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Environmental Monitoring Report

For Calendar Year 1980

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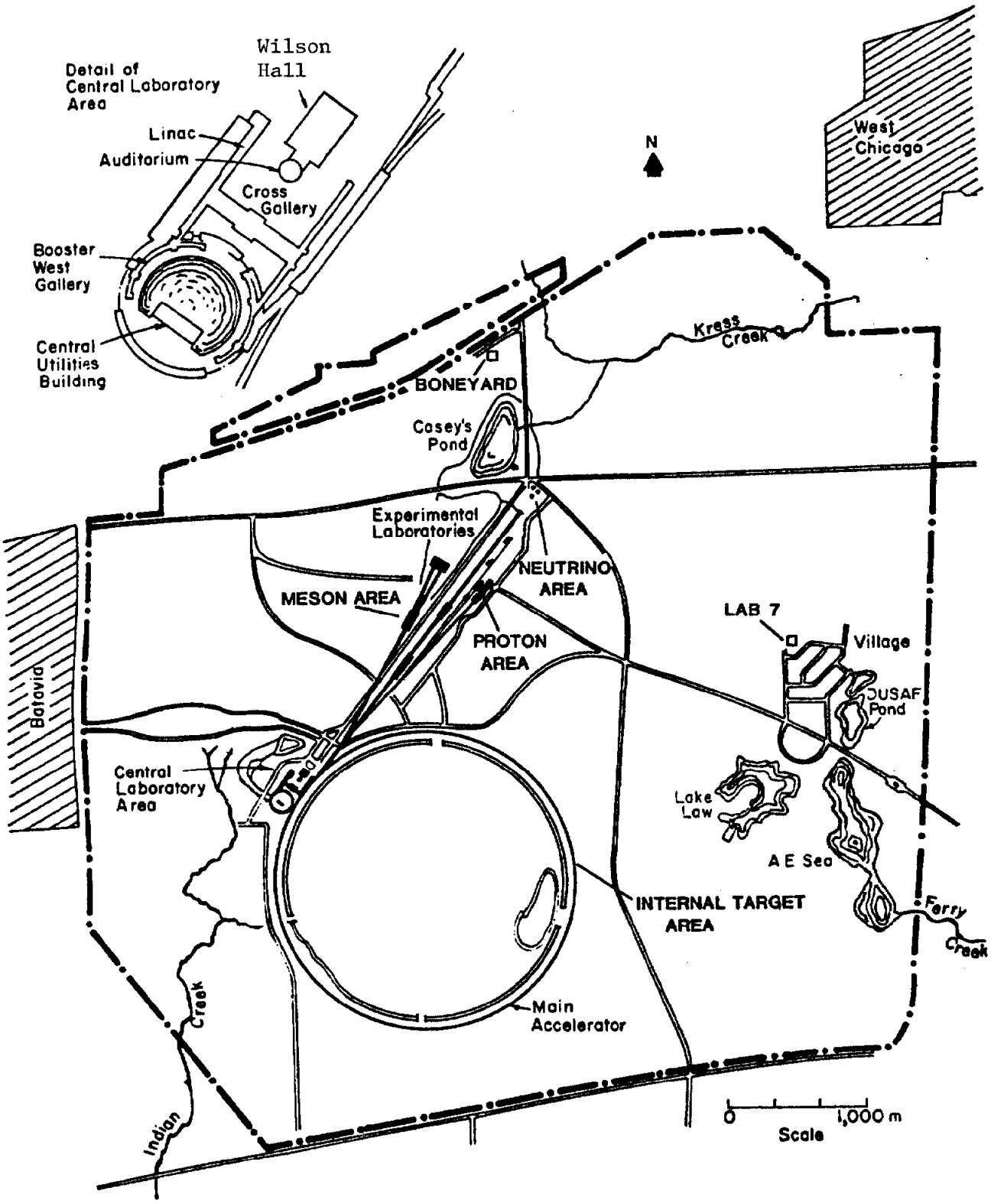
1. Introduction

This report gives the results of the environmental monitoring program at Fermi National Accelerator Laboratory (Fermilab) for Calendar Year (CY-) 1980. The Fermilab Facility is a proton synchrotron with an original design energy of 200 GeV (billion electron volts). As a result of accelerator improvements, protons were accelerated to an energy of 500 GeV in 1976 and operation at 400 GeV is now routine. The primary purpose of the installation is fundamental research in high energy physics. In addition, cancer patients are being treated using neutrons released by the interaction of 66 MeV protons from the second stage of the accelerator.

The proton beam extracted for high energy physics from the 2 km (1.2 mi) diameter main accelerator is taken to three different experimental areas on site (Meson, Neutrino and Proton Areas in Fig. 1). All three of these areas received proton beams for the first time in 1972. Radioactivity is produced as a result of the interaction of the accelerated protons with matter. Operation of the accelerator produces some radiation which penetrates the shielding material as well as some airborne radioactivity. Also, some radioactivation occurs in the soil and in the water used to cool radioactive components.

Figure 1. - Fermilab Site



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Since the Fermilab site is open to the public, this free access necessitates a thorough evaluation of the on-site discharges as well as the potential for off-site releases of radioactive effluents. Thus, an extensive monitoring program tailored to these needs is being carried out.

Monitoring results are also reported for non-radioactive pollutants. Included as pollutants are pesticides used in weed, insect, rodent, and algae control.

Also, a corrosion inhibitor containing zinc and chromium (as chromate) was formerly used in one of the water systems. Discharge underground and subsequent surfacing required monitoring. Although the use of chromates has been discontinued, monitoring for chromates has continued in CY- 1980. The CY-1980 results are reported as well as those from monitoring the performance of the sewage treatment plant on site. Discharges of suspended solids from this plant have sometimes exceeded permit limits.

Fermilab is located in the greater Chicago area (Fig. 2) on a 27.5 km^2 (10.6 mi^2) tract of land in an area which is rapidly changing from farming to residential use. There are many municipalities in the

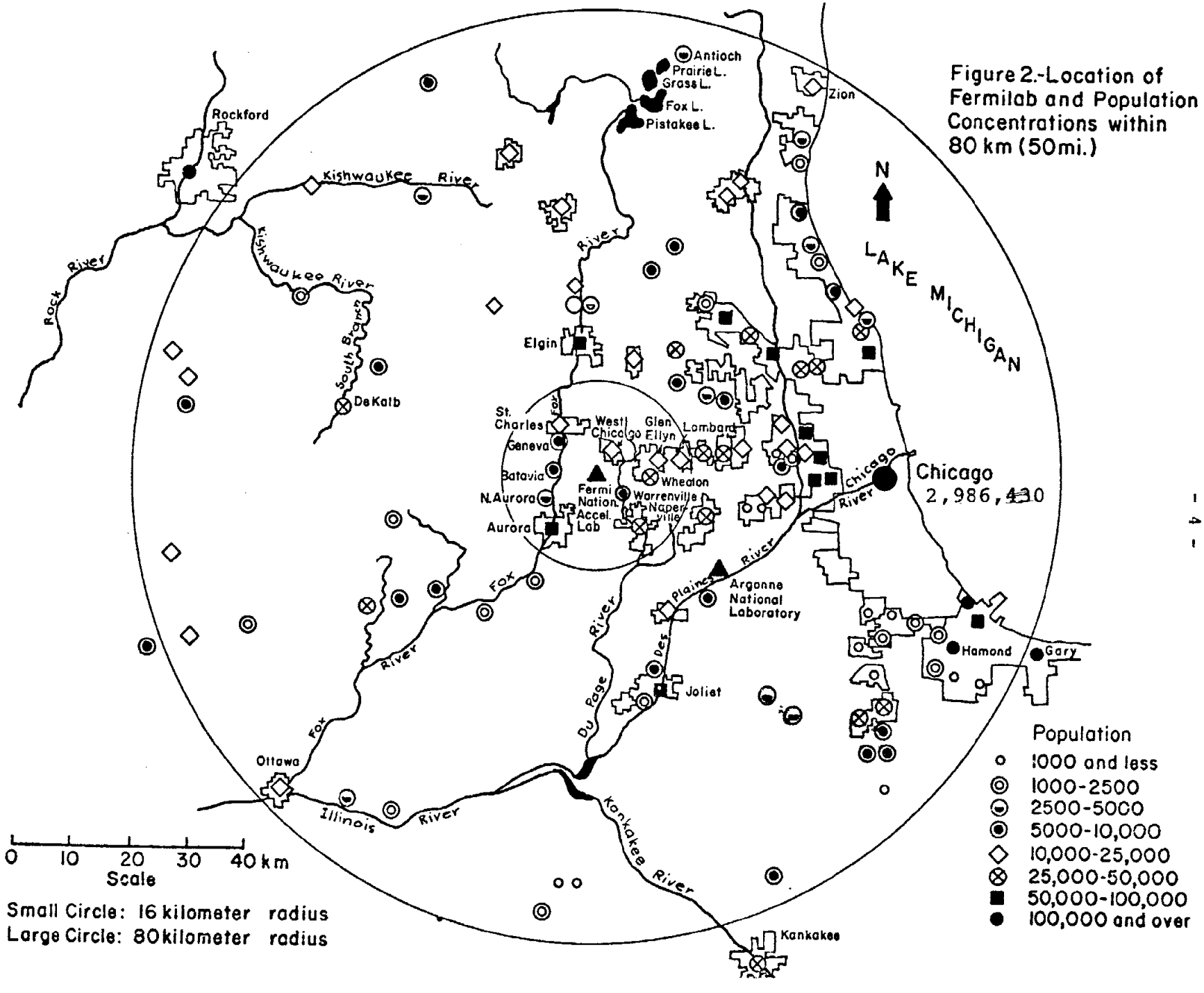

Figure 2.-Location of Fermilab and Population Concentrations within 80 km (50mi.)

vicinity, resulting in a distinct pattern of high population concentration. Within a 3 km (2 mi) distance from the Laboratory boundaries, Batavia (pop. 12,169*), Warrenville (pop. 7,185*), and West Chicago (pop. 12,444*) can be found.

