Fermi National Accelerator Laboratory
P.O. Box 500, Batavia, Illinois 60510

Fermilab 90/51
1104.100
UC-41

Site Environmental Report

For Calendar Year 1989

May 1, 1990

J. D. Cossairt

Operated by Universities Research Association, Inc.
Under Contract with the United States Department of Energy,
Chicago Operations Office, Batavia Area Office

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FOR CALENDAR YEAR 1989

by

J. Donald Cossairt, Editor

May 1, 1990

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1. Introduction

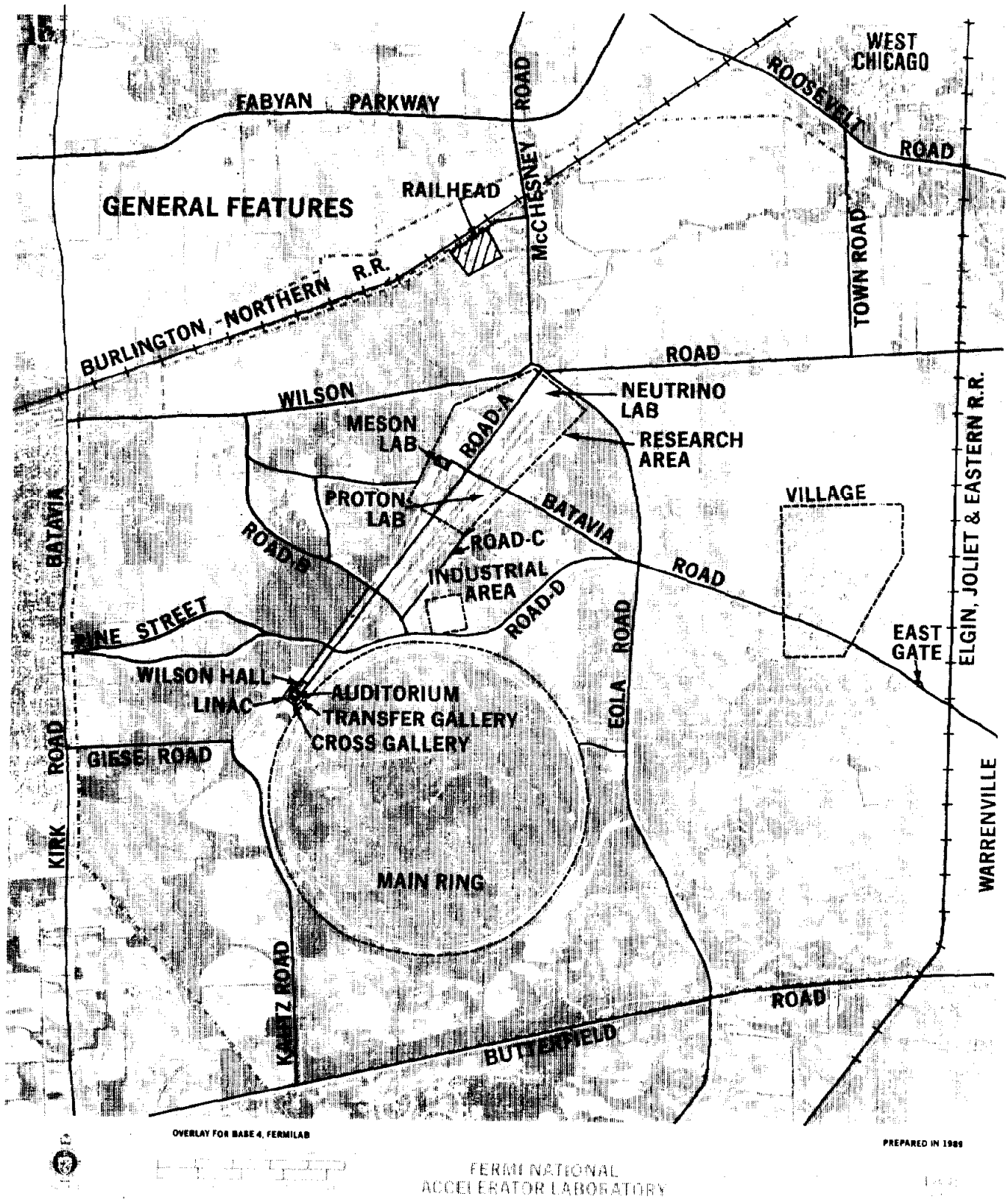
This report summarizes the environmental activities and their results at Fermi National Accelerator Laboratory (Fermilab) for Calendar Year (CY-) 1989.

The facility consists of a series of proton accelerators which became operational in 1972, producing higher energy protons than any other accelerator. As a result of accelerator improvements, the original design energy of 200 GeV (billion electron volts) was gradually raised and operation at 400 GeV was routine between 1976 and 1982 using conventional magnets. Then a ring of superconducting magnets was added which doubled the energy while using less electrical power.

The primary purpose of the installation is fundamental research in high-energy physics. Up to 1986 this research was performed by extracting protons from the final accelerator (now a synchrotron using superconducting magnets). These protons were directed onto fixed targets after being extracted from the superconducting synchrotron called the TEVATRON. Colliding beam studies, collisions of protons and antiprotons each having 900 GeV, were conducted for the first time in 1987. These collisions were detected at four locations inside the TEVATRON. In addition, cancer patients are being treated using neutrons released by the interactions of 66 MeV protons from the Linac (linear accelerator), the second stage of the series of accelerators.

When the proton beam is extracted for fixed target physics from the 2 km (1.2 mi.) diameter main accelerator, the protons are delivered to three different experimental areas on-site. These are the Meson, Neutrino and Proton Labs located in the Research Area (Fig. 1). These three areas received proton beams for the first time in 1972 when extraction of protons from the accelerator was achieved. For colliding beam studies, antiprotons are produced by extracting 120 GeV protons from the ring of conventional magnets inside the main accelerator tunnel. These protons strike a fixed target and the negatively charged antiprotons are collected. Radioactivity is produced as a result of the interaction of the accelerated protons with matter. Operation of the accelerator produces some airborne radioactivity as well as some radiation which penetrates the shielding material. Also, some radioactivation occurs in the water used to

FIGURE 1


GENERAL FEATURES
FABYAN PARKWAY
RAILHEAD
McCHESNEY ROAD
WEST CHICAGO
ROOSEVELT ROAD
TOWN ROAD
BURLINGTON NORTHERN R.R.
WILSON ROAD
NEUTRINO LAB
MESON LAB
ROAD-A
RESEARCH AREA
PROTON LAB
BATAVIA ROAD
VILLAGE
ROAD-B
ROAD-C
INDUSTRIAL AREA
ROAD-D
EOLA ROAD
PINE STREET
EAST GATE
ELGIN, JOLIET & EASTERN R.R.
WILSON HALL
LINAC
AUDITORIUM
TRANSFER GALLERY
CROSS GALLERY
KIRK ROAD
GIESE ROAD
MAIN RING
KAUTZ ROAD
BUTTERFIELD ROAD
WARRENVILLE
OVERLAY FOR BASE 4, FERMILAB
PREPARED IN 1969
FERMI NATIONAL ACCELERATOR LABORATORY

cool beam components and in the soil around the accelerator tunnel and external beam lines. A thorough evaluation has been made of the on-site discharges as well as the potential for off-site releases of radioactive and nonradioactive effluents. An extensive monitoring program is being carried out to verify that radiation exposures as well as nonradioactive releases are far below the permissible 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 vicinity, resulting in a distinct pattern of increasing population concentration eastward toward Chicago (Fig. 3). Within a 3 km (2 mi.) distance from the Laboratory boundaries, Batavia (pop. 15,697) (Si90), Warrenville (pop. 9,300) (Re90), and West Chicago (pop. 13,200) (Re90) can be found (Fig. 2).

The two major environmental features near the Laboratory are the Fox River to the west, and the west branch of the DuPage River which passes east of the site. The Fox River flows south through Batavia with an average of 1529 million liters (404 million gallons) per day from October 1, 1988 through September 30, 1989. The west branch of the DuPage River flows south with an average of 203 million liters (54 million gallons) per day for the same period through Warrenville (Fig. 2) (Du90). The rainfall on-site during 1989 was 66.04 cm (26.00 in) (Il90). The land on the site is relatively flat as a result of past glacial action. The highest area, with an elevation of 244 m (800 ft) above mean sea level (MSL) is near the western boundary. The lowest point, with an elevation of 218 m (715 ft) above MSL is toward the southeast. The drainage of the groundwater 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 wells usually drilled 360 m (1200 ft) deep into the Cambrian-Ordovician aquifer system (Sa82). Also, there are many individual private wells drilled into the shallow silurian aquifer system around 30 m (100 ft) below the surface.

The primary source of drinking water on the Fermilab site is the shallow Silurian dolomite aquifer (Sa82). Wells 1 and 3 (Fig. 4) are the main wells and

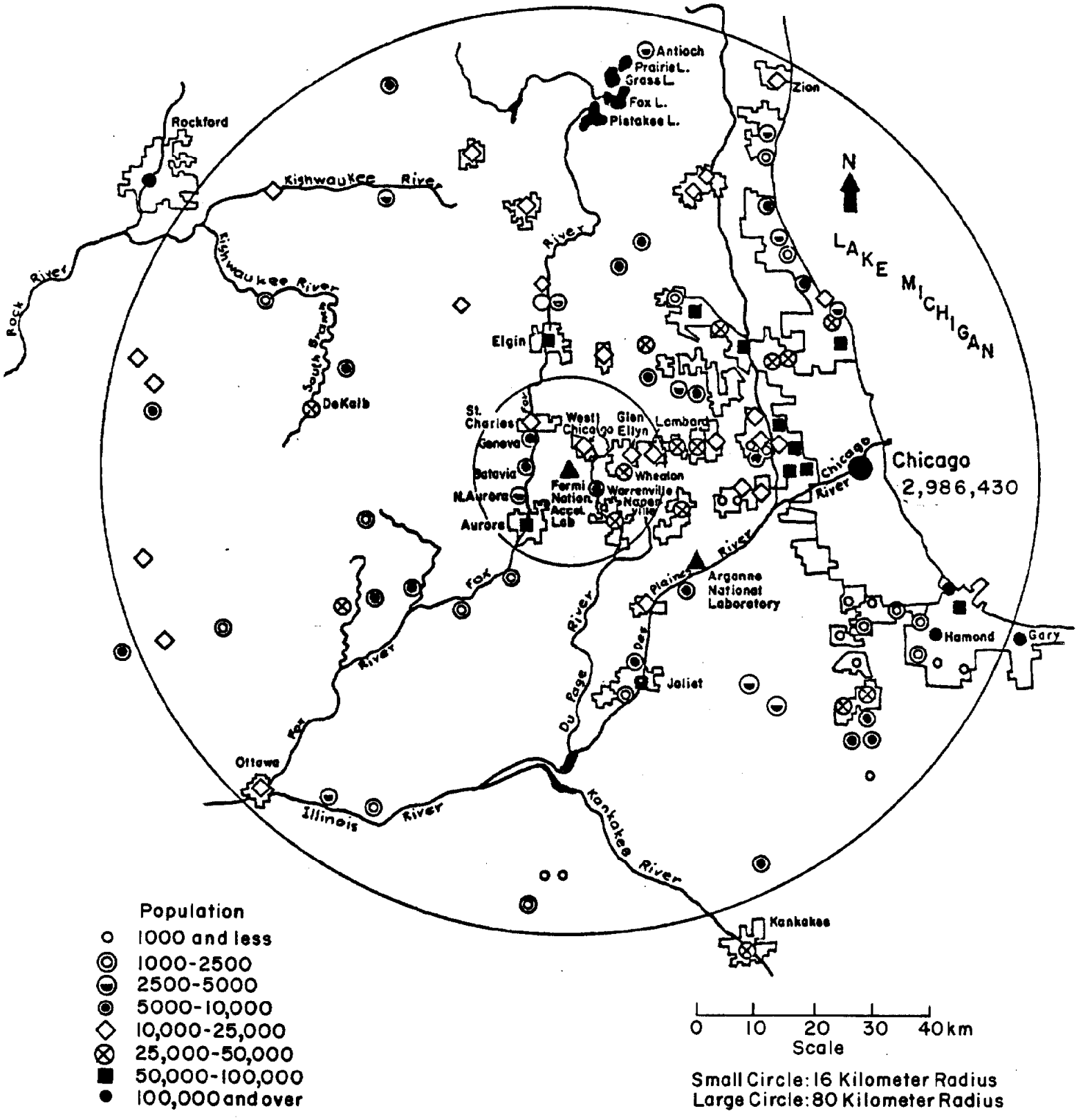
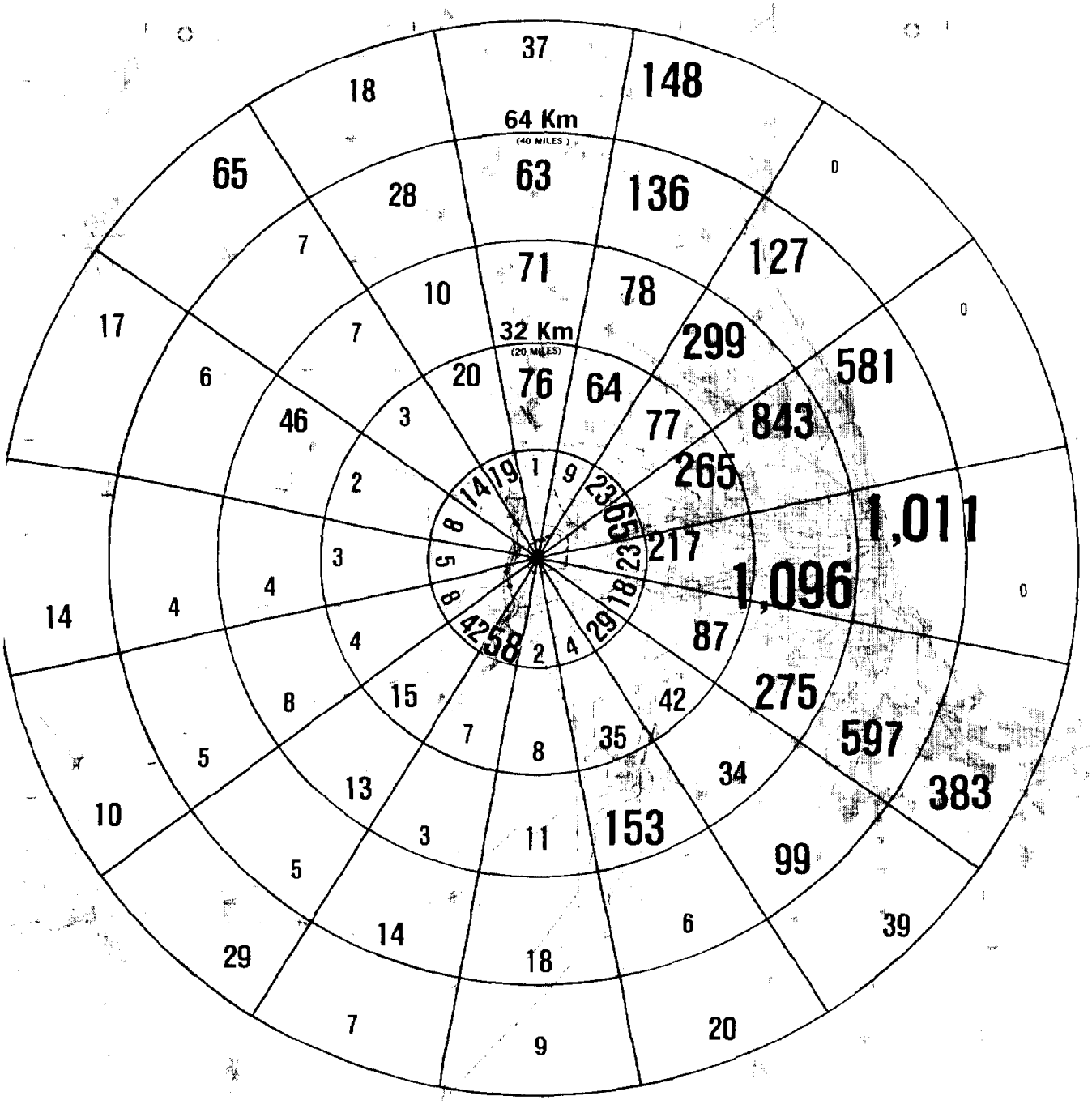


Figure 2 - Location of Fermilab and Population Concentrations within 80 km (50 mi.)

1979

FIGURE 3



NOTE: NUMBERS REPRESENT NEAREST 1000.

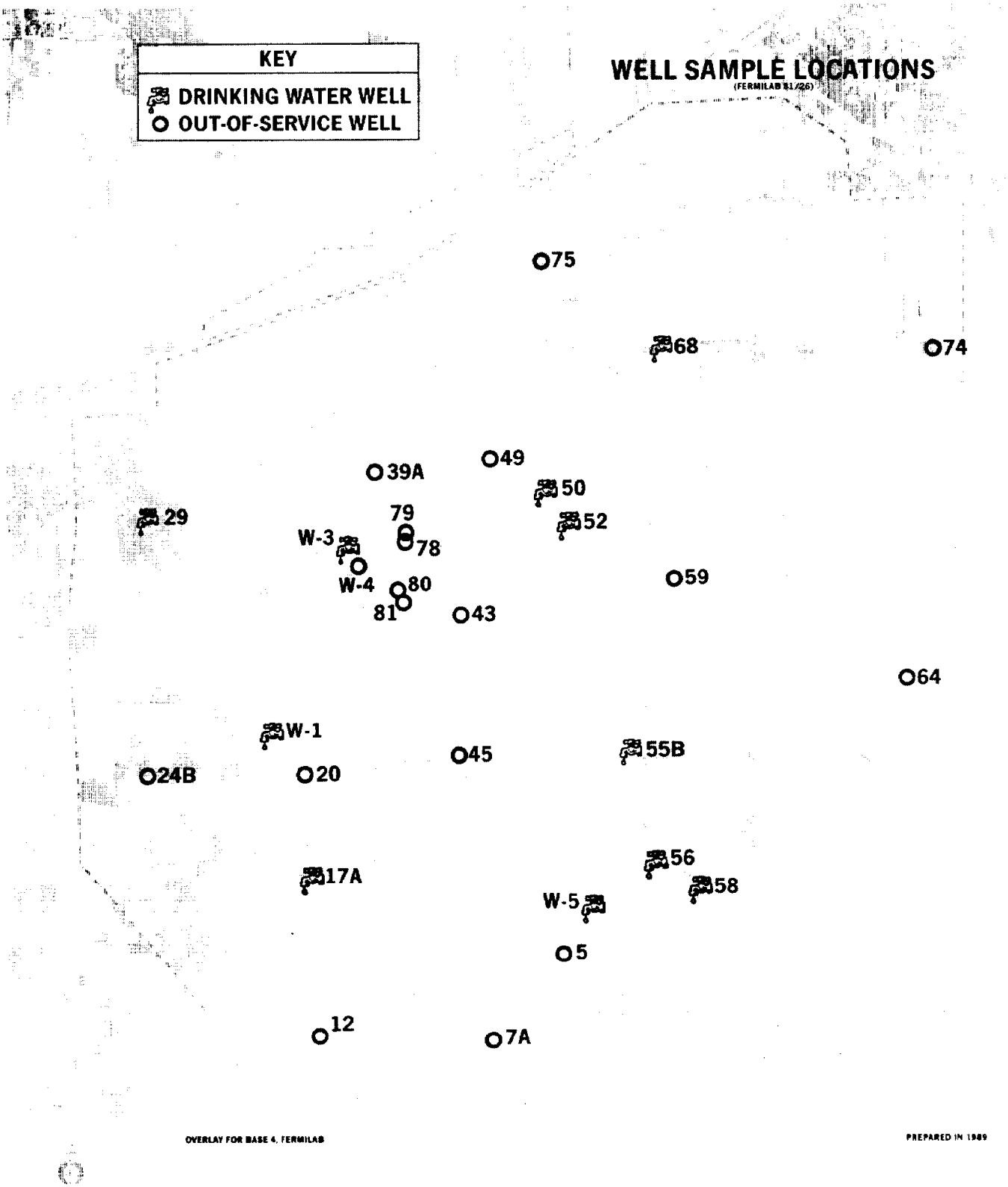
POPULATION DISTRIBUTION - 1980
(1980 CENSUS)

OVERLAY FOR BASE 1, FERMILAB

REGIONAL AREA SURROUNDING FERMI NATIONAL ACCELERATOR LABORATORY

PREPARED IN 1982
DOE

FIGURE 4


KEY
DRINKING WATER WELL
OUT-OF-SERVICE WELL
WELL SAMPLE LOCATIONS
(FERMILAB 81/26)
75
68
74
49
39A
50
29
79
52
W-3
78
W-4
80
59
81
43
64
W-1
45
55B
24B
20
56
17A
58
W-5
5
12
7A
OVERLAY FOR BASE 4, FERMILAB
PREPARED IN 1989

collect water from 20 to 70 m (65 to 220 ft) below the surface. Water for the Village (Fig. 1) was obtained from Warrenville to the east beginning in January 1987 and service from Well 62 in the Village (Fig. 5) was terminated at that time. A new well (W-5 in Fig. 4) went into service the end of November 1988, supplying drinking water to the new colliding beam facility at D0. The rainfall collected in ponds on the site are used for cooling the accelerator and some experimental area facilities through heat exchangers. The surface cooling water supply is augmented as necessary by pumping water from the nearby Fox River.

