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# OFF-SITE MONITORING FOR THE MIGHTY OAK NUCLEAR TEST

by

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## LIST OF ABBREVIATIONS AND SYMBOLS

### ABBREVIATIONS

| | |
|---|---|
| ICRP | -- International Commission on Radiological Protection |
| I-131 | -- radioactive iodine isotope, a radionuclide |
| MDC | -- Minimum Detectable Concentration |
| μrem | -- microrem = one millionth of a rem |
| mrem | -- millirem = one thousandth of a rem |
| $m^3$ | -- cubic meter, about 35 cubic feet |
| pCi | -- picocurie - unit representing 2.22 atoms decaying per minute |
| rem | -- unit of dose = 100 ergs per gram x modifying factors |
| Xe-133 | -- radioactive xenon isotope, a radionuclide |

# INTRODUCTION

The Mighty Oak event was a low-yield (less than 20 kt) test conducted in the T-tunnel on the Nevada Test Site (NTS) on April 10, 1986. As with all nuclear explosives tests conducted on the NTS, the Nuclear Radiation Assessment Division deployed personnel and equipment in the area downwind from the test location to measure any radioactivity which might be released as a result of the test. The normal monitoring networks for detecting airborne or other radioactivity were also operating. These networks and the operating procedures are described in annual reports entitled "Off-Site Environmental Monitoring Report," the latest issue of which has the report number EPA-600/4-85-035.

During and immediately following the detonation of Mighty Oak, no radioactivity related to that test was detected by the off-site radiation safety personnel or by the monitoring networks. Following the Mighty Oak event the DOE Test Controller notified the Nuclear Radiation Assessment Division (NRD) that a ventilation procedure would be instituted within the next several days to purge the tunnel of airborne radioactive materials so that personnel could re-enter the tunnel to recover equipment and records. Ventilation or purging of a tunnel involves the extraction of tunnel air with clean air make-up, filtration of the extracted air through particulate and charcoal filters, and further dilution with clean make-up air prior to environmental release. As a result of this procedure, most of the radioactive noble gases in the tunnel air and a very small fraction of other radionuclides are discharged into the atmosphere.

To more readily follow the steps in the purging procedures described below, a schematic drawing of the outer portions of the tunnel is shown in Figure 1.

## PROCEDURES

Purging of the tunnel, when the amount of radioactivity contained therein is high enough that it may be detectable off site, is performed only when the wind will carry the radioactivity into unpopulated or sparsely populated areas so that exposures will be as low as reasonably achievable. To insure this, purging is performed only when meteorological data from the Weather Service indicates an acceptable wind direction and speed. NRD is then notified of the planned purging schedule so that special noble gas samplers and air samplers equipped with particulate and charcoal filters can be placed in appropriate locations to supplement the routine monitoring networks.

After the purging and requisite sampling period the noble gas and air filter samples are collected and returned to the laboratory for analysis. The noble gas and air samplers are re-started in place or moved to new locations as necessary. The noble gas samples are analyzed for xenon-133 and krypton-85 and the air filters are analyzed for gamma-emitting radionuclides (e.g. iodine-131) by means of gamma spectrometry.

