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FINAL REPORT OF THE RADIOLOGICAL SURVEILLANCE PROGRAM FOR THE PROJECT GASBUGGY PRODUCTION TEST

May 15, 1973 to November 6, 1973

by the
Monitoring Applications Laboratory
National Environmental Research Center

U. S. ENVIRONMENTAL PROTECTION AGENCY
Las Vegas, Nevada

Published August 1974

This work performed under a Memorandum of
Understanding No. AT(26-1)-539
for the
U. S. ATOMIC ENERGY COMMISSION

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ABSTRACT

A production test of the Project Gasbuggy nuclear-stimulated natural gas well (GB-ER) was conducted from May 15, 1973, through November 6, 1973. This test was sponsored by the El Paso Natural Gas Company, the Atomic Energy Commission, and the U. S. Bureau of Mines. The test well, located about 88 km (55 mi) east of Farmington, New Mexico, had been shut-in for about 42 months since an earlier production test. Data furnished by the El Paso Natural Gas Company indicate that a total of about 49 Ci of ^{3}H and about 4.7 Ci of ^{85}Kr was released into the atmosphere during the flaring of about 3.03 million cubic meters (107 MMCF) of natural gas.

For the purpose of determining the impact of the production test on the environment, environmental monitoring was provided by the U. S. Environmental Protection Agency, National Environmental Research Center-Las Vegas. Aerial and ground surveillance teams collected environmental samples prior to, during, and after the production test. During the environmental monitoring program, samples of air were analyzed for ^{85}Kr, and samples of atmospheric moisture, vegetation, soil, precipitation, and surface water were analyzed for ^{3}H. Based upon wind patterns and aircraft trackings, samples were collected where the maximum concentrations of these nuclides would be expected to be found. In addition, aerial and ground sampling was done where maximum concentrations were most likely to be found at times of the day during which maximum and minimum atmospheric mixing conditions occurred. Also, contaminated water removed from the gas was stored and injected into the flare at higher than normal rates during most of the surveillance operations.

Out of 13 compressed air samples collected during the production test, one had a ^{85}Kr concentration (21 ± 1.0 pCi/m^3) which was higher than normal and may indicate a contribution from the production test. Tritium levels above estimated background (1000 pCi/l H_2O) were found in some samples of each type of environmental media collected with the exception of surface water. From the highest concentration of ^{3}H measured in atmospheric moisture samples, it is concluded that any direct exposure to hypothetical off-site receptors was below

0.4% of the Concentration Guide for a suitable population sample in an uncontrolled area as listed in the Atomic Energy Commission's Manual, Chapter 0524, "Standards for Radiation Protection."

The analytical results of post-flaring sample collection showed concentrations of ^{3}H above estimated background on 10 out of 25 post-flaring vegetation samples that were collected from all four compass quadrants surrounding the flare stack. One of 25 soil samples collected showed a concentration of ^{3}H slightly above the estimated background. There are no guides for vegetation or soil; however, all vegetation samples collected were native uncultivated shrubs which would not constitute additional exposure to the off-site population.

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INTRODUCTION

Under a Memorandum of Understanding between the Atomic Energy Commission (AEC) and the Environmental Protection Agency (EPA), the EPA's National Environmental Research Center-Las Vegas (NERC-LV) carried out a program of off-site radiological surveillance for a Project Gasbuggy production test during 1973. Project Gasbuggy was a joint Government-Industry project for the purpose of testing the feasibility of increasing the yield of natural gas wells by detonating a nuclear device below the gas-bearing formation, thus increasing the permeability of the host rock. The detonation took place on December 10, 1967, about 88 km (55 mi) east of Farmington, New Mexico. This report describes the procedures and results of the NERC-LV surveillance program.

This surveillance consisted of the collection of environmental samples on the ground during pre-flaring, flaring, and post-flaring periods. During flaring operations, periodic in-cloud aerial sampling and tracking were done with an EPA aircraft. The surveillance was a continuation of Project Gasbuggy surveillance programs starting with pre-detonation, detonation, re-entry and initial flaring operations. The results of previous Gasbuggy surveillance programs have been reported earlier.[1-5]

The purpose of this test was to obtain data which would provide a more thorough understanding of the reservoir characteristics of the chimney and fracture zones created by the initial detonation after the well had been closed-in for about 42 months since a previous production test. Details of the purpose and nature of this flaring operation have been described by the U.S. Atomic Energy Commission.[6] Briefly, the test consisted of an initial rapid draw-down phase, a steady-pressure phase with low flare rates, and a final rapid pressure draw-down phase accompanied by high rates of gas flaring. The initial draw-down phase began on May 15, 1973, and the well was shut-in on November 6, 1973.

Table 1 lists the cumulative gas flared, the average gas flaring rate, and the estimated quantities of radionuclides released for consecutive 7-day

periods. In addition, Table 1 shows when EPA aircraft and mobile monitors were conducting their surveillance activities. As shown in Table 1, water that had been extracted from the natural gas and stored in tanks was introduced into the flare as steam principally at the beginning and end of the flaring period. Water was removed from the gas so that more accurate flow-rate measurements could be made. The later water injection, in the form of steam injected into the flare, was done for the production test to simplify disposal of the ^{3}H contaminated water. The information provided in Table 1 was furnished by the El Paso Natural Gas Company.[7]

Surveillance for the Gasbuggy production test was first begun with pre-flaring sample collection on May 3-8, 1973, for the purpose of establishing a base-line for comparing results obtained during flaring and post-flaring surveillance. Following the pre-flaring sampling, flaring surveillance operations were undertaken during May 19-21, 1973, when maximum flow and steam injection occurred, and during July 25-26, 1973, a period when steady flow at a reduced rate had been established. A final post-flaring surveillance operation was conducted during November 6-8, 1973.

Each operation is treated as complete in itself and includes the specific description of operational procedures and results. A discussion of the total environmental impact is presented in the Summary and Conclusion section.

GENERAL OPERATIONAL PROCEDURES

From previous surveillance programs for Project Gasbuggy, the radionuclides of primary concern had been identified as ^{3}H and ^{85}Kr.[2] In air these nuclides may both be of public health significance, whereas in other environmental media, such as water, vegetation, and soil, only the ^{3}H may be a potential hazard due to its relatively rapid assimilation into the environment in the form of moisture. Krypton-85 is chemically inert and does not readily combine with most environmental media. For these reasons all surveillance attempts were directed toward the detection of both ^{3}H and ^{85}Kr in air and to the detection of ^{3}H in other environmental media such as water, vegetation, and soil in areas surrounding the test well.

Aerial Surveillance

Aerial surveillance was provided by an EPA turbo-Beech aircraft equipped with an Environment/One Condensation Nuclei Monitor (CNM) and air sampling equipment. The CNM was used to detect and track the effluent plume discharged from the 15-meter flaring stack because the plume was invisible, and radioactivity levels were too low to be detected with conventional instruments. The CNM measured the concentration of condensation nuclei, generated by flaring operations, per unit volume of air. The CNM output was recorded on a strip-chart recorder located in the aircraft crew chief's instrument panel. This chart was annotated with names of appropriate landmarks on the ground so that the record of plume location could be used to position mobile monitors.

Because of the anticipated low radioactivity levels, samples were collected only from the plume, to the extent possible. Air samples were collected in a one-cubic-meter plastic bag which was filled in approximately 10 seconds while the aircraft passed through the plume at a speed of about 160 knots, true air speed. A compressor then drew the air from the bag through a canister of 13X molecular sieve for collection of water vapor and compressed the remainder of the sample into a tank. The adsorbed water vapor was analyzed for ^{3}H, and the compressed air sample was analyzed for ^{85}Kr and radioxenon.

Ground elevation at the 15 m (50 ft) flare stack was 2190 m (7200 ft) above mean sea level (MSL).* Terrain within 3.2 km (2 mi) of the flare stack varied from 2130 m (7000 ft) to 2260 m (7400 ft). The general procedure was to perform an initial spiral descent from approximately 900 m (3000 ft) above the surface at a 1.6 km (1.0 mi) radius from the flare stack. A descent rate of 150 m (500 ft) per minute was maintained. This spiral descent identified the height of the plume and its direction of movement. Several passes were then made across the plume near the surface in order to locate positions for placement of mobile ground monitors. Because of the inherent delay in the CNM response (on the order of 2 to 5 seconds), these passes were made on reciprocal headings to obtain a fix on the plume centerline and edges. In most cases, a mobile monitor was then positioned downwind of the plume, and an aerial grab sample was collected over his location with a one-cubic-meter bag. When possible, the procedure was repeated farther downwind out to a distance of 8.0 km (5.0 mi). During the May and July sampling periods, the aircraft attempted to locate the effluent beyond 8.0 km (5.0 mi) of the flare stack. The maximum distance at which plume material was detected was 11 km (7.0 mi).

Ground Monitoring

In addition to the normal complement of equipment for the collection of water, vegetation, air, and other environmental samples, the NERC-LV mobile monitors were equipped with sampling apparatus designed for sampling ^{3}H in atmospheric moisture and for sampling noble gases. Each monitor carried several molecular sieve sampling heads for atmospheric moisture collection. The heads consisted of a polyvinylchloride cylinder, 12.7 cm (5 in) long and 6.3 cm (2.5 in) in diameter, containing 300 g of 13X molecular sieve. The intake end of the sampling head held a 7.6-cm (3-in) diameter particulate filter (used primarily to prevent the introduction of foreign substances), and the outlet was equipped with a pipe-fitting attached to a dry-gas meter. Airflow was provided by a portable vacuum pump powered by a 12-volt battery.

*All elevations in this report are above MSL unless otherwise stated.

Special 24-volt DC air compressors were carried by several monitors for the collection of compressed air samples. The air was pumped into a pressure tank until a pressure of 2.8 MPa (400 psig) was obtained. This was approximately equal to one cubic meter of air at atmospheric pressure at the sampling altitude.

For soil collection, a 30.5-cm (12-in) square steel frame, 2.5 cm (1 in) deep, was pressed into the ground until it was level with the surface. Soil within the frame was then removed with a trowel. All of the soil samples were collected to a depth of 2.5 cm (1 in) except for profile samples taken at Station 9 (Figure 1). These profile samples are identified in the tables.