The land within the site boundary was primarily farm land before the State of Illinois acquired it for the DOE Fermilab site although the small village of Weston (population 380 at that time) was located on the eastern side (Fig. 1). Much of the land, approximately 9.3 km^2 (2300 acres), has remained in crop production, primarily corn. A total of 2.4 km^2 (593 acres) has been planted in native prairie vegetation to date. The village of Weston has provided residences for visiting scientists as well as support facilities for the research program.

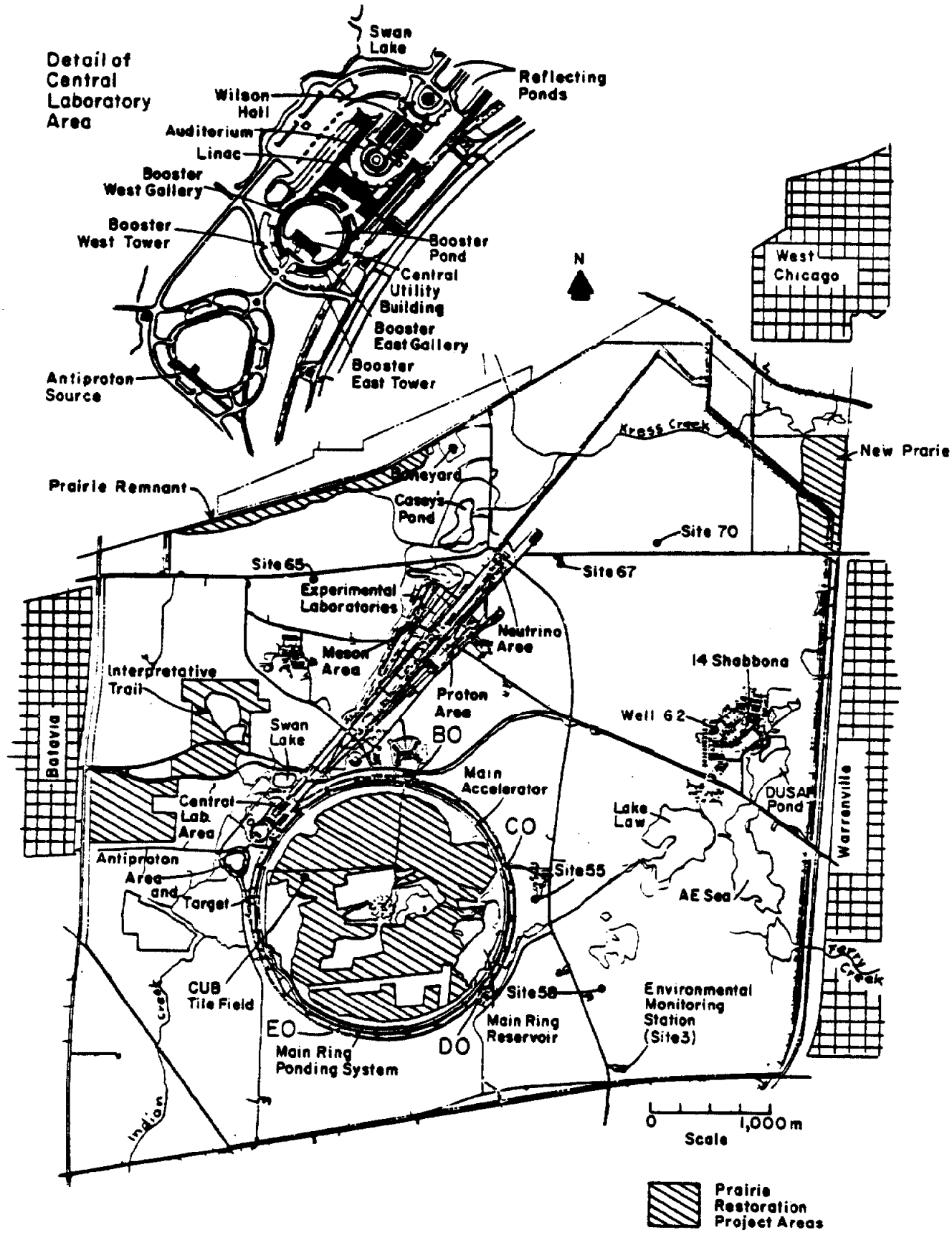
2. Summary

During CY-1989, operation of the high-energy accelerators consisted of a collider run using 900 GeV beams of protons and antiprotons. The large Collider Detector Facility (CDF) at B0, as well as smaller detectors installed at C0, D0, and E0 (Fig. 5) took data. This run began in January 1989 and ended in June 1989.

As a result of operation of the accelerator as a collider, some airborne radionuclides are released from the target station and storage rings (the Antiproton Source) used to produce the antiprotons. During CY-1989, the total release from the vent stack at the Antiproton Source (near the antiproton target in Fig. 5) was measured to be 82 Curies of ^{11}C, ^{13}N, ^{38}Cl, ^{39}Cl and ^{41}Ar.

Other sources of ionizing radiation due to accelerator operations reported in past years are due to operation of the fixed target experimental areas. These operations produce ionizing radiation in the form of both muons and airborne radioactivity. Since these areas were not operated during CY-1989, these sources of radiation were not present.

Figure 5 - Fermilab Site



1939

The maximum site boundary dose rate (fence line assuming 24 hr/day exposure) from the radioactive material stored at the Railhead (Fig. 1) was 1.1 mrem for CY-1989. The Railhead is closer to the site boundary than is the nearest house. Thus the maximum individual potential radiation exposure is lower and amounted to 0.2 mrem during CY-1989.

The total potential radiation exposure to the general off-site population from operations during CY-1989 was 1.9 person-rem (Table 6). This is lower than the estimate of 3.3 person-rem for CY-1988 due to reduced dose rates from the Railhead and the operations of the accelerator only as a collider. Since the exposure is only from penetrating radiation and short-lived airborne radionuclides, the 50 year dose commitment from operations in 1989 will be the same as the effective dose equivalent received in 1989 reported here.

A summary of off-site releases of radioactive effluents in CY-1989 is given in Table 1. The total release of airborne radioactivity was 82 Ci from venting of air containing short half-life radionuclides. The off-site release of tritium (^{3}H) in surface water totaled approximately 908 mCi, compared with 336 mCi in CY-1988 (Ba89) (see a more detailed explanation in Section 4.4.2). The increase was the result of more water leaving the site during CY-1989. Water left the site via the Kress Creek spillway for 61% of the year in 1989 compared with 51% the year before. The primary source of tritium in water reaching Casey's Pond from drainage ditches in the Research Area was tritiated water discharging from an underdrain system beneath a target and beam dump system. The target was the primary target in the Neutrino Area. The target received most of the protons accelerated by Fermilab. After the CY-1982 operating period ended, the target was moved to a new location with a different underdrain system. Thus, the tritium released in CY-1989 was essentially from operations before CY-1983.

Table 1

Summary of Radioactivity Released to the Off-Site Environment in CY-1989

Release Point	Radionuclide	Pathway	Release in Curies
AP0 Enclosure	^{11}C, ^{13}N, ^{41}Ar	Air	82
Debonding Oven	^{3}H	Air	0.0006
Kress Creek Spillway	^{3}H	Water	0.908

1989

There were no abnormal occurrences which had an impact on the facility and its operations in CY-1989.

3. Environmental Program Information

3.1 Environmental Program Description

The National Environmental Policy Act of 1969, as amended, mandates the Federal Policy to restore and enhance the environment and to attain the widest range of beneficial use without degradation. Since its inception, Fermilab has endeavored to protect and enhance the environment. For over ten years a prairie restoration project has been in progress on the 1.57 km^2 (388 acre) plot inside the main accelerator ring (Main Ring in Fig. 1). In the past several years the prairie project has been expanded to include areas outside the ring (Fig. 5). The total outside is 0.83 km^2. (206 acres). In 1989 Fermilab was designated a National Environmental Research Park. In another effort to enhance the environment, farm houses were moved from their original locations to a site at the south end of the Village (Fig. 1) and renovated to provide housing for scientists performing experiments at Fermilab rather than abandoned and allowed to deteriorate. Some farm wells were maintained for monitoring and others were properly sealed to prevent inadvertent contamination of the aquifer. Ponds and lakes were created to control surface run-off and provide cooling water for the accelerator and experimental areas. Over 40,000 trees have been planted to improve the environment. In addition, strong emphasis has been placed on the control of chemical and radioactive materials as potential sources of environmental pollution. Adequate shielding has been provided for preventing exposure from penetrating radiation.

The Fermilab environmental and effluent radiological monitoring program follows, in general, the guidance given in the Department of Energy (DOE) Order 5400.1, draft Order 5400.XY, and in the reports A Guide for Environmental Radiological Surveillance at DOE Installations (Co81) and A Guide for Effluent Radiological Measurements at DOE Installations (Co83). This includes adherence to the standards given in other existing DOE orders, in particular, parts of DOE Order 5480.1A (DOE81), Chapter XI, which pertains to permissible doses due to radioactive releases.

The emphasis has been placed on potential environmental exposure pathways appropriate to high-energy physics laboratories. These pathways include external exposure and internal exposure. The external exposure is from direct penetrating radiation and airborne, short-lived, radionuclides. The internal exposure is from ^{3}H and ^{22}Na in water, primarily potential drinking water. There is one unique characteristic at Fermilab which requires consideration. That is the use of large volumes of sand and gravel in two locations to assist in stopping the high-energy protons and secondary particles. Although the groundwater beneath these two areas is protected by membranes impervious to water and by underdrain systems to collect the water, radiological monitoring of soil and water is done to ensure that no radioactivity reaches drinking water supplies. See Section 4.4.4. Monitoring results are also reported for nonradioactive pollutants. Included as pollutants are pesticides used in weed, insect, rodent, and algae control.

3.2 Summary of Environmental Monitoring Performed in CY-1989

Fermilab performed extensive environmental monitoring in CY-1989, while the colliding beam and fixed target research programs were in progress, on three types of accelerator-produced radiation: penetrating, airborne, and waterborne. During this year of operation solely as a collider, by far the dominant source of penetrating radiation was gamma rays. The airborne radionuclides ^{11}C, ^{13}N, ^{38}Cl, ^{39}Cl, and ^{41}Ar as well as the waterborne radionuclides ^{3}H (tritium) and ^{22}Na were monitored.

For airborne effluents, due to the antiproton source, a continuously operating stack monitor recorded the concentration released from the stack emitting the radioactivity. Surface water and groundwater samples were analyzed to determine concentrations of tritium and other accelerator-produced radionuclides. The fraction of the year the water left the site was determined by weekly inspections of the Kress Creek spillway.

The data on radioactive effluents was reported to the Department of Energy via the Effluent and On-Site Discharge Information Systems operated for the Department of Energy by EG&G, Idaho.

Additional monitoring for radionuclides in soil and sediment on the site has been done to investigate other possible pathways to the off-site environment.

The results during the operations in CY-1989 were much better than the applicable standards in every case. In particular, the highest site boundary penetration radiation level was 1.5% of the relevant standard in CY-1985, negligible in CY-1986, 13% in CY-1987, 1.6% in CY-1988, and 1.1% in CY-1989. Airborne radionuclide concentrations and waterborne concentrations were below detection limits. See Section 7 for applicable standards.

Monitoring for chemical pollutants in drinking water systems on the site is done periodically. Three distribution systems were sampled in CY-1989 on a monthly basis in accordance with IEPA schedule. Overall the results indicated good water quality in all the wells sampled.

The Laboratory performs coliform tests on unchlorinated well water supplies on the site. When greater than four colonies per 100 ml are found in a sample, the well is chlorinated and subsequently retested. No fecal coliform was found in these unchlorinated supplies and none was chlorinated in CY-1989.

Creeks and ponds are sampled semiannually for pH, dissolved oxygen, biochemical oxygen demand, suspended solids, and fecal coliform (Table 4). Results met standards for waters in general use in CY-1989 except for high fecal coliform readings in Kress Creek and Indian Creek and pH in the Fox River.

3.3 Environmental Permits

The magnet debonding oven has an Illinois Environmental Protection Agency permit (I.D. No. 043807AAI, Application No. 79070012) which expires March 5, 1994. There have been no cases of noncompliance.

Fermilab has interim status under the Resource Conservation and Recovery Act (RCRA) (USEPA I.D. No. IL6890030046) to operate a hazardous waste storage facility. This status will continue until the Illinois Environmental Protection Agency has processed Fermilab's Part B application which was submitted in November 1989. The facility is in compliance with the RCRA regulations. Regulated chemical wastes are stored in the facility as well as a limited amount

of mixed waste. Typical regulated chemical wastes are hazardous wastes, polychlorinated biphenyls (PCBs), and used oil. The only drum quantity mixed waste is ^{241}Am and lead debris from a fire in 1987. Only wastes generated by Fermilab are stored at the facility awaiting proper disposal elsewhere.

Emco Wheaton coaxial vapor recovery systems have been installed on all gasoline dispensing equipment at Fermilab under a permit (I.D. No. 043807AAI, Application No. 86020057) issued by the Illinois Environmental Protection Agency (IEPA). The permit expires on February 13, 1991. There have been no compliance problems with the systems.

Fermilab has an IEPA permit (I.D. No. 043807AAI, Application No. 87110096) for three natural gas boilers at the Central Utility Building (Fig. 5), two natural gas boilers at the Wide Band Lab in the Proton Area (Fig. 5), and one propane gas boiler at Industrial Building #2 in the Industrial Area (Fig. 1). A grit blast operation at Industrial Building #2 is also included on the latter permit.

IEPA issued a permit (I.D. No. 043807AAI, Application No. 89090071) on November 28, 1989, to Fermilab for two natural gas fired hot water boilers, one each at Lab A (Neutrino Area) and the Meson Detector Building. These boilers are replacements for existing electric hot water boilers at each facility.

Fermilab has received a permit (I.D. No. 043807AAI, Application No. 88010042) for operation of a vapor degreaser at Industrial Building #3 in the Industrial Area. No permit was needed for the new septic field installed near D0 (north of W-5 in Fig. 4). It was classified as a Class 5 injection well in CY-1988. The CUB tile field (Fig. 5) is also a Class 5 injection well.

Fermilab has an IEPA air pollution control open burning permit (I.D. No. 089801, Application No. B8903024) for 200 acres heavy and 100 acres light, cover prairie for ecological management. The permit was issued March 14, 1989. It has been renewed through November 30, 1990, as of November 16, 1989. Burning occurred in the spring of 1989 on the prairie restoration project, primarily near the center of the site. Open burning was conducted in such a manner as not to create a visibility hazard on roadways, railroad tracks, or airfields. Other standard conditions for open burning were also carried out. Because of the large

size of the Laboratory property (6800 acres), the smoke from the fire caused no off-site problems.

IEPA issued a permit (I.D. No. 089801AAD, Application No. 89080089) on October 30, 1989, to Fermilab for radionuclide emissions associated with accelerator operations. The other source of radionuclide emissions at Fermilab is the debonding oven. This facility debonds failed magnets for repair by decomposing epoxy at a high temperature (800°F). A revised IEPA permit (I.D. No. 043807AAI, Application No. 79070012) was issued on November 2, 1989.

Also, IEPA issued a permit (I.D. No. 043807, Application No. B8909039) to Fermilab to allow burning of one gallon of motor fuel per session of firefighting instruction on September 26, 1989. It expired December 26, 1989.

3.4 Assessments and Impact Statements

No formal environmental assessments and no environmental impact statements were prepared in either draft or final form during CY-1989 at Fermilab. During 1989, two Memoranda-to-file (MTF's) documenting NEPA reviews of two Fermilab projects were issued by the Chicago Operations Office Manager. These projects are the Fermilab Linear Accelerator Upgrade and the Fermilab Science Education Center. The MTF's document findings that the proposed actions warrant preparation of neither an environmental assessment nor an environmental impact statement. There is also an on-going program in place to routinely evaluate new projects and modifications to existing operations and facilities to determine if there is a significant potential for impact. Also, see Section 6 for the evaluation of operations conducted in CY-1989.

3.5 Summary of Significant Environmental Activities

3.5.1 Prairie Restoration Activities

In the early 1970's Fermilab began a prairie restoration project on the 1.57 km^2 (388 acre) plot inside the main accelerator (Fig. 5). In CY-1984 some Fermilab land (0.11 km^2 or 28 acres) outside this plot was plowed and seeded with prairie plants. Since then additional prairie planting has been done (Fig. 5), resulting in a total of 0.83 km^2 (206 acres) outside the main accelerator.

In CY-1986 a small remnant of original prairie was found along the Burlington Northern Railroad tracks near the northern site boundary. In CY-1988 another remnant was found near the eastern site boundary north of Batavia Road. This remnant is near the Elgin, Joliet, and Eastern Railroad tracks. The occasional fires in the past along the railroad rights-of-way probably were responsible for the preservation of the remnants.