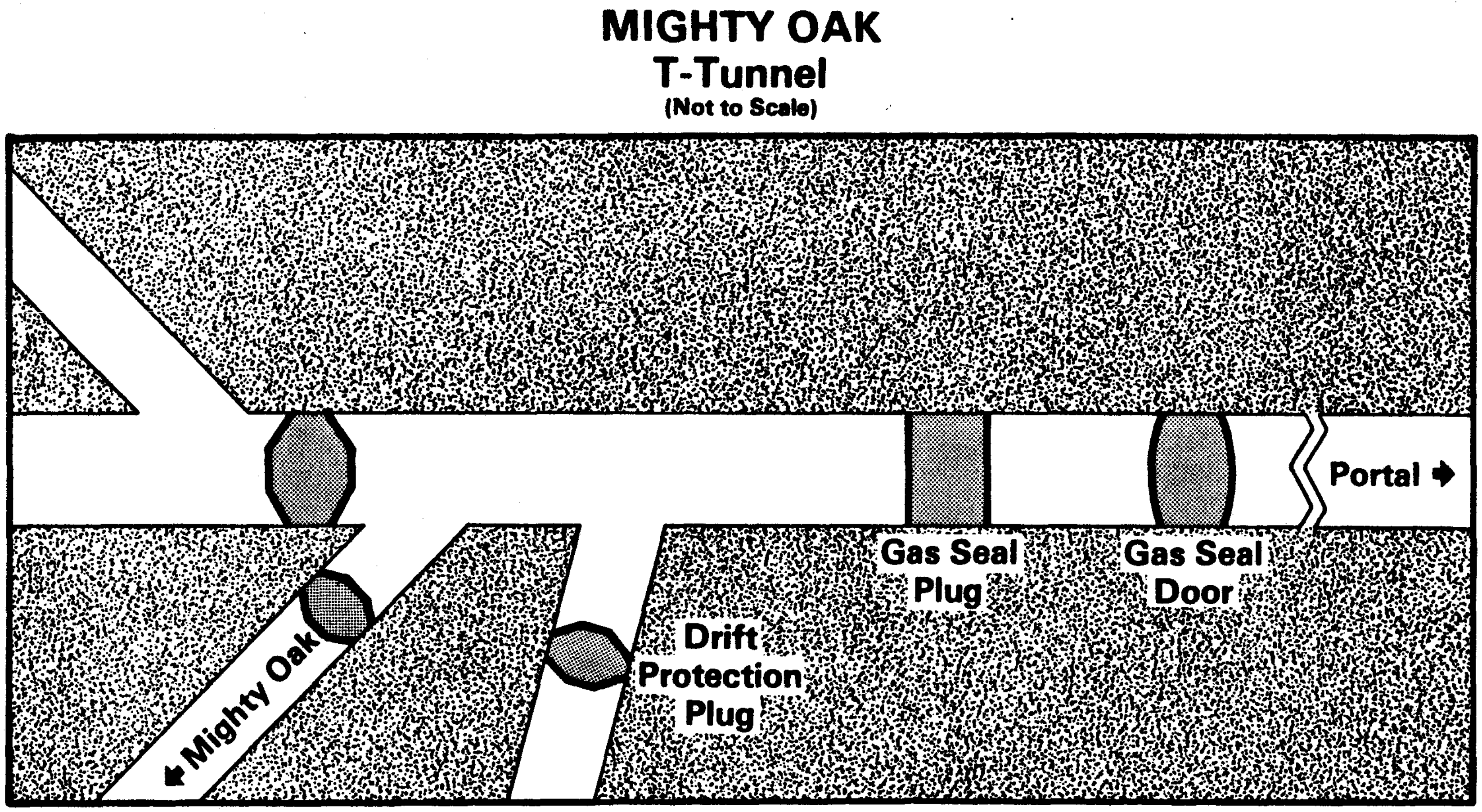


Figure 1. Schematic diagram of a test tunnel.

TABLE 1. PURGING AND MONITORING SCHEDULE

| Date 1986 | Wind Sector | Purging Times - PST | Sampler Locations | Comments |
|---|---|---|---|---|
| 04/16 | Hiko-Rachel | 1445-1500 | Medlin Rn., Rachel, Hiko, Alamo | Relieved excess pressure between Gas Plug and Drift Protection Plug. |
| 04/22 | Reed-Rachel | 1000 4/22 to 1030 4/23 | Twin Springs Rn., Hiko, Medlin Rn., Reed Rn. turn-off, Pioche, Penoyer Farm | Purging of tunnel between the Gas Plug and Drift Protection Plug. |
| 04/25 | Rachel-Alamo | 1030-1400 | Hiko, Glendale, Penoyer Farm, Twin Springs Rn., Medlin Rn. | Purging of the tunnel behind the Drift Protection Plug. |
| 04/28 to 04/30 | Rachel-Alamo | 1000 4/28 to 0300 4/29 1030 to 1500 4/29 | Hiko, Penoyer Farm, Medlin Rn. | Purging of the tunnel behind the Drift Protection Plug. |
| 04/30 to 05/5 | Hiko to Warm Springs | 1400 to 1800 4/30 1000 to 1930 5/1 0930 5/2 to 0520 5/4 | Hiko, Twin Springs Rn., Penoyer Farm, Medlin Rn. | Purging of the tunnel behind the Drift Protection Plug. |
| 05/5 to 05/09 | variable | continuous after 1540 on 5/4 | Hiko, Twin Springs Rn., Penoyer Farm | Purging of the tunnel behind the Drift Protection Plug. |

The purging times and sampler locations are shown in Table 1 for the period from April 16, the initiation of the purging, until May 9. Special sampling was discontinued after May 9 following return of airborne xenon concentrations to background levels. Location of the special samplers and centerline wind directions during purging are shown in Figure 2.

