SLAC-218

ANNUAL ENVIRONMENTAL MONITORING REPORT

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HEALTH PHYSICS STAFF

PLANT ENGINEERING DEPARTMENT

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INTRODUCTION

The Stanford Linear Accelerator Center (SLAC) is located two miles west of the Stanford campus in San Mateo County, California. Its boundaries include Sand Hill Road on the north, and San Francisquito Creek on the south. The land slopes to the south toward San Francisquito Creek. The total length of the accelerator and experimental areas is approximately three miles, and is oriented almost east-west. Figures 1 and 2 locate SLAC with respect to the surrounding vicinity.

SLAC is a large research laboratory devoted th theoretical and experimental research in high energy physics and to the development of new techniques in high energy accelerator particle detectors. The main tool of the laboratory is a two mile long linear accelerator. This accelerator produces beams of electrons with energies up to 22 billion electron volts (22 GeV). It can also accelerate positrons, the "antiparticles" of the electrons, up to 15 GeV. The work is carried out under the sponsorship and financial support of the Department of Energy.

Authorization of the project was given by the U. S. Congress in 1961. Construction of the accelerator started in 1962, and was completed in 1966. Research consisting of numerous and varied experiments has been under way since late 1966.

Summary

Environmental monitoring results continue to demonstrate that, except for penetrating radiation, environmental radiological impact due to SLAC operation is not distinguishable from natural environmental sources. During 1978, the maximum neutron dose near the site boundary

was 6.6 mrem. This represents about 6.6% of the annual dose from natural sources at this elevation, and 1.3% of the technical standard of 500 mrem per person annually.[1] Results appear in Table 2.

There have been no measurable increases in radioactivity in ground water attributable to SLAC operations since 1966. Because of major new construction, well water samples were not collected and analyzed during 1978. Construction activities have also temporarily placed our sampling stations for the sanitary and storm sewers out of service. They will be re-established as soon as construction activities permit.

Airborne radioactivity released from SLAC continues to make only a negligible environmental impact, and results in a site boundary annual dose of less than 0.01 mrem; this represents less than 0.01% of the annual dose from the natural radiation environment, and about 0.002% of the technical standard.

MONITORING TECHNIQUES AND STANDARDS

Concentration Guides for Liquid Effluent

Because of the nature of the radionuclides produced at SLAC, the appropriate Concentration Guide (CG) for liquid effluents is $3 \times 10^{-6}\mu Ci/m\ell$. This is true because the following isotopes are not produced at SLAC:

^{90}Sr, ^{125}I, ^{126}I, ^{129}I, ^{210}Pb, ^{210}Po, ^{211}At, ^{223}Ra, ^{224}Ra,

^{226}Ra, ^{227}Ac, ^{228}Ra, ^{230}Th, ^{231}Pa, ^{232}Th, ^{248}Cm, ^{254}Cf, ^{256}Fm,

natural thorium.[1]

Concentration Guides for Airborne Radioactivity

The Concentration Guides (CGs) for airborne radioactivity appear in Reference 1. They were derived from dose standards which require that no individual in the general population be exposed to greater than 500 mrem in one year.

Airborne radioactivity produced as the result of operations is short-lived; i.e., the half-lives range from two minutes to one and eight tenths hours, and are in gaseous (not particulate) form. These isotopes include the following

TABLE 1

GASEOUS RADIOACTIVITY RELEASED TO ATMOSPHERE

Isotope	Half-Life	CG μCi / mℓ
^{15}O	2.1 minutes	5 10^{-8}(a)
^{13}N	9.9 minutes	5 10^{-8}(a)
^{11}C	20.5 minutes	5 10^{-8}(a)
^{41}Ar	1.8 hours	4 10^{-8}

(a) Calculated from Reference 3, assuming total submersion.

Since we do not routinely release airborne radioactivity while the beam is on, and require a waiting period before turning on the exhaustors, the only radioisotope released is ^{41}Ar. By far the greater proportion of exposure an individual may receive, under any circumstances, from the radioelements listed in Table 1 is from whole body immersion. Thus, for an individual to receive a whole body dose of 500 mrem annually requires a continuous exposure to a large cloud of ^{41}Ar whose average concentration equals $4 \times 10^{-8}\mu Ci/cm^3 (Ci/m^3)$ for an entire year.

Analysis Techniques for Airborne Radioactivity

The accelerator and beam switchyard (BSY) areas are vented by 20 fans: the discharge point is just slightly above roof elevation. The total exhaust rate for the accelerator is 60 m^3/s, and the BSY is 40 m^3/s. The accelerator and BSY are not normally vented while the electron beam is on. If personnel entry has to be made during an operating cycle, the area is vented for 10 minutes prior to entry and after the electron beam has been shut off. The release of radioactivity is, therefore, infrequent, and only for brief periods of from 30-60 munutes. The accelerator does not represent a measurable source of gaseous or particulate radioactivity due to low activating potential.

Each BSY ventilation fan is interlocked with a radioactive gas detector comprised of a Geiger-Mueller detector, power supply, rate meter, strip chart recorder and air pump. The electronics are in continuous operation, and the recorder and air pump are interlocked with the ventilation fan so that they operate only when the machine is being vented.