The Fermilab restoration is one of the largest prairie sites in the country. The harvesting of seeds is done by volunteers and by the Roads and Grounds group of the Business Services Section and the environmental aspects receive the attention of a prairie committee consisting of laboratory personnel and outside university representatives. In CY-1987 mechanical harvesting yielded about 4000 kg (9000 lbs) of uncleaned prairie seeds, the largest harvest to date. An additional 2000 kg (approximately 4400 lbs) of seeds was harvested in CY-1988. In 1989 volunteers collected 5778 kg (13000 lbs) of prairie seeds. Fermilab conducts routine burning of the prairie restoration areas with assistance from the prairie committee and volunteers.

In June, 1989, an interpretive trail through restored prairie was formally opened on the occasion of the dedication of the National Environmental Research Park at Fermilab.

3.5.2 Summary of Prehistoric Archaeological Work at Fermilab

In the early 1970's Ann Early surveyed all of the Fermilab property that was in cultivated fields or in construction areas. Twenty-four American Indian archaeological sites were identified (Ea70 and Ea71).

In 1986 Robert J. Jeske was hired to relocate the identified sites and to evaluate the archaeological work. He validated Early's work and identified a twenty-fifth site (Je87).

In the fall of 1987 and spring of 1988 Midwest Archaeological Research Services (MARS) under the direction of R. Jeske and R. Lurie tested six prehistoric sites in plowed fields, determining that none were eligible for the National Register of Historic Places NRHP (Lu89).

In the summer of 1988 the Gazebo site was tested and found to be NRHP eligible. Also, all previously unsurveyed areas at Fermilab were surveyed by MARS. A twenty-sixth site was identified. In the fall of 1989 Fermilab employees who had collected artifacts on-site, were interviewed and their collections photographed. This resulted in the confirmation of some of Ann Early's sites and added a twenty-seventh site to the list (Lu90).

Fermilab and DOE are in the process of establishing a Programmatic Agreement with the Advisory Council of Historic Preservation and the Illinois State Historic Preservation Agency for management of archaeological resources at the Lab.

3.5.3 Bird Survey

Birds represent a major constituent in vertebrate wildlife population at Fermilab. Documentation of their variety and numbers was undertaken from 1987 through 1989. Two hundred thirty eight species of birds were observed including 28 species that are on the state list of threatened and endangered species. The wide range of habitats and the sheltered conditions, e.g., no hunting allowed on the site, have made breeding successful - 80 species raised young during this period (By89).

3.5.4 Removal of PCB Capacitors

The Laboratory has continued its aggressive program to remove large PCB capacitors. As a result the initial inventory of over 2000 large PCB capacitors was reduced from 106 to 16 by the end of CY-1989. In order to comply with an October 1988 date for polychlorinated biphenyl (PCB) control, Fermilab has removed large PCB capacitors from the Booster accelerator tunnel (Fig. 5) and from the Capacitor Tree adjacent to the Master Substation (northwest corner of intersection of Roads A and B in Fig. 1). The total number remaining on the site is only 16 compared to over 2000 when the PCB regulations were promulgated in 1979.

3.5.5 Environmental Survey Items

The U.S. Department of Energy Environmental Survey for Fermi National Accelerator Laboratory was conducted from September 14 to September 25, 1987. The purpose of this effort was to identify, via baseline surveys, existing environmental problems and areas of environmental risk at Fermilab. This survey was part of a larger effort to rank the findings on a DOE-wide basis and establish priorities for addressing the environmental problems found. The Survey team consisted of two members from the DOE Headquarters in Washington, D.C., and seven independent specialists with expertise in dealing with different types of environmental problems. Fermilab continues to submit, on a semiannual basis, a detailed report called the Environmental Survey Action Plan to DOE. The major survey action items, along with routine waste handling operations, are incorporated in the DOE's Five-Year Plan for Environmental Restoration and Waste Management. The following summarizes significant action in response to this Survey.

The Survey team found that the missing mineral oil from the T82A transformer spill (Ba86) in 1985 could have potentially been as high as 22,710 l (6000 gal.). During the Survey approximately 475 l (125 gal.) was located in a vault under the Capacitor Tree near the Master Substation. This oil entered the vault by flowing down an open electrical cable duct on the transformer pad the night the spill occurred. Oil also is collecting in a sump in an underground enclosure about 7.5 m (25 ft) east of the transformer pad. The sump collects water near the footings of the enclosure about 6 m (20 ft) below the ground surface. In CY-1986 about 190 l (50 gal.) of oil was collected. In CY-1987 about 208 l (55 gal.) more was collected. In CY-1988 38 l (10 gal.) was collected. None was recovered in CY-1989.

In CY-1988 six holes were drilled near the spill location to search for additional oil. An oil stain was found on one of the soil samples from the hole closest to the transformer pad. There was also a thin oil layer on top of the perched water table at that point. Thus, there is evidence for oil above the clay layer which starts at about 5 m (16 ft) below the surface.

Three monitoring wells were installed for future water sampling at different depths below the surface. The deepest extends to 12 m (40 ft). During

1989

1989, an assessment by an outside consultant was completed. Although mineral oil was positively observed in the subsurface, the oil could only be grossly quantified and mapped. It appeared to be confined to a subsurface zone in the immediate vicinity of the original spill and above the perched water table. It is concluded that soil contamination appears to be restricted to the immediate vicinity of the spill. The presence of low permeability clay renders the oil highly immobile. It is thus concluded that this leak is an improbable source of groundwater contamination.

The Survey team found that discharges of chromates (Ba75a) from 1974 to 1976 to the old CUB perforated pipe field may be a source of soil and groundwater contamination. They found no evidence of contamination, but felt that more sampling was needed. In 1988 five shallow (4.6 m or 15 ft) sampling holes and two deeper (11.6 m or 38 ft) holes were drilled in the perforated pipe field to search for chromates. The soil samples were analyzed for chlorides and total chromium. Sodium chloride from regeneration of resins has been discharged continually into that area since 1972 and provides a good tracer (Ba73). A distinct chloride plume was found showing migration along the top of the low permeability clay layer (Yorkville till) toward the southeast. The only chromium level above background was near the surface and that sample did not have hexavalent chromium above the detection limit of 10 mg/kg.

One boring hole was made downstream of the chloride plume. Samples from that hole did not contain any elevated chromium levels. Thus, there is no evidence for migration of chromates in advance of the chloride plume. The holes were cased and water from them will be sampled in the future to monitor for chromates. Surface sampling was conducted during 1989 by an outside consultant. The EP toxicity test for chromium from a sample inside and immediately surrounding the perforated pipe resulted in leachate concentrations of less than 100 micrograms/liter. This is much less than the 5 milligrams/liter threshold for declaring this material to be hazardous waste, but it would still be considered regulated waste. Advice is to be sought from a consultant concerning the advisability of removing the tile field, since it is planned to phase out the use of the tile field by sending the effluent to the City of Batavia sewage system. Water sampling from the monitoring wells show concentrations far below the maximum given in the Safe Drinking Water Act. These studies have concluded that the perforated tile field poses no threats or significant groundwater

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contamination, soil contamination, and sediment contamination. There is also no evidence for migration of the chromates.

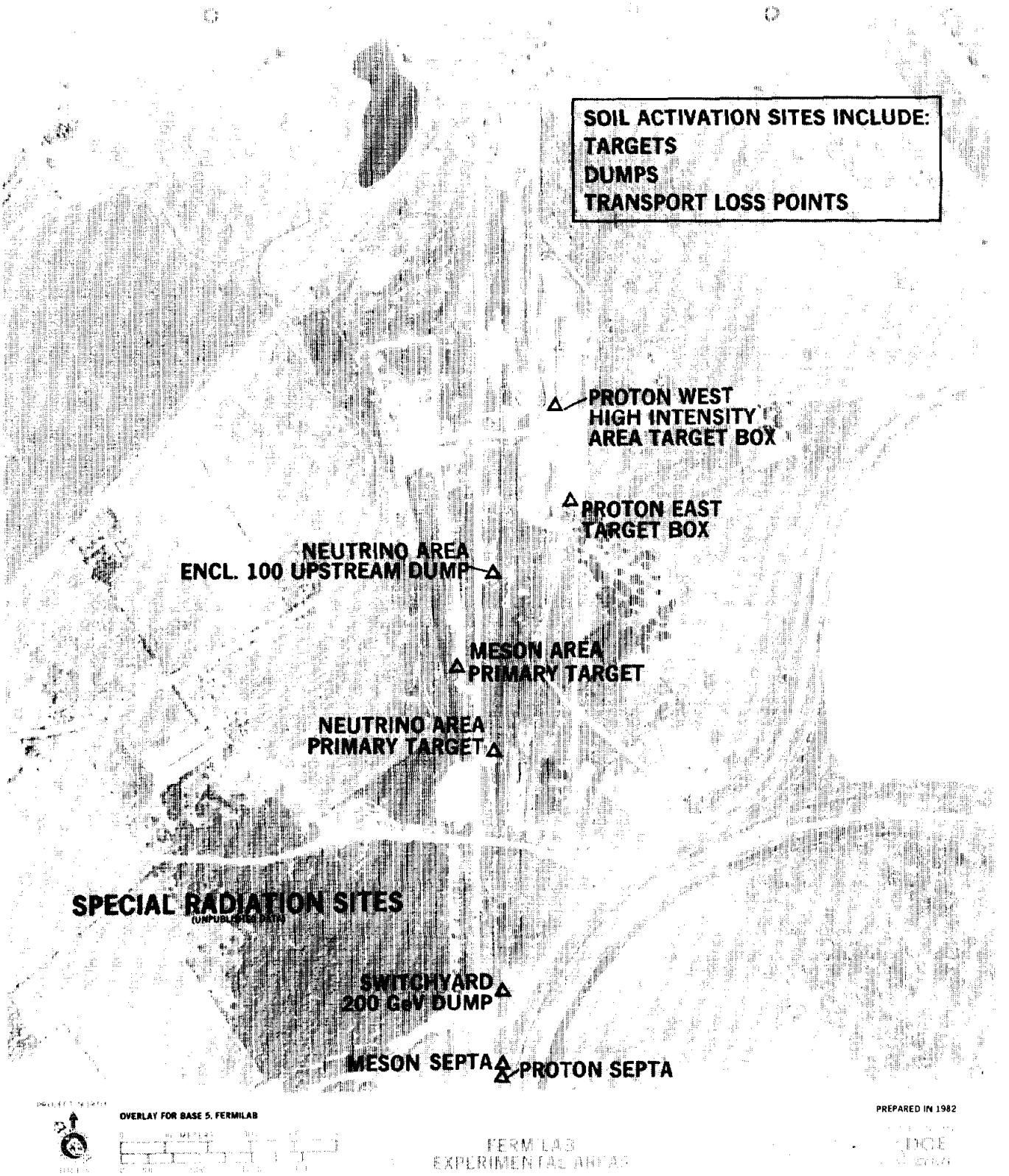
Some PCB spills occurred during removal of the capacitors from the Capacitor Tree and some PCB contamination remained from earlier leaks at the time of the Survey. Cleanup work was already in progress at the time of the Survey. The team listed that contamination in their findings. The total amount of PCB spilled is estimated to be below the reportable quantity of 4.54 kg (10 lbs) (40CFRa). Three cleanup efforts were made in CY-1988. The sampling at the end of each cleanup indicated residuals above the TSCA cleanup criterion of 10 parts per million (ppm) PCB. During 1989, the fourth cleanup was done. The metal surfaces of the Capacitor Tree have been successfully cleaned and a contaminated manhole cover replaced. Sampling results indicate that TSCA cleanup requirements have been met except for the bottom of one of the manholes where some contaminated sludge was found. Efforts will continue in CY-1990 to successfully meet the TSCA cleanup requirements.

Soil radioactivation has occurred due to prior accelerator operations near the N01 and M01 target areas (Neutrino Area and Meson Area primary targets in Fig. 6) and the NW4 beam dump (Neutrino Area Encl. 100 Upstream Dump in Fig. 6) as a result of fixed target experiments. The Survey team was not satisfied with the characterization of the soils beneath the underdrains or the groundwater monitoring systems in use at that time. Six 45° sampling holes were made beneath the target areas and beam dump in CY-1988 for the purposes of sampling the soil for ^{3}H and ^{22}Na and searching for a high permeability sand and gravel layer which could shunt radioactivity laterally away from wells sampling the deeper lying aquifer nearby. Monitoring wells for future shallow water sampling at these locations were also installed in these holes. These holes were described more fully last year (Ba89).

The presence of radionuclides in samples of soil from these holes could indicate some downward movement from the target or dump above. Only samples from one hole, north of the Neutrino Area primary target contained positive indications. During 1989, three additional sampling holes were drilled in this region to investigate this indicated problem (Fig. 9). New additional monitoring wells have been installed in these holes, to be used as future monitoring points. The results of the analysis indicates that the 1988 drilling

1989

FIGURE 6


SOIL ACTIVATION SITES INCLUDE:
TARGETS
DUMPS
TRANSPORT LOSS POINTS
PROTON WEST
HIGH INTENSITY
AREA TARGET BOX
PROTON EAST
TARGET BOX
NEUTRINO AREA
ENCL. 100 UPSTREAM DUMP
MESON AREA
PRIMARY TARGET
NEUTRINO AREA
PRIMARY TARGET
SPECIAL RADIATION SITES
SWITCHYARD
200 GeV DUMP
MESON SEPTA
PROTON SEPTA
OVERLAY FOR BASE 5, FERMILAB
PREPARED IN 1982
FERMILAB
EXPERIMENTAL AREAS

may have led to an incorrect conclusion. It now seems that samples taken from the lower levels of the drilling in 1988 may have been contaminated from the expected higher concentrations near the level of the underdrains due to an inappropriate drilling technique. More details are given in section 4.4.4

The soil borings have not found any sand and gravel layer beneath the Neutrino Area primary target which would provide a mechanism to carry radionuclides away horizontally. There is evidence for some sand and gravel around elevation 218 m (715 ft) near the M01 target and around 217 m (712 ft) near the NW4 beam dump and at other places on-site. There has been no evidence found for a continuous layer which could provide a pathway for the horizontal movement of water over large distances.

3.5.6 Leaking Underground Gasoline Tanks

During 1989 two underground gasoline storage tanks were removed because they were found to be leaking. One was located at Site 55 and the other was at 30 Sauk in the Village area. These tanks, and surrounding contaminated soil, have been removed and will be disposed of properly. The Illinois Environmental Protection Agency must approve of final closure plans for these two excavations.

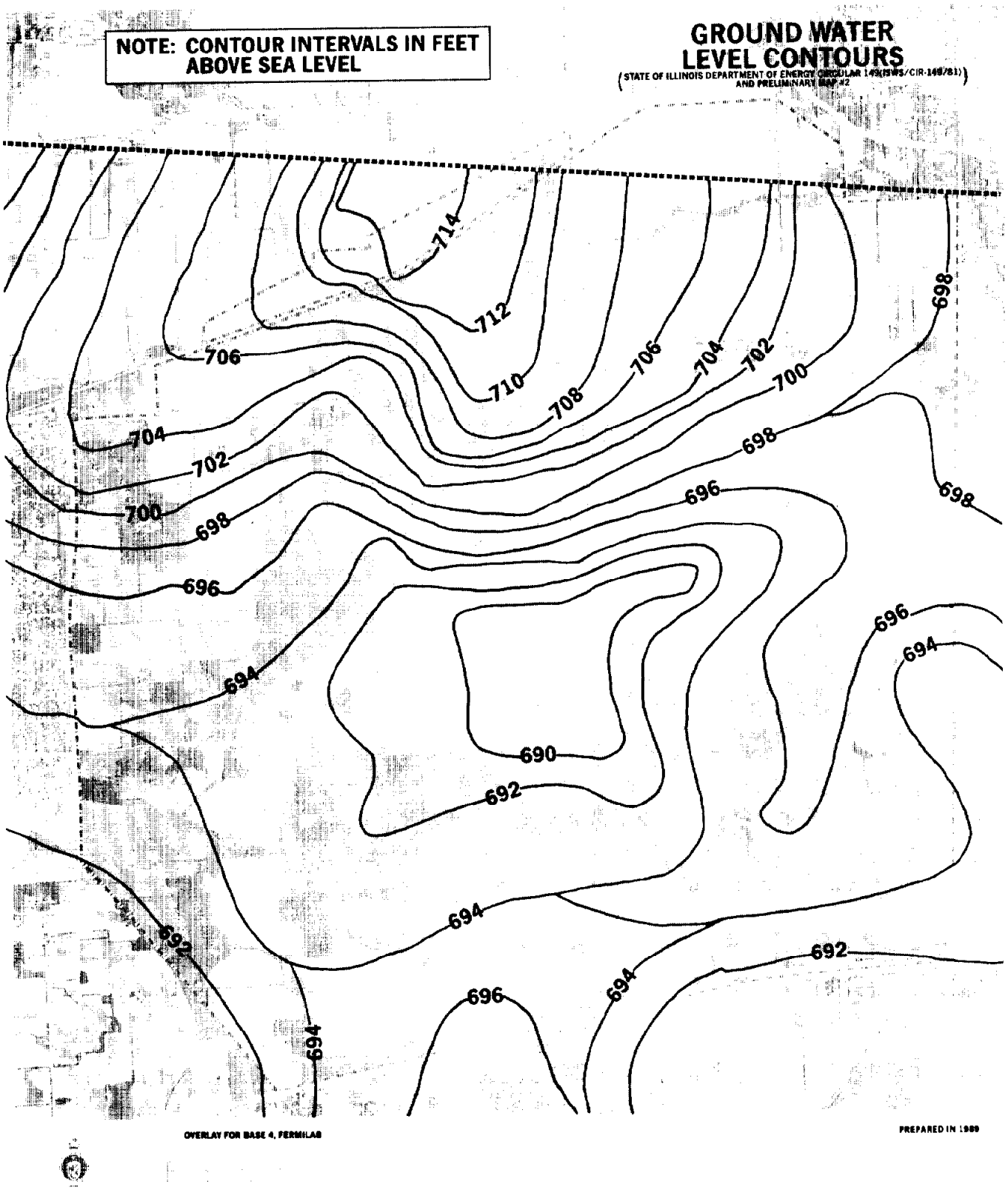
3.6 Summary of Hydrogeology

The Fermilab site has thick glacial till consisting primarily of low permeability clay (La71). This clay forms a barrier to the downward percolation of any water containing radioactivity. Beneath the clay the first layer of rock is a dolomite of Silurian age (Sa82). Its fractured upper 3 m (10 ft) and the saturated sand and gravel immediately above it in most places carry sufficient water for individual farm needs. The water level contours for this aquifer are shown in Fig. 7. Note that the water from the Research Area flows toward Well 1, the primary on-site drinking water supply (Fig. 2). Groundwater leaves the site and flows southwest toward the Fox River and southeast toward the West Branch of the DuPage River.

