2.18 inches). This drought, in conjunction with the past several years of reduced annual precipitation, had major effects on the biota of the NTS, and influences of man could be considered minor in comparison. The effects of the drought were seen on all phases of monitoring and are exemplified in the results from the control baseline study plot in Yucca Flat.

Ephemeral plants occur in abundance most years in the desert vegetation. During 1989, however, there were no germinating rainfall events. Below about 6000 feet in elevation, the number of ephemerals was measured as 0 per 1000 square meters of area, an unprecedented low record. Above 6000 feet in elevation, there was slight germination observed and very poor growth and reproduction, with growth occurring largely in the introduced grass species

(a) "ICP metals" refers to substances which have been subjected to the "inductively coupled plasma" test. This is a test for the presence of certain metals.

(b) "EPTox metals" refers to substances that have been subjected to the "extraction procedure toxicity" test. This is a test for the presence of heavy metals and whether these metals will leach from a soil matrix under controlled laboratory conditions.

Bromus tecterum and the annual *Halogeton glomeratus*. Neither species is common above 6000 feet except in disturbed areas.

Perennial shrubs in the southern portion of the NTS remained largely dormant throughout the year. Many of the shrubs and large portions of the bunch grass populations died during 1989. Table 6.5 illustrates an approximate 30 percent decline in live perennial plants at the baseline monitoring plot in southwestern Yucca Flat. In the higher altitudes, sagebrush (*Artemisia tridentata*) showed a small amount of new growth, but almost no flowers or fruit. Evergreen species were water stressed, but the majority of healthy individuals appeared to survive. Effects of human activities on the NTS were much less widespread than the observed effects due to the reduced precipitation.

6.2.2 FAUNA

The effect of the drought on lizard populations (*Uta stansburiana*) can be seen in Table 6.6. On the baseline control plot in Yucca Flat, numbers of adults increased due to good reproduction in 1987 and 1988. Numbers of hatchlings were very low in 1989, however, because most females did not lay eggs in 1989. It may be expected that adult lizard populations will be reduced in 1990 because of the poor 1989 reproduction. Small mammals on the NTS are largely of a small, granivorous rodent species. Surveys of the control baseline plot occurred in the Spring and showed declines of 40 to 50 percent in numbers between 1988 and 1989 for the most common species (Table 6.7). Later trapping suggested reproduction was poor during the summer of 1989, so further declines are also expected for 1990.

During 1989 an effort was made to monitor the numbers of both horses and deer on the NTS. The deer population was roughly estimated to be between 800 and 1600 animals, which is consistent with estimates made in the late 1970s. The number of feral horses on the NTS numbered approximately 50 individuals, with 45 having been positively identified by individual markings recorded in photographs. Only four or five foals were observed in 1989. There were approximately 34 water sources (springs and well reservoirs) that were

Table 6.5 Survival of Perennial Plants on Three 100-m^2 Transects on a Pristine Monitoring Plot, Yucca Flat, NTS

	Live Plants		
Transect	1988	1989	Percent Survival
1	397	279	70
2	352	255	72
3	353	239	68

Table 6.6 Estimated Densities (n/ha ± 2 se) of the Lizard *Uta stansburiana* in Summer on a Pristine Plot in Yucca Flat, NTS

	1987	1988	1989
Adults	33 ± 6	42 ± 13	55 ± 11
Hatchlings	123 ± 18	101 ± 34	11 ± 5

Table 6.7 Estimated Densities (n/ha ± 2 se) of Common Mammals in April 1988 and May 1989 on the Pristine Plot in Yucca Flat, NTS

Species	1988	1989
Dipodomys merriami (Merriam's Kangaroo Rat)	5.9 ± 0.3	3.7 ± 0.0
Dipodomys microps (Great Basin Kangaroo Rat)	6.3 ± 0.9	3.6 ± 0.7
Perognathus longimembirs (Little Pocket Mouse)	23 ± 2	11 ± 2

monitored for horse utilization; only seven water sources, of which all are man-made except one (Captain Jack Spring), are presently being utilized by feral horses. The estimated range of the feral horses is centered near or in the Eleana Range, in Areas 2, 12, 15, 17, and 19 of the NTS.

6.2.3 CRATER ENVIRONMENTS

Biological monitoring work was conducted in three subsidence craters during 1989 to characterize the effects of cratering due to underground testing on the biota. Crater environments were found to be complex.

In the center of the craters, a mini-playa develops that is devoid of vegetation. On the areas of the crater disturbed by scraping, the vegetation that reappears is dominated for a few years by the introduced Russian thistle (*Salsola* sp.). Indian rice grass (*Oryzopsis hymemoides*) invades the craters, and populations on the north-facing slopes were found to be higher than on the south-facing slopes. Most shrubs present before cratering survived, but the change in slope apparently leads to some erosion, affecting shrub seed deposition and germination. Long-term changes are to be expected in the craters' vegetation patterns.

Lizard and small mammal populations in subsidence craters appeared to be complex, probably due to the complex vegetation patterns. Differences in species composition between craters and the control areas outside them were observed, but conclusions could not be drawn as to effects of the cratering. Disturbances of vegetation that occurred during drilling and staging operations for a test may have had just as great an effect.

7.0 ENVIRONMENTAL OCCURRENCES

7.1 RADIOLOGICAL OCCURRENCES

Daniel A. Gonzalez

Radiological releases from seepage or releases from post-test drill-back or during tunnel re-entry activities are considered as normal operational releases, reported elsewhere in this report. There were no other radiological environmental occurrences at the NTS in 1989.

7.2 NONRADIOLOGICAL OCCURRENCES

Carl S. Soong

Nonradiological environmental occurrences included one incident of disposal of uncontaminated drilling mud in a closed landfill and three incidents of spilled or leaked petroleum products. These incidents were reported as unusual occurrence reports, nonconformance reports, or unplanned releases.

7.2.1 UNUSUAL OCCURRENCE REPORTS (UORs)

During 1989 two UOR events were reported as being environmentally significant. UORs are prepared for environmental, health, and safety episodes or incidents in accordance with DOE Order 5000.3, "Unusual Occurrence Reporting System."

UOR - DRILLING MUD DISPOSAL

On June 2, 1989 (0945 hours), a drilling mud disposal subcontractor unloaded uncontaminated drilling mud at the U3ai/be subsidence crater. The crater had been closed to dumping of either hazardous or nonhazardous material as of March 10, 1989. The subcontractor was instructed by drilling department supervision to dispose of the mud at the same location which had always been used, after a radiological protection technician (RPT) had surveyed and released the load as uncontaminated. When the driver arrived at U3ai/be, the posted signs prohibited the disposal of hazardous materials; no sign had been posted regarding nonhazardous material. The driver, having been informed by the RPT that the mud was uncontaminated (nonhazardous), dumped the mud into the crater. That afternoon, waste management personnel discovered the dumped drilling mud.

Corrective Action

Future disposal of drilling mud will be at the authorized disposal sites, selected by the site operating contractor and DOE/NV. The sites will be managed as Class III Landfills and regulated as such by the state of Nevada.

UOR - AIRCRAFT FUEL SPILL

On June 21, 1989 (0800 hours), an aircraft was being fueled at fuel pit #3 at the Desert Rock Airstrip near Mercury, Nevada, when a leak was observed on the outgoing side of the Totalizer meter within the pit. Approximately 30 gallons of Jet A fuel had been discharged into the bottom of the pit. To facilitate repairs an additional 10 gallons of fuel was drained from the lines and pumped into the pit. As a result of repair work, another leak was created on

the incoming fuel line and approximately 20 more gallons of fuel was released into the pit. There was a total loss of 60 gallons of Jet A fuel.

Corrective Action

Gaskets were replaced and operational checks were performed on the refueling hose with no discrepancies noted. The area was washed down by the NTS Fire Department. Checks of the fuel pit by personnel refueling the aircraft are now required prior to all fueling operations.

7.2.2 NONCONFORMANCE REPORTS (NCRs)

Environmental occurrences at the NTS that do not involve regulatory compliance are reported and addressed through an operating contractor NCR. One NCR was filed for 1989 activity involving environmental conditions.

NCR - 1978 FUEL LEAK

On December 21, 1989, during an excavation of underground storage tanks (USTs) at Building 115 in Mercury, what appeared to be an asphaltic layer of soil was discovered beneath one of the USTs. Further excavation revealed a suspected leak from diesel fuel tanks previously removed in 1978. Historical data later confirmed that a tank had been replaced in 1978 because it was leaking diesel fuel. The leak, which is estimated at 100,000 gallons, had apparently become a solidified mass.

Corrective Action

Pursuant to verbal affirmation from the state (Nevada Division of Environmental Protection), the excavation was back-filled. A soil gas survey was conducted to estimate the contaminant plume extent. It was concluded that the majority of the diesel fuel plume migration was vertical with limited lateral migration. A research proposal to study the plume migration will be submitted to the state in 1990. Very little is known about contaminant plumes of this type in desert environments.

7.2.3 UNPLANNED RELEASES

There were two additional unplanned releases of nonradiological contaminants (petroleum products) in 1989 at the NTS that did not require UOR or NCR reporting. A PCB release and a hydraulic fluid release, both of which occurred in 1988, were cleaned up.

PETROLEUM PRODUCT SPILLS

Well 3 Yard, Area 6

During the month of June, oil had leaked from transformers located in the Warehouse C Yard, staining the soil. Soil samples were collected and tested for PCBs. Results of sampling were negative for PCBs, and the soil was scraped up and disposed of in a Class I landfill. Only labeled, non-PCB transformers will be stored in the warehouse yard in the future. PCB and PCB-contaminated transformers will be stored at the Area 6 Lineman's Shop.

Area 25 Heliport

On September 11, 1989, an unplanned release of JP4 fuel occurred at 1030 hours. The release occurred when a fuel truck experienced a break in a line, which resulted in the loss of 35 to 40 gallons of fuel onto the asphalt landing area. The NTS Fire Department diluted the fuel with approximately 200 gallons of water and allowed it to evaporate. No cleanup was required and the spill was less than the reportable quantity of 50 gallons.

1988 PCB RELEASE CLEANUP

In September 1988 a capacitor, located in Building 5100, Area 27, burst and contaminated the basement of the building. There was no release to the outside environment. Continued decontamination in 1989 resulted in 17 swipe samples being collected to verify the effectiveness of

cleanup efforts. These efforts failed to achieve the cleanup levels mandated by the Toxic Substances Control Act for low-contact, indoor industrial surfaces of less than 10 µg/100-cm^2 swipe. Further cleanup efforts are slated for 1990. All cleanup wastes were disposed of offsite in a permitted disposal facility.

1988 HYDRAULIC FLUID SPILL CLEANUP

In June 1988 a hydraulic seal on a large transport vehicle failed, contaminating soil in the storage yard of Building 4221, Area 25. Soil samples analyzed revealed that no regulated contaminants were present. The soil was cleaned up in 1989 and disposed of in a Class I landfill.

8.0 RADIOACTIVE AND MIXED WASTE DISPOSAL

Robert J. Straight

Two radioactive waste disposal facilities are operated on the NTS. The Area 5 Radioactive Waste Management Site (RWMS) received low-level and mixed wastes generated at other DOE facilities during 1989. Waste is disposed of in shallow pits, trenches, and intermediate-depth, large-diameter augured shafts. Transuranic (TRU) wastes are stored in surface containers pending shipment to the Waste Isolation Pilot Plant (WIPP) in New Mexico. The Area 3 Bulk Waste Management Facility (BWMF) is used for disposal of low-level waste that cannot be packaged for disposal at the Area 5 RWMS. Environmental monitoring includes air sampling, swipe monitoring for gross radioactivity, radon sampling, and vadose zone monitoring for hazardous constituents.

8.1 WASTE DISPOSAL OPERATIONS

The Radioactive Waste Management Project was established at the NTS in January 1971. On that date, the first of six trenches was opened for the disposal of radioactive waste materials from the NTS.

In 1978 operations expanded to include the disposal of low-level waste (LLW) generated at other DOE facilities. Disposal in shallow pits, trenches, large-diameter augured shafts, and subsidence craters is accomplished at two different sites, thirteen miles apart: the RWMS in Area 5 and the BWMF in Area 3.

Eighteen DOE waste generators were authorized to send waste materials to the NTS for disposal in 1989. These were: Bendix/Kansas City, the Defense Nuclear Agency, EG&G/Energy Measurements, EG&G Mound Technologies, EG&G/Santa Barbara, EPA/Las Vegas, General Atomics, the Lawrence Livermore National Laboratory, Lockheed, the Lovelace Foundation, Mason & Hanger, the New Brunswick Laboratory, Rockwell/Rocketdyne, the Rockwell/Rocky Flats Plant, Sandia Laboratories/Livermore, the U.S. Army/Aberdeen, the U.S. Navy, and Westinghouse Materials Company of Ohio. Hazardous waste disposal operations at the NTS required the shipment of hazardous materials to licensed disposal facilities offsite. No disposal of hazardous materials was done at the NTS except as constituents of the mixed waste received from the Rocky Flats Plant.

RADIOACTIVE WASTE MANAGEMENT SITE

The RWMS occupies approximately 700 acres of the Frenchman basin in the southeastern part of the NTS. It is located in Area 5, 14 miles north of the NTS main gate. Area 5 includes much of the Frenchman Flat playa where nuclear tests were conducted in the 1950s to determine civilian and other effects of nuclear weapons.

The Frenchman basin is bounded on the north by the Massachusetts Mountains, Black Ridge, and Mt. Salyer to the west; the Buried Hills and Ranger Mountains to the east; and Mercury Ridge to the south. The general surface rock type in the area is alluvial sediment. The basin is filled with up to 1000 feet of these sediments, which have collected there from the surrounding mountains.

The disposal site is located on a relatively flat alluvial fan extending southward from the Massachusetts Mountains, which lie approximately two miles away. In the vicinity of the disposal site, the slope of the terrain is two percent toward the mountains. Toward the west, the general slope is also upward, approximately three percent. Two shallow dry washes cut through the site from the northwest; an earthen dike has been constructed along the northern border of the RWMS to prevent water flow into the disposal area from this direction.

There are no permanent sources of surface water or water wells at the RWMS; domestic water supplies for the site are obtained from storage tanks. The distance to groundwater is approximately 800 feet; preliminary modeling studies have shown the travel time from the surface to be thousands of years.

The RWMS contains the low-level waste management unit which is comprised of the LLW disposal unit, the TRU waste storage cell, and the Greater Confinement Disposal (GCD) unit. Of the 732 acres of the RWMS, 92 acres are fully fenced, posted with warning signs, and in current use for LLW waste disposal operations.

The Mixed Waste Management Unit (MWMU) is located just north of the RWMS and will be part of routine disposal operations. This area, covering approximately 24 acres, will contain 18 landfill cells to be used for mixed waste disposal. During 1989 the MWMU was operated under RCRA interim status authorization from the state of Nevada, pending approval of the permit application.

