PPPL--2862

DE93 008517

PRINCETON PLASMA PHYSICS LABORATORY (PPPL) ANNUAL SITE ENVIRONMENTAL REPORT FOR CALENDAR YEAR 1991

BY

V. L. Finley

and

J. R. Stencel

Table of Contents

Page

Table of Contents i
List of Tables iii
List of Figures iv
1.0 EXECUTIVE SUMMARY 1
2.0 INTRODUCTION 3
2.1 General 3
2.2 Description of the Site 6
3.0 1991 ENVIRONMENTAL COMPLIANCE SELF-ASSESSMENT 8
3.1 Compliance Summary 8
3.1.1 Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) 8
3.1.2 Clean Air Act (CAA) 9
3.1.3 Clean Water Act (CWA) 10
3.1.4 Endangered Species Act (ESA) and National Historic Preservation Act (NHPA) 11
3.1.5 Executive Order (EO) 11988, "Floodplain Management" and 11990, "Protection of Wetlands" 11
3.1.6 Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) 12
3.1.7 National Environmental Policy Act (NEPA) 12
3.1.8 Resource Conservation and Recovery Act (RCRA) 12
3.1.9 Safe Drinking Water Act (SDWA) 13
3.1.10 Toxic Substance Control Act (TSCA) 13
3.2 Current Issues and Actions 13
3.3 Environmental Permits 14
3.3.1 Clean Air Act (CAA) 15
3.3.2 Clean Water Act (CWA) 15
3.3.3 Resource Conservation and Recovery Act (RCRA) 16
3.3.4 Miscellaneous Permits 16
3.4 January 1 - April 1, 1992 Environmental Compliance Summary 17
4.0 ENVIRONMENTAL PROGRAM INFORMATION 18
4.1 Assessment of Radiation Dose to the Public 18
4.2 Assessment of Nonradioactive Pollutants 19
4.3 Pollution Prevention and Waste Minimization 19
4.4 Regulations and Safety Criteria 20
4.5 Future Program Expansion 20
4.5.1 Meteorological 20
4.5.2 Water Quality 20
4.5.3 Radioactive Effluents 21
4.5.4 Nonradioactive Effluents 21
5.0 ENVIRONMENTAL RADIOLOGICAL PROGRAM INFORMATION 22
5.1 Radiological Emissions and Doses 22
5.1.1 Penetrating Radiation 22
5.1.2 Sanitary Sewage 23
5.1.3 Special Radiation Surveys 24
5.1.4 Airborne Radioactivity 25
5.2 Unplanned Releases 26
5.3 Environmental Monitoring 26
5.3.1 Waterborne Radioactivity 26
5.3.2 Foodstuffs 28
5.3.3 Soil, Grass, and Vegetation 28
6.0 ENVIRONMENTAL NON-RADIOLOGICAL PROGRAM INFORMATION 29
6.1 NJPDES Data 29

6.1.1 Surface and Storm Water 29
6.1.2 Groundwater Assessment 30
6.2 Other Non-Radiological Data 33
6.2.1 Other Emissions Monitoring Data 33
6.2.2 Continuous Release Reporting 38
6.2.3 Environmental Occurrences 38
6.2.4 SARA Title III Reporting Requirements 40
7.0 GROUNDWATER PROTECTION 41
8.0 QUALITY ASSURANCE 42
9.0 ACKNOWLEDGEMENTS 43
10.0 REFERENCES 44

List of Tables

		Page
Table 1.	TFTR/BPX Radiological Design Objectives and Regulatory Limits	51
Table 2.	Critical Pathways	52
Table 3	Monitoring Program Covering Critical Pathways	53
Table 4.	Population of Municipalities Within 0-10 Miles of PPPL	54
Table 5.	Population of Counties Within 0-50 Miles of PPPL	55
Table 6.	Population of Metropolitan Areas Within 50 Miles of PPPL	56
Table 7.	1985 Population Estimates Within Annular Sectors, 0-10 Miles	57
Table 8.	1995 Population Estimates Within Annular Sectors, 0-10 Miles	58
Table 9.	2000 Population Estimates Within Annular Sectors, 0-10 Miles	59
Table 10.	2005 Population Estimates Within Annular Sectors, 0-10 Miles	60
Table 11.	2010 Population Estimates Within Annular Sectors, 0-10 Miles	61
Table 12.	1985 Population Estimates Within Annular Sectors, 10-50 Miles	62
Table 13.	1995 Population Estimates Within Within Annular Sectors, 10-50 Miles	63
Table 14.	2000 Population Estimates Within Within Annular Sectors, 10-50 Miles	64
Table 15.	2010 Population Estimates Within Within Annular Sectors, 10-50 Miles	65
Table 16.	Sectorized Population Data to 1 Mile	66
Table 17.	Environmental Permits	67
Table 18.	Summary of 1991 Airborne Emissions and Doses from TFTR	68
Table 19.	Tritium in Precipitation for 1991	69
Table 20.	Precipitation at PPPL for 1991	70
Table 21.	Tritium Concentrations in Surface Water and Groundwater for 1991	71
Table 22.	Tritium Concentrations in Soil/Sod and Biota Moisture for 1991	71
Table 23.	Surface Water Analysis for Bee Brook, Locations B1 and B2	72
Table 24.	Surface Water Analysis for D&R Canal, C1 and Ditch #5, D1	72
Table 25.	Water Analysis for Water Supply, E1 and the Millstone River, M1	73
Table 26.	Surface Water Analysis for Plainsboro, Locations P1 and P2	73
Table 27.	Detention Basin Influent Analysis (NJPDES)	73
Table 28.	Surface Water Analysis for Ditch #5, Location D2 (NJPDES DSN 001A)	74
Table 29.	1991 Release Reports	75
Table 30.	Fertilizer, Pesticides, and Herbicide Application	76
Table 31.	Volatile Organic Compounds in Groundwater: 1991 Results	78
Table 32.	Underground Storage Tank Monitoring Program Results - August 1991	79
Table 33.	Underground Storage Tank Monitoring Program Results - November 1991	79
Table 34.	Groundwater Analysis for Well MW-14, MW-15, and MW-16	80
Table 35.	Groundwater Analysis for Wells D-11 and D-12	81
Table 36.	Groundwater Analysis for Well TW-2 and TW-3	81
Table 37.	Groundwater Volatile Organics Analysis (May 1991)	82
Table 38.	Groundwater Volatile Organics Analysis (August 1991) and Detention Basin Volatile Organic Analysis (September 1991)	83
Table 39.	Groundwater Base Neutral Analysis	84
Table 40.	PPPL REML QA/QC from EPA/Las Vegas and DOE/EML	86
Table 41.	QA Sample Data	87

List of Figures

		Page
Figure 1.	The Princeton Beta Experiment-Modification (PBX-M)	88
Figure 2.	The Tokamak Fusion Test Reactor (TFTR)	89
Figure 3.	Wind Rose Joint Frequency Data for TFTR at 10 m	90
Figure 4.	Wind Rose Joint Frequency Data for TFTR at 30 m	91
Figure 5.	Wind Rose Joint Frequency Data for TFTR at 60 m	92
Figure 6.	Annual Average Tempertaure at TFTR	93
Figure 7.	Annual Average Absolute Humidity at TFTR Site 1983-1991	94
Figure 8.	Annual Average Relative Humidity at TFTR Site 1983-1991	94
Figure 9.	Annual Average Wind speed at TFTR Site 1983-1991	95
Figure 10.	Comparison of Monthly Average Wind Speed between 1984 and 1990 at 30 m Elevation	95
Figure 11.	Aerial View of the Forrestal Campus	96
Figure 12.	C- and D-Sites of the Forrestal Campus, PPPL	97
Figure 13.	80 km (50-mile) Radius of PPPL Site	98
Figure 14.	Immediate Site Vicinity (5 Mile Radius)	99
Figure 15.	Layout of James Forrestal Campus	100
Figure 16.	1985 Population Estimates Within Annular Sectors (0-10 Miles)	101
Figure 17.	1995 Population Projections Within Annular Sectors (0-10 Miles)	102
Figure 18.	2000 Population Projections Within Annular Sectors (0-10 Miles)	103
Figure 19.	2005 Population Projections Within Annular Sectors (0-10 Miles)	104
Figure 20.	2010 Population Projections Within Annular Sectors (0-10 Miles)	105
Figure 21.	1985 Population Projections Within Annular Sectors (10-50 Miles)	106
Figure 22.	1995 Population Estimates Within Annular Sectors (10-50 Miles)	107
Figure 23.	2000 Population Estimates Within Annular Sectors (10-50 Miles)	108
Figure 24.	2005 Population Estimates Within Annular Sectors (10-50 Miles)	109
Figure 25.	2010 Population Estimates Within Annular Sectors (10-50 Miles)	110
Figure 26.	C- and D-Site Environmental Monitoring Locations	111
Figure 27.	Millstone River Basin Offsite Water Sample Locations	112
Figure 28.	1991 TFTR Stack Tritium	113
Figure 29.	1991 Air Tritium (HTO)	114
Figure 30.	1991 Air Tritium (HT)	115
Figure 31.	1991 Surface Water HTO	116
Figure 32.	1991 Precipitation and Rain Water HTO	117
Figure 33.	1991 Ground (Well) Water HTO	118
Figure 34.	1991 Elizabethtown City Water Tritium (HTO) Concentration	119
Figure 35.	1991 Tritium (HTO) in Biota	120
Figure 36.	1991 Soil Tritium (HTO)	121
Figure 37.	Potentiometric Surface of the Bedrock Aquifer at PPPL	122
Figure 38.	Potential Flow Paths of Spilled Water	123
Figure 39.	Off-site Monitoring Locations	124
Figure 40.	C & D site Monitoring Wells Location Map	125
Figure 41.	Shallow Groundwater Potentiometer Map, January 13, 1992	126

1.0 EXECUTIVE SUMMARY

During Calendar Year 1991 (CY91), there were no accidents, incidents, or occurrences that had a significant impact on the Princeton Plasma Physics Laboratory (PPPL) facilities, the environment, or program operations. Assessment of the cleanup of underground storage tank (UST) hydrocarbons discovered in 1988 was enhanced by conducting a groundwater assessment program on the 72 acres leased to the Department of Energy (DOE) by Princeton University. Location of the monitoring wells was based on 1) the Petrex® soil gas results [Ne90]* which indicated solvents in several areas at the site due to past spills, 2) proximity to the USTs, and 3) the guidance of the New Jersey Department of Environmental Protection and Energy (NJDEPE). A groundwater assessment program, which began at the end of 1990 with the installation of 16 wells and two piezometers, indicated: the surface mounding effect of the open underground storage tanks (UST) excavation was driving the contamination into the groundwater; and the presence of volatile organic compounds (most probably from solvents) was found in only three well locations on site. The results from this assessment were submitted to the NJDEPE in March 1991. NJDEPE's Bureau of Case Management will likely require PPPL to remediate the groundwater at the site based on an agreement between Princeton University and NJDEPE.

A waste minimization program plan was revised by PPPL's waste minimization team in 1991. This plan was finalized in April 1992; it recognized that PPPL has implemented many steps to minimize waste, a requirement of the Resource Conservation and Recovery Act (RCRA), prior to any formal DOE requirement. The plan suggests steps to further reduce the use of hazardous materials and waste disposal requirements through the training of employees and the further assessment of waste streams. Several non-toxic cleaners were compared to solvent-based cleaners with surprisingly good results. In 1991, the Laboratory conducted further tests in a laboratory environment for compatibility and effectiveness and has introduced these new materials for routine use.

Surface water analyses for both radioactive and nonradioactive pollutants have shown nothing above normally expected background values. Ambient tritium levels at less than 100 pCi/liter (3.7 Bq/liter) were measured in on-site well water. These data are in agreement with previous measurements by PPPL and the U.S. Geological Survey (USGS) results [St88c, St91]. Soil and vegetation samples were collected and analyzed for free

*[ ] denotes References, see pg. 44.

water tritium as part of the continuing baseline studies. To date, no studies have been undertaken to look at organically bound tritium (OBT).

Off-site surface water, soils, and biota continued to be analyzed for radioactive baselines in CY91. Passive tritium monitors, tested in field modeling experiments in Canada in 1987 [Gr88a], were used in four on-site area monitors, one stack monitor, and one off-site monitor. Six off-site locations within 1 km of TFTR were sited and were presented to the local government planning board in 1991 for placement as off-site tritium air monitors. These differential atmospheric tritium samplers (DATS) are high sensitivity monitors which are able to detect changes in the ambient levels [Gr88b].

Radiation exposure, via airborne effluents into the environment, is at insignificant levels. A tritium stack monitor was added to the Tokamak Fusion Test Reactor (TFTR) stack even though it was not required by National Emission Standard for Hazardous Air Pollutants (NESHAPs) requirements. From deuterium-deuterium (D-D) fusion reactions during TFTR experimental operations, approximately 0.075 Ci (2.8 GBq) of tritium and 0.128 Ci of ^{41}Ar from air activation were produced in 1991. This amount of radionuclides was released to the air via the TFTR stack. Less than .485 mCi (17.9 MBq) of tritium oxide (HTO) was released to the sanitary sewer. Prompt radiation, which is radiation emitted during operations, is detectable at extremely low-levels during high-power pulses from TFTR by using high-sensitivity instrumentation. A special study was conducted in 1990 by the DOE Environmental Measurements Laboratory (DOE/EML) to verify former PPPL Health Physics (HP) Branch measurements. The EML measurements confirmed the acceptability of HP neutron dose equivalent measurements [Ku91]. The integrated dose equivalent* at the site boundary from TFTR operations was less than 1 mrem (0.01 mSv) for CY91 for measured, prompt radiation plus calculated tritium and air activation releases.

PPPL has emphasized environment, safety, and health (ES&H) in accordance with DOE requirements at all of their facilities. The expectations are that the Laboratory will excel in ES&H as it has already done in its fusion research program. The efforts are geared not only to full compliance with applicable local, state, and federal regulations, but to a level of excellence which includes state-of-the-art monitoring and best management practices.

*In all cases used in this report, the whole body is the critical organ and the term dose equivalent can be considered to be synonymous with the term effective dose equivalent.

2.0 INTRODUCTION

2.1 General

This report gives the results of the environmental activities and monitoring programs at the Princeton Plasma Physics Laboratory (PPPL) for CY91. The report is prepared to provide the U.S. Department of Energy (DOE) and the public with information on the level of radioactive and nonradioactive pollutants, if any, added to the environment as a result of PPPL operations, as well as environmental initiatives, assessments, and programs. The objective of the Annual Site Environmental Report is to document evidence that DOE facility environmental protection programs adequately protect the environment and the public health.

The Princeton Plasma Physics Laboratory has engaged in fusion energy research since 1951. The long-range goal of the U.S. Magnetic Fusion Energy Research Program is to develop and demonstrate the practical application of fusion power as an alternate energy source. In 1991, PPPL had both of its two large tokamak devices in operation: namely, the Tokamak Fusion Test Reactor (TFTR) and the Princeton Beta Experiment-Modification (PBX-M); PBX-M completed its new modifications and upgrades and resumed operation in November 1991. A new machine, the Tokamak Physics Experiment (TPX), replaced the cancelled Burning Plasma Experiment (BPX) as PPPL's next machine; it is planned for a 1999 start up.

The Princeton Beta Experiment (PBX), the predecessor of PBX-M, after achieving a ratio of plasma pressure to magnetic pressure in excess of 5% in CY84 experiments, was shut down at the end of 1985 to undergo modifications to permit further examination of theoretical predictions on plasma shaping and stabilization of kink modes by means of a close-fitting conducting wall. The addition of new coils and stabilizer plates within the vessel, new power supplies, and a new control system began in 1986. The modified device, PBX-M (Fig. 1), came back into operation in October 1987. In CY88, an indentation of the plasma of 25% was achieved, lower q(a) values obtained, and H-modes at lower power attained. In CY89, the effectiveness of the passive plates in stabilizing kink modes and access to higher plasma pressure ($\beta \sim 6.8\%$) were assessed. A Safety Assessment Document (SAD) was published for the PBX in 1984 [Fl84], which indicated that the PBX did not pose any potential environmental concerns. A new SAD published for the PBX-M in 1988 reached the same conclusion [St88a]. A third SAD was approved prior to the start-up of the upgraded PBX-M in FY91 [SAD91].

The TFTR (Fig. 2), which had its first full year of operation in CY83, had an increase in total neutron production in 1987 to a yearly total of 3×10^{18} [He88], in 1988 of 9.04×10^{18} [He89], in 1989 of 6.4×10^{18} [Ja90a], in 1990 of 2.3×10^{19} [Ja90b], and in 1991, these numbers reduced to 1.56×10^{18} [Ja92] because of limited operations. The higher neutron production has increased the activation level of the machine to the point where health physics surveys are required in the test cell following a machine run and before any personnel entry is permitted for inspection, routine maintenance, or installation work. In addition, tritium from D-D reactions, which was absorbed in graphite and measured during the opening of the vessel in 1987, 1988, 1990, and 1991, posed the first known health physics contamination challenges for any tokamak operations. The experience gained from the 1987 opening was beneficial for the similar openings in 1988-89 and has helped to streamline operations for the 1990-91 opening.

The TFTR is a toroidal magnetic fusion energy research device in which a deuterium-tritium (D-T) plasma is magnetically confined and heated to extremely high temperatures by neutral-beam injectors and radio-frequency waves. A major achievement in 1986 was an increase in neutron production and fusion power by operating in what is now called the "supershot" pulse mode. Using this technique, a new record temperature of greater than 400 million degrees Celsius has been achieved. Ion Cyclotron Radio-Frequency (ICRF) heating became operational in 1988. The D-T operations were scheduled to begin in 1990; however, reprogramming and a budget cut announced in November 1988 have resulted in a schedule delay so that D-T experiments will begin in mid 1993. A small amount of tritium (<1000 Ci) will be brought onsite in late 1992 to use in the testing of the TFTR tritium storage and cleanup systems. The safety analyses completed for this program are addressed in Safety Analysis Reports for the Project [PSAR78 and FSAR82]. In 1988, the Final Safety Analysis Report (FSAR) was being updated to reflect revised operational requirements and parameters using tritium. This effort was initiated again in FY91 and is expected to be completed in 1992.

Although PPPL operates C-site as an unfenced site, with access controls for security purposes, it is considered to be open to the public for environmental purposes. D-site is entirely fenced, with access controls which do not allow free access to the TFTR. The free access of C-site has necessitated a thorough evaluation of the on-site discharges as well as the potential for off-site releases of radioactive and toxic nonradioactive effluents. An extensive monitoring program, which is tailored to these needs, has been instituted and expanded over recent years. The PPPL radiological environmental monitoring program generally follows the guidance given in two DOE reports: namely, A Guide for: Environmental Radiological Surveillance at U.S. Department of Energy Installations [Co81] and Environmental Dose Assessment Methods for Normal Operations at DOE Nuclear Sites (PNL-4410) [St82]. This includes adherence to the standards given in DOE Orders, in particular, DOE Order 5400.5 [DOE90a], which pertains to permissible dose equivalents and concentration guides and gives guidance on maintaining exposures "to as low as reasonably achievable" (ALARA). On January 1, 1989, DOE Order 5480.11 guidelines came into effect [DOE89]. While this order did not have a major impact on PPPL operations, the order did incorporate some changes in personnel monitoring requirements. DOE Order 5400.1 [DOE90b] requires an environmental monitoring plan. This plan was completed in CY91. Specific criteria for implementing these standards on TFTR are contained in a TFTR Operational Safety Requirement (OSR/TFTR/0-2F-C). The TFTR radiological design objectives and regulations are shown in Table 1.

An environmental survey was conducted in June 1988 by DOE/HQ as part of an intensive evaluation at all DOE sites. No significant environmental concerns surfaced at PPPL as a result of this audit. An oil spill in 1988 by an outside vendor has led to a project of incorporating its cleanup with underground storage tank leak elimination and their replacement. In addition, groundwater contamination was a concern, and a Petrex® soil gas survey was accomplished over the entire site in the spring of 1990 [Ne90]. A groundwater assessment program was prompted by the results of the soil gas survey, the UST issue, and New Jersey Pollutant Discharge and Elimination System (NJPDES) permit requirements; the results of this assessment program are discussed in more detail below.

The emphasis of the radiation monitoring program has been placed on exposure pathways appropriate to fusion energy projects at PPPL. These pathways include external exposure from direct penetrating radiation and, eventually, during D-T from airborne radionuclides, such as ^{41}Ar, ^{13}N, ^{16}N, and internal exposure from radionuclides, such as ^{3}H in air and water. Six major, critical pathways are considered as appropriate (see Table 2). Prompt radiation, i.e., that which is emitted immediately during operations, was also considered and is being measured. The monitoring program, as envisioned by the TFTR Final Safety Analysis Report [FSAR82], has been updated to reflect the current environment around TFTR (see Table 3). At present, the radioactive pollutant potential to the environment by any pathway is essentially nonexistent. Small amounts of tritium are produced from D-D reactions [approximately 0.075 Ci (2.8 GBq) in 1991 if all neutrons measured are assumed to be D-D produced]. A tritium monitor was installed on the TFTR stack in late 1990. Low-levels of tritium (< 2 nCi/g) are now detectable in pump oils. Also, tritiated water (HTO) is detected in the vacuum vessel air (outgassing from the carbon tiles) during the maintenance and upgrade period [St88b]. HTO is considered to be 25,000 times more hazardous than tritium as a gas (HT or T_2), because it is more readily assimilated into the body in the form of water. While most tritium planned for use at TFTR will be in the form of HT or T_2, accident analyses generally consider a conservative approach and look at releases as being HTO.

Preliminary meteorological considerations and associated methodology, which were established at the time of the installation of PPPL's first meteorological tower, were reported in Section 2 of the TFTR FSAR. Subsequently, improved methodologies were implemented, and a new meteorological tower was erected and began operation in November 1983 [Mc83]. The improved measurements and methodologies are being included in the updated FSAR being prepared for tritium operations. Data have been collected for eight years using the monitors on the new tower (Figs. 6-10). Wind-rose plots from the data for the first eight years (1984-91) are shown in Figs. 3, 4, and 5. A tracer gas-release test was conducted during the period from July to September 1988 to look at site-specific air-diffusion parameters (see 5.2.2). These tests were commissioned to determine actual site conditions versus model predictions in relation to future activities. The test results indicated that actual dispersion and dilution of effluents in the vicinity of PPPL is enhanced by up to a factor of 16 over that predicted by Nuclear Regulatory Commission approved standard Gaussian diffusion models [St89]. Additionally, as a result of these tracer gas-release tests, a 10-m wind speed and wind-direction sensor was added to the meteorological tower in 1990 to monitor PPPL on-site meteorology more precisely. The U.S. Environmental Protection Agency (EPA) was petitioned through the Princeton Area Office (DOE/PAO) to use the more realistic χ/Q values from these tests in the AIRDOS-EPA model used for the National Emission Standard for Hazardous Air Pollutants (NESHAPs) calculations. Approval was received in 1991.

2.2 Description of the Site

The Princeton Plasma Physics Laboratory is located at the C- and D-sites of the James Forrestal Research Campus of Princeton University (Figs. 11 and 12). As shown in Fig.

13, the location is in central New Jersey within Middlesex County. The site is surrounded by undisturbed areas with forest, open grass areas, corn fields, and a small brook (Bee Brook) running next to its eastern boundary. The closest urban centers are New Brunswick, 14 miles to the northeast, and Trenton, 12 miles to the southwest. Major metropolitan areas, including New York City, Philadelphia, and Newark, are within 50 miles of the site. As shown in Fig. 14, the municipalities of Princeton, Plainsboro, Kingston, West Windsor, and Cranbury, among others, are in the immediate vicinity of the site. Also, the main campus of Princeton University, located primarily within the Borough of Princeton, is approximately three miles to the west of the site. The general layout of the facilities at the C- and D-sites of Forrestal Campus is indicated in Fig. 15; the specific location of TFTR is at D-site.

A demographic study was completed in CY87 as part of the requirement for the Environmental Assessment for the Burning Plasma Experiment (BPX) [Be87a]. Other information gathered and updated from previous TFTR studies included socioeconomic information [Be87b] and an ecological survey [En87]. The demographic data were based on the 1980 census and show both estimated and projected data out to the year 2010 (Tables 4 to 16 and Figs. 16 to 25) in a zone from 1 mile out to 50 miles.

The PPPL site is in the center of a highly urbanized region extending from Boston, Massachusetts, to Washington, D.C., and beyond. The previous population projections for the states of New Jersey, New York, and Pennsylvania had indicated a substantial population increase within 50 miles of the PPPL site. The actual change from 1970 to 1980, as indicated by the census in these two years, was not as large as had been expected. In fact, the population in New York City and Philadelphia decreased. The Princeton area continues to experience a substantial increase in new business moving into the Route 1 corridor near the site. This increase, however, has not been as great as the projections had indicated. As a summary, population data were divided into annular sectors. It was prepared in 1986 for use with several standard codes used for the determination of off-site dose equivalent due to the release of activated air radionuclides and tritium [Ko86a]. Table 16 shows data supplied by the Princeton Forrestal Center on the population within one mile of the TFTR site. The numbers indicated have been divided by four to obtain an equivalent exposure for habitation [Ko86b].

3.0 1991 ENVIRONMENTAL COMPLIANCE SELF-ASSESSMENT

3.1 Compliance Summary

It is PPPL's considered intention to be in compliance with all applicable state, federal, and local environmental regulations. As a result of PPPL's self-assessments, DOE Chicago audits, and DOE/HQ Tiger Team action plans, PPPL continues actions to enhance its compliance efforts, especially in the area of strict documentation requirements. The status of each applicable environmental statute is listed below:

3.1.1 Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)

The PPPL is not involved with CERCLA mandated cleanups or compliance activities. Presently, under the requirements for SARA Title III, PPPL submits an annual inventory in order to be in compliance with CERCLA. As a result of the 1991 Tiger Team assessment, an action plan was developed to conduct a more thoroughly documented Preliminary Site Assessment/Site Investigation for CERCLA inventory of past hazardous substances. This activity is planned for 1993.

Emergency Planning and Community Right to Know Act, SARA Title III.

Title III of the 1986 SARA amendments to CERCLA created a system for planning responses to emergency situations involving hazardous materials and for making information regarding the use and storage of hazardous materials available to the public. Under SARA Title III, PPPL is required to provide an inventory of hazardous substances stored on the site, Materials Safety Data Sheets (MSDS), and completed SARA Tier I forms listing each hazardous substance stored by users above a certain threshold planning quantity (typically 10,000 pounds, but lower for certain compounds) to applicable emergency response agencies. The table on page 10 lists hazardous compounds at PPPL, reported under SARA Title III for 1991.