The gas monitors for the BSY collect particulate samples during venting and have revealed negative results. During this period, no particulate radioactivity above background was detected. This agrees with previous "grab" samples collected in the exhaust stream.

Penetrating Radiation Monitoring Techniques

Seven Peripheral Monitoring Stations (PMS) have provided continuously recorded data concerning radiation levels (γ and n) near SLAC boundaries. Their positions are located in Figures 3 and 4.

Radiation information is obtained with a Geiger tube for gamma detection, and a paraffin-moderated BF_3 neutron detector calibrated with a Pu-Be neutron source. The resultant sensitivities are such that a γ flux from ^{60}Co exposed to an average value of 1 mR/hr for one hour will be recorded as $\sim 10^4$ counts on the Geiger tube channel, and a neutron flux having an average value for one hour of 1 mrem/hr will be recorded as $\sim 10^5$ counts on the BF_3 channel. The hourly printout cycle of the Sodeco register is programmed by two clock motors with cam actuated switches and associated electronic circuitry. This programmer automatically interrupts data acquisition, generates a print command, resets the digits in parallel, and reverts to the normal condition of serial counting of incoming data pulses. Dead time per printout cycle is less than 20 seconds per hour.

In connection with the pulse pair resolution limitation of the Sodeco register mentioned above, an important feature of this system involves the pulser which drives the register. It is of the nonparalyzable type. This means that if the instantaneous counting rate (20 counts/sec) is ever exceeded, the register will merely not count the pulses in excess of its maximum rate. It can count at this maximum rate continuously (72,000 counts/hr).

MONITORING RESULTS

Penetrating Radiation Monitoring

The measured annual dose to the general population from accelerator operations is almost entirely from fast neutrons and is characterized as skyshine from SLAC's research area. Estimates of individual and general population whole body dose can be calculated from the PMS data, based on estimates of distance and population density near SLAC. During 1978 only two stations were operated due to construction activities. PMS-5 is located at the most sensitive location. Historically this station has always been used to calculate population dose since it records the maximum dose at our site boundary.

From this population estimate and the measured radiation dose near the site boundary, we can estimate both the average individual dose and the population dose from SLAC operations. From 1974 data, we arrive at a population of 2040 persons who are included in the pool exposed to 1 mrem or more for the calendar year 1978. The man-rem dose was 3.1, and the average individual dose was 1.5 mrem, or approximately 1.5% increase over the average dose from natural background radiation (100 mrem/y).

Monitoring for Airborne Radioactivity

During 1977, 0.36 Ci of short-lived gaseous radioactivity was released into the atmosphere from SLAC. Particulate samplers continue to demonstrate that radioactivity in this form is not released from SLAC. When corrected for dilution, this resulted in an average off-site concentration of 0.5×10^{-11} Ci/m^3. This concentration is compared to the CG for ^{41}Ar, which is 4×10^{-8} Ci/m^3.

We emphasize that the model used to calculate off-site concentration applies to the plume centerline, and is not corrected for vertical and horizontal plume spread. Also, the model is not corrected for wind direction or velocity. The estimate of off-site concentration is, therefore, conservative and overestimates the actual concentration at the site boundary by factors of 2-10.

NONRADIOACTIVE EFFLUENT

Waste Water

Waste water from SLAC is discharged in basically three directions:

(1) Sanitary sewer.

(2) Storm sewer effluent is released to natural open ditches. The ditches conduct this water to San Francisquito Creek by surface flow or by seepage. Both these liquid effluents (1) and (2) eventually reach San Francisco Bay, about six miles to the east.

(3) About 40% of the water leaves the site as water vapor via the four cooling towers.

Typical amounts are 7.6×10^4 m^3/year to the sanitary sewer; 1.5×10^5 m^3/year to the creek and 1.5×10^5 m^3/year evaporated. In addition, an average of 9×10^5 m^3/year fall as rain on the 472 acre site, also flowing to the creek. Thus, the SLAC effluent to the creek is diluted by an average factor of 6 by natural runoff.

Two continuous sampling stations monitor the effluents of both the sanitary sewer and the storm sewer and have been in operation since the summer of 1971. The sanitary sewer sampling station is at Manhole No. 4, northeast of the Central Laboratory. All SLAC sanitary sewage flows through this point. A pump continuously samples the effluent at the rate of 5 m per minute, which is stored in drums at that point. At the end of each quarter, the contents of the drums are mixed, and 1 liter samples are removed for chemical-radiological analysis. Because of heavy construction these stations were inoperative during 1978.

It should be noted that the sampling rate is constant at all times regardless of the flow rate, and thus tends to give relatively greater weight to the effluent at lower flow rates when concentrations are likely to be higher. Therefore, this method of sampling is likely to lead to an overestimate thather than an underestimate of concentration.

Sanitary Sewer Effluents

About 20% of SLAC's domestic water supply is released to the sanitary sewer; the remaining 80% leaves the site by evaporation or via San Francisquito Creek. The sanitary sewer outlet at the northeast corner of the site is connected to the Menlo Park Sanitary District. The releases are ordinary sanitary wastes, and the Menlo Park treatment plant discharges its treated wastes directly into San Francisco Bay.