Mixed waste is received only from the DOE Rocky Flats Plant and is presently retreivably disposed of in Pit 3. The first shipment was received in December 1988.

The RWMS (as well as the BWMF) accepts only waste materials which are defense related. All waste must meet the requirements of DOE Order 5820.2A, "Radioactive Waste Management," as well as the NTS-specific criteria in NVO-325, Nevada Test Site Defense Waste Acceptance Criteria, Certification, and Transfer Requirements, and relevant DOT regulations. The site itself is operated in full compliance with applicable EPA regulations and DOE Orders.

Wastes are usually received in DOT Type A containers, e.g., heavy plywood boxes or 55-gallon steel drums. These are neatly stacked, and the location of each package within the stack is noted in case retrieval is necessary. An eight-foot cap of clean soil, which extends four feet above grade, is eventually placed over the waste materials to effectively isolate them from the biosphere and the environment in general.

Most of the shipments received are tritium- and plutonium-contaminated materials; however, special equipment and facilities are available for handling high specific activity gamma emitters which are received on occasion. Reusable Type B transportation containers are used to ship these materials. An inner container containing the radioactive material is removed from the shipping cask and placed in GCD shafts.

GREATER CONFINEMENT DISPOSAL

GCD (intermediate depth burial) is used as a supplemental disposal method to augment shallow land disposal. This latter method is not suitable for the disposal of certain materials which might constitute special hazards to the public or the environment. As a result the concept of deep burial in augured shafts to a depth of approximately 120 feet was proposed.

Work at the GCD test location was conducted by personnel from the University of California, Berkeley, in an effort to determine the tritium (^3H) emanation rate. Air samples taken from the head space over the main shaft and each satellite hole around the main shaft have shown tritiated water (HTO) concentrations to vary from 3.3 x 10^{-8} µCi/cc of air to 1.2 x 10^{-8} µCi/cc of air, depending upon the location. Tritium gas concentrations were typically lower than the respective HTO concentrations. The Derived Air Concentrations (DACs) of tritium oxide and tritium gas in air for occupational

exposures are 2.0×10^{-5} μCi/cc of air and 5.0×10^{-1} μCi/cc of air, respectively (DOE Order 5480.11, Chg. 1, 7-20-89).

The GCD area at the RWMS is surrounded by an earth berm in an isolated part of the site. Preliminary results have shown an airborne HTO concentration of 5.2×10^{-8} μCi/cc of air and tritium gas concentration of 1.7×10^{-7} μCi/cc of air in the head space inside one covered shaft containing high specific activity tritium waste.

TRANSURANIC WASTE STORAGE

The TRU waste storage cell was used for interim storage of certified TRU waste materials from the LLNL. The waste materials were packaged in steel drums and steel boxes and stored in large steel cargo containers pending shipment to the Waste Isolation Pilot Plant in New Mexico.

BULK WASTE MANAGEMENT FACILITY

The second disposal site is the BWMF in Area 3. It lies at an elevation of 4050 feet and covers approximately 50 acres. It is located in a large valley bounded by mountains and the Nellis Bombing and Gunnery Range. Its climate and topography is similar to that of the site in Area 5. Further details regarding the BWMF are available in DOE report DOE/NV/10327-39 (Gonzalez 1988).

Waste materials which could not be packaged were disposed of at the BWMF, but only LLW was accepted. Much of the waste material buried there is contaminated soil and metal remaining onsite from the atmospheric testing of nuclear weapons at the NTS. During 1989 these materials were collected from individual test or disposal areas, transported to Area 3 by truck, and unloaded in subsidence craters, which resulted from surface ground collapse after underground nuclear detonations. As layers of waste material have been added, waste has been covered with uncontaminated soil until the crater is filled.

Two craters, U3ax and U3bl, were filled in this manner. Between 1974 and 1988, 208,000 cubic meters of contaminated material were consolidated at this location. An eight-foot cap of clean soil extending four feet above the grade was placed over the craters to isolate them and the waste they contain. In compliance with RCRA, a closure plan for this location has been submitted to the state of Nevada. Approval was pending at the end of 1989.

The Atmospheric Testing Debris Disposal Program, formerly known as the Waste Consolidation Project, was restarted on August 1, 1989, and discontinued on September 11, 1989. The material collected was placed at the Area 3 ah/at site during this period.

CONTAMINATED DRILLING MUD DISPOSAL

The state of Nevada previously denied the DOE Nevada Operations Office permission to reinject contaminated drilling muds and fluids into nuclear test device emplacement holes (used for testing in vertical shafts) and, by implication, disposal in tunnel areas adjacent to the nuclear test location in the Rainier Mesa tunnels. In September 1989 the state agreed that post-test drill-back mud that is contaminated with radioactivity but does not contain hazardous materials at levels regulated by RCRA may be placed back into the event cavity. Drill mud containing RCRA-regulated material is to be solidified and disposed of at the mixed waste disposal facility in Area 5. Non-RCRA drill mud that is not contaminated with radioactivity is to be disposed of by the mixing of mud with soil and then covering it with a layer of soil. This procedure also applies to post-test reentry drilling operations in the tunnels.

8.2 WASTE DISPOSAL ENVIRONMENTAL MONITORING

At the RWMS airborne particulate material was collected at nine sites around the perimeter fence and from six sites within the fence. At the BWMF four samplers were deployed around the perimeter fence.

In both cases the air flow rate was 100 liters per minute, continuously.

The sampling media, which consisted of four-inch, glass-fiber filters and charcoal cartridges, were collected weekly. The cartridges and filters used in the samplers were analyzed for gross beta and gamma activity. Members of the ^{238}U and ^{232}Th decay chains and ^{40}K were the most frequently detected, but in very low concentrations, typically below the detection limits of the analytical instrumentation.

Thermoluminescent dosimeters were deployed at 16 locations around the RWMS to obtain long-term radiation readings and were collected quarterly. Due to the nature of the operations at the RWMS, very little contamination was detected other than that from naturally-occurring radioactive materials. Stringent packaging requirements, unloading protocols, monitoring, and limited access worked together to keep contamination levels at a minimum and to prevent the spread of what small amounts of contamination were detected.

AIRBORNE TRITIUM MONITORING

The primary airborne contaminant at the RWMS is ^{3}H. Due to its tendency to migrate with soil moisture, it represents the greatest potential for human exposure at that site. Seven megacuries have been buried at the RWMS, and special monitoring was performed at locations of higher risk to operating personnel.

Samplers for tritium oxide were located together with the particulate samplers. The tritium samplers consisted of a column of silica gel, a pump for drawing air through the desiccant, and a rotameter to measure the sampling rate. Samples were collected routinely every three to four weeks, during which approximately 340 cubic meters of air were sampled. Three indoor monitoring stations were established where the potential for exposure was higher. The results of the samples taken at these locations are summarized in Table 8.1.

WATER SAMPLING

There were few opportunities to collect water samples of any kind at either disposal site during 1989. When samples could be collected following a precipitation event, they were taken from areas of high traffic whenever possible and analyzed for gamma emitters. No activity above background levels was found in any of the samples taken during 1989.

AREA MONITORING

Swipe samples (smears) were taken as checks on the radiological integrity of the various facilities in Areas 5 and 3 and analyzed in those areas. They were taken from offices, lunchrooms, work surfaces, laboratories, vehicles, etc., on routine schedules or as needed. No gross alpha or gross beta activity above background levels were found in any of the samples from either site during 1989.

Table 8.1 Indoor Tritium Concentrations at the NTS Radioactive Waste Management Site - 1989

	x 10^{-11} µCi HTO per cc of air		
Station Number	Maximum	Minimum	Average
CETO-2	176	1.23	28
Bldg. 5-7	13.9	0.787	5.7
GCD Test	258	1.47	130

RADON SAMPLING

Approximately 290 curies of waste material containing uranium and thorium is in temporary storage in an isolated location at the RWMS pending final disposal there. The materials were packaged in wooden boxes which in turn were stored in 28 steel cargo containers. These containers were passively ventilated through holes in the container walls, and samples of the atmosphere inside have been taken as needed from these vent holes. The containers were located inside a fenced area which was posted with warning signs, and the containers have not been opened because of the airborne contamination known to be present in them.

Results of the sampling of these containers showed widely varying amounts of ^{222}Rn in the interiors. The radon was obviously seeping through the walls of the containers or around the lids since it was seen that the radon daughters (^{218}Po, ^{214}Pb, and ^{214}Bi) were not in equilibrium with the parent. This implied that the radon was not remaining in the containers long enough for equilibrium to be established (four hours).

Air samples taken from within the storage containers showed radon concentrations to be quite variable from one container to the next, but generally less so from one sampling period to the next for the same location. In 1989 these concentrations ranged from 2.8×10^{-5} µCi/L to 9.1×10^{-7} µCi/L of air.

In addition to the airborne alpha emitters present, accumulation of ^{214}Bi inside these containers constituted an additional gamma hazard besides that of the parent material. Ventilation reduced the hazards from penetrating radiations and was in keeping with the philosophy of keeping doses as low as reasonably achievable (ALARA).

VADOSE ZONE MONITORING

As part of the mixed waste disposal project, a method for monitoring a waste stack has been needed to give an indication of leakage of hazardous materials onto the floor of the disposal pit. Work has been proceeding on installation of this monitoring system to detect contaminants in the upper levels of the vadose (unsaturated) zone long before they might reach the deep water table.

Because of the very low levels (parts per billion) of hazardous materials which must be detected in order to give early warning of a leak, a very sensitive analytical technique is needed. This has been developed, but many natural interferences have been found. This has greatly complicated the process of characterization of the "background" soil. The process of inserting soil gas samplers can easily contaminate clean soil to the extent that small amounts of foreign materials may go undetected; these foreign materials might be indicative of migration of hazardous materials.

It has been found that collection of materials of interest on small charcoal tubes from soil gas samples and thermal desorption of the collected materials into a gas chromatograph provides excellent analytical sensitivity. This appears to be the most promising method for accomplishing future work.

9.0 DOSE ASSESSMENT (EPA 1990)

Stuart C. Black

The extensive offsite environmental surveillance system operated around the NTS by the EPA measured no radiological exposures that could be attributed to NTS operations. Calculation of potential dose to offsite residents, based on onsite source emission measurements and use of the EPA's AIRDOS-PC model, resulted in a maximum calculated dose of 1.5 x 10^{-4} mrem (0.00015 mrem) to a resident of Pahrump, Nevada, 80 kilometers south of the NTS Control Point. Monitoring network data indicated a 1989 dose of 67 mrem from normal background radiation at Pahrump. The calculated population dose to the 8400 residents living within 80 kilometers of the Control Point was 1.1 x 10^{-3} person-rem (0.0011 person-rem, or 1.1 x 10^{-5} person-sievert).

9.1 ESTIMATED DOSE FROM NTS ACTIVITIES

The estimate of effective dose equivalent to the offsite population due to NTS activities was based on the total release of radioactivity from the Site in 1989 as listed in Table 2.1. As no radioactivity of recent NTS origin was detectable offsite by the various monitoring networks, no measurable exposure to the population living around the NTS would have been expected. To confirm this expectation, a calculation of estimated dose was performed using EPA's AIRDOS-PC model. The individuals exposed were considered to be all of those living within a radius of 80 kilometers of the NTS Control Point, a total of 8400 individuals. The individual with the maximum calculated dose from airborne NTS radioactivity would have been continuously present at Pahrump, Nevada, 80 kilometers south of the NTS. That maximum dose was 1.5 x 10^{-4} mrem (1.5 x 10^{-6} mSv). The population dose within 80 kilometers would have been 1.1 x 10^{-3} person-rem (1.1 x 10^{-5} person-Sv).

During calendar year 1989 there were four sources for possible radiation exposure to the population of Nevada that were measured by offsite monitoring networks. The four sources were:

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

The estimated dose equivalent exposures from these sources to people living near the NTS are calculated separately in the following subsections.

Table 2.2 summarizes the annual effective dose equivalents due to operations at the NTS during 1989.

9.2 ESTIMATED DOSE FROM WORLDWIDE FALLOUT

From the monitoring networks described in previous sections of this report, the following concentrations of radioactivity were found:

- Tritium (^{3}H) [0.24 x 10^{-12} µCi/mL of air (9 mBq/m^3)].
- ^{85}Kr [26 x 10^{-12} µCi/mL of air (0.98 Bq/m^3)].
- ^{90}Sr [0.64 x 10^{-9} µCi/mL in milk (24 mBq/L)].
- ^{137}Cs [28 pCi/kg in beef liver (1 Bq/kg)].
- $^{239+240}Pu$ [24 fCi/kg in beef liver (0.9 fBq/kg)].

The dose is estimated from these findings by using the assumptions and dose conversion factors as follows:

- The adult breathing rate is 8400 m^3/year, milk intake (for a 10-year old) is 160 L/year, liver consumption is 0.5 lb/week = 11.8 kg/year.
- Meat consumption is 248 g/day; when liver consumption is subtracted, this is 78.7 kg/year.

The dose conversion factors are based on the annual limit of intake (ALI) divided by 50 to convert to public ALI in becquerels, then multiplied by 100 and by 0.037 and inverted to convert to mrem/pCi:

- ^{3}H (6.2 x 10^{-8} mrem/pCi).
- ^{90}Sr (1.8 x 10^{-4} mrem/pCi).
- ^{137}Cs (4.5 x 10^{-5} mrem/pCi).
- $^{239+240}Pu$ (9 x 10^{-4} mrem/pCi).
- ^{85}Kr (1.6 x 10^{-4} mrem/year per pCi/m^3).
- ^{133}Xe (2 x 10^{-4} mrem/year per pCi/m^3).

As an example calculation, the following is the result for ^{3}H:

- 0.24 pCi/m^3 x 8400 m^3/year x 6.2 x 10^{-8} mrem/pCi = 0.12 x 10^{-3} mrem.

Also:

- ^{98}Sr (0.64 x 160 L/year x 1.8 x 10^{-4} = 18 x 10^{-3} mrem).
- ^{137}Cs (28 x 11.8 x 4.5 x 10^{-5} = 15 x 10^{-3} mrem).
- $^{239+240}Pu$ (24 x 10^{-3} pCi/kg x 11.8 x 9 x 10^{-4} = 0.26 x 10^{-3} mrem).
- ^{85}Kr (26.4 x 1.6 x 10^{-4} = 4.2 x 10^{-3} mrem).

Therefore, exposure to worldwide fallout causes a dose equivalent equal to the sum of the above or 37 x 10^{-3} mrem (0.37 x 10^{-3} mSv).

9.3 ESTIMATED DOSE FROM RADIOACTIVITY IN NTS DEER

The highest measured concentrations of radionuclides in mule deer tissues occurred in deer collected on the NTS.