The two major environmental features near the Laboratory are the Fox River to the west, which flows south through Batavia with an average of 1900 million liters (500 million gallons) per day, and the west branch of the DuPage River which passes east of the site flowing south with an average of 265 million liters (70 million gallons) per day through Warrenville. The rainfall on site during 1980 was 100 cm (39 in).[1] The land on the site is relatively flat with a high area, elevation 244 m (800 ft) above mean sea level (MSL), near the western boundary and low point, elevation 218 m (715 ft), above MSL, toward the southeast. The drainage of the ground water and most of the surface water is toward the southeastern corner of the Laboratory, toward the DuPage River. A somewhat smaller amount drains to the southwest, toward the Fox River. The drinking water in many of the surrounding communities comes from deep

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*1980 U. S. Census; Preliminary Report PHC 80-P-15

wells usually drilled 360 m (1200 ft) deep into the Cambrian/Ordovician aquifer system.[2]

The mean wind speed for the 15-year period from 1950-1964 was 3.4 m/sec (7.6 mi/hr) at Argonne National Laboratory (ANL). The direction is quite variable with the observation of more southwesterly winds than from any other direction. In CY-1980 the mean wind speed was 3.6 m/sec (8.1 mi/hr).[3] Fermilab is about 30 km (19 mi) from ANL and the terrain between them is relatively flat. From April 1979 until April 1980 a meteorological tower was in operation at the northeast corner of the Fermilab site.[4] Wind speeds determined using an anemometer mounted on this tower were in good agreement with those obtained at ANL. However, wind directions averaged over one hour were within 40° only about half the time.

2. Summary

The accelerator operated routinely at 400 GeV during CY-1980 with about half the number of protons accelerated during CY-1980 as in CY-1979. The total number of protons accelerated in 1980 was 1.2×10^{19}. The lower total was the result of an extended shutdown from the end of June until the middle of November for construction and because of a shortage of operating funds. Typical operation was at about 40 percent of the design intensity of 5×10^{13} protons per acceleration cycle. Thus, environmental monitoring in CY-1980 was done under operation conditions not grossly different from those in the past and those expected in the future.

During CY-1980 there were no abnormal occurrences which had an impact on the facility and its operation. Chromate corrosion inhibitors, which were used in the past in water treatment systems and have a potential for environmental pollution, were not used this year. Neither was copper sulfate, which was used the preceding year to control algae and weed growth in ditches. Spraying for noxious weeds was limited to 0.24 km^2 (60 acres) rather than the 10 km^2 (2500 acres) sprayed with 2,4D in previous years.

The maximum potential radiation exposure at the site boundary during CY-1980 was 0.3 mrem compared to

2 mrem last year. This dose would correspond to 0.06 percent of the standard of 500 mrem for an individual who is not a radiation worker (Section 5).

The total potential radiation exposure to the general off-site population from Fermilab operations during CY-1980 was 1 person-rem compared to 3 person-rem last year. The reduction of potential exposure occurred primarily because the off-site muon dose was negligible this year.

Airborne radioactivity was released across the site boundary in small amounts throughout the year from the stacks ventilating a Neutrino Area enclosure where the proton beam strikes a target. The radioactive gas was primarily ^{11}C, total quantity released was 1.3 kCi, and the maximum dose at the site boundary was 0.3 mrem for 1980. The average concentration at site boundary based on measurements at the stack was 0.06 percent of the Concentration Guide (Sections 3.2 and 5). There was also a controlled release of tritium produced in helium gas near a target in the Meson Area. This tritiated helium was released continuously until the end of June, when an extended shutdown began. There were no measurable releases the remainder of the year. The total amount of tritium released was 240 mCi. The average tritium concentration

at the site boundary was about 0.00001 percent of the Concentration Guide (Sections 3.2 and 4), resulting in a negligible off-site exposure. The off-site release of tritium in surface water totaled 240 mCi, five times last year's release, primarily because water flowed off the site for 7.5 months compared to less than two months in 1979.

3. Monitoring, Data Collection, Analysis and Evaluation

The three types of accelerator-produced radiation requiring environmental monitoring are discussed below. These radiations have direct pathways to the off-site population. Other more indirect pathways, such as through the food chain, have received much less attention to date. The decision on what to monitor is based on the type of operation, radionuclides released, potential hazard, and monitoring results from this and other high energy physics laboratories.

3.1 Penetrating Radiation

Operation of the accelerator at current energies and intensities results in production of some penetrating radiation (primarily muons and neutrons) outside the shielding. Although the shielding has been designed to be adequate for this operation, monitoring for purposes of determining actual radiation levels both on and off the site is necessary.

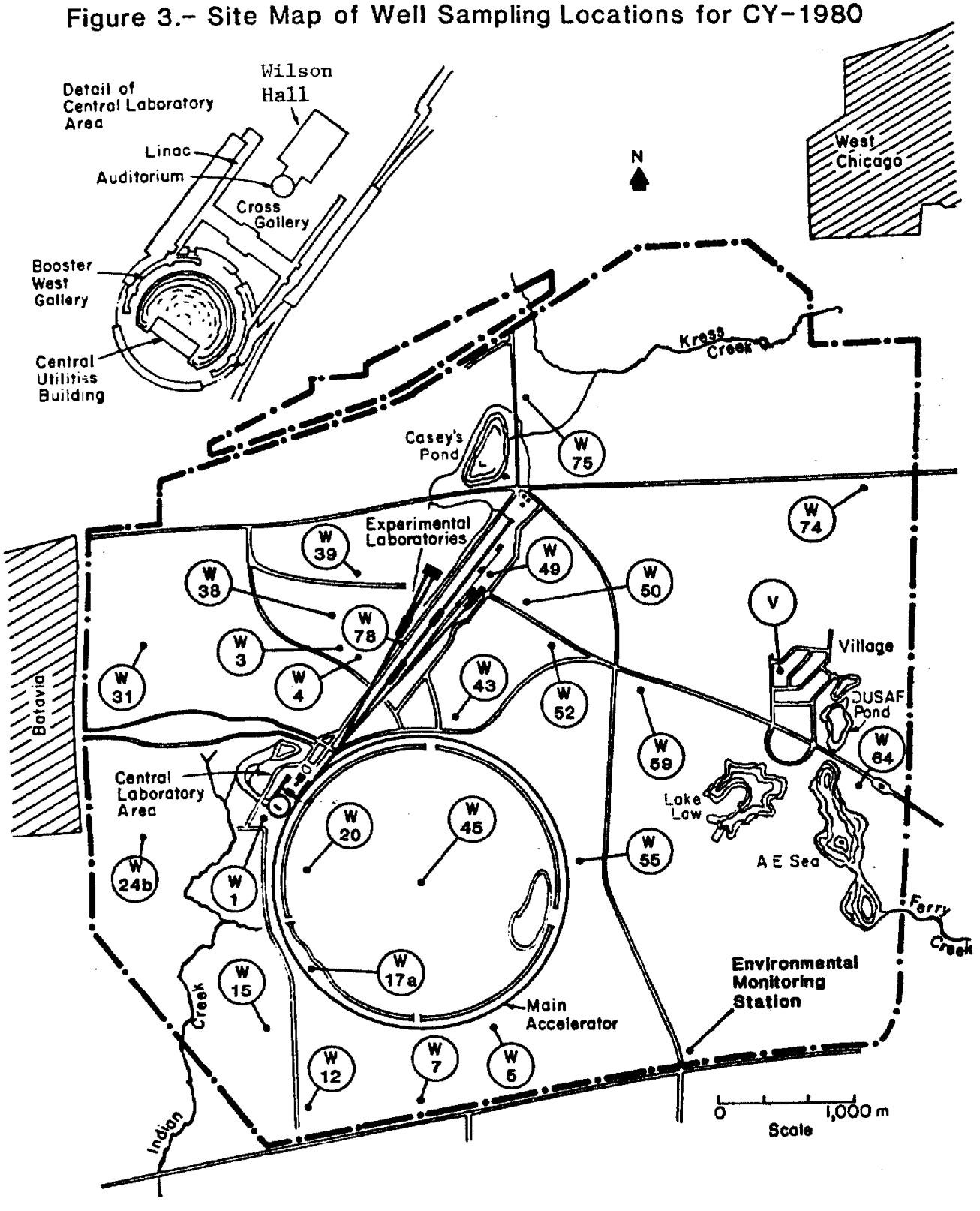
A large network of detectors was used to monitor penetrating radiation. At the end of CY-1980 there were approximately 200 detectors deployed around the site for the main purpose of protecting on-site personnel. The majority of these detectors

were connected to a data logger which automatically recorded the radiation levels for subsequent examination.[6] Seven detectors were used primarily for environmental radiation monitoring. Five were large volume, 110 liter, ionization chambers for gamma-ray and charged particle detection. Three of the five were located in the Neutrino Area, one was at the Boneyard, and one was at Lab 7 (Fig. 1). The remaining two detectors were large scintillation counters. One of these is located near the site boundary (Environmental Monitoring Station in Fig. 3). The other is used near the experimental areas (W43 in Fig. 3) to detect ^{11}C in the Neutrino Area radioactive gas releases.