Section 304 of SARA Title III requires that the Local Emergency Planning Committee (LEPC) and state emergency planning agencies be notified of accidental or unplanned releases of certain hazardous substances to the environment. In order to ensure compliance with such notification provisions, PPPL procedure, "Non-Emergency Release Notification and Reporting," will include SARA Title III requirements.

The New Jersey Department of Environmental Protection and Energy (NJDEPE) administers the SARA Title III reporting for EPA and has modified the Tier I form to include SARA Title III reporting requirements and NJDEPE reporting requirements.

HAZARD CLASS

Compound	Fire	Sudden Release of Pressure	Reactive	Acute Health Hazard	Chronic Health Hazard
Ammonia		✔		✔	
Bromotrifluoromethane		✔		✔	
Carbon dioxide		✔		✔	
Dichlorodiflouromethane		✔		✔	
Fuel Oil	✔				
Gasoline	✔				✔
Helium		✔			
Nitrogen		✔			
Petroleum Oil	✔				
Polychlorinated Biphenyls					✔
Sulfur Hexafluoride		✔			
Sulfuric acid			✔	✔	

3.1.2 Clean Air Act (CAA)

The PPPL was in compliance with the requirements of the CAA in 1991. The NJDEPE 1990 Air Emission survey was completed and returned to the NJDEPE. Since the 1987 survey, PPPL has terminated three air permits: an unleaded gasoline underground storage tank vent, boiler #1 stack vent, and oil storage tank vent #1. Preparation for additional air emission permits is currently under way as the result of a self-assessment by PPPL and the DOE Tiger Team assessment findings. Two activities, fire extinguisher training contained and controlled live-burn of gasoline (about 5 gallons or less) and installation/operation of the blue-printing machine, were exempted from permits by NJDEPE.

PPPL has added a stack sampler to the TFTR facility for tritium releases. While we believe this will meet NESHAPs radionuclide emission requirements for upcoming tritium operations, the EPA has not yet made their final ruling on PPPL's plans for future stack release monitoring. The monitoring system currently exceeds existing requirements as current releases produce insignificant dose equivalent to any member of the public. As a result of their inspection of PPPL facilities in February 1992, EPA Region II determined that PPPL was presently in compliance with NESHAPs requirements (i.e., during non-tritium operations).

3.1.3 Clean Water Act (CWA)

The PPPL is in compliance with all requirements of the CWA. An assessment of groundwater has been undertaken as part of an effort that followed identified leaking underground storage tanks (USTs) containing heating oil and vehicle fuel. Based on the results of the soil gas survey of the entire site, which identified potential solvent contamination, groundwater monitoring wells were placed to correlate the results of the soil gas survey and to define the impact of the USTs. An additional study to determine the detention basin's impact to groundwater was performed pursuant to NJDEPE's direction under PPPL's NJPDES groundwater discharge permit. A survey of solvent and hazardous constituent usage [MP91f]at PPPL was conducted and submitted at the request of NJDEPE.

The PPPL continues to operate under the expired NJPDES surface water discharge permit while awaiting renewal from NJDEPE in accordance with New Jersey requirements. During 1991, one non-compliance for the exceedance of the total suspended solid limit (50 mg/l) occurred in March (180 mg/l). The exceedance of total suspended solids was investigated and may be properly described as a one time occurrence; however, steps were taken to prevent future recurrence. Due to the issuance of storm-water regulations, PPPL and DOE/PAO requested NJDEPE to review the site's storm-water runoff, which does not drain to the detention basin. In addition, PPPL and DOE/PAO asked that the filter backwash discharge at the Delaware & Raritan Canal pumphouse be reviewed as a possible new discharge point. As a result of these inquiries, NJDEPE directed DOE/PAO to submit a NJDPES application for these discharge points; the application has been submitted.

Under the CWA and applicable New Jersey regulations, PPPL reported 19 releases of petroleum, petroleum products, and hazardous substances to the NJDEPE in CY91. The magnitude of most of these releases was from one-half pint to five gallons of product leaking or spilling onto pavement. Of these 19 releases, three were releases onto unpaved ground (hydraulic oil from an air compressor, gasoline from a fork lift truck, and transformer oil into a sump), and three releases were oil from parking lot runoff which was observed in the detention basin; the remaining thirteen releases were on paved roadway or parking areas, which were readily cleaned. Under guidance received from EPA and NJDEPE, leaks similar to the parking lot runoff and leaks onto the pavement no longer are required to be reported, unless a reportable quantity under CERCLA requirements is released.

3.1.4 Endangered Species Act (ESA) and National Historic Preservation Act (NHPA)

The PPPL occupies 72 acres of the Forrestal Campus of Princeton University. Previous environmental statements and the current approved Environmental Assessment (EA) for the TFTR have indicated that there are no endangered species or items relating to the NHPA on site.

3.1.5 Executive Order (EO) 11988, "Floodplain Management" and 11990, "Protection of Wetlands"

The PPPL is in compliance with the EO 11990, "Protection of Wetlands." Previously, there was a question about the dirt-spoil pile from excavations for TFTR construction which was placed in an area (1977-78) prior to wetlands determinations. DOE/PAO requested a wetlands delineation from NJDEPE; they determined that the pile lies within the 50 foot transition zone, but not within the wetlands proper.

The PPPL is in compliance with the EO 11988, "Floodplain Management." As a result of the Tiger Team assessment, it was suggested that the PPPL HAZMAT facility may be 4 inches below the 500-year floodplain and not protected, which may be a violation if the HAZMAT facility is considered a "critical" facility under 10 CFR 1022 [CFR90]. PPPL determined that the HAZMAT facility is indeed a "critical" facility. The only unanswered question remains here: whether the HAZMAT facility, a "critical" facility, lies within the 500-year floodplain. A determination of the exact location of the 500-year floodplain relative to PPPL facilities is planned. If the HAZMAT facility is found to be located with this floodplain, plans will be made to protect the facility against a 500-year flood.

3.1.6 Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA)

The use of herbicides, pesticides, and fertilizers is done by using certified subcontractors who meet all the requirements of FIFRA (Table 30). The PPPL Facilities Engineering Division (FED) monitors this subcontract; no herbicides, pesticides, or fertilizers are stored or disposed of onsite.

3.1.7 National Environmental Policy Act (NEPA)

The PPPL had two major NEPA documents under consideration in 1991. An Environmental Assessment (EA) for the BPX underwent review; however, this project was cancelled. An update to the TFTR 1975 environmental statement has been addressed with an EA for the proposed deuterium-tritium (D-T) modifications and operations. The TFTR D-T EA was approved, and a Finding of No Significant Impact (FONSI) for the D-T Program was signed by DOE-EH on 1/17/92. The public in the PPPL area was informed of the EA via two public meetings and placement of the EA in local libraries. A procedure was developed and implemented in 1991 to ensure that all proposed PPPL activities received adequate and timely NEPA review. Approximately 350 PPPL activities received NEPA reviews in 1991, and the vast majority of these were determined to be Categorical Exclusions in accordance with the NEPA regulations and guidelines of the Council on Environmental Quality (CEQ) and DOE.

3.1.8 Resource Conservation and Recovery Act (RCRA)

The Laboratory is in compliance with all terms and conditions required of a hazardous waste generator. The HAZMAT facility is used for the temporary storage of hazardous wastes, and these wastes are removed offsite for treatment, storage, or disposal within the 90 day temporary storage requirement.

PPPL is also in compliance with all requirements of the RCRA mandated Underground Storage Tank Program (see 3.1.3 above in relation to UST leaks). These tanks are registered with the NJDEPE Bureau of Underground Storage Tanks (BUST); tank and pipe testing, inventory control inspections, and records are maintained for all USTs onsite.

3.1.9 Safe Drinking Water Act (SDWA)

The PPPL receives its drinking water from the Elizabethtown Water Company. While Elizabethtown is responsible for providing safe drinking water, PPPL does test incoming water. In addition, periodic testing for potential problems within the on-site drinking water distribution system is undertaken.

3.1.10 Toxic Substance Control Act (TSCA)

The PPPL is in compliance with all terms and conditions of TSCA by protecting human health and the environment by requiring that specific chemicals be controlled and regulations restricting their use be implemented. The last of PPPL's polychlorinated biphenyls (PCBs) transformers were removed from the site in 1990, and only 646 (of originally 6,005 capacitors) PCB-regulated capacitors were left on site at the end of 1991.

3.2 Current Issues and Actions

The ongoing, environmental compliance issue is the request for an adjudicatory hearing by DOE under the current New Jersey Pollutant Discharge and Elimination System (NJPDES) discharge to groundwater permit. The DOE is contesting the permit requirement that monitoring wells with a monitoring program be placed off-site on Princeton University property at PPPL expense when the University volunteered to cover these requirements. The DOE and PPPL are awaiting a hearing date and have, however, come into compliance with all permit mandated activities.

Since 1986, Princeton University has performed groundwater investigations on the James Forrestal Campus. The PPPL and DOE/PAO have been involved in similar studies on C- and D-sites since 1990 under the direction of NJDEPE. The case geologist from NJDEPE informed PPPL that the Bureau of Federal or State Case Management within the Division of Site Remediation would be reviewing the situation of volatile organic compounds (VOCs) in groundwater. NJDEPE's Bureau of Case Management will likely require PPPL to remediate the groundwater at the site based on an agreement between Princeton University and NJDEPE.

The PPPL was audited by a DOE Tiger Team between 2/11/91 and 3/12/91. PPPL had identified over 70% of the Tiger Team findings in its own self-assessment; however, many of those findings not identified were in the environmental area. There were 54 environmental findings, none of which represented situations that presented an immediate risk to public health or to the environment or that warranted an immediate cessation of operations. Of these findings, 38 were related to requirements of DOE Orders, federal or state regulations, or PPPL directives or procedures. Sixteen (16) of the findings were related to best-management practices. In addition, there were 166 safety and health concerns and 26 management concerns. An Action Plan was finalized by PPPL in April 1991 and approved and officially released by DOE/HQ in April 1992. Of these 612 milestones, nearly 50% have been completed by April 1992.

PPPL has added a stack sampler to the TFTR facility for tritium releases, and while we believe this will meet NESHAPs radionuclide emission requirements for upcoming tritium operations, the EPA has not yet made their final ruling on PPPL's plans for future stack release monitoring. The monitoring system currently exceeds existing requirements as current releases produce insignificant dose equivalent to any member of the public. As a result of their inspection of PPPL facilities in February 1992, EPA Region II determined that PPPL was presently in compliance with NESHAPs requirements (i.e., during non-tritium operations).

Title VI, "Stratospheric Ozone Protection," of the Clean Air Act Amendments of 1990 mandates the recovery of substances which deplete ozone in the upper atmosphere. Those substances listed in the act include certain chlorofluorcarbons or CFCs and halon, for example; both of these substances are used at PPPL as coolants and fire suppressants, respectively. In order to reduce the amount of these ozone depleters, PPPL is looking at substitute products, recovery and recycling units, and preventive measures to prevent harmful releases to the atmosphere.

3.3 Environmental Permits

Environmental permits are maintained by PPPL (See Table 17). A discussion of the environmental permits by the applicable statutes is listed in this table .

3.3.1 Clean Air Act (CAA)

The Laboratory maintains permits for 4 boiler vent stacks, 1 fuel oil storage tank vent, 1 diesel tank vent, 2 degreaser vents, and 2 emergency diesel generator exhaust stacks. All permits for these emissions are current (renewal applications submitted for 5 permits which expired on 3/31/92), and all equipment under permit is operated within the permit specifications. As a result of a PPPL self-assessment prior to the Tiger Team, PPPL noted that some new permits may be required, not because of an emission limit trigger point, but because of process equipment used in the exhaust process. The Tiger Team addressed two additional sources which should be considered for the permitting process. This air permitting program is presently being implemented. NJDEPE has publicly stated that in the next few years, site-wide permits will be issued, which would include air permits.

3.3.2 Clean Water Act (CWA)

The Laboratory maintains two permits under the New Jersey Pollution Discharge Elimination System (NJPDES) for discharges to surface water and groundwater. The permits are for a detention basin, which discharges to Bee Brook, and for non-point source infiltration of the detention basin waters to groundwater. The NJDEPE issued a new permit number for the groundwater discharge permit. An adjudicatory hearing was requested for the groundwater permit, because several of the permit conditions are contested. In the interim, however, the permit is being maintained in full compliance including those conditions being contested in the requested hearing. Despite the timely submittal of the application, the surface water permit has not been reissued by the NJDEPE. In accordance with NJDEPE regulations, PPPL has been operating under its old permit since October 1989. In addition, PPPL and DOE/PAO asked that the filter backwash discharge at the Delaware & Raritan Canal pumphouse be reviewed as a possible new discharge point. As a result of these inquiries, NJDEPE directed DOE/PAO to submit a NJDPES application for these discharge points; the application has been submitted.

In 1991, NJDEPE inspectors audited PPPL's surface water discharges twice, and the groundwater discharges once. The result of both inspections were "conditionally acceptable." The first rating was determined by 1) the failure of the analytical laboratory to collect DSN001A samples in January 1991, and 2) the presence of VOCs in wells on-site; the second by the occurrence of the total suspended solid exceedance. All conditions had been reported to NJDEPE per the NJPDES reporting requirements.

During the NJDEPE's review of the TFTR D-T EA, an issue regarding the elevation of the temperature in Bee Brook was raised. In accordance with the New Jersey Surface Water Quality Standards, the temperature of the discharged water was not to exceed a temperature difference (Δt) greater than 2.8°C (5.0°F) above ambient water temperature at any time. It has been noted that during times in the winter the delta t (Δt) exceeded the 2.8°C limit. A significant part of the discharged waster is groundwater, produced from dewatering the ground below the TFTR research device. The temperature of this groundwater remains relatively constant at approximately 12.8°C while the surface water nears 0°C in winter. At present, theTFTR foundation dewatering performed produces in excess of an estimated 60,000 to 80,000 gallons per day of groundwater, which is discharged to the detention basin. Plans are in progress to more accurately determine the total daily flow and investigate a permit or other administrative variance from the receiving stream temperature criteria.

3.3.3 Resource Conservation and Recovery Act (RCRA)

The PPPL maintains EPA Number (NJ1960011152) for RCRA generator status. The Laboratory is in compliance with all terms and conditions required of a "generator" status.

The PPPL maintains, and is in compliance with registrations for 4 USTs in operation on the site and the 1 abandoned fuel tank. Note that the UST program is a part of RCRA compliance activities.

3.3.4 Miscellaneous Permits

The PPPL maintains permits for medical waste generation as required by the NJDEPE and for the purchase of potable water from the Elizabethtown Water Company. An agreement is in place with the New Jersey Water Authority until the year 2009 to draw water from the Delaware and Raritan canal system for cooling-water needs and fire-fighting capabilities. PPPL is in compliance with all terms and conditions of these permits.

3.4 January 1 - April 1, 1992 Environmental Compliance Summary

The first quarter of calendar year 1992 has produced the following changes from the 1991 summary:

- An NJPDES discharge application has been submitted. The discharge points are 1) C-site's storm-water runoff, which does not drain to the detention basin, DSN002A, and 2) the filter backwash discharge at the Delaware & Raritan Canal pumphouse, DSN003A.

- An update to the TFTR 1975 environmental statement has been addressed with an EA for the proposed deuterium-tritium (D-T) modifications and operations. The TFTR D-T EA was approved, and a Finding of No Significant Impact (FONSI) for the D-T Program was signed by DOE-EH on 1/17/92. The public in the PPPL area was informed of the EA via two public meetings.

4.0 ENVIRONMENTAL PROGRAM INFORMATION

The monitoring-program implementation has followed a phased approach commensurate with the potential hazards and the needs of an expanding program. Nonradioactive water-pollutant monitoring has been conducted for many years. A more extensive program was begun in 1979, which included eight surface water sampling points (four on-site and four off-site). In addition, four groundwater sites (two former drinking water wells and two wells near the TFTR liquid effluent collection tanks), along with the potable water supply, were monitored through November 1989. In November 1989, two former wells were dropped from the program, and seven new wells were added as part of the New Jersey Pollutant Discharge and Elimination System (NJPDES) permit requirements. Current NJPDES permit requirements include one detention basin discharge point for the surface water permit, two influent surface water points for the groundwater permit, and seven (7) groundwater wells.

Monitoring for sources of potential radiological exposures is extensive. Real-time prompt gamma/neutron-environmental monitoring began on the TFTR site in 1981 to establish baselines prior to machine operation. Four monitoring stations are located at the TFTR facility boundary [formally called the exclusion zone boundary (EZB)]. Neutron monitors were added at these locations at the end of CY84. Passive tritium monitors were added in CY87. Radiological-water samples are being collected at the same locations as the nonradioactive-sample points (see Figs. 26 and 27). Soil and biota samples are also being analyzed for tritium baselines. One off-site, baseline, tritium-air monitor was added in CY89, and six others were sited in 1991 and began operations in February 1992.

4.1 Assessment of Radiation Dose to the Public

The PPPL is located in the metropolitan region between New York City and Philadelphia. Census data indicate that approximately 16 million people live within 80 km (50 miles) of the site and approximately 212,000 within 16 km (10 miles) of PPPL. The detailed distribution of population as a function of distance is given in Tables 4-16. Because of ever-increasing, commercial growth in this area, a demographic update was planned for TFTR, but was completed as a requirement for the BPX Environmental Assessment [Be87a]. Also, a radiological assessment was completed for BPX [Mc89].

The overall, integrated, effective-dose equivalent from all sources (excluding natural background) to a hypothetical individual residing at the nearest business was calculated to be 0.012 mrem (0.12 μSv) for CY91 [St92] using the EPA COMPLY code [EPA89]. This effective-dose equivalent was calculated after postulating that all the tritium produced during TFTR D-D operations and Argon-41 produced from air activation was released to the environment. Detailed person-rem calculations for the surrounding population were not performed because the value would be insignificant in comparison to the approximately 100 mrem (1 mSv) each individual receives from the natural background, exclusive of radon, in New Jersey. However, scaling to calculated data was done and indicates a value of only 3.3×10^{-2} person-rem (3.3×10^{-4} person-Sievert) out to 80 km (see Table 18).

4.2 Assessment of Nonradioactive Pollutants

There were no activities during CY91 that created problems with respect to nonradioactive pollutants. The oil spill from underground tanks (overfill incident and leaking piping from the USTs), which presented some potential minor environmental impacts, is being addressed and is discussed below.

Polychlorinated biphenyls (PCB's) and other hazardous/toxic materials continue to be disposed of in accordance with EPA requirements. All wastes are treated, stored, or disposed of by licensed waste handlers at offsite locations. Herbicides, pesticides, and fertilizers were used in very limited quantities, mainly, restricted to landscape or pest elimination activities.

4.3 Pollution Prevention and Waste Minimization

The PPPL has a pollution prevention and waste minimization plan as required by DOE Order 5400.1 [DOE90b]. A survey was completed in June 1990 [CEE90] and indicated that PPPL had already taken many appropriate steps in waste minimization by product substitution and volume reduction. In FY91-92, a more detailed program was undertaken to further the testing and use of non-hazardous products such as "TPC Solvent®" and "Citrikleen®" in place of "Inhibisol®," acetone, and alcohol. Further investigation of possible means for source reduction will begin with waste-stream identification. Possibly, solvent recovery units will be purchased; this activity is being considered.

4.4 Regulations and Safety Criteria

The appropriate Radiation Protection Standard for penetrating radiation was taken from DOE Order 5480.11. Specific criteria for implementing these standards are contained in PPPL Environment, Safety, and Health Directive (ESHD) 5008, Section 10, and specifically for TFTR in Operational Safety Requirements, in particular, OSR/TFTR/0-2F-C. The concentration guides, used in the analyses of surface water samples for radioactivity, were taken from DOE Order 5400.5, Chapter III. The derived concentration guides for airborne activity are taken from the same DOE Order. Tritiated water, for example, is listed as 1×10^{-7} μCi/ml.

Air and Water Pollution Standards for nonradioactive pollutants were taken from the New Jersey Administrative Code (NJAC), Department of Environmental Protection and Energy 7:27-1, ***et seq***, 7:14-1, ***et seq***, and 7:14A-1, ***et seq***, respectively. The appropriate regulations for PCBs and hazardous waste are found in the U.S. Code of Federal Regulations, 40 CFR 761 and 40 CFR 260-265, respectively.

4.5 Future Program Expansion

4.5.1 Meteorological

A meteorological tower was installed in November 1983 [Mc83]. Data from this system has been used in dose calculations for the TFTR FSAR. Data were also evaluated by the Burning Plasma Experiment (BPX) project in relation to siting the BPX at PPPL. Plans for FY93 include hooking up a real-time output of the meteorological data for D-T operations. Instrumentation was added at 10 m in 1990 to collect wind speed and direction in addition to the present instruments at 30 and 60 m (Figs. 9 & 10). Precipitation, now collected independent of the tower instrumentation, will be added to the readout units of the tower along with barometric pressure.

4.5.2 Water Quality

The initial phases of a groundwater monitoring program began in CY85. Analysis of water samples from two D-site wells was added to the monitoring program in CY86 utilizing USGS data. PPPL took over the water quality program on these two wells in December 1987. New wells were added in response to new state requirements for a groundwater discharge permit and as a result of UST spills and soil gas testing (see below). This expanded groundwater program will help to more fully understand our regional groundwater flow, surrounding area (off-site) groundwater contamination, and in anticipation of requirements for a new, major, research device.

4.5.3 Radioactive Effluents

A. Air, Gaseous and Particulates

Based on collected data, a decision was made in CY84 to limit the specific air and particulate real-time monitors at the EZB to only a beta detector. Particulate air sampling has been accomplished as a best-management practice and not because of a particular source term. This sampling was discontinued because of a DOE Tiger Team finding to change from a low-volume air sampler to a high-volume air sampler.

Environmental tritium monitors tested in CY86 were deployed at the EZB in CY87. These were to be extended to off-site locations in CY88 but were delayed because of budget reductions at the end of the year. A baseline station was established off-site during 1989 at an 8-mile distance in the northwesterly direction. It was relocated to a slightly more northerly direction at approximately the same distance in 1991. Six new stations were approved by the Plainsboro Planning Board for off-site locations within 1 km of the TFTR exhaust stack in 1991. Actual start-up began in February 1992.

B. Off-Site Radiological Water and Biota Monitoring

An off-site, grab sample, water-analysis program is well established. Soil and vegetation sampling is under way and will continue. Biota (strawberries, peas, etc.) are collected from the local area, and the recovered water is analyzed for tritium. The tritium content of the biota and, in general, the soil and vegetation follow the tritium content in the precipitation which can be highly variable over the year.

4.5.4 Nonradioactive Effluents

Air-effluent standards will continue to be met by following the guidelines of the NJDEPE. Any potential toxic materials will be monitored and disposed of in accordance with applicable regulations and accepted guidelines.

5.0 ENVIRONMENTAL RADIOLOGICAL PROGRAM INFORMATION

5.1 Radiological Emissions and Doses

5.1.1 Penetrating Radiation

Operation of the Princeton Beta Experiment-Modification (PBX-M) results in the production of some penetrating radiation (primarily bremsstrahlung X rays and neutrons). Because the PBX-M has no roof shield, sky-shine radiation (primarily neutron) is seen at the TFTR EZB site monitoring stations. The shielding installed for the PBX-M machine has kept the total dose equivalents in occupied areas below occupational-exposure guidelines. Sky-shine radiation from the neutron production by PBX-M generally adds less than 1 mrem (0.01 mSv) to the D-site environs [St91a; St91b]. PBX-M operation was limited in 1991 and thus had no impacts to the environment.

It is stated Laboratory policy that when occupational exposures have the potential to exceed 1,000 mrem/y (10 mSv/y), the appropriate project manager must petition the PPPL Environment, Safety, and Health (ES&H) Executive Board for an exemption. This value is 20% of the DOE legal limit for occupational exposure. In addition, the Laboratory applies the DOE ALARA (as low as reasonably achievable) policy to all its operations. This philosophy for control of occupational exposure means that environmental radiation levels, as a result of experimental device operation, are also very low and acceptable. To illustrate this point, a 1,000 mrem dose equivalent from direct radiation at the outer TFTR test cell wall will result in less than 10 mrem (0.1 mSv) at the facility boundary.

The design objective for TFTR is to stay below 10 mrem/y (0.1 mSv/y) above natural background from all sources of radiation at the PPPL site boundary. The TFTR, like other tokamaks, produces bremsstrahlung radiation from the electrons striking internal hardware at the end of a pulse. These X rays, in the range of 0 to 20 MeV, also produce photoneutrons.

Injection of deuterium neutral beams began at the end of CY84. With these D-D runs, the neutron fluxes have increased each year as the neutral-beam heating power has increased. In 1985, the neutron production was on the order of 5×10^{16} for the entire year. This number increased to 2.4×10^{18} in CY86, to 3×10^{18} during a short run year in CY87, and to 9.04×10^{18} in CY88, and because of limited operation (also more plasma transport experiments and less supershots), the number reduced to 6.4×10^{18} in CY89. In 1990, the neutron production was 2.3×10^{19} [Ja90b], and in 1991 because of limited operations the value was 1.56×10^{18} [Ja92]. Additional shielding was added to the TFTR test cell walls in the middle of CY85. This added shielding has prevented the addition of any significant penetrating radiation to the environs due to TFTR operation.

The TFTR real-time site boundary monitors are Reuter-Stokes Sentri 1011 pressurized ionization chambers and ^{3}He-moderated neutron detectors. The electronics in the ionization chambers were modified to allow the integration of any prompt radiation resulting from a TFTR machine pulse which may be above natural background. These data are stored and processed using the Central Instrumentation, Control, and Data Acquisition (CICADA) computer system. Four of these monitoring stations are placed at the TFTR facility boundary (see Fig. 26). In addition, eight ionization chambers of lower sensitivity, paired with neutron monitors, are located nearer the TFTR device (four outside the test cell wall, three in the basement, and one on the roof). These eight detector locations are for personnel safety and are not considered environmental detectors ***per se***. However, data collected from them are used to help correlate the environmental measurements. Besides the moderated ^{3}He and fission neutron detectors, Bonner-type-moderated LiI(Eu) detectors were also used for monitoring neutron dose equivalents at various locations throughout the TFTR facility. Monitors are calibrated and traceable to the National Institute for Standards and Technology (NIST)æformerly the National Bureau of Standards (NBS).