The maximum values were:

Tissue	^{3}H	$^{239+240}Pu$
Liver (pCi/kg)	87 x 10^{3}	0.19
Muscle (pCi/kg)	17 x 10^{3}	0.06

The ^{3}H concentration was calculated by using 5.8 x 10^{5} pCi/L in blood, assuming liver was 15 percent blood and muscle was 3 percent blood (ICRP-23).

In the unlikely event that one such deer was collected by a hunter in offsite areas, the hunter's intake could be calculated. Assuming 3 pounds of liver, 100 pounds of meat, and the radionuclide concentrations listed above, the dose equivalents would be:

- Liver: 1.36 [(87 x 10^{3} x 6.2 x 10^{-8}) + (0.19 x 9 x 10^{-4})] = 8 x 10^{-3} mrem.
- Muscle: 45.4 kg [(17 x 6.2 x 10^{-8}) + (0.06 x 9 x 10^{-4})] = 50 x 10^{-3} mrem.

Thus, approximately 0.06 mrem would be delivered to one individual consuming the stated quantity of meat and assuming no radioactivity was lost in food preparation. About 97 percent of this dose equivalent was from the ^{3}H content of the meat.

9.4 DOSE FROM BACKGROUND RADIATION

In addition to external radiation exposure due to cosmic rays and gamma radiation from naturally-occurring radionuclides in soil (^{40}K, uranium, and thorium daughters, etc.), there is a contribution from ^{7}Be that is formed in the atmosphere by cosmic ray interactions with oxygen and nitrogen. The annual average ^{7}Be concentration measured by the offsite air surveillance network was 0.11 pCi/m^3. With a dose conversion factor for inhalation of 2.6×10^{-7} mrem/pCi, this equates to 3×10^{-8} mrem, a negligible quantity when compared with the pressurized ion chamber network measurements that vary from 52 to 165 mR/year, depending on the location.

9.5 SUMMARY

The individual with the calculated (modeled) highest exposure to NTS effluent during 1989 was someone living in Pahrump, Nevada, where the NTS exposure, plus that due to worldwide fallout, plus background would add to: (0.0002 + 0.04 + 67) mrem = 67 mrem (0.67 mSv). Both the NTS and worldwide distributions contribute a negligible amount of exposure compared to natural background.

10.0 ONSITE DOSE FROM AIRBORNE RELEASES (1980-1989)

Daniel A. Gonzalez

During the period between 1980 and 1989, four nuclear test events resulted in discharges of radioactivity sufficient to be detected offsite. Air surveillance analysis data taken during post-event gas seepages and/or planned releases are presented and attributed to specific nuclear tests conducted during 1980, 1985, and 1986. Both air particulate and noble gas data are presented when available; noble gas sampling began in 1982.

This section compares the levels of radionuclides released into the environment to the applicable concentration guides for both radiation workers and members of the general public. Exposure to activity detected by monitoring equipment located close to the surface ground zero (SGZ) and points of discharge could provide radiation dose to a hypothetical worker. However, even under the conservative assumptions that a worker was present at the source of discharge, the dose contribution to this hypothetical worker was a very small percentage of the annual dose guidelines.

RIOLA EVENT

Beginning the last week of September 1980, elevated levels of airborne beta radioactivity were detected on several of the permanent air monitoring stations throughout the Yucca Flats region. The increase was determined to originate from radioactive seepage from the RIOLA site; a Yucca Flats event conducted on September 25, 1980.

The overall increase during the latter half of the year was on the order of 1.5 times the typical NTS airborne beta activity. Air samplers throughout the NTS registered low but discernable quantities of beta activity above normal NTS levels. The identification and documentation of the event and the corresponding elevated levels may be found in the Environmental Surveillance Report for the Nevada Test Site (January 1980 through December 1980). Briefly, the airborne beta activity average from all air sampling stations for July though December of 1980 (which includes the data taken during the RIOLA event) was 5.3×10^{-14} µCi/mL. The gross beta activity average for January though June 1980 was 2.4×10^{-14} µCi/mL, which is considered to be a typical baseline gross beta activity at the NTS. To compare the beta activity detected to DACs (the DAC, or Derived Air Concentration, is described below), the conservative assumption was taken that all of the beta activity detected originated from the decay of ^{90}Sr.

The DAC is the concentration of an airborne radionuclide which will result in a dose to an average man exposed over a 40-hour week, 50-week year (breathing the nuclide and/or being immersed within a radioactive cloud of the nuclide) meeting the dose guideline set by the International Commission on Radiological Protection, (ICRP) in their 1977 Publication 30. The DACs presented are the currently applicable guides for radiation workers at DOE facilities and are listed in DOE Order 5480.11, "Radiation Protection for Occupational Workers." The DOE has also published guides for members of the general public in DOE Order 5400.5, "Radiation Protection of the Public and the Environment." This DOE Order presents Derived Concentration Guides (DCGs), which are calculated in similar fashion to the DACs, the difference being that DCGs

are applicable for members of the general public and DACs are applicable for radiation workers. In this section, comparisons are made to DACs because the data results are based on a sampler located inside the NTS, close to the source of discharge. There are no members of the general public at the sampling locations. Also, the data discussed in this section are compared to the current limits rather than those applicable at the time of the event, because the current limits are equal to or more restrictive than previous limits.

The average beta activity was 5.3×10^{-14} µCi/mL for the last six months of 1980. This concentration is 0.003 percent of the DAC for ^{90}Sr. Therefore, had a radiation worker been exposed to this concentration of ^{90}Sr *for the entire work year*, the worker would have received 0.003 percent of their allowable limit. The maximum single station weekly sampling result occurring during the week of September 29 was 21.2×10^{-14} µCi/mL.

In November the gross beta levels again began to rise to a maximum of 28.5×10^{-14} µCi/mL. This increase in beta activity was determined to originate from the fallout of a foreign atmospheric nuclear test. Therefore, the six-month average of 5.3×10^{-14} µCi/mL contained beta activity originating from both the RIOLA seepage and the foreign atmospheric test.

MISTY RAIN

MISTY RAIN was the name given to an underground test conducted within the N Tunnel complex in Rainier Mesa. The event was conducted April 6, 1985. Fission product gases from the ventilation (or purging) of the tunnel complex following this event were detected.

In addition to the air sampling equipment already a part of the monitoring network at the Rainier Mesa site, portable noble gas samplers were distributed in the vicinity of the tunnel ventilation system prior to the planned purge. These noble gas samplers captured a predetermined quantity of air continuously over a one-week period for later analysis at the laboratory. This noble gas sampling equipment was able to detect the presence of ^{85}Kr and ^{133}Xe when deployed in close proximity to the source of discharge.

Particulate Monitoring

Particulate air sampling results from the monitoring stations located within a 15-mile perimeter of the MISTY RAIN site showed no significant increase of beta activity during the month of April. The sampler located at the Area 12 Complex, the air sampling station closest to the detonation point, displayed no difference between the first half-year average beta activity and the second half-year average beta activity of 1.5×10^{-14} µCi/mL. Other air samplers located in Areas 2, 9, 10, and 15 also failed to detect any elevated beta activity. Gamma spectroscopy analysis of these air samples did not detect the presence of radionuclides.

Noble Gas Monitoring

As previously mentioned, noble gas samplers were located near the discharge source and at other stations throughout the NTS as part of the ongoing network of noble gas samplers. A permanent noble gas sampling station was located at the Area 12 Complex. Other noble gas monitoring stations close to the event site were located at the Area 20 Camp, Area 15 EPA Farm, Area 1 BJY, and at the Area 1 Gravel Pit site.

The noble gas sampling data acquired from the samplers located close to the discharge source are presented in Table 10.1, "MISTY RAIN Noble Gas Monitoring Results." Included in Table 10.2 are results from noble gas sampling conducted at other permanent stations.

The maximum concentration of ^{133}Xe occurred the week of April 8th through the 14th. The concentration 9.7×10^{3} pCi/m^3 is 0.001 percent of the DAC for a radiation worker. The ^{133}Xe activity is compared to the DAC for radiation workers because there were no members of the public at the point of discharge. The concentration of ^{133}Xe reaching members of the general

Table 10.1 MISTY RAIN Noble Gas Sampling Results

Location	Start Date	Stop Date	pCi/m³ ^{85}Kr ± 2s	pCi/m³ ^{133}Xe ± 2s
Area 12, U12n Weather Station	04/08/85	04/14/85	N/A	1600 ± 24
Area 12, U12n Mesa	04/09/85	04/17/85	N/A	<< 26
Area 12, U12n RAM No. 2	04/08/85	04/14/85	N/A	9700 ± 58
Area 12, U12n RAM No. 2	04/08/85	04/14/85	650 ± 134	400 ± 37
Area 12, Complex	04/03/85	04/11/85	22 ± 41	70 ± 11
Area 20, Camp	04/10/85	04/15/85	23 ± 5	19 ± 8

N/A = Not available.

Table 10.2 Noble Gas Concentrations at Other Sampling Stations - March and April 1985

Event Name	Start Date	Stop Date	pCi/m³ ^{85}Kr ± 2s	pCi/m³ ^{133}Xe ± 2s
TIERRA	04/01/85	04/10/85	23 ± 5	<< 20
KAPPELI	04/01/85	04/10/85	91 ± 5	<< 17
KAPPELI	04/10/85	04/15/85	20 ± 6	<< 17
KAPPELI	04/15/85	04/22/85	66 ± 5	<< 19
COALORA[a]	03/20/85	03/27/85	28 ± 5	300 ±15
COALORA	03/20/85	03/27/85	24 ± 5	680 ±15
VAUGHN	03/27/85	04/01/85	23 ± 6	46 ±13
VAUGHN	04/02/85	04/08/85	26 ± 4	<< 17

(a) The noble gas sampling equipment deployed near the COALORA event (February 1983) surface ground zero was for the purpose of ascertaining any possible consequences of VAUGHN (March 1985) on an old event site.

public would be dramatically lessened from dispersion as well as radioactive decay. The onsite noble gas sampling network has detected ^{85}Kr in concentrations of approximately 30 pCi/m³. This radionuclide, produced during fission, originates not only from nuclear weapons research, but also from the nuclear power industry. Another common radionuclide produced during fission is ^{133}Xe. However, this radionuclide has a relatively short half-life of 5.25 days. Thus, the presence of this nuclide in the environment, even in small concentrations, is a clear indicator of a recent and most likely nearby fission event.

Conclusion

Although measurable quantities of radioactive noble gases from the MISTY RAIN nuclear test were vented from the tunnel complex to the atmosphere, the dose to a worker, even when in close proximity to the discharge point, was below guidelines. Comparing the maximum concentrations of ^{133}Xe from the MISTY RAIN event to the ^{133}Xe DAC, the allowable limit is orders of magnitude above the levels detected. Supporting this conclusion is the lack of measurable concentrations of airborne particulate radiation.

GLENCOE - MIGHTY OAK EVENT

These two unrelated events, GLENCOE in the Yucca Flats and MIGHTY OAK in the Rainier Mesa tunnel complex, occurred close in time. The event GLENCOE was held in Area 2 on March 22, 1986, and the MIGHTY OAK event followed less than one month later in Area 12 on April 10, 1986.

Activity originating from these events was detected by the onsite environmental surveillance air samplers.

Particulate Monitoring

Elevated levels of airborne beta activity were not detected at any of the permanent particulate monitoring stations located within a 15-mile radius of the GLENCOE SGZ. Elevated levels of beta activity occurred following the planned tunnel purging of the MIGHTY OAK nuclear test. The data were presented in the Radiological Effluent and Onsite Area Monitoring Report for the Nevada Test Site (January 1986 through December 1986).

The annual average of 4.8×10^{-14} µCi/mL of beta activity from the NTS air sampling network corresponds to 0.002 percent of the DAC for ^{90}Sr. Breathing air containing ^{90}Sr activity at one DAC will deliver a 5-rem dose to an average radiation worker. Therefore, breathing at 0.002 percent of one DAC delivers 0.0001 rem to the hypothetical NTS worker working the entire year at locations of highest concentration.

The increase in the concentration of particulate radioactivity, which began early May, 1986, continued until the end of May when concentrations once again dropped to typical NTS levels. However, there were two unrelated events which contributed to these elevated concentrations: the planned tunnel venting following the MIGHTY OAK event and the accident at the Chernobyl reactor in the Soviet Union. Due to these facts, the data results contain activity originating from two separate incidents and it is not easy to determine the percentage of activity from MIGHTY OAK from the total activity detected. Although not within the scope of this section, it would appear that comparing the West Coast U.S. fallout radionuclide concentrations detected assumedly from Chernobyl (as measured by the EPA and other agencies) to the levels detected within the NTS may provide an indication of the contribution of activity originating from the MIGHTY OAK planned tunnel ventilation.

Noble Gas Monitoring

Noble gas concentrations above normal NTS levels were detected during the week of the GLENCOE event at a permanent station less than two miles from the SGZ. The concentrations of ^{85}Kr and ^{133}Xe are presented in Table 10.3, "GLENCOE Noble Gas Monitoring Results." MIGHTY OAK also released measurable quantities of noble gases, and those results are presented in Table 10.4, "MIGHTY OAK Noble Gas Monitoring Results."

These two events occurred within a short period of time. It appears likely that the GLENCOE event concluded its seepage into the NTS environment prior to the MIGHTY OAK event planned ventilation of the tunnel complex.

Table 10.3 GLENCOE Noble Gas Monitoring Results

			pCi/m^3	
Location	Start Date	Stop Date	$^{85}Kr \pm 2s$	$^{133}Xe \pm 2s$
Area 1, BJY	03/25/86	04/02/86	298 ± 5	3500 ± 52
Area 1, BJY	03/25/86	04/02/86	N/A	2500 ± 27

N/A = Not available.

Noble gas samplers were deployed at the MIGHTY OAK site days prior to the planned tunnel ventilation. A review of the data suggests that the event did not discharge noble gases until the planned ventilation of the tunnel complex. However, ^{133}Xe was detected in samples taken at permanent monitoring stations during the last week of April and first week of May.

Xe-133 was detected at the Area 20 Camp during the early part of May. It appears that another event occurring the 22nd of April named JEFFERSON in Area 20 may have contributed to the elevated concentrations detected by the Area 20 Camp sampler.

The maximum concentration of noble gases detected from the GLENCOE event were 3.5×10^3 pCi/m^3 of ^{133}Xe and 298 pCi/m^3 of ^{85}Kr. This translates to 0.004 percent of the ^{133}Xe DAC and 0.0003 percent of the ^{85}Kr DAC. The maximum concentration of ^{133}Xe discharged from the MIGHTY OAK event was 1.1×10^4 pCi/m^3, which is 0.01 percent of the DAC for ^{133}Xe.