Analytical Procedures

Sample analysis was done at the NERC-LV laboratory. Each atmospheric moisture sample was transferred to a heating vessel where the water was elutriated at 350° C with a dry He purge. Recovery of water from the absorber normally exceeded 95%. This water was then re-distilled to eliminate possible interference by other contaminants. The ^{3}H concentration in the re-distilled water was determined by liquid scintillation spectrometry. This was accomplished by taking 5 ml of the recovered water, 5 ml of a ^{3}H standard (for counting effiiency), and 5 ml of ^{3}H-free water (for instrument background). The solution was then diluted with 20 ml of a dark-adapted scintillation cocktail. The sample, standard, and background mixtures were counted for 200 minutes in a liquid scintillation spectrometer optimized for ^{3}H.[8] The minimum detectable concentration (MDC) for ^{3}H was determined to be about 200 pCi/l of H_2O at the 95% confidence level, based upon the 200-minute count and 5 ml of atmospheric water.

Snow and surface water samples were re-distilled and analyzed in the same manner as the water from the molecular sieves. Moisture from vegetation and soil samples was recovered by vacuum distillation. The recovered water was re-distilled and analyzed in the same manner as the water from the molecular sieve samples.

Compressed air samples, about one cubic meter in volume, were analyzed for ^{85}Kr and radioxenon by gas chromatography and liquid scintillation techniques as described by Stevenson and Johns.[9] The MDC for these radionuclides at the 95% confidence level is 5 pCi/m^3 and 2 pCi/m^3, respectively.

PRE-FLARING SAMPLE COLLECTION AND RESULTS
MAY 5-8, 1973

Sampling Procedures

During the pre-flaring sampling program, 17 locations were selected within a 32-km (20-mi) radius of the flare stack. Three ponds within an 11-km (7-mi) radius of the flare stack were selected for surface water samples. Not all types of samples were collected at all of the 17 pre-selected sampling locations. During the pre-flaring sampling period, 2 compressed air, 10 atmospheric moisture, 17 vegetation, 18 soil, 3 water, and 2 snow samples were collected. Figures 1 and 2 show the sampling locations. Other sampling locations numbered 18 and higher were added during the production test.

Results

Since one of the two compressed air samples was lost, only one result for ^{85}Kr prior to flaring operations was available. This sample showed a ^{85}Kr concentration of 17 ± 1.0 pCi/m^3 of air. This is similar to values reported in the literature. Andrews[10] reported a mean concentration of 16 ± 4.0 pCi/m^3 (± two standard deviations) which was calculated from the results of weekly samples collected from a continuously-operated air sampler at Las Vegas, Nevada, over the twelve-month period April 1972 through March 1973. Also, from estimates of projected releases of ^{85}Kr from nuclear facilities throughout the world, Bernhardt[11] predicted that the atmospheric concentration of ^{85}Kr would be 13 pCi/m^3 in 1970 and 25 pCi/m^3 in 1975.

Tables 2 through 6 show the analytical results and the two-sigma counting errors of all other samples collected prior to flaring operations. The ranges and averages of the ^{3}H concentrations in each sample type are as follows:

Sample Type	No. of Samples	^3H Concentration, pCi/l H_2O Maximum	Minimum	Average
Surface water	3	<240	<240	<240
Snow	2	410 ± 240	380 ± 250	400
Soil	18	500 ± 240	<240	323
Vegetation	17	1200 ± 260	<240	570
Atmospheric moisture	10	650 ± 240	<200	390

In the computation of the average concentrations, the values less than the MDC were set equal to the MDC. The two-sigma counting error is given for each maximum and minimum concentration above the MDC.

The pre-flaring samples were collected as a cursory check on background concentrations of ^3H with the understanding that seasonal and geographical variations in background can not be precisely defined with the limited number of samples collected. During a surveillance program for Project Gasbuggy in previous years, a ^3H background concentration of about 1000 pCi/l of water was used.[2] Although ^3H concentrations have been known to occasionally vary above this concentration, such as the 1200 pCi/l concentration for a pre-flaring vegetation sample, the 1000 pCi/l value for background is used throughout this report with the acknowledgment that the background concentration is variable.

FLARING SURVEILLANCE PROCEDURES AND RESULTS
MAY 19-21, 1973

May 19, 1973

During the morning of May 19, 1973, the aircraft flew a mission to determine characteristics of drainage winds and to collect air samples at a time when no tritiated water was being injected into the flare. Mobile monitors were not involved in the morning sampling effort.

Until 0930 hours the plume was moving 330° from the flare stack following a ridge along the north side of Leandro Canyon (Figure 1). A grab sample was collected at 0905 hours, 1.9 km (1.2 mi) northwest of the flare stack at an altitude of 2440 m (8000 ft). In this area the terrain ranges in altitude from 2190 m (7200 ft) to 2260 m (7400 ft). At 0917 hours, a spiral descent was started. The top of the plume was identified at 2590 m (8500 ft) with the maximum concentrations of nuclei at 2320 m (7600 ft). Condensation nuclei concentration at 2440 m (8000 ft) during sampling was within a factor of two of the concentration measured at 2320 m (7600 ft) during the spiral descent.

At 0939 hours, the plume was again detected at 1.6 km (1 mi) east of the flare stack at an altitude of 2350 m (7700 ft). At 0946 hours, a spiral descent was started 3.7 km (2.3 mi) east of the flare stack where the plume top was found to be at 2680 m (8800 ft) with the maximum concentration of nuclei at 2320 m (7600 ft) over ground elevation of 2200 m (7200 ft). A grab sample was collected in two halves at the plume centerline on two successive passes at 2320 m (7600 ft) at 1002 hours.

Unstable atmospheric conditions caused moderate turbulence and directional instability of the plume as well as vertical mixing. At 1002 hours, the plume width at 3.7 km (2.3 mi) east of the flare stack was about 7 km (4.5 mi). The morning mission was terminated at that time.

On the afternoon of May 19, at 1330 hours, the aircraft returned to the area along with the mobile monitors for the purpose of conducting a coordinated

aerial-ground sampling mission. Water injection into the flare had begun at 1200 hours and was continued until 1600 hours. Malfunction of the CNM prevented plume detection until 1405 hours when a spiral descent was started 2.1 km (1.3 mi) east of the flare stack. The plume top was found at 2900 m (9500 ft). Mobile monitors were sent to Stations 18 and 19 (Figure 2) to start atmospheric moisture sampling and to collect vegetation and soil samples. Meanwhile, the maximum concentration of nuclei was found at 2590 m (8500 ft) and an aerial grab sample was collected at that elevation at 1423 hours over Station 19, 1.6 km (1 mi) at 110° from the flare stack. Further investigation by the aircraft indicated the plume base to be above ground level. Highly unstable atmospheric conditions soon made plume detection impossible and the aerial and ground operations were terminated at approximately 1500 hours.

May 20, 1973

Water injection into the flare began at 0800 hours. Difficulties with the CNM prevented making measurements until 0857 hours. Without aircraft tracking information, and assuming that downslope drainage winds were similar to those on May 19, mobile monitors were directed to begin atmospheric moisture sampling at Stations 8, 11, and 20 (Figure 2). Doppler radar results showed westerly winds over the mobile monitor locations varying from 5 knots at the surface to 20-25 knots 910 m (3000 ft) above the surface.

The CNM began functioning properly and a spiral descent was begun on a 1.6-km (1-mi) radius around the flare stack at 0900 hours. The plume top was found at 2740 m (9000 ft) with the maximum concentration of nuclei at 2590 m (8500 ft). Mobile monitors were sent to Stations 18 and 19 to begin sampling, and an aerial grab sample was collected over Station 19. This sample was taken at 2590 m (8500 ft) at 0925 hours.

The aircraft established a north-south pattern about 8.0 km (5 mi) east of the flare stack. The pattern showed the plume to be centered at 75° from the flare stack. A mobile monitor started atmospheric moisture sampling at this location (Station 21) at 1020 hours. A spiral descent by the aircraft

over Station 21 showed the plume top at 3350 m (11,000 ft), with the maximum concentration of nuclei at 3200 m (10,500 ft). Most of the plume material was above 2740 m (9000 ft), but some material was detected down to 30 m (100 ft) above ground level, which is 2160 m (7100 ft) at this location.

At this time, the plume seemed to be centered over Station 21 with the north edge passing over Station 9 and the south edge passing over Station 19. Mobile monitors were directed to take compressed air samples at Stations 19 and 20.

A second spiral descent was made by the aircraft in the vicinity of Station 21 where the plume centerline was located at 2740 m (9000 ft). A grab sample was taken at this point at 1040 hours. Because of fluctuating plume height due to turbulence, this sample may not have been collected at the centerline. Malfunction of the CNM prevented an afternoon mission.

Vegetation and soil samples were collected at Stations 8, 9, 11, 18, 19, 20, and 21 (Figures 1 and 2).

May 21, 1973

Mobile monitors arrived in the area at 0645 hours and determined that the direction of the downwind drainage winds was generally NNW of the flare stack. Mobile monitors were sent to Stations 8, 11, and 20 where they began atmospheric moisture sampling. The Station 8 monitor began sampling at 0725 hours, and Stations 11 and 20 at 0715. Injection of water into the flare was supposed to have started at 0700 hours; however, some problems were encountered which delayed water injection until 0725 hours.

The aircraft began tracking at 0745 hours and the plume material was found to be on a heading of 330° from the flare stack. A grab sample was collected over Station 20 at an altitude of 2320 m (7600 ft) at 0800 hours. Indications were that the plume was moving in a more northerly direction and by 0815 hours, the plume was centered on a 30° trajectory. The mobile monitor at Station 11 then started another atmospheric moisture sample at 0800 hours. In addition, an atmospheric moisture sample was started at Station 22 at 0825 hours.

The aircraft began a spiral descent around the flare stack at 0830 hours at an altitude of 2900 m (9500 ft), and descended to within 61 m (200 ft) of the surface. The plume material was found to be rising nearly vertically due to very light winds. Several spiral descents and ascents were accomplished during the next hour; however, no plume material was found beyond 1.6 km (1 mi) of the flare stack. At about 0840 hours, a slight indication of plume material was found at 30 m (100 ft) above ground level at 0.4 km (0.25 mi) northwest of the flare stack. A mobile monitor had already started atmospheric moisture sampling at Station 18.