5.1.2 Sanitary Sewage

Drainage from TFTR sumps is collected in the Liquid Effluent Collection (LEC) tanks; each of three tanks has a total capacity of 15,000 gallons. Prior to release of these tanks to the sanitary sewer system, i.e., Stony Brook Regional Sewerage Authority (SBRSA), a sample is collected and analyzed for tritium concentration. All samples for 1991 showed that concentrations, and therefore, the effluent, were within the allowable limits set by New Jersey regulations (1Ci/y) and by DOE Order 5400.5.

5.1.3 Special Radiation Surveys

A. EG&G Radiation Survey (Flyover)

In August 1980, EG&G Idaho, Inc., under DOE contract, conducted an aerial-radiological survey of PPPL and surrounding areas [St81]. The detection system consisted of 20 sodium iodide detectors, a multichannel analyzer, and a magnetic-tape recording system. The nominal gamma-ray, exposure-rate range observed was 8 to 10 mR/h. Detected radioisotopes were consistent with normal background emitters. Since conditions have not changed at C- or D-sites since 1980, there is no need at this time to repeat the survey.

B. National Oceanic and Atmospheric Administration (NOAA)

The Air Resources Laboratories Field Research Division (ARLFRD) of the National Oceanic and Atmospheric Administration (NOAA), Idaho Falls, Idaho, conducted atmospheric dispersion studies using tracer gases from July through September 1988. This group specializes in air quality by doing research on the physics of the lower atmosphere with emphasis on the processes contributing to atmospheric transport, dispersion, and deposition and on the development of numerical models using the results of this research. This study is being used to understand and predict human influence on the environment, especially with regard to the atmospheric transport and diffusion of toxic effluents [St89].

While Nuclear Regulatory Commission (NRC) standard-approved Gaussian models, which are normally used to calculate atmospheric diffusion to support radiological dose assessments, are appropriate for sites in open terrain, they underestimate atmospheric dilution for sites like PPPL where potential sources of release are located in the midst of a complex of buildings. These buildings generate mechanical turbulence which increases atmospheric dilution and reduces dose. The field tests conducted by NOAA were performed to obtain a more realistic empirical description of actual atmospheric diffusion at PPPL in relation to TFTR. The results indicate a factor of up to approximately 16 less potential dose equivalents than that calculated by using NRC Gaussian models. The EPA was petitioned by DOE/PAO to utilize this real-time data for use in calculations using AIRDOS-EPA, a required code for annual NESHAPs calculations. The EPA approved this request in 1991. In 1990, DOE authorized the use of the EPA COMPLY code for NESHAPs calculations.

C. Lawrence Livermore National Laboratory (LLNL) Seismic Study

The PPPL Environment, Safety, and Health Division (ESHD) initiated and provided technical direction for a contract with LLNL to perform a seismic hazard analysis for the PPPL site in 1989. This study, which was based on the latest methodology accepted by the Nuclear Regulatory Commission (NRC) for seismic analysis of Eastern U.S. nuclear power plants, indicated that the earthquake parameters applied to the TFTR project met and exceeded the current applicable DOE requirements [Sa89].

D. DOE Environmental Measurements Laboratory (EML) Radiation Measurements

A radiation measurement survey was accomplished by the EML in 1990. The measurements used high sensitivity instruments and confirmed ES&H Division Health Physics measurements, which indicate that the neutron dose equivalents during operational periods in occupied areas and at the TFTR facility boundary are much less than the original conservative code calculations. The final results were published in 1991 [Ha91].

5.1.4 Airborne Radioactivity

Radioactivation of air and the release of tritium in measurable concentrations (by EPA accepted measurement criteria) are not expected until TFTR D-T operations. A silica-gel, environmental-tritium monitor was tested in 1986 and was placed in operation during the summer of 1987. With experience gained in a Canadian tritium release modeling experiment and in the field at PPPL, the monitor is now using a molecular sieve in place of silica gel [Gr88b]. Based on D-D neutron production during CY91, it is estimated that a maximum of approximately 0.075 Ci (2.8 GBq) of tritium could have ..en added to the environs outside the TFTR facility. Tritium was detected in TFTR effluent samples by a Differential Atmospheric Tritium Sampler (DATS). The sampling system that was in place indicated an actual stack-emission value of less than 0.02 Ci (0.74 GBq). The passive sampling results are shown in Fig. 28. The 1991 tritium-dose projections assume that all of the tritium was released. Our actual experience with the absorption and adsorption of tritium in TFTR vessel-graphite tiles in 1987 indicates that some tritium produced over the last few years by D-D reactions has been retained in the tiles [St88b]. The tiles retain approximately one-third of the tritium produced during D-D reactions.

The projected dose equivalent at the nearest business from 0.075 Ci of tritium and 0.128 Ci of ^{41}Ar (produced by neutron activation of the test cell air during TFTR D-D experiments) was 12 mrem (120 nSv), based on the use of the COMPLY Code [EPA89]. When actual

NOAA c/Q values are used, the calculated values are even smaller, approximately 0.2 mrem (2 nSv) (see Table 18). An upgraded stack sampling system installed in 1990 will provide measured tritium emission for 1991 for any tritium concentrations exceeding the minimal detectable levels of the DATS. Evaluations of proper laminar flow and mixing for acceptable monitoring data are now under discussion with the EPA. Measurements at the TFTR fence line have shown ambient levels in the range of 1 to 5 pCi/m^3 of elemental and oxide tritium concentrations (Figs. 29 & 30). These measurements were made with the DATS [Gr88b]. Argon-41 (^{41}Ar) is a potential air activation product from neutrons produced from D-D reactions. Its maximum production in 1991 was 128 mCi (4.7 GBq), with an estimated dose equivalent at the nearest off-site business of 0.14 mrem (1.4 nSv) using NOAA c/Q data (see Table 18).

In November 1983, a three-level, 60 meter tower was installed for gathering meteorological data. Eight years' worth of data have now been collected. The wind-rose data for the first six years of tower operation are shown in Figs. 3, 4, and 5. Analysis indicates that the site is dominated by neutral to moderately stable conditions, with moderately unstable to extremely unstable conditions occurring less than a few percent of the time. Average surface winds are about 2.1 m/s and rise to about 4.1 m/s at 60 m [Ko86a]. Based on data from this tower and NOAA tracer-gas, release-modeling, as well as effluent concentrations measured at the TFTR stack, real time dose projections will be made during the D-T operations phase to ensure compliance with applicable regulatory requirements.

5.2 Unplanned Releases

There were no unplanned radiological releases at PPPL in CY91.

5.3 Environmental Monitoring

5.3.1 Waterborne Radioactivity

A. Surface Water

Surface-water samples at eight locations (four on-site and four off-site) have been analyzed for tritium and photo emitters (Table 21). Five of these locations have been monitored since CY82. Downstream sampling occurs after the mixing of effluent and ambient water is complete. Locations are indicated on Figs. 26, 27, and 39.

Sample analysis has shown no unusual background radionuclides. Tritium analysis by liquid scintillation methods has shown tritium values to be less than 100 pCi/liter (3.7 Bq/liter) on all samples analyzed to date (Fig. 31). Tritium enrichment procedures are used on some samples to provide increased sensitivities. Rain-water samples collected and analyzed ranged from less than 10 to 154 pCi/liter (see Table 19 and Fig. 32), which was similar to the 1985 range of 45 to 160 pCi/liter, the 1986 range of 40 to 140 pCi/liter, the 1987 range of 26 to 144 pCi/liter, the 1988 range of 34 to 105 pCi/liter, and the 1989 range of 7 to 90 pCi/liter. The reason for these variations can be explained as follows: HT and HTO, mainly from prior world-wide, above-ground, weapons tests, go into the stratosphere and are returned to the troposphere by turbulence. The HT slowly converts to HTO. Furthermore, the residence time in the atmosphere is on the order of years. There is a variation of HTO in rain water as the stratosphere slowly turns over, with very little exchange between the stratosphere and troposphere in the winter months [Os88]. The peak values are slowly decreasing over the years, which is consistent with the decay of tritium with no large inventories being added.

In 1988, PPPL initiated the collection of precipitation and monitored levels starting with the second quarter. While 1988 was a dry year, 1989 and 1990 were relatively wet years with over 55 inches (140 cm) of precipitation in 1989 and 50.3 inches (128 cm) of precipitation in 1990. In 1991 the precipitation level at PPPL was 45 inches(114 cm) (see Fig. 32 and Table 20 [Ch92].

B. Groundwater

Seven existing on-site wells—W4, W5, D11, and D12 on C-site (Fig. 33), and TW1, TW3, and TW10 on D-site—were sampled (Table 21). As a part of continuing efforts to characterize the site, a more comprehensive groundwater program was initiated in June 1985 through the USGS. This program entailed the drilling of several monitoring wells on the TFTR site in order to help profile the groundwater system. The final USGS survey report was issued in 1987 [Le87]. This report indicated a cone of depression created by the TFTR sump system (Fig. 37 & 38). The samples collected from two of the wells (TW1 and TW10 at D-site) were analyzed for tritium by PPPL. The sample results were consistent with previous testing accomplished by PPPL and the USGS and indicated tritium levels less than 100 pCi/liter (3.7 Bq/liter). These values are consistent with surface-water measurements. The results for 1991 are also less than 100 pCi/liter (3.7

Bq/liter), as expected, and because the pool of water tends to average out HTO added by precipitation, the large variation noted in precipitation is not seen in the groundwater.

C. Drinking Water

Potable water is supplied by the public utility, Elizabethtown Water Co. In April 1984, a sampling point at the input to PPPL was established (E1 location) to provide baseline data for water coming onto the site. Radiological analysis has included gamma spectroscopy and tritium-level determination. Tritium levels (Fig. 34) are similar to surface (Fig. 31) and well waters (Fig. 33) with measurements indicating less than 100 pCi/liter (3.7 Bq/liter); also, only naturally occurring gamma-emitting radioisotopes have been detected. Radium and radon levels have not been measured in the potable water system by PPPL.

5.3.2 Foodstuffs

Foodstuffs collected and analyzed in CY91 during the growing season included peas, strawberries, raspberries, tomatoes, corn, and a pumpkin. They were collected from area farmers or gardens. The variation shown in detected HTO levels of 21 to 63 pCi/liter (see Fig. 35 and Table 22) is indicative of the variation of HTO in precipitation.

5.3.3 Soil, Grass, and Vegetation

Off-site sampling locations were established in late 1985 (see Fig. 39). In 1991, some sampling points were relocated because of construction in the area in 1990 and also to be near the newly positioned air-monitoring stations. Soil and grass samples collected on-site and off-site in 1991 indicated tritium levels below 100 pCi/liter (3.7 Bq/liter) (see Fig. 36 and Table 22). Laboratory techniques for doing these analyses were perfected in CY84 [Gr85], and the techniques are documented in the various controlled procedures of the Radiological Environmental Monitoring Laboratory. These baselines are being established because surface soils and vegetation are among the best indicators of tritium deposition after a release [Jo74], [Mu77], [Mu82], [Mu90]. The present, measured concentrations are consistent with those of tritium in the environment.

6.0 ENVIRONMENTAL NON-RADIOLOGICAL PROGRAM INFORMATION

6.1 NJPDES Data

6.1.1 Surface and Storm Water

Monthly water chemistry reports for D2 (PPPL designation) or DSN 001A (permit designation), compiled from the data of Table 28, were submitted to the state of New Jersey in 1991 in accordance with PPPL's New Jersey Pollutant Discharge Elimination System (NJPDES) permit, NJ0023922. The PPPL was well within the allowable limits for all testing parameters during CY91, except for total suspended solids (TSS). In March 1991, the TSS permit limit of 50 mg/l was exceeded by a TSS value of 130 mg/l. It is believed that this occurrence was due to rain washing exposed soil into the storm drains, thus elevating the TSS level in the discharge. No data for January 1991 is available, because the analytical laboratory did not collect samples during that month. This oversight was corrected through meetings with the laboratory and the development of sampling procedures, including the setting of the sampling schedule.

Cooling-water treatment was changed from a chromate-based corrosion inhibitor to a nonchromate inhibitor in June 1983. Water analyses downstream of the detention basin (see Table 23) have not indicated concentrations of any environmental pollutants, in general, above applicable codes, regulations, or standards with the exception of temperature during the winter months. There are instances when the downstream-station (B2) temperature was higher than 2.8°C or 5°F (NJ Surface Water Quality Criteria) above the upstream station (B1) ambient temperature. The difference in temperature, or Dt, is due to the Dt between groundwater and surface water in the colder months of the year. The temperature of groundwater is relatively constant (12.8°C/55°F) while surface water temperatures fluctuate with air temperature. The PPPL believes that the amount of groundwater being pumped to dewater building foundations (TFTR, D-site MG, and Laboratory Office Building), and not the process water from the cooling tower or boiler blowdown, is responsible for the higher temperatures observed in the winter. In the summer, the Dt is not only less than 2.8°C, but at times the discharge temperature was equal to, or less than, the ambient temperature.

In the past, one cooling tower discharged to the storm water sewers, which are routed to the permitted surface water discharge, and the second to the sanitary sewers. The Stony

Brook Sewage Authority had requested that the second cooling tower also discharge to the surface water. This change is authorized under our current permits per discussions with the NJDEPE. The changeover was completed in CY91.

Storm water and process water, which includes cooling tower and boiler blowdown, are discharged into surface waters and are governed at C- and D-sites by NJPDES Permit No. NJ0023922 (effective date November 1, 1984 expiration date October 31, 1989). This permit is still in effect while NJDEPE reviews the new application request and prepares the new permit. All process water and most runoff water from C- and D-sites now pass through a detention basin. Approximately 158.3 million gallons discharged through the detention basin in CY91. Storm-water discharge (DSN 002A) points (west side of C-site) which do not run into the detention basin are included in the surface-water, renewal permit application. Upgrades to the detention basin, made in 1986, included an oil-spill detection and alarm system. As a result of minor problems following the transformer-oil leak in 1988 [St88d] and the 1988 DOE Environmental Survey (see 6.7.2), another analysis of this system determined that the best long-term, best-management practice and environmental solution is to line the detention basin and to install more reliable oil sensors. This project is funded, and completion is expected in CY92.

6.1.2 Groundwater Assessment

After the application for the the groundwater permit, which was filed in 1986, the NJDEPE proposed the addition of monitoring wells around the detention basin and three wells off of DOE-leased property. While DOE has requested a hearing on the off-site well aspects of the permit requirements, PPPL came into compliance with the existing permit requirements in November 1989. Monitoring of the off-site wells (MW14, 15, and 16—see Fig. 39) has not shown any contaminants and, therefore, closure of the wells or turnover to Princeton University will be requested of the NJDEPE when the permit renewal application in 1993.

Low levels (ppb range) of volatile organic compounds were detected in three on site wells. Due to these occurrences, the results of the the soil-gas survey (conducted in 1990), UST issues, and NJPDES permit requirements, a groundwater assessment was initiated in November 1990, as directed by NJDEPE. The objective of the assessment was twofold: (1) determine the impact of the underground storage tanks on groundwater and (2) correlate the soil-gas survey results with groundwater quality.

Sixteen wells and two piezometers were installed in December 1990 and were sampled in January 1991. The results of the investigation (Table 31) were: 1) low-levels of semivolatile organics were detected in the wells closest to the underground storage tank (UST) excavation adjacent to the FED building [MP91a], and 2) low-levels of volatile organic compounds (tetrachloroethylene, trichloroethylene, and trichloroethane) were identified in wells located on both C- and D-sites [MP91b].

There were two significant conclusions drawn from the groundwater quality data. The first is that the open excavation was creating a mounding effect and was driving the contamination into the groundwater (see Fig. 41). The second conclusion was that the presence of chemical contaminants in groundwater was found in only three well locations (1. MW-3 west of CAS building, 2. MW-5S, MW-6I and 6S, MW-7I and 7S near FED building, and 3. MW-9 east of RESA building) of the eighteen wells (see Figure 40), which were installed near the UST excavation and the areas identified as "hot spots" during the soil-gas survey [Ne90]. The first finding is further explained by the removal of a confining layer when the tanks were originally installed and later when the surrounding soils were excavated due to the UST leak. The reports were submitted to NJDEPE in March 1991.

The NJDEPE reviewed these reports and approved the closure of the excavation pits in July 1991 with the following conditions: 1) a well couplet (one shallow and one intermediate depth, MW-8S and MW-8I) be installed immediately south of the excavation, 2) monthly water elevations be measured and contour maps drawn, and 3) quarterly monitoring samples be collected and analyzed for total petroleum hydrocarbons and annually for volatile organic compounds. The new wells were installed in August 1991 and sampled two weeks after well completion; the second quarter samples were collected in November 1991 (Table 32 & 33) [MP91g and h]. The NJDEPE required a second year of monitoring as a condition for allowing the remainder of the contaminated soil to stay in the excavation (eastern excavation) [NJDEPE91c]. The western excavation was filled in CY91. The eastern excavation was filled to the level of the utility lines (about 3 feet below grade) in March 1992. Following the completion of repairs to the utility lines and paving over the clean fill, closure is expected by late summer 1992.

Regarding the volatile organic contaminants detected in the groundwater, the case was referred to the NJDEPE Bureau of State Case Management. The significance of this referral to the Bureau of State Case Management is that the NJDEPE could require PPPL to conduct groundwater remediation actions directed through an agreement between Princeton University and NJDEPE.

In correspondence with DOE [NJDEPE90], the NJDEPE required PPPL to submit a usage survey of solvents and other hazardous substances. In September 1991, PPPL and DOE/PAO submitted a report, "Solvent and Hazardous Constituent Usage Survey," [MP91f] to NJDEPE. The survey showed that there are petroleum hydrocarbons and solvents present in most buildings at PPPL. The solvent 1,1,1-trichloroethane (TCA) is widely used throughout the Laboratory; however, substitute solvents/detergents are being made available and used wherever suitable.

In 1991 an investigation of the groundwater in the vicinity of the C-site Motor Generator (MG) building 1,000-gallon, diesel-oil tank was conducted; the tank, which supplies the emergency diesel generator, had a loose fitting that leaked and subsequently was repaired. No petroleum hydrocarbons (PHC) were detected in the groundwater. The Discharge Investigation and Corrective Action Report (DICAR) [MP91c] was submitted to the NJDEPE in April 1991. No further action is planned until the removal of the tank occurs, at which time more soil removal may be required, based on the levels of PHC detected in the soil borings.

In March 1991, the impact of the detention basin on groundwater was investigated, primarily by recording the levels of water in the detention basin and the water levels in wells D-11, D-12, and MW-9 (control well). The results of this study [MP91d] were that the basin does not appear to discharge to the surrounding groundwater, but rather the groundwater is discharging to the basin at all times except when the basin is at the maximum level. Therefore, a mounding effect was not observed, and the detention basin should not be contributing any contamination to the groundwater.

In late 1990, the RESA building hydraulic-oil spill was reported to the NJDEPE. A new, groundwater-monitoring well adjacent to the spill was required by NJDEPE. Well MW-13 was installed in April 1991, and samples were collected in May and June 1991. Indications are that no residual of the hydraulic oil is present in the groundwater; however, relatively high concentrations of PCE were detected at 200 mg/l and 140 mg/l (Table 31). A report was prepared and submitted to NJDEPE in October 1991 [MP91e]. This well, MW-13, will be incorporated into the overall regional hydrogeological study.

6.2 Other Non-Radiological Data

6.2.1 Other Emissions Monitoring Data

A. Airborne Effluents [Ki91]

The PPPL has New Jersey Department of Environmental Protection and Energy (NJDEPE) air permits for its four C-site boilers and one fuel tank vent (a 15,000-gallon, diesel tank vent—E#8). The five permit certificates, numbered 061295 through 061299, were renewed in 1987 and expired on March 31, 1992; applications have been submitted for the renewal of these permits. Four additional air permits include a vapor degreaser located in the TFTR Hot Cell, a vapor degreaser located in the Field Coil Power Conversion (FCPC) building, the TFTR emergency generator diesel engine, and the C-site emergency generator diesel engine.

Measurements of actual boiler emissions are not required. Emissions were initially calculated using formulas supplied by the NJDEPE [Ki88]. These formulas are based solely on the percent sulfur and the number of gallons of oil burned per hour in each boiler. PPPL utilizes an ENERAC POCKET 50® combustion-efficiency analyzer to indicate the boiler efficiency, oxygen content, flue-gas temperature, and carbon-dioxide content of the stack gas for both oil and natural-gas fuels. This information is recorded and entered into a log book by the boiler operators. This is done to optimize boiler efficiency and to reduce fuel costs in accordance with DOE Order 4330.2C [DOE88b].

The PPPL requested that NJDEPE review the need for a permit for the blueprint machine located in the New Engineering Wing. This machine uses ammonia, which is vented to the atmosphere. The NJDEPE determined that this machine did not require an air permit. Also, permission to allow PPPL to burn approximately one gallon of gasoline during the fire extinguisher training courses was granted by Plainsboro Township, following the NJDEPE's decision that the live burn was not subject to an air permit.

The Air Emission Survey for 1990 was completed and returned to NJDEPE. Under the definition of a major facility (one which emits <25 tons of nitrous oxides annually), PPPL emits more than a total of 25 tons of nitrous oxides (NO_X) per year from the four boilers; on a per boiler basis, each unit emits less than 25 tons of NO_X annually.

B. <u>Drinking Water</u>

Potable water is supplied by the public utility, Elizabethtown Water Co. The PPPL used approximately 20.9 million gallons in CY91. This is a significant reduction from years prior to 1987 because of the changeover to Delaware & Raritan (D&R) Canal water for the cooling-water systems. Water-quality analysis at the input to PPPL was initiated in CY84 to measure nonradioactive pollutants (Table 25, E1 location), as well as to measure potential radioactive pollutants exclusive of radium or radon.

C. <u>Process (nonpotable) Water</u>

Nonpotable water is pumped by PPPL from the D&R Canal as authorized by a permit agreement with the New Jersey Water Supply Authority. The present agreement gives PPPL the right to draw up to one million gallons of water per day for process and fire-fighting purposes for the period beginning July 1984 and ending on June 30, 2009. Renewal is expected at the end of the present contract. Filtration to remove suspended solids is the primary treatment. The filter-backwash discharge (DSN 003A) is included as a separate discharge point in the surface-water permit renewal application. In 1986, a multimedia sand filter was installed to allow the source of the D-site cooling tower make-up water to be changed from potable water to process-water supply. The PPPL used approximately 43.0 million gallons of canal water during CY91 [Ki92]. The sampling point (C1) was established to provide baseline data for process water coming on-site. Table 24 indicates results of water quality analysis at the canal.

D. <u>Surface Water</u>

Surface water is monitored for potential nonradioactive pollutants both on-site and at surface-water discharge pathways (upstream and downstream) off-site. The additional sampling locations, Bee Brook, Ditch #5, Delaware & Raritan Canal, Elizabethtown Water Company, Millstone River, and Plainsboro sampling points (See Figs. 26, 27, and 39, and Tables 23, 24, 25, and 26), are not required by regulations, but are a part of a PPPL best-management practice.

E. <u>SPCC</u>

An updated Spill Prevention Control and Countermeasures (SPCC) Plan was prepared by an environmental consultant in January 1985; this plan underwent extensive review and revision in CY91 [MP92]. The final plan was completed in early CY92; it is incorporated as a supplement to the PPPL Emergency Preparedness Plan. This last update was delayed until after the EPA issued the Final Regulations for Underground Storage Tanks (UST).

PPPL will install five, new above-ground tanks to replace all of its underground tanks by CY94.

F. Sanitary Sewage

Sanitary sewage is discharged to the publicly-owned treatment works operated by South Brunswick Township at the Stony Brook Regional Sewerage Authority. Flow rates are measured by the PPPL sanitary-sewage metering station and indicated a total volume discharge of approximately 15.6 million gallons in CY91. Sampling of PPPL discharges, performed by the publicly-owned treatment works in the past, had determined that pretreatment is unnecessary. Therefore, PPPL is in compliance with the EPA Pretreatment Regulation, 40 CFR Part 403. However, new sampling requirements are expected in CY92. When these regulations are promulgated, PPPL will implement the requirements.

During the DOE Tiger Team assessment, the lack of a treatment works approval (TWA) by NJDEPE for the PPPL Calibration and Service Laboratory building (CASL) sewage-holding tank was cited by the team. Subsequently, PPPL found that no TWA was submitted for the TFTR liquid effluent collection tanks (LECTs). The TWA applications for the CASL tank, LEC tanks, and the upgrades to the detention basin (a new project) are being filed with NJDEPE in CY92 to correct the lack of TWA appplications.

G. Herbicides, Fertilizer, and Pesticides [Ra92]

During CY91, the use of herbicides, pesticides, and fertilizers was managed by PPPL's Facilities Engineering Division (FED) utilizing an outside contractor. These materials are applied in accordance with state and federal regulations. Herbicides are applied by a certified applicator. Table 30 lists the quantities applied during CY91. No herbicides, pesticides, or fertilizers are stored onsite; therefore, no disposal of these types of regulated chemicals is required by PPPL.

H. Polychlorinated Biphenyls (PCBs)

Beginning in CY82, PPPL started a program to dispose of PCB-containing capacitors, transformers, and other similarly contaminated items. During the early phases of the program, all stored items in a GSA (General Services Administration) Warehouse in Belle Mead, New Jersey, were discarded through approved disposal contractors. Remaining PCB items were labeled, as required by EPA regulations, and an inventory, inspection, and status report program was initiated. At the beginning of CY84, PPPL still had 15 PCB transformers and 6,005 large capacitors containing PCBs. In CY84, 375 large and 54 small PCB capacitors were disposed of, as well as the oil and containers of two transformers. In 1985, an additional 1,330 large capacitors and 22 small capacitors were removed properly from the site. In 1986, a few small capacitors but no transformers were discarded. In 1987, two transformers containing 700 gallons of PCB fluid were disposed. In addition, 1,145 gallons of less than 500 ppm PCB fluid were generated from reworked and reclassification of six PCB transformers to non-PCB transformers, and 391 capacitors were disposed. In 1988, 1,696 capacitors and four small transformers were removed. In 1989, 273 capacitors were disposed while an additional 1,108 were removed from service. Eleven transformers were disposed along with one contaminated transformer containing 113 gallons of PCB fluid (186 ppm). In 1990, the remaining PCB transformers were disposed, leaving only one contaminated transformer (>50 ppm) on site. This transformer became a noncontaminated transformer in 1991. At the end of 1991, PPPL was left with only 646 large regulated capacitors. PCB capacitors are being disposed as they are taken out of service. Disposal records are listed in the Annual Hazardous Waste Generators Report [La92].