Conclusion

The GLENCOE event by itself did not discharge levels of radionuclides into the NTS environment capable of producing a dose to a radiation worker of more than 0.01 percent of dose guidelines. The air particulate results did not display an increase of beta activity. Overall, only noble gases were detected at a permanent station located a few miles away. The planned ventilation of the tunnel complex following the MIGHTY OAK event was responsible for the discharge of noble gases to the environment. The concentration of ^{133}Xe detected at a nearby sampling station was 1.1×10^4 pCi/m^3, which is 0.01 percent of the DAC for

Table 10.4 MIGHTY OAK Noble Gas Sampling Results

			pCi/m^3	
Location	Start Date	Stop Date	$^{85}Kr \pm 2s$	$^{133}Xe \pm 2s$
Perimeter	04/10/86	04/14/86	26 ± 4	< 14
Road	04/10/86	04/14/86	30 ± 3	< 9
Perimeter	04/14/86	04/21/86	26 ± 3	< 13
Road	04/14/86	04/21/86	29 ± 4	110 ± 10
Road	04/14/86	04/21/86	26 ± 3	110 ± 12
Perimeter	04/21/86	04/25/86	26 ± 4	130 ± 13
Perimeter	04/21/86	04/25/86	21 ± 6	150 ± 14
Road	04/21/86	04/28/86	29 ± 4	1200 ± 24
Perimeter	04/25/86	04/30/86	28 ± 3	3200 ± 32
Perimeter	04/25/86	04/30/86	N/A	2700 ± 31
Road	04/28/86	05/07/86	44 ± 5	11000 ± 82
Road	04/28/86	05/07/86	N/A	11000 ± 96
Perimeter	05/08/86	05/13/86	27 ± 5	710 ± 17
Perimeter	05/08/86	05/13/86	32 ± 4	213 ± 10
Road	05/07/86	05/13/86	47 ± 7	470 ± 20
Perimeter	05/13/86	05/20/86	29 ± 3	190 ± 11
Perimeter	05/13/86	05/20/86	N/A	190 ± 14
Road	05/13/86	05/20/86	40 ± 5	330 ± 17
Perimeter	05/21/86	05/28/86	30 ± 2	< 19
Road	05/20/86	05/28/86	26 ± 4	< 34

N/A = Not available.

radiation workers. Both airborne particulates and noble gases were detected throughout the NTS following the planned ventilation of the tunnel complex, but the fallout from the Chernobyl accident contributed to the levels detected.

Detection of elevated particulate radioactivity occurred in most of the NTS air samplers. Many of the permanent noble gas samplers located throughout the NTS also detected ^{85}Kr and ^{133}Xe.

SUMMARY

Activity from the four events examined in this document was detected by monitoring equipment located throughout the NTS. However, the concentrations of radionuclides detected and consequently any dose to NTS workers resulting from exposure would be on the order of 10^{-2} to 10^{-3} percent of radiation control guidelines.

11.0 QUALITY ASSURANCE

Data quality assurance for onsite environmental monitoring programs involved both internal and external quality assurance programs to ensure the representativeness and the integrity of data and analytical results. A suite of interlaboratory comparisons was conducted. Offsite monitoring quality assurance activities by the EPA included development of data quality objectives as required for all Agency projects involving environmental measurements.

11.1 ONSITE MONITORING QUALITY ASSURANCE

Kevin R. Krenzien and Yun Ko Lee

Onsite environmental monitoring quality assurance consisted of nonradiological and radiological programs. The nonradiological program included sample acceptance and control criteria, quality control (QC) procedures, and interlaboratory comparisons through participation in the National Institute of Occupational Safety and Health (NIOSH) Proficiency Analytical Testing (PAT) program, the American Industrial Hygiene Association (AIHA) Asbestos Analysts Registry (AAR) program, the AIHA bulk asbestos analysis program, National Voluntary Laboratory Accreditation Program (NVLAP), and the College of American Pathologists analysis of lead in blood program. Proficiency testing through participation in the EPA Contract Laboratory Program (CLP) was begun. The external quality assurance intercomparison program for radiological data quality assurance consisted of participation in the DOE Quality Assessment Program (QAP) administered by the DOE Environmental Measurements Laboratory (EML), the Nuclear Radiation Assessment and Cross Check Program (NRACC) conducted by the EPA Environmental Monitoring Systems Laboratory, Las Vegas (EMSL-LV), and the quality assessment program sponsored the International Reference Center for Radioactivity (IRCR) of the World Health Organization (WHO).

11.1.1 ONSITE NONRADIOLOGICAL MONITORING

Onsite nonradiological samples were analyzed by the onsite operations contractor (REECo) and two CLP commercial laboratories during 1989. Most of the samples for organic analyses were sent to Datachem Laboratories, Salt Lake City, or to Sierra Technical Services, Las Vegas, while onsite laboratories were being remodeled and upgraded during 1989. Samples included industrial hygiene air monitoring samples, asbestos monitoring program samples, environmental water and soil samples, and PCB samples.

The quality of analytical data and results produced was safeguarded with a program which included calibration of all instrumentation, use of standard analytical procedures, the inclusion and analysis of QC samples, and continuation of personnel training to maintain qualified staff. Prior to release, all analytical results were reviewed relative to accepted QC data.

The onsite laboratory continued to participate in a number of external quality

assurance (QA)/QC programs and maintained all external agency accreditations while progressing to achieve EPA CLP equivalency.

The QA program included:

- Specific sample acceptance criteria and maintenance of sample custody.
- Calibration of all analytical instrumentation.
- A program of preventative and periodic maintenance for all systems which were crucial to data quality.
- Use of National Institute of Standards and Technology (NIST) or EPA traceable standards and reference materials.
- Spikes, blanks, and blind replicates as a measure of QA samples.
- Review of QC charts to assure control of methods and processes.
- Review of analytical data before final results were released.

The onsite laboratory participated in QA programs operated by the AIHA, NIST, NIOSH, and EPA.

SAMPLE ACCEPTANCE AND CONTROL

Samples submitted to the onsite laboratory included a chain-of-custody form and an appropriate sample data sheet before they were accepted by the sample custodian. The sample custodian also checked the sample to ensure proper collection procedures were used, samples were transported correctly (i.e., organic samples were refrigerated), and sample holding times were not exceeded. If the samples met the laboratory sample acceptance criteria, they were logged into the Sample and Analysis Management System (SAM). The samples were then stored in a locked, walk-in cooler until a chemist was prepared to analyze the samples. If a sample was not destroyed during analysis, it was returned to the walk-in cooler for storage and future disposal. All sample transactions continued to be documented using the field-generated, chain-of-custody form.

QUALITY CONTROL

A program of daily, weekly, and monthly preventative maintenance was followed. This program included monitoring of laboratory water quality, monitoring of refrigerator temperatures, and ensuring the accuracy of analytical balances. The preventative maintenance program also included periodic service by manufacturer technicians. A maintenance logbook and a separate sample run logbook were maintained for each analytical instrument.

Analytical instrumentation was calibrated before the analysis of a sample batch. A multi-standard calibration curve had to exhibit a correlation coefficient of 0.995 or greater before the analytical data could be reported.

Check samples were run periodically throughout a sample batch. These analyses insured that the instrument calibration remained valid during the batch analysis.

Trip, field, holding, and method blanks were analyzed to insure that cross-contamination did not affect the final analytical result.

Spikes to measure analytical recovery were analyzed at a rate of 1 in 11. The spike results were plotted on QC charts and had to fall within three standard deviations of a population mean before sample results were verified. If the spike results did not meet this criteria, the cause of the discrepancy was determined and the sample batch was reanalyzed.

Sample replicates were prepared and analyzed at a rate of 1 in 11. The relative percent difference (RPD) was calculated for the replicate samples and plotted on QC charts. The RPD had to be within three standard deviations of the population before the sample results were approved. The sample batch was reanalyzed if this criterion was not met.

Before being released, all sample data and results underwent three levels of review. Peers reviewed the sample data for errors involving standard preparation and calculations. The quality coordinator reviewed the data and results to assure that all QC criteria had been met. The laboratory supervisor reviewed the data and results before certifying and transmitting the final results.

INTERLABORATORY COMPARISON PROGRAMS

External QA/QC program included participation in the NIOSH PAT program, AIHA AAR program, AIHA bulk asbestos analysis program, NIOSH NVLAP bulk asbestos analysis program, and College of American Pathologists (CAP) analysis of lead in blood program. Participation in the EPA CLP quarterly proficiency testing program was begun.

All of these programs require participating laboratories to analyze proficiency samples at various intervals throughout the year.

The standard sample matrices (air monitoring filters, bulk asbestos samples, blood samples, soil, and water) contained one or more analytes in known amounts. After the results were analyzed, they were forwarded to the sponsoring laboratory for comparison to the reference value and the results of other participating laboratories. These programs served to identify analytical problems requiring corrective action.

Tables 11.1, 11.2, and 11.3 are summaries of interlaboratory comparison results during 1989. As bulk asbestos results are qualitative and based on identification, no results for both AIHA and NVLAP bulk asbestos programs are given. However, the laboratory continued to maintain its accreditation in both of these programs. The results were generally within performance limits required by the sponsoring agencies. Causes for results which were not within acceptable performance limits were investigated, and corrective actions were taken to prevent reoccurrence.

Table 11.1 NIOSH PAT Program Interlaboratory Comparison - 1989

Analysis and Date	REECo Result	Reference Value[a]	Ratio[b]	Performance Limits[a]	No. of Labs[c]
Pb					
02/23/89	0.0412	0.0395	1.04	0.0366 - 0.0455	356
	0.0262	0.0244	1.07	0.0204 - 0.0285	356
	0.0823	0.0785	1.05	0.0696 - 0.0874	356
	0.0543	0.0523	1.04	0.0453 - 0.0595	356
05/25/89	0.0206	0.0175	1.18	0.0147 - 0.0205	353
	0.0339	0.0310	1.09	0.0271 - 0.0350	353
	0.0605	0.0585	1.03	0.0539 - 0.0633	353
	0.0445	0.0434	1.03	0.0382 - 0.0487	353
08/23/89	0.0776	0.0774	1.00	0.0689 - 0.0859	354
	0.0632	0.0622	1.02	0.0549 - 0.0696	354
	0.0514	0.0515	1.00	0.0436 - 0.0594	354
	0.0368	0.0348	1.06	0.0307 - 0.0389	354

(a) The known value provided by the NIOSH PAT Program.
(b) Ratio = REECo Result/Reference value.
(c) The number of participating laboratories that reported results for the analysis.

Table 11.1 (NIOSH PAT Comparison, cont.)

Analysis and Date	REECo Result	Reference Value[a]	Ratio[b]	Performance Limits[a]	No. of Labs[c]
Pb (cont.)					
11/21/89	0.0490	0.0485	1.01	0.0440 - 0.0531	362
	0.0677	0.0658	1.03	0.0597 - 0.0719	362
	0.0330	0.0334	0.99	0.0297 - 0.0373	362
	0.0431	0.0426	1.01	0.0387 - 0.0467	362
Cd					
02/23/89	0.0075	0.0079	0.95	0.0067 - 0.0092	356
	0.0120	0.0125	0.96	0.0109 - 0.0143	356
	0.0167	0.0176	0.95	0.0157 - 0.0197	356
	0.0097	0.0101	0.96	0.0086 - 0.0116	356
05/25/89	0.0174	0.0187	0.93	0.0169 - 0.0207	352
	0.0132	0.0139	0.95	0.0125 - 0.0154	352
	0.0090	0.0090	1.00	0.0084 - 0.0098	352
	0.0072	0.0069	1.04	0.0062 - 0.0078	352
08/23/89	0.0123	0.0129	0.95	0.0116 - 0.0143	354
	0.0056	0.0060	0.93	0.0116 - 0.0143	354
	0.0095	0.0098	0.97	0.0088 - 0.0110	354
	0.0156	0.0167	0.93	0.0150 - 0.0185	354
11/21/89	0.0117	0.0119	0.98	0.0108 - 0.0131	360
	0.0146	0.0148	0.99	0.0133 - 0.0164	360
	0.0088	0.0090	0.98	0.0080 - 0.0100	360
	0.0097	0.0100	0.97	0.0090 - 0.0110	360
Zn					
02/23/89	0.0863	0.0880	0.98	0.0751 - 0.1010	355
	0.1253	0.1222	1.02	0.1027 - 0.1417	355
	0.2100	0.2091	1.00	0.1844 - 0.2340	355
	0.1514	0.1521	1.00	0.1310 - 0.1733	355
05/25/89	0.1301	0.1328	0.98	0.1164 - 0.1492	351
	0.1708	0.1718	0.99	0.1479 - 0.1957	351
	0.1019	0.1031	0.99	0.0907 - 0.1155	351
	0.1592	0.1589	1.00	0.1425 - 0.1754	351
08/23/89	0.1031	0.1022	1.01	0.0890 - 0.1154	351
	0.1353	0.1369	0.99	0.1216 - 0.1523	351
	0.0791	0.0762	1.04	0.0658 - 0.0867	351
	0.1715	0.1807	0.95	0.1621 - 0.1994	351
11/21/89	0.0857	0.0885	0.97	0.0774 - 0.0996	360
	0.1158	0.1170	0.99	0.1058 - 0.1282	360
	0.1558	0.1589	0.98	0.1416 - 0.1763	360
	0.1894	0.1909	0.99	0.1702 - 0.2118	360

(a) The known value provided by the NIOSH PAT Program.
(b) Ratio = REECo Result/Reference value.
(c) The number of participating laboratories that reported results for the analysis.

Table 11.1 (NIOSH PAT Comparison, cont.)