The quantity of discharge for 1978 was $\sim 7 \times 10^4$ m^3. This amount is not unusual for a facility employing about 1,000 people, and does not constitute a burden on the Menlo Park Sanitary District. The amount is rather constant the year around, and relatively insensitive to the accelerator operating cycle.

Storm Sewer Effluents

Water effluent discharged into the storm sewer is a combination of (1) cooling tower blowdown, (2) water runoff from SLAC landscaping irrigation, (3) rainwater runoff during the winter and (4) miscellaneous uses, mainly once-through cooling of various small systems.

About a quarter of the $3.8 \times 10^5 m^3$ of water per year used at SLAC flows as waste water to the creek.

The largest potential source of chemical effluents discharged to San Francisquite Creek is cooling tower blowdown water, discharged to three natural open ditches. There are four towers of the induced-draft counterflow type. The primary system in all cases is a closed-loop, low-conductivity system. Tower 101 is located at the Central Utility Building, and provides cooling for laboratories and shops of the Campus Area. Tower 1201 is adjacent to the accelerator, and is meant to cool the injector, positron source, and the first accelerator mile. Tower 1202, also adjacent to the accelerator, cools the second mile, while Tower 1701, near the Beam Switchyard and Research Area, provides cooling for these areas.

The cooling tower water is chemically treated with silica and an organic algaecide compound. The blowdown water is basically source water whose solutes are concentrated by a factor of 4-6.

The cooling tower effluents are subject to control by the State of California, California Regional Water Quality Control Board, NPDES No. CA0028398, Order No. 78-73, October 1, 1978. The discharge permit states the maximum permissible concentrations of settable solids, oil and grease as well as maximum temperature and permissible range of pH. It sets forth a monitoring schedule describing the types of sampling and minimum frequency of analysis. Each tower's effluent is analyzed separately. Results of non-radioactive water monitoring for 1978 appear in Table 4.

As a water conservation measure, all blowdown from Tower 101 is transported to one of the three other towers. Any effluent would therefore appear in the results for Towers 1201, 1701 and 1202.

TABLE 2

ANNUAL PENETRATING RADIATION DOSE EQUIVALENT
MEASURED NEAR SLAC's BOUNDARIES - 1978

	Gamma			Neutron, mrem			Percent Standard (b)
	Background + Source	Background	Source	Background + Source	Background	Source (d)	
5	85	88	(a)	16.6	10.0	6.6	1.3
6	76	80	(a)	12.0	10.8	0.8	0.16

(a) Difference between background radiation and source contribution falls within normal variation of background values, and all are consistent with zero. Because these values are the difference between relative large numbers, each having fluctuations, negative numbers may occur.

(b) Standard from U. S. Energy Research and Development Administration Manual, Chapter 0524, 500 mrem per year.

(c) All other stations out of service due to heavy construction (see text).

(d) Owing to uncertainties in the neutron spectrum at the site boundary, and in the assignment of a quality factor, the neutron dose may be overestimated by a factor of two (see text).

TABLE 3

SUMMARY OF RADIATION MEASUREMENTS
BY PATHWAY DURING CALENDAR 1978

Exposure Pathway	Maximum Annual Dose mrem	Percent of Standard	Man-Rem Estimate	
			SLAC	Background
Penetrating	6.6[a]	1.3	3.1	204
Water	(b)			50[d]
Airborne	(c)		(c)	
Total	6.6	1.3	3.1	250

[a] Maximum measured value at PMS 5.

[b] Because of heavy construction, water samples were not collected (see text).

[c] Below significant levels.

[d] 25 mrem per person for internal dose from natural radioactivity[5] or ~50 man-rem to population near SLAC.

TABLE 4

NONRADIOACTIVE EFFLUENT DISCHARGE MONITORING REPORT

(COOLING TOWER BLOWDOWN)

1978

Parameter	Sample Frequency	Range or MDL	Units	Stand	Cooling Tower 1201 Min(1)	Max	Aver	Cooling Tower 1701 Min(1)	Max	Aver	Cooling Tower 1202 Min(1)	Max	Aver
FLOW	Continuous	Meter	Gal/d	NA	0	38,200	3400	0	37,730	4000	0	39,300	2500
pH	Continuous	0.1 to 14.0		6.0 to 9.0	7.5	8.9	NA	7.2	8.3	NA	7.7	9.4	NA
TEMPERATURE	Daily	0.5	°F	85	56	76	63.5	56	77	66.7	56	78	65
SETTLABLE SOLIDS	Monthly	≥ 0.1	mg/l	0.1	-	0.1	-	-	0.3	-	-	0.4	-
Total Suspended Solids	Monthly	≥ 0.1	mg/l	20	-	9.0	-	-	26	-	-	33	-

MDL is minimum detectable level of concentration analyses.

NA - not applicable

(1) Cooling Tower Blowdown is activated by a conductivity controller and this is intermittent.