In July 1991, PPPL initiated a program to remove old fluorescent light fixtures and to replace them with energy efficient fixtures. Prior to 1979, nearly all light ballasts were made with capacitors which contained PCBs. Those light ballasts which were not marked "non-PCB" were assumed to be PCB and were placed in drums. By the end of the program in March 1992, fifteen drums containing these ballasts were filled and were sent to a licensed PCB incinerator for disposal.

I. Hazardous Wastes

Responsibility for this program rests with the PPPL Hazardous Material Coordinator under the supervision of the Head, Office of the Environmental Restoration/Waste Management Administration (ER/WM). A facility (HAZMAT building) was set up in CY82 for temporary storage of hazardous materials. A new area was built in 1986. This facility has concrete floors with containment walls, fire alarms, security surveillance, fire extinguishers, an eye-wash station, an emergency shower, and telephones. Improvements to the facility, following experience gained from operational needs, were made in CY88. A concern in 1990 was the flaking of the epoxy sealant used throughout the entire building. In 1991, the flooring in the HAZMAT building was removed and replaced with a new coating of epoxy sealant. A question brought out during the DOE Tiger Team assessment indicates a resolution is needed on some areas of the facility being within the 500-year flood plain when the definition of "critical facility" per 10 CFR 1022 is applied [CFR90].

This issue will be addressed by using the new site plan, which is due to be finished in CY92, to determine the location of the facility in relation to the 500-year flood plain. A request has been made to EM to fund upgrades to the facility in FY93, if needed.

The Hazardous Waste Generator Annual Report (EPA ID number NJ1960011152) has been submitted for 1991 in accordance with EPA requirements [La92]. During 1991, 95,028 pounds of solid materials and 3,180 gallons of liquid waste were disposed at EPA-certified treatment, storage, and disposal facilities. These totals included 52,419 pounds of PCBs (oil plus containers) and oil-contaminated soil from a on-site spill . It should be noted that a significant fraction of the waste was oil-contaminated soil from oil-spill cleanups. Outside of oil-contaminated soil and PCB disposal, approximately 43,000 pounds and 3,200 gallons of other hazardous waste (including containers) were shipped for disposal.

J. U.S. Geological Survey Study

A groundwater study by the U.S. Geological Survey (USGS) began in 1985 and was completed in 1987 [Le87]. While this special study was predicated on a spill of tritium from the liquid effluent collection tanks (LECTs), it more appropriately addresses the general groundwater quality and flow patterns in the region near the TFTR facility. Figure 37 shows the potentiometric surface of the bedrock aquifer from this report. The report also indicated that the sumps under the TFTR complex create a cone of depression (Fig. 38). These data are being used in conjunction with the present groundwater studies. In 1991, USGS continued to record groundwater elevations from two monitoring wells located north of TFTR. The USGS also presented PPPL some data developed in an unrelated study on naturally occurring radioactivity in the ground. Uranium-enriched rocks can be a source of radioactivity in groundwater [Sz87, Za87].

K. DOE/HQ Environmental Survey

A comprehensive environmental survey was conducted by DOE/HQ utilizing outside subcontractors during the month of June 1988. This survey was a part of a DOE program which looked at 45 of their facilities. No significant environmental impact findings were noted at PPPL during this survey. A plan of action for findings was forwarded to DOE, and except for long-lead time items, the findings have been closed out. Soil sampling for petroleum hydrocarbons from former spills and for chromium in soils from previous use in cooling towers was accomplished in November 1988 [DOE88a]. Data from this sampling effort have not shown any significant contamination requiring any follow-up action by PPPL.

L. DOE/CH Audit/Appraisal

In August 1991, DOE/CH conducted their audit/appraisal which investigated the following areas: Environmental Protection, Quality Assurance, Industrial Hygiene, Safety Analysis Review System, and Health Physics. No major findings were identified during this audit/appraisal; an action plan for findings was provided to DOE. Many of the findings have been closed, and the status of the remaining open items is reported on a quarterly frequency. Most corrective activities should be completed and closed in CY92.

6.2.2 Continuous Release Reporting

Under CERCLA's reporting requirement for the release of a listed hazardous substance in quantities equal to or greater than its reportable quantity, the National Response Center is notified and the facility is required to report annually to EPA. Because PPPL has not released any CERCLA hazardous substances, no "Continous Release Reports" have been filed with EPA.

6.2.3 Environmental Occurrences

Nineteen releases were reported to the NJDEPE Hotline, and confirmation reports submitted in CY91 (Table 29). In accordance with reporting requirements, notifications were made to the NJDEPE, because these release events posed a potential threat to the environment. No reports to the National Response Center (NRC) were made since there were no releases which exceeded the reportable quantities (RQ) for any listed substance.

Of the nineteen reported releases, thirteen were releases of small quantities of petroleum/petroleum products (11 releases) or hazardous substances (2 releases) onto paved areas [Fi91c, f-j, and l-r]. During these events, the amount of material released ranged from about one-half pint to 5 gallons and was easily cleaned up without impacts to water or ground.

The second category of releases was oil sheens on the detention basin (3 releases). Two of the reported oil-sheen events were reported on the same day and were attributed to parking lot oil [Fi91b], and the third was possibly due to a crane [Fi91e], which was leaking oil onto the roadway, not far from a catch basin. In the first case, PPPL contacted Region II Office of the Environmental Protection Agency (EPA) and discussed the situation of the need to notify the NRC each time an oil sheen is observed on the detention basin, i.e., each time it rained and parking lot runoff flowed into the basin. On March 13, 1991, PPPL received a letter from EPA [EPA91] stating that PPPL had made the initial notification and did not need to report any future oil sheens due to parking-lot runoff. If more than the usual amount of oil was observed, then PPPL would need to investigate possible sources. On November 25, 1991, PPPL received from the NJDEPE [NJDEPE91a] a similar letter regarding notification of oil on the detention basin.

The third category has the three releases (3) to water or ground. The first report was identified in November 1990 (NJDEPE case #90-11-01-1524) [Fi91a]. The confirmation report was submitted to NJDEPE in January 1991. At the Research Equipment Storage and Assembly building (RESA), hydraulic oil from an air compressor, located outside of the building, was leaking; the release involved about one gallon of hydraulic oil onto the ground beneath the wooden floor of the storage trailer. Oily soil was removed, and samples were collected. The excavation reached a depth of about four feet; the sample-analysis results indicated that oil was not present; however, other contaminants were identified. The excavation was backfilled with clean fill, and the release confirmation report with the analysis was submitted. In February 1991, the NJDEPE directed PPPL to install a groundwater-monitoring well downgradient of the release [NJDEPE91b]. Because the direction of groundwater flow in this area is toward the north, it would have meant placing the well inside of the RESA building. Instead, the well (MW-13) was installed directly over the area of the release. Two rounds of samples were collected and analyzed for volatile organics (VOCs) (Table 31) and base neutral compounds. In October 1991, a report [MP91e] was submitted to NJDEPE; the results of the study showed that the highest levels of VOCs (140 and 200 mg/l) were found in this well. The PPPL recommended that this case be incorporated into the site-wide groundwater studies.

The second release resulted from a leak in a small gasoline tank of a PPPL fork lift truck [Fi91d], which was parked on a gravel/dirt lot. About one gallon of gasoline was released onto the ground; the remaining gasoline was drained from the tank. Following the removal of the contaminated soil, a sample from the bottom of the hole was analyzed. Because of the relatively small amount of gasoline spilled and the short length of time it was on the ground, the cleanup effort for this release was minor.

NJDEPE Case #91-8-5-0938-49, transformer oil in the sump, was due to a loose hose connection on a transformer. The connection was tightened, and the area of stone affected by the dripping oil was removed. Because it rained heavily later that week, the sump nearby the transformer was checked for oil. Oil was found in the sump, and the pump was immediately shut off and tagged out-of-service. Consequently, no oil was observed in the detention basin. The oily water was pumped out of the sump into 55-gallon drums; cleanup of the oily stone could not be completed until TFTR shutdown, at which time removal work in the switchyard could be safely accomplished.

Other miscellaneous releases within PPPL facilities did not require notification of the NJDEPE or the National Response Center. All releases are responded to immediately by an in-house Emergency Services Unit (ESU), who act as first-responders. Outside consultants are under contract to provide clean-up services if it is required. Because of the prompt internal response and vigilance by employees, the 1991 releases resulted in no significant impacts to the environment.

6.2.4 SARA Title III Reporting Requirements

The NJDEPE administers the SARA Title III reporting for EPA Region II. The modified Tier I form includes SARA Title III and NJDEPE specific reporting requirements. PPPL submitted the SARA Title III report to NJDEPE in February 1992. No significant changes from the previous year were noted.

The report included information about twelve compounds used at PPPL. Of the twelve, five compounds are in their gaseous form and are classified as sudden releases of pressure hazards, and two are also acute health hazards. There are eight liquid compounds; nitrogen is used in both gaseous and liquid forms. Fuel oil, gasoline, and petroleum oil are flammables; bromotrifluoromethane, dichlorodifluoromethane, and sulfuric acid are acute health hazards; sulfuric acid is reactive, too. PCB's and gasoline are listed as chronic health hazards.

7.0 GROUNDWATER PROTECTION

As part of our NJPDES permit, groundwater sampling was begun at the end of 1989 on seven additional wells (D-11, D-12, MW-14, MW-15, MW-16, TW2, and TW3). The data are indicated in Tables 34 through 39. Until January 1992, the permit number was the same number as the surface water, NJ0023922, with an effective date of May 1, 1989, and an expiration date of May 1, 1994. However, the new permit number is NJ0086029 and has the same expiration date.

Other monitoring data included base neutrals and volatile organics (Tables 37, 38, & 39) and general chemistry for the detention basin inflows (Table 27) and monitoring wells (Tables 34, 35, & 36). The solvents, PCE, TCE, and TCA, were all found in trace amounts in wells D-11, D-12, and TW-3 and in the inflow from D-site during the August 1991 sampling; but they were indicated in well D-12 only during the May 1991 sampling (Tables 31 & 37).

In February 1991, NJDEPE and PPPL split water samples collected from the inflow pipes that empty into the TFTR sump. All inflow results indicated the presence of PCE and TCA, but no other VOCs (Table 31).

Groundwater assessment (see 6.7.4) initiated in 1990 was completed early in 1991. To further characterize groundwater quality, the direction of flow, and the source of contamination, future investigations are anticipated for the end of CY93. The delay is due in part to a study, CERCLA Inventory of Past Hazardous Releases, which will be performed in late CY92-CY93, and funding for additional work is not expected until fiscal year (FY) 1993.

8.0 QUALITY ASSURANCE

Analysis of environmental samples for radioactivity was accomplished in-house by the Radiological Environmental Monitoring Laboratory (REML). The REML procedures follow the EPA HASL-300 Manual [Vo82] or other nationally recognized standards. Approved analytical techniques are documented in the REML procedures. PPPL participates in the EPA (Las Vegas) program and the DOE Environmental Measurements Laboratory (EML) in New York City. These programs provide blind samples for analysis and subsequent comparison to values obtained by other participants, as well as to known values. Results are shown in Table 40.

Split and duplicate samples are analyzed by the subcontractor laboratory, Northeastern Analytical Corporation. The results of these samples are shown in Table 41. This laboratory participates in a state of New Jersey QA program and has quality assurance plans [NAC90].

In CY84, PPPL initiated a program to have its radiation-counting laboratory certified by the state of New Jersey through the EPA Quality Assurance (QA) program. In March 1986, the REML facilities and procedures were reviewed and inspected by EPA/Las Vegas and the NJDEPE. The laboratory was certified for tritium analysis in urine and water and recertified in these areas in 1988, 1989, 1990, and 1991. While the certification was expected to have been extended to gamma spectroscopy in 1990, as all of the blind samples to date have been within expected detection limits (see Table 40), an official site visit has not yet been made by NJDEPE to authorize this certification.

9.0 ACKNOWLEDGEMENTS

M. Lewis, D. Speed, and J. Gilbert compiled the data for radiation analysis. L. Umbaugh, E. Panik, and R. Leuenberger performed in-house radiochemical analyses, and R. Frankenfield, K. Chase, and J. Lehner worked on instrument installation and calibration. These individuals are staff members of the PPPL ES&H Division, Health Physics Branch. W. Slavin, Head, Industrial Hygiene Branch, reviewed nonradioactive pollutant analysis data. C. Kircher furnished all water-utilization information. E. Rabiger also furnished the fertilizer, herbicide, and pesticide data. J. Levine, Head, Environment and Health Branch, provided NESHAPs calculations. S. Larson and J. Scott are responsible for hazardous-waste disposal. Various other PPPL individuals have reviewed the manuscript.

This work is supported by the U.S. Department of Energy Contract No. DE-AC02-76CHO3073.

10.0 REFERENCES

Be87a Bentz, L. K., and Bender, D. S., 1987, "Population Projections, 0-50 Mile Radius from the CIT Facility: Supplementary Documentation for an Environmental Assessment for the CIT at PPPL," EGG-EP-7751, INEL, Idaho Falls, Idaho.

Be87b Bentz, L. K., and Bender, D. S., 1987, "Socioeconomic Information, Plainsboro Area, New Jersey: Supplementary Documentation for an Environmental Assessment for the CIT at PPPL," EGG-EP-7752, INEL, Idaho Falls, Idaho.

CEE90 Corporate Environmental Engineering, June 1990, "Waste Minimization Study and Industrial Products Review," Corporate Environmental Engineering, Inc., Princeton, NJ, A Report to PPPL under Subcontract No. S-03225-G.

CFR90 Title 10, Code of Federal Regulations, Part 1022, "Compliance with Floodplain/Wetlands Environmental Review Requirements."

Ch92 Chase, K., 1/2/92, "Annual Precipitation Report (1991)," Princeton Plasma Physics Laboratory, Internal Memo.

Co81 Corley, J. P. et al., 1982, A Guide for: Environmental Radiological Surveillance at U.S. Department of Energy Installations DOE/EP-023, (National Technical Information Service).

DOE88a Environmental Survey Sampling and Analysis Plan, November 1988, PPPL S&A Plan, INEL/EG&G report to DOE.

DOE88b DOE Order 4330.2C, 3/23/88, In-House Energy Management.

DOE89 DOE Order 5480.11, 7/20/89, Radiation Protection for Occupational Workers.

DOE90a DOE Order 5400.5, 6/5/90, Radiation Protection of the Public and the Environment.

DOE90b DOE Order 5400.1, 6/29/90, General Environmental Protection Program.

En87 Envirosphere Company, 1987, "Ecological Survey of Compact Ignition Tokamak Site and Surroundings at Princeton University's Forrestal Campus," Envirosphere Company, Division of Ebasco, Report to INEL for the CIT.

EPA89 US Environmental Protection Agency, October 1989, Users Guide for the Comply Code, EPA 520/1-89-003.

EPA91 US Environmental Protection Agency, 3/13/91, Bruce Sprague, Chief, Response and Prevention Branch, to Joseph Stencel, PPPL ES&H Deputy Division Head, letter.

Fi91a Finley, V., January 1991, "Environmental Protection Spill Cleanup Report EP91-01, Hydraulic Oil Incident, November 1, 1990," VLF-004, NJDEP ID. No. 90-11-01-1524, PPPL Internal Report of the Environmental Protection Committee.

Fi91b Finley, V., March 1991, "Environmental Protection Spill Cleanup Report EP91-02, Detention Basin Oil Incident, February 6, 1991," VLF-030, NJDEP ID. No. 91-2-6-

1233-05 and 91-2-6-1706-20, PPPL Internal Report of the Environmental Protection Committee.

Fi91c Finley, V., April 1991, "Environmental Protection Spill Cleanup Report EP91-03, School Bus Diesel Fuel Incident, February 21, 1991," VLF-031, NJDEP ID. No. 91-2-21-1503-07, PPPL Internal Report of the Environmental Protection Committee.

Fi91d Finley, V., April 1991, "Environmental Protection Spill Cleanup Report EP91-04, Fork Lift Truck Gasoline Spill, February 25, 1991," VLF-032, NJDEP ID. No. 91-2-25-1524-05, PPPL Internal Report of the Environmental Protection Committee.

Fi91e Finley, V., May 1991, "Environmental Protection Spill Cleanup Report EP91-05, Detention Basin Oil Incident, March 15, 1991," VLF-067, NJDEP ID. No. 91-3-15-1201-18, PPPL Internal Report of the Environmental Protection Committee.

Fi91f Finley, V., May 1991, "Environmental Protection Spill Cleanup Report EP91-06, Kutz-It ® Drum Spill Incident, April 11, 1991," VLF-074, NJDEP ID. No. 91-4-11-1209-02, PPPL Internal Report of the Environmental Protection Committee.

Fi91g Finley, V., June 1991, "Environmental Protection Spill Cleanup Report EP91-07, Brake Fluid Spill Incident, May 22, 1991," VLF-074, NJDEP ID. No. 91-5-22-1155-12, PPPL Internal Report of the Environmental Protection Committee.

Fi91h Finley, V., July 1991, "Environmental Protection Spill Cleanup Report EP91-08, Engine Coolant Leak Incident, June 11 1991," VLF-085, NJDEP ID. No. 91-6-11-1402-39, PPPL Internal Report of the Environmental Protection Committee.

Fi91i Finley, V., August 1991, "Environmental Protection Spill Cleanup Report EP91-09, Parking Lot Oil Spill Incident, July 9, 1991," VLF-110, NJDEP ID. No. 91-7-9-1028-34, PPPL Internal Report of the Environmental Protection Committee.

Fi91j Finley, V., September 1991, "Environmental Protection Spill Cleanup Report EP91-10, Oil Spill Incident, August 5, 1991," VLF-121, NJDEP ID. No. 91-8-5-0901-35, PPPL Internal Report of the Environmental Protection Committee.

Fi91k Finley, V., September 1991, "Environmental Protection Spill Cleanup Report EP91-11, Transformer Oil Spill Incident, August 5, 1991," VLF-122, NJDEP ID. No. 91-8-5-0938-49, PPPL Internal Report of the Environmental Protection Committee.

Fi91l Finley, V., October 1991, "Environmental Protection Spill Cleanup Report EP91-12, Engine Coolant Leak Incident, August 29, 1991," VLF-134, NJDEP ID. No. 91-8-29-1450-25, PPPL Internal Report of the Environmental Protection Committee.

Fi91m Finley, V., October 1991, "Environmental Protection Spill Cleanup Report EP91-13, Oil Spill Incident, September 6, 1991," VLF-135, NJDEPE ID. No. 91-9-6-0822-52, PPPL Internal Report of the Environmental Protection Committee.

Fi91n Finley, V., November 1991, "Environmental Protection Spill Cleanup Report EP91-14, Gasoline Spill Incident, October 2, 1991," VLF-147, NJDEPE ID. No. 91-10-2-0934-55, PPPL Internal Report of the Environmental Protection Committee.

Fi91o Finley, V., November 1991, "Environmental Protection Spill Cleanup Report EP91-15, Diesel Oil Spill Incident, October 16, 1991," VLF-148, NEJDEP ID. No. 91-10-16-1631-13, PPPL Internal Report of the Environmental Protection Committee.

Fi91p Finley, V., November 1991, "Environmental Protection Spill Cleanup Report EP91-16, Hydraulic Oil Spill Incident, October 28, 1991," VLF-150, NJDEPE ID. No. 91-10-16-1631-13, PPPL Internal Report of the Environmental Protection Committee.

Fi91q Finley, V., November 1991, "Environmental Protection Spill Cleanup Report EP91-17, Oil Spill Incident, October 28, 1991," VLF-149, NJDEPE ID. No. 91-10-28-1557-17, PPPL Internal Report of the Environmental Protection Committee.

Fi91r Finley, V., November 1991, "Environmental Protection Spill Cleanup Report EP91-18, Diesel Oil Spill Incident, November 8, 1991," VLF-152, NJDEPE ID. No. 91-11-8-1140-29, PPPL Internal Report of the Environmental Protection Committee.

Fl84 Fleming, R. B., *et al.*, February 1984, Safety Assessment Document for the Princeton Beta Experiment, Princeton Plasma Physics Laboratory (unpublished).

FSAR82 Final Safety Analysis Report, Tokamak Fusion Test Reactor Facilities, Princeton Plasmas Physics Laboratory, 1982.

Gr85 Griesbach, O. A., and Stencel, J. R., "An Environmental Monitoring Program for a Fusion Test Reactor," Proceedings of the 18th Midyear Topical Meeting of the Health Physics Society, Colorado Springs, CO, Jan. 6-10, 1985, pp.227-233.

Gr88a Griesbach, O. A., and Stencel, J. R., "Operational Experience with the DATS Sampler During the Canadian Tritium Modeling Experiment, " Fusion Technology, 14, Part 2A, Sept. 1988, 1199-1202.

Gr88b Griesbach, O. A., and Stencel, J. R., "The PPPL Differential Atmospheric Tritium Sampler (DATS)," Proceedings of the 22nd Midyear Topical Meeting of the Health Physics Society, San Antonio, TX, Dec.4-8, 1988, pp. 374-380.

Ha91 Hajnal, F., *et al.*,. International Environmental Measurements Laboratory Report, "Measurements of Nuetron Readiation Fields at The Princeton Tokamak Fusion Test Reactor (TFTR)," April 1991.

He88 Hendel, H., 1988, personal communication.

He89 Hendel, H., 1989, personal communication.

Ja90a Jassby, D., 1990, personal communication.

Ja90b Jassby, D., 1990, personal communication.

Ja92 Jassby, D., February 1992, "TFTR Neutron Production for 1991-1992," PPPL Internal Memo.

Jo74 Jordan, C. F., Stewart, M., and Kline, J., 1974, "Tritium Movement in Soils: The Importance of Exchange and High Initial Dispersion," Health Physics, 27, pp. 37-43.

Ki88 Kircher, C., 3/14/88, "Calculations for Boiler Emissions, " Princeton Plasma Physics Laboratory, Internal Memo.

Ki92 Kircher, C.,2/18/91, "Annual Environmental Report for CY91," Princeton Plasma Physics Laboratory, Internal Memo.

Ko86a Kolibal, J., *et al*, 1986, Meteorological Data Summaries for the TFTR from January 1984 to December 1985, Princeton Plasma Physics Laboratory Report No. PPPL-2369.

Ko86b Kolibal, J., 3/24/86, "Sectorized Agricultural and Population Data Estimates," EAD-1442, Plasma Physics Laboratory Internal Memo.

Ku91 Kugel, H., 1991, personal communication.

La92 Larson, S. B., 3/92, "1991 Hazardous Waste Report Detailing Princeton Plasma Physics Laboratory's Hazardous Waste Activity for Calendar Year 1991."

Le87 Lewis, J. C. and Spitz, F. J., 1987, "Hydrogeology, Ground-Water Quality, and The Possible Effects of a Hypothetical Radioactive-Water Spill, Plainsboro Township, New Jersey," U.S. Geological Survey Water-Resources Investigations Report 87-4092, West Trenton, NJ.

Mc83 McCarthy, E. F., and Errera, L. J., 8/15/83, Final Monitoring Plan: Tokamak Fusion Test Reactor Meteorological Monitoring Program, TRC Consultants, Inc., 800 Connecticut Blvd., East Hartford, CT 06108.

Mc89 McKenzie-Carter, M. A. and Lyon, R. E., "Methodology for Assessing the Radiological Consequences of Radioactive Releases from the CIT Facility at PPPL," EGG-ESE-8600, Idaho National Engineering Laboratory (INEL) Informal Report (August 1989) 73 pp.

MP91a Malcolm Pirnie, February 1991, Underground Storage Tank/Groundwater Investigation, 4 volumes.

MP91b Malcolm Pirnie, February 1991, Investigation of Correlation Between Petrex® Soil Gas Survey Results and Groundwater Quality, 4 volumes.

MP91c Malcolm Pirnie, March 1991, Study of Detention Basin Impact on Groundwater Elevations and Flow Direction, Addendum to : Investigation of Correlation Between Petrx® Soil Gas Survey Results and Groundwater Quality.

MP91d Malcolm Pirnie, April 1991, Discharge Investigation and Corrective Action Report, Case #90-10-22-1141.

MP91e Malcolm Pirnie, August 1991, Impact of Hydraulic Fluid Spill on Groundwater Quality.

MP91f Malcolm Pirnie, August 1991, Solvent and Hazardous Constituent Usage Survey.

MP91g Malcolm Pirnie, September 1991, Underground Storage Tank Excavation Area Groundwater Monitoring First Quarter Report, 2 volumes.

MP91h Malcolm Pirnie, December 1991, Underground Storage Tank Excavation Area Groundwater Monitoring Second Quarter Report.

MP92 Malcolm Pirnie, April 1992, Certified by R. P. Brownell, P. E. , Spill Prevention Control and Countermeasure (SPCC) Plan for Princeton Plasma Physics Laboratory.

Mu77 Murphy, C. E., Jr., Watts, J. R., and Corey, J. C., 1977, "Environmental Tritium Transport from Atmospheric Release of Molecular Tritium," Health Physics, 33, 325-331.

Mu82 Murphy, C. E., Jr., Sweet, C. W., and Fallon, R. D., 1982, "Tritium Transport Around Nuclear Facilities," Nuclear Safety, 23, 667-685.

Mu90 Murphy, C. E., Jr., 1990, The Transport, Dispersion, and Cycling of Tritium in the Environment, Savannah River Site Report, WSRC-RP-90-462, UC702, 70 pp.

NAC90 Northeastern Analytical Corporation, July 90, Quality Assurance/Quality Control QA/QC Plan, Northeaster Analytical Corporation, Marlton, NJ, NAC/ENL: QA100.00.

Ne90 Nelson, D., September 1990, Final Report on the Findings of the Petrex Soil Gas Survey Conducted at Princeton Plasma Physics Laboratory on the Forrestal Campus in Plainsboro, New Jersey, Northeast Research Institute, Inc. Report, Farmington, Conn.

NJDEPE90 NJ Department of Environmental Protection and Energy (NJDEPE), May 25, 1990, W. S. Samsel, Chief, Bureau of Aquifer Protection to H. C. Mix, DOE/PAO, letter.

NJDEPE91a NJ Department of Environmental Protection and Energy (NJDEPE), November 3, 1991, Robert J. Kotch, P.E. P.P., Chief, Bureau of Discharge Prevention to Potentially Affected Party, letter.

NJDEPE91b NJ Department of Environmental Protection and Energy (NJDEPE), February 14, 1991, Irene Kropp, Bureau of Groundwater Pollution Abatement, to H. C. Mix, DOE/PAO, "Re: Monitoring Well Installation at Hydraulic Oil Contamination Site Princeton Plasma Physics Laboratory."