Analysis and Date	REECo Result	Reference Value[a]	Ratio[b]	Performance Limits[a]	No. of Labs[c]
Silica					
02/23/89	0.1110	0.1050	1.06	0.0562 - 0.1965	111
	0.0748	0.0740	1.01	0.0335 - 0.1643	111
	0.0405	0.0401	1.01	0.0159 - 0.1018	111
	0.0606	0.0534	1.13	0.0204 - 0.1404	111
05/25/89	0.0652	0.0863	0.75	0.0435 - 0.1717	105
	0.0599	0.0805	0.74	0.0436 - 0.1487	105
	0.0636	0.1332	0.48	0.0641 - 0.2773	105
	0.0307	0.0449	0.68	0.0192 - 0.1056	105
08/23/89	0.0697	0.0817	0.85	0.0435 - 0.1538	109
	0.0686	0.0676	1.01	0.0412 - 0.1111	109
	0.1040	0.1074	0.97	0.0662 - 0.1745	109
	0.1520	0.1674	0.91	0.0863 - 0.3252	109
11/23/89	0.0543	0.0603	0.90	0.0296 - 0.1233	112
	0.0801	0.0887	0.90	0.0526 - 0.1496	112
	0.1860	0.1962	0.95	0.1135 - 0.3396	112
	0.0992	0.1341	0.74	0.0805 - 0.2235	112
Asbestos					
02/23/89	339.0	466.9	0.73	240.9 - 767.2	1025
	555.0	666.6	0.83	331.3 - 1118.2	1025
	353.0	305.9	1.15	145.5 - 525.3	1025
	658.0	944.3	0.70	428.9 - 1660.5	1025
05/25/89	182.1	247.1	0.74	57.6 - 568.8	1048
	556.6	731.1	0.76	221.8 - 1535.8	1048
	387.8	549.4	0.71	176.1 - 1129.6	1048
	656.0	795.8	0.82	286.7 - 1559.4	1048
08/23/89	1055.0	802.5	1.31	454.2 - 1249.6	1136
	1962.0	1130.9	1.73	602.3 - 1824.9	1136
	894.0	602.2	1.48	348.2 - 925.3	1136
	505.0	371.7	1.36	174.0 - 643.6	1136
11/23/89	209.0	148.5	1.41	37.3 - 334.1	1203
	442.0	399.6	1.11	138.6 - 795.8	1203
	823.0	823.6	1.00	279.9 - 1654.0	1203
	308.0	241.4	1.28	72.6 - 508.9	1203
			Solvents[d]		
BNZ					
08/23/89	0.1491	0.1418	1.05	0.1063 - 0.1774	357
	0.1828	0.1754	1.04	0.1438 - 0.2070	357
	0.2754	0.2704	1.02	0.2201 - 0.3207	357
	0.2360	0.2337	1.01	0.1864 - 0.2811	357

(a) The known value provided by the NIOSH PAT.
(b) Ratio = REECo Result/Reference value.
(c) The number of participating laboratories that reported results for the analysis.
(d) Solvent abbreviations: BNZ=Benzene.

Table 11.1 (NIOSH PAT Comparison, cont.)

Analysis and Date	REECo Result	Reference Value[a]	Ratio[b]	Performance Limits[a]	No. of Labs[c]
		Solvents[d] *(cont.)*			
CFM					
05/25/89	0.7056	0.6971	1.01	0.6000 - 0.7942	346
	0.9053	0.9318	0.97	0.8333 - 1.0303	346
	0.3686	0.3610	1.02	0.3007 - 0.4214	346
	0.4962	0.5036	0.99	0.4262 - 0.5810	346
CTC					
02/23/89	0.6943	0.6518	1.07	0.5473 - 0.7564	362
	0.8879	0.8600	1.03	0.7252 - 0.9949	362
	1.1433	1.0786	1.06	0.9126 - 1.2447	362
	0.4318	0.3852	1.12	0.3023 - 0.4683	362
05/25/89	0.7974	0.7702	1.04	0.6636 - 0.8768	346
	0.4346	0.3670	1.18	0.2739 - 0.4603	346
	1.0060	1.0115	0.99	0.8605 - 1.1626	346
	0.8151	0.8082	1.01	0.6541 - 0.9625	346
11/23/89	0.2933	0.3184	0.92	0.2430 - 0.3940	352
	1.0210	1.0516	0.97	0.8373 - 1.2661	352
	0.7546	0.8143	0.93	0.6917 - 0.9371	352
	0.5720	0.6019	0.95	0.4977 - 0.7062	352
DCE					
02/23/89	0.7542	0.6848	1.10	0.5836 - 0.7861	362
	0.8685	0.8276	1.05	0.7379 - 0.9173	362
	0.6287	0.5403	1.16	0.4649 - 0.6158	362
	1.1438	1.1063	1.03	0.9724 - 1.2402	362
05/25/89	1.0440	1.0080	1.04	0.8631 - 1.1529	346
	1.1680	1.1524	1.01	1.0244 - 1.2804	346
	0.9166	0.9205	1.00	0.8154 - 1.0256	346
	0.8151	0.8082	1.01	0.6541 - 0.9625	346
11/23/89	0.9869	1.0249	0.96	0.8696 - 1.1803	352
	0.4758	0.5183	0.92	0.4061 - 0.6305	352
	0.7058	0.7673	0.92	0.6496 - 0.8850	352
	0.5840	0.6428	0.91	0.5400 - 0.7456	352
OXY					
08/23/89	1.0700	1.0565	1.01	0.9296 - 1.1834	357
	1.4760	1.4097	1.05	1.2295 - 1.5901	357
	0.9732	0.9372	1.04	0.8037 - 1.0707	357
	1.5970	1.5765	1.01	1.3886 - 1.7644	357

(a) The known value provided by the NIOSH PAT.
(b) Ratio = REECo Result/Reference value.
(c) The number of participating laboratories that reported results for the analysis.
(d) Solvent abbreviations: CFM=Chloroform, CTC=Carbon Tetrachloride, DCE=1,2 Dichloroethane, OXY=o-Xylene.

Table 11.1 (NIOSH PAT Comparison, cont.)

Analysis and Date	REECo Result	Reference Value[a]	Ratio[b]	Performance Limits[a]	No. of Labs[c]
		Solvents [d] *(cont.)*			
TCE					
02/23/89	1.2043	1.1675	1.03	1.0106 - 1.3245	362
	0.7686	0.7561	1.02	0.6625 - 0.8497	362
	1.0918	1.0490	1.04	0.9214 - 1.1767	362
	0.6169	0.5883	1.05	0.5000 - 0.6766	362
11/23/89	1.0240	0.4452	2.30	0.3384 - 0.5522	352
	1.3290	0.7930	1.68	0.6321 - 0.9539	352
	1.1290	0.5760	1.96	0.4482 - 0.7038	352
	1.4260	0.9006	1.58	0.7547 - 1.0465	352
TOL					
08/23/89	1.0280	1.0315	1.00	0.8984 - 1.1647	357
	1.3330	1.3212	1.01	1.1677 - 1.4747	357
	1.5800	1.5831	1.00	1.4021 - 1.7642	357
	0.8601	0.8665	0.99	0.7571 - 0.9760	357

(a) The known value provided by the NIOSH PAT.
(b) Ratio = REECo Result/Reference value.
(c) The number of participating laboratories that reported results for the analysis.
(d) Solvent abbreviations: TCE=Trichloroethylene, TOL=Toluene.

Table 11.2 CAP Program Interlaboratory Comparison - 1989

Analysis and Date	REECo Result	Reference Value[a]	Ratio[b]	Performance Limits[a]	No. of Labs[c]
Blood Pb					
03/13/89	26.5	31.66	0.84	21.0 - 43.7	196
	37.3	42.10	0.89	30.0 - 56.5	196
	33.8	40.12	0.84	26.0 - 55.0	196
06/12/89	32.2	33.89	0.95	21.0 - 47.2	203
	31.5	33.87	0.93	20.0 - 47.3	205
	32.7	33.77	0.97	19.7 - 45.8	203
09/11/89	8.8	8.26	1.07	1.6 - 15.0	209
	41.3	41.61	0.99	28.0 - 56.0	212
	38.8	37.50	1.03	25.0 - 51.0	211

(a) The known value provided by the CAP blood lead survey program.
(b) Ratio = REECo Result/Reference value.
(c) The number of participating laboratories that reported results for the analysis.

Table 11.3 AAR Program Interlaboratory Comparison - 1989

Analysis and Date	REECo Result[a]	Reference Value[c]	Ratio[b]	Performance Limits[c]
Quantitative Asbestos				
02/21/89	204	220	0.93	110 - 440
	150	220	0.68	110 - 440
	350	357	0.98	178 - 714
	318	357	0.89	178 - 714
	890	868	1.02	434 - 1736
	720	868	0.83	434 - 1736
	617	646	0.96	323 - 1292
	662	646	1.02	323 - 1292
07/18/89	391	390	1.00	195 - 780
	366	390	0.94	195 - 780
	272	390	0.70	195 - 780
	763	760	1.00	380 - 1520
	761	760	1.00	380 - 1520
	685	760	0.90	380 - 1520
	790	542	1.46	271 - 1084
	606	542	1.12	271 - 1084
	675	542	1.25	271 - 1084
	143	160	0.89	80 - 320
	173	160	1.08	80 - 320
	186	160	1.16	80 - 320
10/18/89	151	178	0.85	89 - 356
	210	178	1.18	89 - 356
	117	178	0.66	89 - 356
	782	787	0.99	394 - 1575
	854	787	1.09	394 - 1575
	691	787	0.88	394 - 1575
	376	365	1.03	182 - 729
	507	365	1.39	182 - 729
	325	365	0.89	182 - 729
	520	417	1.25	208 - 833
	484	417	1.16	208 - 833
	205	417	0.49	208 - 833

(a) Individual analyst results reported by REECo.
(b) RATIO = REECo Result/Reference Value.
(c) The known value provided by the Asbestos Analysts Registry.

11.1.2 ONSITE RADIOLOGICAL MONITORING

The 1989 QA program for onsite radiological environmental monitoring covered air, air effluent, surface water, ground water, and thermoluminescent dosimeter (TLD) ambient gamma monitoring for radioactive materials. Radiological sample collection, radiochemical analyses, and radiological monitoring of NTS samples were performed by the onsite operations contractor (REECo). The onsite laboratory maintained both internal and external QC programs to ensure that the data and analytical results collected were representative of the actual concentrations in the environment.

Large numbers of environmental samples were collected at various locations on the NTS on routine schedules in support of the testing programs and the Radioactive Waste Management Project. Samples from all locations were collected using well-established standard operating procedures. Current data for each environmental medium were compared to both recent results and historical data for each location to ensure that deviation from previous conditions were identified and promptly evaluated. Review of analytical results relative to the applicable orders and standards of the DOE was performed on a daily basis to ensure that potential problems were noted in a timely manner.

A QA/QC program of radiological monitoring was maintained to ensure that the monitoring data generated could be used to accurately evaluate the environmental impacts from NTS operations. The continuous QA program focused on the following practices:

- Personnel training and work assignment qualifications.
- Sample acquisition documentation.
- Sample chain-of-custody control.
- Procedural compliance.
- Yield determination of radiochemistry procedures.
- Analytical QA including blanks, spikes, and replicates being used as QC samples to verify the maintenance of procedural control.
- Calibration of sampling, analytical, and counting instruments.
- Routine source and background count checks for counting systems.
- QC data and QC charts review to assure control of methods and processes.
- Review of analytical data before reporting.
- Use of NIST-traceable standards and reference materials for instrument calibration and QC samples.
- External audits and surveillances.
- Internal compliance surveillances.
- Actively participating in the interlaboratory QA programs conducted by the DOE, EPA, and WHO.

SAMPLE CONTROL

Environmental monitoring samples were collected throughout the NTS and analyzed according to documented standard operating procedures. Any sample submitted for analysis was identified with a unique packet number and was accompanied with a laboratory service request and chain-of-custody form. Personnel receiving the sample examined it and verified the information furnished on the accompanying forms. The sample preparation technician readied the sample materials for analyses. All samples were logged in through the Laboratory Data Analysis System (LDAS) resident on the laboratory computer. Samples requiring chemical processing were signed out by appropriate radiochemistry laboratory personnel. Samples ready to be counted were signed out by radioanalysis counting laboratory personnel. When analysis was completed, the sample was returned to the sample custodian. Completed samples were normally stored for at least two months before being disposed of. When any samples were transferred to another person, verification signatures were required by both the persons submitting and receiving the samples.

INSTRUMENT CONTROL

Sampling, measuring, and test equipment used in the performance of quantitative measurements for the purpose of data production were controlled and calibrated with specific calibration requirements. All calibration standards used for calibration purposes were traceable to NIST and had the same geometry and matrix as the

samples which were to be counted. In general each radiological counting instrument was certified for each radionuclide measured. The efficiencies of counting instruments were established using standards prepared from NIST reference materials or certified reference materials traceable to the NIST. When a gamma spectrometer was certified, a plot of efficiency versus energy was prepared to identify errors in the calibration of individual radionuclides and to determine the efficiencies of radionuclides for which standards were not available. Counter backgrounds were measured regularly. Counters were decontaminated if background measurement showed evidence of above-background radiation levels.

Gamma spectrometers were set to count check sources of known activities on a daily basis. The peaks' centroid energies were compared against the expected energies. Daily performance tests were performed with a NIST-traceable multiradionuclide standard with known radioactivities. The activities of three isotopes (^{241}Am, ^{137}Cs, and ^{60}Co) were calculated using production mode computer algorithms, then compared with previous values. Instrument performance check activities and pertinent data were recorded in the individual instrument logbooks. Control charts were prepared for all gamma spectrometers.

Radioactive check sources of known activities were used for instrument performance tests of alpha spectrometers. The sample holders of the spectrometers were cleaned at least once a week and prior to performing the instrument performance tests. The peak channel (the full width at half maximum) and the count rate for each peak were recorded in the individual instrument logbook and were compared with both previous values and established acceptance criteria. Weekly background checks were performed and documented.

Proportional counters were set to count background and check sources of known activities on a daily basis. Data were recorded in the individual instrument logbooks for comparison to previously acquired values, and control charts were prepared for instrument performance monitoring.

Liquid scintillation counters were set to count background and standards of known activity, along with each batch of ten or less samples analyzed. Data were recorded in the instrument logbooks. The instruments were under service and maintenance contracts with each instrument's manufacturer for calibration and maintenance.

For all counting instruments, performance test data were accumulated and presented to the laboratory radioanalysis supervisor to be permanently filed. If data obtained from background and/or source checks were considered outside the instrument control limits or showed any inconsistencies, the cause of the problem was investigated and corrective actions initiated. If the problem was found to be originated by the counting instrument, the instrument was removed from service. Any nonconforming instrument was repaired and recertified before it was allowed to be placed back in service. Performance histories of the counting instruments were maintained in records.

RADIOANALYSIS CONTROL

Personnel handling sample collection, preparation, and analysis were trained, qualified, and certified for their work assignments by their supervisors. Standard analytical methods used in radiochemistry analyses were basically identified with those prescribed in HASL-300 for analyses of radionuclides. Drinking water samples were analyzed using basically EPA procedures. In some of the radiochemistry procedures, NIST-traceable standards were used, whenever feasible, as tracers to determine the chemical yield of the procedure. The yield was compared to previously determined acceptable control limits to provide an immediate evaluation of the process. Spiked samples were prepared from NIST-traceable materials for various analyses. Whenever it was practical, blanks, spikes, and replicates were

submitted as QC samples to be analyzed along with every lot of field samples so that accuracy and precision of the analysis could be determined. The ratio of the number of QC samples to that of field samples analyzed varied depending on the types of analysis. Specific QC procedures were established and documented for each analysis. The laboratory QC program mandated that at least ten percent of the samples in each sample lot analyzed be QC samples. However, in real practice, the number of QC samples analyzed was usually greater than the ten percent minimum.