Beneath the silurian dolomite are older formations laid down by sedimentation during the Cambrian and Ordovician periods when the region was under sea water. These consist of dolomite and sandstone with perhaps some

1989

FIGURE 7


NOTE: CONTOUR INTERVALS IN FEET ABOVE SEA LEVEL
GROUND WATER LEVEL CONTOURS
(STATE OF ILLINOIS DEPARTMENT OF ENERGY CIRCULAR 145(ISWS/CIR-145/81))
AND PRELIMINARY MAP #2
714
712
706
710
708
706
704
702
700
698
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702
700
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690
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692
OVERLAY FOR BASE 4, FERMILAB
PREPARED IN 1989

shale. The sandstone aquifer at approximately 300 m (1000 ft) below the surface provides sufficient volumes of water for local municipal water supplies.

The spillways should be noted as shown on the map of surface water drainage (Fig. 8). In the event of an accidental spill, backup efforts will be concentrated at those points to stop the flow of any hazardous substance if it cannot be contained closer to the discharge point.

4. Environmental Radiological Program Information

4.1 Environmental Radiation Monitoring

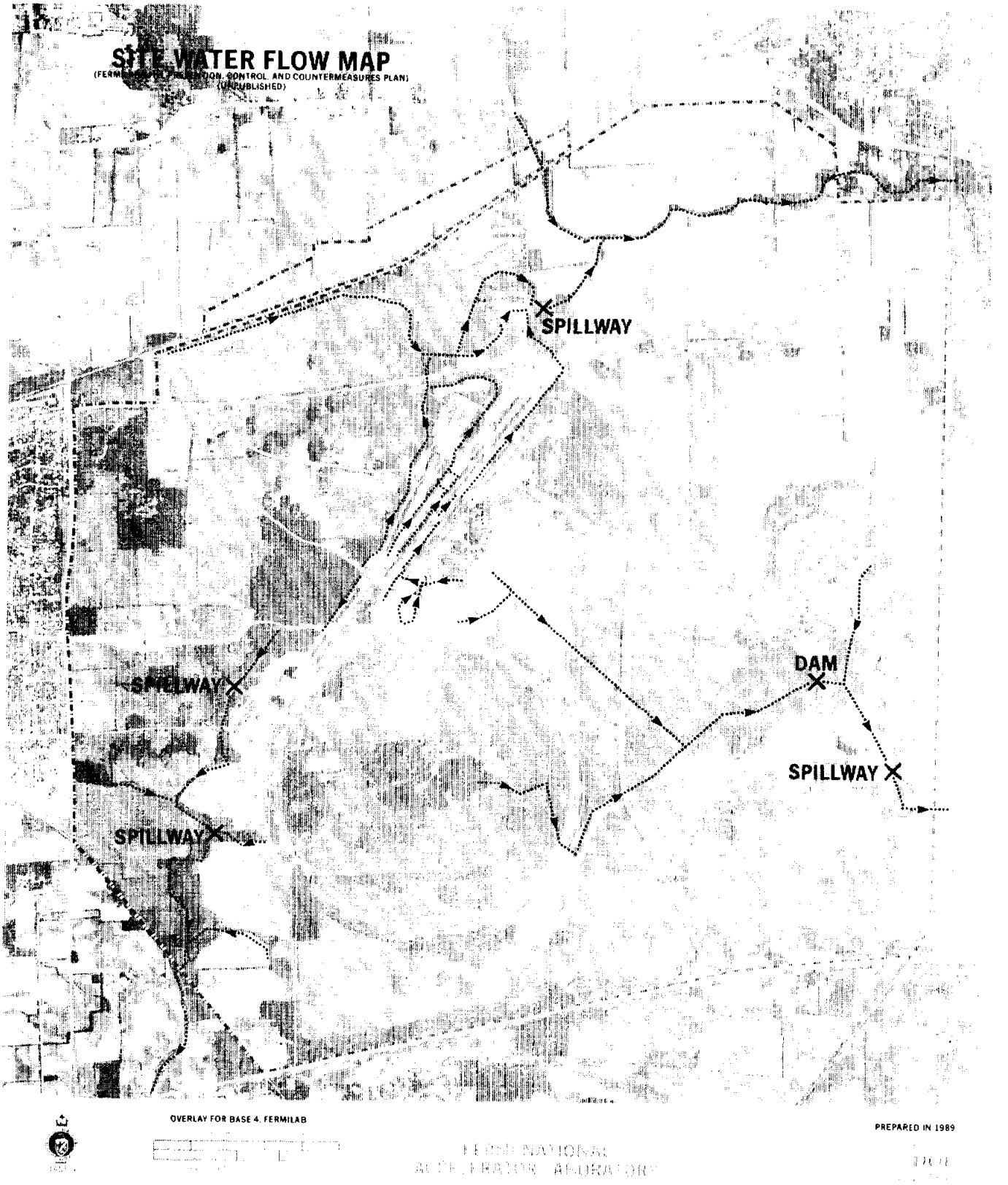
Three types of accelerator-produced radiation are monitored - penetrating radiation, airborne radioactivity, and waterborne radioactivity. These radiations usually have direct pathways to the off-site population. Other more indirect pathways, such as through the food chain, have received much less attention 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.

4.2 Penetrating Radiation

During operation of the TEVATRON as a collider, much fewer protons are accelerated to the high energies needed to produce a significant dose off-site due to muons or neutrons. Thus no measurements of these radiation fields were required during 1989. The only significant source of off-site radiation exposure due to penetration radiation was, then, due to gamma rays from the Railhead storage area.

A network of detectors was used to monitor penetrating radiation. At the end of CY-1989 there were approximately 100 detectors deployed around the site with the primary purpose of controlling on-site radiation. The majority of these detectors were connected to a data logger which automatically recorded the radiation levels for subsequent examination (Aw71). In CY-1989 four detectors were used primarily for environmental radiation monitoring. One was a large volume, 110 liter, ionization chamber (called a Hippo) used to detect gamma rays and charged particles at its location near the Boneyard at the Railhead (Fig. 5). Another was a large scintillation counter located along with another Hippo at

FIGURE 8


SITE WATER FLOW MAP
(UNPUBLISHED)
SPILLWAY
SPILLWAY
SPILLWAY
DAM
SPILLWAY
OVERLAY FOR BASE 4, FERMILAB
PREPARED IN 1989

Site 3 (Fig. 5) near the site boundary. The last was a tissue-equivalent ion chamber located at 14 Shabbona in the Village (Fig. 5). Approximately 60 environmental TLD's, exchanged and read each quarter, provide additional information for site boundary and radiation levels site wide.

The primary radioactive materials storage area on-site - the Boneyard - is also the primary source of off-site gamma radiation. Activated accelerator components and shielding, primarily iron and concrete, are stored in the Boneyard at the Railhead (Fig. 1) for future disposal or reuse following radioactive decay. As shown in Fig. 5, the Boneyard, which is a secure area, lies close to the site boundary. In 1987 radioactive material was moved into a new cave constructed at the southwest corner of the Boneyard. In addition, there was an area nearby designated for radioactive material storage for future use. A large amount of low-level radioactive material is stored in that area. The site boundary dose for CY-1989 was determined using thermoluminescent dosimeters (TLD's) and the large volume ion chamber (Hippo). Data obtained previously using a hand-held NaI (Tl) scintillator established the rate of decrease with distance (Ba89). The radiation level at the nearest site boundary was 1.1 mrem for CY-1989. The maximum exposure to the individual living closest to that point on the site boundary would have been 0.2 mrem for 1989, assuming 24 hour per day occupancy. The distance from the site boundary to the residence was 460 m (1500 ft). Thus, the dose to a member of the public in CY-1989 from the Boneyard was lower than the site boundary (fence line) dose.

4.3 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, radioactivation 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.

During the first five months of CY-1989 the Antiproton Source was in operation and 120 GeV protons were focused onto a target (Antiproton target in

1989

Fig. 5) to produce antiprotons. This target was a source of radioactive gas resulting from interaction in air of secondary particles leaving this target. Because this target is heavily shielded and the air volume is small, there are many thermal neutrons also radioactivating the air. The result is a mixture of primarily ^{11}C and ^{41}Ar with smaller amounts of ^{13}N, ^{38}Cl, and ^{39}Cl in air. The ^{41}Ar has a half-life of 1.8 hours and is produced by neutron capture in ^{40}Ar. Air contains about 1% argon which is essentially ^{40}Ar. Interaction of high-energy secondary particles with nitrogen and oxygen in the air produces 20 minute half-life ^{11}C and 10 minute half-life ^{13}N. Interaction of high energy neutrons with argon in the air is probably the source of 37 minute half-life ^{38}Cl and 58 minute half-life ^{39}Cl (Bu89). The total release was 82 Ci from the Antiproton Area Stack (colliding beam operation).

The site boundary concentrations were calculated using the computer program AIRDOSE-EPA (Mo79, Mo86) (a gaussian plume diffusion model). Wind conditions for O'Hare Airport about 43 km (27 mi) away were used as input. The terrain between Fermilab and the airport is relatively flat. The maximum dose equivalent to an individual member of the general population for CY-1989, due to the source, was 0.02 mrem. This is 0.08% of the 25 mrem/year limit in effect during CY-1989.

A debonding oven was placed in operation during CY-1979 in the Industrial Area (Fig. 1). Its purpose is to debond magnets by decomposing the epoxy adhesives at high temperatures. Most of these conventional magnets are radioactive and have failed after years of accelerator operation in the Main Ring tunnel. The gaseous effluent was measured during the acceptance test on June 8, 1979, conducted for the Illinois EPA and contained only ^{3}H at very low-levels. The tests were primarily performed to measure nonradioactive emissions. 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 seven percent of the Derived Concentration Guide (Section 7). The stack is approximately 10 m (30 ft) high. Using the computer program AIRDOSE-EPA gives a negligible percentage of the applicable Concentration Guide at the site boundary.

The number of radioactive magnets debonded in CY-1989 was 4 corresponding to a total release of 0.64 mCi of ^{3}H into the air. The radioactivity in the

magnets was similar to that in the 1979 test, thus the 1979 data are still valid. In CY-1989 the wind conditions were similar to those in past years.

4.4 Monitoring Surface and Groundwater for Accelerator-Produced Radioactivity

All current Fermilab water sampling locations for detection of accelerator-produced activity are shown in Figs. 4, 9, and 12.

4.4.1 Groundwater Sampling

Radioactivation of soil can occur near the primary beam targeting and beam dump areas. Older targeting stations and dumps were designed with "bathtubs" to contain radionuclides produced in these areas, preventing their migration to the aquifer. Later design strategies substituted massive concrete and steel shields within beam enclosures to minimize soil radioactivation and groundwater contamination. Water samples from thirty-eight wells/monitoring holes are analyzed at least once and as often as four times per year. Sampling frequency is determined by a well's proximity to areas of soil activation. Samples are analyzed for the following accelerator-produced radionuclides: ^{3}H, ^{7}Be, ^{22}Na, ^{45}Ca, ^{54}Mn, and ^{60}Co.

Many of the groundwater samples are taken from old out of service farm wells on-site. Additional wells and boring holes have been installed to provide better monitoring in areas of potential soil activation.

In 1989 groundwater samples for radiochemical analysis were collected from the following wells on-site:

19 from Drinking water supply wells
43 from Out of service farm wells
54 from Monitoring wells/boring holes

Figure 4 indicates the location for the out of service and drinking water wells that are sampled. Five of the samples taken from drinking water wells were collected from three on-site non-community, non-transient water supply wells (W-1, W-3, W-5). Water from W-4, a deep well (1432 feet) was also analyzed for radon as well as accelerator-produced radionuclides.

FIGURE 9

MONITORING WELL AND BORING LOCATION DIAGRAM

FERMI NATIONAL ACCELERATOR LABORATORY

FOR ENVIRONMENTAL SAFETY GROUP

BORING	EASTING	NORTHING	ELEV.
*S-1055	100250.0	102800.0	746.2'
*S-1056	99955.0	102850.0	752.4'
*S-1057	99544.6	103905.8	750.6'
S-1058	99952.7	103459.7	750.4'
S-1059	99958.9	103749.9	747.5'
S-1060	100049.0	104810.1	751.4'
S-1061	99498.9	104243.7	753.4'
S-1062	99492.9	104274.6	754.1'
S-1063	99477.3	104344.6	757.3'
S-1087	99959.4	103731.8	946.0'
S-1088	99960.0	103770.9	945.6'
S-1089	99953.7	103777.5	944.6

* = BEDROCK WELL

STS Consultants Ltd.
Consulting Engineers

BORING LOCATION DIAGRAM
ANGLE HOLES AT NEUTRINO TARGET AREA
FERMI NATIONAL ACCELERATOR LABORATORY
BATAVIA , ILLINOIS

DRAWN BY	GRS	10-89
CHECKED BY	DLG	10-89
APPROVED BY		
SCALE 1"=400'	FIGURE NO. 1	
STS DRAWING NO. 25635-XH		

1989

Out of service wells and monitoring/boring holes samples are collected only after completely purging the well casing and allowing time for recharge or after clearing two bore volumes, whichever happens first.

Well sampling frequency is based on the following rationale:

1. Wells 39, 43, 45A, 49, 59, 78, 79, 80, 81 and S-1059 were scheduled for quarterly sampling because they are closest to the areas of maximum soil activation and/or are in the direction the water is expected to flow in the aquifer.

2. Wells W-1, W-3, 5, W-5, 17A, 20, 24B, 29, 55B, S-1058, S-1060, S-1061, S-1062, and S-1063 were scheduled for semiannual sampling, less frequent than those in #1 due to less potential for radioactivity.

3. The remaining wells W-4, 7, 12, 50, 52, 56, 58, 64, 68, 74, and 75A were scheduled for an annual sample because they are near the site boundary or serve as back-up to more frequently sampled wells.

In 1989 the scheduled sampling frequencies were met with one exception, W-1 was only sampled once due to trouble in scheduling because of repairs to the well. The samples from W-3 and W-5 were analyzed for gross alpha, gross beta, and ^{131}I in addition to the usual six accelerator-produced radionuclides. The sample from W-4 included analysis for ^{226}Ra, ^{228}Th, and ^{232}Th. In all cases no measurable accelerator-produced radioactivity was reported in any out of service or drinking water supply well. Tritium was detected in water collected from S-1059, S-1063, and a new monitoring well installed in 1989, S-1087 (Co90).

4.4.2 Surface Water Sampling

In early beam enclosures "bathtubs" were installed underneath primary beam target stations and dumps to contain the radionuclides produced in the environs of the target or dumps and to prevent their further migration to the aquifer. Later beam lines designs incorporated massive steel and concrete shields within beam enclosures to minimize radioactivation of surrounding soil and thus eliminated the need for "bathtubs." The water collected by underdrains within the "bathtubs" is received in retention pits and after sampling is either pumped

into neighboring sumps to be discharged to surface water or pumped into drums to be disposed as radioactive waste. Twenty retention pit samples were analyzed in 1989.

Underdrains that collect water from outside of "bathtubs" and from around footings of buildings and beam enclosures discharge to surface waters via ditches. Radionuclide concentrations are monitored in selected sumps, ditches, and surface waters. They are analyzed for the presence of ^{3}H and in some cases ^{22}Na, ^{7}Be, ^{60}Co, ^{45}Ca, and ^{54}Mn. The frequency of sampling is determined both by the history of radioactivity in that area and the potential for radioactivity based upon operational parameters. Generally speaking, sumps closest to the areas of maximum soil activation are sampled more frequently. The four sumps reported as EIS-ODIS reportable discharge points (N01SP4, M01SP3, NW4SP1, and NTSBSP1) in 1988 were scheduled for more frequent sampling with nearly bimonthly sampling planned. This frequency was met at all EIS-ODIS points except NTSBSP1 which was dry most of the year.

The surface water from the experimental areas (Fig. 5) flows into Casey's Pond except during wet seasons. During these seasons, the pond fills up (68 million liters or 18 million gal. capacity) 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 (Figs. 5 and 8). There were no discharges of radioactivity totaling greater than 1 mCi from a closed loop water system leak in CY-1989.

Casey's Pond and the ditches that receive water from the experimental areas and drain to Casey's Pond are sampled annually for accelerator-produced radionuclides. Kress Creek is sampled each week the water is observed leaving site via the Kress Creek spillway. Surface water from the experimental areas (Fig. 5) left the site via Kress Creek for approximately 61% of the year in CY-1989, a 10% increase over CY-1988. Other lakes and ponds are sampled at least once per year. There were no measurable concentrations of accelerator-produced radionuclides in any of the samples taken from creeks, ponds, lakes, or ditches this year.

A summary of sumps with detectable tritium levels can be found in Table 2.

Table 2
Tritium Detected in Sump Water Samples
(Tritium Concentration (C) in pCi/ml)

Collection Point	Number of Samples	*C Max	*C Min	*C Mean	Percentage of Concentration Guide (%)
AP0	1	11.2	11.2	11.2	0.56
G4(NTSBSP1)	1	28.8	28.8	28.8	1.44
G5(NTSBSP2)	5	58.0	<3.0	20.3	1.02
G7(N01SP2)	3	4.0	<3.0	2.9	0.15
G8(N01SP3)	2	5.13	<3.0	4.1	0.21
G9(N1=N01SP4)	6	117.0	32.06	62.2	3.11
MF4(M01SP2)	5	16.0	4.34	9.8	0.49
MF5(M01SP3)	6	88.0	46.1	61.8	3.09
NM1(NM1SP)	5	18.1	<3.0	9.2	0.46
NM2C(NM2SP3)	2	3.3	3.0	3.2	0.16
N2(NW4SP1)	4	303.0	41.8	187.7	9.39
NW5(NW5 Manhole)	1	8.0	8.0	8.0	0.40
PW8(PW6SP2)	2	3.6	<3.0	3.3	0.17
PW9(PW6SP3)	2	4.0	<3.0	3.5	0.18

*C Max is the highest concentration detected in a sample from that location
C Min is the lowest
C Mean is the average

4.4.2.1 System (EIS/ODIS)

Fermilab uses the following criteria for reporting radioactive effluent releases (off-site) and discharges (on-site) to DOE in its Annual EIS/ODIS Report:

1. Any one time release or discharge which is greater than the concentration guide of 1000 pCi/ml for tritium, or the equivalent for any other radionuclide, and greater than one mCi total activity.

2. Any ongoing release or discharge with an average concentration greater than 20 pCi/ml of tritium, or the equivalent for any other radionuclide, and greater than one mCi total activity for the calendar year.

Using this criteria we reported 4 liquid discharge points and 4 liquid effluent releases for CY-1989. The sumps reported as discharge points were M01SP3, N01SP4, NW4SP1, and NTSBSP2. The reported discharge points were the ditches receiving the waters from these sumps and emptying into Kress Creek. The total off-site release to surface waters attributable to these sumps, though not measurable in surface water samples, is calculated based on average radionuclide concentrations found in sumps and sump discharge volumes. In CY-1989 an

1989

estimated total of 908 mCi of tritium was released off-site by these sumps. This is a substantial increase over the 336 mCi tritium reported in CY-1988. This increase reflects the 10% increase in water leaving the site and the addition of NTSBSP2 as a major new contributor with an estimated 265 mCi discharged. Although the average tritium concentration for NTSBSP2 was low, the hour meter showed copious quantities of water being pumped out by this sump. It is suspected that this sump pump may actually have been running without discharging water for a good part of the year. This is currently under investigation. There were no one time releases of waters with concentrations greater than 1000 pCi/ml tritium.