APPENDIX A

Atmospheric Dispersion Model

In 1966, an independent evaluation of meterological regimes at SLAC was performed.[4] From this study, an empirical mathematical model was developed. The model that is used predicts the centerline concentration very well, but overestimates the total dosage values.

$$\frac{\chi_P}{Q} = \frac{G}{u} \left(\frac{X}{X_0}\right)^{-1.75 + \frac{b(1-C)}{u}}$$

where χ_P = centerline concentration (Ci/m^3)

Q = source strength (Ci/s)

$G = 8\ m^{-2}$

u = mean wind speed (m/s)

X = distance from source (m)

$X_0 = 2$ m

C = fraction of sky covered by low clouds

$b = 0.5$ m/s (day); $b = 1.2$ m/s (night).

Figure 5 summarizes peak concentration per unit source strength as a function of wind speed and atmospheric stability at a fixed distance of 400 meters (roughly the distance from the source to SLAC's boundaries). To characterize atmospheric stability, the degree of cloud cover is indicated for day and nighttime regimes. This method is based upon Pasquill's data for cloud expansion for various stability categories.

For a wind speed of 2 m/s atmospheric dilution factors--for determining centerline concentrations--range between 2×10^{-5} and

1.5×10^{-3}. For purposes of estimating radiation dose at the site boundary, neutral conditions are assumed, and a generally conservative dilution factor of 4.5×10^{-4} s/m^3 is used in calculation of average concentration at the site boundary. (See Figure 5, Curve 1.0 .)

APPENDIX B

Model for Potential Dose Assessment

According to Chapter 0513 "Effluent for Environmental Monitoring and Reporting," an assessment of whole body man-rem dose to the general population within 50 miles (80 km) of SLAC is required. Our site boundary dose due to accelerator operation is detectable, and is <20 mrem per year from penetrating radiation. Integrating a population dose of small values out to 50 miles becomes an exercise in numerical analysis that results in questionable dose estimates. This is true because of the questionable assumptions that must be made to explain the behavior of neutrons at large distances from the source. We have, therefore, modified the distance term to include individual annual doses down to 1 mrem, which corresponds to a distance of <1 mile from a central point representative of the source of neutrons. The 1 mrem value is approximately 1% of the total nautral background dose, and any further extrapolation is unjustified because the difference in population dose from natural background and SLAC operations cannot be reasonably determined.

There are three major pathways leading to human exposure: (1) airborne, (2) food chain, and (3) direct exposure to penetrating radiation. Of the three major pathways listed above, only direct exposure to penetrating radiation is of any measurable significance from SLAC operations. The source of this exposure is from neutrons resulting from the absorption of high energy electrons and photons in the experimental area creating energetic particles, some of which escape from the heavily shielded areas.

In order to make an accurate and realistic assessment of radiation exposure to the public at low doses, it is necessary that exposure from the natural radiation environment be known. This is true because the instruments used for this purpose respond to natural radiation sources as well as man-made sources, and the portion due to natural radiation must be subtracted from the raw results. The population exposure assessments appearing in this document are, in all cases, overstatements of the true impact. Hence, the resulting values are representative of an upper limit of the possible range.

While the annual neutron dose from accelerator operations at the site boundary is measurable, it amounts to <25% of the total annual individual dose from natural background radiation. According to an EPA report, the average dose from cosmic, terrestial, and internal radiation in California is 125 mrem.[5] For purposes of comparison, we have rounded this number off to 100 mrem.

Another quantity of interest is the population dose in units of man-rem. This is simply the product of the average individual dose and the total population exposed. For example, if there are 2000 people exposed to an average annual background does of 0.1 rem (100 mrem), then the population dose is 0.1 x 2000, or 200 man-rem from natural background radiation. The annual variation of exposure to natural background radiation may vary by ±20%, largely caused by the difference of naturally occurring uranium, thorium, and potassium present in the ground and in building materials where people live and work. This value is also affected by weather conditions which may increase or decrease the amount of randon/thoron present in the atmosphere at any given time.

There are two major problems associated with this determination that affect overall accuracy of the measurement. First, the conversion of neutron flux to dose requires that the spectrum of neutrons at the measurement point be known. In order to characterize the SLAC neutron spectrum, a much larger source term is required. Since the quality factor (QF) is a function of energy, we have selected a QF of 10 as best characterizing the energy spectrum produced by SLAC. We feel that this is an overestimate by a factor of approximately 2. This degree of conservation overestimates the actual dose, also by a factor of approximately 2. Until a useful experiment can be performed, with neutron yields of sufficient intensity, the QF cannot be determined with any better precision.

A second problem with this sort of extrapolation is the behavior of neutrons at large distances. Most of the high energy accelerator laboratories have made measurements and have derived formulas for predicting this behavior.[8] Unfortunately, all such measurements are unique to each facility because of deisgn differences, type of machine, and surrounding topography. Here, again, we have chosen a conservative formula for calculating the dose at distances other than the point of measurement. Lindebaum[6] gave a method for evaluating skyshine neutrons which was later verified by Ladu et al.[7] using Monte Carlo techniques. Lindenbaum approximated the falloff by $e^{-R/\lambda}/R$, where R is in feet, and λ = 830 feet. This equation fits the SLAC data fairly well, and is the one used to predict doses beyond our measuring station (Figure 6). In order to derive a correction for large distances unique for SLAC, we will need a much larger intensity to determine a more precise correction for distance. We feel that the methods used and reported in this document may overestimate the true population dose by at least a factor of 2 or greater.