NJDEPE91c NJ Department of Environmental Protection and Energy (NJDEPE), March 2, 1992, Irene Kropp, Bureau of Groundwater Pollution Abatement, to H. C. Mix, DOE/PAO, "Re: Correspondence Dated January 24, 1992 - Soil Sampling Results from Underground Storage Tank (UST) Excavations."

Os88 Ostlund, G., University of Miami, private communication, November 1988.

PSAR78 Preliminary Safety Analysis Report, Princeton Plasma Physics Laboratory Tokamak Fusion Test Reactor, 1978.

Ra92 Rabiger, E., February 1992, "1991 Pesticide, Herbicide, and Fertilizer Report," Princeton Plasma Physics Laboratory internal memo.

REML90, March 1990, Radiological Environmental Monitoring Laboratory Manual, Princeton Plasma Physics Laboratory Health Physics Document.

Sa89 Savy, J. B., "Princeton Plasma Physics Laboratory (PPPL) Seismic Hazard Analysis," UCID Report-21829 (October 1989) 138 pp.

SAD91 Safety Assessment Document (SAD) for the Princeton Beta Experiment - Modified (PBX-M), October 25, 1991, 136 pp.

St81 Steiner, P. A., 1981, An Aerial Radiological Survey of the Princeton Plasma Physics Laboratory and Surrounding Area, U.S. DOE Remote Sensing Laboratory Report, EGG-1182-1806, UC-41.

St82 Strenge, D. L., Kennedy, W. E., Jr, and Corley, J. P., 1982, Environmental Dose Assessment Methods for Normal Operations of DOE Nuclear Sites, PNL-4410/UC-11.

St88a Stencel, J. R. and Parsells, R. F., Editors, April 1988, Safety Assessment Document (SAD) for the Princeton Beta Experiment Modification (PBX-M), Princeton Plasma Physics Laboratory Report PPPL-2496.

St88b Stencel, J. R., Gilbert, J. D., Griesbach, O. A., and Greco, J. M., "TFTR Health Physics Tritium Measurements Following D-D Operations," Fusion Technology, 14, Part 2A; 1047-1053; Sept. 1988.

St88c Stencel, J. R., May 1988, Environmental Monitoring Report for Calendar Year 1987, Princeton Plasma Physics Laboratory Report PPPL-2496.

St88d Stencel, J. R., 1988, "Environmental Protection Spill Cleanup Report EP88-01, NB Transformer, January 19, 1988," DEP ID #88-01-19-1617, Internal PPPL Environmental Protection Committee Report.

St89 Start, G. E., Dickson, C. R., Sagendorf, J. F., Ackermann, G. R., Clawson, K. L., Johnson, R. C., and Hukari, N. F., "Atmospheric Diffusion for Airflows in the Vicinity of the James Forrestal Campus, Princeton University," Final Report, U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Environmental Research Laboratories, Air Resources Laboratory Field Research Division, Idaho Falls, Idaho, Vol. 1 (May 1989) 84 pp, Vol. 2 (June 1989) 385 pp.

St90 Stencel, J. R., August 1990, "Environmental Protection Spill Cleanup Report EP90-2, Nitric Acid-Acetone Incident August 9, 1990," JRS-1841, NJDEP ID. No. 90-08-09-1320, PPPL Internal Report of the Environmental Protection Committee.

St91a Stencel, J. R., and Turrin, R. P., March 1991, Environmental Monitoring Report for Calendar Year 1989, Princeton Plasma Physics Laboratory Report PPPL-2739.

St91b Stencel, J. R., and Finley, V. L.. December 1991, Environmental Monitoring Report for Calendar Year 1990, Princeton Plasma Physics Laboratory Report PPPL-2800.

St92 Stencel, J. R., April 29, 1992, letter to H. C. Mix, DOE/PAO, "Calendar Year (CY1991) Air Emissions Annual Report to the Environmental Protection Agency."

Sz87 Szabo, Z. and Zapecza, O. S., "Relation Between Natural Radionuclide Activities and Chemical Constituents in Groundwater in the Newark Basin, New Jersey," Radon, Radium, and Other Radioactivity in Groundwater, Hydrogeologic Impact and Application to Indoor Airborne Contamination, Proceedings of the National Water Well Association Conference, April 7-9, 1987, Somerset, NJ, available from Lewis Publishers.

Tu90 Turrin, R. P., April 1990, "Environmental Protection Spill Cleanup Report EP90-1, Chromium Sands Spill in the Plant Maintenance and Engineering Yard," RPT-66, NJDEP ID. No. 90-03-23-1551, PPPL Internal Report of the Environmental Protection Committee.

Vo82 Volchok, H. L., and de Planque, G., 1982, EML Procedures Manual HASL 300, Department of Energy, Environmental Measurements Laboratory, 376 Hudson St., NY, NY 10014.

Za87 Zapecza, O. S. and Szabo, Z., "Source and Distribution of Natural Radioactivity in Groundwater in the Newark Basin, New Jersey," Radon, Radium, and Other Radioactivity in Groundwater, Hydrogeologic Impact and Application to Indoor Airborne Contamination, Proceedings of the National Water Well Association Conference, April 7-9, 1987, Somerset, NJ, available from Lewis Publishers.

Table 1. TFTR Radiological Design Objectives and Regulatory Limits[a]

CONDITION		PUBLIC EXPOSURE[b]		OCCUPATIONAL EXPOSURE	
		REGULATORY LIMIT	DESIGN OBJECTIVE	REGULATORY LIMIT	DESIGN OBJECTIVE
ROUTINE OPERATION Dose equivalent to an individual from routine operations (rem per year, unless otherwise indicated)	NORMAL OPERATIONS	0.1 Total, 0.01[c] Airborne, 0.004 Drinking Water	0.01 Total	5	1
	ANTICIPATED EVENTS $(1 > P \geq 10^{-2})$	0.5 Total (including normal operation)	0.05 per event		
ACCIDENTS Dose equivalent to an individual from an accidental release (rem per event)	UNLIKELY EVENTS $10^{-2} > P \geq 10^{-4}$	2.5	0.5	(e)	(e)
	EXTREMELY UNLIKELY EVENTS $10^{-4} > P \geq 10^{-6}$	25	5[d]	(e)	(e)
	INCREDIBLE EVENTS $10^{-6} > P$	NA	NA	NA	NA

P = Probability of occurrence in a year.

(a) All operations must be planned to incorporate the radiation safety guidelines, practices and procedures included in PPPL ESHD 5008, Section 10.

(b) Evaluated at the PPPL site boundary.

(c) Compliance with this limit is to be determined by calculating the highest effective dose equivalent to any member of the public at any offsite point where there is a residence, school, business or office.

(d) For design basis accidents (DBAs), i.e., postulated accidents or natural forces and resulting conditions for which the confinement structure, systems, components and equipment must meet their functional goals, the design objective is 0.5 rem.

(e) See PPPL ESHD-5008, Section 10, Chapter 12 for emergency personnel exposure limits.

Table 2. Critical Pathways

Path I.D.	Discharge Pathway		
A1	Atmospheric --->		Whole Body Exposure
A2	Atmospheric --->		Inhalation Exposure
A3	Atmospheric --->		Deposition on Soil & Vegetation, Ingestion, Whole Body Exposure
L1	Liquid Water Way --->		Drinking Water Supply --> Man
L2	Liquid	Water Way --->	External Exposure
L3	Liquid	Water Way --->	Fish ---> Man

Table 3. Monitoring Program Covering Critical Pathways

Type of Sample	Critical Path I.D.	Sample Point Description	Sampling Frequency	Analysis
Surface	L1,L2,L3 & A3	1) Cooling Water Discharge Drainage 2) Bee Brook Upstream & Downstream 3) D&R Canal	Monthly	Tritium and Gamma Spectroscopy
Soil & Sod	A3	Within 1 km radius		Tritium and Gamma Spectroscopy
Biota (Fruits & Vegetables)	A3	Within 3 km radius	Seasonal	Tritium & Gamma Spectroscopy
Surface Water	L1, L2	Liquid Effluent Collection Tanks	As Required by Filling	Tritium and Gamma Spectroscopy, Volume
Air	A1-A3	Test Cell	Continuous	Activated Air (Gross β) ^3H (HT and HTO)
Air	A1-A3	Vault	Continuous	^3H (HT and HTO)
Air	A1-A3	HVAC Discharge (Stack)	Continuous	Activated Air (Gross β) HT and HTO, Particulates, Volume
Direct & Air (on-site)		4 Locations at TFTR Facility Boundary	Continuous	γ, n, ^3H (HT and HTO), Gross β for activated air & particulates with Gamma Spectroscopy, TLD
Direct & Air (off-site)		6 Locations off-site within 1 km radius	Continuous (integrated)	^3H (HT and HTO), TLD for air γ, Gamma Spec. for particulates

Table 4*

Population of Municipalities Within 0-10 Miles of PPPL
1985-2010

Municipality	1985[1]	1995	2000	2005	2010	
Mercer County (Total)[2]	317,685	349,700	359,400	364,200	377,100	Mercer County (Total)
Mercer County (Part)	190,683	219,550	228,100	230,550	240,500	Mercer County (Part)
East Windsor Twp.	22,682	24,750	26,000	26,350	29,350	East Windsor Twp.
Hightstown Borough	4,494	5,050	5,100	5,100	5,100	Hightstown Borough
Hamilton Twp.	85,766	88,850	90,000	91,200	94,450	Hamilton Twp.
Hopewell Twp.	11,040	13,025	15,000	15,200	16,200	Hopewell Twp.
Hopewell Borough	2,013	2,075	2,100	2,100	2,100	Hopewell Borough
Pennington Borough	2,232	2,300	2,300	2,350	2,400	Pennington Borough
Lawrence Twp.	22,804	31,100	33,900	34,000	34,100	Lawrence Twp.
Princeton Twp.	14,202	14,550	14,700	14,900	15,400	Princeton Twp.
Princeton Borough	12,031	12,650	12,700	12,700	12,700	Princeton Borough
Washington Twp.	3,719	8,650	8,800	8,900	9,200	Washington Twp.
West Windsor Twp.	9,700	16,550	17,550	17,750	19,500	West Windsor Twp.
Middlesex County (Total)[2]	626,703	695,432	724,610	760,800	791,800	Middlesex County (Total)
Middlesex County (Part)	121,984	171,183	192,396	202,000	219,100	Middlesex County (Part)
Cranbury Twp.	2,145	5,695	8,033	8,450	8,800	Cranbury Twp.
East Brunswick Twp.	40,770	43,630	44,753	47,000	50,900	East Brunswick Twp.
Helmetta Borough	973	965	949	950	950	Helmetta Borough
Monroe Twp.	19,255	28,711	34,737	36,500	38,200	Monroe Twp.
Jamesburg Borough	4,402	4,723	4,805	5,050	5,050	Jamesburg Borough
North Brunswick Twp.	25,427	31,495	33,916	35,600	37,000	North Brunswick Twp.
Plainsboro Twp.	9,040	15,662	17,161	18,000	20,700	Plainsboro Twp.
South Brunswick Twp.	19,972	40,304	48,042	50,450	57,500	South Brunswick Twp.
Somerset County (Total)[2]	210,318	250,025	263,800	279,765	295,730	Somerset County (Total)
Somerset County (Part)	65,276	89,280	97,820	106,610	115,400	Somerset County (Part)
Franklin Twp.	33,952	47,945	52,790	57,790	62,790	Franklin Twp.
Hillsborough Twp	22,652	28,485	30,900	33,375	35,850	Hillsborough Twp.
Montgomery Twp.	7,970	12,145	13,420	14,725	16,030	Montgomery Twp.
Rocky Hill Borough	702	705	710	720	730	Rocky Hill Borough
Monmouth County (Total)[2]	530,913	568,100	591,600	604,300	613,450	Monmouth County
Millstone Twp.	4,234	5,617	7,000	9,286	11,571	Millstone Twp.

* Taken from Bender [Be87a].

[1] New Jersey Department of Labor. Population Estimates for New Jersey, July 1, 1985.

[2] See methodology in Appendix of Be87a for details on the source and derviation of County and Municipal Projections.

Table 5*

Population of Counties Within 0-50 Miles of PPPL
1985-2010

County	1985 Estimates	1995 Projections	2000 Projections	2005 Projections	2010 Projections	
New Jersey[1]	7,562,000	8,154,000	8,450,300	8,685,200	8,895,700	New Jersey
Atlantic	205,100	245,100	260,100	272,300	283,200	Atlantic
Bergen	841,200	861,800	878,700	891,900	904,000	Bergen
Burlington	380,100	437,100	467,200	494,900	521,300	Burlington
Camden	488,100	555,400	577,200	597,300	616,700	Camden
Essex	845,700	794,000	795,500	779,900	762,300	Essex
Gloucester	207,100	234,500	249,100	263,500	277,400	Gloucester
Hudson	555,900	560,100	548,100	528,500	507,300	Hudson
Hunterdon	92,800	104,500	113,000	121,900	131,000	Hunterdon
Mercer	317,700	349,700	359,400	364,200	377,100	Mercer
Middlesex	626,700	695,432	724,610	760,800	791,800	Middlesex
Monmouth	530,900	568,100	591,600	604,300	613,450	Monmouth
Morris	417,100	479,900	510,500	540,800	570,500	Morris
Ocean	380,000	449,600	484,400	515,800	545,900	Ocean
Passaic	461,400	468,600	469,100	466,500	462,000	Passaic
Somerset	210,318	250,025	263,800	279,765	295,730	Somerset
Sussex	119,600	146,100	159,600	172,900	185,700	Sussex
Union	506,700	534,500	539,700	540,900	540,000	Union
Warren	85,200	92,700	96,200	99,300	101,900	Warren
New York[2]	17,783,000	18,314,022	18,548,262	18,750,076	18,948,273	New York
Bronx	1,198,598	1,199,410	1,205,047	1,213,270	1,224,052	Bronx
Kings	2,248,139	2,228,361	2,232,835	2,242,890	2,254,228	Kings
Nassau	1,332,393	1,344,197	1,333,458	1,315,938	1,292,457	Nassau
New York	1,455,619	1,454,633	1,454,251	1,456,292	1,456,707	New York
Queens	1,917,172	1,919,057	1,925,510	1,933,829	1,953,634	Queens
Richmond	371,679	419,706	443,048	465,818	489,111	Richmond
Pennsylvania[3]	11,863,674	12,100,149	12,101,253	12,161,780	12,222,306	Pennsylvania
Bucks	512,705	576,716	601,168	636,276	673,345	Bucks
Chester	334,311	379,733	395,958	418,726	442,802	Chester
Delaware	557,180	541,442	531,068	525,279	519,554	Delaware
Lehigh	277,914	291,083	294,836	300,762	306,808	Lehigh
Monroe	78,967	104,133	117,583	134,162	153,079	Monroe
Montgomery	663,164	692,521	698,281	712,666	727,346	Montgomery
Northhampton	231,430	244,668	249,000	255,275	261,707	Northhampton
Philadelphia	1,637,434	1,599,620	1,513,674	1,472,959	1,433,333	Philadephia

* Taken from Bender [Be87a].

[1] Office of Demographic and Economic Analysis, N.J. Department of Labor and Industry, 1986.

[2] State Data Center, New York State Department of Commerce, 1985.

[3] State Data Center, Pennsylvania Department of Commerce, 1986. See methodology in Be87 Appendix for details on 2005 and 2010 projections.

Table 6*

Population of Metropolitan Areas Within 50 Miles of PPPL

Metropolitan Areas[1]	1980 Census	July 1985 Estimate	Percent Change
Allentown-Bethlehem MSA (NJ Portion)	84,429	85,200	0.9%
Jersey City, NJ PMSA	556,972	555,900	-0.2%
Monmouth-Ocean PMSA	849,211	910,900	7.3%
Middlesex-Somerset-Hunterdon PMSA	886,383	929,800	4.9%
New York, NY CMSA	8,274,961	8,410,058	1.6%
Newark, NJ PMSA	1,879,147	1,889,000	0.5%
Bergen-Passaic PMSA	1,292,970	1,302,600	0.7%
Philadelphia, PA PMSA (NJ Portion)	1,034,109	1,075,300	4.0%
Trenton, NJ PMSA	307,863	317,700	3.2%

* Taken from Bender [Be87a].

[1] MSA = Metropolitan Statistical Area
CMSA = Consolidated Metropolitan Statistical Area
PMSA = Primary Metropolitan Statistical Area

Source: State of New Jersey, Department of Labor; New York State Department of Commerce

Table 7*

1985 Population Estimates Within Annular Sectors, 0-10 Miles

Sector	0-1 Miles	1-2 Miles	2-3 Miles	3-4 Miles	4-5 Miles	5-10 Miles	Total 0-10 Miles	Sector
N	0	100	289	0	68	4,666	5,123	N
NNE	0	20	290	2,497	4,334	9,600	16,741	NNE
NE	0	0	0	0	0	16,799	16,799	NE
ENE	0	1,160	204	200	100	3,792	5,456	ENE
E	0	0	200	100	10	10,238	10,548	E
ESE	0	100	1,600	1,200	219	3,469	6,588	ESE
SE	113	1,200	0	253	161	18,964	20,691	SE
SSE	362	50	150	0	600	8,255	9,417	SSE
S	0	734	3,837	2,312	1,760	4,156	12,799	S
SSW	3	0	2,500	600	100	27,788	30,991	SSW
SW	0	805	10	250	50	18,525	19,640	SW
WSW	0	739	1,000	1,019	1,449	8,095	12,302	WSW
W	0	1,735	5,820	6,777	2,386	6,253	22,971	W
WNW	40	437	772	3,139	0	2,013	6,401	WNW
NW	0	1,020	866	300	350	3,526	6,062	NW
NNW	0	600	499	200	502	7,093	8,894	NNW
Totals	518	8,700	18,037	18,847	12,089	153,232	211,423	Totals

* Taken from Bender [Be87a]

Table 8*

1995 Population Estimates Within Annular Sectors, 0-10 Miles

Sector	0-1 Miles	1-2 Miles	2-3 Miles	3-4 Miles	4-5 Miles	5-10 Miles	Total 0-10 Miles	Sector
N	0	134	387	0	91	6,241	6,853	N
NNE	0	27	388	3,340	5,242	12,841	21,838	NNE
NE	0	0	0	486	902	21,084	22,472	NE
ENE	0	1,551	273	268	689	5,072	7,853	ENE
E	0	0	268	134	1,678	13,695	15,775	E
ESE	0	827	2,140	1,605	2,235	5,195	12,002	ESE
SE	151	1,605	291	338	493	20,928	23,806	SE
SSE	484	1,454	894	166	803	11,042	14,843	SSE
S	0	982	4,675	3,093	2,354	5,559	16,663	S
SSW	4	188	3,344	2,522	2,908	32,176	41,142	SSW
SW	0	1,077	332	544	2,796	21,450	26,199	SW
WSW	0	989	2,828	1,130	1,594	10,828	17,369	WSW
W	0	2,321	6,005	6,963	2,487	9,277	27,053	W
WNW	53	585	800	3,256	128	4,438	9,260	WNW
NW	0	1,365	898	335	468	4,716	7,782	NW
NNW	0	803	668	268	671	9,487	11,897	NNW
Totals	692	13,908	24,191	24,448	25,539	194,029	282,807	Totals

* Taken from Bender [Be87a]

Table 9*

2000 Population Estimates Within Annular Sectors, 0-10 Miles

Sector	0-1 Miles	1-2 Miles	2-3 Miles	3-4 Miles	4-5 Miles	5-10 Miles	Total 0-10 Miles	Sector
N	0	146	421	0	99	6,792	7,458	N
NNE	0	29	422	3,635	5,560	13,974	23,620	NNE
NE	0	0	0	656	1,217	22,582	24,455	NE
ENE	0	1,688	297	292	895	5,520	8,692	ENE
E	0	0	292	146	2,261	14,904	17,603	E
ESE	0	1,081	2,329	1,747	2,940	5,799	13,896	ESE
SE	164	1,747	393	368	609	21,615	24,896	SE
SSE	527	1,945	1,154	224	874	12,016	16,740	SSE
S	0	1,069	4,968	3,366	2,562	6,050	18,015	S
SSW	4	254	3,639	3,869	3,890	33,710	45,366	SSW
SW	0	1,172	252	469	4,566	22,473	28,932	SW
WSW	0	1,076	2,354	1,169	1,645	11,784	18,028	WSW
W	0	2,526	6,070	7,028	2,522	10,334	28,480	W
WNW	58	637	810	3,297	173	5,286	10,261	WNW
NW	0	1,485	909	347	509	5,132	8,382	NW
NNW	0	874	727	292	730	10,316	12,939	NNW
Totals	753	15,729	25,037	26,905	31,052	208,287	307,763	Totals

* Taken from Bender [Be87a]

Table 10*

2005 Population Estimates Within Annular Sectors, 0-10 Miles

Sector	0-1 Miles	1-2 Miles	2-3 Miles	3-4 Miles	4-5 Miles	5-10 Miles	Total 0-10 Miles	Sector
N	0	151	435	0	102	7,014	7,702	N
NNE	0	30	436	3,754	5,688	14,431	24,339	NNE
NE	0	0	0	725	1,344	23,187	25,256	NE
ENE	0	1,743	307	302	978	5,701	9,031	ENE
E	0	0	302	151	2,496	15,392	18,341	E
ESE	0	1,184	2,405	1,804	3,224	6,043	14,660	ESE
SE	169	1,804	434	380	656	21,892	25,335	SE
SSE	544	2,143	1,259	247	903	12,409	17,505	SSE
S	0	1,104	5,086	3,476	2,646	6,248	18,560	S
SSW	4	281	3,758	4,211	4,286	34,329	46,869	SSW
SW	0	1,210	277	492	5,038	22,986	30,003	SW
WSW	0	1,111	2,496	1,185	1,666	12,170	18,628	WSW
W	0	2,609	6,096	7,054	2,536	10,761	29,056	W
WNW	60	658	814	3,313	191	5,628	10,664	WNW
NW	0	1,534	913	352	526	5,300	8,625	NW
NNW	0	903	751	302	754	10,651	13,361	NNW
Totals	777	16,465	25,769	27,748	33,034	214,142	317,935	Totals

* Taken from Bender [Be87a]

Table 11*

2010 Population Estimates Within Annular Sectors, 0-10 Miles

Sector	0-1 Miles	1-2 Miles	2-3 Miles	3-4 Miles	4-5 Miles	5-10 Miles	Total 0-10 Miles	Sector
N	0	161	465	0	109	7,505	8,240	N
NNE	0	32	466	4,016	5,971	15,441	25,926	NNE
NE	0	0	0	875	1,625	24,521	27,021	NE
ENE	0	1,865	328	322	1,161	6,099	9,775	ENE
E	0	0	322	161	3,016	16,468	19,967	E
ESE	0	1,411	2,574	1,930	3,852	6,580	16,347	ESE
SE	182	1,930	525	407	749	22,503	26,306	SE
SSE	582	2,580	1,491	300	965	13,278	19,196	SSE
S	0	1,181	5,347	3,719	2,831	6,685	19,763	S
SSW	5	339	4,021	4,965	5,161	35,696	50,187	SSW
SW	0	1,295	333	542	6,080	23,797	32,047	SW
WSW	0	1,189	2,808	1,219	1,711	13,021	19,948	WSW
W	0	2,791	6,154	7,112	2,568	11,703	30,328	W
WNW	64	703	822	3,349	230	6,383	11,551	WNW
NW	0	1,641	923	363	563	5,671	9,161	NW
NNW	0	965	803	322	807	11,408	14,305	NNW
Totals	833	18,083	27,382	29,602	37,409	226,759	340,068	Totals

* Taken from Bender [Be87a]

Table 12*

1985 Population Estimates Within Annular Sectors, 10-50 Miles

Sector	10-20 Miles	20-30 Miles	30-40 Miles	40-50 Miles	Total 10-50 Miles	Sector
N	66,118	36,704	181,881	68,882	353,586	N
NNE	134,838	226,290	341,211	488,415	1,190,754	NNE
NE	178,403	431,968	1,293,973	3,522,231	5,426,575	NE
ENE	142,397	220,455	1,076,490	1,449,544	2,888,886	ENE
E	52,020	121,842	75,175	0	249,037	E
ESE	38,489	41,729	135,843	0	216,061	ESE
SE	14,219	81,760	179,854	5,852	281,685	SE
SSE	2,926	13,262	20,520	36,784	73,492	SSE
S	5,446	57,129	11,859	2,908	77,342	S
SSW	54,390	61,310	117,286	196,892	429,878	SSW
SW	230,879	361,455	1,147,177	1,032,046	2,771,556	SW
WSW	52,379	151,542	311,433	299,453	814,807	WSW
W	13,955	39,888	106,238	64,611	224,693	W
WNW	8,287	12,555	15,439	252,047	288,328	WNW
NW	13,920	18,653	66,682	86,917	186,172	NW
NNW	26,092	13,716	34,241	22,704	96,753	NNW
Totals	1,034,758	1,890,257	5,115,303	7,529,287	15,569,605	Total

* Taken from Bender [Be87a]

Table 13*

1995 Population Estimates Within Annular Sectors, 10-50 Miles

Sector	10-20 Miles	20-30 Miles	30-40 Miles	40-50 Miles	Total 10-50 Miles	Sector
N	77,600	43,286	209,880	82,344	413,110	N
NNE	151,656	244,555	345,449	501,569	1,243,229	NNE
NE	189,192	466,816	1,282,528	3,531,064	5,469,602	NE
ENE	149,614	244,189	1,075,798	1,444,205	2,913,807	ENE
E	48,224	130,379	80,443	0	259,046	E
ESE	33,170	44,653	147,906	0	225,728	ESE
SE	15,551	95,456	212,796	6,924	330,726	SE
SSE	3,462	15,691	24,278	43,521	86,953	SSE
S	3,798	65,696	13,638	3,437	86,568	S
SSW	58,457	70,504	134,375	224,101	487,438	SSW
SW	254,358	385,409	1,167,023	1,035,758	2,842,548	SW
WSW	55,741	167,298	319,088	309,761	851,889	WSW
W	13,209	44,869	115,585	68,595	242,258	W
WNW	9,332	14,133	17,280	265,316	306,061	WNW
NW	15,675	21,005	72,663	91,959	201,302	NW
NNW	29,653	15,445	38,640	25,334	109,071	NNW
Totals	1,108,692	2,069,384	5,257,370	7,633,889	16,069,335	Totals

* Taken from Bender [Be87a]

Table 14*

2000 Population Estimates Within Annular Sectors, 10-50 Miles

Sector	10-20 Miles	20-30 Miles	30-40 Miles	40-50 Miles	Total 10-50 Miles	Sector
N	81,590	45,762	223,566	89,117	440,035	N
NNE	158,049	250,338	354,421	507,150	1,269,959	NNE
NE	193,977	478,786	1,286,928	3,538,387	5,498,078	NE
ENE	152,903	256,310	1,081,795	1,447,794	2,938,803	ENE
E	47,314	135,772	83,771	0	266,857	E
ESE	31,627	46,500	154,983	0	233,110	ESE
SE	16,320	102,409	229,267	7,460	355,455	SE
SSE	3,730	16,906	26,158	46,890	93,683	SSE
S	3,687	70,220	14,577	3,655	92,139	S
SSW	60,661	75,359	142,235	234,143	512,399	SSW
SW	262,872	389,374	1,137,316	1,011,964	2,801,526	SW
WSW	57,234	172,994	316,136	311,387	857,751	WSW
W	13,585	46,771	118,755	69,700	248,812	W
WNW	10,091	15,112	18,138	269,393	312,733	WNW
NW	16,950	22,713	75,734	93,637	209,035	NW
NNW	31,170	16,701	40,885	26,602	115,358	NNW
Totals	1,141,761	2,142,027	5,304,664	7,657,280	16,245,732	Totals

* Taken from Bender [Be87a]

Table 15*

2010 Population Estimates Within Annular Sectors, 10-50 Miles

Sector	10-20 Miles	20-30 Miles	30-40 Miles	40-50 Miles	Total 10-50 Miles	Sector
N	91,018	51,262	250,373	102,263	494,916	N
NNE	172,722	258,877	362,497	510,423	1,304,520	NNE
NE	209,861	499,736	1,260,255	3,552,301	5,522,153	NE
ENE	164,784	277,228	1,099,303	1,464,153	3,005,468	ENE
E	47,676	140,787	86,865	0	275,327	E
ESE	30,472	48,217	163,289	0	241,978	ESE
SE	17,263	114,276	258,374	8,407	398,321	SE
SSE	4,203	19,052	29,479	52,843	105,577	SSE
S	4,009	78,351	16,265	4,007	102,632	S
SSW	65,172	84,086	156,390	252,607	558,255	SSW
SW	284,516	410,918	1,123,253	998,753	2,817,440	SW
WSW	61,714	190,521	321,293	322,263	895,791	WSW
W	15,337	52,386	128,998	73,884	270,605	W
WNW	11,698	17,340	20,389	281,867	331,295	WNW
NW	19,650	26,331	81,471	98,437	225,889	NW
NNW	34,761	19,362	45,199	28,849	128,171	NNW
Totals	1,234,856	2,288,731	5,403,694	7,751,059	16,678,339	Totals

* Taken from Bender [Be87a]

Table 16. (Ku86b)

Sectorized Population Data To 1 Mile

		radial distances (m)*				
		50	125	375	1105	2416
	n	0	0	0	377	486
S	nnw	0	0	63	0	469
	nw	0	0	0	20	416
E	wnw	0	0	0	800	830
	w	0	0	103	0	1587
C	wsw	0	0	116	192	749
	sw	0	0	116	317	12
T	ssw	0	0	0	950	247
	s	0	0	317	317	820
O	sse	0	0	0	0	3848
	se	0	0	18	0	64
R	ese	0	0	73	0	60
	e	0	0	73	0	30
	ene	0	0	18	34	17
	ne	0	0	0	250	66
	nne	0	0	0	186	25

* The radii shown are midpoints of the sector radial boundaries.