3.1.1 Muons

The Mobile Environmental Radiation Laboratory (MERL) was used for determining the exposure levels at the site boundary and for locating the source of penetrating radiation (muons) discovered several years ago behind the Muon Laboratory, a facility in the Neutrino Area (Fig. 4).[5,7,8] The MERL is a four-wheel-drive vehicle equipped with two 20 cm x 20 cm (8 in x 8 in) scintillation counters, one approximately 15 cm (6 in) behind the other. Coincidence electronics

Figure 3.- Site Map of Well Sampling Locations for CY-1980



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associated with the scintillation counters was used to determine the direction and radiation levels of the penetrating radiation (muons). Information on the expected arrival time and intensity of the particles, based on accelerator operation, was sent to the MERL via transmitter to aid in the measurements. Dose measurements were made at the site boundary with the scintillation counters while recording the number of counts from one of the 110 liter ionization chambers placed in the path of the muons much closer to the source. The counts from that ionization chamber were recorded for the entire year through the data logger and the natural background subtracted to determine the annual dose at the site boundary. Muons from the Neutrino Area in CY-1980 resulted in negligible exposures, primarily because the Muon Laboratory was not in operation. The coils in the large magnet in the Muon Laboratory were removed and new superconducting coils installed during the period.

Muons from the Proton Area (Fig. 4) were also measured in CY-1980. Because these are produced in underground enclosures the muons were either absorbed in the soil or left the site at too high an elevation to result in an exposure to the off-site population.

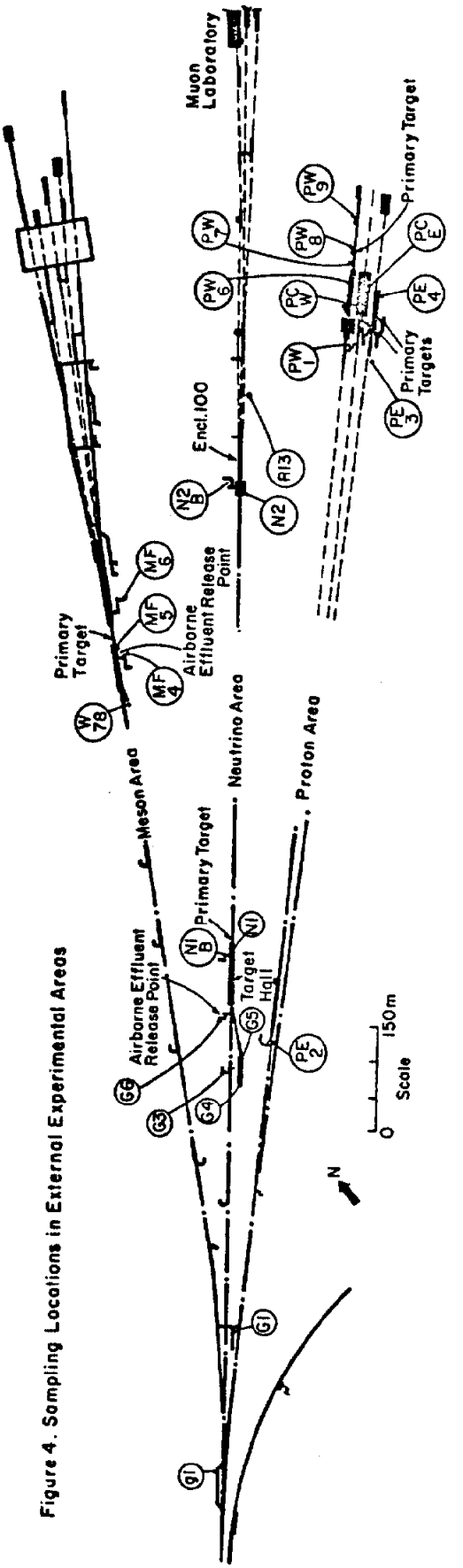

Figure 4. Sampling Locations in External Experimental Areas

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3.1.2 Neutrons

Neutrons which penetrated the shielding were detected in the vicinity of the primary targets (Fig. 4) in the Proton Area in CY-1980. The location where neutrons were detected was so far from site boundaries that the annual dose at site boundary from neutrons was negligible. On-site exposures were kept low by fencing the areas having measurable dose rates and excluding the public from these areas.

3.1.3 Gamma Rays

In May 1977 E G & G, Inc., under Energy Research and Development Administration (now U.S. Department of Energy) contract, conducted an aerial radiological survey of Fermilab and surrounding area.[9] The detection system used consisted of 20 NaI(Tℓ) scintillation counters each 12.7 cm diameter by 5.1 cm thick (5" x 2") mounted in a helicopter. Data were recorded on magnetic tape and analyzed with the aid of computer techniques.

Flight paths were 100 m (300 ft) apart at an altitude of 100 m (300 ft) with location determined by referencing to radio beacons placed on nearby water towers. The area covered was approximately 6 km by 6 km (4 mi x 4 mi) with the Laboratory in the center. The results indicated three areas where radiation was

significantly higher than natural background.[5] All three of these were locations where radioactive materials were stored. One of these, the Fitzgerald Barn, has been razed and the material moved to the Lundy Barn just south of the Boneyard (Fig. 1). The Lundy Barn was constructed of shielding blocks, hence it reduced the environmental radiation levels. The second of the three areas is Lab 7 in the Village (Fig. 1). Most of the radioactive material has been removed from Lab 7 and sent off site for burial. Dose rates in the three nearby houses occupied in 1977 and 1978 has been reduced to background levels.[5]

In June 1979 the house adjacent to Lab 7 was converted back to a residence and since that time has provided sleeping accommodations for three visiting experimenters. Even with most of the radioactive materials removed from Lab 7 the experimenters received some exposure. If one takes the most conservative approach and assumes 24-hour occupancy, one obtains a "worst-case" exposure of approximately 15 mrem for each experimenter during CY-1980 from radioactivity in Lab 7. This is three percent of the standard of 500 mrem for an individual who is not a radiation worker.

The third of the three areas detected during the aerial survey is the primary radioactive waste disposal

storage area on site - the Boneyard. As shown in Fig. 1, this area lies close to the site boundary. On the north side there is an earth berm to prevent any direct radiation from leaving the site. Since the survey, shielding has been added above and on all sides of those radioactive materials which would produce high radiation levels without shielding. This was done to protect Fermilab workers as well as reduce the off-site dose. The items responsible for most of the site boundary dose rate were disposed of in an approved off-site burial ground in late CY-1979. Radiation levels at the site boundary closest to the Boneyard were at background levels in CY-1980.

3.2 Airborne Radioactivity

Radioactivation of air in measurable concentrations will occur wherever the proton beam or the spray of secondary particles resulting from its interactions with matter passes through the air. Along most proton beam lines (paths of the protons from the accelerator) the protons travel inside evacuated pipes. Thus, radio-activation of air is now usually caused by secondary particles. Monitoring of such activation is carried out for purposes of personnel exposure control. Under no circumstances is the off-site concentration of airborne

radioactivity expected to approach the limits for uncontrolled areas set forth in the Department of Energy Manual, Chapter 0524 (DOE Manual 0524).

Radioactive gas, primarily ^{11}C, was produced by interaction of secondary particles with air. Monitoring was carried out by detecting the beta particles emitted in the radioactive ^{11}C decay. A release of 1.3 kCi occurred from the labyrinth stack (Airborne Effluent Release Point in Fig. 4) in the Neutrino Area during 1980. From measurements made at the stack and calculations based on a Gaussian plume diffusion model,[10] the expected dose at the site boundary for 1980 was 0.3 mrem, which corresponds to 0.06 percent of the applicable Concentration Guide [11] (Section 5).

Tritiated helium was released continuously from the Meson Area Target Box as the tritium was produced from January 1, 1980 until the extended shutdown beginning June 24, 1980. The release was negligible for the remainder of the year. The total activity released for the year was 240 mCi of ^{3}H. The Gaussian plume diffusion model was used with neutral wind conditions to calculate the site boundary ^{3}H concentration. The average site boundary concentration for the release was less than 2×10^{-14} μCi/mℓ or a negligible percentage

(0.00001 percent) of the applicable Concentration Guide given in the DOE Manual Chapter 0524 (see Section 5).

A new facility, a debonding oven, was placed in operation in CY-1979 (near W43 in Fig. 3). Its purpose is to debond magnets by decomposing the epoxy adhesives at high temperatures. Most of these magnets are radioactive, having failed during accelerator operations. The gaseous effluent has been measured during the acceptance test on June 8, 1979 conducted for the Illinois EPA and contains only ^{3}H at very low levels. The test utilized a typical 6 m (20 ft) long magnet reading 0.8 mrem/hr at 0.3 m (1 ft) from the surface and 8 mrem/hr in the bore tube where the protons traveled. The total amount of ^{3}H released from this magnet was 160 μCi at a stack concentration of 1.3×10^{-8} μCi/mℓ or about 20 percent of the Concentration Guide (Section 5) corresponding to 500 mrem per year. The stack is approximately 10 m (30 ft) high. Using the Gaussian plume diffusion model[10] with neutral wind conditions gives a negligible percentage of the applicable Concentration Guide at the site boundary. Eighteen magnets were debonded in CY-1980, and the total tritium release from this stack was approximately 3 mCi.