## RESULTS

The results from the analyses of the special samples collected during the purging are shown in Tables 2 and 3. Also operating during this time were the routine Air Surveillance Network (ASN - 30 locations, Figure 3), the Noble Gas and Tritium Surveillance Network (NGTSN - 15 locations, Figure 4), the Pressurized Ion Chamber Network (PIC - 23 locations), and thermoluminescent dosimeters at 127 locations. The PIC's are at all the NGTSN stations shown in Figure 4 plus Complex 1, Furnace Creek, Lathrop Wells, Nyala, Stone Cabin Ranch, Tikaboo Valley and Twin Springs Ranch. These routine networks operate continuously year round. Other than background levels of krypton-85, the only radioactivity detected by these networks were xenon-133 concentrations of 36 and 38 pCi/$m^3$ at Rachel and Alamo, respectively, in 1 week samples collected April 23 through April 30. Of all the samples collected the week ending May 9, only that collected at Rachel (operated 4/30 to 5/7) had a detectable xenon concentration (Table 2). This was most likely due to the purging from May 1 to May 4 since no xenon was detected in the sample collected at Penoyer Farm, which is closer to the NTS, during the period May 5 to May 9.

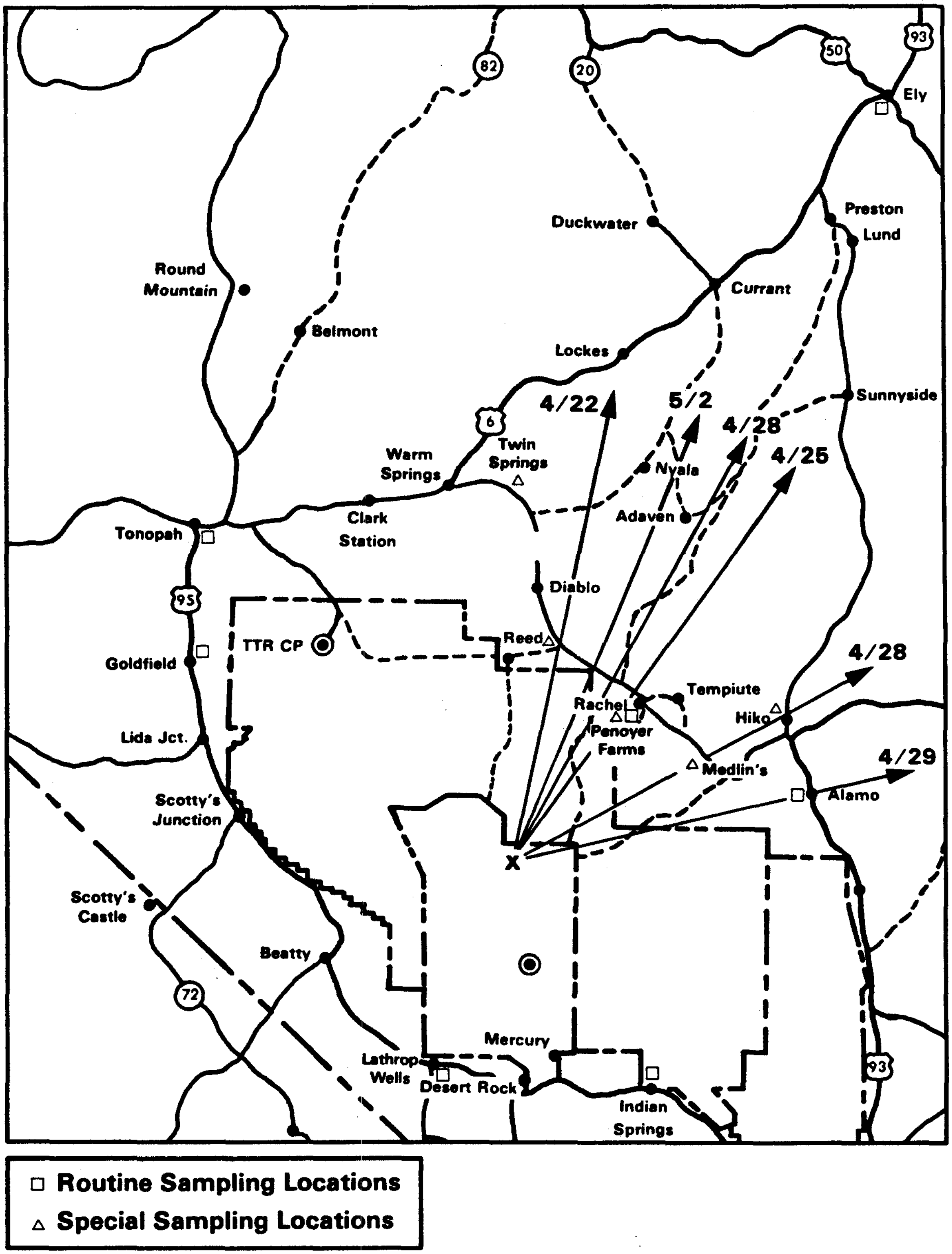


Figure 2. Special sampler locations and centerline winds.

TABLE 2. XENON-133 SPECIAL STUDY-MIGHTY OAK

| Location | Start Day | Start Time Hour | Run Time Hours | Result pCi/m$^3$ |
|---|---|---|---|---|
| Alamo, NV | 04/09* | 1030 | 169 | ND |
| | 04/16 | 1140 | 23 | ND |
| | 04/16* | 1150 | 167 | ND |
| | 04/23* | 1230 | 168 | 38 ± 7 |
| | 04/30* | 1145 | 169 | ND |
| Reed Rn. Turnoff | 04/22 | 1030 | 23 | 81 ± 10 |
| Glendale, NV | 04/25 | 1200 | 25 | ND |
| Hiko, NV | 04/16 | 1100 | 23 | ND |
| | 04/21 | 1300 | 48 | ND |
| | 04/25 | 1100 | 23 | 270 ± 7 |