The population activity close to SLAC, i.e., within 1 mile, is a mixture of commerce and residential dwellings. The occupancy factor--the proportion of time throughout the year that these structures are occupied--is assumed to be 1/4 for business activities, and 1.0 for private dwellings. The number of people is estimated for each type of structure, multiplied by the occupancy factor, and summed to estimate the total population that might be continuously present. (See Figure 4.)

REFERENCES

1. U.S. Energy Research and Development Administration Manual, Chapter 0524, Standards for Radiation Protection.

2. W. R. Nelson, "Radioactive Ground Water Produced in the Vicinity of Beam Dumps," Stanford Linear Accelerator Center Report No. SLAC-TN-65-16 (July 1965).

3. Recommendations of the International Commission on Radiological Protection, Publication 2 (Pergamon Press, London, 1959).

4. J. A. Murray, L. M. Vaughn, anf R. W. McMullen, Atmospheric Transport and Diffusion Characteristics for Selected Daytime Meterological Regimes at SLAC, Memorandum Report No. 326-1, Metronics Aerosol Laboratory, 21 December 1967.

5. "Estimates of Ionizing Radiation Doses in the United States, 1960-2000," U.S. Environmental Protection Agency Report No. ORP/CSD 72-1 (1972).

6. S. J. Lindenbaum, "Shielding of High Energy Accelerators," Int. Conf. on High Energy Accelerators, Brookhaven, 1961.

7. M. Ladu et al., "A Contribution to the Skyshine Study," Nucl. Instr. and Meth. 62, 51 (1968).

8. T. M. Jenkins, "Accelerator Boundary Doses and Skyshine," Health Physics 27, 251 (1974).

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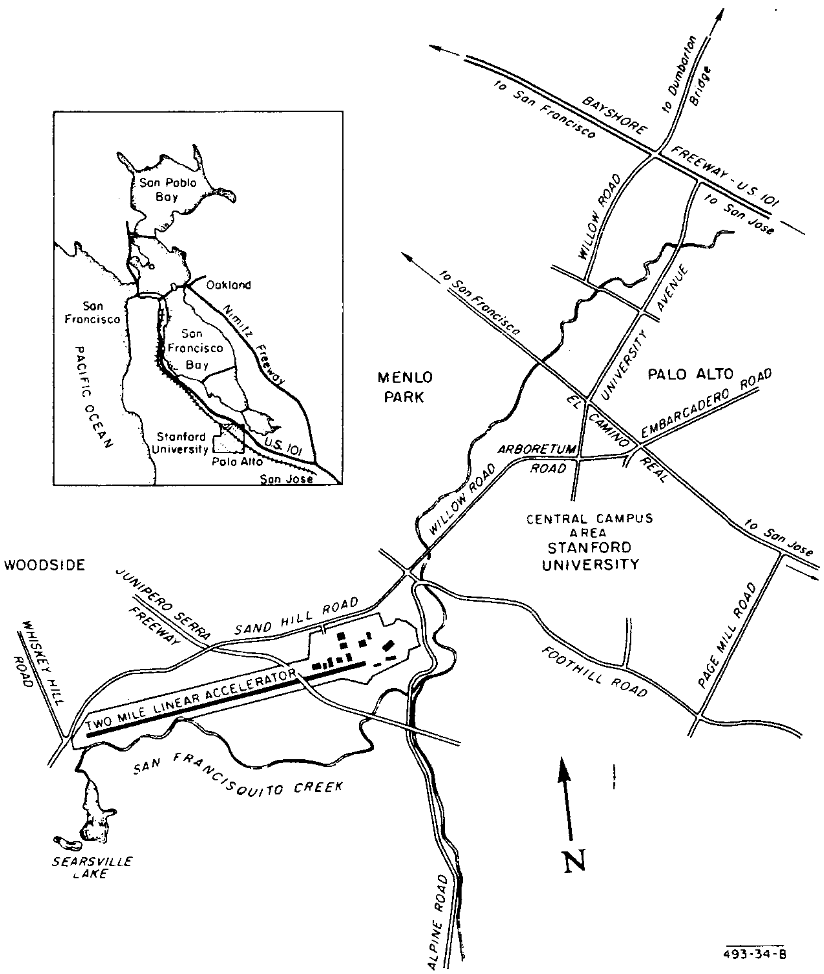


FIG. 1--Site location relative to Stanford University and surrounding communities.