3.3 Waterborne Radioactivity

During accelerator operations, some radioactivation of the soil will occur.[12,13] Leaching of these radionuclides into the ground water provides a possible mechanism for transport of Fermilab-produced radionuclides into the surface run-off waters and aquifer. Hence, a broad program of ground water monitoring for radioactivity is maintained. Measurements are also made of on-site concentrations of radionuclides in Fermilab surface waters and in closed loop (recirculating) cooling systems which are sources of potential off-site releases.

Water samples are collected periodically on site and from surface waters off site. They are analyzed for the presence of those radionuclides which are produced in and leachable from Fermilab soils in measurable quantities.[12] This group of radionuclides also includes those produced in water directly. Analyses are made for ^{3}H, ^{7}Be, ^{22}Na, ^{45}Ca, ^{54}Mn and ^{60}Co. The latter is hardly leachable (approximately 0.1 percent); however, it has been detected in discharges during regeneration of water treatment resin.

Water samples were collected from the following types of wells on site:

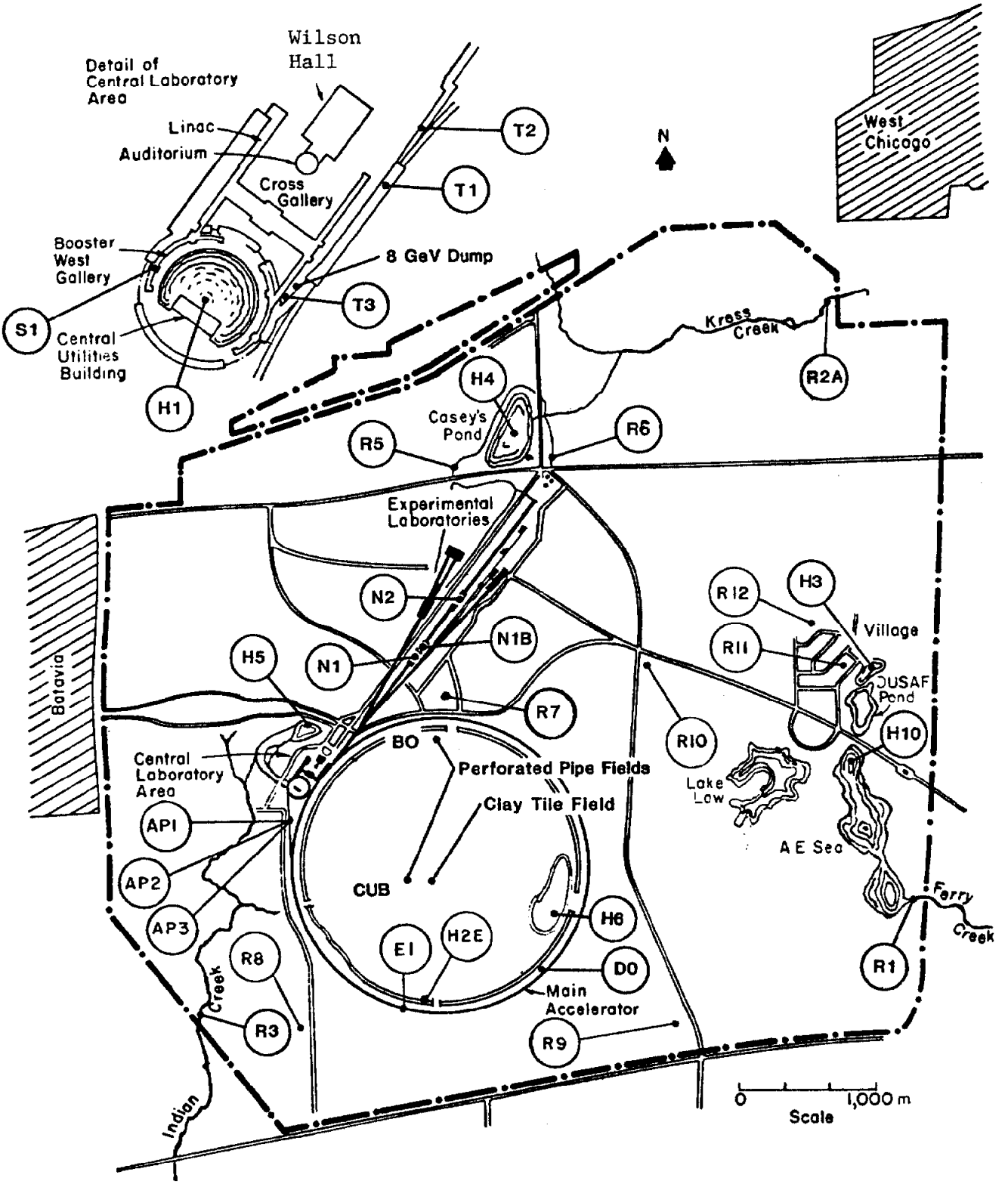
1. Farm Wells - Approximately 30 m Deep - 35 Samples
2. Fermilab Water Supplies - Approximately 70 m Deep - 6 Samples
3. Fermilab Deep Well Emergency Supply - 436 m Deep - 1 Sample

Water samples were also collected from sumps, creeks, and rivers. All surface and ground water samples were analyzed by Eberline, Midwest Facility, 245 Roosevelt Road, West Chicago, Illinois 60185, during CY-1980. Each monthly shipment included at least one sample containing known amounts of several of the accelerator-produced radionuclides to check the accuracy of the assays. See Section 4.

3.3.1 Results of Analyses

The Fermilab CY-1980 water sampling locations for detection of accelerator-produced activity are shown in Figs. 3, 4 and 5. No accelerator-produced radionuclides were reported in water samples taken from the three creeks leaving the site (Fig. 5). Five samples were obtained from Kress Creek and four each from Ferry Creek and Indian Creek. River water samples were obtained once during CY-1980 from the Fox River in Aurora and from

Figure 5. - Site Map of Surface Water Sampling Locations for CY-1980



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the west branch of the DuPage River in Warrenville. Neither river is utilized as a drinking water supply. No evidence for accelerator-produced radionuclides was found.

The Village water supply (V in Fig. 3) is the Laboratory's only community water supply. Quarterly water samples were collected and a composite analyzed for naturally occurring as well as reactor and accelerator-produced radionuclides. No activity was found using very low detection limits. See Section 5. The same was true for composite samples from Fermilab's other two drinking water systems providing water to more than 25 persons a day. These (W1, with W3 as back-up, and W55 in Fig. 3) supply water to Wilson Hall (formerly called the Central Laboratory) and to the Internal Target Area (Fig. 1). No accelerator-produced radionuclides were detected in the 36 samples taken from the on-site wells.

3.3.1.1 Tritium

The results for on-site tritium measurements yielding detectable levels in surface waters are given in Table 1 (Fig. 4). All other sampling points were essentially at background levels. The sumps collect waters from around the footings of the buildings and enclosures. This water is considered surface water.

TABLE 1

Tritium Detected in On-Site Water Samples

Collection Point	Number of Samples Collected	Tritium Concentration C (μCi/mℓ)*			Percentage of Relevant Standard
		C max	C min	C mean	
MF4 Sump	3	1.9×10^{-3}**	2.8×10^{-5}	1.3×10^{-4}	4.3
MF5 Sump	5	1.6×10^{-4}	3.4×10^{-5}	6.0×10^{-5}	2.0
MF6 Sump	1	2.9×10^{-6}	2.9×10^{-6}	2.9×10^{-6}	0.1
N1 Sump	7	1.1×10^{-4}	$< 3 \times 10^{-6}$	5.9×10^{-5}	2.0
N1B Sump	2	6.4×10^{-6}	4.0×10^{-6}	5.2×10^{-6}	0.2
N2 Sump	7	5.5×10^{-4}	8.5×10^{-6}	2.0×10^{-4}	6.7
N2B Sump	2	3.0×10^{-5}	1.1×10^{-5}	2.1×10^{-5}	0.7
PCE Sump	3	2.2×10^{-5}	$< 3 \times 10^{-6}$	1.0×10^{-5}	0.3
PCW Sump	3	5.0×10^{-6}	$< 3 \times 10^{-6}$	3.6×10^{-6}	0.1
PE4 Sump	5	1.5×10^{-5}	6.0×10^{-6}	8.9×10^{-6}	0.3
PW1 Sump	2	6.0×10^{-6}	4.1×10^{-6}	5.0×10^{-6}	0.2
PW8 Sump	5	3.2×10^{-5}	3.0×10^{-6}	1.0×10^{-5}	0.3
PW9 Sump	2	5.7×10^{-6}	5.0×10^{-6}	5.4×10^{-6}	0.2

*C max is the highest concentration detected in any sample from that location and C min is the lowest. C mean is the average for all samples from one location.

**This reported concentration is believed to be spurious. See Section 3.3.1.1 This value was not used in determining C mean.

Only aquifers are called ground waters. The total off-site release in surface waters was 240 mCi of tritium this year compared with 48 mCi last year. This large increase was primarily because surface water from the experimental areas left the site for 7.5 months in 1980 compared to less than two months in 1979. The release occurred at less than 0.3 percent of the Concentration Guide (Section 5 below) and made a negligible contribution to the potential off-site dose.

The surface water from the experimental areas flows into Casey's Pond except during periods of rainfall. Then, the pond fills up and barricades are placed at the two entrances to the pond to keep the water from flooding the pump room. When these barriers, called stop logs, are in place, the water bypasses the pond and leaves the site via Kress Creek.

The following unplanned tritium releases occurred in CY-1980:

1. The Proton East Chiller Closed Loop Water System developed leaks during CY-1980. None of the discharges raised the tritium concentration in the sumps (PE-3 and PE-4 in Fig. 4) to more than 20 percent of the relevant standard. The total amount of tritium from those releases was approximately 3.6 mCi and was discharged on site.