DATA CONTROL

An internal QA/QC program was implemented to control and document the accuracy and precision of data generated. Sample and counting data were entered (or acquired) and stored on an appropriate data base of the laboratory LDAS computer. Counting data were processed, and results were generated. Pertinent information on the samples and their analyses were recorded. Analytical results were reported with the uncertainty limits and a minimum detection limit. Radionuclide concentrations were reported as calculated even when they were less than the error limits or were negative. Analytical results were subjected to screening and peer review for correctness and accuracy. Analytical results were reviewed by the laboratory radioanalysis supervisor before being distributed and/or reported. Results of QC samples were promptly checked against the corresponding known values and examined with standard statistical methods. Control charts were plotted with 2σ and 3σ control limits. If any result was found to be outside the control limits, the root cause of the problem was investigated and corrected, and the entire sample lot was reanalyzed.

Results were transferred to the REECo ShareBase 8000 Computer System for the Historical Data Base and held for archives. Safeguards over the computer facility were provided as outlined in DOE Order 1360.2 to assure quality through the protection of data and results.

EXTERNAL QUALITY ASSURANCE ASSESSMENT PROGRAMS

In addition to implementing the internal QA/QC program, the radioanalytical laboratory continued to participate in interlaboratory comparison and quality assessment programs in 1989.

One of these programs was the QAP conducted by the DOE/EML. The second program was the NRACC conducted by the EMSL-LV of the EPA. Under both programs, a variety of standardized samples were sent to the participating laboratories at intervals throughout the year. Such standard samples consisted of various environmental media (e.g., water, air filters, soil, milk, foodstuffs, vegetation, and tissue ash) containing one or more radionuclides in known amounts. After the samples were analyzed by the laboratories, the results were forwarded to the program sponsor for comparison with the known values and with the results from other participating laboratories. Both DOE/EML and EPA/EMSL have established criteria for evaluating the accuracy and precision of results (Jarvis and Siu 1981, Sanderson and Scarpitta 1989, and Sanderson and Scarpitta 1990). These programs served as a regular means of evaluating the performance of the radioanalytical laboratories and provided indications where corrective actions were needed. During 1989 the laboratory also participated in the quality assessment program sponsored by the IRCR/WHO. Analytical results were sent to IRCR/WHO, but no information feedback was received from IRCR/WHO in 1989 for evaluation. Summaries of the 1989 results in the interlaboratory comparison and quality assessment programs conducted by the EPA/EMSL and DOE/EML were provided in Tables 11.4 and 11.5. The 20 percent indicator shown in these tables serves as a convenient measure of overall relative performance of the participating laboratories and should not be used as a sole determinant for accuracy. As illustrated in Tables 11.4 and 11.5, the REECo results were generally within the control limits determined by the program sponsors. The few results outside the control limits were investigated, and

corrective actions were taken to correct the problems if deemed necessary.

COMPLIANCE AUDITS AND SURVEILLANCE

The REECo onsite laboratory was audited for compliance by the Environmental Protection Division of the DOE Nevada Operations Office and the REECo Quality Assurance Division. During 1989 the laboratory conducted internal surveillances on both the radiochemistry and radioanalysis functions for QA practices. Compliance and performance was evaluated during the DOE/EML Tiger Team Assessment and Technical Safety Appraisal of the NTS at the end of 1989. Recommendations made by the audit and surveillance reports were implemented in 1989 or will be implemented in early 1990.

RECENT DEVELOPMENT OF THE QA/QC PROGRAM

QA activities continue to be influenced by programmatic changes. As required by DOE Order 5400.1 and the NTS Environmental Protection Implementation Plan, specific QA and data verification program requirements will be addressed and incorporated into the analytical functions of the onsite laboratory.

The REECo laboratory has committed to a data verification procedure. One of the requirements for participation in the program was that at least ten percent of all calculated analytical values had to be recalculated by another analyst or supervisor. If any calculations were in error, the entire set had to be recalculated.

Table 11.4 Results of EPA/EMSL Nuclear Radiation Assessment and Cross Checks

Analysis and Date	Water Samples, pCi/L REECo[a]	EPA/EMSL[b]	Control Limits[c]	Ratio of REECo/ EMSL	No. of Labs.[d]	No. of Labs. within ±20%[e]
Gross Alpha						
01/20/89	5.00 ± 0.00	8.00 ± 5.00	0.00 - 16.7	0.63	153	62
04/18/89	19.0 ± 0.0	29.00 ± 7.00	16.88 - 41.12	0.66	124	54
05/12/89	28.0 ± 2.0	30.00 ± 8.00	16.14 - 43.86	0.93	148	66
09/22/89	2.00 ± 1.00	4.00 ± 5.00	0.00 - 12.66	0.50	151	48
10/31/89	34.7 ± 1.2	49.00 ± 12.00	28.22 - 69.78	0.71	115	67
Gross Beta						
01/20/89	3.67 ± 0.58	4.00 ± 5.00	0.00 - 12.7	0.92	152	26
04/18/89	37.0 ± 4.6[f]	57.00 ± 5.00	48.34 - 65.66	0.65	119	72
05/12/89	44.3 ± 1.25	0.00 ± 5.00	41.34 - 58.66	0.89	155	75
09/22/89	4.67 ± 0.58	6.00 ± 5.00	0.00 - 14.66	0.78	153	55
10/31/89	28.0 ± 1.0	32.00 ± 5.00	23.34 - 40.66	0.88	119	82
^{3}H						
02/24/89	2796.7 ± 68.1	2754.0 ± 356.0	2137.4 - 3370.6	1.02	119	91
06/23/89	3873.3 ± 342.4	4503.0 ± 450.0	3723.6 - 5282.4	0.86	124	91
10/20/89	3430.0 ± 226.1	3496.0 ± 364.0	2865.5 - 4126.5	0.98	126	85
^{51}Cr						
02/10/89	236.7 ± 23.7	235.0 ± 24.0	193.4 - 276.6	1.01	124	94

(a) Average value [± 1 standard deviation (s)] reported by REECo.
(b) The known value (± 1s) reported by EPA/EMSL.
(c) The control limits determined by EPA/EMSL.
(d) The number of participating laboratories reporting results for the analysis.
(e) The percentage of participating laboratories reporting an average value that is within ± 20 percent of the EPA/EMSL value.
(f) Value is outside the control limits determined by EPA/EMSL.

Table 11.4 (EPA/EMSL, cont.)

Analysis and Date	Water Samples, pCi/L REECo[a]	EPA/EMSL[b]	Control Limits[c]	Ratio of REECo/ EMSL	No. of Labs.[d]	No. of Labs. within ±20%[e]
^{60}Co						
02/10/89	12.00 ± 1.00	10.00 ± 5.00	1.34 - 18.66	1.20	122	79
06/09/89	32.0 ± 8.3	31.00 ± 5.00	22.34 - 39.66	1.03	127	87
10/06/89	35.7 ± 3.1	30.00 ± 5.00	21.34 - 38.66	1.19	125	92
^{65}Zn						
02/10/89	170.3 ± 7.6	159.0 ± 16.0	131.3 - 186.7	1.07	129	95
06/09/89	173.3 ± 27.7	165.0 ± 17.0	135.6 - 194.4	1.05	127	93
10/06/89	117.7 ± 6.5	129.0 ± 13.0	106.48 - 151.52	0.91	125	95
^{89}Sr						
01/06/89	37.0 ± 1.0	40.0 ± 5.0	31.3 - 48.7	0.93	67	78
04/18/89	6.3 ± 1.2	8.00 ± 5.00	0.00 - 16.66	0.79	62	56
05/05/89	4.0 ± 1.7	6.00 ± 5.00	0.00 - 14.66	0.67	64	58
10/31/89	6.7 ± 2.5	15.00 ± 5.00	6.34 - 23.66	0.45	65	78
^{90}Sr						
01/06/89	30.3 ± 1.5[f]	25.0 ± 1.5	22.4 - 27.6	1.21	73	89
04/18/89	5.7 ± 0.6	8.00 ± 1.50	5.40 - 10.60	0.71	65	80
05/05/89	6.0 ± 1.0	6.00 ± 1.50	3.40 - 8.60	1.00	68	78
10/31/89	8.0 ± 1.0	7.00 ± 1.50	4.40 - 9.60	1.14	68	79
^{106}Ru						
02/10/89	175.0 ± 21.3	178.0 ± 18.0	146.8 - 209.2	0.98	127	91
06/09/89	155.0 ± 18.7[f]	128.0 ± 13.0	105.5 - 150.5	1.21	124	85
10/06/89	177.0 ± 1.0	161.0 ± 16.0	133.29 - 188.71	1.10	123	87
^{131}I						
02/17/89	No Data[g]	106.0 ± 11.0	87.0 - 125.1	--	85	77
08/04/89	No Data[g]	83.00 ± 8.00	69.14 - 96.86	--	97	91
^{133}Ba						
06/09/89	53.3 ± 6.7	49.00 ± 5.00	40.34 - 57.66	1.09	118	86
10/06/89	56.3 ± 3.5	59.00 ± 6.00	48.61 - 69.39	0.95	122	93
^{134}Cs						
02/10/89	9.67 ± 0.58	10.0 ± 5.0	1.34 - 18.66	0.97	123	85
04/18/89	19.7 ± 3.1	20.00 ± 5.00	11.34 - 28.66	0.99	101	83
06/09/89	40.0 ± 2.7	39.00 ± 5.00	30.34 - 47.66	1.03	127	91
10/06/89	27.7 ± 2.1	29.00 ± 5.00	20.34 - 37.66	0.96	125	89
10/31/89	5.3 ± 0.6	5.00 ± 5.00	0.00 - 13.66	1.06	87	76
^{137}Cs						
02/10/89	11.0 ± 0.0	10.0 ± 5.0	1.34 - 18.66	1.10	125	78
04/18/89	19.7 ± 4.0	20.00 ± 5.00	11.34 - 28.66	0.99	101	87
06/09/89	22.0 ± 5.2	20.00 ± 5.00	11.34 - 28.66	1.10	125	85
10/06/89	56.7 ± 4.0	59.00 ± 5.00	50.34 - 67.66	0.96	125	95
10/31/89	4.3 ± 2.1	5.00 ± 5.00	0.00 - 13.66	0.86	88	64

(a) Average value (± 1s) reported by REECo.
(b) The known value (± 1s) reported by EPA/EMSL.
(c) The control limits determined by EPA/EMSL.
(d) The number of participating laboratories reporting results for the analysis.
(e) The percentage of participating laboratories reporting an average value that is within ± 20% of the EPA/EMSL value.
(f) Value is outside the control limits determined by EPA/EMSL.
(g) No data provided.

Table 11.4 (EPA/EMSL, cont.)

Analysis and Date	REECo[a]	EPA/EMSL[b]	Control Limits[c]	Ratio REECo/ EMSL	Labs. No. of Labs.[d]	No. of within ±20%[e]
Water Samples, pCi/L						
^{226}Ra						
04/18/89	4.3 ± 1.0	3.50 ± 0.50	2.63 - 4.37	1.23	80	74
10/31/89	7.3 ± 1.2	8.40 ± 1.30	6.15 - 10.65	0.87	81	74
^{228}Ra						
04/18/89	No Data[g]	3.60 ± 0.50	2.73 - 4.47	--	68	63
10/31/89	3.9 ± 1.7	4.10 ± 0.60	3.06 - 5.14	0.95	73	70
^{239}Pu						
01/13/89	4.00 ± 0.36	4.20 ± 0.40	3.51 - 4.89	0.95	39	82
08/18/89	2.70 ± 0.10	2.80 ± 0.30	2.28 - 3.32	0.96	42	88
U(Nat)						
04/18/89	No Data[g]	3.00 ± 6.00	0.00 - 13.39	--	84	51
10/31/89	7.0 ± 0.0	12.00 ± 6.00	1.61 - 22.39	0.58	76	79
Air Filter Samples, pCi/Filter						
Gross Alpha						
03/31/89	21.7 ± 0.6	21.00 ± 5.00	12.34 - 29.66	1.03	128	67
08/25/89	6.0 ± 1.0	6.00 ± 5.00	0.00 - 14.66	1.00	119	62
Gross Beta						
03/31/89	61.3 ± 0.6	62.00 ± 5.00	53.34 - 70.66	0.99	131	83
08/25/89	— As per report from EPA/EMSL, the beta results are invalid —					
^{90}Sr						
03/31/89	20.3 ± 1.2	20.00 ± 1.50	17.40 - 22.60	1.02	60	82
^{131}I						
08/25/89	— As per report from EPA/EMSL, the ^{131}I results are invalid —					
^{137}Cs						
03/31/89	28.3 ± 1.5	20.00 ± 5.00	11.34 - 28.66	1.42	119	66
08/25/89	No Data[g]	10.00 ± 5.00	1.34 - 18.66	--	107	72
Milk Samples, pCi/L						
K(Tot)						
04/28/89	No Data[g]	1600.0 ± 80.0[h]	1461.4 - 1738.6[h]	--	64	94
^{89}Sr						
04/28/89	No Data[g]	39.00 ± 5.00	30.34 - 47.66	--	33	52
^{90}Sr						
04/28/89	No Data[g]	55.00 ± 3.00	49.80 - 60.20	--	39	90
^{137}Cs						
04/28/89	No Data[g]	50.00 ± 5.00	41.34 - 58.66	--	79	94

(a) Average value (± 1s) reported by REECo.
(b) The known value (± 1s) reported by EPA/EMSL.
(c) The control limits determined by EPA/EMSL.
(d) The number of participating laboratories reporting results for the analysis.
(e) The percentage of participating laboratories reporting an average value that is within ± 20% of the EPA/EMSL value.
(f) Value is outside the control limits determined by EPA/EMSL.
(g) No data provided.
(h) In unit of mg/L.