Table 17. NJDEPE ENVIRONMENTAL PERMITS As Of August 11, 1992

	NJDEPE Permit No.	Type	Issue Date	Expiration Date	Status
1	0086029	NJPDES Groundwater	4/1/89	5/1/94	In compliance. Adjudicatory hearing pending in relation to wells placed at B-site. Sampled 8/12/92. Submitted annual fee.
2	0023922	NJPDES Surface water	9/28/84	10/31/89	Awaiting NJDEPE approval of new permit; submitted annual fee.
3	092187	TFTR Diesel Exhaust	10/24/89	10/24/94	Current
4	096074	C-site Diesel Exhaust	6/28/90	6/28/95	Current
5	094831	Hot Cell Degreaser Vent	3/30/90	6/16/97	Current
6	090735	FCPC Building Degreaser Vent	6/6/89	5/31/95	Current. Awaiting NJDEPE inspection.
7	826	Elizabethtown Water	4/1/91	3/31/93	Current.
8	148539	Underground Storage Tank Registration	4/1/91	3/31/92	Submitted renewal applications for DOE/PAO
9	089962	Diesel Tank E8 Vent	12/13/88	12/13/93	Current
10	061295	Boiler #2 Stack Vent	3/31/82	3/31/92	Sent renewal application to DOE/PAO on 3/24/92; DEPE trying to locate file
11	061296	Boiler #3 Stack Vent	3/31/82	3/31/92	Sent renewal application to DOE/PAO on 3/24/92; DEPE trying to locate file
12	061297	Boiler #4 Stack Vent	3/31/82	3/31/92	Sent renewal application to DOE/PAO on 3/24/92; DEPE trying to locate file
13	061299	Boiler #5 Stack Vent	3/31/82	3/31/92	Sent renewal application to DOE/PAO on 3/24/92; DEPE trying to locate file
14	061298	Oil Storage Tank Vent No. 2	3/31/82	3/31/92	Sent renewal application to DOE/PAO on 3/24/92; DEPE trying to locate file
15	0128306	Medical Waste Generator	7/22/91	7/21/92	Submitted annual report to DOE/PAO on 7/16/92
16	DR-18A	Delaware and Raritan Canal Water Use Agreement	7/1/84	6/30/2009	Current
17	12471	REML Laboratory Certification	7/1/91	6/30/92	Received NJDEPE renewal forms; awaiting check

Table 18. SUMMARY OF 1991 EMISSIONS AND DOSES FROM TFTR

RADIO-NUCLIDE & PATHWAY	QUANTITY RELEASED IN 1991[1]	EDE AT THE SITE BOUNDARY	EDE AT THE NEAREST BUSINESS[2]	POPULATION DOSE WITHIN 80 KM[3]
Tritium (HTO) (air)	0.075 Ci[4]	2×10^{-4} mrem[5]	5.5×10^{-5} mrem[6]	2.4×10^{-3} person-rem[7]
Ar-41 (air)	0.128 Ci[4]	5×10^{-4} mrem[8]	1.4×10^{-4} mrem[6]	7.5×10^{-4} person-rem[9]
Direct & Scattered Neutrons and Gamma Radiation	————	8×10^{-4} mrem[10]	2×10^{-4} mrem[11]	Negligible
Tritium (HTO) (water)	3.5×10^{-3} Ci[12]	7×10^{-5} mrem[13]	————	1×10^{-4} person-rem[14]
Total	————	1.6×10^{-3} mrem	4.0×10^{-4} mrem	3.3×10^{-3} person-rem
Background	————	600 mrem[15]	600 mrem[15]	1.6×10^{6} person-rem

[1]Tritium & ^{41}Ar quantities are based on production of 1.56×10^{18} D-D neutrons in 1991.

[2]At Princeton Bank Building, 351 meters east of TFTR stack.

[3]Based on year 1995 population figures as utilized for Draft TFTR D-T EA. See Table 4 of Bentz and Bender, 1987.

[4]As per letter, Stencel, PPPL to Mix, DOE on 4/29/92, "Calendar Year (CY) 1991 Air Emissions Annual Report to the Environmental Protection Agency (EPA)," JRS-2370.

[5]Based on NOAA X/Q [Start, 1989]; 0.075 Ci x 2.6×10^{-3} mrem/Ci.

[6]Based on 28% of the NOAA X/Q at the site boundary [Start, 1989].

[7]Scaling from values used for the Draft TFTR D-T EA, we get (0.075 Ci/500 Ci) x 16.2 person-rem = 2.4×10^{-3} person-rem.

[8]Based on NOAA X/Q [Start, 1989]; 0.128 Ci x 4.0×10^{-3} mrem/Ci.

[9]Scaling from values used for the Draft TFTR D-T EA, we get (0.128 Ci/115 Ci) x 0.67 person-rem = 7.5×10^{-4} person-rem.

[10]Based on 5×10^{-22} mrem/D-D neutron as per Draft TFTR-FSAR Amendment No. 2, Section 4.9.4.

[11]Based on inverse square decrease between site boundary (176 meters) and nearest business (351 meters).

[12]Released from Liquid Effluent Collection Tanks (LECT) to Stony Brook Sewer Authority treatment facility via PPPL sanitary sewer system.

[13] Based on usage of 1×10^{10} liters/yr for Stony Brook treatment facility, as per Draft TFTR D-T EA, the dose to a person who drank all his/her water from the waterway (Millstone River) into which the treatment facility discharged in 1991 would be $[(3.5 \times 10^{-3}$ Ci/yr$)(/1 \times 10^{10}$ l/yr$)] \times [(4$ mrem$)/(2 \times 10^{-8}$ Ci/l$)] = 7 \times 10^{-5}$ mrem.

[14]Based on use of Millstone River as drinking water source for 500,000 people for 1 day per year (estimate by Elizabethtown Water Company of actual use is a few hours once every several years).

[15] Based on 100 mrem annual background dose exclusive of radon, plus dose due to exposure to average radon concentration in Plainsboro homes (Memo, J. Greco to J. Levine, 11/13/90, "Radon Dose Equivalent," JMG-160).

Table 19. Tritium in Precipitation for 1991

Precipitation Collection Dates	Period	^3H Concentration pCi/liter
1/1/91 - 1/7	1	No Precipitation
1/7 - 1/14	2	17
1/14 - 1/21	3	22
1/21 - 1/28	4	154
1/28 - 2/4	5	No Precipitation
2/4 - 2/11	6	70
2/11 - 2/18	7	59
2/18 - 2/25	8	75
2/25 - 3/5	9	28
3/5 - 3/11	10	45
3/12 - 3/19	11	41
3/19 3/25	12	26
3/25 - 4/1	13	77
4/1 - 4/8	14	No Precipitation
4/8 - 4/15	15	42
4/15 - 4/22	16	21
4/22 - 4/29	17	60
4/29 - 5/6	18	24
5/6 - 5/13	19	No Precipitation
5/13 - 5/20	20	44
5/20 - 5/28	21	20
5/28 - 6/3	22	No Precipitation
6/3 - 6/10	23	Sample Lost
6/10 - 6/17	24	67
6/17 - 6/24	25	53
6/24 - 7/1	26	43
7/1 - 7/8	27	47
7/8 - 7/15	28	48
7/15 - 7/22	29	51
7/22 - 7/29	30	57
7/29 - 8/4	31	49
8/4 - 8/11	32	No Precipitation
8/11 - 8/19	33	83
8/19 - 8/26	34	118
8/26 - 9/2	35	No Precipitation
9/2 - 9/9	36	52
9/9 - 9/16	37	No Precipitation
9/16 - 9/23	38	15
9/23 - 9/30	39	31
9/30 - 10/7	40	36
10/7 - 10/14	41	74
10/14 - 10/21	42	43
10/21 - 10/28	43	No Precipitation
10/28 - 11/4	44	No Precipitation
11/4 - 11/11	45	17
11/11 - 11/18	46	No Precipitation
11/18 - 11/25	47	35
11/25 - 12/5	48	25
12/5 - 12/9	49	30
12/9 - 12/14	50	38
12/14 - 1/6/92	51	17

Table 20. Precipitation at PPPL for 1991

Start Date	Week	Inches	Inch/month	Month	Accumulation
2-Jan-91	1	0.200			0.200
7-Jan-91	2	2.500			2.700
14-Jan-91	3	0.960			3.660
21-Jan-91	4	0.150			3.810
28-Jan-91	5	0.450	4.260	JAN	4.260
4-Feb-91	6	0.650			4.910
11-Feb-91	7	0.400			5.310
18-Feb-91	8	0.450			5.760
25-Feb-91	9	2.300	3.800	FEB	8.060
4-Mar-91	10	0.400			8.460
11-Mar-91	11	1.200			9.660
18-Mar-91	12	0.900			10.560
25-Mar-91	13	0.850	3.350	MARCH	11.410
1-Apr-91	14	0.000			11.410
8-Apr-91	15	0.475			11.885
15-Apr-91	16	2.615			14.500
22-Apr-91	17	0.850			15.350
29-Apr-91	18	0.700	4.640	APRIL	16.050
6-May-91	19	1.200			17.250
13-May-91	20	0.150			17.400
20-May-91	21	0.000			17.400
27-May-91	22	0.700	2.050	MAY	18.100
3-Jun-91	23	0.150			18.250
10-Jun-91	24	0.875			10.125
17-Jun-91	25	1.750			20.875
24-Jun-91	26	1.425	4.200	JUNE	22.300
1-Jul-91	27	0.500			22.800
8-Jul-91	28	2.000			24.800
15-Jul-91	29	0.000			24.800
22-Jul-91	30	2.000			26.800
29-Jul-91	31	0.375	4.875	JULY	27.175
5-Aug-91	32	2.880			30.055
12-Aug-91	33	1.000			31.055
19-Aug-91	34	2.055			33.110
26-Aug-91	35	0.000	5.935	AUG	33.110
2-Sep-91	36	0.200			33.310
9-Sep-91	37	0.000			33.310
16-Sep-91	38	1.050			34.360
23-Sep-91	39	2.620			36.980
30-Sep-91	40	0.150	4.020	SEPT	37.130
7-Oct-91	41	0.400			37.530
14-Oct-91	42	1.350			38.880
21-Oct-91	43	0.000			38.880
28-Oct-91	44	0.000	1.750	OCT	38.880
4-Nov-91	45	0.600			39.480
11-Nov-91	46	0.130			39.610
18-Nov-91	47	1.370			40.980
25-Nov-91	48	0.400	2.500	NOV	41.380
2-Dec-91	49	2.140			43.520
9-Dec-91	50	0.755			44.275
16-Dec-91	51	0.000			44.275
23-Dec-91	52	0.800	3.695	DEC	45.075

Table 21. Tritium Concentrations in Surface Water and Groundwater for 1991*

Location—>	B1	B2	C1	D1	D2	E1	M1	P1	P2
Collection Date									
1/17/91	36	37	37	51	46	35	32	42	32
1/29/91	47	51	52	44	48	44	40	48	44
2/11/91	43	50	50	46	48	44	50		41
3/11/91	41	52	41	61	52	51	49	53	46
4/9/91	52	41	45	56	51	57	48	56	54
5/6/91	45	38	46	51	42	51	47	42	47
5/14/91	46	45	54	47	50	55	44	47	50
6/5/91		39	50	46	56	49	45	55	38
7/10/91	47	33	55	55	43	45	55		63
8/5/91	52	50	60	54	61	44	48	47	51
8/14/91	69	53	59	35	55	55	39	62	68
9/9/91	57	62	72		48	55	52	64	56
10/2/91	40	56	55	56	57		30	30	45
10/15/91	32	55	44	50	38	36		38	
11/12/91	65	53	55	64		53	51	64	55
12/3/91	35	36	48	40	49	41	38	47	35

Location—>	TW1	TW3	TW10	D11	D12	W4	W5
Collection Date							
2/11/91	44	45	53	37	36	30	56
5/15/91	41	45	46	44	48	37	45
8/12/91	38	57	50	51	52	49	52
11/11/91	57		35				

Table 22. Tritium Concentrations in Soil/Sod and Biota Moisture for 1991*

Location—>	S11	S12	S13	S14	S15	S16	S17	S18	S19
Collection Date									
3/25/91	45	50	54		49	58	20	42	51
6/2691	58		42		53	56	70	54	
8/27/91	59		58		68	74	82	61	82
10/9/91	50		49		41	21	41	55	25
12/8/91	34/58	30	34/57	42/38	34	39/70	38/41		

Location—>	Peas	Straw-berries	Rasp-berries	Toma-toes	Corn	Pump-kins
Collection Date						
June	63	21				
August			24	59		
September					63	56

* All measurement values are in pCi/liter.

Table 23. 1991 Surface Water Analysis
for Bee Brook, Locations B1 and B2

Units	5/14/91 (B1)	8/14/91 (B1)		5/14/91 (B2)	8/14/91 (B2)
Chromium, mg/l	0.013	0.011		0.013	<0.01
pH, units	6.60	7.60		6.50	7.5
Phenolics as phenol, mg/1	<0.1	<0.1		<0.1	<0.1
Chemical Oxygen Demand, mg/1	<20.0	58.0		<20.0	<20.0
Biochemical Oxygen Demand, 5-day total, mg/1	<4.0	<4.0		<4.0	<4.0
Temperature, °C	18	22		19	24
Petroleum Hydrocarbons by IR, mg/1	<1.0	<1.0		<1.0	<1.0
Ammonia-N, mg/1	<0.5	<0.5		<0.5	2.0
Total Suspended Solids, mg/1	17.0	19.0		26.0	14.0
Total Dissolved Solids, mg/1	150.0	190.0		170.0	170.0
Flow, Approximate GPM	871	190		1,195	3,000

Table 24. 1991 Surface Water Analysis
for D&R Canal, C1, and Ditch #5, D1

Units	5/14/91 (C1)	8/14/91 (C1)		5/14/91 (D1)	8/14/91 (D1)
Chromium, mg/l				0.015	0.011
pH, units	6.40	7.30		7.20	7.70
Phenolics as phenol, mg/1	<0.1	<0.1		<0.1	<0.1
Chemical Oxygen Demand, mg/1	<20.0	<20.0		29.0	26.0
Biochemical Oxygen Demand, 5-day total, mg/1	<4.0	<4.0		<4.0	<4.0
Temperature, °C	23	22		19	25
Petroleum Hydrocarbons by IR, mg/1	<1.0	<1.0		<1.0	<1.0
Ammonia-N, mg/1	<0.5	2.5		0.98	0.98
Total Suspended Solids, mg/1	17.0	17.0		18.0	12.0
Total Dissolved Solids, mg/1	110.0	140.0		140.0	150.0
Flow, Approximate GPM					1100

Blank indicates no measurement.

Table 25. 1991 Surface Water Analysis
for Potable Water Supply, E1, and Millstone River, M1

Units	5/14/91 (E1)	8/14/91 (E1)	5/14/91 (M1)	8/14/91 (M1)
pH, units	6.20	7.10	6.00	7.30
Phenolics as phenol, mg/1	<0.1	<0.1	<0.1	<0.1
Chemical Oxygen Demand, mg/1	<20.0	<20.0	29.0	37.0
Biochemical Oxygen Demand, 5-day total, mg/1	<4.0	<4.0	<4.0	<4.0
Temperature, °C	15	22	25	26
Petroleum Hydrocarbons by IR, mg/1	<1.0	<1.0	<1.0	<1.0
Ammonia-N, mg/1	<0.5	0.70	0.56	1.5
Total Suspended Solids, mg/1	9.4	<0.5	23.0	11.0
Total Dissolved Solids, mg/1	120.0	200.0	61.0	76.0

Table 26. 1991 Surface Water Analysis
for Plainsboro, Locations P1 and P2

Units	5/14/91 (P1)	8/14/91 (P1)	5/14/91 (P2)	8/14/91 (P2)
pH, units	6.10	7.10	6.00	7.60
Phenolics as phenol, mg/1	<0.1	<0.1	<0.1	<0.1
Chemical Oxygen Demand, mg/1	<20.0	29.0	35.0	40.0
Biochemical Oxygen Demand, 5-day total, mg/1	<4.0	<4.0	5.9	<4.0
Temperature, °C	20	21	25	28
Petroleum Hydrocarbons by IR, mg/1	<1.0	<1.0	<1.0	<1.0
Ammonia-N, mg/1	<0.5	1.3	<0.5	1.4
Total Suspended Solids, mg/1	18.0	6.7	7.8	11.0
Total Dissolved Solids, mg/1	71.0	77.0	54.0	86.0

Table 27. 1991 Detention Basin Influents Analysis (NJDPES)

Units	5/14/91 (Inflow 1)	8/14/91 (Inflow 1)	5/14/91 (Inflow 2)	8/14/91 (Inflow 2)
pH, units	6.70	7.10	6.50	6.90
Phenolics as phenol, mg/1	<0.1	<0.1	<0.1	<0.1
Chemical Oxygen Demand, mg/1	<20.0	<20.0	<20.0	23.0
Biochemical Oxygen Demand, 5-day total, mg/1	<4.0	<4.0	<4.0	
Petroleum Hydrocarbons by IR, mg/1	<1.0		<1.0	
Ammonia-N, mg/1	<0.5	<0.5	<0.5	<0.5
Settleable Solids, %	<.0.010	0.040	<0.010	0.011
Total Dissolved Solids, mg/1	150	190	200	180
Chromium, mg/l	0.012	<0.01	0.013	0.012

Blank indicates no measurement.

Table 28. 1991 Monthly Surface Water Analysis for Ditch #5, Location D2 (NJPDES-DSN 001A).

Units	2/28	3/15	4/11	5/14	5/29	6/14	7/9	8/14	9/10	9/10	10/8	11/12	12/13
Chromium total,mg/1	<0.01	<0.01	<0.01	0.012	<0.01	<0.01	<0.01	0.012	0.013	0.010	<0.01	<0.01	<0.01
pH, units	6.84	7.30	7.30	7.30		7.28	7.30	8.0	7.50	7.50	7.78	7.60	7.10
Phenolics Phenol, mg/1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Chemical Oxygen Demand, mg/1	26.0	29.0	<20.0	32.0	<20.0	<20.0	<20.0	<20.0	20.0	20.0	28.0	<20.0	<20.0
Biochemical Oxygen Demand, 5-day total, mg/1	<4.0	<4.0	<4.0	<4.0	4.6	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0	<4.0
Petroleum Hydrocarbons by IR, mg/1	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0
Ammonia-N, mg/1	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	2.0	<0.5	<0.5	<0.5	<0.5	<0.5
Total Suspended Solids, mg/1	17.0	130.0	34.0	23.0	50.0	5.0	<5.0	12.0	36.0	49.0	14.0	9.0	7.0
Total Dissolved Solids, mg/1	110.0	150.0	160.0	150.0	140.0	170.0	150.0	180.0	130.0	110.0	190.0	180.0	110.0
Temperature°C	9.0	7.0	13.0	18.0		19.0	24.0	27.0	22.0	22.0	17.0	11.0	12.0
Flow, GPM	9.0	15	6,045	1,102		4,174	5,049	10,000	4,338		4,974	7,940	13,666

Blank indicates no measurement.

TABLE 29. 1991 RELEASE REPORT

NJDEPE CASE #	PPPL #	TITLE	TYPE of RELEASE
90-11-1-1524	EP-01	Hydraulic Oil Incident (RESA Building)	1 gallon on ground; well installed
91-2-6-1233-05 & 91-2-6-2-1706-20	EP-02	Detention Basin Oil Incident (two occurrences)	Parking lot runoff
91-2-21-1503-07	EP-03	School Bus Diesel Fuel Incident	1 pint diesel fuel on pavement
91-2-25-1524-05	EP-04	Fork Lift Truck Gasoline Spill	1 gallon gasoline on ground
91-3-15-1201-18	EP-05	Detention Basin Oil Incident	Hydraulic oil leaking from crane into storm drain - no estimated amt.
91-4-11-1209-02	EP-06	Kutz-It® Drum Spill Incident	5 gallons product on pavement
91-5-22-1155-12	EP-07	Brake Fluid Spill Incident	1 quart brake fluid on pavement
91-6-11-1402-39	EP-08	Engine Coolant Leak Incident	1 gallon engine coolant on pavement
91-7-9-1028-34	EP-09	Parking Lot Oil Spill Incident	2 quarts motor oil in pavement
91-8-5-0901-35	EP-10	Oil Spill Incident	2 quarts motor oil in pavement
91-8-5-0938-49	EP-11	Transformer Oil Spill Incident	10 gallons of mineral oil on stone and into sump
91-8-29-1450-25	EP-12	Engine Coolant Leak Incident	1 gallon engine coolant on pavement
91-9-6-0822-52	EP-13	Oil Spill Incident	3 quarts motor oil on pavement
91-10-2-0934-55	EP-14	Gasoline Spill Incident	1 pint gasoline on pavement
91-10-16-1631-13	EP-15	Diesel Oil Spill Incident	1 quart diesel oil on pavement
91-10-17-1442-08	EP-16	Hydraulic Oil Spill Incident	2 quarts hydraulic oil on pavement
91-10-28-1557-17	EP-17	Oil Spill Incident	1/2 pint motor oil on pavement
91-11-8-1140-29	EP-18	Diesel Oil Spill Incident	1 pint diesel oil on pavement

TABLE 30. FERTILIZER, HERICIDE, AND PESTICIDE APPLICATION

DATE	LOCATION	PRODUCT	AMOUNT
FERTILIZER:			
5/11/91	C & D sites lawns	Urea	175 gals.
HERBICIDES :			
7/9/91	C & D-sites - nonturfed/	Roundup 2%	2 gals.
	stone areas	Surflan	1.2 gals.
8/17/91	C & D-sites - nonturfed/	Roundup 1%	3.5 gals.
8/21/91	stone areas		
PESTICIDES:			
1/15/91	B162 & Cafeteria	Maki Rodent Bait Glue Boards	1 pkg.
	Cafeteria	Ficam Plus	16 oz.
1/16/91	LOB 313,309, 320	Sevin Dust	8 oz.
2/5/91	QA Trailers	Maki Rodent Bait	4 pkgs.
	Cafeteria	Ficam Plus	26 oz.
	Cafeteria	Safrotin	4 oz.
2/15/91	D-241	Tri-die PT230	3 oz.
2/26/91	New Engineering Wing	Dursban L. O.	8 oz.
3/1/91	ESU	Cynoff	6 oz.
3/25/91	Dispensary	Dursban L. O.	16 oz.
3/28/91	C-site boundary trailers	Maki	8 pkgs.
4/2/91	Kitchen	Ficam Plus	1.5 qts.
	Kitchen	Orthene PT 280	5 oz.
	Kitchen	Rodent Bait Glue Boards	8
	Theory and ESU	Cynoff E. C.	24 oz.
	ESU	Dursban Granular	4 lbs.
4/8/91	B114 Central Files	Cynoff E. C.	10 oz.
	Receiving Trailer	Ficam Plus	46 oz.
	Receiving Trailer	Roach Router	1/2 oz.
4/11/91	Kitchen Store Rooms	Glue Traps	8
	L232, L220	Bell Block Bait	2 Blocks
4/17/91	Cylinder Storage Building	Cynoff W. P.	16 oz.
4/25/91	ES&H Trailers	Cynoff W.P.	1 qt.
	B143, Booth 6	Cynoff E. C.	13 oz.
4/30/91	Rafters of LEC Tanks	Avtriol in Corn	6 oz.
5/1/91	Kitchen	Rat Glue Traps	20
5/3/91	New Engineering Wing	Ficam Plus	2 qts.
5/7/91	New Engineering Wing	Ficam Plus	26 oz.
	Kitchen	Ficam Plus	32 oz.
	Kitchen	Roach Router	4 oz.
5/9/91	Maintenance	Cynoff E. C.	16 oz.
	Library	Ficam Plus	36 oz.
	B116 Ladies Room	Ficam Plus	8 oz.
5/13/91	B142	Cynoff E. C.	4 oz.
5/20/91	ES&H Trailers	Cynoff E. C.	16 oz.
5/23/91	LOB Back Door, B160	Ficam Plus	10 oz.
5/24/91	ES&H Trailers	Cynoff E. C.	16 oz.
5/30/91	Cafeteria	Maki Rodent Pks.	2 pkgs.
	Cafeteria	Bell Block Bait	4 oz.
6/4/91	Booth 6, ESU, EMCS Control Room, Kitchen	Ficam Plus	110 oz.