2. Another leak which occurred was from the Neutrino Area Train Closed Loop Water System. Radioactive water leaked into the retention pit and then out of the pit through a crack in its side wall. This water drained into the neighboring sump pit (N1 in Fig. 4). Some water remained in the retention pit and was pumped into drums for solidification and disposal as radioactive waste. An attempt was made to seal the crack in the wall, but this was not successful. The amount of tritium released to the off-site environment is estimated to be 5 mCi.

3. There were also two releases from the Neutrino Area Enclosure 100 Sump (N2 in Fig. 4) which occurred during the summer construction period when radionuclides were being leached from the sand and gravel around the uncovered Enclosure 100 Upstream Dump. One occurred at 400 pCi/mℓ and the other at 550 pCi/mℓ. The total release of approximately 7.6 mCi left the site.

4. Water in a ditch next to radioactive steel shielding (R7 in Fig. 5) showed a peak tritium concentration of 8.6×10^{-5} μCi/mℓ. This water, containing less than 1 mCi of tritium, remained

on site. The steel was subsequently placed in the Neutrino Area (N2 in Fig. 5) as muon shielding. A drainage system was provided to collect any water leaching radionuclides from the steel.

A routine analysis of water from the MF4 sump in the labyrinth of the Meson Area Target Hall in December 1980 gave a tritium concentration of 1.9×10^{-3} μCi/mℓ. There were no other radionuclides detected. A subsequent sample gave 2×10^{-5} μCi/mℓ, consistent with previous samples. This sump collects water from around the footings of the enclosure and from outside the impervious membrane under the Meson Area Target Box. The sump collecting water from inside the impervious membrane was sampled on the same day and the water had a tritium concentration of only 5.9×10^{-5} μCi/mℓ. There were no leaks of the closed loop water system reported; hence the high concentration in the sump is not understood and is believed to be spurious. The sampling frequency for that sump has been increased in case there is a problem.

3.3.1.2 Beryllium

Concurrent with the production of ^{3}H with 12 year half-life is the production of ^{7}Be with 53 day half-life in the closed cooling water systems. The ^{7}Be is

chemically active and is easily removed from the water by the resins used to maintain water purity. These resins are regenerated in two separate systems located at the Central Utilities Building (Fig. 5). The ^{7}Be is precipitated out of the regeneration effluent and is disposed of as radioactive waste in an off-site burial ground in the case of the Main Ring Water Treatment System. The discharge from the other system, which regenerates resin from the small tanks used throughout the site, is sent to a clay tile field inside the main accelerator (Fig. 5). There it percolates into the soil about 60 cm (2 ft) below the surface. The short half-life of ^{7}Be and its strong chemical affinity with the soil ensure that the release will place no burden on the environment.

Surfacing of resin regeneration effluent in the clay tile field was detected in December 1980. The ^{7}Be concentration in the silt at the point of surfacing was 8 pCi/g. The tile field was excavated and repairs made.

Silt samples taken from the three creeks near the site boundary showed no ^{7}Be or other radionuclides. The detection limit for ^{7}Be in silt was approximately 1 pCi/g. A silt sample was also taken in the sump discharge path near the Neutrino Target Hall (N1 in Figs. 4 and 5). Residual accelerator-produced activity in the silt sample was 3 pCi/g with ^{22}Na and ^{54}Mn detected.

3.3.2 Vegetation Sampling

The vegetation sampling program initiated in CY-1978 was continued in CY-1980. A sample was taken near the ^{3}H exhaust in the Meson Area (Fig. 4). All vegetation was removed during construction near the exhaust stack venting radioactive gas in the Neutrino Area. Hence, no sample was obtained there. Radioactivity was found in that vegetation last year.[5] Samples were taken in the vicinity of discharges from sumps collecting water in areas having the most soil activation resulting from direct interactions of the primary protons or the secondary particles they produce.

The results of the vegetation sampling are given in Table 2 for cases where radionuclides were detected. The peak concentrations given are based on the weight of the unprocessed sample. From previous results[5] the radionuclide ^{7}Be is expected to be present as surface contamination while ^{22}Na and ^{60}Co are most likely incorporated into the plants. No radionuclides were detected in samples from the DO, MF5, PW8, and T2 sump discharge areas.

TABLE 2

Vegetation Sampling Results

Location	Radionuclides	Concentration (pCi/g)
N2 Sump Discharge Area	^{7}Be	51
	^{22}Na	5.3
	^{60}Co	0.3
N1 Sump Discharge Area	^{22}Na	2.6
Meson Stack	^{3}H	34

3.3.3 Soil Activation

Since the percolation rates for water in Fermilab soils are calculated to be very low - less than 1 m (3 ft) per year[14] - analyses of well waters do not provide the early warning desired for detection of accelerator-produced radioactivity in the ground water. To provide such a warning soil samples were taken from the vicinity of targets and other locations where proton interactions result in some radioactivation of the soil. Many radionuclides were detected but since the major long-lived ones leachable from Fermilab soils were ^{3}H and ^{22}Na, quantitative measurements were made only on those.[12] The results have been presented elsewhere.[5,15]

In CY-1980 the most radioactive soil on site, the soil shielding the Neutrino Area primary target, was dug up to install a new proton transport line. The soil was placed back in the excavation after the construction was completed. The entire operation was completed in one day, a day on which the probability of rain and hence leaching of radionuclides was near zero. There was, in fact, no precipitation that day. A section of the new transport line pipe approximately 0.5 m (20 in) in diameter and 38 m (125 ft) in length was placed at the

bottom of a 4.5 m (15 ft) excavation in one piece to reduce radiation exposure and decrease the time required.

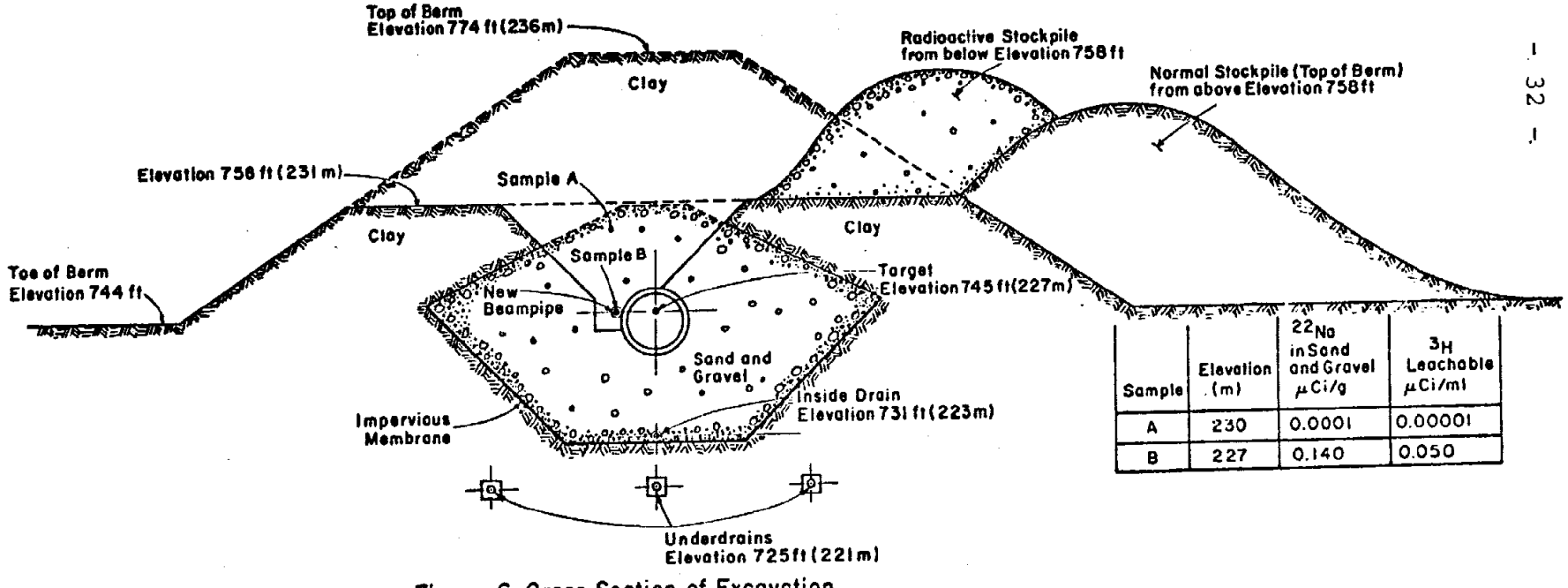
Soil (sand and gravel) samples taken from the excavation were leached using a volume of water equal in weight to the sample. The peak ^{3}H concentration found was 0.05 μCi/mℓ. This was the expected ^{3}H concentration based on the sampling done in CY-1975 and the number of protons incident on the primary target in the meantime.[15] The 4.5 m (15 ft) of clay above the sand and gravel has been effective in protecting the sand and gravel from leaching (Fig. 6).

3.4 Nonradioactive Pollutants

3.4.1 Airborne Effluents

A magnet debonding oven in the Industrial Building complex (W43, Fig. 3) was placed in operation in CY-1979, and was used to debond 18 magnets in CY-1980. It consists of an electrically heated oven operating at 450°C (850°F) with a propane fired afterburner operating at ≥760°C (1400°F) to assure complete oxidation of all combustion products.