Aircraft tracking continued to indicate that the plume was rising nearly vertically above the flaring stack and that unstable air was causing directional instability of the plume material. At about 0945 hours, wind speeds increased causing the plume to move along the surface on an ESE direction. A mobile monitor started atmospheric moisture sampling at Station 23, 3.5 km (2.2 mi) at 126° from the flare stack at 1004 hours. Shortly thereafter, wind speeds decreased and the plume again began rising vertically. The aircraft took a final grab sample at 3050 m (10,000 ft) 3.2 km (2 mi) southeast of the flare stack at 1025 hours. Water injection ceased at 1015 hours when the stored water was exhausted so that this sample may not have been from that portion of the plume containing injected water. The aerial mission was terminated at this time.

Surface water samples were collected at Stations 27 through 31, and vegetation samples were collected at Stations 17, 22, and 23. In addition, soil samples were collected at Stations 22 and 23. The ground monitoring mission was terminated by 1200 hours.

Results of Aerial Operations

Tables 7 and 8 list the analytical results of all samples collected by the aircraft during the May 19-21 surveillance mission. Of the seven aerial atmospheric moisture samples that were collected, four contained concentrations of ^{3}H above 1000 pCi/l of H_2O. The maximum concentration of ^{3}H was 2800 pCi/l of H_2O. This concentration expressed as 24 ± 2.9 pCi/m^3 of air is 0.04% of the Concentration Guide specified in the AEC Manual, Chapter 0524, for a suitable

population sample in an uncontrolled area.[12] The associated compressed air samples did not show concentrations of ^{85}Kr that could definitely be considered to be above background except for the sample collected at an azimuth of 330° and a distance of 1.9 km (1.2 mi) from the flare stack on May 19. This sample, which had a ^{85}Kr concentration of 21 ± 1.0 pCi/m^3, was slightly higher than all others collected during the period May 19-21 and higher than the 95% confidence interval of the annual average of ^{85}Kr concentrations measured in Las Vegas.[10] Since an atmospheric moisture sample collected at the same time showed a ^{3}H concentration above background, it is possible that a portion of this ^{85}Kr concentration was the result of flaring operations.

Ground Monitoring Results

Tables 9 through 12 list the results of all samples collected on the ground with the exception of two compressed air samples collected at Stations 19 and 20. The compressed air sample from Station 19 was lost in analysis. The sample from Station 20, collected between 0910 and 0940 hours on May 20, had a ^{85}Kr concentration of 15 ± pCi/m^3.

Of the 16 molecular sieve samples collected, five showed concentrations of ^{3}H above 1000 pCi/l H_2O. The maximum ^{3}H concentration was 4100 ± 310 pCi/l H_2O (14 ± 1.1 pCi/m^3 of air) at Station 18, 1.4 km (0.9 mi) 77°. This is less than 0.02% of the Concentration Guide for continuous exposure for a suitable population sample in an uncontrolled area.[12]

Only one vegetation sample showed a ^{3}H concentration that was above the estimated background of 1000 pCi/l H_2O, and none of the soil samples exceeded the estimated background. A vegetation sample collected at Station 18 had a ^{3}H concentration of 1200 pCi/l H_2O. Since this sample was collected at the same location as the highest atmospheric moisture sample, it is possible that the slightly elevated ^{3}H concentration was the result of flaring operations.

Five surface water samples were collected at Stations 27 through 31 within 16 km (10 mi) of the flare stack. None of the five samples showed elevated levels of ^{3}H.

FLARING SURVEILLANCE PROCEDURES AND RESULTS

JULY 25-26, 1973

July 25, 1973

The aircraft began tracking at 0705 hours. From the usual spiral descent and ascent, the plume was detected 1.8 km (1.1 mi) west of the flare stack at 0730 hours, between the ridge north of Leandro Canyon and Station 25. Mobile monitors were sent to Stations 8 and 24, and started atmospheric moisture sampling. A compressed air sample was also taken at Station 24. Water injection started at 0700 hours and ended at 1050 hours when the stored water was exhausted.

In the air the plume was detected at 2350 m (7700 ft) over terrain of 2320 m (7600 ft) 4.8 km (3 mi) at 260° from the flare stack. A grab sample was collected in two halves on passes over Station 27 at 0746 and 0754 hours. The first pass was at 2260 m (7400 ft) and the second was at 2230 m (7300 ft). The ground elevation along this route is 2160 m (7100 ft). The heading of the plume was determined to be about 260° from the flare stack and a ground monitor was positioned at Station 25 where an atmospheric moisture sample was started at 0811 hours.

At 0830 hours, the aircraft located the plume starting at the flare stack and continuing down Leandro and La Jara Canyons to Highway 17; then west along Vaqueros Canyon. Plume contact was maintained the entire length of this pass at an elevation of about 60 m (200 ft) above the surface. Mobile monitors were dispatched to Stations 11 and 13 to obtain atmospheric moisture samples. At 0839 hours, an aerial grab sample was collected at the junction of La Jara and Vaqueros Canyons, at 2070 m (6800 ft) about 60 m (200 ft) above the surface 8.0 km (5 mi) at 300° from the flare stack. A third grab sample was collected at 0931 hours 2010 m (6600 ft) in Vaqueros Canyon 8.0 km (5 mi) at 290° from the flare stack. This sample was collected about 30 m (100 ft) above the canyon floor of 2010 m (6500 ft). The aerial mission was concluded at this time. Mobile monitors collected vegetation and soil samples at all stations where atmospheric moisture samples were taken (Stations 8, 11, 13, 24, and 25). This terminated the surveillance for July 25.

July 26, 1973

A spiral descent by the aircraft starting at 0730 hours, identified the plume top about 2260 m (7400 ft) between 260° and 290° from the flare stack. Prior to this time mobile monitors had been sent to Stations 8 and 13 to try to sample early morning drainage winds. Atmospheric moisture sampling was started at Station 13 at 0625 hours, and at Station 8 at 0717 hours. Based upon the aircraft information, other mobile monitors were sent to Stations 24 and 26 where they collected atmospheric moisture samples.

By 0750 hours the wind speed had decreased to near zero moving slowly to the northwest. A pass over Station 25 at 2190 m (7200 ft) at 0757 hours, indicated a slight trace of plume material. An aerial grab sample was collected at 0817 hours at 2440 m (8000 ft) between Leandro Canyon (300°) and Station 25. Following a spiral descent around the flare stack a second grab sample was taken at 2320 m (7600 ft), 1.3 km (0.8 mi) from the flare stack between 270° and 300°. By 0851 hours the plume was identified at 2350 m (7700 ft) 330° from the flare stack about 2 km (1.2 mi) out. By 0908 hours the plume was still moving in the same direction and was detected over La Jara Canyon at 2290 m (7500 ft), 4.8 km (3 mi) from the flare stack. A grab sample was taken at 0913 hours between 6.4 km (4 mi) and 8.0 km (5 mi) at 2320 m (7600 ft) on a heading of 320°.

Based upon the trajectory established by the aircraft, a mobile monitor was sent to Station 20 and began atmospheric moisture sampling at 0920 hours. Aerial tracking was terminated at 1000 hours with the last contact at 1.6 km (1 mi) to 3.2 km (2 mi) north of the flare stack. At that time (0940 hours) the Doppler radar showed the winds over the surface to be about 2 knots from 180°.

Vegetation samples were collected at Stations 9, 17, 18, 19, 20, and 23. Soil samples were collected at Stations 9, 18, 19, 20, 23, and 26. The soil sample at Station 9 was a profile sample consisting of surface to 2.5 cm (1 in) 2.5 cm to 7.6 cm (3 in), and 7.6 cm to 15.2 cm (6 in). Surface water samples were collected at Stations 27, 28, 30, and 31. This terminated the surveillance for July 26.

Results of Aerial Operations

Tables 13 and 14 list the results of aerial operations for the July 25-26 flaring. Six atmospheric moisture samples were collected by the aircraft. Tritium concentrations were of the same magnitude as the May flaring surveillance with four samples above background and a maximum of 4000 ± 300 pCi/l H_2O in a sample collected 1.8 km (1.1 mi) from the flare stack on an azimuth of 260°. This concentration, expressed as 48 ± 3.6 pCi/m^3 of air was 0.07% of the Concentration Guide for a suitable population sample in an uncontrolled area.[12] Associated compressed air samples did not show ^{85}Kr concentrations above anticipated background. The compressed air samples were also analyzed for radioxenons. No concentrations of radioxenons were found above the detection limit of 2.0 pCi/m^3 of air. All samples with ^3H concentrations above 1000 pCi/l were collected during injection of water on July 25.

Ground Monitoring Results

Tables 15 through 19 list the analytical results of all samples collected by ground monitors.

Ground level sampling of atmospheric moisture showed definite concentrations of ^3H above background at Stations 8, 11, 13, 24, and 25. All of these Stations, with the exception of Station 13, were within 2 km (1.2 mi) of the flare stack in a sector from 220° to 341°. Station 13 was 8 km (5 mi) from the flare stack on an azimuth of 300°. The maximum concentration of ^3H occurred at Station 11, 0.5 km (0.3 mi) at 341° from the flare stack. This concentration was 49,000 pCi/l H_2O, which was equivalent to 300 pCi/m^3 of air. This was about 0.4% of the Concentration Guide for a suitable population sample.[12] All of the above samples were collected on July 25, 1973 during which time water was being injected into the flare.

Vegetation and soil samples showed concentrations of ^3H above background at Station 11. A vegetation sample collected on July 25 at Station 11 had a ^3H concentration of 22,000 pCi/l H_2O, and a soil sample collected at the same location had a ^3H concentration of 5800 pCi/l H_2O.

Four surface water samples were also collected. None of the samples showed elevated levels of ^3H.

POST-FLARING SAMPLE COLLECTION AND RESULTS
NOVEMBER 6-8, 1973

Sampling Procedures

Post-flaring environmental samples were collected from the Gasbuggy Project area on November 6, 7, and 8, 1973. Of the 26 soil and vegetation sampling locations used throughout the flaring period, vegetation and soil samples were collected at all stations except two. Only vegetation was collected at Station 17, and only soil was collected at Station 26. Shut-in of the test well was accomplished at 1235 hours on November 6; however, water containing ^{3}H was steamed until November 7. A few of the more remote samples were collected on the morning of November 6, but were considered to be post-flaring samples.