| | 04/28 | 1030 | 48 | 116 ± 20 |
| | 04/30 | 1100 | 120 | ND |
| | 05/05 | 1130 | 95 | ND |
| Pioche, NV | 04/22 | 1100 | 96 | ND |
| Rachel, NV | 04/09* | 0930 | 168 | ND |
| | 04/16 | 1040 | 22 | ND |
| | 04/16* | 1015 | 168 | ND |
| | 04/23* | 1200 | 166 | 36 ± 7 |
| | 04/30* | 1000 | 169 | 26 ± 8 |
| Penoyer Farm | 04/22 | 1200 | 22 | 23 ± 6 |
| | 04/25 | 1000 | 17 | ND |
| | 04/28 | 1115 | 49 | 210 ± 7 |
| | 04/30 | 1245 | 121 | 35 ± 7 |
| | 05/05 | 1400 | 92 | ND |
| Medlin Rn. (Tikaboo Valley) | 04/16 | 1130 | 22 | ND |
| | 04/22 | 0800 | 28 | ND |
| | 04/25 | 1300 | 11 | 550 ± 15 |
| | 04/28 | 1235 | 47 | 120 ± 6 |
| | 04/30 | 1130 | 120 | ND |
| Twin Springs Rn. | 04/21 | 1020 | 48 | ND |
| | 04/25 | 1000 | 26 | insufficient |
| | 04/30 | 1430 | 120 | 124 ± 8 |
| | 05/05 | 1500 | 92 | ND |

*NGTSN samples

TABLE 3. SPECIAL AIR FILTER SAMPLES - pCi/m$^3$

| Location | Date Off | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 4/17 | 4/23 | 4/26 | 4/30 | 5/5 | 5/7 | 5/8 | 5/5-5/9 | 5/10 |
| Alamo | GSN* | GSN | GSN | GSN | | | | I-131- 0.5 | I-131- 1.2 |
| Glendale | | | GSN | | | | | | |
| Hiko | GSN | GSN** | GSN | GSN | GSN | | | I-131- 0.2 | I-131- 1.2 |
| Lathrop Wells | GSN | GSN | GSN | GSN | GSN | GSN | I-131- 0.10 | I-131- 0.9 | I-131- 1.9 |
| Medlin Rn. | GSN | GSN** | GSN | GSN | GSN | | | | |
| Penoyer Farm | | GSN | GSN | GSN | GSN | | | I-131- 0.20 | |
| Pioche | | | GSN | | | | | | |
| Rachel | GSN | GSN | | GSN | GSN | GSN | GSN | | I-131- 1.5 |
| Reed Rn Turnoff | | GSN** | | | | | | | |
| Twin Springs | | GSN** | GSN | | GSN | GSN | GSN | I-131- 0.1 | I-131- 4.6 |

*GSN - gamma spectrum negligible

** - beryllium-7 detected, a natural radionuclide

NOTE: First detectable Chernobyl fallout found 5/7 in air samples from Denver CO, Elko NV, Delta, Milford and Bryce Canyon UT, and in snow from Mt. Charleston.