The AP0 stack, our only reportable air discharge point, released an estimated 82 curies of airborne radioactivity.

4.4.2.2 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. The tritium remains in the cooling water system. These resins are regenerated in two separate systems located at the Central Utility Building (Fig. 5). The effluent from these two systems is sent to a settling tank for removal of almost all of the radioactivity before it is sent to the clay tile field inside the Main Ring (see Sect. 5.5.3) (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 any residual radioactivity released will place no burden on the environment. The amount of ^{7}Be discharged to the tile field in CY-1989 was very small; however trace amounts were detected in the CUB Tile Field soil. See Section 4.4.3.

4.4.3 Soil and Sediment Sampling

Sampling and analysis of soil for radionuclides can be a useful approach to determining the accumulated amounts of airborne/waterborne long-lived radioactive contaminants that deposit on the ground. The radiochemical composition of soil/sediment was measured at 16 sample sites in 1989. At each ventilation stack location one composite sample of soil was taken from 15-20 one inch diameter

cores of the top 5 cm of the sample plot. A trowel or scoop was used to collect 10 subsamples of the top 5 cm of silt and sediment instream at each creek sample location. The procedure for collecting samples at sump discharges was the same as for creeks with samples being taken as close to the discharge pipe as possible. The CY-1989 soil/sediment sampling results are in Table 3.

The presence of ^{137}Cs (Table 3) indicates fallout from previous atmospheric nuclear testing. The ^{60}Co could be from fallout or accelerator-produced, but appears to be all accelerator-produced based on the locations. The ^{7}Be is most likely accelerator-produced. The radionuclides ^{22}Na and ^{54}Mn are only accelerator-produced. Note that ^{7}Be and ^{60}Co are slightly elevated in the sample from the CUB Tile Field, even when compared to most sump discharge sediment results.

Table 3

CY-1989 Soil/Sediment Sampling Results

Location	Concentration (pCi/g)					(pCi/ml)
	^{7}Be	^{22}Na	^{54}Mn	^{60}Co	^{137}Cs	^{3}H
Ferry Creek at Site Boundary	ND	ND	ND	ND	0.41±0.12	
Kress Creek entering site	ND	ND	ND	ND	0.36±0.11	
Kress Creek leaving site	ND	ND	ND	ND	0.17±0.05	
Indian Creek at Site Boundary	ND	ND	ND	ND	ND	
AP0 Stack***	1.13±0.25	ND	ND	ND	0.08±0.02	3.45±0.41
AP0 Stack*	1.14±0.32	ND	ND	ND	ND	
N01SP4	ND	0.10±0.02	ND	0.03±0.01	ND	
N01 Stack**	ND	ND	ND	ND	ND	14.5±1.5
N01 Stack*	ND	ND	ND	ND	ND	
N01 Spur Stack***	ND	ND	0.04±0.01	0.02±0.01	ND	1.61±0.23
N01 Spur Stack*	ND	ND	ND	ND	ND	
M01SP3	0.48±0.22	0.23±0.08	0.20±0.06	0.11±0.03	0.16±0.05	
M01 Stack***	ND	ND	ND	ND	ND	<1.0
NW4SP1	ND	0.38±0.12	0.05±0.02	0.08±0.02	ND	
Site 12	ND	ND	ND	ND	0.25±0.05	
CUB Tile Field	3.54±1.10	ND	0.07±0.03 (^{57}CO)	0.07±0.02 0.03±0.02	0.28±0.09	

*Dried Sample
**Tritium concentration determined from distillate
***Tritium concentration determined from leachate
ND = Not Detectable

4.4.4 Soil Activation

Because the percolation rates for water in Fermilab soils are calculated to be very low, certainly less than 1 m (3 ft) per year (I178) - analyses of well waters do not provide the early warning desired for detection of accelerator-produced radioactivity in the groundwater. On the other hand, these low percolation rates also make the probable transit times of the radionuclides in the water to be long compared with their lifetimes. 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. Because the major long-lived radionuclides leachable from Fermilab soils are ^{3}H and ^{22}Na, quantitative measurements were made only on those (Bo72). Most of the soil activation occurred around the Neutrino Area primary target located in the Target Tube until 1982. Between 1982 and 1988 the target was located in a new enclosure 300 ft south of the Target Tube. At the end of February 1988 the neutrino production program was completed.

Six 45° bore holes (S-1058 through S-1063) were made in CY-1988 beneath the primary targets and beam dumps in use in the Meson and Neutrino Areas (Figs. 6 and 9) between 1972 and 1982. These targets and dumps had sand and gravel "bathtubs" (impervious liners or membranes filled with sand and gravel) beneath them. Soil was sampled outside and beneath the bathtubs to a depth of more than 6 m (20 ft) below the lowest underdrains. The Neutrino Area holes were drilled at the north (downstream) end of the Target Tube and under the retention pit in the N01 Enclosure just south (upstream) of the Target Tube.

As reported in more detail last year (Ba89), one of the 45° boring holes drilled in 1988 along the Neutrino decay pipe resulted in soil samples showing positive values of tritium but no ^{22}Na. Figure 10 shows the geometry of the well (denoted S-1059) along with the concentrations found in the CY-1988 study plotted as a function of depth using a standard method of extracting the tritium by evaporation which has consistently yielded higher values than other techniques. The concentrations found from elevations below the underdrains are typical of concentrations found in the water emerging from the underdrains, a result in contradiction to the expected decrease in concentration with depth below that level. Thus, it was suspected that this single well may have had its lower levels contaminated from above during the drilling process. As a part of the

1989

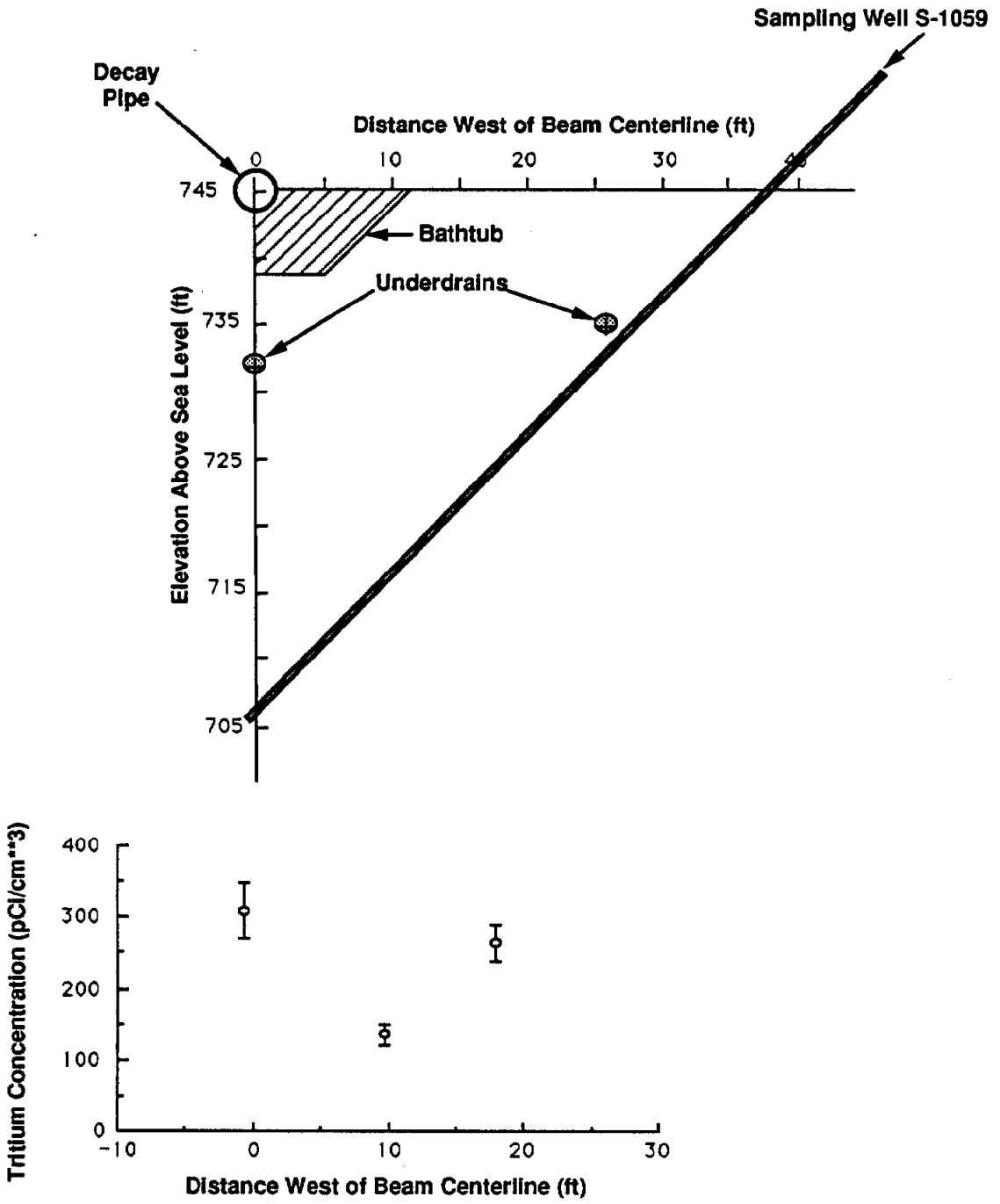


Figure 10 Cross section of the Neutrino Berm at location of Sampling Well S-1059 (drilled in 1988) along with a plot of tritium concentration found as a function of distance west of beam center.

1987

1988 project, three deep wells (79, 80, 81) shown in Fig. 4 were installed down to the limestone bedrock aquifer. These reach elevations near 670 feet and are denoted S-1055 (676 ft.), S-1056 (669 ft.), and S-1057 (669 ft.) in Fig. 9. No tritium has been detected in any of these three wells, down to similar limits of detection (0.2 pCi/l).

In order to resolve the questions raised by the results from well S-1059, further drilling was done in late summer, 1989. Three additional soil borings were completed and monitoring holes were installed in each. These three wells (S-1087, S-1088, and S-1089) are in the immediate vicinity of S-1059 (Fig. 9). Each hole was drilled at 45 to 50° from the vertical to approximately the same depth as S-1059 and was cased with an 8" steel casing as the drilling progressed through the saturated zone in the vicinity of the underdrains to minimize downward infiltration of water and contaminants from the level of the underdrains. After this was done fifty-five soil samples were collected and sent for analysis using heat to collect evaporate as was done in the samples collected in 1988 exhibiting the higher concentrations. Only one of the holes, S-1087, indicates the presence of ^{3}H.

The concentrations are graphed as a function of distance west of the beam line and are shown along with the drilling geometry for this monitoring hole in Fig. 11. The maximum concentration was found nearly precisely at the point closest to the beam center line, as expected if the radionuclides are not moving downward at a significant rate. The subsurface exploration also identified two significant water-bearing layers in the subsurface that correspond to these elevations. The first is a shallow perched water table within the underdrain material and the second is a sandy clay and silt lens encountered about 32 ft. below grade level. After completion of the soil sampling, monitoring wells were installed at various depths: one shallow (S-1088, sealed at about 730 ft.), one intermediate (S-1089, sealed at about 724 ft.), and one deep (S-1087 sealed at about 706 ft.).

The drilling subcontractor also reported some conclusions concerning the hydrogeological conditions. In summary, the upper layers contained gray silty clay and clayey silt. These were underlain by more porous brown sandy silt and silty fine sand which appears to surround the underdrain. Below the underdrain level are natural undisturbed sediments consisting of a thick unit of gray silty

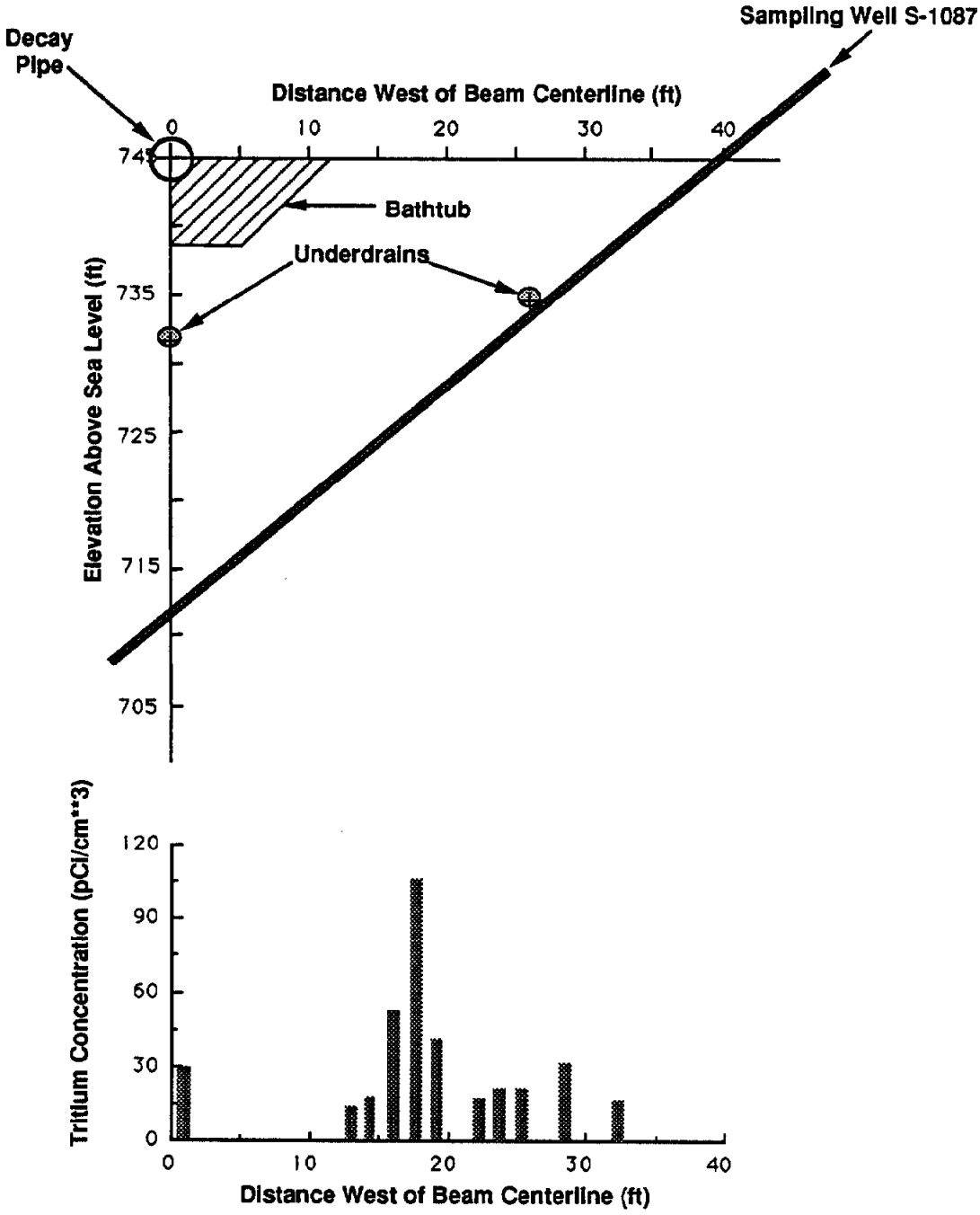


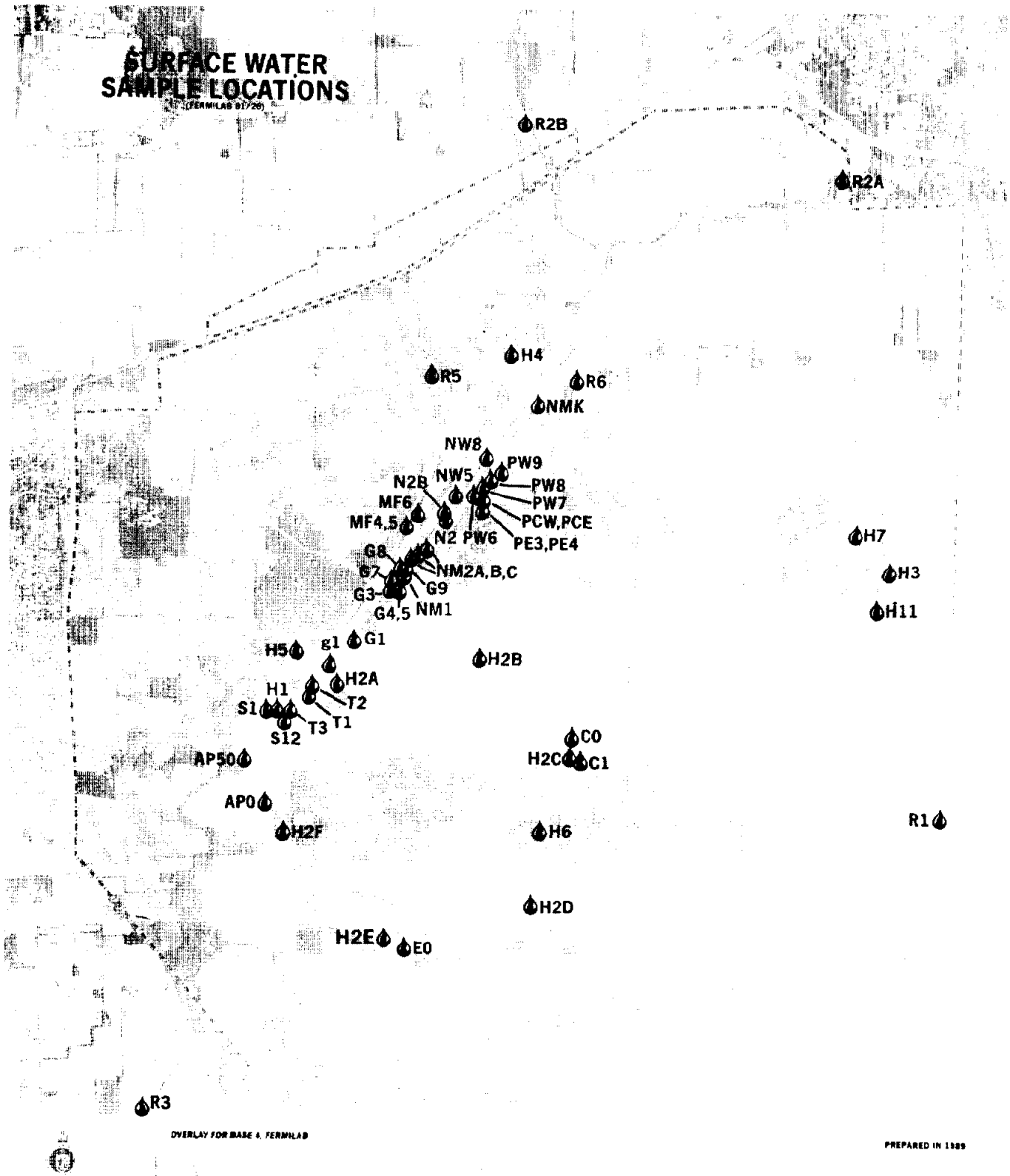
Figure 11 Cross section of the Neutrino Berm at the location of Sampling Well S-1087 (drilled in 1989) along with a plot of tritium concentration found as a function of distance west of beam center.

clay with trace sand and gravel content and some cobbles. Between 714 ft. and 707 ft. above sea level, a sequence of softer, wet to saturated sediments were found and these were underlain by a very hard, gray silty clay with trace sand and gravel. The results of "falling head permeability tests" indicated hydraulic conductivities ranging between 3 x 10^{-8} cm/sec to 5 x 10^{-8} cm for samples collected at elevations between 721 ft. to 713 ft. These conductivities correspond to an approximate maximum movement of less than 3/4 inch per year.