Only three of the five water sampling locations were sampled. No water was available at Bullsnake Pond and John Mills Lake (Stations 29 and 31).

Results of Post-Flaring Sample Collection

Tables 20, 21, and 22 list the analytical results of all samples collected after flaring was completed.

Post-flaring vegetation sampling results showed levels of ^{3}H above background in all four compass quadrants surrounding the flare stack. Of the 25 stations where vegetation was collected, ten had concentrations of ^{3}H greater than 1000 pCi/l of H_2O. No obvious pattern existed in relation to distance and direction for those stations where elevated levels of ^{3}H were found. The maximum concentration of ^{3}H was found in a vegetation sample at Station 20, 2 km (1.2 mi) 330°. This sample had a ^{3}H concentration of 26,000 pCi/l of H_2O. This value is about five times greater than the next highest vegetation sample (5500 pCi/l H_2O) which was collected at Station 21, 8.2 km (5.0 mi) 75°.

Of the 25 stations where soil samples were collected, only Station 10 0.5 km (0.3 mi) 102°, had a concentration of ^{3}H above 1000 pCi/l H_2O. This sample contained 1700 pCi/l H_2O of ^{3}H.

Three surface water samples were collected. None of these samples showed ^{3}H concentrations above background.

SUMMARY AND CONCLUSION

During the production test conducted at the Project Gasbuggy site from May 15 to November 6, 1973, natural gas containing ^{85}Kr and ^{3}H was flared continuously. On several occasions tritiated water, which had been removed from the natural gas, was converted to steam and injected into the flaring plume. The flow rate at which the natural gas was flared varied as shown on Figure 3. Figure 3 also shows when steam containing ^{3}H was injected into the flaring plume and when aerial and ground sampling was conducted by NERC-LV personnel. The primary radionuclides of concern were identified from previous surveillance programs for Project Gasbuggy to be ^{3}H and ^{85}Kr, of which a total of 48.93 Ci and 4.69 Ci, respectively, was released into the atmosphere during this production test.[7]

Aerial sampling detected concentrations of ^{3}H above background levels in the plume on each mission flown during the periods May 19-21 and July 25-26. The concentrations of ^{85}Kr in all air samples collected during flaring operations were considered to be at background levels (~17 pCi/m^3), except for one sample collected on May 19 which had a ^{85}Kr concentration of 21 ± 1.0 pCi/m^3. This concentration is less than 0.02% of the Concentration Guide for a suitable population sample in an uncontrolled area.[12] The highest concentration of ^{3}H detected in aircraft samples was 48 ± 3.6 pCi/m^3 of air in a sample collected on July 25 at an elevation of 2290 m (7500 ft), 1.8 km (2.8 mi) at 260° from the flare stack. This concentration is less than 0.07% of the Concentration Guide for continuous exposure to a suitable population sample in an uncontrolled area.[12]

Mobile monitors on the ground, who were positioned in the plume downwind of the stack by personnel in the aircraft, also collected atmospheric moisture samples containing ^{3}H above estimated background during each sampling period in May and July. The highest ^{3}H concentration in atmospheric moisture samples collected by mobile monitors on the ground was collected at Station 11, an unpopulated location, on July 25. This concentration, which was 300 pCi/m^3 of air, is less than 0.4% of the Concentration Guide for a suitable population sample in an uncontrolled area.[12]

Tritium concentrations above estimated background concentrations were found in some vegetation and soil collected during the July 25-26 surveillance operations and the November 6-8 post-flaring surveillance; no elevated ^{3}H concentrations were detected in these sample types during the May 19-21 surveillance. No surface water samples showed concentrations of ^{3}H above estimated background. The highest ^{3}H concentration in vegetation (26,000 pCi/l of H_2O) was measured in a sample collected at Station 20 on November 7, 2 km (1.2 mi) 333^{o} from the flare stack. The highest ^{3}H concentration in soil (1700 pCi/l H_2O) was measured in a sample collected at Station 10 on November 7, 0.5 km (0.3 mi) 102^{o} from the flare stack.

From the highest concentrations of ^{3}H which were measured in atmospheric moisture samples, it is concluded that any direct exposures to the off-site population were all below 0.4% of the Concentration Guide for this radionuclide. There are no concentration guides for ^{3}H in vegetation or soil. However, all vegetation samples were native, uncultivated shrubs, which are not used for human consumption or known to be of consideration in the food chain of area residents.

All concentrations of radionuclides detected should be considered as maximum since considerable effort was made to sample at times, places, and under atmospheric conditions when plume material was most likely to be on or near the surface at maximum concentrations. In addition, much of the sampling of atmospheric moisture was done when stored, tritiated water was being deliberately injected at higher than normal rates into the flare. References to exposures to a suitable population sample are more hypothetical than real, since all samples containing concentrations of ^{3}H above estimated background were collected at unpopulated locations.

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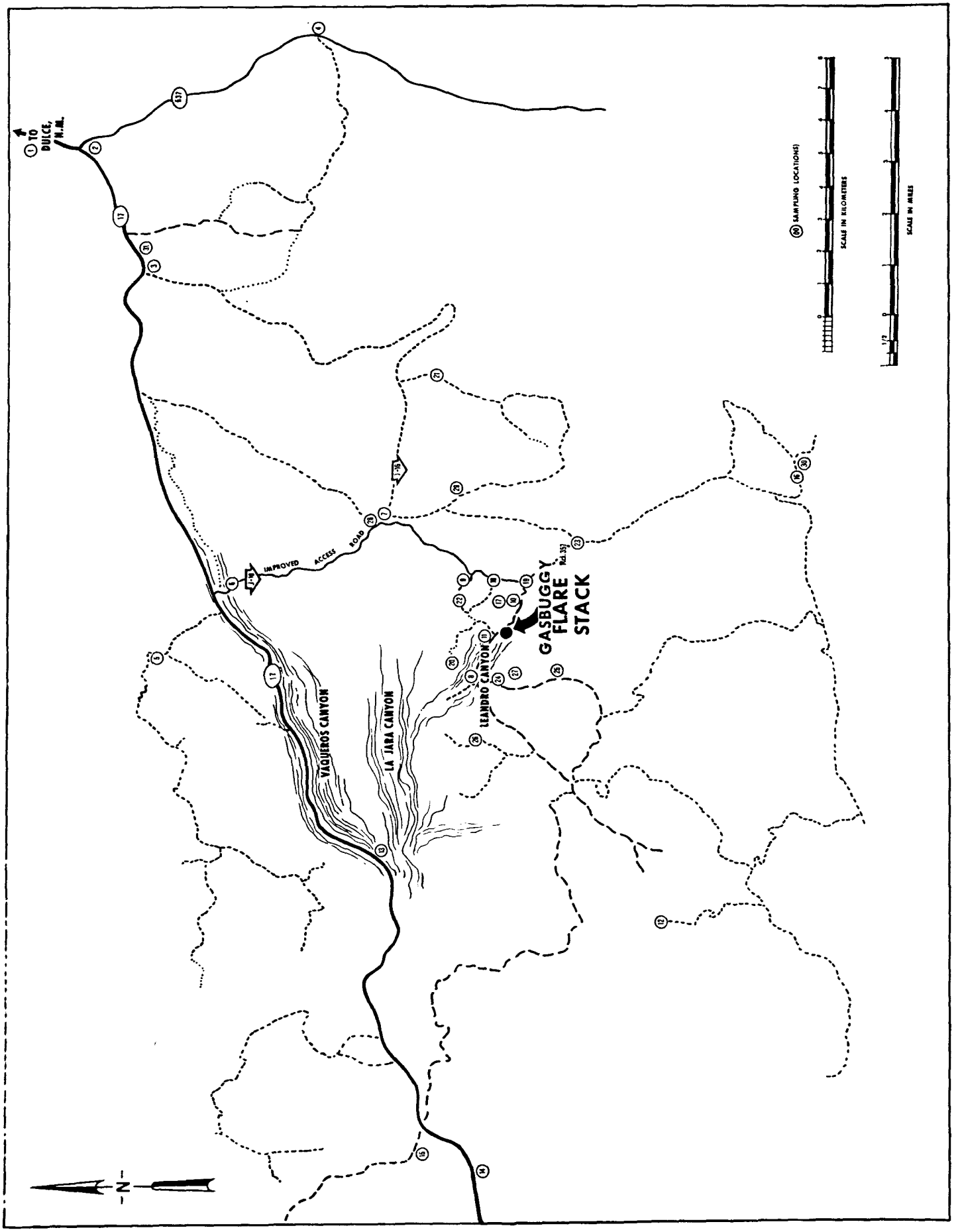