This debonding oven was installed under a construction permit issued by the Illinois Environmental



Sample	Elevation (m)	^{22}Na in Sand and Gravel $\mu Ci/g$	^{3}H Leachable $\mu Ci/ml$
A	230	0.0001	0.00001
B	227	0.140	0.050

Figure 6. Cross Section of Excavation
Three Meters (10 ft) from Target

0861

Protection Agency (IEPA). A fully documented acceptance test of emissions, including particulates, NO_x and hydrocarbons, was performed by the Almega Corporation and IEPA has granted an operating permit. The debonding process removes approximately 57 kg (125 lb) of cured bonding epoxy from each magnet.

3.4.2 Water Utilization

3.4.2.1 Domestic Water Supplies

The domestic water supply at Fermilab is essentially provided by two wells pumping from an aquifer approximately 70 m (220 ft) deep. One (W1 in Fig. 3) is located in the Central Laboratory area and the other (V in Fig. 3) supplies the separate Village system. A third well (W3 in Fig. 3) pumps from the same aquifer and supplies water to the Main Site System when demand exceeds the capacity of W1.

These wells have chlorination systems and our water laboratory tests for pH, chlorine and fecal coliform monthly. Test results conformed to Illinois standards during 1980. Our average use from these wells was 413,000 ℓ/day (109,000 gal/day), down from 1979.

3.4.2.2 Industrial Water Ponding Systems

There are several water systems used for cooling magnets and for fire protection:

The Industrial Cooling Water (ICW) System consists of Casey's Pond (H4 in Fig. 5) at the end of the Neutrino Beam Line and underground mains to fire hydrants and sprinkler systems throughout the Main Site and Wilson Hall. Casey's Pond is supplied by surface drainage and can also be supplied by pumping from the Fox River. The pond, holding 68,000,000 ℓ (18,000,000 gal) is accessible to the public.

The Swan Lake/Booster Pond System (H5 in Fig. 5) is used for cooling purposes at the Central Utilities Building (C.U.B.). Water is pumped from the Booster Pond into a ditch in which it runs by way of a small West Pond into Swan Lake. The water is then returned to the Booster Pond by a return ditch. Water is also pumped from Swan Lake to N1 Service Building for cooling purposes, from which it returns by a surface ditch. This system can be supplied water from the ICW System

and it overflows into Indian Creek, from which it may be pumped into the Main Ring System.

The Main Ring Ponding System consists of a series of interconnecting canals completely encircling the interior of the Main Ring with a large reservoir pond at C4 (H6 in Fig. 5). This water is used in heat exchangers at the Service Buildings for cooling the Main Ring magnets. The system is generally supplied by surface drainage, although make-up water can be pumped from Casey's Pond. The system overflows into Lake Law (Fig. 5). The public is excluded from the area inside the Main Ring, and hence the Main Ring Ponding System, when the accelerator is in operation.

The water in these systems meets or exceeds the quality requirements of water in general use in Illinois (Section 5).

3.4.2.3 Other Lakes and Ponds

Surface drainage from the eastern portion of the site flows into Lake Law, DUSAF Pond and the AE Sea (Fig. 5). The chlorinated effluent from the

Village sewage treatment plant oxidation pond (H3 in Fig. 5) also flows into DUSAF Pond. These lakes and ponds are accessible to the public, and they are the head waters of Ferry Creek.

3.4.2.4 Tests for Pollutants

Semi-annual tests are made of water samples taken where the three creeks leave the site (Fig. 5), as well as from Casey's Pond and the Fox River. Results for 1980 are found in Table 3. Tests for fecal coliform bacteria are made monthly in our water laboratory.

TABLE 3

Site Wide Water Quality Report For CY-1980

	pH		DO mg/ℓ		BOD5 mg/ℓ		Susp. Solids mg/ℓ		Fecal Coliform # per 100 mℓ	
	April	Oct	April	Oct	April	Oct	April	Oct		
Ferry Creek	8.3	8.1	11.3	9.5	7.0	5.5	29.0	23.0	High Ave Low	226 45 0
Kress Creek	8.0	7.9	9.6	9.9	1.6	6.9	14.0	2.0	High Ave Low	226 86 0
Indian Creek	8.1	8.1	9.6	10.4	0.7	7.3	9.0	24.0	High Ave Low	360 104 0
Casey's Pond	8.3	8.3	10.2	10.0	8.7	7.4	13.0	16.0	High Ave Low	100 21 0
Fox River	8.8	8.6	9.8	11.6	8.0	5.1	25.0	38.0	High Ave Low	340 46 0

1980

3.4.3 Sewage Treatment

An authorization permit to discharge under the National Pollutant Discharge Elimination System (NPDES) has been obtained for the Village Oxidation Pond (H3 in Fig. 5). Monthly testing results for 1980 are in Table 4.

TABLE 4

Village Sewage Treatment Plant

Monthly Averages Report for CY-1980

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
pH	7.8	7.9	8.2	8.0	8.0	7.8	8.7	8.8	8.0	8.3	8.1	8.6
BOD5 mg/ℓ	8.0	8.3	8.8	8.5	8.6	1.6	8.8	7.1	5.6	5.7	5.9	4.7
Suspended Solids mg/ℓ	4.0	12.0	25.0	19.0	6.0	4.5	29.5	18.0	9.0	11.5	16.0	22.0
Fecal Col. #/100 mℓ	0	0	0	0	0	0	0	0	0	0	0	0

The Main Site sewer system was hooked into the City of Batavia system June 26, 1979 and has been delivering sewage to the Batavia sewage treatment plant since that time.

The NPDES permit for the Village sewer system was renewed by IEPA in 1979 and the limits for 30 days average BOD5 and suspended solids were reduced from 30 mg/ℓ and 37 mg/ℓ to 10 mg/ℓ and 12 mg/ℓ, respectively. Subject to the limits of the new permit, the Village system exceeded the limits for suspended solids, six times in CY-1980, in spite of treatments with Aquazine to control algae. Part of the increase in suspended solids is believed to be associated with infiltration of rain water run-off. A program has begun to reduce that infiltration. Repair and/or raising of 44 manhole casings was completed in CY-1980.

3.4.4 Chemical Treatment of Water Systems

Chemical treatment of our various water systems is required each year to control the growth of algae and aquatic weeds. Only EPA registered agents are administered by trained personnel following the manufacturer's directions.

3.4.4.1 Dalapon

Dalapon was used to treat drainage ditches for control of cattail growth. Applications were made to ditches in the external experimental areas and along the Main Ring Road inside the main accelerator. A total 327 kg (720 lb) was applied to an estimated 24 km (15 mi) of drainage ditches.

3.4.4.2 Chlorine

In addition to the routine chlorination of the domestic water systems, the swimming pool and the Village Oxidation Pond, a new chlorination system for the Swan Lake cooling pond system has proved successful in helping to eliminate the need for chromate treatment of the cooling towers. Chlorine is added to the cooling water for a period of 30 minutes four times a day at a rate which results in a chlorine concentration of 0.5 ppm as the cooling water leaves the equipment.

3.4.4.3 Aquazine

As previously mentioned, it was necessary to treat the Village Oxidation Pond to control algae growth and reduce suspended solids. The pond

was treated a total of four times in CY-1980, following the manufacturer's application instructions. The quantity of Aquazine used each time was 68 kg (150 lbs).

3.4.5 Heavy Metals and Other Toxic Materials

The continued success of the Swan Lake cooling pond system again made it possible to eliminate the use of chromates in 1980. Although it was necessary to use the cooling towers during the warm summer months, it was not necessary to treat the towers and thus no chromate compounds were pumped into the Main Ring tile field.

Continued testing for chromate, copper and zinc from various waters and wells was conducted in 1980. Results of these tests are shown in Table 5.

TABLE 5

Heavy Metal Analyses for CY-1980

Location and Date	Copper mg/ℓ	Zinc mg/ℓ	Chromium (hexavalent) mg/ℓ
Sample Date - April 23, 1980 - Well No. 45	0.011	3.51	< 0.01
Sample Date - August 8, 1980 - Central Utility Building Regen. Sample No. 4	0.299	0.269	< 0.02
Sample Date - September 26, 1980 - Well No. 45	0.020	.67	< 0.05
Sample Date - December 17, 1980 - Ditch at the Meson Hill Water at R-5 (Fig. 5)	0.020	0.020	< 0.05
Sample Date - December 19, 1980 - Village Well	0.017	0.109	< 0.01
Sample Date - December 19, 1980 - DUSAF Pond at H-10 (Fig. 5)	0.020	0.015	< 0.01
Main Ring Pond C-4 at H-6 (Fig. 5)	0.003	0.010	< 0.01
Well 55	0.006	0.114	< 0.01
Well 17A	0.006	0.849	< 0.01

It should be noted that Well #45 tested above the limit for zinc in April 1980 but was below when retested in September. This well is sampled but not in use otherwise. All other waters and wells are within standards set by the IEPA for waters in general use. (See Section 5).

During 1980 there were several instances where small polychlorinated biphenyl (PBC) spills occurred, resulting from leakage or capacitor failure. In one case, a vehicle damaged the cooling fin on a transformer whose oil contained greater than 500 mg/ℓ (parts per million) PCB. Approximately 8 ℓ (2 gal) of liquid spilled before the leak was sealed. First efforts to clean up the spill gave a residual PCB level of 380 mg/ℓ. Results have not yet been received following the second attempt. This transformer is located at the D1 Service Building (near DO in Fig. 5). The liquid spilled into the gravel hardstand and did not reach any water course.