Table 11.5 Results of the DOE/EML Quality Assessment Program

Analysis and Date	Air Samples, pCi/Filter REECo[a]	DOE/EML[b]	Mean[c]	Ratio of REECo/ EML	No. of Labs.[d]	No. of Labs. within ±20%[e]
^{3}H						
04/89	6.30 ± 3.0%	6.31 ± 7.0%	6.07	1.00 ± 0.10	31	81
^{54}Mn						
04/89	0.437 ± 11%	0.300 ± 6.0%	0.314	1.46 ± 0.35	36	91
^{57}Co						
04/89	0.791 ± 1.0%	0.880 ± 5.0%	0.816	0.90 ± 0.06	34	91
^{60}Co						
04/89	0.847 ± 11%	0.940 ± 5.0%	0.881	0.90 ± 0.22	36	94
^{90}Sr						
04/89	0.575 ± 0.5%	0.550 ± 3.0%	0.574	1.05 ± 0.04	23	95
^{134}Cs						
04/89	2.43 ± 8%	2.73 ± 5.0%	2.49	0.89 ± 0.15	37	91
^{137}Cs						
04/89	2.40 ± 8%	2.55 ± 5.0%	2.51	0.94 ± 0.17	37	94
^{239}Pu						
04/89	5.70×10^{-3} ± 4.0%	5.90×10^{-3} ± 5.0%	6.30×10^{-3}	0.97 ± 0.10	26	82
	Soil Samples, pCi/gram					
^{40}K						
04/89	2.01×10^{1} ± 7%	2.41×10^{1} ± 1.0%	2.56×10^{1}	0.83 ± 0.13	29	79
^{137}Cs						
04/89	1.63×10^{1} ± 3.0%	2.08×10^{1} ± 3.0%	2.26×10^{1}	0.78 ± 0.05	36	72
^{239}Pu						
04/89	0.193 ± 7.5%[f]	0.420 ± 5.0%	0.434	0.46 ± 0.08	22	87
^{7}Be						
04/89	1.71×10^{3} ± 8.5%	1.95×10^{3} ± 5.0%	1.70×10^{3}	0.88 ± 0.16	35	77
^{60}Co						
04/89	1.40×10^{2} ± 11%	1.26×10^{2} ± 4.0%	1.23×10^{2}	1.11 ± 0.24	38	86
^{90}Sr						
04/89	2.77 ± 7.5%	2.39 ± 1.0%	2.70	1.16 ± 0.17	17	55
^{125}Sb						
04/89	1.19×10^{2} ± 16%	0.968×10^{2} ± 5.0%	0.753×10^{2}	1.23 ± 0.42	15	20

(a) Average value (± 1s) reported by REECo.
(b) The known value ± 1 standard error of the mean as reported by DOE/EML.
(c) The mean value computed from all reported results which are within the range of 0.5 to 2.0 times of the DOE/EML known value.
(d) The number of participating laboratories reporting results for the analysis.
(e) The percentage of participating laboratories reporting a result which is within ± 20% of the DOE/EML known value.
(f) The range defined by the 99% confidence limits of the REECo value (e.g. REECo value ± 3s) does not include the DOE/EML known value and the ratio of REECo/EML is outside the 0.5-1.5 range.

Table 11.5 (DOE/EML cont.)

Analysis and Date	REECo[a]	DOE/EML[b]	Mean[c]	Ratio of REECo/ EML	No. of Labs.[d]	No. of Labs. within ±20%[e]
	Air Samples, pCi/Filter					
^{134}Cs 04/89	1.58×10^{2} ± 9%	1.58×10^{2} ± 5.0%	1.41×10^{2}	1.00 ± 0.20	36	77
^{137}Cs 04/89	2.05×10^{2} ± 7%	1.89×10^{2} ± 5.0%	1.86×10^{2}	1.08 ± 0.17	38	84
^{144}Ce 04/89	3.95×10^{2} ± 11%	3.27×10^{2} ± 6.0%	3.17×10^{2}	1.21 ± 0.28	30	70
^{239}Pu 04/89	0.134 ± 11%[f]	0.270 ± 9.0%	0.258	0.50 ± 0.12	21	64
	Vegetation Samples, pCi/gm					
^{40}K 04/89	2.56×10^{1} ± 7.5%	2.61×10^{1} ± 1.0%	2.85×10^{1}	0.98 ± 0.15	28	88
^{90}Sr 04/89	3.98 ± 1.0%	3.75 ± 0.0%	4.01	1.06 ± 0.03	16	76
^{137}Cs 04/89	1.61 ± 6%	1.60 ± 2.0%	1.75	1.01 ± 0.13	32	72
^{239}Pu 04/89	1.33×10^{-2} ± 7.5%	2.20×10^{-2} ± 10%	2.28×10^{-2}	0.60 ± 0.11	19	59
	Water Samples, Bq/L					
^{3}H 09/89	0.381×10^{3} ± 2%	0.395×10^{3} ± 2%	0.347×10^{3}	0.96 ± 0.05	35	77
^{54}Mn 09/89	0.684×10^{2} ± 7%	0.650×10^{2} ± 8%	0.671×10^{2}	1.05 ± 0.17	42	90
^{57}Co 09/89	0.121×10^{3} ± 4.5%	0.135×10^{3} ± 8%	0.138×10^{3}	0.90 ± 0.12	41	97
^{60}Co 09/89	0.149×10^{3} ± 5%	0.155×10^{3} ± 8%	0.157×10^{3}	0.96 ± 0.13	43	95
^{90}Sr 09/89	0.287×10^{2} ± 1%	0.317×10^{2} ± 0%	0.342×10^{2}	0.91 ± 0.02	25	96
^{134}Cs 09/89	0.644×10^{2} ± 6.5%	0.683×10^{2} ± 8%	0.644×10^{2}	0.94 ± 0.15	42	95
^{137}Cs 09/89	0.733×10^{2} ± 7%	0.683×10^{2} ± 7%	0.722×10^{2}	1.07 ± 0.17	43	93
^{239}Pu 09/89	0.286×10^{0} ± 7.5%	0.350×10^{0} ± 1%	0.260×10^{0}	0.82 ± 0.12	25	8

(a) Average value (± 1s) as reported by REECo.
(b) The known value ± 1 standard error of the mean as reported by DOE/EML.
(c) The mean value computed from all reported results which are within the range of 0.5 to 2.0 times of the DOE/EML known value.
(d) The number of participating laboratories reporting results for the analysis.
(e) The percentage of participating laboratories reporting a result which is within ± 20% of the DOE/EML known value.
(f) The range defined by the 99% confidence limits of the REECo value (e.g. REECo value ± 3s) does not include the DOE/EML known value and the ratio of REECo/EML is outside the 0.5-1.5 range.

Table 11.5 (DOE/EML cont.)

Analysis and Date	Soil Samples, Bq/kg REECo[a]	DOE/EML[b]	Mean[c]	Ratio of REECo/ EML	No. of Labs.[d]	No. of Labs within ±20%[e]
^{40}K 09/89	0.418×10^{3} ± 8%	0.561×10^{3} ± 4%	0.573×10^{3}	0.75 ± 0.13	30	66
^{90}Sr 09/89	0.407×10^{1} ± 8%	0.573×10^{1} ± 2%	0.628×10^{1}	0.71 ± 0.12	16	12
^{137}Cs 09/89	0.551×10^{3} ± 4%	0.642×10^{3} ± 2%	0.682×10^{3}	0.86 ± 0.08	34	70
^{239}Pu 09/89	0.147×10^{2} ± 5%	0.171×10^{2} ± 24%	0.159×10^{2}	0.86 ± 0.23	23	78
^{7}Be 09/89	0.142×10^{3} ± 5.5%	0.123×10^{3} ± 2%	0.118×10^{3}	1.15 ± 0.13	36	83
^{54}Mn 09/89	0.530×10^{1} ± 7.5%	0.417×10^{1} ± 5%	0.430×10^{1}	1.27 ± 0.20	37	72
^{60}Co 09/89	0.100×10^{2} ± 6%	0.817×10^{1} ± 3%	0.845×10^{1}	1.22 ± 0.15	37	86
^{134}Cs 09/89	0.104×10^{2} ± 5%	0.933×10^{1} ± 2%	0.839×10^{1}	1.11 ± 0.12	37	72
^{137}Cs 09/89	0.489×10^{1} ± 7%	0.358×10^{1} ± 3%	0.373×10^{1}	1.37 ± 0.21	37	81
^{144}Ce 09/89	0.933×10^{1} ± 8.5%	0.708×10^{1} ± 7%	0.740×10^{1}	1.32 ± 0.25	36	77
^{239}Pu 09/89	0.170×10^{-1} ± 8.5%	0.180×10^{-1} ± 2%	0.173×10^{-1}	0.94 ± 0.16	23	60
	Vegetation Samples, Bq/kg					
^{40}K 09/89	0.104×10^{4} ± 7%	0.129×10^{4} ± 3%	0.143×10^{4}	0.81 ± 0.12	27	55
^{90}Kr 09/89	0.175×10^{4} ± 0%	0.183×10^{4} ± 6%	0.156×10^{4}	0.96 ± 0.06	17	52
^{137}Cs 09/89	0.426×10^{2} ± 9%	0.479×10^{2} ± 2%	0.494×10^{2}	0.89 ± 0.16	31	64
^{239}Pu 09/89	0.191×10^{0} ± 19%[f]	0.745×10^{-1} ± 10%	0.898×10^{-1}	2.56 ± 0.99	14	28

(a) Average value (± 1s) as reported by REECo.
(b) The known value ± 1 standard error of the mean as reported by DOE/EML.
(c) The mean value computed from all reported results which are within the range of 0.5 to 2.0 times of the DOE/EML known value.
(d) The number of participating laboratories reporting results for the analysis.
(e) The percentage of participating laboratories reporting a result which is within ± 20% of the DOE/EML known value.
(f) The range defined by the 99% confidence limits of the REECo value (e.g. REECo value ± 3s) does not include the DOE/EML known value and the ratio of REECo/EML is outside the 0.5-1.5 range.

11.2 OFFSITE MONITORING QUALITY ASSURANCE

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The quality of offsite monitoring data produced by the EPA Environmental Monitoring Systems Laboratory (EMSL-LV) was also assured by a comprehensive quality assurance program. Elements of the quality assurance program included local standard operating procedures (SOPs) which defined methods of sample collection, handling, sample control, analysis, data validation, trending, and reporting. These SOPs supported the goal of the quality assurance program in maintaining the quality of results within established limits of acceptance, with the primary purpose of determining human exposures to radiological hazards in the environment.

DATA QUALITY OBJECTIVES

The EPA, as an Agency, requires all projects involving environmentally-related measurements to develop data quality objectives (DQOs). DQOs must clearly define the level of uncertainty that a decision maker is willing to accept in results derived from environmental data. DQOs contain quantitative statements relating to the decision to be made, how environmental measurements will be used, time and resource constraints on data collection, descriptions of the data or measurements to be made, specifications of which portions of the physical systems from which samples will be collected, and the calculations that will be performed on the data in order to arrive at a result.

DATA VALIDATION

An essential element of QA is the validation of data. Four categories of data validation methods were employed by EPA/EMSL-LV:

- Procedures which were applied routinely to ensure adherence of acceptable analytical methods.
- Those that ensure that completeness of data was attained.
- Those which were used to test the internal comparability for a given data set.
- Procedures for comparing data sets with historical data and other data sets.

Completeness is the amount of data successfully collected with respect to that amount intended in the design, and comparability refers to the degree of similarity of data from different sources included in a single data set. All data was reviewed by supervisory personnel to ensure that sufficient data had been collected and the conclusions were based upon valid data. Completeness is an important part of quality, since missing data might reduce the precision of estimates, introduce bias, and thus lower the level of confidence in the conclusions.

QUALITY CONTROL

The QC portion of the EPA/EMSL-LV QA program consisted of routine use of methods and procedures designed to achieve and maintain the specified level of quality for the given measurement system. Accuracy of analysis was achieved through the regular determination of bias and precision of the results.

Bias is defined as the difference between the data set mean value (or sample average for statistical purposes) and the true or reference value (EPA 1987). The EPA/EMSL-LV participated in the EPA, DOE/EML, and WHO laboratory inter-comparison cross-check studies. The results of the EPA intercomparison study are discussed later in this section. Blank samples and samples "spiked" with known quantities of radionuclides were also routinely run. Internal "blind spiked"

samples were also entered into the normal chain of analysis. Blind samples are spiked with measured amounts of radionuclides, but those measurements are unknown to the analyst before analysis of the sample.

Precision is the degree of mutual agreement among individual measurements made under prescribed conditions (EPA 1987). As a minimum, ten percent of all samples were collected and analyzed in duplicate, and results compared.

In addition, instruments were calibrated with standards directly or indirectly traceable to the NIST (formerly National Bureau of Standards) or NIST-approved EPA-generated sources, performance checks were routinely accomplished, control charts of background and check source data were maintained, and preventive maintenance on equipment was scheduled and performed.

HEALTH PHYSICS OVERSIGHT

All analytical results received a final review by the health physics staff of the EPA Dose Assessment Branch for completeness and comparability. Trends of increasing or decreasing amounts of radionuclides in the environment were identified, and potential risks to humans and the environment were determined based on the data.

PRECISION OF ANALYSIS

A duplicate sampling program was initiated for the purpose of routinely assessing the errors due to sampling, analysis, and counting of samples obtained from the surveillance networks maintained by the EPA/EMSL-LV.

The program consisted of the analysis of duplicate or replicate samples from the Air Sampling Network, Noble Gas and Tritium Surveillance Network, Milk Sampling Network, Long-Term Hydrological Monitoring Program, and Dosimetry Network. As the radioactivity concentration in samples collected from the Long-Term Hydrological Monitoring Program and the Milk Sampling Network were usually below detection levels, most duplicate samples for these networks were prepared from spiked solutions. The noble gas samples were generally split for analysis, and duplicate samples were collected in the Air Sampling Network. Since two thermoluminescent dosimeter cards consisting of three themoluminescent phosphors each were used at each station of the Dosimetry Network, no additional samples were necessary.

At least 30 duplicate samples from each network were normally collected and analyzed over the report period. The standard deviation was obtained by taking the square root of the variance. Table 11.6 summarizes the sampling information for each surveillance network (Snedecor et al. 1967).

For expressing the precision of measurement in common units, the coefficient of variation ($s/\bar{x}$) was calculated for each sample type. These are displayed in Table 11.7 for those analyses for which there were adequate data (Nelson 1975).

To estimate the precision of counting, approximately ten percent of all samples were counted a second time. The first results were unknown to the second analyst. Since all such replicate counting gave results within the counting error, the precision data in Table 11.7 represents errors principally in analysis.

ACCURACY OF ANALYSIS

Data from the analysis of intercomparison samples were statistically analyzed and compared to known values and values obtained from other participating laboratories. A summary of the statistical analysis is given in Table 11.8, which compares the mean of three replicate analyses with the known value. The normalized deviation is a measure of the accuracy of the analysis when compared to the known concentration. The determination of this parameter was explained in detail in the reference (Jarvis and Siu 1981). If the value of this parameter (in multiples of standard normal deviate, without units) lay between control limits of -3 and +3, the precision or accuracy of the analysis was within normal

Table 11.6 Offsite Surveillance QA Samples and Analyses for Duplicate Sampling Program - 1989

Surveillance Network	Number of Sampling Locations	Samples Collected	Sets of Duplicate Samples Collected	Number Per Set	Sample Analysis
ASN	114	2288	110	2	Gross beta, γ spectrometry
NGTSN	18	710 (^{85}Kr) 734 (^{133}Xe)	53 -	2	^{85}Kr, ^{3}H, H_2O, HTO, ^{133}Xe
Dosimetry	133	531	531	6	Effective dose from gamma
MSN	33	394	129	2	^{40}K, ^{89}Sr, ^{90}Sr, ^{3}H
LTHMP	217	816	416	2	^{3}H

Table 11.7 Offsite Surveillance QA Sampling and Analytical Precision - 1989

Surveillance Network	Analysis	Sets of Replicate Samples Evaluated	Coefficient of Variation (%)
ASN	^{7}Be	6	59
NGTSN	^{85}Kr	53	6.8
Dosimetry	TLD	531	6.9
MSN	^{90}Sr	24	11.6
LTHMP	^{3}H $^{3}H^{+}$ (enriched ^{3}H)	44 68	2.1[a] 7.8[a]

(a) Median value.

statistical variation. However, if the parameters exceeded these limits, one suspected that there was some other than normal statistical variation that contributed to the difference between the measured values and the known value. As shown by Table 11.8, all but three analyses were within the control limit, the three analyses which exceed 3σ are footnoted.