Several conclusions can be drawn from this work. First, drilling monitoring holes without installing casings as the drilling proceeds has considerable potential for providing a "short circuit" downward. Such a phenomenon is the best explanation for the 1988 results concerning well S-1059. A second conclusion is that no concentrations of the radionuclides of concern exceeding drinking water limits have been found below the approximate level of the underdrains, except for the now questionable results from S-1059. The sample from the bottom of S-1087 taken at the time of its initial installation also slightly exceeded 20 pCi/ml. Subsequent water samples taken from this level have measured concentrations less than a detection limit of 3 pCi/ml. Thus, it is concluded that the initial measurement may have included a "puddle" due to the drilling process which has now been removed by the pumping inherent to the sampling process. Thus, even without considering the leaching process necessary to actually remove the radioactivity, additional dilution processes, or finite downward migration times, no significant risk to any drinking water supplies is found. The hydrogeological information identified in these studies also provides additional evidence for a very slow, or even negligible, migration rate of water from the vicinity of these target stations to aquifers. The migration times are indicated to be quite long compared with the radioactive half-lives of both ^{3}H (12.3 years) and ^{22}Na (2.6 years). A final conclusion is that the wells presently installed are adequate to monitor any conceivable migration of radionuclides. No additional monitoring wells are needed.

In CY-1983 a new target and dump system was put into operation to abort any errant protons inside the Main Ring tunnel. The well-shielded dump was placed just outside the tunnel (near C1 in Fig. 12). It was provided with a sampling underdrain which normally is not pumped (Ba86, Ba75b). The drains adjacent to the Main Ring tunnel lead to sump pits equipped with pumps, hence water in the region around the tunnel and above the underdrains is normally kept free of

FIGURE 12


SURFACE WATER
SAMPLE LOCATIONS
R2B
R2A
H4
R5
R6
NMK
NW8
PW9
N2B
NW5
PW8
MF6
PW7
MF4,5
PCW,PCE
N2
PW6
PE3,PE4
G8
G7
NM2A,B,C
G3
G9
G4,5
NM1
H7
H3
H11
H5
g1
G1
H2B
H2A
H1
T2
S1
T3
T1
S12
C0
H2C
C1
AP50
AP0
H2F
H6
R1
H2D
H2E
E0
R3
OVERLAY FOR BASE 4, FERMILAB
PREPARED IN 1989

standing water. The region below the Main Ring drains is not. The abort dump itself is sealed watertight. Drains inside have remained dry. The part of the dump below the Main Ring tunnel drains sits in water, permitting leaching of tritium produced in the sand and gravel surrounding the dump. Water samples from the underdrain beneath the dump contain tritium and ^{22}Na. The concentrations are below the DOE Concentration Guides for release to surface waters (Section 9).

5. Environmental Monitoring for Nonradioactive Pollutants

5.1 Domestic Water Supplies

The primary drinking water supply at Fermilab in CY-1989 was provided by a well pumping from an aquifer approximately 70 m (220 ft) deep. This well (W-1 in Fig. 4) is located in the Central Laboratory Area. A second well (W-3 in Fig. 4) pumps from the same aquifer and supplies water to the Main Site system when demand exceeds the capacity of the Central Laboratory well (W-1 in Fig. 4). Since January 28, 1987, the Village system is supplied from Warrenville, the neighboring community to the east. A new well (W-5 in Fig. 4), became operational in November 1988 to supply water to a colliding beams experiment at D0.

The Main Site system is chlorinated at the Central Utility Building when Well #1 is providing water. The alternate supply source, Well #3, has its own reservoir and chlorinator. Monthly samples for total coliform per 100 ml were sent to IEPA for analysis for both systems. Two violations occurred in CY-1989; D0 and Main Site. The new system at D0 is also a chlorinated system but used sodium hypochlorite rather than chlorine gas. The chlorine level in these chlorinated drinking water supplies is tested each workday. The average use from Well #1 and Well #3 combined was approximately 117,000 gal./day during 1989.

Well #29 has a high sulfate concentration and ion exchange resins are used to treat the water. Several other wells are just above the standard for total dissolved solids. Well #50 has a high total organic carbon value compared to other wells. This might indicate organic infiltration. This well is behind a former farm house. There is evidence for a dug well east of the existing well. Thus, there is a potential pathway for organic pollutants to reach the well.

5.2 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 (Fig. 5) at the end of the Neutrino Beam Line and underground mains to fire hydrants and sprinkler systems throughout the Central Laboratory Area and Experimental Areas. Casey's Pond is supplied by surface drainage and can be supplied by pumping from the Fox River. The pond holds 68,000,000 liters (18,000,000 gal.).

The Swan Lake/Booster Pond System (Fig. 5) is used for cooling purposes at the Central Utility Building (CUB). 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 NS1 Service Building (near G9 in Fig. 12) 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 (Figs. 5 and 8).

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 inside the Main Ring Ponding System (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 (Figs. 5 and 8).

5.3 Other Lakes and Ponds

Surface drainage from the eastern portion of the site flows into Lake Law, DUSAF Pond and the AE Sea (Figs. 5 and 8). These lakes and ponds are accessible to the public, and they are the headwaters of Ferry Creek.

Semiannual tests are made of water samples taken where the three creeks leave the site (R1, R2A, and R3 in Fig. 12), as well as from Casey's Pond and the Fox River. Results of the tests for pH, dissolved oxygen, five-day biochemical oxygen demand, (BOD5), suspended solids, and fecal coliform for 1989 are found in Table 4. Tests for fecal coliform bacteria were made monthly. Levels above 200

Table 4

Site Wide Water Quality Report for FY-1989

	pH		DO mg/l		B0D5 mg/l		Susp. Solids mg/l		Fecal Coliform mg/l	
	April	Oct	April	Oct	April	Oct	April	Oct	April	Oct
Ferry Creek	6.9	7.4	6.6	7.6	8.2	19	50	42	10	67
Kress Creek	7.8	7.5	7.4	9.1	1.2	2	8	30	230	TNTC**
Indian Creek	8.2	7.4	11	9.2	2.5	2	14	12	220	Confluant
Casey's Pond	8.6	7.5	8.6	6.2	2.1	3	30	5	20	4
Fox River	9.1	8.7	9	9.9	8.5	6	31	30	50	0
General Standards	6.9	9	Not less than 5.0 at any time		*		*		Mean of 200	

*There are standards for effluent from treatment works or waste water sources, but no general standards
**TNTC is "too numerous too count"

were found in Indian Creek and Kress Creek in CY-1989. The explanation for the high readings have not been found. Fecal coliform bacteria are found in recent deposits of fecal material from warm-blooded animals.

5.4 Sewage Treatment

On December 22, 1986, the Village sewage collection system was connected to the City of Warrenville system and has been delivering sewage to the Naperville Springbrook Treatment Plant via that system since then. The Naperville plant is a modern sewage treatment system with ample capacity. The Main Site sewer system was connected to the City of Batavia system June 26, 1979, and has been delivering sewage to the Batavia sewage treatment plant since that time. The IEPA terminated the NPDES permit for the Village Oxidation Pond on May 12, 1987, at the Department of Energy's request.

5.5 Chemical Treatment of Water Systems

Some chemical treatment of our various water systems is required each year to control the growth of algae and aquatic weeds. Only EPA registered chemical agents are used. These are applied by trained personnel licensed by the State of Illinois and following the manufacturer's directions.

5.5.1 Chlorine

In addition to the routine chlorination of the Main Site water system and the swimming pool, a 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. Only one piece of equipment within the plant is chlorinated at a time. Consequently the concentration of chlorine entering the Swan Lake system is significantly reduced from 0.5 ppm.

Bromine was used for the first time in 1987 for water treatment at Fermilab. Water pumped from Casey's Pond was treated with a 1-Bromo-3chloro-5,5-dimethyl hydantoin chemical in a pellet form. This chemical, Nalco 85WT-

037/7343, is supplied by Nalco Chemical Company, One Nalco Center, Naperville, Illinois 60566. The bromamines formed when the chemical reacts with agricultural based amines are more effective biocides than chloramines. Thus, better control of biological growth in the heat exchangers in the Research Area is expected using this treatment instead of chlorination. No treatment has been done in the past because air towers rather than industrial water heat exchangers were used. A comprehensive monitoring program to minimize the amount of chemical required has been initiated. The total available halogen was adjusted to be 0.2 g/l or less in the water as it leaves the heat exchangers. The total amount of Nalco 85WT-037 used in CY-1989 was only 113 kg (250 lbs).

5.5.2 Aquazine

The various ponds at Fermilab were periodically treated in an attempt to control algae growth and reduce suspended solids. Aquazine was applied to the Main Ring Ponding System, the Swan Lake/Booster Pond System, the Village Oxidation Pond, and the reflecting ponds by Wilson Hall in CY-1989 (Fig. 5). (The total applied quantity of Aquazine, containing 80% simazine: 2-chloro-4, 6-bis (ethylamino)-s-triazine, was 272 kg (600 lbs).)

5.5.3 Heavy Metals and Other Toxic Materials

No heavy metals were used for water treatment of the cooling towers. The chlorinated Swan Lake cooling pond water was passed through the cooling system and a biodispersant, Nalco 7349, was added which lifted deposits from the metal surfaces so they could be oxidized by the chlorine. The biodispersant was fed intermittently with the rate of application adjusted to maintain a peak concentration of 20 mg/l. Nalco 7349 is a polyglycol manufactured by Nalco Chemical Company. Another Nalco product, Nalco 7387, was applied continuously to maintain less than 1 mg/l with a peak total phosphorus concentration of 1.3 mg/l. Nalco 7387 is an organophosphorus compound which prevents scale information. It does not have the toxic properties of organic phosphorus esters found in some restricted-use pesticides (Wo81). A total of 12750 kg (28,050 lbs) of Nalco 7387 was used and about 10% that much Nalco 7349.

Trace amounts of heavy metals and copious quantities of sodium chloride have been discharged into the CUB Tile Field (tile field in Fig. 5) inside the

Main Ring in the past. Copper is the primary heavy metal. It is an impurity removed by the ion exchange resins used to keep the conductivity of closed loop water systems low. These mixed-bed resins are regenerated using hydrochloric acid and sodium hydroxide. When the two chemicals combine after traversing the resins, salt (NaCl) is formed. Trace amounts of ^{7}Be are also removed (Section 4.4.2.2). A settling tank was used beginning in CY-1986 to remove salt and ^{7}Be from the effluent from resin regeneration. The salt is being stored to allow ^{7}Be levels to decrease by radioactive decay. Concentration of the radionuclides by reducing the water content with a press and then drying the salt in an oven has resulted in detection of ^{60}Co in the salt.

6. Evaluation of Environmental Impacts

6.1 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 (Fig. 3) (Du82). There are 326,645 people within 16 km (10 mi) of the center of the main accelerator based on the 1980 census results compared to 265,677 counted in the 1970 census. The detailed distribution of population as a function of distance and direction from Fermilab is given in Table 5 (Du82). The population distribution close to Fermilab is shown in Fig. 13.

The maximum dose rate at the site boundary in CY-1989 from Fermilab operations was 1.12 mrem for CY-1989. The point where that exposure occurred is along the northeastern site boundary. This is approximately 0.3% of the average effective dose equivalent to individuals due to natural sources (NRC90). The dose rate at the site boundary due to the Boneyard was 1.1 mrem but decreased to only 0.2 mrem at the location nearest residence.

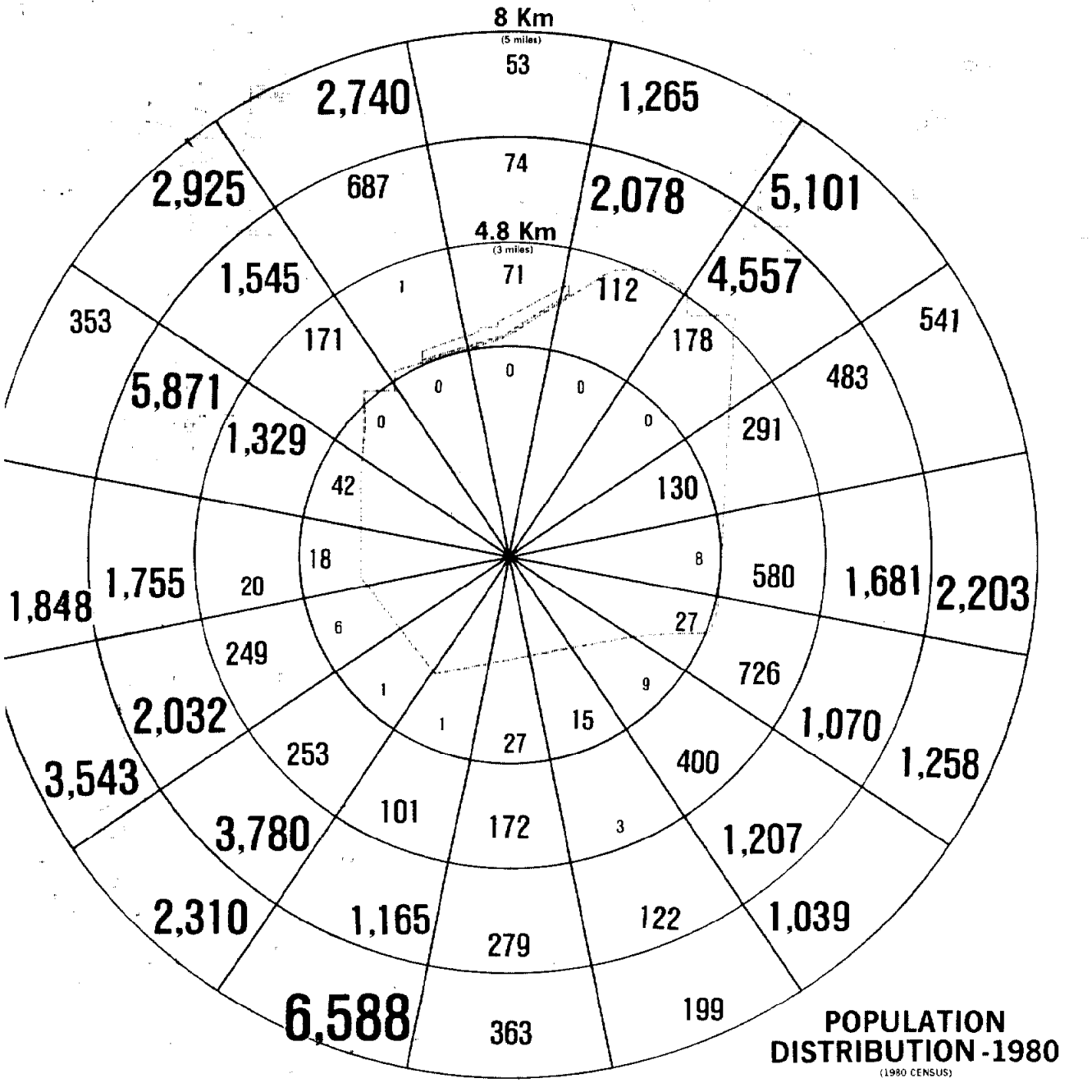
The radiation exposure to the general population from operation of Fermilab in CY-1989 was approximately 1.9 person-rem (Table 6). This exposure was from penetrating radiation and from airborne radionuclides. This total is to be compared with a total of approximately 2.4 million person-rem to the population within 80 km (50 mi) from natural background radioactivity. Based on typical United States radiation exposures from diagnostic x-rays, nuclear medicine treatments, and other artificial sources an additional 500,000 person-rem would be expected for the population in the Chicago area with 80 km (50 mi) of Fermilab

Table 5

Incremental Population Data in Vicinity of Fermilab, 1980

DISTANCE, KILOMETERS FROM CENTER OF MAIN RING	LATITUDE = 41.832					LONGITUDE = 88.251			
	0-8	8-16	16-32	32-48	48-64	64-80	80-97	97-113	113-128
DISTANCE, MILES	0-5	5-10	10-20	20-30	30-40	40-50	50-60	60-70	70-80
DIRECTION									
N	198	1110	77247	75658	63188	37183	30696	28459	149892
NNE	3455	5821	68274	76075	120930	145415	100858	173092	87495
NE	9836	12718	78701	292724	139718	0	0	0	0
ENE	1445	63784	263526	840460	551913	0	0	0	0
E	4472	18423	218631	1107254	924752	0	0	33317	56442
ESE	3081	15075	92242	268040	597113	379986	196888	78056	17600
SE	2655	25167	37956	34405	106938	38944	24651	11963	10027
SSE	339	3262	44203	148699	7962	21154	70503	10828	13195
S	841	1336	8604	10301	17011	11089	6640	4354	11967
SSW	7855	49656	8635	3492	17420	6373	25217	24588	10469
SW	6344	35851	13598	15566	5317	30917	36362	13671	13226
WSW	5830	2205	5578	6322	4509	10930	8474	11704	12175
W	3641	971	2941	5339	5111	13693	8445	28768	49103
WNW	7595	851	3018	42762	6723	21231	40449	13891	37012
NW	4641	9607	3297	7974	7358	65288	157549	71682	28229
NNW	3428	15152	22722	10674	29830	17952	29399	24276	58430
TOTAL	65656	260989	949173	2945745	2605793	800155	736131	528649	555262
CUMULATIVE TOTAL	65656	326645	1275818	4221563	6827356	7627511	8363642	8892291	9447553

FIGURE 13


8 Km
(5 miles)
4.8 Km
(3 miles)
53
74
71
2,740
1,265
687
2,078
2,925
5,101
1,545
112
4,557
353
171
178
541
5,871
483
1,329
291
42
130
1,848
1,755
20
18
8
580
1,681
2,203
6
27
249
726
2,032
1
9
1,070
1
15
27
253
400
1,258
3,543
101
172
3
3,780
1,207
2,310
1,165
122
1,039
279
6,588
363
199
POPULATION
DISTRIBUTION - 1980
(1980 CENSUS)
OVERLAY FOR BASE 3, FERMILAB
FERMI NATIONAL ACCELERATOR
LABORATORY AND VICINITY
PREPARED IN 1982
DOE

in CY-1989 (NRC90). (NOTE: Increased natural background exposures taken from this ref. are due to enhanced understanding of the indoor radon problem.)

The magnet debonding oven was used to debond 4 radioactive magnets in CY-1989. The resulting ^{3}H release from the debonding oven stack had negligible impact.