Analyses were made of oil from 85 transformers on site in CY-1980 whose PCB content was unknown. Fifteen were found to contain PCB concentrations greater than 50 mg/ℓ (ppm). The highest concentration reported was 6865 mg/ℓ (ppm). The samples were collected by Power Transformer Services, Inc., Box 232, Somers, Wisconsin 53171 and the analyses performed by Associated Analysists, 11515 W. North Avenue, Milwaukee, Wisconsin 53226.

A spill of ethylene glycol (10% solution in water) occurred in the Proton Area in July while the water from the area was flowing into Casey's Pond rather than off the site. The total amount of ethylene glycol released was 380 ℓ (100 gal). No ethylene glycol was detected in a sample of pond water taken several months later, indicating that it had biodegraded.

Sampling of silt and run-off water was done in CY-1980 for fields treated with pesticides. The locations sampled were R8, R9, R10, R11, and R12 in Fig. 5. A concentration of 3000 ppm was found in a silt sample analyzed for Aatrex 80W. No environmental impact is expected. See Section 3.5.3.1. Analyses were made for eight other pesticides including 2,4D. Not one of these was detected. The detection limit for 2,4D was 10 ppm and the detection limit for the other pesticides was 100 ppm. The analyses were performed by Gabriel and Associates, 1814 North Marshfield, Chicago, Illinois 60622.

3.5 Environmental Impact

3.5.1 Assessments of Potential Radiation Dose to the Public

Fermi National Accelerator Laboratory is located in the densely populated Chicago Area. There are about eight million people living within 80 km (50 mi) of

the site.[16] There are approximately 350,000 people within 16 km (10 mi) of the center of the main accelerator based on the preliminary 1980 census results compared to 265,677 counted in the 1970 census.[17] The detailed distribution of population as a function of distance and direction from Fermilab is not yet available for the 1980 census. Thus, the distribution from the 1970 census was used and corrections made based on the information available from the 1980 census.[18]

The dose rate at the site boundary from Fermilab operations was essentially all from airborne radioactivity in CY-1980 along the northeast boundary. The distribution of airborne radioactivity was almost isotropic.

The radiation exposure to the general population from operation of Fermilab in CY-1980 was about 1.2 person-rem. Approximately 1 person-rem was from airborne radioactivity (^{11}C). The exposures are given in Table 6.

TABLE 6

Summary of Population Exposures for CY-1980

Within an 80 km (50 mi) Radius of Fermilab

Source	Contribution to Population Exposures (person-rem)
Airborne Radioactivity from Neutrino Area	1.0
Gamma Rays from Lab 7*	0.2
TOTAL	1.2

*On-site exposure to individual members of the general population assuming 24 hour per day occupancy. Gamma rays from the Boneyard made a negligible contribution this year.[4]

1980

The exposure from muons was determined by starting with the dose to an individual at the site boundary and calculating dose versus distance from the point on site where the penetrating radiation (Section 3.1) originated to 80 km (50 mi) from the site using the inverse square of the distance and summing over the appropriate numbers of individuals.

The exposure from airborne releases was calculated starting with the 1.0 mrem per year dose rate at the site boundary obtained using the Gaussian plume diffusion model and determining dose versus distances out to 80 km (50 mi) from the site including ^{11}C decay.

The site boundary dose rate was calculated for a given one of the 16 sectors for which population data was available from the 1970 census. The source term used was the concentration and rate of flow from the Neutrino Area Labyrinth Stack. The average wind speed for the year was used rather than the detailed speeds and directions at a set of given times. The contributions from adjacent sectors were added since the distances to the site boundaries were large enough to result in diffusion across sector boundaries. Since most of the exposure occurred within 16 km (10 mi)

from the site, the result based on the distribution of population from the 1970 census was increased by 30 percent based on the growth since 1970 reflected in the preliminary 1980 census results for this region.

Several of the closed loop cooling systems are reaching levels where potential off-site releases, from these loops, would be detectable but not hazardous. Some off-site release of radioactive water occurred while Casey's Pond (H4 in Fig. 3), the reservoir receiving water from discharges in the three external areas to which protons are delivered, was full. The mean concentration of tritium during the period of release was less than one percent of the Concentration Guide for uncontrolled areas. Also, drinking water in the area is taken from wells rather than from the creek receiving the discharge. Hence, the dose from the release is negligible.

3.5.2 Assessment of Nonradioactive Pollutant Releases

Although it was necessary to chemically treat some waters to control the growth of algae and weeds during CY-1980, these treatments have been kept as low as possible in order to protect wildlife and fish. The application of these chemicals was at levels well

within guidelines established by the State of Illinois. No deleterious effects on off-site waters were expected or observed (based on sampling of the waters leaving the site). The Swan Lake Ponding System (Section 3.4.2.2) has been successful in eliminating the need for chromate treatment and subsequent disposal.

There was no significant environmental impact resulting from the operation of the magnet debonding oven (Section 3.4.1). There were no other activities during CY-1980 which created problems with respect to non-radioactive airborne effluents. Heating is accomplished by use of natural gas, liquefied propane gas, or electricity. The bulk of the heating is supplied by natural gas fired boilers located in the Central Utilities Building. The effluents from these boilers are analyzed annually to maintain proper combustion efficiency. Small spills of hazardous materials continued to occur from time to time, but these were cleaned up and no significant environmental impact has resulted. There was one on-site discharge of ethylene glycol into Casey's Pond in CY-1980 with negligible impact.

3.5.3 Potential Impact of Other Toxic Substances

3.5.3.1 Pesticides

In addition to the water treatments mentioned in Section 3.4.4, the following EPA registered herbicides, insecticides and rodenticides were applied by trained personnel following the manufacturer's instructions:

PRAMITOL 25E, in 20% solution, was sprayed on approximately 20,000 m^2 (five acres) to control weed growth around service buildings, air conditioner pads, parking lots, hardstand (gravel) areas, and electrical substations throughout the site. A total of 379 ℓ (100 gal) was applied during 1980.

Instead of 2,4D Amine which was applied in previous years for control of noxious weeds, in CY-1980 a different 2,4D product called Decamine (EPA Registration No. 677-276-AA) was used. Also, spraying was done on only 0.24 km^2 (60 acres)

instead of the 10 km^2 (2500 acres) sprayed in CY-1979. Decamine and MCPP (EPA Registration No. 359-539-AA) were applied in equal amounts 1.9 ℓ (4 pints) each in 76 ℓ (20 gal) of water per 4,000 m^2 (1 acre). A total of 114 ℓ (30 gal) of each pesticide was used for control of weeds in the turf of the Village, farm sites, Wilson Hall, and external experimental areas.

Corn was planted on 9.72 km^2 (2403 acres) by licensees who applied pesticides and fertilizers. These pesticides (herbicides and one soil insecticide) and their application rates were approved by a land management consultant hired by Fermilab. The approved soil insecticide (COUNTER-15G) was applied to 5.63 km^2 (1390 acres) at the rate of 3.2 kg/4000 m^2 (7 lbs/acre). See Table 7.

TABLE 7

Pesticides Applied by Corn Plot Licensees

Plot Size		Pesticide	Total Applied in CY-1980	
(km^2)	(acres)		(kg or ℓ)	(lbs or gal)
0.675	167	Bladex	150 kg	330 lbs
0.675	167	Atrazine	882 kg	1940 lbs
3.42	846	Atrazine		
3.42	846	Lasso	800 ℓ	211 gal
5.63	1390	Aatrex 80W	1260 kg	2780 lbs
5.63	1390	Sutan Plus 6.7E	2630 ℓ	695 gal
5.63	1390	Counter 15G	4420 kg	9730 lbs.

Sampling was done in CY-1980 for residues of 2,4D, Bladex, Atrazine, Aatrex 80W, Sutan Plus, Counter 15G, Pramitol, Diquat (used in previous years) and Roundup (used in previous years) mentioned above. See Section 3.4.5. No evidence was found for any environmental impact. A concentration of 3000 ppm of Aatrex 80W was found in a silt sample taken in a

cornfield on November 26, 1980. Destruction of Aatrex 80W is accelerated by moist warm soil conditions. Thus, over a two year period with such conditions from time to time, Aatrex 80W concentrations would be expected to decrease to the few ppm level or lower.[21]

For mosquito control, an ultra low volume application of CYTHION Premium Grade Malathion was performed at 19 different times. Approximately 15 ℓ (4 gal) of CYTHION were used in each application and the following areas were covered: Village and Sauk Circle just south of the Village (Fig. 3), Sites 29, 38 and 43 (W29, W38, and W43 in Fig. 3), the Meson, Proton and Neutrino experimental areas (Fig. 1), and the Industrial Areas (near W43 in Fig. 3).

EATON's AC Formula 50, a rodenticide, was placed in pan-type feeders inside approximately 40 outdoor electrical substations to reduce rodent nesting in this high voltage equipment. Approximately 1.8 kg (4 lbs) was used in CY-1980.

The services of a contract exterminator, licensed by the State of Illinois and using EPA registered pesticides, was retained during 1980 for the control of miscellaneous pests found in kitchens, laboratories and living areas throughout the site.

3.5.3.2 Polychlorinated Biphenyls

An inventory of polychlorinated biphenyls (PCBs) is maintained, and a Status Report as of January 1, 1980 listed 11 pure askarel-filled transformers, 62 contaminated transformers and 4470 large capacitors in use or storage for future use. These PCB items have been labeled as required.

There are four askarel-filled transformers in service without secondary containment (curbing) and one spare without curbing. In addition, 61 Main Ring Pulse Power Supply transformers contain from 1% - 9% PCBs and are classified as PCB transformers. None of these have containment curbing. There is a plan to reduce PCB levels to less than 50 ppm in these 61 transformers in approximately five years.