Figure 1. Gasbuggy Sampling Locations

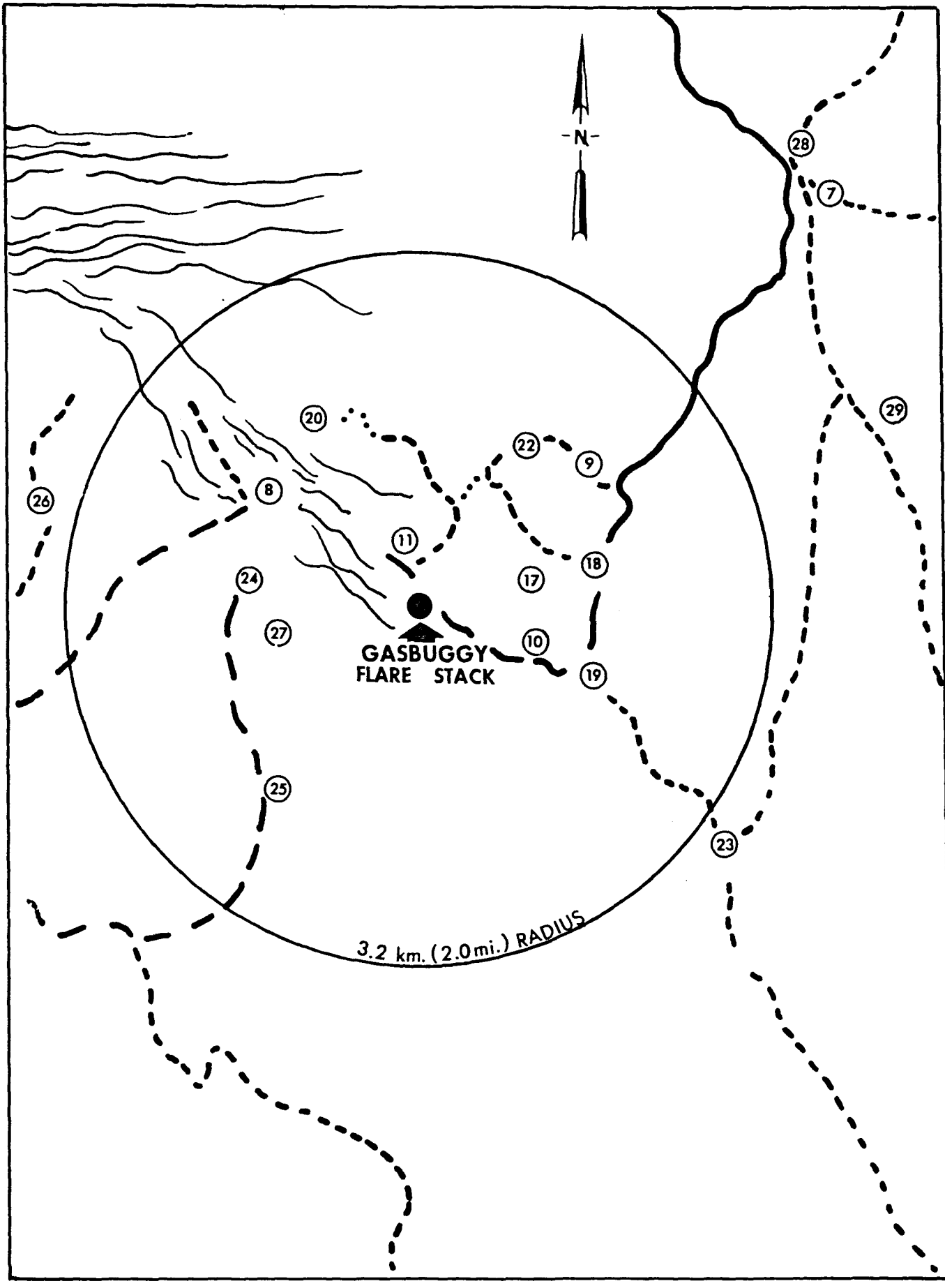

Figure 2. Close-In Gasbuggy Sampling Locations

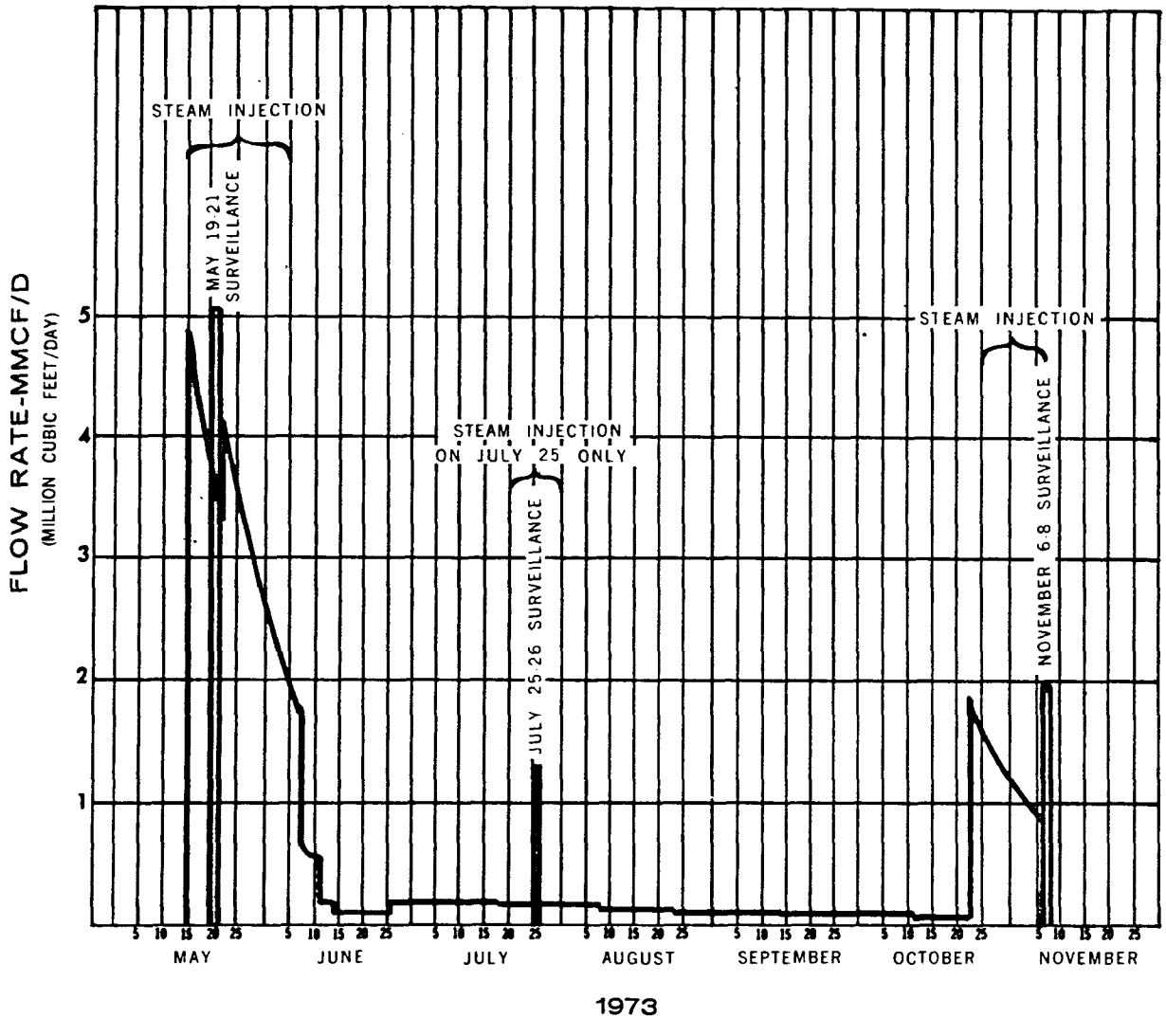

Figure 3. Variation of Natural Gas Flow Rate During Flaring Period

Table 1. Quantities[a] of Natural Gas Flared and Radioactivity Released During Project Gasbuggy Production Test May 15-November 6, 1973

Seven-Day Flaring Period Ending Midnight	Volume of Natural Gas Flared (MMCF)	^{85}Kr Released (Ci)	^{3}H Released in Gas (Ci)	^{3}H Released by Steam Injection into Flare (Ci)	(Dates)	Total ^{3}H Released (Ci)
5/21[b,c]	25.692	1.28	6.09	3.30	5/16,19,20,21	9.39
5/28	24.050	1.24	6.33	3.37	5/24,28	9.70
6/4	16.957	0.88	5.13	4.50	5/29,30, 6/1,3	9.63
6/7[c]	4.713	0.21	1.55	2.61	6/5,6	4.16
Totals for First Drawdown	71.412	3.61	19.10	13.78		32.88
6/13[c]	2.880	0.12	0.68	-		0.68
6/20	.731	0.02	0.10	-		0.10
6/27	.867	0.02	0.13	-		0.13
7/4	1.298	0.04	0.25	-		0.25
7/11	1.284	0.04	0.26	-		0.26
7/18	1.257	0.04	0.25	-		0.25
7/25[d]	1.105	0.03	0.22	0.90	7/25	1.12
8/1	1.054	0.03	0.21	-		0.21
8/8	1.034	0.03	0.21	-		0.21
8/15	.938	0.03	0.17	-		0.17
8/22	.937	0.03	0.17	-		0.17
8/29	.807	0.02	0.14	-		0.14

Table 1. Quantities[a] of Natural Gas Flared and Radioactivity Released During Project Gasbuggy Production Test May 15-November 6, 1973

Seven-Day Flaring Period Ending Midnight	Volume of Natural Gas Flared (MMCF)	^{85}Kr Released (Ci)	^{3}H Released in Gas (Ci)	^{3}H Released by Steam Injection into Flare (Ci)	(Dates)	Total ^{3}H Released (Ci)
9/5	.802	0.02	0.14	-		0.14
9/12	.809	0.02	0.14	-		0.14
9/19	.677	0.02	0.11	-		0.11
9/26	.574	0.01	0.10	-		0.10
10/3	.676	0.02	0.11	-		0.11
10/10	.654	0.01	0.10	-		0.10
10/17	.506	0.01	0.08	-		0.08
10/23[c]	.393	0.01	0.06	-		0.06
Totals for Steady Pressure Phase	19.283	0.57	3.63	0.90		4.53
10/29[c]	9.230	0.28	2.36	2.58	10/26,27,29	4.94
11/5	7.214	0.22	1.82	3.75	10/31,11/2,4,5	5.57
11/7[c,e]	.450	.01	.10	.91	11/6,7	1.01
Totals for Second Drawdown	16.894	0.51	4.28	7.24		11.52
Totals for Production Test	107.589	4.69	27.01	21.92		48.93

[a]All data supplied by El Paso Natural Gas Company. Gas flow measurements were made by El Paso Natural Gas Company. Radioactivity measurements were made by Eberline Instrument Corporation.

[b]Ground and aerial surveillance was conducted on May 19, 20, and 21, 1973.

[c]Represents flow for periods not seven full days long: 6.5 days, 2.5 days, 6.5 days, 5.5 days, 6.5 days, and 0.5 days respectively.

[d]Ground and aerial surveillance was conducted on July 25 and 26, 1973.

[e]Ground surveillance was conducted on November 6-8, 1973.

Table 2. Analytical Results of Pre-Flaring Water and Precipitation Samples Collected May 1973, for Project Gasbuggy Production Test

Station No.	Azimuth and Distance (°)	(km)[a]	Date/Time Collected	Source	^3H Concentration (pCi/1 H_2O)
30	151	10.5 (6.5)	5/3 1130	Pond	<240
27	269	1.3 (0.8)	5/5 1145	Pond	<240
10	102	0.5 (0.3)	5/6 0945	Snow	380± 250
11	341	0.5 (0.3)	5/6 1000	Snow	410± 240
29	71	4.8 (3.0)	5/6 1225	Pond	<240

a = Distance in miles is given in parentheses.