Table 6

Summary of Population Exposures for CY-1989 Within an 80 km (50 mi.) Radius of Fermilab

Sources	Contributions to Population Exposures (person-rem)
Penetrating radiation (gamma rays) from the Boneyard	1.2
Airborne radioactivity from the Antiproton Area	0.7
TOTAL	1.9

Some releases of radioactive water occurred from sumps collecting water from under areas where protons interacted. About 61% of this volume of water left the site while Casey's Pond (Fig. 5), 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 Derived Concentration Guide for prolonged exposure to the general population. Also, drinking water in the area is taken from wells rather than from the creek receiving the discharge. Hence, the dose from the release was negligible.

Between April and July 1987, a radon survey was conducted at Fermilab. The survey included Village residences, office areas and beam tunnels. The charcoal canister method (Co76) was used. A total of 41 canisters were used in this study. Four locations had results greater than the EPA residential standard of 4 pCi/l (Section 8). None of these locations has a high occupancy factor. The highest result was 8.0 pCi/l and the geometric mean was 1.4 x/+ 2.3 pCi/l.

The results of the survey do not indicate a need for remedial action in any area. Based on measurements covering a large portion of the site, it appears that the site is a normal radon concentration area.

6.2 Assessment of Nonradioactive Pollutant Releases

Although it was necessary to chemically treat some waters with aquazine to control the growth of algae and weeds during CY-1989, efforts were made to keep these treatments as low as possible in order to protect wildlife and fish. Aquazine is biodegradable and no environmental impact is expected. There is a program to look for persistent chemicals in the Fermilab environment periodically.

There were no activities during CY-1989 which created problems with respect to nonradioactive 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 Utility Building. These boilers are adjusted annually to maintain proper combustion efficiency.

6.3 Potential Impact of Other Toxic Substances

6.3.1 Pesticides

In addition to the water treatments mentioned in Section 5.5, the following EPA registered herbicides, insecticides and rodenticides were applied by licensed personnel following the manufacturer's instructions.

For broad leaf noxious weed control of the bison pasture 114 l (30 gal.) of 2,4-D Amine was applied to 32 hectares (80 acres) in 1989.

Roundup, containing 40% isopropylamine salt of N-(phosphonomethyl) glycine, and 40.4% Surflan A.S., containing Oryzalin (3,5-dinitro-N4,N4-dipropylsulfanil-amide) were applied in equal amounts around bases of trees, fire hydrants, sign posts, foundations, and liquified petroleum gas tanks to control annual and perennial grasses and weeds. The rate of application was approximately two liters (one-half gal.) each per 0.4 hectare (acre). The weeds and grasses treated were in the Village and Sauk Circle just south of the Village (Fig. 1), along major Fermilab roads, around Wilson Hall, Collider Detector Facility near the Industrial Area, Industrial Area, New Muon Laboratory, Neutrino Area bubble chamber, Experimental Areas Operations Center and Sites 38, 50, 52, 56, 58, and 64 (Figs. 4 and 5).

Spike 80W, a non-selective herbicide containing 80% tebuthiuron N-[5-(1,1-dimethylethyl)-1,3,4-thiadiazol-2-yl]-N,N' dimethylurea, was applied to 12 acres to control vegetation on gravel hardstands in the following areas: Master Substation and Village electrical substations, Meson and Proton areas, CHL, Bubble Chamber yards, and the Main Ring service buildings.

Corn was planted by licensees in CY-1989 on 3.43 km^2 (848.3 acres). Licensees are persons who pay the Laboratory for use of a portion of the land on the site for agricultural purposes. Pesticides were applied as follows:

677.2 kg (1493 lbs.) Aatrex Nine-0 herbicide, containing 2-chloro-4-ethyalmino-6-isopropylamino-s-triazine 85.5%, was applied at a rate of 1.76 lbs. per acre with 1 qt. of crop oil per acre to 848.3 acres of corn.

37.0 kg (81.5 lbs.) Lasso herbicide, containing 45.5% Alachlor [2-chloro-2,6-diethyl-N-(Methoxymethyl)acetanilide] at a rate of 2 qts. per acre, was applied to 163 acres of corn.

38.6 l (10.19 gal.) Banvel herbicide, containing 48.2% Dimethylamine salt of dicamba (3,6-dichloro-o-anisic acid), was applied to 163 acres of corn at a rate of 1/2 pint per acre.

665.4 kg (1,467 lbs.) Counter insecticide, containing 15% terbufos (S-{[(1,1-dimethylethyl)thio] methyl}0, 0-diethyl phosphorodithioate) applied to 163 acres.

Soybeans were planted by licensees in CY-1989 on 713.3 acres. The following pesticides were applied to this land:

337.9 l (89.16 gal.) of Basagran herbicide, containing 42% bentazon (3-(1methylethyl)-1H-2,1,3-benzothiadiazin-4-(3H)-one 2.2-dioxide applied to 713.3 acres.

506.1 l (133.74 gal.) of Fusilade 2000 herbicide, containing 13% fluazitop-p-butyl: butyl 2-(4.5-trifluoromethyl-2-pyridi/oxy) phenoxyproprionate applied to 713.3 acres.

290 l (76.63 gal.) low volatile 2,4-D ester, containing 65.5% isoctyl ester of 2,4-Dichlorophenoxyacetic acid was applied to 613.9 acres of soybeans at a rate of 1 pint per acre.

For mosquito control, an ultra low volume application of CYTHION Premium Grade Malathion insecticide was performed at only two different times. Approximately 11 liters (2.8 gal.) of CYTHION were used in each application at Sites 29 and 58 (Figs. 4 and 5).

Contrac Rat and Mouse Bait, EPA #12455-36, a rodenticide containing 0.005% 3-[3-(4'Bromo-[1,1'-biphenyl]-4-yl)-3-hydroxy-1-phenylpropyl]-4-hydroxy-2H-1-benzopyran-2-one was placed in pan-type feeders inside approximately 40 outdoor electrical substations to reduce rodent nesting in this high voltage equipment. Approximately 11.3 kg (25 lbs) was used in CY-1989.

The services of a contract exterminator, licensed by the State of Illinois and using EPA registered pesticides, was retained during CY-1989 for the control of miscellaneous pests found in kitchens, laboratories and living areas throughout the site.

6.3.2 Polychlorinated Biphenyls

An inventory of polychlorinated biphenyls (PCBs) still on the site is maintained. PCB inspections are performed and records are maintained as required by TSCA (40CFRb). As of January 1, 1990, there were 43 PCB transformers and 13 PCB contaminated transformers in use or in storage for use. The inventory of large PCB capacitors in use, in storage for use or in storage for disposal was reduced from 106 to 16 in CY-1989. The capacitors were disposed of by incineration in an off-site EPA-approved incinerator. Efforts are being made to obtain non-PCB substitutes for those few still in service.

6.3.3 Hazardous Wastes

Responsibility for disposal of hazardous waste was assigned to the Safety Section in CY-1979 and a hazardous waste handling and storage facility was developed at Site 55 (Fig. 5). This facility is roofed and fenced, and has a hardstand and 4 concrete containment areas. An additional facility with concrete

containment area for PCBs has been used in past years at Site 3 where the Environmental Monitoring Station is located (Fig. 5). This facility was intended for inside storage of hazardous materials which are for future use. This usage of Site 3 for storage was phased out in CY-1989. In CY-1982 a PCB storage building was constructed at Site 55 which is much farther from the site boundary than Site 3. This structure now houses all PCB items awaiting disposal. In CY-1984 a heated chemical waste storage building was added at Site 55. This facility was completed in 1985 and has a hood and an indoor shower and eyewash. It also has indoor containment areas to segregate acids and bases. Typical wastes are solvents, oils, laboratory chemicals, asbestos, acids, and bases.

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 (north of the Meson Lab, Fig. 1) to scatter muons and provide some additional shielding. To assure that none of these materials is hazardous to the environment and none will contribute to the contamination of surface or groundwaters, 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 which operates a permit system for deposition with permanent records. The Safety Section monitors this program. In 1982 burial of wood, paper and other wood products on the hill was halted.

In order to efficiently organize the collection of drum quantities hazardous waste, a number of satellite accumulation areas have been established to collect the waste. An ongoing program has been established to improve these areas by including provision for secondary containment for the ones that are outdoors. At Site 55, wastes are stored in a hazardous waste storage facility. The permit status of this facility is discussed in Section 3.3.

6.3.4 Heavy Metals

Copper sulfate is no longer used to treat the ponding systems. Copper solution from the etching of printed circuit boards was disposed of as hazardous waste or recycled. Chromate treatment of the cooling towers has been replaced by biodegradable treatments. All residences on the site were sampled for lead in drinking water. All were in compliance with new regulations. Thus, the environmental impact from heavy metals is and should continue to be negligible.

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6.3.5 Chlorides

The potential environmental impact of release of chlorides from the resin regeneration process into the CUB clay tile field (Fig. 5) has been evaluated. The process uses sodium hydroxide and hydrochloric acid, yielding sodium chloride (salt) and water. Assuming the salt released in one year (before CY-1986) all ends up in the nearest drinking water well (W-1 in Fig. 4) and is diluted in the water normally pumped from the well for one year, the concentration would be less than 25% of the applicable limit of 250 mg/l. See Section 9. Thus, the environmental impact should be minimal. A similar result was found for the impact from salt applied to Fermilab roads in the winter. Disposal of large volumes of salt in the CUB Tile Field was halted in CY-1986.

6.3.6 Ethylene Glycol

Ethylene glycol is used in various cooling systems at Fermilab. In November 1989 there were two spills of ethylene glycol to the environment (Meson Lab, CHL). Expedient cleanup of the spills and further dilution of any remaining ethylene glycol before it reached Casey's Pond prevented any adverse environmental impacts.

The leak that developed in an underground pipe at NW8 in late 1987 and continued until February 1988 has been remedied.

A new leak of ethylene glycol solution developed in the Proton beam lines in December 1989. This leak was fixed. Releases to the environment were insignificant.

6.3.7 Chlorofluorocarbons

A mixture of chlorofluorocarbons (Freon 115 and 116) having high vapor pressure became contaminated with oil (about 10% by volume) when a bubble chamber piston seal failed. The mixture was placed in a propane gas storage tank awaiting disposal. During early CY-1988 a leaking valve was discovered on the propane tank. Approximately 520 l (137 gal.) of chlorofluorocarbons had vented.

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The remaining Freon mixture has been transferred into compressed cylinders and is in storage for disposal at Site 55.

7. Quality Assurance in CY-1989

7.1 Quality Control

Environmental water samples collected in CY-1989 were analyzed by International Technology (IT) Corporation, 1550 Bear Creek Road, Oak Ridge, Tennessee 37831. In addition, some samples were counted at the Fermilab Nuclear Counting Laboratory. All ^{45}Ca and ^{3}H analyses were done by IT Corporation. Chemical separations have been found necessary for ^{45}Ca assay in the presence of ^{22}Na and other radionuclides. Each shipment to IT included at least one sample prepared at Fermilab containing a known amount of at least one accelerator-produced radionuclide.

Environmental samples collected for chemical analysis in 1989 were sent to our contracted vendor, National Environmental Testing, Inc. (NET), Bartlett, IL. Fermilab's environmental samples are collected, handled and preserved according to prescribed EPA methods. At the vendor, the samples are extracted and analyzed also using standard EPA methods. Since confidence levels specified by Fermilab depend upon the intended use of the data, they are set by Fermilab after consultation with NET, usually on a sample by sample basis. NET is certified for potable water analyses by the Illinois Environmental Protection Agency (IEPA) and participates in the USEPA's quality assurance program for analysis of water supplies (WS) and water pollutants (WP). They have been selected as a participant in the USEPA's Contract Laboratory Program (CLP).

7.1.1 Analytical Procedures at IT Corporation

IT Corporation analyzes water samples using similar procedures to those described previously (Ba82). Liquid scintillation counting is done using the scintillator "Pico-FluorLLT" and a counting system, both of which were manufactured by Packard Instrument Co., Inc., 2200 Warrenville Road, Downers Grove, Illinois 60515. Gamma spectroscopy is done with intrinsic germanium semiconductor detectors with efficiencies 20% to 30% that of a 7.6 cm dia. x 7.6 cm high NaI (Tl) scintillator. Alpha detection is done using a scintillation counter after whatever specific chemical separation is required. Screening for

^{45}Ca is done by liquid scintillation counting. Any necessary chemical separation of ^{45}Ca is followed by beta counting using gas-flow proportional counters (Ha88).

The samples were subjected to the appropriate one of the following analyses:

Type 1a: Test for ^{3}H (tritium), ^{7}Be, ^{22}Na, ^{45}Ca, ^{54}Mn, and ^{60}Co at surface water sensitivities. See Table 7.

Type 2a: Test for all of the above at groundwater sensitivity plus total radium (the sum of ^{223}Ra, ^{224}Ra, and ^{226}Ra) and total thorium (the sum of ^{228}Th and ^{232}Th).

Type 3a: Chemical separation of ^{45}Ca before its determination; otherwise the same as Type 1a.

Type 4a: ^{3}H only, at surface water sensitivity.

Type 5a: Chemical separation of ^{45}Ca and analysis for ^{45}Ca only, using surface water sensitivity.

Type 6a: The same as Type 1a except at groundwater sensitivity.

Type 7a: The same as Type 4a except at groundwater sensitivity following distillation.

Type 8a: Test for gross alpha, gross beta, ^{3}H, ^{131}I, and ^{134}Cs at groundwater sensitivity. This analysis is performed on drinking water systems on-site which supply water to more than 25 people during the workday.

Type 9a: Test for Sr-90 only, at groundwater sensitivity.

Separate analyses of two aliquots from the same sample bottle is indicated by changing the letter "a" to the letter "b" on the Type designation.

The specifications for the above analyses are given in Table 7.

Table 7
Specifications for the Analyses of Accelerator-Produced Radionuclides in Water

Radionuclide	CONCENTRATION GUIDE FOR POPULATION (pCi/ml) Surface Water	Groundwater	SPECIFIED SENSITIVITY AND PRECISION* (pCi/ml) Surface Water	Groundwater
^{3}H	2000	20	3.0	1.0
^{7}Be	1000	40	0.5	0.5
^{22}Na	10	0.40	0.3	0.22
^{45}Ca	50	2	0.3	0.006
^{54}Mn	50	2	0.1	0.07
^{60}Co	5	0.2	0.1	0.02

* The precision and sensitivity are stated for the 95% confidence level (approximately two standard deviations).
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.

7.1.2 Quality Assurance Samples

During CY-1989 Fermilab and IT Corporation participated in the DOE Environmental Measurements Laboratory (EML) quality assurance program (Sa89, Sa90). Results are given in Tables 8, 9, 10, and 11. All ^{3}H samples were done by the vendor in CY-1989 (Section 4.4). Fermilab sent quality assurance samples monthly to IT Corporation. See Table 11. The range of radiochemical spikes were prepared to test our vendor's ability to achieve the required sensitivity for each parameter and their reliability in detecting accelerator-produced radionuclides at or below the concentration guide standards. See Table 7.

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Table 8

EML Quality Assurance Program Results for Fermilab (Sa89)

Sample Date	Sample Type	Lab Code	Isotope	SER	Reported Value	%Error	EML Value	Ratio Rp/EML	+/-	Units
4/89	Air	FN	^{7}Be	1	0.111E+04	8	0.195E+04	0.57	0.06	pCi/filter
"	"	"	^{7}Be	2	0.111E+04	8	0.195E+04	0.57	0.06	"
"	"	"	^{60}Co	1	0.803E+02	5	0.126E+03	0.64	0.05	"
"	"	"	^{60}Co	2	0.783E+02	5	0.126E+03	0.62	0.05	"
"	"	"	^{125}Sb	1	0.532E+02	4	0.968E+02	0.55	0.04	"
"	"	"	^{125}Sb	2	0.540E+02	4	0.968E+02	0.56	0.04	"
"	"	"	^{134}Cs	1	0.950E+02	3	0.158E+03	0.60	0.04	"
"	"	"	^{134}Cs	2	0.956E+02	3	0.158E+03	0.61	0.04	"
"	"	"	^{137}Cs	1	0.122E+03	8	0.189E+03	0.65	0.06	"
"	"	"	^{137}Cs	2	0.121E+03	8	0.189E+03	0.64	0.06	"
4/89	Soil	"	^{137}Cs	1	0.230E+02	8	0.208E+02	1.11	0.10	pCi/g
4/89	Veg.	"	^{137}Cs	1	0.154E+01	8	0.160E+01	0.96	0.08	"
4/89	Water	"	^{54}Mn	1	0.320E+00	12	0.300E+00	1.07	0.15	pCi/ml
"	"	"	^{60}Co	1	0.900E+00	6	0.940E+00	0.96	0.08	"
"	"	"	^{134}Cs	1	0.266E+01	3	0.273E+01	0.97	0.06	"
"	"	"	^{137}Cs	1	0.255E+01	9	0.255E+01	1.00	0.11	"

Table 9

EML Quality Assurance Program Results for Fermilab (Sa90)

Sample Date	Sample Type	Lab Code	Isotope	SER	Reported Value	%Error	EML Value	Ratio Rp/EML	+/-	Units
9/89	Air	FN	^{7}Be	1	0.969E+02	15	0.123E+03	0.79	0.12	Bq/filter
"	"	"	^{7}Be	2	0.116E+03	15	0.123E+03	0.94	0.15	"
"	"	"	^{54}Mn	1	0.373E+01	15	0.417E+01	0.89	0.15	"
"	"	"	^{54}Mn	2	0.413E+01	14	0.417E+01	0.99	0.15	"
"	"	"	^{60}Co	1	0.725E+01	11	0.817E+01	0.89	0.10	"
"	"	"	^{60}Co	2	0.856E+01	11	0.817E+01	1.05	0.12	"
"	"	"	^{134}Cs	1	0.786E+01	9	0.933E+01	0.84	0.08	"
"	"	"	^{134}Cs	2	0.900E+01	9	0.933E+01	0.96	0.09	"
"	"	"	^{137}Cs	1	0.322E+01	15	0.358E+01	0.90	0.15	"
"	"	"	^{137}Cs	2	0.381E+01	15	0.358E+01	1.06	0.17	"
"	"	"	^{144}Ce	1	0.577E+01	15	0.708E+01	0.81	0.14	"
"	"	"	^{144}Ce	2	0.669E+01	15	0.708E+01	0.94	0.17	"
9/89	Soil	"	^{40}K	1	0.575E+03	8	0.561E+03	1.02	0.10	Bq/kg
"	"	"	^{137}Cs	1	0.702E+03	8	0.642E+03	1.09	0.10	"
"	"	"	^{238}U	1	0.428E+02	15	0.217E+02	1.97	0.43	"
9/89	Veg.	"	^{40}K	1	0.133E+04	8	0.129E+04	1.03	0.10	"
"	"	"	^{60}Co	1	0.806E+02	6	0.816E+02	0.99	0.06	"
"	"	"	^{137}Cs	1	0.465E+02	8	0.479E+02	0.97	0.09	"
9/89	Water	"	^{54}Mn	1	0.672E+02	8	0.650E+02	1.03	0.12	Bq/l
"	"	"	^{57}Co	1	0.131E+03	6	0.135E+03	0.97	0.10	"
"	"	"	^{60}Co	1	0.160E+03	6	0.155E+03	1.03	0.11	"
"	"	"	^{134}Cs	1	0.676E+02	5	0.683E+02	0.99	0.10	"
"	"	"	^{137}Cs	1	0.732E+02	8	0.683E+02	1.07	0.12	"
"	"	"	^{144}Ce	1	0.136E+03	8	0.132E+03	1.08	0.13	"