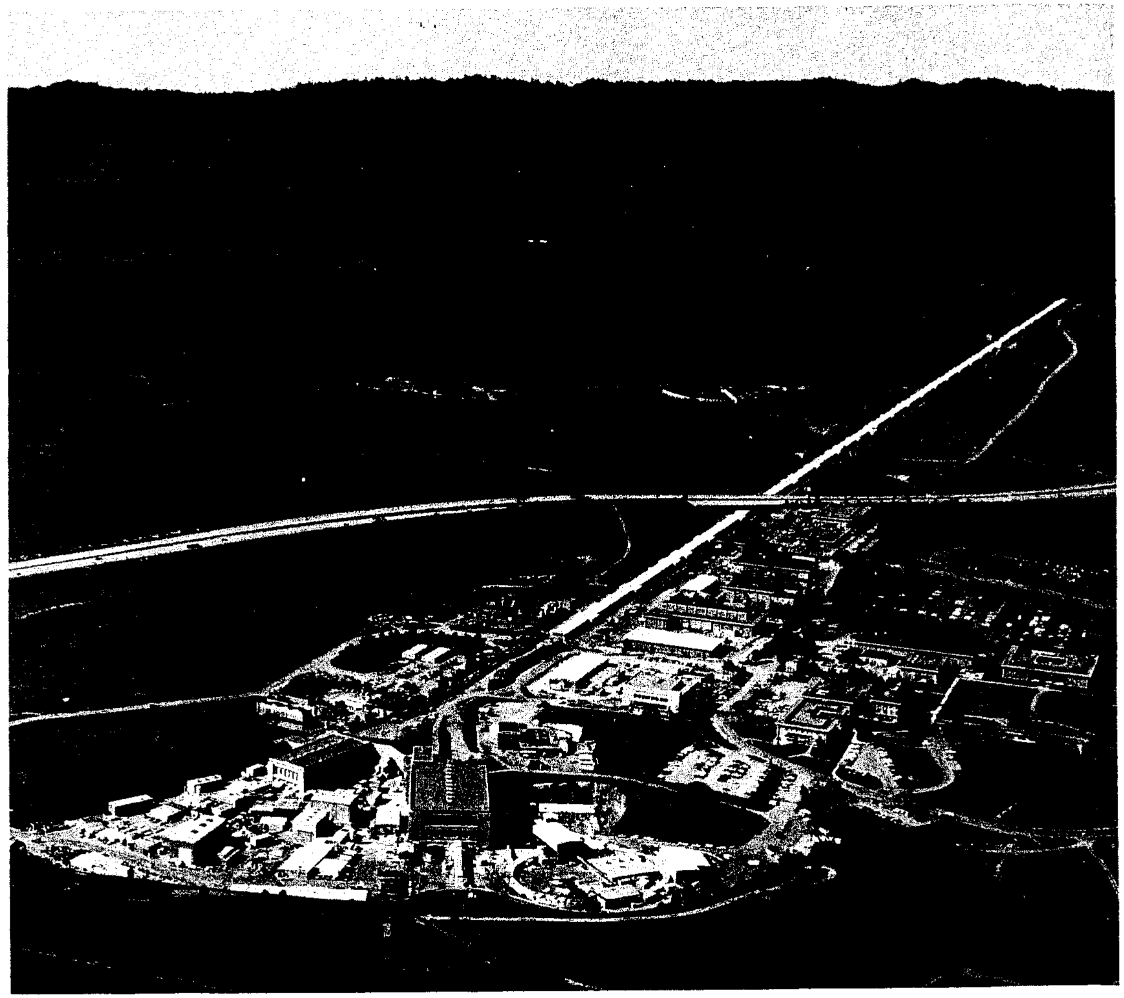
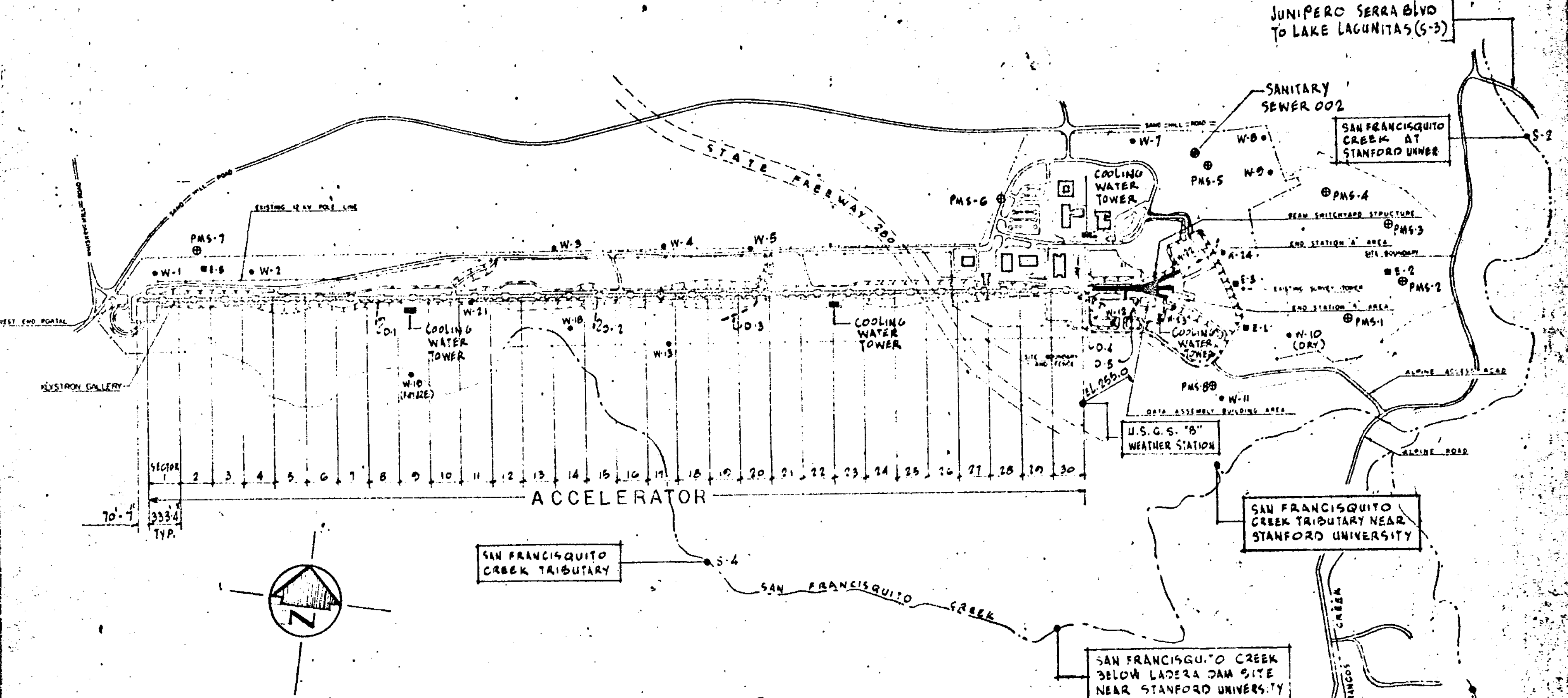