TABLE 30. FERTILIZER, HERICIDE, AND PESTICIDE APPLICATION (continued)

DATE	LOCATION	PRODUCT	AMOUNT
PESTICIDES CONTINUED:			
6/5/91	CAS Building	Cynoff E. C.	10 oz.
6/19/91	ES&H Trailers, LOB Ext. Cubicle D, DOE Rm 288, 290, 292, and Theory A141	Ficam Plus	31 oz.
6/27/91	A116, A118	Cynoff E. C.	13 oz.
7/2/91	B113, Kitchen, ESU	Ficam Plus	60 oz.
	Kitchen	Roach Router	3 oz.
7/12/91	Switchyard, ICRF Switchyard	Cynoff W. P.	5 gals.
7/22/91	ESU	Tri-Die	8 oz.
7/23/91	Bldg. 3	FDS Can Fogger	6 oz.
	New Engineering Wing	Cynoff E. C.	8 oz.
7/29/91	Bone Yard Trailers, Gas Cylinder Heads of Diborane	Cynoff W. P.	12 oz.
8/6/91	B113, Kitchen	Dursban L. O.	44 oz.
	ESU	Cynoff E. C.	8 oz.
	B145	Sevin Dust	4 oz.
	B145	Orthene PT 280	2 oz.
	Kitchen	Roach Router	4 oz.
8/13/91	LOB	Drione Dust	30 oz.
8/14/91	Kitchen Crawl Space	Maki Rodent Pks.	10 bags
8/16/91	LOB Penthouse/Facility	Cynoff W. P.	1 qt.
	Roofs	Sevin Dust	2 oz.
8/21/91	B211	Bell Block Bait	4 oz.
8/22/91	B374	Sevin Dust	1/2 oz.
8/26/91	Visitors' parking	Tri-die PT 230	2 oz.
	FED Electrical Shop	Cynoff E. C.	8 oz.
8/28/91	B101	Ficam	2 oz.
8/30/91	LOB	Sevin Dust	4 oz.
9/3/91	B210 & B211	Sevin Dust	8 oz.
		Safrotin Aerosol E. C.	1 oz.
	Kitchen	Dursban L. O.	40 oz.
		Roach Router	4 oz.
		Sevin Dust	1/2 lb.
9/6/91	B210 & 211	Sevin Dust	6 oz.
9/19/91	ESU	Cynoff E. C.	6 oz.
10/1/91	ESU	Ficam Plus	22 oz.
	Kitchen, B113	Pyrid	52 oz.
	Kitchen	Roach Router	4 oz.
10/8/91	A145	Cynoff E. C.	4 oz.
10/22/91	New D-site Trailers	Dursban L. O.	9 oz.
	New D-site Trailers -outside	Dursban - granular	4 lbs.
10/25/91	Admin. Vending Area	Ficam Plus	4 oz.
11/5/91	B113, ESU, Kitchen	Pyrid	43 oz.
	Kitchen	Roach Router	4 oz.
11/21/91	MOD II	Tri-die PT 230	1 oz.
	Security Vending Area	Cynoff E. C.	8 oz.
12/3/91	Kitchen, ESU, CICADA B113	Ficam Plus	1 pt.
	Kitchen	Roach Router	3 oz.

TABLE 31. VOLATILE ORGANIC COMPOUNDS IN GROUNDWATER: 1991 RESULTS

PARAMETER (Detection Limit)	MW-3 1/7/91	MW-5S 1/7/91	MW-6I 1/7/91	MW-6S 1/7/91	MW-7I 1/7/91	MW-7S 1/7/91	MW-9 1/7/91	TFTR 2/8/91 Sump SW	TFTR 2/8/91 Sump W	TFTR 2/8/91 Sump N
Chloroform (5)				2 J	12	11				
Chloroethane (5)							10			
1,1-Dichloroethane (5)				13			58			
1,1 -Dichloroethene (5)										
Trans 1,2-Dichloroethene (5)	1 J			1 J			3 J			
Trans 1,2-Dichloroethane (5)										
Trans 1,3-Dichloropropane (5)										
Trichloroethane (TCA) (5)	4 J	97	3 J	34	1 J	1 J	11	8	13	9
Trichloroethene (TCE) (5)	88		6		9	10	4 J			
Tetrachloroethene (PCE) (5)		4 J	15	4 J			68	5	12	10
Carbon Tetrachloride					2 J	2 J				

PARAMETER (Detention Limit)	MW-13 5/1/91	D-12 5/6/91	MW-13 6/12/91	D-11 8/13/91	D-12 8/13/91	TW-3 8/13/91	Inflow 2 9/16/91 D-site
Chloroform (5)				2 J			2 J
Chloroethane (5)							
1,1-Dichloroethane (5)		5			4 J		
1,1 -Dichloroethene (5)							
Trans 1,2-Dichloroethene (5)	1 J	2 J	2 J				
Trans 1,2-Dichloroethane (5)					2 J	2 J	
Trans 1,3-Dichloropropane (5)							
Trichloroethane (TCA) (5)	2 J	1 J	2 J	1 J	1 J		
Trichloroethene (TCE) (5)	4 J	2 J	3 J		3 J	14	
Tetrachloroethene (PCE) (5)	200	9	140	4 J	14	31	3 J
Toluene (5)			1 J				

Units expressed in µg/l.
J = below the limits of reliable quantification.

TABLE 32. UNDERGROUND STORAGE TANK (UST) MONITORING PROGRAM RESULTS
August 1991

PARAMETER (Detection Limit)	MW-4 8/21/91	MW-6S 8/21/91	MW-6I 8/21/91	MW-7S 8/21/91	MW-7I 8/21/91	MW-8S 8/22/91	MW-8I 8/22/91	Field Blank	Trip Blank	NJDEPE Limit
PETROLEUM HYDROCARBONS	<1000	<1000	1300	<1000	<1000	<1000	<1000	<1000	<1000	1000
VOLATILE ORGANICS (TOTAL)						<5	179	<5	<5	10
1,1-Dichloroethane (5)						<5	4J	<5	<5	10
Trans 1,2-Dichloroethene (5)						<5	10	<5	<5	10
Chloroform (5)						<5	33	<5	<5	10
Trichloroethene (TCE) (5)						<5	16	<5	<5	10
Tetrachloroethene (PCE) (5)						<5	116	<5	<5	10
Carbon Tetrachloride						<5	6	<5	<5	10
SEMI-VOLAITLE ORGANICS (TOTAL)						<5	3J	<5		50
Dimethylphthalate						<5	3J	<5		50

NJDEPE Limit - Informal NJDEPE Limit.
Blank indicates no measurements made.
J - Below the limits of reliable quantitation

TABLE 33. UNDERGROUND STORAGE TANK (UST) MONITORING PROGRAM RESULTS
November 1991

PARAMETER (Detection Limit)	MW-4 11/12/91	MW-6S 11/12/91	MW-6I 11/12/91	MW-7S 11/12/91	MW-7I 11/12/91	MW-8S 11/12/91	MW-8I 11/12/91	Field Blank	Trip Blank	NJDEPE Linit
PETROLEUM HYDROCARBONS	<1000	<1000	<1000	<1000	<1000	<1000	<1000	<1000	<1000	1000

Tables 34. 1991 Groundwater Analysis for Wells MW14, MW15, and MW16

Units	2/12 MW14	5/16 MW14	8/13 MW14	11/12 MW14	2/12 MW15	5/16 MW15	8/13 MW15	11/12 MW15	2/12 MW16	5/16 MW16	8/13 MW16	11/12 MW16
Chromium, mg/l			<0.025	<0.025			<0.025	<0.025		<0.025	<0.025	
Lead, dissolved, mg/l			<0.005	<0.005			<0.005	<0.005		<0.005	<0.005	
pH, units	5.60	4.60	5.40	6.00	5.90	5.20	5.80	6.30	6.20	5.50	6.30	7.00
Phenolics as phenol, mg/l			<0.1	<0.1			<0.1	<0.1			<0.1	<0.1
Nitrate-N, mg/l			2.5	1.9			2.0	<1.0			3.6	<1.0
Total Organic Carbon, mg/l			1.2				<1.0				6.1	
Total Organic Halides, mg/l			0.054				<0.010				0.13	
Petroleum Hydrocarbon by IR, mg/l			<1.0				<1.0				<1.0	
Ammonia-N, mg/l		<0.5	<0.5	<0.5		<0.5	<0.5	<0.5		<0.5	<0.5	0.84
Chloride, mg/l			10.0	5.0			30.0	10.0			<3.0	14.0
Total Dissolved Solids, mg/l	44.0	89.0	210.0	88.0	52.0	69.0	110.0	93.0	130.0	180.0	370.0	450.0
Sulfate, mg/l	18.0	8.0	21.0	5.0	11.0	<5.0	18.0	<5.0	31.0	21.0	66.0	14.0
Conductivity, µhmos/cm	83	80	110	60	83	75	100	85	240	220	460	370

Blank indicates no measurement.

Table 35. 1991 Groundwater Analysis for Wells D11 and D12

Units	2/12 D11	5/16 D11	8/13 D11	11/12 D11	2/12 D12	5/16 D12	8/13 D12	11/12 D12
Chromium, mg/l			<0.025	<0.025			<0.025	<0.025
Lead, dissolved,mg/l			<0.005	<0.005			<0.005	<0.005
pH, units	5.50	5.60	5.60	7.00	5.00	5.00	5.00	5.60
Phenolics as phenol, mg/l			<0.1	<0.1			<0.1	<0.1
Nitrate-N, mg/1			2.8	<1.0			<1.0	<1.0
Total Organic Carbon, mg/1			<1.0				<1.0	
Total Organic Halides, mg/1			0.17				0.14	n/d
Petroleum Hydrocarbons by IR, mg/1			<1.0				<1.0	
Ammonia-N, mg/1		<0.5	<0.5	<0.5		<0.5	<0.5	<0.5
Chloride, mg/1			25.0	30.0			20.0	10.0
Total Dissolved Solids, mg/1	130.0	140.0	160.0	160.0	98.0	180.0	170.0	140.0
Sulfate, mg/1	22.0	12.0	32.0	10.0	37.0	24.0	36.0	13.0
Conductivity, µhmos/cm	200	170	190	190	150	140	150	170

Table 36. 1991 Groundwater Analysis for Wells TW2 and TW3

Units	2/12 TW2	5/16 TW2	8/13 TW2	11/12 TW2	2/12 TW3	5/16 TW3	8/13 TW3	11/12 TW3
Chromium, mg/l			<0.025	<0.025			<0.025	<0.025
Lead, dissolved,mg/l			<0.005	<0.005			<0.005	<0.005
pH, units	7.40	6.70	6.90	7.70	7.00	6.90	6.80	7.90
Phenolics as phenol, mg/l			<0.1	<0.1			<0.1	<0.1
Nitrate-N, mg/l			<1.0	<1.0			<1.0	<1.0
Total Organic Carbon, mg/l			<1.0				<1.0	
Total Organic Halides, mg/l			0.049				0.12	
Petroleum Hydrocarbons by IR, mg/l			<1.0				<1.0	
Ammonia-N, mg/l		<0.5	<0.5	<0.5		<0.5	<0.5	<0.5
Chloride, mg/l			15.0	9.0			30.0	30.0
Total Dissolved Solids, mg/l	180.0	230.0	100.0	210.0	210.0	240.0	310.0	260.0
Sulfate, mg/l	22.0	11.0	21.0	8.0	20.0	10.0	25.0	9.0
Conductivity, µhmos/cm	310	270	300	220	370	340	330	260

Blank indicates no measurement.

Table 37. Groundwater Volatile Organics Analysis for May 1991

	Collection Date--->		5-16-91	
Units	**Parameter**	***D-11***	***D-12***	***TW-3***
µg/l	Chloromethane	<10	<10	<10
µg/l	Bromomethane	<10	<10	<10
µg/l	Vinyl Chloride	<10	<10	<10
µg/l	Chloroethane	<10	<10	<10
µg/l	Methylene Chloride	<5	1JB	<5
µg/l	Acrolein	<20	<20	<20
µg/l	Acrylonitrile	<20	<20	<20
µg/l	Trichlorofluoromethane	<5	<5	<5
µg/l	1,1-Dichloroethane	<5	<5	<5
µg/l	1,1-Dichloroethane	<5	5	<5
µg/l	Trans-1,2-Dichloroethane	<5	2J	<5
µg/l	Chloroform	<5	<5	<5
µg/l	1,2-Dichloroethane	5	<5	<5
µg/l	1,1,1-Trichloroethane	2J	1J	<5
µg/l	Carbon Tetrachloride	<5	<5	<5
µg/l	Bromodichloromethane	<5	<5	<5
µg/l	1,2-Dichloropropane	<5	<5	<5
µg/l	cis-1,3-Dichloropropane	<5	<5	<5
µg/l	Trichloroethane	<5	2J	<5
µg/l	Dibromochloromethane	<5	<5	<5
µg/l	1,1,2-Trichloroethane	<5	<5	<5
µg/l	Benzene	<5	<5	<5
µg/l	trans-1,3-Dichloropropane	<5	<5	<5
µg/l	2-Chloroethylvinylether	<10	<10	<10
µg/l	Bromoform	<5	<5	<5
µg/l	Tetrachloroethane	5	9	<5
µg/l	1,1,2,2-Tetrachloroethane	<5	<5	<5
µg/l	Toluene	<5	<5	<5
µg/l	Chlorobenzene	<5	<5	<5
µg/l	Ethylbenzene	<5	<5	<5
µg/l	1,3-Dichlorobenzene	<5	<5	<5
µg/l	1,2 & 1,4-Dichlorobenzenes	<10	<10	<10

J indicates a value below the reliable limit of detection.
B indicated parameter also measured in trip blank (4J).

Table 38. Groundwater Volatile Organics Analysis for August 1991 and Detention Basin Volatile Organics Analysis for September 1991

	Collection Date--->		8-13-91		9/16/92	9/16/92
Units	**Parameter**	***D-11***	***D-12***	***TW-3***	***Inflow 1***	***Inflow 2***
µg/1	Chloromethane	<10	<10	<10	<10	<10
µg/1	Bromomethane	<10	<10	<10	<10	<10
µg/1	Vinyl Chloride	<10	<10	<10	<10	<10
µg/1	Chloroethane	<10	<10	<10	<10	<10
µg/1	Methylene Chloride	<5	<5	<5	<5	<5
µg/1	Acrolein	<20	<20	<20	<20	<20
µg/1	Acrylonitrile	<20	<20	<20	<20	<20
µg/1	Trichlorofluoromethane	<5	<5	<5	<5	<5
µg/1	1,1-Dichloroethane	<5	<5	<5	<5	<5
µg/1	1,1-Dichloroethane	<5	4J	<5	<5	<5
µg/1	Trans-1,2-Dichloroethane	<5	2J	2J	<5	<5
µg/1	Chloroform	2J	<5	<5	<5	2J
µg/1	1,2-Dichloroethane	<5	<5	<5	<5	<5
µg/1	1,1,1-Trichloroethane	1J	1J	<5	<5	<5
µg/1	Carbon Tetrachloride	<5	<5	<5	<5	<5
µg/1	Bromodichloromethane	<5	<5	<5	<5	<5
µg/1	1,2-Dichloropropane	<5	<5	<5	<5	<5
µg/1	cis-1,3-Dichloropropene	<5	<5	<5	<5	<5
µg/1	Trichloroethene	<5	3J	14	<5	<5
µg/1	Dibromochloromethane	<5	<5	<5	<5	<5
µg/1	1,1,2-Trichloroethane	<5	<5	<5	<5	<5
µg/1	Benzene	<5	<5	<5	<5	<5
µg/1	trans-1,3-Dichloropropane	<5	<5	<5	<5	<5
µg/1	2-Chloroethylvinylether	<10	<10	<10	<10	<10
µg/1	Bromoform	<5	<5	<5	<5	<5
µg/1	Tetrachloroethane	4J	14	31	<5	3J
µg/1	1,1,2,2-Tetrachloroethane	<5	<5	<5	<5	<5
µg/1	Toluene	<5	<5	<5	<5	<5
µg/1	Chlorobenzene	<5	<5	<5	<5	<5
µg/1	Ethylbenzene	<5	<5	<5	<5	<5

J indicates a value below the reliable limit of detection.

Table 39. Groundwater Base Neutrals Analysis for August 1991

	Collection Date--->	8-13-91						
Units	Parameter	D-11	D-12	MW-14	MW-15	MW-16	TW-2	TW-3
mg/l	N-nitrosodimethylamine	<10	<10	<10	<10	<10	<10	<10
mg/l	bis(2-Chloroethyl)ether	<10	<10	<10	<10	<10	<10	<10
mg/l	1,3-Dichlorobenzene	<10	<10	<10	<10	<10	<10	<10
mg/l	1,4-Dichlorobenzene	<10	<10	<10	<10	<10	<10	<10
mg/l	1,2-Dichlorobenzene	<10	<10	<10	<10	<10	<10	<10
mg/l	bis(2-Chloroisopropyl)ether	<10	<10	<10	<10	<10	<10	<10
mg/l	N-Nitroso-di-n-propylamine	<10	<10	<10	<10	<10	<10	<10
mg/l	Hexachloroethane	<10	10	<10	<10	<10	<10	<10
mg/l	Nitrobenzene	<10	<10	<10	<10	<10	<10	<10
mg/l	Isophorone	<10	<10	<10	<10	<10	<10	<10
mg/l	bis(2-Chloroethoxy)Methane	<10	<10	<10	<10	<10	<10	<10
mg/l	1,2,4-Trichlorobenzene	<10	<10	<10	<10	<10	<10	<10
mg/l	Naphthalene	<10	<10	<10	<10	<10	<10	<10
mg/l	Hexachlorobutadiene	<10	<10	<10	<10	<10	<10	<10
mg/l	Hexachlorocyclopentadiene	<10	<10	<10	<10	<10	<10	<10
mg/l	2-Chloronaphthalene	<10	<10	<10	<10	<10	<10	<10
mg/l	Dimethylphthalate	<10	<10	<10	<10	<10	<10	<10
mg/l	Acenaphthylene	<10	<10	<10	<10	<10	<10	<10
mg/l	Acenaphthene	<10	<10	<10	<10	<10	<10	<10
mg/l	2,4-Dinitrotoluene	<10	<10	<10	<10	<10	<10	<10
mg/l	2,6-Dinitrotoluene	<10	<10	<10	<10	<10	<10	<10
mg/l	Diethylphthalate	<10	<10	<10	<10	<10	<10	<10
mg/l	4-Chlorophenyl-phenylether	<10	<10	<10	<10	<10	<10	<10
mg/l	Fluorene	<10	<10	<10	<10	<10	<10	<10
mg/l	N-Nitrosodiphenylamine	<10	<10	<10	<10	<10	<10	<10
mg/l	1,2-diphenylhydrazine	<10	<10	<10	<10	<10	<10	<10
mg/l	4-Bromophenyl-phenylether	<10	<10	<10	<10	<10	<10	<10
mg/l	Hexachlorobenzene	<10	<10	<10	<10	<10	<10	<10
mg/l	Phenathrene	<10	<10	<10	<10	<10	<10	<10
mg/l	Anthracene	<10	<10	<10	<10	<10	<10	<10
mg/l	Di-n-Butylphthalate	<10	<10	<10	<10	<10	<10	<10
mg/l	Fluoroanthene	<10	<10	<10	<10	<10	<10	<10

Table 39. Groundwater Base Neutrals Analysis for August 1991 (continued)

mg/1	Benzidine	<50	<50	<50	<50	<50	<50	<50
mg/1	Pyrene	<10	<10	<10	<10	<10	<10	<10
mg/1	Butylbenzylphthalate	<10	<10	<10	<10	<10	<10	<10
mg/1	3,3'-Dichlorobenzidine	<20	<20	<20	<20	<20	<20	<20
mg/1	Benzo (a) Anthrazene	<10	<10	<10	<10	<10	<10	<10
mg/1	Bis(2-ethylhexyl)Phthalate	<10	<10	<10	<10	<10	<10	<10
mg/1	Chrysene	<10	<10	<10	<10	<10	<10	<10
mg/1	Di-n-octylphthalate	<10	<10	<10	<10	<10	<10	<10
mg/1	Benzo (b) fluoranthene	<10	<10	<10	<10	<10	<10	<10
mg/1	Benzo (k) Fluoranthene	<10	<10	<10	<10	<10	<10	<10
mg/1	Benzo (a) Pyrene	<10	<10	<10	<10	<10	<10	<10
mg/1	Indeno (1,2,3-cd) Pyrene	<10	<10	<10	<10	<10	<10	<10
mg/1	Dibenzo (a,h) Anthracene	<10	<10	<10	<10	<10	<10	<10
mg/1	Benzo (g,h,i) Perylene	<10	<10	<10	<10	<10	<10	<10

J indicates a value below the reliable limit of detection.

Table 40. PPPL REML QA/QC from EPA/Las Vegas and DOE/EML*

Radioisotope		pCi/L Known Value	pCi/L Control Limits	pCi/L PPPL Values
	DATE-->	**February 91 (water) - EPA Las Vegas**		
H-3		4,418	3,651 to 5,184	4,403
C-60		40	31 to 49	38.6
Zn-65		149	123 to 175	152
Ru-106		186	153 to 219	167
Cs-134		8	0 to 16	7.6
Cs-137		8	0 to 16	9.3
Ba-133		75	61 to 89	70
	DATE-->	**June 91 (water) - EPA Las Vegas**		
H-3		12,480	10,314 to 14,645	12,208
C-60		10	1.3 to 18.7	10.3
Zn-65		108	89 to 127	123
Ru-106		149	123 to 175	142.6
Cs-134		15	6 to 24	13.3
Cs-137		14	5 to 23	14.6
Ba-133		62	52 to 72	64.6
	DATE-->	**October 91 (water) - EPA Las Vegas**		
H-3		2454	1843 to 3064	2277
C-60		29	20 to 38	30
Zn-65		73	61 to 85	69
Ru-106		199	164 to 234	212
Cs-134		10	1.3 to 18.7	10.3
Cs-137		10	1.3 to 18.7	10.3
Ba-133		98	81 to 115	102.6
	DATE-->	**June 91 (water) - EML/DOE NYC**		
H-3		361	180 to 541	356
Mn-54		213	106 to 319	233
Co-57		230	115 to 345	234
Co-60		201	100 to 301	201
Cs-137		169	84 to 253	167
Ce-144		35.1	17 to 52	37.8
	DATE-->	**December 91 (water) - EML/DOE NYC**		
H-3		100	50 to 150	90
Mn-54		103	51 to 154	106
Co-57		166	83 to 249	183
Co-60		291	145 to 436	312
Cs-137		46	23 to 69	50
Ce-144		226	113 to 339	240
	DATE-->	**December 91 (air) - EML/DOE NYC**		
Be-7		53.8	26.9 to 80.7	60.9
Mn-54		24.3	12.2 to 36.4	24.7
Co-57		16.6	8.3 to 24.9	17.9
Co-60		23.0	11.5 to 34.5	23.4
Cs-137		28.0	14.0 to 42.0	29.3
Ce-144		50.8	25.4 to 76.2	49.9

*

REML = PPPL Radiological Environmental Monitoring Laboratory
EPA/Las Vegas = Environmental Protection Agency's Laboratory in Las Vegas
DOE/EML = The Department of Energy's Environmental Measurements Lab in New York City

Table 41. QA Sample Data

Units	5/14	5/29	9/10	9/10
Chromium total,mg/1	0.012	<0.01	0.013	0.010
pH, units	7.30		7.50	7.50
Phenolics Phenol, mg/1	<0.1	<0.1	<0.1	<0.1
Chemical Oxygen Demand, mg/1	32.0	<20.0	20.0	20.0
Biochemical Oxygen Demand, 5-day total, mg/1	<4.0	4.6	<4.0	<4.0
Petroleum Hydrocarbons by IR, mg/1	<1.0	<1.0	<1.0	<1.0
Ammonia-N, mg/1	<0.5	<0.5	<0.5	<0.5
Total Suspended Solids, mg/1	23.0	50.0	36.0	49.0
Total Dissolved Solids, mg/1	150.0	140.0	130.0	110.0
Temperature°C	18.0		22.0	22.0
Flow, GPM	1,102		4,338	

Blank indicates no measurement.