The analytical methods were further checked by Laboratory participation in

Table 11.8 EPA QA Intercomparison Results - 1989

Analysis	Month	Mean of Replicate Analyses (10^{-9} µCi/mL)	Known Value	Normalized Deviation from Known Concentration
Water Studies				
^{3}H	June	4874	4503	1.4
	October	3835	3496	1.6
^{51}Cr	February	235.3	235.0	0.0
^{60}Co	February	10.0	10.0	0.0
	June	30.7	31.0	-0.1
	October	30.7	30.0	0.2
^{65}Zn	February	167.7	159.0	0.9
	June	171.7	165.0	0.7
	October	134.3	129.0	0.7
^{89}Sr	January	25.7	40.0	-5.0
	April	8.7	8.0	0.2
	May	7.7	6.0	0.6
	September	14.0	14.0	0.0
	October	11.0	15.0	-1.4
^{90}Sr	January	25.3	25.0	0.4
	April	8.3	8.0	0.4
	May	5.3	6.0	-0.8
	September	8.7	10.0	-1.5
	October	7.3	7.0	0.4
^{106}Ru	February	166.3	178.0	-1.1
	June	112.7	128.0	-2.0
	October	150.3	161.0	-1.2
^{131}I	February	105.3	106.0	-0.1
	August	84.7	83.0	0.4
^{133}Ba	June	48.3	49.0	-0.2
	October	60.7	59.0	0.5
^{134}Cs	February	9.0	10.0	-0.3
	June	35.7	39.0	-1.2
	October	26.3	29.0	-0.9
	October	4.7	5.0	-0.1

Table 11.8 (EPA QA Intercomparison, cont.)

Analysis	Month	Mean of Replicate Analyses (10^{-9} µCi/mL)	Known Value	Normalized Deviation from Known Concentration
Water Studies (cont.)				
^{137}Cs	February	10.3	10.0	0.1
	June	20.3	20.0	0.1
	October	59.7	59.0	0.2
	October	5.9	5.0	0.0
U(Nat)	March	5.3	5.0	0.1
	April	2.0	3.0	-0.3
^{239}Pu	January	4.4	4.2	1.0
Milk Studies				
^{89}Sr	April	47.7	39.0	3.0
^{90}Sr	April	48.7	55.0	-3.7
^{137}Cs	April	49.0	50.0	-0.3
Air Filter Studies				
Gross Alpha	March	20.0	21.0	-0.3
	August	5.0	6.0	-0.3
Gross Beta	March	64.3	62.0	0.8
^{137}Cs	March	20.3	20.0	0.1
	August	9.7	10.0	-0.1

the semiannual Department of Energy Quality Assurance Program conducted by the Environmental Measurements Laboratory, New York, New York. The results from these tests (Table 11.9) indicated that this laboratory's results were of acceptable quality.

To measure the performance of the contractor laboratory that analyzed the animal tissues, a known amount of activity was added to several sets of bone as samples. The reported activity was compared to the known amount in Table 11.10 together with the calculated bias and precision. The average bias for ^{239}Pu was -16 percent, and the average bias for ^{90}Sr was -22. The average precision determined from three sets of duplicate ash samples was 79 percent for ^{239}Pu and 17 percent for ^{90}Sr at background levels, but was 5.4 percent and 0.4 percent respectively, for a duplicate spiked sample.

Table 11.9 QA Results from DOE Program - 1989

EPA EMSL-LV Analysis	EML Month	Ratio Results	Results	EPA/EML
^{7}Be in air	April	2.07×10^{3}	1.95×10^{3}	1.06
	Sept.	1.28×10^{2}	1.23×10^{2}	1.04
^{54}Mn in air	Sept.	4.77	4.17	1.14
^{60}Co in air	April	1.35×10^{2}	1.26×10^{2}	1.07
	Sept.	9.18	8.17	1.12
^{134}Cs in air	April	1.55×10^{2}	1.58×10^{2}	0.98
	Sept.	9.21	9.33	0.99
^{137}Cs in air	April	2.13×10^{2}	1.89×10^{2}	1.13
	Sept.	4.22	3.58	1.18
^{144}Ce in air	April	3.90×10^{2}	3.27×10^{2}	1.19
	Sept.	9.14	7.08	1.29
^{239}Pu in air	April	2.50	2.70	0.93
	Sept.	1.76×10^{2}	18.0	0.98
^{137}Cs in soil	April	29.1	20.8	1.40
	Sept.	7.44×10^{2}	6.42×10^{2}	1.16
^{239}Pu in soil	April	4.26×10^{-1}	4.20×10^{-1}	1.01
	Sept.	15.7	17.1	0.92
^{137}Cs in vegetation	April	1.77	1.60	1.11
	Sept.	5.19	47.9	1.08
^{239}Pu in vegetation	Sept.	2.44×10^{-2}	2.20×10^{-2}	1.11
^{3}H in water	April	6.18	6.31	0.98
	Sept.	4.00×10^{2}	3.95×10^{2}	1.01
^{54}Mn in water	Sept.	66.2	65.0	1.02
^{57}Co in water	Sept.	1.37×10^{2}	1.35×10^{2}	1.01
^{60}Co in water	Sept.	1.53×10^{2}	1.55×10^{2}	0.99

Table 11.9 (DOE Program, cont.)

Analysis	Month	EPA EMSL-LV Results	EML Results	Ratio EPA/EML
^{90}Sr in water	April	5.37×10^{-1}	5.50×10^{-1}	0.98
	Sept.	40.2	31.7	1.27
^{134}Cs in water	April	2.27	2.73	0.83
	Sept.	61.5	68.3	0.90
^{137}Cs in water	April	2.48	2.55	0.97
	Sept.	69.7	68.3	1.02
^{239}Pu in water	April	6.08×10^{-3}	5.90×10^{-3}	1.03
	Sept.	2.67×10^{-1}	3.50×10^{-1}	0.76

Table 11.10 QA Results for the Bioenvironmental Program - 1989

Sample ID and Shipment Number (Bone Ash)	Nuclide	Activity Added pCi/g Bone Ash	Activity Reported pCi/g Bone Ash
Spiked Samples			
Ash-1 78	^{239}Pu	0	$(1.2 \pm 0.7) \times 10^{-3}$
	^{90}Sr	0	2.3 ± 0.64
Ash-2 78	^{239}Pu	0	$(19 \pm 12) \times 10^{-3}$
	^{90}Sr	0	4.6 ± 1.03
Ash-3 78	^{239}Pu	0.0885	0.13 ± 0.03
	^{90}Sr	22.34	20.1 ± 0.3
Ash-4 78	^{239}Pu	0.0897	0.11 ± 0.03
	^{90}Sr	22.65	19.9 ± 0.3
Ash-1 80	^{239}Pu	0.0863	0.085 ± 0.012
	^{90}Sr	21.8	16.1 ± 2
Ash-2 80	^{239}Pu	0.0944	0.11 ± 0.015
	^{90}Sr	23.8	20 ± 3
Ash-3 80	^{239}Pu	0	$(1.2 \pm 1.9) \times 10^{-3}$
	^{90}Sr	0	2.3 ± 0.1

Table 11.10 (Bioenvironmental Program QA, cont.)

Sample ID and Shipment Number	Nuclide	Activity Added pCi/g Bone Ash	Activity Reported pCi/g Bone Ash
Spiked Samples (cont.)			
Ash-1	^{239}Pu	0.436	0.55 ± 0.08
81	^{90}Sr	0	0.5 ± 0.08
Ash-2	^{239}Pu	0.431	0.52 ± 0.06
81	^{90}Sr	0	0.5 ± 0.07
Ash-3	^{239}Pu	0	(0.8 ± 1.4) x 10^{-3}
81	^{90}Sr	2.633	2.3 ± 0.08
Ash-4	^{239}Pu	0	(7.0 ± 3.0) x 10^{-3}
81	^{90}Sr	2.666	2.5 ± 0.1
Ash-5	^{239}Pu	0	(1.0 ± 2.0) x 10^{-3}
81	^{90}Sr	0	0.5 ± 0.07
Duplicate Samples			
Bone Cow #2	^{239}Pu	0	(1.5 ± 1.7) x 10^{-3}
80	^{90}Sr	0	1.0 ± 0.06
Dup-Bone Cow #2	^{239}Pu	0	(1.3 ± 1.5) x 10^{-3}
80	^{90}Sr	0	0.97 ± 0.06
Liver-Cow #2	^{239}Pu	0	(5.3 ± 3.7) x 10^{-3}
80			
Dup Liver-Cow #2	^{239}Pu	0	(1.2 ± 0.7) x 10^{-3}
80			
Bone-Cow #5	^{239}Pu	0	(1.7 ± 1.8) x 10^{-3}
81	^{90}Sr	0	0.41 ± 0.04
Dup Bone-Cow #5	^{239}Pu	0	(1.1 ± 1.5) x 10^{-3}
81	^{90}Sr	0	0.46 ± 0.04
Liver-Cow #5	^{239}Pu	0	0.025 ± 0.009
81			
Dup Liver Cow #5	^{239}Pu	0	-0.018 ± 0.008
81			

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BIBLIOGRAPHIC DATA FOR GEOGRAPHIC INFORMATION SYSTEM FIGURES

Some of the map figures contained in this report were generated by the EG&G/Energy Measurements, Inc., using geographic information system (GIS) technology. A GIS is a computer mapping package that is used to input, store, analyze, display, and output spatially referenced digital data. Each map figure in this document generated using the GIS is an integrated product derived from several data sources. Because these figures are presented at page-size for this publication, source data is not reported on each map. The following is a bibliography identifying the source materials used to create each thematic layer. Together these digital data layers enabled the final compilation of the map products displayed in this report.

The perspective image shown as Figure 1.3 was produced using both digital image processing and GIS techniques. Image processing algorithms enabled the geometric correction of a Thematic Mapper satellite image to a digital map base, creating a geocoded image. Digital map information from the GIS was integrated with the geocoded image, creating an image map. The image map was then transformed, in combination with a digital elevation model, producing the perspective view.

Figure 1.1 NTS Location (presentation scale: 1:4,000,000)

"Nevada Test Site Administrative Boundary and Operational Areas, Nevada Test Site Coordinate Map, Site Plan and Insert," Holmes and Narver, Inc., Energy Support Division, Drawing Number 090-094-C7.2, revised June 8, 1987.

"Nellis Air Force Range Administrative Boundary, Nellis Air Force Base Range Chart, Edition 3," Defense Mapping Agency, Map Number NRCXX01, revised February 1988.

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Figure 1.2 NTS Area Designations, Principle Facilities, and Testing Areas (presentation scale: 1:500,000)

"Nevada Test Site Administrative Boundary and Operational Areas, Nevada Test Site Coordinate Map, Site Plan and Insert," Holmes and Narver, Inc., Energy Support Division, Drawing Number 090-094-C7.2, revised June 8, 1987.

"Principle Features and Facilities, Nevada Test Site Road and Facility Map," Holmes and Narver, Inc., Energy Support Division, revised April 18, 1986.

Figure 1.3 Topography of the NTS and Vicinity

Landsat images; the image scene identification numbers are 51186-17453 and 51186-17455, acquired May 13, 1987, by EOSAT Company.

Digital Elevation Models; the 1:250,000 scale digital elevation models for the Caliente, Death Valley, Goldfield, and Las Vegas 1° x 2° maps were obtained from the U.S. Geological Survey.

"Nevada Test Site Administrative Boundary and Operational Areas, Nevada Test Site Coordinate Map, Site Plan and Insert," Holmes and Narver, Inc., Energy Support Division, Drawing Number 090-094-C7.2, revised June 8, 1987.

Figure 1.5 Surface Drainage Channel Pattern for the NTS (presentation scale: 1:500,000)

"Nevada Test Site Administrative Boundary and Operational Areas, Nevada Test Site Coordinate Map, Site Plan and Insert," Holmes and Narver, Inc., Energy Support Division, Drawing Number 090-094-C7.2, revised June 8, 1987.

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Figure 1.6 Basic Lithologic Structure of the NTS (presentation scale: 1:500,000)

"Nevada Test Site Administrative Boundary and Operational Areas, Nevada Test Site Coordinate Map, Site Plan and Insert," Holmes and Narver, Inc., Energy Support Division, Drawing Number 090-094-C7.2, revised June 8, 1987.

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Figure 1.7 Drill Hole Locations on the NTS (presentation scale: 1:500,000)

"Nevada Test Site Administrative Boundary and Operational Areas, Nevada Test Site Coordinate Map, Site Plan and Insert," Holmes and Narver, Inc., Energy Support Division, Drawing Number 090-094-C7.2, revised June 8, 1987.

Drill Holes; digital coordinate data file provided by the Lawrence Livermore National Laboratory, 1989, from Fenix and Scisson's "Nevada Test Site Drilling and Mining Summary through June 1989."

Figure 1.8 Groundwater Table Elevations at the NTS (presentation scale: 1:500,000)

"Nevada Test Site Administrative Boundary and Operational Areas, Nevada Test Site Coordinate Map, Site Plan and Insert," Holmes and Narver, Inc., Energy Support Division, Drawing Number 090-094-C7.2, revised June 8, 1987.

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Figure 1.9 Groundwater Hydrologic Units of the NTS and Vicinity (presentation scale 1:1,250,000)

"Nevada Test Site Administrative Boundary and Operational Areas, Nevada Test Site Coordinate Map, Site Plan and Insert," Holmes and Narver, Inc., Energy Support Division, Drawing Number 090-094-C7.2, revised June 8, 1987.

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Figure 1.10 1989 Wind Rose Patterns for the NTS (presentation scale 1:500,000)

"Nevada Test Site Administrative Boundary and Operational Areas, Nevada Test Site Coordinate Map, Site Plan and Insert," Holmes and Narver, Inc., Energy Support Division, Drawing Number 090-094-C7.2, revised June 8, 1987.

"Principle Features, Nevada Test Site Road and Facility Map," Holmes and Narver, Inc., Energy Support Division, revised April 18, 1986.

Wind roses were provided by the NOAA Weather Services Nuclear Support Office, located at Las Vegas, Nevada.