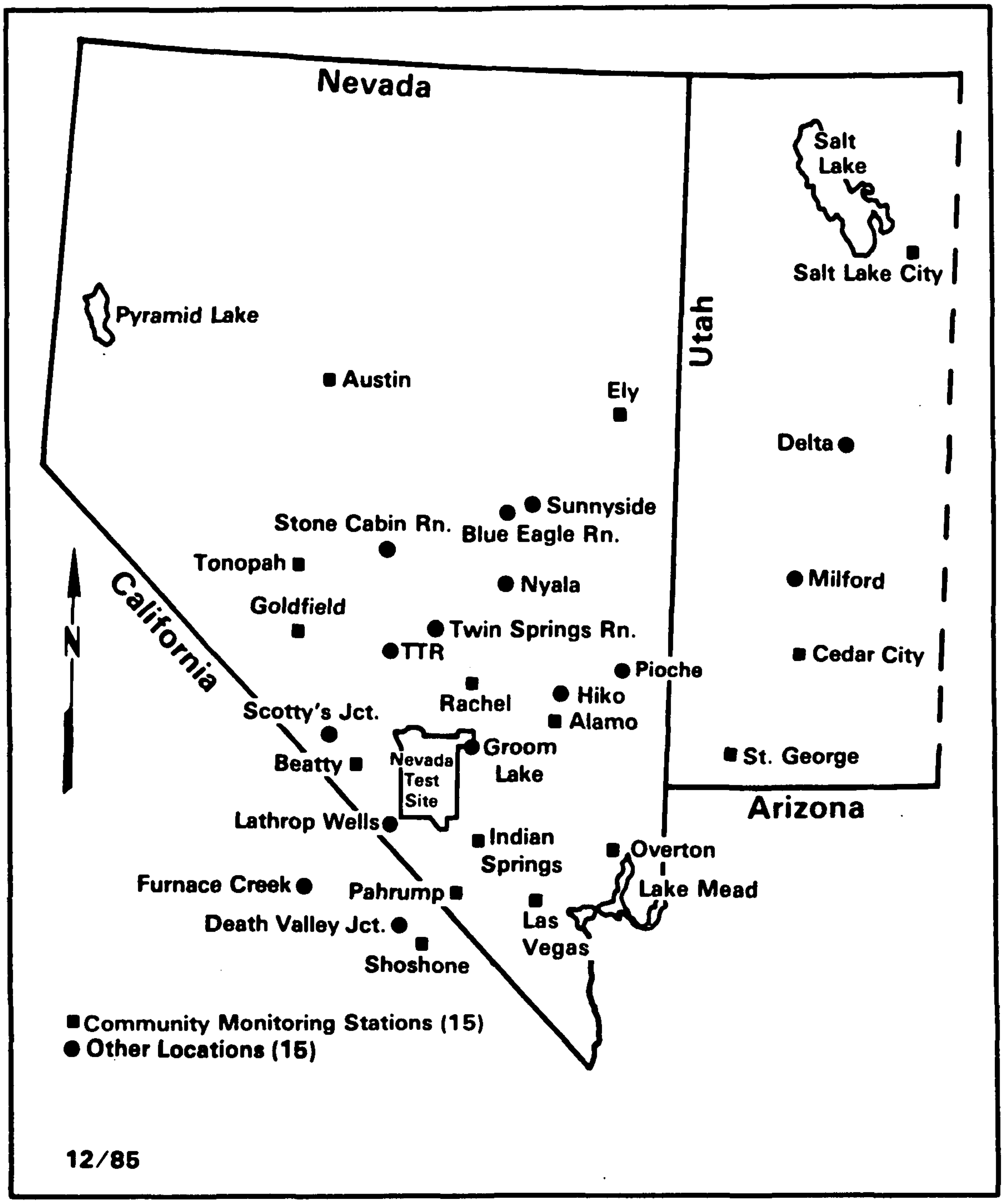


Figure 3. Air Surveillance Network stations (1985).