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Table 10

EML Quality Assurance Program Results for IT Corporation (Sa89)

Sample Date	Sample Type	Lab Code	Isotope	SER	Reported Value	%Error	EML Value	Ratio Rp/EML	Ratio +/-	Units
4/89	Air	AS	^{7}Be	1	0.150E+04	26	0.195E+04	0.77	0.21	pCi/filter
"	"	"	^{54}Mn	1	0.200E+01	50	0.374E+01	0.53	0.27	"
"	"	"	^{60}Co	1	0.110E+03	18	0.126E+03	0.87	0.16	"
"	"	"	^{90}Sr	1	0.300E+01	33	0.239E+01	1.26	0.42	"
"	"	"	^{125}Sb	1	0.100E+02	20	0.968E+02	0.10	0.02	"
"	"	"	^{134}Cs	1	0.110E+03	18	0.158E+03	0.70	0.13	"
"	"	"	^{137}Cs	1	0.150E+03	20	0.189E+03	0.79	0.16	"
"	"	"	^{144}Ce	1	0.290E+03	31	0.327E+03	0.89	0.28	"
"	"	"	^{239}Pu	1	0.300E+00	66	0.270E+00	1.11	0.75	"
"	"	"	^{241}Am	1	0.300E+00	66	0.225E+00	1.33	0.90	"
"	"	"	^{238}U	1	0.300E+00	66	0.900E-01	3.33	2.23	"
4/89	Soil	"	^{40}K	1	0.240E+02	20	0.241E+02	1.00	0.21	pCi/g
"	"	"	^{90}Sr	1	0.800E+00	25	0.190E+01	0.73	0.19	"
"	"	"	^{137}Cs	1	0.200E+02	15	0.208E+02	0.96	0.15	"
"	"	"	^{239}Pu	1	0.400E+00	25	0.420E+00	0.95	0.24	"
"	"	"	^{241}Am	1	0.200E+00	29	0.210E+00	0.95	0.29	"
4/89	Veg.	"	^{40}K	1	0.270E+02	22	0.261E+02	1.03	0.23	"
"	"	"	^{90}Sr	1	0.360E+01	13	0.375E+01	0.96	0.13	"
"	"	"	^{137}Cs	1	0.150E+01	20	0.160E+01	0.94	0.19	"
"	"	"	^{239}Pu	1	0.800E-01	12	0.220E-01	3.64	0.59	"
"	"	"	^{241}Am	1	0.160E-01	31	0.150E-01	1.07	0.51	"
"	"	"	^{238}U	1	0.240E-01	37	0.120E-01	2.00	0.90	"
4/89	Water	"	^{3}H	1	0.600E+01	16	0.631E+01	0.95	0.18	pCi/ml
"	"	"	^{54}Mn	1	0.320E+00	15	0.300E+00	1.07	0.18	"
"	"	"	^{57}Co	1	0.850E+00	10	0.880E+00	0.97	0.12	"
"	"	"	^{60}Co	1	0.920E+00	9	0.940E+00	0.98	0.11	"
"	"	"	^{90}Sr	1	0.590E+00	15	0.550E+00	1.07	0.17	"
"	"	"	^{134}Cs	1	0.230E+01	8	0.273E+01	0.84	0.09	"
"	"	"	^{137}Cs	1	0.250E+01	16	0.255E+01	0.98	0.17	"
"	"	"	^{239}Pu	1	0.700E-02	28	0.590E-02	1.19	0.34	"
"	"	"	^{241}Am	1	0.400E-02	19	0.450E-02	0.89	0.21	"
"	"	"	^{238}U	1	0.500E-02	20	0.440E-02	1.14	0.24	"

Table 11

EML Quality Assurance Program Results for IT Corporation (Sa90)

Sample Date	Sample Type	Lab Code	Isotope	SER	Reported Value	%Error	EML Value	Ratio Rp/EML	+/-	Units
9/89	Air	AS	^{7}Be	1	0.100E+03	26	0.123E+03	0.81	0.21	Bq/filter
"	"	"	^{54}Mn	1	0.400E+01	27	0.417E+01	0.96	0.27	"
"	"	"	^{60}Co	1	0.770E+01	18	0.817E+01	0.94	0.17	"
"	"	"	^{90}Sr	1	0.210E+00	28	0.200E+00	1.05	0.30	"
"	"	"	^{134}Cs	1	0.740E+01	14	0.933E+01	0.79	0.12	"
"	"	"	^{137}Cs	1	0.340E+01	26	0.358E+01	0.95	0.25	"
"	"	"	^{144}Ce	1	0.700E+01	32	0.708E+01	0.99	0.33	"
"	"	"	^{239}Pu	1	0.210E+00	28	0.180E-01	11.67	3.34	"
"	"	"	^{241}Am	1	0.600E-01	16	0.180E-01	3.33	0.67	"
"	"	"	^{238}U	1	0.200E-01	50	0.900E-02	2.22	1.11	"
9/89	Soil	"	^{40}K	1	0.557E+03	21	0.561E+03	0.99	0.21	Bq/kg
"	"	"	^{90}Sr	1	0.421E+01	19	0.573E+01	0.73	0.14	"
"	"	"	^{137}Cs	1	0.631E+03	19	0.642E+03	0.98	0.19	"
"	"	"	^{239}Pu	1	0.161E+02	26	0.171E+02	0.94	0.34	"
"	"	"	^{241}Am	1	0.318E+01	19	0.222E+01	1.43	0.32	"
"	"	"	^{ug}U	1	0.218E+01	20	0.171E+01	1.27	0.32	"
9/89	Veg.	"	^{40}K	1	0.142E+04	18	0.129E+04	1.10	0.21	"
"	"	"	^{90}Sr	1	0.756E+03	14	0.183E+04	0.41	0.06	"
"	"	"	^{137}Cs	1	0.470E+02	19	0.479E+02	0.98	0.19	"
"	"	"	^{283}U	1	0.410E+00	26	0.600E+00	0.68	0.20	"
9/89	Water	"	^{3}H	1	0.386E+03	14	0.395E+03	0.98	0.15	Bq/l
"	"	"	^{54}Mn	1	0.670E+02	14	0.650E+02	1.03	0.17	"
"	"	"	^{57}Co	1	0.135E+03	10	0.135E+03	1.00	0.13	"
"	"	"	^{60}Co	1	0.155E+03	9	0.155E+03	1.00	0.12	"
"	"	"	^{90}Sr	1	0.355E+02	14	0.317E+02	1.12	0.16	"
"	"	"	^{134}Cs	1	0.590E+02	10	0.683E+02	0.86	0.11	"
"	"	"	^{137}Cs	1	0.710E+02	14	0.683E+02	1.04	0.17	"
"	"	"	^{144}Ce	1	0.135E+03	15	0.132E+03	1.02	0.18	"
"	"	"	^{239}Pu	1	0.250E+00	28	0.350E+00	0.71	0.20	"
"	"	"	^{241}Am	1	0.430E+00	18	0.333E+00	1.29	0.29	"
"	"	"	^{238}U	1	0.220E+00	27	0.167E+00	1.32	0.36	"

Table 12
Fermilab Quality Assurance Program Results for IT Corporation*

Sample Number	Radionuclide	Prepared Concentration (pCi/ml)	Ratio of IT Corp. Result to Prepared Concentration
8901	^{3}H	952	1.09
	^{7}Be	9.14	1.05
	^{22}Na	.77	0.90
	^{45}Ca	419	0.90
	^{54}Mn	.37	0.97
	^{60}Co	3.89	0.98
8902	^{3}H	4.76	0.88
	^{7}Be	17.7	0.96
	^{22}Na	38.5	0.91
	^{45}Ca	30.0	0.86
	^{54}Mn	54.2	1.06
	^{60}Co	.78	0.96
8903	^{3}H	2.27	1.28
	^{7}Be	.18	Ok
	^{22}Na	.72	0.93
	^{45}Ca	.15	0.69
	^{54}Mn	.06	Ok
	^{60}Co	.08	0.87
8904	^{3}H	9.04	1.01
8905	^{3}H	4.67	2.40; 1.03**
	^{7}Be	.91	0.87
	^{22}Na	.21	Ok
	^{45}Ca	25.05	0.76
	^{54}Mn	.28	0.98
	^{60}Co	.08	Ok
8906	^{3}H	90.0	1.05
8907	^{3}H	90.0	1.13
8908	^{3}H	1961	1.11
8909	^{3}H	9.66	7.97
	^{22}Na	21.9	0.95
	^{45}Ca	1.31	0.99
	^{54}Mn	80.1	1.04
	^{60}Co	12.0	1.08
8910	^{3}H	103	0.98
	^{22}Na	10.5	0.89
	^{45}Ca	1.01	0.97
	^{54}Mn	19.0	1.11
	^{60}Co	23.5	0.82
8911	^{3}H	11.7	1.03
8913	^{3}H	2.27	1.32; 1.23**
	^{7}Be	.18	Ok
	^{22}Na	.72	0.86
	^{45}Ca	.15	0.74
	^{54}Mn	.06	Ok
	^{60}Co	.08	0.75
8914	^{3}H	9.04	1.11

Sample Number	Radionuclide	Prepared Concentration (pCi/ml)	Ratio of IT Corp. Result to Prepared Concentration
8915	^{3}H	4.67	2.33; 1.00**
	^{7}Be	0.91	0.86; 0.55**
	^{22}Na	0.21	Ok
	^{45}Ca	25.1	0.40; 0.36**
	^{54}Mn	.28	0.95; 0.79**
	^{60}Co	.08	Ok
8916	^{3}H	89.3	1.01
8917	^{3}H	90.0	1.33
8918	^{3}H	1961	1.08
8919	^{3}H	9.66	8.08
	^{22}Na	21.9	0.90
	^{45}Ca	1.31	0.92
	^{54}Mn	80.1	0.99
	^{60}Co	12.0	1.03
8920	^{7}Be	.49	Ok
	^{45}Ca	1.00	0.78
	^{60}Co	23.46	0.93
	^{3}H	103	0.96
	^{54}Mn	19.0	1.06
	^{22}Na	10.46	0.80
8921	^{3}H	11.7	0.09

*Samples prepared by Fermilab and sent with shipments of environmental samples.
**Reanalysis results.
Ok = means vendor reported results correctly as less than the required sensitivity.

7.2 Additional Quality Assurance Efforts

The scope of the environmental protection program at Fermilab has broadened over the years. The Laboratory has doubled in personnel from the number employed when the first proton beam was extracted from the main accelerator in 1972. Regulations have changed. Much more emphasis is now being placed on control of hazardous wastes and other nonradioactive pollutants.

As the inventory of radionuclides with potential for release to the environment has grown, the environmental monitoring program has expanded. More remote pathways have been explored and additional sampling points have been added. Special investigations have been made to measure concentrations and to detect any unexpected movement of radionuclides. These investigations would provide any necessary early warnings, giving time to take action before an off-site problem occurs.

Fermilab has a number of closed water systems which build up inventories of radionuclides, primarily tritium. These are sampled periodically to provide information useful for spill control. The precautions taken are imposed based upon the potential environmental impact. Once the concentration exceeds that which can be released according to DOE regulations (Section 8), then a spill plan is written and becomes part of the Laboratory's Spill Prevention, Control, and Countermeasures Plan (SPCC Plan).

When spills occur from closed loop cooling systems, sump pumps are shut off in the vicinity and samples taken to determine whether or not the water in the sump pits can be released. One of the lessons learned from spills is that a leak of water into a vacuum system in a radiation area can result in much higher tritium concentrations in the water pumped out than expected. The water vapor removes tritium from components. Other radionuclides are not removed, so a gamma ray survey meter does not detect the problem.

The Laboratory has strengthened its environmental review program. All new projects requiring project directives and/or affecting land management on the site receive a comprehensive environmental review. The review program includes considerations, such as threatened and endangered species, cultural resources, wetlands, and flood plains, specifically addressed in the National Environmental Policy Act (NEPA).

In addition, the Laboratory has strengthened its waste collection and auditing programs. Hazardous waste generators on the site are now required by regulation (40CFRc) to have a waste minimization program. The Laboratory documents these efforts in an annual report to the State of Illinois. This report also gives the quantities and types of hazardous waste generated, stored on-site, and disposed of off the site. The Laboratory does not have an on-site hazardous waste disposal facility.

Some radioactive water solidified in CY-1986 and some low-level radioactive scrap metal which normally have been declared waste and shipped off-site for burial were recycled by using them in the construction of shielding blocks since CY-1987. These blocks are being used for reducing the exposure from higher level radioactive materials at the Boneyard (Fig. 5). The composition of these blocks is recorded in the Decontamination and Decommissioning File.

8. SARA Title III Chemical Inventory Findings

In late FY-1989 Fermilab conducted a sitewide chemical inventory in accordance with the requirements of SARA Title III. Additional information on quantities, on-site locations, and nonhazardous materials was also collected to facilitate on-site management of chemicals. Inventory results showed 3433 chemical entries representing 2662 different materials in 81 locations. The most frequent entries were common solvents: acetone (54), ethanol (30), methanol (24), and isopropanol (20). The total volume in large quantity entries (individual containers >4 l) was ~660,000 l (170,000 gal.), but 77% of this was gasoline-contaminated soil from a leaking underground tank cleanup. The total volume in small quantity entries is estimated to be less than ~10,000 l (2500 gal.).

The distribution of large quantities entries, excluding the contaminated soil, is shown in the following table. About half of the list would not be considered RCRA hazardous (ethylene glycol, oils, epoxies, and half of "other"). The most interesting finding from an environmental standpoint is the relatively large amounts of chlorofluorocarbons (~14% of total volume). Most of the small quantity materials are adhesives, coatings, fillers, fluxes, cleaners, pesticides, photochemicals, and analytical chemicals.

Nearly 80% of the large quantity materials were housed in only three areas: Site 55 (35%), Site 38 (29%), and the Industrial Complex (15%). Nearly two-thirds of the materials at the Site 55 Hazardous Waste Storage Area were oil and ethylene glycol. Other major components at this location included 1,1,2-trichloro-1,2,2-trifluoroethane and petroleum distillates. The Site 38 Stock Areas contained a wide variety of materials: two-thirds of the volume was made up of Freon 11, ethylene glycol, ethanol, and 1,1,2-trichloro-1,2,2-trifluoroethane. More than half of the materials in the Industrial Complex were epoxy components with much of the balance made up of solvents and heat transfer liquids.

DISTRIBUTION OF LARGE QUANTITY MATERIALS IN SARA III INVENTORY FERMILAB 1989*

	Volume	
	liters	gallons
HEAT TRANSFER LIQUIDS	31560	8301
Ethylene glycol based	22900	6034
Freon 11	8400	2200
Freon 22	260	67
PETROLEUM OILS	29200	7680
SOLVENTS	33122	8722
1,1,2-Trichloro-1,2,2-trichfluoroethane	11900	3136
Ethanol	8136	2141
Acetone	6832	1798
Petroleum distillates	4549	1197
1,1,2-Trichloroethane	1235	325
Isopropanol	240	64
Glid-strip	230	61
EPOXIES (var. products)	11320	2980
CORROSIVES	10080	2650
Sodium hydroxide	4600	1210
Hydrochloric acid	3590	945
Copperbrite	1240	325
Ferric chloride	650	170
OTHER	38561	10152
TOTAL	153842	40485

*Excludes ~500 m^3 of gasoline-contaminated soil

9. References

The appropriate Radiation Protection Standard for penetrating radiation applied to individuals in uncontrolled areas was taken from the DOE Order 5480.1A, Chapter XI.7. The annual dose limit for whole body exposure is 500 mrem when applied to occasional exposures such as might occur during an accident. The appropriate standard for a prolonged period of exposure of the general population is 100 mrem/yr including exposures from drinking water and airborne radioactivity. Exposures to the public from routine Fermilab operations must meet the regulations corresponding to prolonged periods.

The Concentration Guides used in the analyses of the surface water samples for radioactivity were taken from the draft DOE Order 5400.XY and DOE Order 5480.1, Chapter XI, (replacing Table II, Column 2), Derived Concentration Guides

1989

(DCG) - Concentrations of Radionuclides in Water and Air that could be Continuously Consumed or Inhaled, Respectively, and Not Exceed an Effective Dose Equivalent of 100 mrem/year. The specifications are given in Table 10. These Derived Concentration Guides are based on guidance given in International Commission on Radiological Protection (ICRP) Publications 23, 26, and 30, Pergamon Press, New York. For tritium the Derived Concentration Guide is 2×10^{-7} μCi/ml. For ^{11}C the Derived Concentration Guide, for prolonged exposures, is 2×10^{-8} μCi/ml because submersion dose must be included for ^{11}C. Of the 100 mrem/year for prolonged exposure, a maximum of only 25 mrem/year per person is allowed from airborne radioactivity. This regulation is imposed by the United States Environmental Protection Agency (EPA) and is found in the U.S. Code of Federal Regulations 40 CFR 61. The source for EPA guidance on radon exposure is document EPA-OPA-86-004, issued in August 1986. The recommended residential limit is 4 pCi/l.

The Concentration Guide used in the analyses of groundwater samples for tritium was taken from the U.S. Environmental Protection Agency regulations for community drinking water systems (40CFRb). 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. Thus, of the 100 mrem/yr permitted for prolonged exposure of the general population, only 4 mrem is allowed from drinking water. The proposed EPA regulation based on ICRP-30 lists 9×10^{-5} μCi/ml for ^{3}H. The Concentration Guides for the other radionuclides in Fermilab's analyses of groundwater samples have been determined by dividing the Derived Concentration Guides (DCG) in the draft DOE Order 5400.XY by 25 (Table 8). These agree well with the proposed EPA regulations. The specified sensitivity and precision of the analyses have been reduced to well below these Concentration Guides (to at most 10% of the Guide).

The Air and Water Pollution Standards for nonradioactive pollutants were taken from Chapters 2 and 3 of the State of Illinois Pollution Control Board Rules and Regulations (I175). The waters on-site were considered to be in the "general use" category. The value for total hexavalent chromium for general water quality of 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, for silver are 0.1 and 0.005 mg/l respectively, and for cyanide are 0.025 mg/l for both. The maximum contaminant level for chloride in water for general use is

500 mg/l and the level of total dissolved solids is 1000 mg/l. In public drinking water the standards for chloride and total dissolved solids are 250 mg/l and 500 mg/l, respectively (I1b). The Air Quality Standards limit the release for oxides of nitrogen to 136 g (0.3 lbs) per 252 million calories (per million btu's) of actual heat input in any one hour. Release of sulfur dioxide shall not exceed 2000 ppm (I175).

The appropriate regulations for PCBs and hazardous wastes are found in the U.S. Code of Federal Regulations 40 CFR 761 and 40 CFR 260-265, respectively. The concentration limit is 2 ppm for human consumption of fish (21CFR).

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