FIG. 2--Air view of SLAC site showing the two-mile accelerator, the research facility, and the principal laboratories and shops.



GENERAL SITE PLAN

FIGURE 3

SAMPLE STATION LEGEND

- W PERIPHERAL WELLS
- S SURFACE WATER
- E ENVIRONMENTAL PLOTS
- PMS PERIPHERAL MONITORING STATIONS
- D SUBDRAINS

GRAPHIC SCALE

1000' 0 1000' 2000'

SCALE: 1" = 1000'

FIG. 4--SLAC research yard and surrounding community.

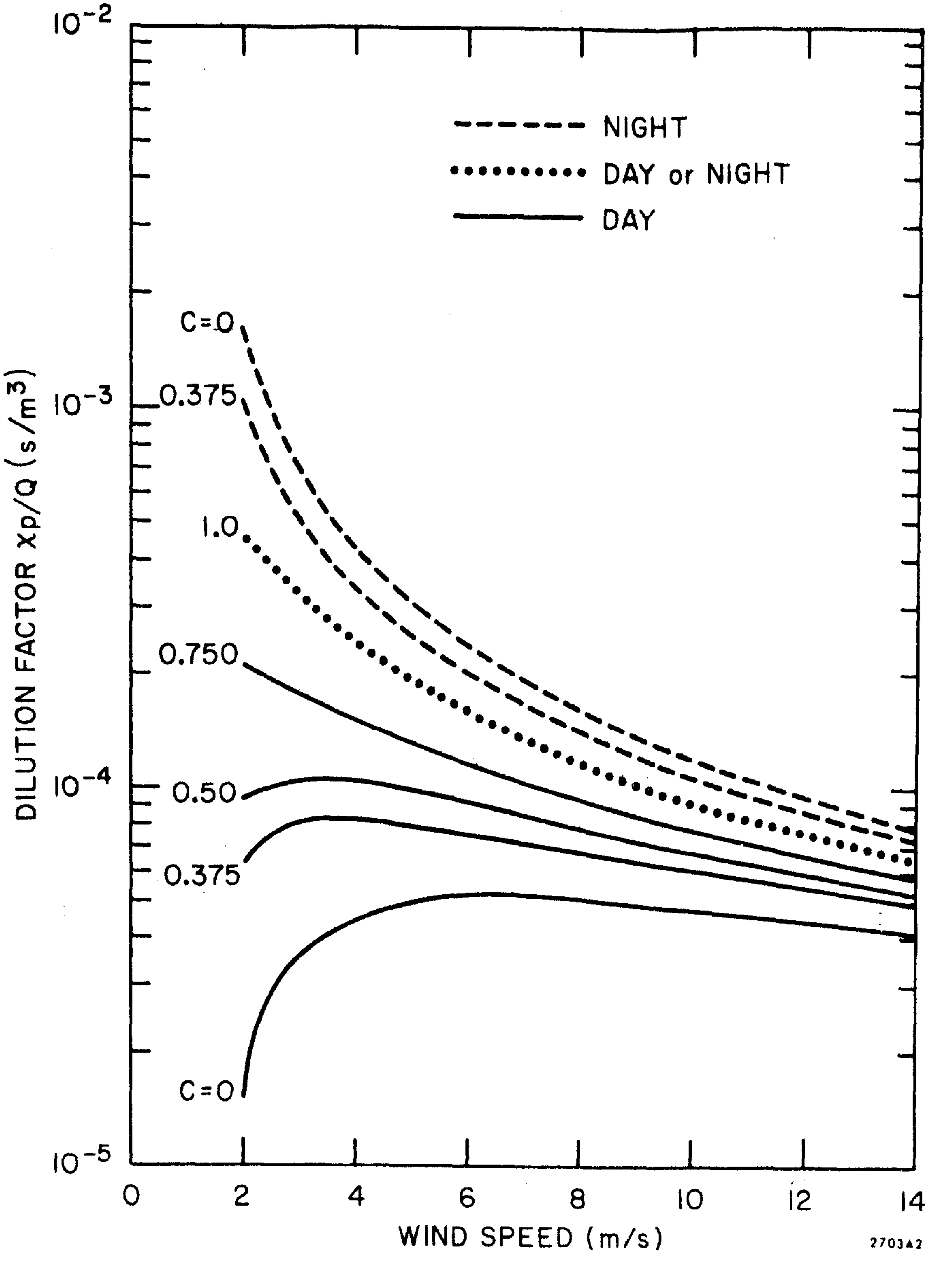


FIG. 5--Centerline dilution factor for various atmospheric conditions as a function of wind speed.

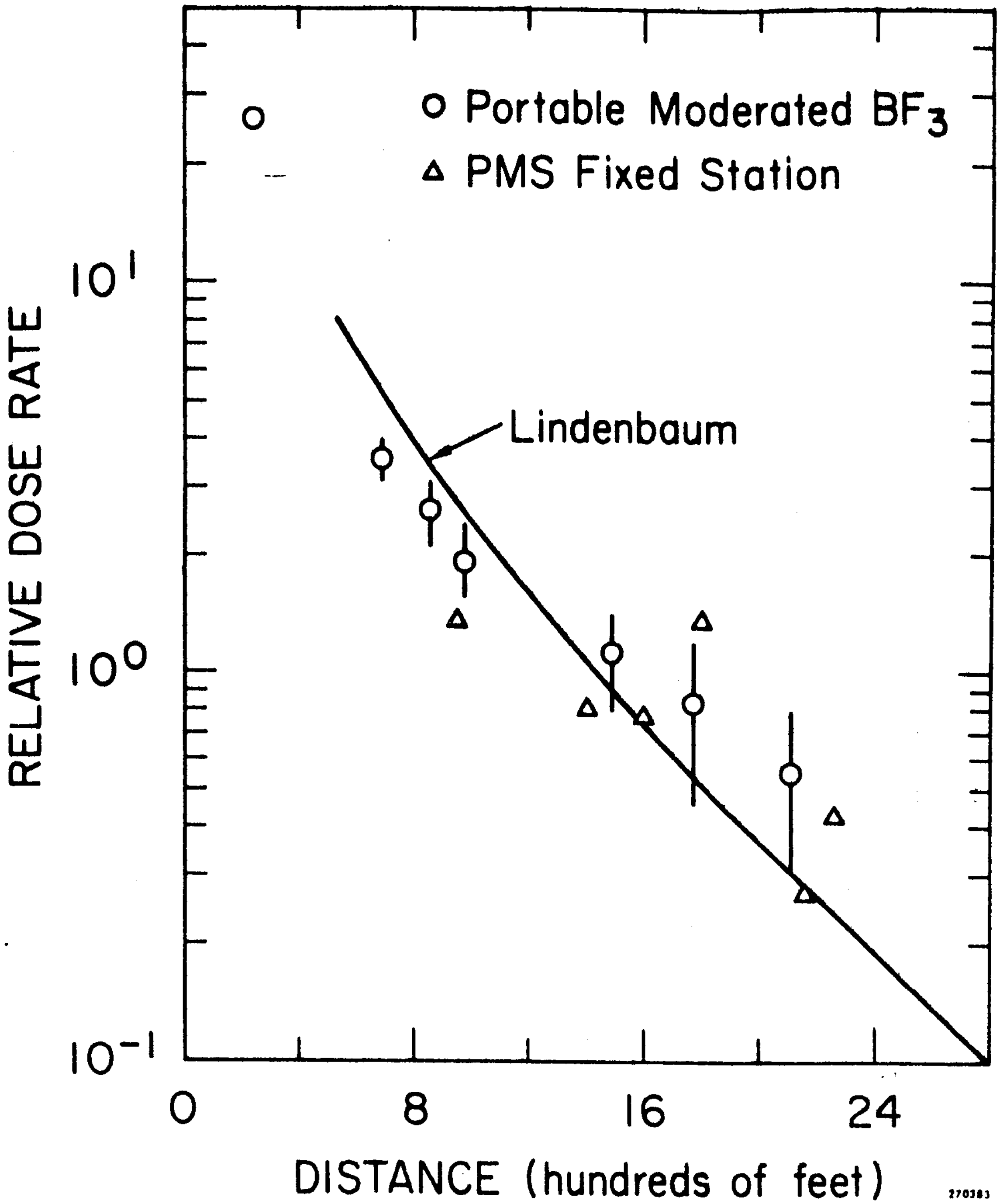


FIG. 6--Measurements made along a line between ESA and site boundary.