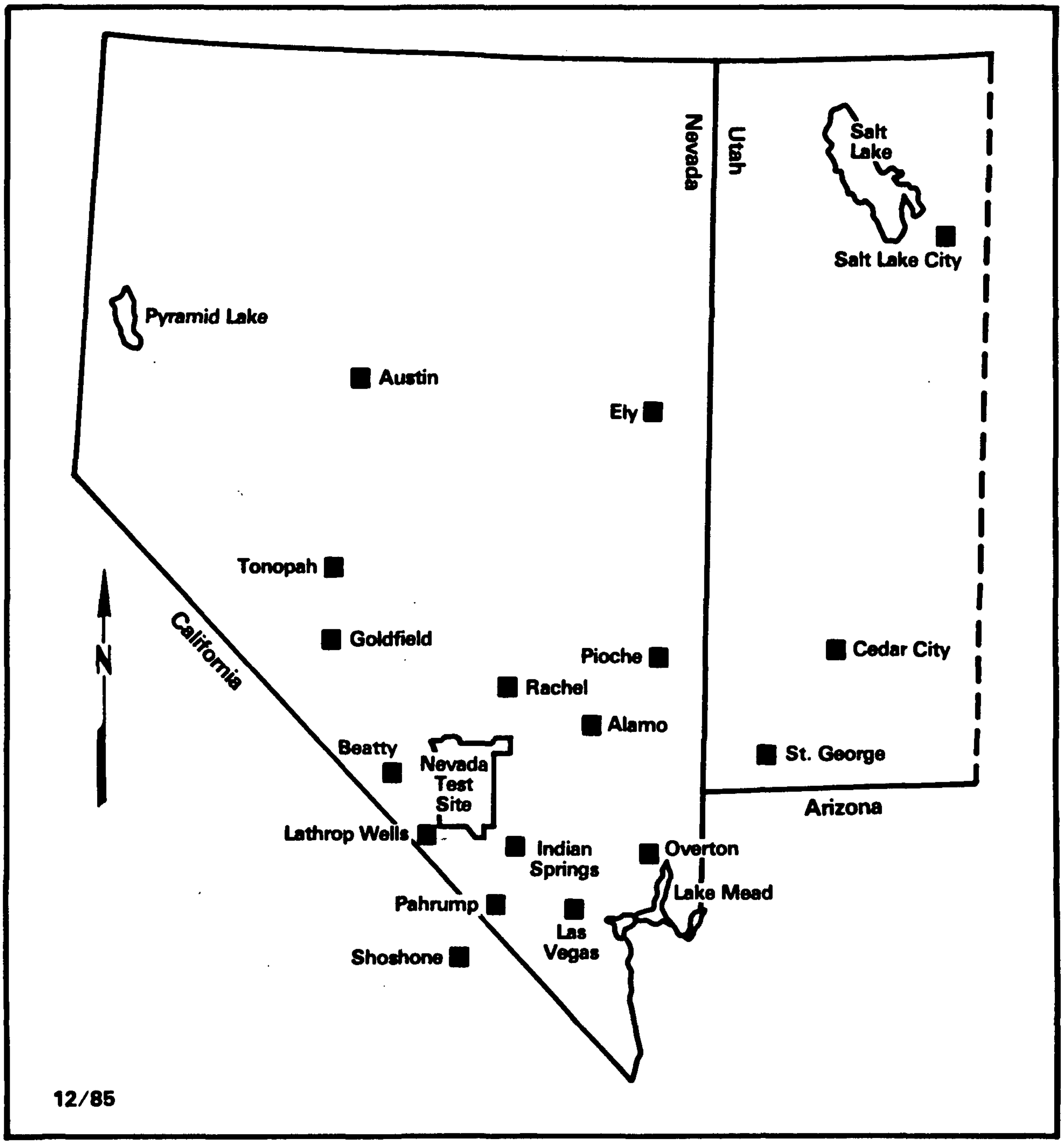


Figure 4. Noble Gas and Tritium Surveillance Network sampling locations.

## SUMMARY AND CONCLUSIONS

During the purging procedure following the Mighty Oak event, special sampling for radioactive noble gases and other airborne radioactivity was performed. The location of the special samplers and their operating times were determined from information supplied by the U.S. Weather Service and the Nevada Operations Office, U.S. Department of Energy.

For the sampling periods indicated in Table 1, 33 samples were collected and analyzed; 12 indicated the presence of low concentrations of xenon-133. The maximum detected was 550 pCi/$m^3$ for a sampling period of 11 hours at Medlin's Ranch. This should be compared to the continuous exposure of 480,000 pCi/$m^3$ which would be required to reach the annual whole-body dose limit of 100 mrem to a person in the general population as recommended by the ICRP. No gamma-emitting radionuclides were detected on any air filter samples during the period of the purging. The radionuclides shown in Table 3 starting May 8 originated from the reactor accident in the USSR (I-131 = iodine-131). Ruthenium-103 was also detected in some of these early samples.