Table 3. Analytical Results of Pre-Flaring Atmospheric Moisture Samples Collected May 1973, for Project Gasbuggy Production Test

Station No.	Azimuth and Distance (°)	(km)[a]	Date/Time on Date/Time off		Volume (m^3)	Altitude Above MSL (m)[a]	^3H Concentration ($pCi/l\ H_2O$)	(pCi/m^3 air)
8	305	1.8	5/5	1415	6.43	2160	240±	1.2±
		(1.1)	5/5	1500		(7100)	240	1.2
10	102	0.5	5/5	1535	7.79	2190	<200	<0.1
		(0.3)	5/5	1620		(7200)		
11	341	0.5	5/5	1405	5.01	2190	240±	1.0±
		(0.3)	5/5	1450		(7200)	240	1.0
7	43	5.0	5/6	1135	8.10	2070	590±	2.5±
		(3.1)	5/6	1235		(6800)	240	1.0
9	53	2.1	5/6	1015	9.27	2130	650±	2.7±
		(1.3)	5/6	1115		(7000)	240	1.0
13	300	8.0	5/6	1040	5.04	1980	550±	2.3±
		(5.0)	5/6	1140		(6500)	240	1.0
15	280	17.9	5/6	1200	9.89	2010	460±	1.9±
		(11.1)	5/6	1300		(6600)	240	1.0
3	46	16.1	5/7	1140	8.64	2220	480±	2.1±
		(10.0)	5/7	1240		(7300)	240	1.0
5	356	10.9	5/7	1130	7.87	2190	330±	1.5±
		(6.8)	5/7	1240		(7200)	240	1.1
12	241	10.1	5/7	0930	8.47	2130		
		(6.3)	5/7	1030		(7000)	<200	<0.1

a = Altitude in feet above mean sea level (MSL) and distance in miles are given in parentheses.

Table 4. Analytical Results of Pre-Flaring Compressed Air Samples Collected May 1973, for Project Gasbuggy Production Test

Station No.	Azimuth and Distance (°)	(km)[a]	Date/Time on / Date/Time off	Volume (m^3)	Altitude Above MSL (m)	^{85}Kr (pCi/m^3 air)	Xe (pCi/m^3 air)
8	305	1.8 (1.1)	5/5 1050 / 5/5 1117	0.968	2160 (7100)	17± 1.0	<2.0
9	53	2.1 (1.3)	5/5 1235 / 5/5 1305			Samples lost in analyses	

a = Altitude in feet above mean sea level (MSL) and distance in miles are given in parentheses.

Table 5. Analytical Results of Pre-Flaring Vegetation Samples Collected May 1973, for Project Gasbuggy Production Test

Station No.	Azimuth and Distance (°)	(km)[a]	Date/Time Collected	Moisture Content (%)[b]	^3H Concentration (pCi/1 H_2O)	(pCi/kg veg.)
8	305	1.8 (1.1)	5/5 1115	51	<240	<120
9	53	2.1 (1.3)	5/5 1300	58	570± 250	330± 140
10	102	0.5 (0.3)	5/5 1530	62	1200± 260	740± 160
11	341	0.5 (0.3)	5/5 1315	59	530± 250	310± 150
6	10	9.3 (5.8)	5/6 1320	58	380± 260	220± 150
7	43	5.0 (3.1)	5/6 1150	71	500± 240	360± 170
13	300	8.0 (5.0)	5/6 1115	76	530± 260	400± 200
14	273	19.3 (12.0)	5/6 1345	66	440± 260	290± 170
15	280	17.9 (11.1)	5/6 1230	68	560± 260	380± 180
1	34	35.4 (22.0)	5/7 0940	70	570± 250	400± 180
2	49	20.6 (12.8)	5/7 1130	66	550± 260	360± 170
3	46	16.1 (10.0)	5/7 1220	62	490± 260	300± 160
4	73	20.1 (12.5)	5/7 1040	61	670± 250	410± 150
5	356	10.9 (6.8)	5/7 1215	66	720± 240	280± 160

Table 5. (continued) Analytical Results of Pre-Flaring Vegetation Samples Collected May 1973, for Project Gasbuggy Production Test

Station No.	Azimuth and Distance (°)	(km)[a]	Date/Time Collected	Moisture Content (%)[b]	^3H Concentration (pCi/l H_2O)	(pCi/kg veg.)
12	241	10.1 (6.3)	5/7 0945	68	480± 240	330± 160
16	154	10.5 (6.5)	5/8 1000	66	670± 250	440± 160
17	77	0.8 (0.5)	5/8 1000	63	610± 250	380± 160

a = Distance in miles is given in parentheses.

b = Based upon sample wet weight. All samples were native, uncultivated shrubs.

Table 6. Analytical Results of Pre-Flaring Soil Samples Collected May 1973, for Project Gasbuggy Production Test

Station No.	Azimuth and Distance (°)	(km)[a]	Date/Time Collected	Moisture Content (%)[b]	^3H Concentration (pCi/l H_2O)	(pCi/kg soil)
8	305	1.8 (1.1)	5/5 1100	20	360± 260	71± 51
9	53	2.1 (1.3)	5/5 1250	8.6	330± 240	28± 21
9[c]	53	2.1 (1.3)	5/5 1300	15	310± 260	50± 39
9[d]	53	2.1 (1.3)	5/5 1245	16	<260	<42
10	102	0.5 (0.3)	5/5 1530	6.1	400± 240	24± 15
11	341	0.5 (0.3)	5/5 1330	9.1	430± 240	39± 22
6	10	9.3 (5.8)	5/6 1305	14	<260	<36
7	43	5.0 (3.1)	5/6 1210	12	290± 240	35± 29
13	300	8.0 (5.0)	5/6 1100	13	340± 240	43± 30
14	273	19.3 (12.0)	5/6 1330	10	500± 240	51± 25
15	280	17.9 (11.1)	5/6 1215	21	<240	<50
1	34	35.4 (22.0)	5/7 0915	11	<240	<26
2	49	20.6 (12.8)	5/7 1110	14	410± 240	57± 34

Table 6. (continued) Analytical Results of Pre-Flaring Soil Samples Collected May 1973, for Project Gasbuggy Production Test

Station No.	Azimuth and Distance (°)	(km)[a]	Date/Time Collected	Moisture Content (%)[b]	^3H Concentration (pCi/1 H_2O)	(pCi/kg soil)
3	46	16.1 (10.0)	5/7 1200	19	330± 260	64± 50
4	73	20.1 (12.5)	5/7 1100	11	<240	<26
5	356	10.9 (6.8)	5/7 1200	6	360± 240	21± 14
12	241	10.1 (6.3)	5/7 0930	11	260± 240	28± 26
16	154	10.5 (6.5)	5/8 1015	8.5	<260	<22

a = Distance in miles is given in parentheses.
b = Based upon sample wet weight.
c = This sample was collected at a depth of 2.54 cm to 7.62 cm (1 to 3 in).
d = This sample was collected at a depth of 7.62 cm to 15.2 cm (3 to 6 in).

Table 7. Analytical Results of Aircraft Atmospheric Moisture Samples Collected May 1973, for Project Gasbuggy Production Test

Azimuth and Distance (°)	(km)[a]	Date/Time Collected	Volume (m^3)	Altitude Above MSL (m)[a]	^3H Concentration (pCi/l H_2O)	(pCi/m^3 air)
330	1.9 (1.2)	5/19 0905	0.605	2440 (8000)	2800± 340	24± 2.9
95	3.5 (2.2)	5/19 1002	0.785	2320 (7600)	1400± 270	11± 2.1
110	1.6 (1.0)	5/19 1423	0.786	2590 (8500)	690± 340	5.7± 2.8
110	1.6 (1.0)	5/20 0925	0.787	2590 (8500)	2500± 280	12± 2.7
75	8.0 (5.0)	5/20 1040	0.490	2740 (9000)	860± 290	9.5± 3.2
330	2.3 (1.4)	5/21 0800	0.714	2320 (7600)	1300± 270	12± 2.4
145	3.3 (2.0)	5/21 1025	0.792	3050 (10,000)	910± 260	6.3± 1.8

a = Distance in miles and altitude in feet above mean sea level (MSL) are shown in parentheses.

Table 8. Analytical Results of Aircraft Compressed Air Samples Collected May 1973, for Project Gasbuggy Production Test

Azimuth and Distance (°)	(km)[a]	Date/Time Collected	Volume (m^3)	Altitude Above MSL (m)	^{85}Kr Concentration (pCi/m^3 air)
330	1.9 (1.2)	5/19 0905	0.605	2440 (8000)	21± 1.0
95	3.5 (2.2)	5/19 1002	0.785	2320 (7600)	16± 1.1
110	1.6 (1.0)	5/19 1423	0.786	2590 (8500)	17± 1.1
110	1.6 (1.0)	5/20 0925	0.787	2590 (8500)	18± 1.1
75	8.0 (5.0)	5/20 1040	0.490	2740 (9000)	16± 1.0
330	2.3 (1.4)	5/21 0800	0.714	2320 (7600)	14± 1.0
145	3.2 (2.0)	5/21 1025	0.792	3050 (10,000)	12± 1.0

a = Altitude in feet above mean sea level (MSL) and distance in miles are given in parentheses.

Table 9. Analytical Results of Water Samples Collected May 1973, for Project Gasbuggy Production Test

Station No.	Azimuth and Distance (°)	(km)[a]	Date/Time Collected	Source	^{3}H Concentration (pCi/l H_2O)
27	269	1.2 (0.8)	5/20 0905	Pond	350± 250
28	40	5.2 (3.3)	5/21 1315	Pond	320± 250
29	71	4.8 (3.0)	5/21 1300	Pond	440± 250
30	151	10.4 (6.5)	5/21 1135	Pond	470± 250
31	47	16.1 (10.0)	5/21 0645	Pond	330± 250

a = Distance in miles is given in parentheses.