In addition, 15 oil-filled transformers of the 85 recently tested contain greater than 50 ppm PCB. It

is apparent that the removal and disposal of PCBs from transformers site wide is a significant problem and its solution will be costly.

3.5.3.3 Hazardous Wastes

Significant progress was made during 1980 with respect to identification, collection and disposal of hazardous waste in an environmentally acceptable manner. Responsibility for this program was assigned to the Safety Section in CY-1979 and, as mentioned in a preceeding section, a hazardous waste handling and storage facility was developed at Site 55 (W55 in Fig. 3). This facility is roofed and fenced, has hardstand and a concrete containment area. An additional facility with concrete containment area for PCBs was developed at Site 3 where the Environmental Monitoring Station is located (Fig. 3). This facility is for inside storage of hazardous materials which are for future use.

Over the years it has been the practice to deposit excess materials such as lumber, concrete, building materials and earth on the Meson Area shielding hill. To assure that none of these materials are hazardous to the environment and none will contribute to

the contamination of surface or ground waters, a program to control such deposition was developed during 1979. Rules have been promulgated and responsibility for access and control has been assigned to the Roads and Grounds group. The Safety Section monitors this program.

Transite containing asbestos was placed on the Meson Area Hill by mistake in CY-1980. Essentially all of it was recovered and will be disposed of by burial in an approved landfill. The silt in the ditch at the bottom of the hill was tested for asbestos and none was found at a detection limit of 1 ppm. Analysis was performed by Gabriel and Associates, 1814 North Marshfield, Chicago, Illinois 60622.

4. Quality Assurance in CY-1980

Water samples were analyzed by Eberline, Midwest Facility, 245 Roosevelt Road, West Chicago, Illinois 60185, for radioactivity. In addition, such samples were counted at the Fermilab Nuclear Counting Laboratory. Tritium and ^{45}Ca analyses were done only by Eberline since Fermilab does not have the necessary liquid scintillation counting system. Each monthly shipment to Eberline included at least one sample prepared at Fermilab containing known amounts of several of the accelerator-produced radionuclides. Tritium was included every month.

Fermilab and Eberline also analyzed samples received from the DOE Environmental Measurements Laboratory (EML) as part of a quality assurance program. The results obtained are shown in Table 8.[19] The agreement between EML, Fermilab, and Eberline results was within the precision specified by Fermilab for Eberline analyses. See Table 9.

Analyses for chromate, copper, and zinc from surface waters and wells was performed by Aqualab, Inc., Streamwood, Illinois 60103. Quality assurance samples from EML were sent to Aqualab for heavy metals analyses. The two water samples contained copper and zinc but no

TABLE 8

Comparison of Water Analyses

Sample Date	Radio-nuclide	Environmental Measurements Laboratory Results (μCi/mℓ) (x 10^{-6})	Percentage of Concentration Guide for Surface Waters (%)	Fermilab Results (μCi/mℓ) (x 10^{-6})	Eberline Results (μCi/mℓ) (x 10^{-6})	Mean Value for all Participants in Quality Assurance Program (μCi/mℓ) (x 10^{-6})	Percentage of Participants Outside Ratio Range 0.8-1.2
04/80	^{3}H	10.3	1		10 9 10	10.0*	18
10/80	^{3}H	14.9	1		14 13 13	14.7	32
04/80	^{22}Na	1.07	11	1.0	0.9 1.0	1.07	18
04/80	^{60}Co	0.922	9	0.915	0.8 1.0	0.917	20
10/80	^{60}Co	1.97	20	1.86	2.0 2.1 2.1	1.93	17

*Three results excluded out of 17 submitted

TABLE 9

Specifications For The Analyses Of

Accelerator-Produced Radionuclides In Water

Radionuclide	CONCENTRATION GUIDE FOR POPULATION			SPECIFIED SENSITIVITY AND PRECISION*	
	Individual (μCi/mℓ)	Suitable Sample (μCi/mℓ)	Community Water System	Surface Water (μCi/mℓ)	Ground Water (μCi/mℓ)
^{3}H	3×10^{-3}	1×10^{-3}	2×10^{-5}	3×10^{-6}	1×10^{-6}
^{7}Be	2×10^{-3}	6.7×10^{-4}	1.3×10^{-5}	5×10^{-7}	5×10^{-7}
^{22}Na	3×10^{-5}	1×10^{-5}	2×10^{-7}	3×10^{-7}	2×10^{-8}
^{45}Ca	9×10^{-6}	3×10^{-6}	6×10^{-8}	3×10^{-7}	6×10^{-9}
^{54}Mn	1×10^{-4}	3.3×10^{-5}	6.7×10^{-7}	1×10^{-7}	7×10^{-8}
^{60}Co	3×10^{-5}	1×10^{-5}	2×10^{-7}	1×10^{-7}	2×10^{-8}

* The precision and sensitivity are stated for the 68% confidence level (one standard deviation). The precision required is the value specified or ± 10 percent, whichever is the lesser precision. The sensitivity is taken to be the minimum concentration which can be detected within the 68 percent confidence level.

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chromium. Aqualab reported that the sample contained no chromium at a detection limit of 0.01 mg/ℓ (ppm). Aqualab reported copper and zinc results within 20 percent of the EML value for the first sample and within ten percent of the EML value for the second sample. Concentrations in the quality assurance samples were just above the discharge limit of 1 mg/ℓ permitted by the State of Illinois. The concentration permitted for zinc in waters for general use is also 1 mg/ℓ (Section 5); hence, the concentrations represented a good test for zinc. The concentration permitted for copper in waters for general use is 0.02 mg/ℓ. See Section 5. Therefore, a quality assurance sample with lower copper concentration would have resulted in a better test.

Quality assurance samples are needed, also, for PCB analyses. We have sent split samples to Associated Analysts, 11515 W. North Avenue, Milwaukee, Wisconsin 53226 and Gabriel and Associates, 1814 North Marshfield, Chicago, Illinois 60622. Associated Analysts results were higher than Gabriel and Associates, as shown in Table 10.

TABLE 10

Results of PCB Analyses

Sample Description	Associated Analysts Reported PCB Concentration (ppm)	Gabriel and Associates Reported PCB Concentration (ppm)
IB2 Transformer	1120 and 986	720
Giese Road Transformer	479	270
Oil from Main Ring Transformer	20,900	9,400
UD2 Transformer	2.4	1

5. References

The appropriate Radiation Protection Standard for penetrating radiation applied to individuals in uncontrolled areas was taken from the DOE Manual, Chapter 0524, Paragraph II.A. The annual dose for whole-body exposure is 0.5 rem when applied to a suitable sample of the exposed population.

The Concentration Guides used in the analyses of the surface water samples for radioactivity were taken from the DOE Manual, Chapter 0524, Annex A, Table II, Column 2 (Water in Uncontrolled Areas) and reduced by a factor of three where appropriate for a suitable sample of exposed population. The smaller of the values given for soluble and insoluble forms has been used in each case. The specifications are given in Table 9. The Concentration Guides for airborne activity were taken from the same source, Table II, Column 1 (Concentrations in Air in Uncontrolled Areas), and divided by a factor of three for determining the total off-site potential dose to the public. For tritium the Concentration Guide from Table II, Column 1, is 2×10^{-7} μCi/mℓ. For ^{11}C the Concentration Guide, 2×10^{-8} μCi/mℓ, was taken from the calculation by Yamaguchi.[11]

The Concentration Guide used in the analyses of ground water samples for tritium were taken from the U. S. Environmental Protection Agency regulations for community drinking water systems 40CFR141. The maximum contamination level permitted for tritium is 2×10^{-5} μCi/mℓ and corresponds to an annual exposure of 4 mrem if one uses the supply as one's sole drinking water source. Note that this is 50 times more stringent than the DOE regulation for a suitable sample of the general population which corresponds to 170 mrem/year. The Concentration Guide for the other radionuclides in Fermilab's analyses of ground water samples have been determined by dividing the surface water concentrations for a suitable population sample by 50 (Table 9). The specified sensitivity and precision of the analyses have been reduced to well below these Concentration Guides.

A new type of analysis was added this year for Fermilab's public water supplies. In addition to analyses at ground water sensitivities for accelerator-produced radionuclides, gross alpha and gross beta analyses were added.*

*Required only for community water systems.[20]

The purpose was to search for naturally occurring activity and nuclear weapons test fallout products. The maximum contaminant level for combined ^{226}Ra and ^{228}Ra is 0.005×10^{-6} μCi/mℓ. Therefore, a report of alpha activity of $(0.003 \pm 0.003) \times 10^{-6}$ μCi/mℓ in the Village water supply sample (V in Fig. 3) led to an analysis specifically for ^{228}Ra and ^{226}Ra. Neither was found at a detection limit of 0.001×10^{-6} μCi/mℓ.

The Air and Water Pollution Standards for non-radioactive pollutants were taken from Chapters 2 and 3 of the State of Illinois Pollution Control Board Rules and Regulations. The waters on site were considered to be in the "general use" category. The values for total hexavalent chromium for general water quality is 0.05 mg/ℓ. The Standards for total copper at the discharge point and for general water quality are 1.0 and 0.02 mg/ℓ respectively, and for zinc are both 1.0 mg/ℓ for surface water and for well water. The Air Quality Standards limit the releases for SO_2 and oxides of nitrogen to 816 g (1.8 lbs) and 136 g (0.3 lbs) respectively, per 252 million calories (per million btu's) of actual heat input in any one hour.

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