To estimate the whole-body dose from exposure to the measured xenon concentrations listed in Table 2, the air concentration (pCi/$m^3$) is multiplied by the collection time and summed for each site. This sum is then multiplied by a dose conversion factor of $2.4 \times 10^{-5}$ μrem/(pCi-hr/$m^3$) to yield a whole body dose for that location. The dose conversion factor is determined by dividing the annual whole body dose limit (in μrem) by the product of 480,000 pCi/$m^3$ (the Derived Concentration Guide calculated using the International Commission of Radiological Protection Report No. 30) and the number of hours per year (8,766). This whole body dose is then compared to the ICRP whole body dose limit of 100 mrem/yr (100,000 μrem/year) shown as %ICRP. These results are shown below. As an additional comparison, the whole body dose at each location is divided by the background dose rate to determine the extra minutes of equivalent background (min. bkg.) exposure.

| Site | Sum (pCi-hr/m$^3$) | Dose-μrem | % ICRP | min. bkg. |
|---|---|---|---|---|
| Alamo | 6,350 | 0.15 | $1.5 \times 10^{-4}$ | 0.7 |
| Hiko | 11,780 | 0.28 | $2.8 \times 10^{-4}$ | 1.5 |
| Medlin | 11,640 | 0.28 | $2.8 \times 10^{-4}$ | 1.0 |
| Penoyer Farm | 15,030 | 0.36 | $3.6 \times 10^{-4}$ | 1.3 |
| Rachel | 10,370 | 0.25 | $2.5 \times 10^{-4}$ | 0.9 |
| Twin Springs | 13,920 | 0.33 | $3.3 \times 10^{-4}$ | 1.2 |

The pCi-hr/m$^3$ normalized to a daily integrated concentration, averaged for the special samples, is plotted in Figure 5. Also shown are the start of each purge period, the equivalent concentrations from the network shown in Figure 3, and the minimum detectable concentration (MDC) during actual analysis. The plotted values are the results from analysis even though they might be less than the MDC. The detectable concentrations at Alamo and Rachel pushed the network average above the MDC for the period April 23 to April 30. The increase in off-site concentration of xenon-133 from the purging reached a maximum on April 25 and decreased to less than MDC after May 5.

In conclusion, the special monitoring for the tunnel purging following the Mighty Oak test indicated that only xenon-133 was detectable in off-site areas. No radioactivity attributable to Mighty Oak was detectable after May 5, 1986.