Table 10. Analytical Results of Atmospheric Moisture Samples Collected May 1973, on the Ground for Project Gasbuggy Production Test

Station No.	Azimuth and Distance (°)	(km)[a]	Date/Time on / Date/Time off	Volume (m^3)	Altitude Above MSL (m)[a]	^3H Concentration (pCi/1 H_2O)	(pCi/m^3 air)
18	77	1.4	5/19 1445	6.66	2160	4100±	14±
		(0.9)	5/19 1545		(7100)	310	1.1
19	110	1.6	5/19 1445	9.58	2130	1000±	3.3±
		(1.0)	5/19 1545		(7000)	260	0.86
11	341	0.5	5/20 0900	6.66	2190	1500±	8.7±
		(0.3)	5/20 1000		(7200)	260	1.5
20	333	2.0	5/20 0905	7.85	2290	540±	3.0±
		(1.3)	5/20 1005		(7500)	240	1.3
8	305	1.7	5/20 0920	6.49	2160	570±	3.2±
		(1.1)	5/20 1020		(7100)	240	1.3
18	77	1.4	5/20 0940	7.25	2160	2900±	15±
		(0.9)	5/20 1032		(7100)	290	1.5
19	110	1.6	5/20 0942	7.42	2130	880±	4.1±
		(1.0)	5/20 1044		(7000)	240	1.1
21	75	8.2	5/20 1020	8.84	2160	370±	1.8±
		(5.1)	5/20 1150		(7100)	230	1.2
9	53	2.0	5/20 1045	6.97	2130	300±	1.4±
		(1.3)	5/20 1145		(7000)	240	1.1
11	341	0.5	5/21 0715	4.14	2190	510±	3.1±
		(0.3)	5/21 0755		(7200)	240	1.4
20	333	2.0	5/21 0715	8.16	2290	630±	3.3±
		(1.3)	5/21 0815		(7500)	240	1.2
8	305	1.7	5/21 0725	5.86	2160	320±	1.8±
		(1.1)	5/21 0840		(7100)	240	1.3
11	341	0.5	5/21 0800	5.69	2190	450±	2.5±
		(0.3)	5/21 0900		(7200)	250	1.4

Table 10. (continued) Analytical Results of Atmospheric Moisture Samples Collected May 1973, on the Ground for Project Gasbuggy Production Test

Station No.	Azimuth and Distance (°)	(km)[a]	Date/Time on Date/Time off	Volume (m^3)	Altitude Above MSL (m)[a]	^3H Concentration (pCi/l H_2O)	(pCi/m^3 air)
18	77	1.4	5/21 0825	8.72	2160	810±	4.3±
		(0.9)	5/21 0925		(7100)	260	1.4
22	31	1.6	5/21 0832	5.75	2130	1100±	6.1%
		(1.0)	5/21 0924		(7000)	600	3.3
23	126	3.5	5/21 1004	7.72	2230	320±	1.2±
		(2.2)	5/21 1105		(7300)	230	0.87

a = Altitude in feet above mean sea level (MSL) and distance in miles are given in parentheses.

Table 11. Analytical Results of Vegetation Samples Collected May 1973, for Project Gasbuggy Production Test

Station No.	Azimuth and Distance (°)	(km)[a]	Date/Time Collected		Moisture Content (%)[b]	^3H Concentration (pCi/l H_2O)	(pCi/kg veg.)
18	77	1.4 (0.9)	5/19	1520	56	880± 260	490± 150
19	110	1.6 (1.0)	5/19	1500	56	700± 240	390± 130
8	305	1.7 (1.1)	5/20	1315	62	500± 250	310± 160
9	53	2.0 (1.3)	5/20	1105	63	650± 240	410± 150
11	341	0.5 (0.3)	5/20	0945	58	650± 250	370± 140
18	77	1.4 (0.9)	5/20	1010	66	1200± 260	790± 170
19	110	1.6 (1.0)	5/20	1110	63	590± 240	370± 150
20	333	2.0 (1.3)	5/20	1000	72	260± 250	190± 180
21	75	8.2 (5.1)	5/20	1100	67	740± 260	500± 170
17	241	10.0 (6.3)	5/21	1240	69	570± 250	390± 170
22	31	1.6 (1.0)	5/21	0910	73	590± 250	430± 180
23	126	3.5 (2.2)	5/21	1030	60	440± 250	260± 150

a = Distance in miles is given in parentheses.
b = Based upon sample wet weight. All samples were native, uncultivated shrubs.

Table 12. Analytical Results of Soil Samples Collected May 1973, for Project Gasbuggy Production Test

Station No.	Azimuth and Distance (°)	(km)[a]	Date/Time Collected	Moisture Content (%)[b]	^3H Concentration (pCi/1 H_2O)	(pCi/kg soil)
18	177	1.4 (1.9)	5/19 1500	1.2	850± 260	10± 3.1
19	110	1.6 (1.0)	5/19 1515	2.8	580± 240	16± 6.8
8	305	1.7 (1.1)	5/20 1325	4.3	<230	<9.9
9	53	2.0 (1.3)	5/20 1120	0.88	430± 230	3.8± 2.0
11	341	0.5 (0.3)	5/20 1005	2.0	430± 230	8.6± 4.6
18	77	1.4 (1.9)	5/20 1000	2.5	770± 240	19± 6.0
19	110	1.6 (1.0)	5/20 1110	5.8	510± 240	29± 14
20	333	2.0 (1.3)	5/20 1020	3.7	470± 240	17± 8.9
21	75	8.2 (5.1)	5/20 1100	0.92	360± 230	3.3± 2.1
22	31	1.6 (1.0)	5/21 0915	4.8	460± 230	22± 11
23	126	3.5 (2.2)	5/21 1030	1.7	530± 240	91± 4.1

a = Distance in miles is given in parentheses.
b = Based upon sample wet weight.

c = This sample was collected at a depth of 2.54 cm to 7.62 cm (1 to 3 in).
d = This sample was collected at a depth of 7.62 cm to 15.2 cm (3 to 6 in).

Table 13. Analytical Results of Aircraft Atmospheric Moisture Samples Collected July 1973, for Project Gasbuggy Production Test

Azimuth and Distance (°)	(km)[a]	Date/Time Collected	Volume (m^3)	Altitude Above MSL (m)[a]	^3H Concentration (pCi/l H_2O)	(pCi/m^3 air)
260	1.8 (1.1)	7/25 0746	0.798	2260 (7400)	4000± 300	48± 3.6
300	8.0 (5.0)	7/25 0839	0.779	2170 (6800)	1500± 270	15± 2.7
290	8.0 (5.0)	7/25 0931	0.781	2010 (6600)	2000± 270	19± 2.5
260-300	1.8 (1.1)	7/26 0817	0.696	2440 (8000)	990± 260	13± 3.4
270-300	1.3 (0.8)	7/26 0846	0.851	2320 (7600)	760± 240	11± 3.4
320	8.0 (5.0)	7/26 0913	0.848	2320 (7600)	760± 240	9.9± 3.1

a = Altitude in feet above mean sea level (MSL) and distance in miles is given in parentheses.

Table 14. Analytical Results of Aircraft Compressed Air Samples Collected July 1973, for Project Gasbuggy Production Test

Azimuth and Distance (°)	(km)[a]	Date/Time Collected	Volume (m^3)	Altitude Above MSL (m)	^{85}Kr Concentration (pCi/m^3 air)
260	1.8 (1.1)	7/25 0746	0.798	2260 (7400)	13± 0.70
300	8.0 (5.0)	7/25 0839	0.779	2170 (6800)	17± 1.4
290	8.0 (5.0)	7/25 0931	0.781	2010 (6600)	13± 0.70
260-300	1.8 (1.1)	7/26 0817	0.696	2440 (8000)	16± 1.0
270-300	1.3 (0.8)	7/26 0846	0.851	2320 (7600)	13± 1.1
320	8.0 (5.0)	7/26 0913	0.848	2320 (7600)	17± 0.70

a = Altitude in feet above mean sea level (MSL) and distance in miles are given in parentheses.

Table 15. Analytical Results of Atmospheric Moisture Samples Collected July 1973, on the Ground for Project Gasbuggy Production Test

Station No.	Azimuth and Distance (°)	(km)[a]	Date/Time on Date/Time off	Volume (m^3)	Altitude Above MSL (m)[a]	^3H Concentration (pCi/l H_2O)	(pCi/m^3 air)
8	305	1.7 (1.1)	7/25 0736 7/25 0841	6.86	2160 (7100)	6900± 330	33± 1.6
24	282	1.8 (1.1)	7/25 0740 7/25 0840	7.22	2160 (7100)	3900± 280	21± 1.5
25	220	1.9 (1.2)	7/25 0811 7/25 0911	7.45	2160 (7100)	4600± 290	26± 1.7
11	341	0.5 (0.3)	7/25 0855 7/25 0940	6.23	2190 (7200)	49,000± 630	300± 3.9
13	300	8.0 (5.0)	7/25 0902 7/25 1006	7.08	1980 (6500)	1400± 250	8.8± 1.6
13	300	8.0 (5.0)	7/26 0625 7/26 0725	6.15	1980 (6500)	<230	<1.7
8	305	1.7 (1.1)	7/26 0717 7/26 0817	7.87	2160 (7100)	260± 230	1.8± 1.6
24	282	1.8 (1.1)	7/26 0809 7/26 0909	8.87	2160 (7100)	270± 230	2.0± 1.7
26	285	3.5 (2.2)	7/26 0815 7/26 0915	9.38	2260 (7400)	<250	<1.8
20	333	2.0 (1.6)	7/26 0920 7/26 1020	9.24	2290 (7500)	400± 230	2.7± 1.5

a = Altitude in feet above mean sea level (MSL) and distance in miles is given in parentheses.

Table 16. Analytical Results of Water Samples Collected July 1973, for Project Gasbuggy Production Test

Station No.	Azimuth and Distance (°)	(km)[a]	Date/Time Collected	Source	^{3}H Concentration (pCi/l H_2O)
30	154	10.4 (6.5)	7/25 1230	Pond	410± 230
27	269	1.2 (0.8)	7/26 0700	Pond	450± 230
28	40	5.2 (3.3)	7/26 0800	Pond	<240
31	47	16.1 (10.0)	7/26 0700	Pond	400± 230

a = Distance in miles is given in parentheses.