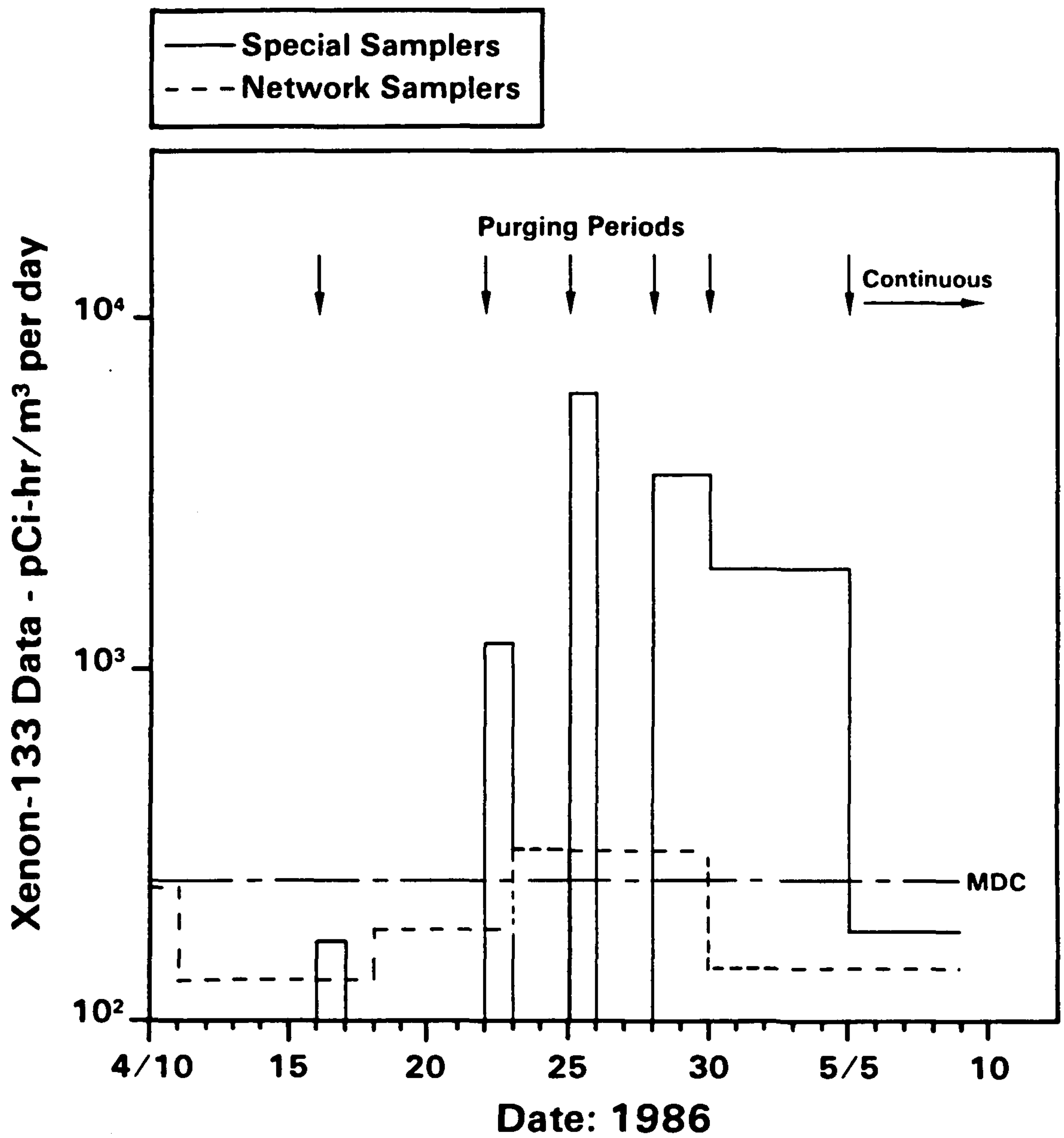


Figure 5. Integrated concentrations of xenon in Special and Routine Network noble gas samples.

The maximum radiation dose to an off-site resident, assuming that person remained outdoors during the total sampling period, would have been 0.36 μrem at Penoyer Farm. This is equivalent to less than 1-1/2 minutes extra exposure to the background radiation at that location. All exposures to residents were negligible fractions of both the ICRP guidelines for exposure of 100 mrem per year (ICRP77) and the U.S. EPA guideline of 25 mrem/yr from airborne radionuclides (EPA85a).

## REFERENCES


EPA85a U.S. Environmental Protection Agency, 1985, National Emission Standards for Department of Energy Facilities, 40 CFR 61 Subpart H, published in FR:50, 5194, February 6, 1985.

EPA85b U.S. Environmental Protection Agency, 1985, Off-Site Environmental Monitoring Report: Radiation Monitoring Around United States Nuclear Test Areas, Calendar Year 1984, Environmental Monitoring Systems Laboratory, Las Vegas, NV Report EPA/600/4-85-035.

ICRP77 International Commission on Radiological Protection, 1977, Recommendations of the ICRP, Pergamon Press, NY, Publication 26 (Revised 1983, Publication 39).

ICRP79 International Commission on Radiological Protection, 1979, Limits for Intakes of Radionuclides by Workers, Pergamon Press, NY, ICRP Publication 30.

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16. ABSTRACT

After a nuclear explosives test, code name Mighty Oak, the tunnel leading to the test point became contaminated with radioactive debris. To re-enter and recover valuable equipment and data, the DOE purged the tunnel air using particulate and charcoal filters to minimize discharge of radioactivity to the atmosphere. During this purging, the EPA established special air samples supplementing their routine air monitoring networks. Analysis of the collected samples for radioactive noble gases and for gamma-emitting radionuclides indicated that only low levels of xenon-133 were released in amounts detectable in populated areas near the Nevada Test Site. The maximum dose to an individual was calculated to be 0.36 microrem, assuming that person remained in the open field at the measurement site during the whole period of the purging.

17. KEY WORDS AND DOCUMENT ANALYSIS

| a. DESCRIPTORS | b. IDENTIFIERS/OPEN ENDED TERMS | c. COSATI Field/Group |
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