Table 17. Analytical Results of Vegetation Samples Collected July 1973, for Project Gasbuggy Production Test

Station No.	Azimuth and Distance (°)	(km)[a]	Date/Time Collected	Moisture Content (%)[b]	^3H Concentration (pCi/l H_2O)	(pCi/kg veg.)
8	305	1.7 (1.1)	7/25 1015	58	920± 240	530± 140
11	341	0.5 (0.3)	7/25 1000	60	22,000± 460	13,000± 280
13	300	8.0 (5.0)	7/25 1030	58	480± 250	280± 150
24	282	1.8 (1.1)	7/25 1010	66	390± 240	260± 160
25	220	1.9 (1.2)	7/25 0945	55	680± 240	370± 160
9	53	2.0 (1.3)	7/26 1120	56	660± 240	370± 130
17	77	0.8 (0.5)	7/26 0715	57	760± 260	430± 150
18	77	1.4 (0.9)	7/26 1100	63	480± 250	300± 160
19	110	1.6 (1.0)	7/26 0830	66	360± 250	240± 170
20	333	2.0 (1.3)	7/26 0945	52	440± 240	230± 120
23	126	3.5 (2.2)	7/26 1005	52	530± 240	280± 120

a = Distance in miles is given in parentheses.

b = Based upon sample wet weight. All samples were native, uncultivated shrubs.

Table 18. Analytical Results of Soil Samples Collected July 1973, for Project Gasbuggy Production Test

Station No.	Azimuth and Distance (°)	(km)[a]	Date/Time Collected	Moisture Content (%)[b]	^3H Concentration (pCi/l H_2O)	(pCi/kg soil)
8	305	1.7 (1.1)	7/25 1010	1.6	540± 240	8.6± 3.8
11	341	0.5 (0.3)	7/25 0945	1.2	5800± 310	70± 3.7
13	300	8.0 (5.0)	7/25 1045	1.7	370± 230	6.3± 3.9
24	282	1.8 (1.1)	7/25 1020	1.2	910± 240	11± 2.9
25	220	1.9 (1.2)	7/25 1000	1.8	520± 240	9.4± 4.3
9	53	2.0 (1.3)	7/26 0745	1.3	270± 230	3.5± 3.0
9[b]	53	2.0 (1.3)	7/26 1100	4.8	300± 230	14± 11
9[c]	53	19.8 (12.5)	7/26 1120	5.7	230± 230	13± 13
18	77	1.4 (0.9)	7/26 1105	1.3	380± 230	4.9± 3.0
19	110	1.6 (1.0)	7/26 0830	1.2	350± 230	4.2± 2.8
20	333	2.0 (1.3)	7/26 1000	1.2	370± 230	4.4± 2.8
23	126	3.5 (2.2)	7/26 1015	1.7	310± 230	5.3± 3.9
26	285	3.5 (2.2)	7/26 0830	1.5	380± 230	5.7± 3.5

a = Distance in miles is given in parentheses.
b = Based upon sample wet weight. All samples were native, uncultivated shrubs.
c = This sample was collected at a depth of 2.54 cm to 7.62 cm (1 to 3 in).
d = This sample was collected at a depth of 7.62 cm to 15.2 cm (3 to 6 in).

Table 19. Analytical Results of Compressed Air Samples Collected July 1973, on the Ground for Project Gasbuggy Production Test

Station No.	Azimuth and Distance (°)	(km)[a]	Date/Time on Date/Time off	Volume (m^3)	^{85}Kr (pCi/m^3 air)	Xe (pCi/m^3 air)
24	282	1.8 (1.1)	7/25 0739 7/25 0805	0.944	15± 0.7	<2.0
24	282	1.8 (1.1)	7/26 0755 7/26 0826	0.933	14± 0.6	<2.0

a = Distance in miles is given in parentheses.

Table 20. Analytical Results of Post-Flaring Water Samples Collected November 1973, for Project Gasbuggy Production Test

Station No.	Azimuth and Distance (°)	(km)[a]	Date/Time Collected	Source	^3H Concentration (pCi/1 H_2O)
27	269	1.2 (0.8)	11/6 1600	Pond	380± 240
28	40	5.2 (3.3)	11/6 1415	Pond	<240
29	71	4.8 (3.0)	11/7 1245	Pond	<240

a = Distance in miles is given in parentheses.

Table 21. Analytical Results of Post-Flaring Vegetation Samples Collected November 1973, for Project Gasbuggy Production Test

Station No.	Azimuth and Distance (°)	(km)[a]	Date/Time Collected		Moisture Content (%)[b]	^3H Concentration (pCi/l H_2O)	(pCi/kg veg.)
1	34	35.4 (22.0)	11/6	1115	58	680± 270	390± 160
2	49	20.4 (12.8)	11/6	1230	48	530± 260	260± 120
3	46	16.1 (10.0)	11/6	1000	43	1400± 390	600± 170
4	73	19.8 (12.5)	11/6	1330	51	860± 270	440± 140
5	356	10.8 (6.8)	11/6	1145	38	320± 260	120± 99
12	241	10.0 (6.3)	11/6	1015	38	3600± 430	1400± 160
14	273	19.3 (12.0)	11/6	0915	41	330± 260	140± 110
15	280	17.7 (11.1)	11/6	1100	33	1400± 390	470± 130
25	220	1.9 (1.2)	11/6	1545	42	570± 260	240± 110
7	43	4.9 (3.1)	11/7	1000	38	910± 260	350± 99
10	102	0.5 (0.3)	11/7	0845	20	1400± 270	280± 54
16	154	10.4 (6.5)	11/7	1330	48	400± 260	190± 120
17	77	0.8 (0.5)	11/7	1600	41	2100± 280	850± 110
20	333	2.0 (1.3)	11/7	1440	49	26,000± 720	12,400± 350

Table 21. (continued) Analytical Results of Post-Flaring Vegetation Samples Collected November 1973, for Project Gasbuggy Production Test

Station No.	Azimuth and Distance (°)	(km)[a]	Date/Time Collected	Moisture Content (%)[b]	^3H Concentration (pCi/l H_2O)	(pCi/kg veg.)
21	75	8.2 (5.1)	11/7 1045	27	5500± 330	1500± 890
23	126	3.5 (2.2)	11/7 1200	56	1200± 380	690± 220
6	10	9.2 (5.8)	11/8 1000	44	740± 370	330± 160
8	305	1.7 (1.1)	11/8 1100	41	440± 260	180± 110
9	50	2.7 (1.3)	11/8 0915	25	700± 270	180± 68
11	341	0.5 (0.3)	11/8 1130	32	<260	<830
13	300	8.0 (5.0)	11/8 0845	50	1700± 390	830± 190
18	77	1.4 (0.9)	11/8 1045	44	600± 260	260± 110
23	110	1.6 (1.0)	11/8 1130	36	<260	<94
22	31	1.6 (1.0)	11/8 1215	24	1800± 400	440± 95
24	282	1.8 (1.1)	11/8 1015	44	400± 260	180± 110

a = Distance in miles is given in parentheses.

b = Based upon sample wet weight. All samples were native, uncultivated shrubs.

Table 22. Analytical Results of Post-Flaring Soil Samples Collected November 1973, for Project Gasbuggy Production Test

Station No.	Azimuth and Distance (°)	(km)[a]	Date/Time Collected	Moisture Content (%)[b]	^3H Concentration (pCi/l H_2O)	(pCi/kg soil)
1	34	35.4 (22.0)	11/6 1130	2.1	<240	<5.1
2	49	20.4 (12.8)	11/6 1245	4.4	280± 240	12± 11
3	46	16.1 (10.0)	11/6 1020	4.1	<240	<9.8
4	73	19.8 (12.5)	11/6 1400	3.2	340± 240	11± 7.7
5	356	10.8 (6.8)	11/6 1145	1.3	<230	<3.0
12	241	10.0 (6.3)	11/6 1015	2.2	260± 240	5.9± 5.3
14	273	19.3 (12.0)	11/6 0915	1.2	<230	<2.8
15	280	17.7 (11.1)	11/6 1100	2.0	240± 240	4.8± 4.8
25	220	1.9 (1.2)	11/6 1545	4.2	<240	<11
26	285	3.5 (2.2)	11/6 1515	3.1	260± 240	8.4± 7.4
7	43	4.9 (3.1)	11/7 1000	1.6	390± 240	6.1± 1.6
10	102	0.5 (0.3)	11/7 0945	5.8	1700± 260	99± 15
16	154	10.4 (6.5)	11/7 1330	3.0	350± 240	11± 7.2

Table 22. (continued) Analytical Results of Post-Flaring Soil Samples Collected November 1973, for Project Gasbuggy Production Test

Station No.	Azimuth and Distance (°)	(km)[a]	Date/Time Collected	Moisture Content (%)[b]	^3H Concentration (pCi/l H_2O)	(pCi/kg soil)
20	333	2.0 (1.3)	11/7 1500	4.0	250± 240	1.0± 1.0
21	75	8.2 (5.1)	11/7 1100	1.9	350± 240	6.6± 4.6
23	126	3.5 (2.2)	11/7 1200	1.9	<240	<4.6
6	10	9.2 (5.8)	11/8 0945	1.6	280± 240	4.5± 3.8
8	305	1.7 (1.1)	11/8 1100	2.8	470± 240	13± 6.7
9	53	2.0 (1.3)	11/8 0915	2.0	310± 240	6.1± 4.8
9[c]	53	2.0 (1.3)	11/8 0915	5.4	510± 240	27± 13
9[d]	53	2.0 (1.3)	11/8 0915	9.5	370± 240	35± 23
11	341	0.5 (0.3)	11/8 1130	2.3	<240	<5.5
13	300	8.0 (5.0)	11/8 0915	5.3	<240	<13
18	77	1.4 (0.9)	11/8 1100	1.9	530± 250	10± 4.8
19	110	1.6 (1.0)	11/8 1145	1.6	260± 240	4.1± 3.8
22	31	1.6 (1.0)	11/8 1200	2.4	<240	<5.8
24	282	1.8 (1.1)	11/8 1015	1.8	340± 240	6.2± 4.3

a = Distance in miles is given in parentheses.

b = Based upon sample wet weight.

c = This sample was collected at a depth of 2.54 cm to 7.62 cm (1 to 3 in).

d = This sample was collected at a depth of 7.62 cm to 15.2 cm (3 to 6 in).

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