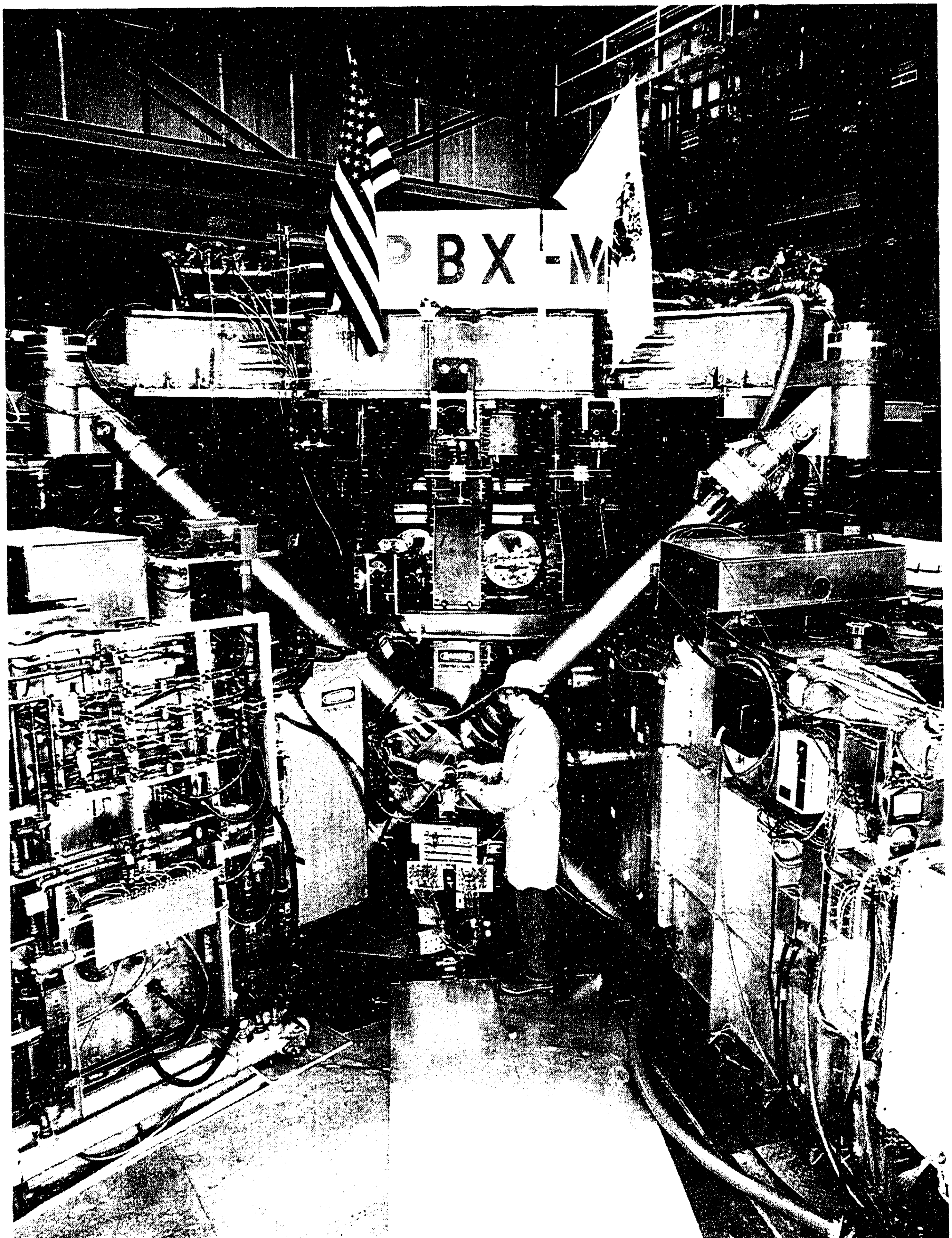


Figure 1. The Princeton Beta Experiment - Modified (PBX-M)

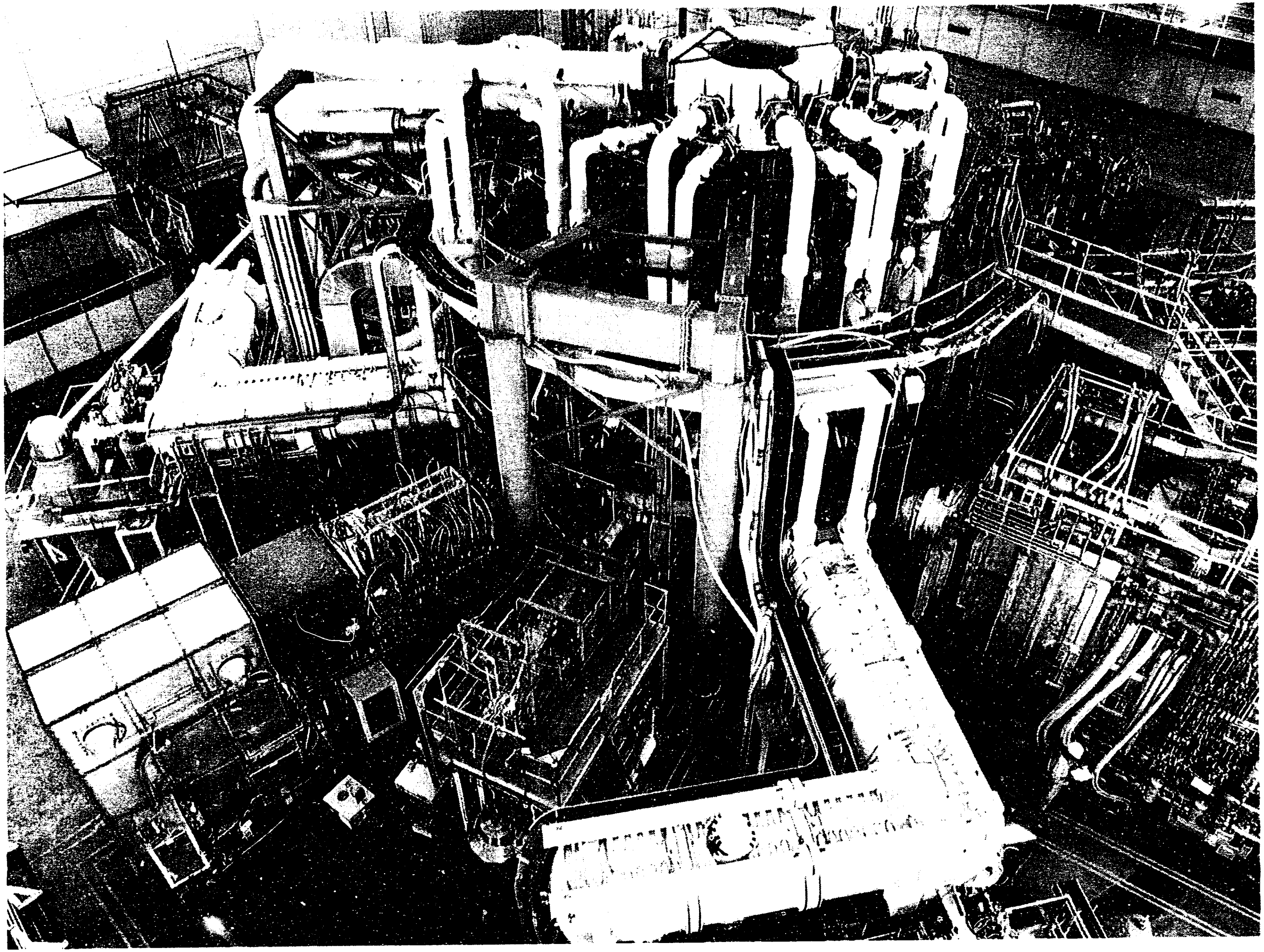


Figure 2. The Tokamak Fusion Test Reactor (TFTR)

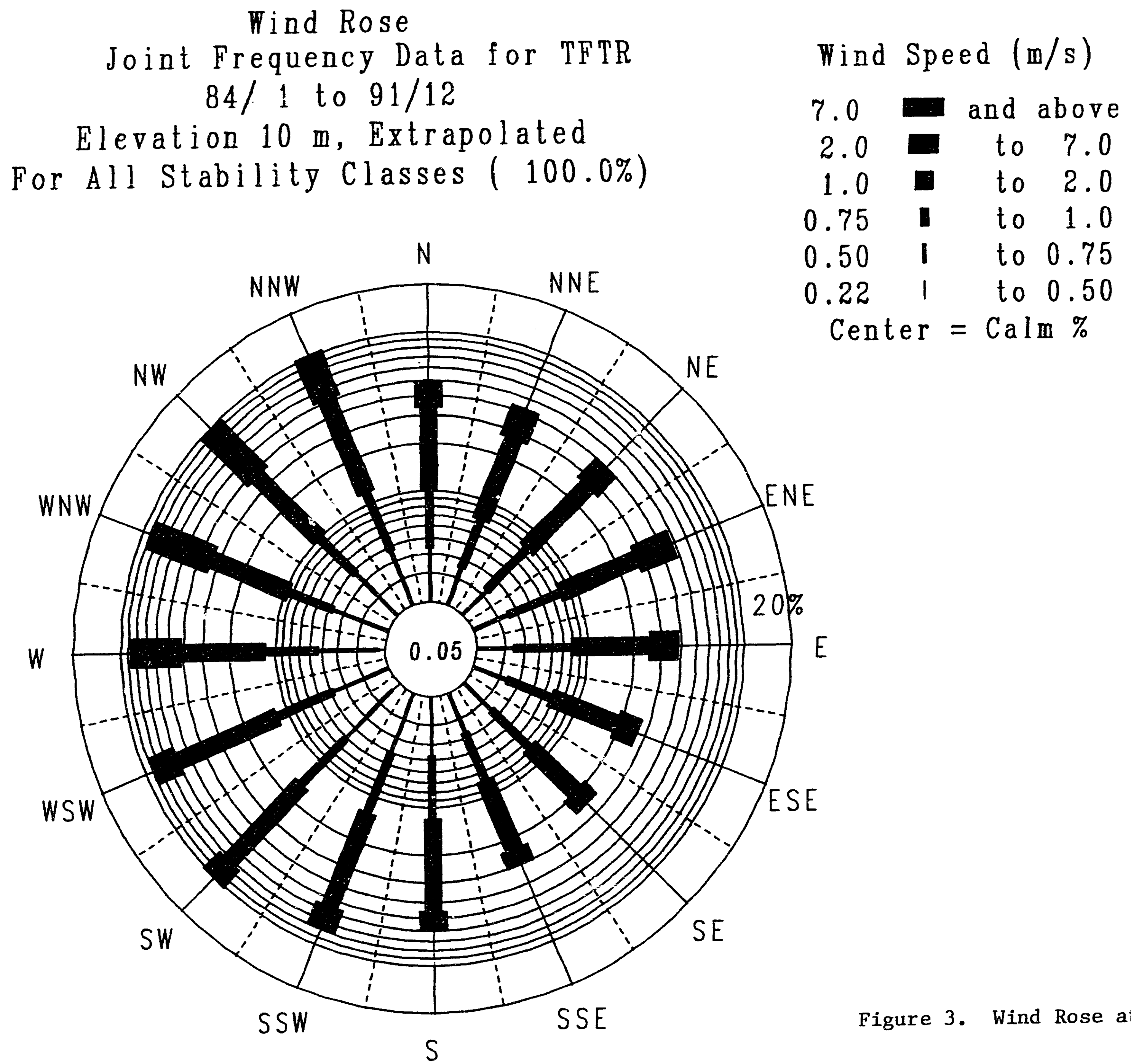


Figure 3. Wind Rose at 10 m.

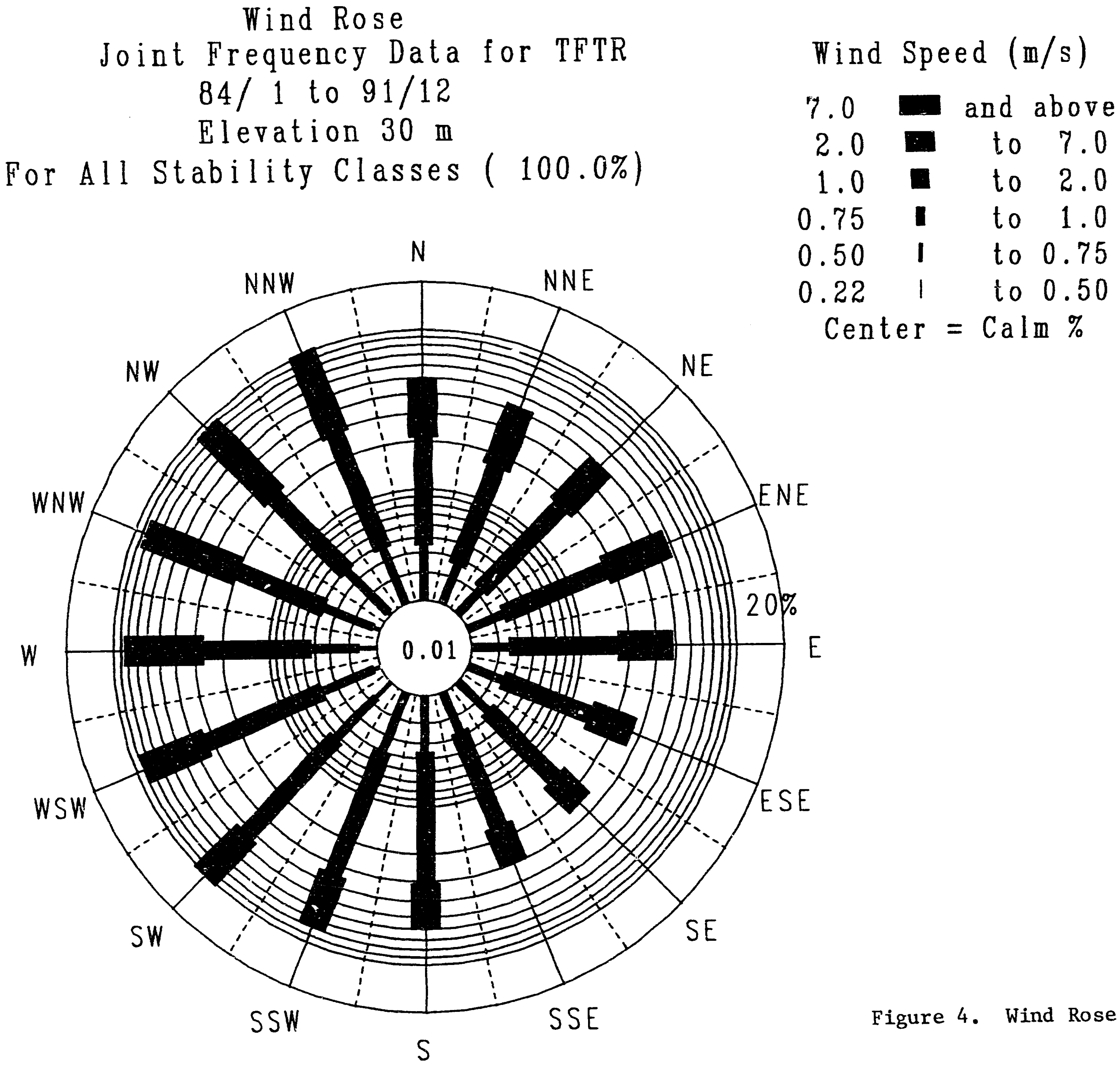


Figure 4. Wind Rose at 30 m.

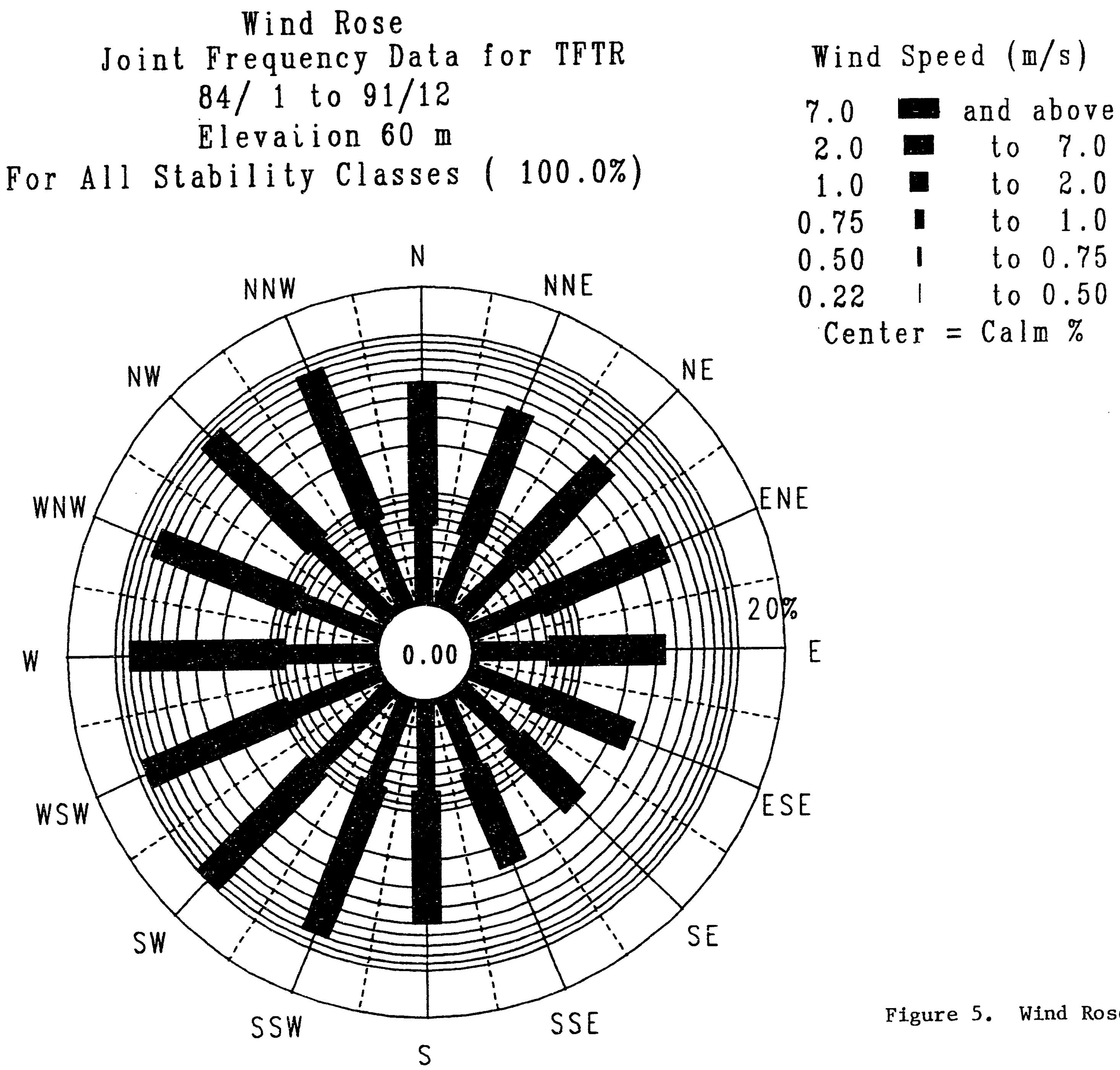


Figure 5. Wind Rose at 60 m.

Figure 6.

Annual Average Temperature at TFTR Site

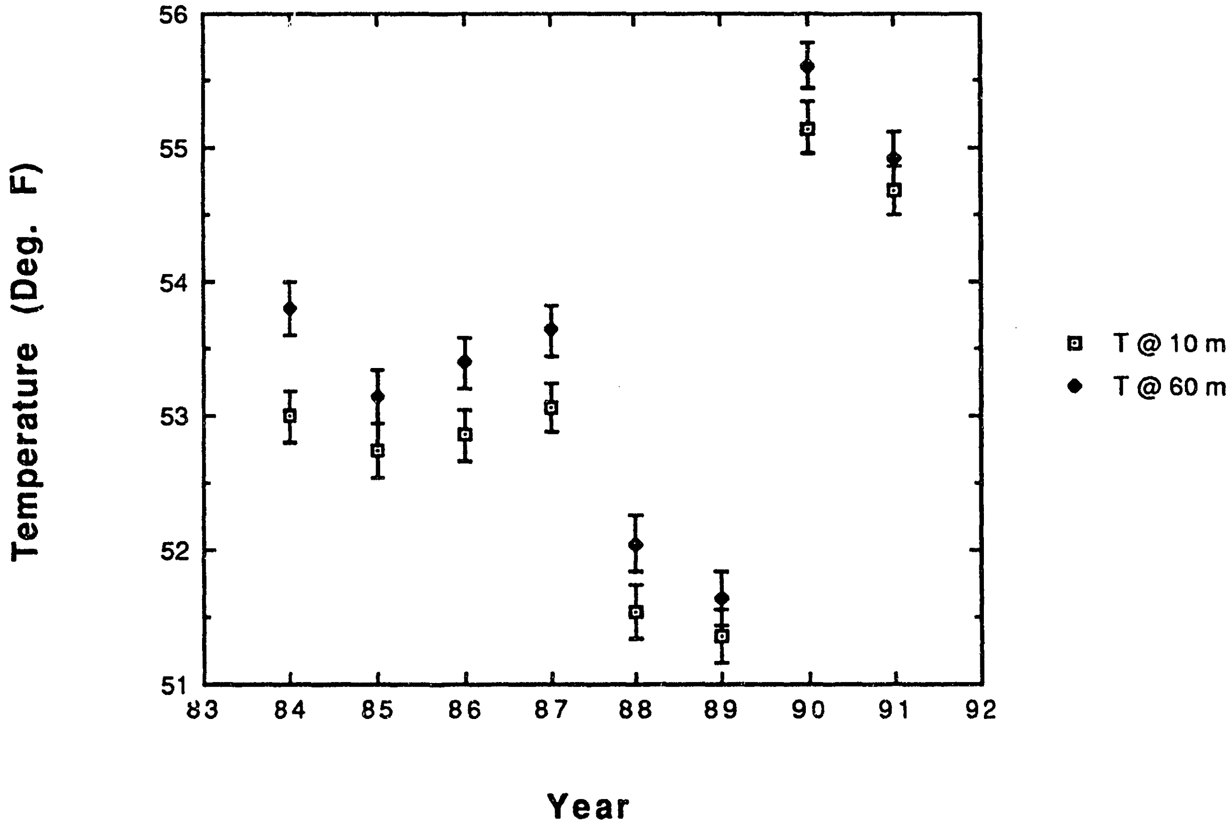


Figure 7.
Annual Average Absolute Humidity at TFTR Site

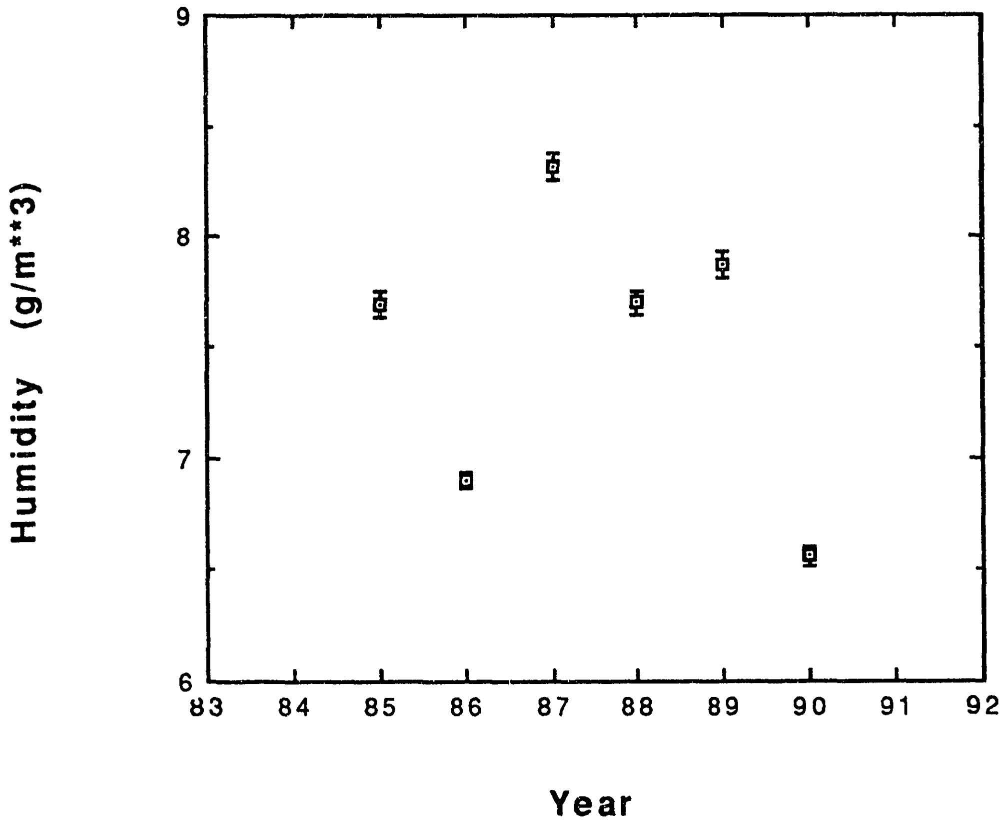


Figure 8.
Annual Average Relative Humidity at TFTR Site

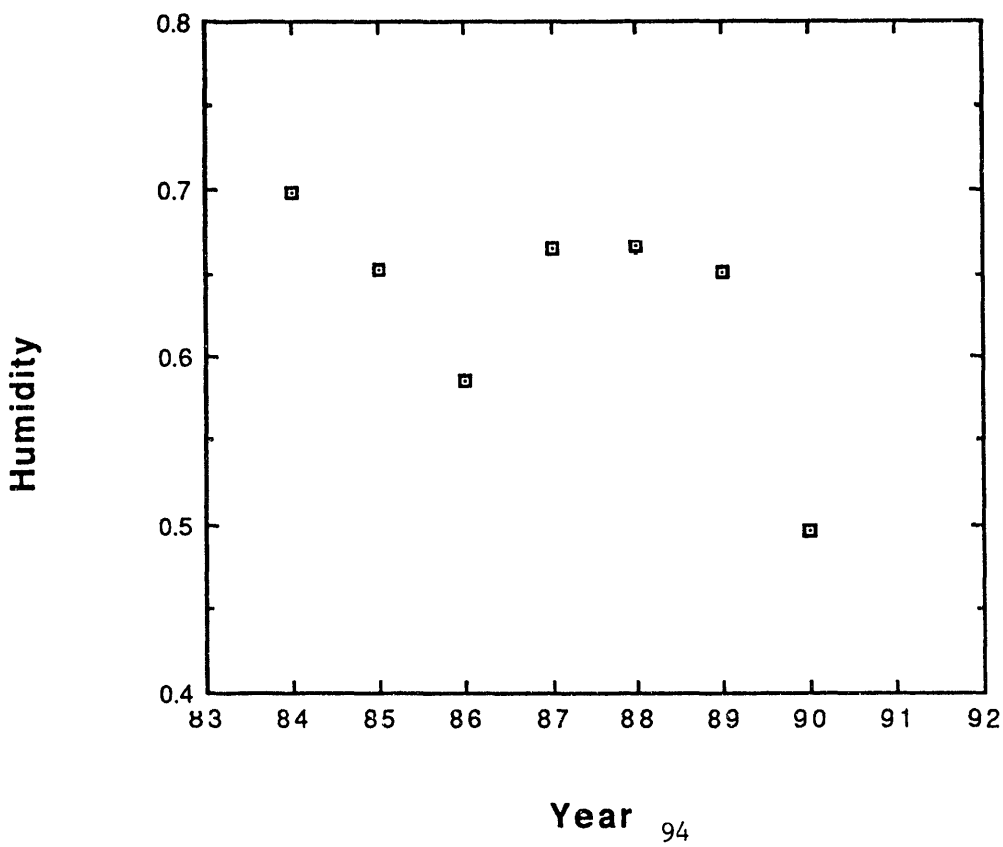


Figure 9.

Annual Average Wind Speed at TFTR Site

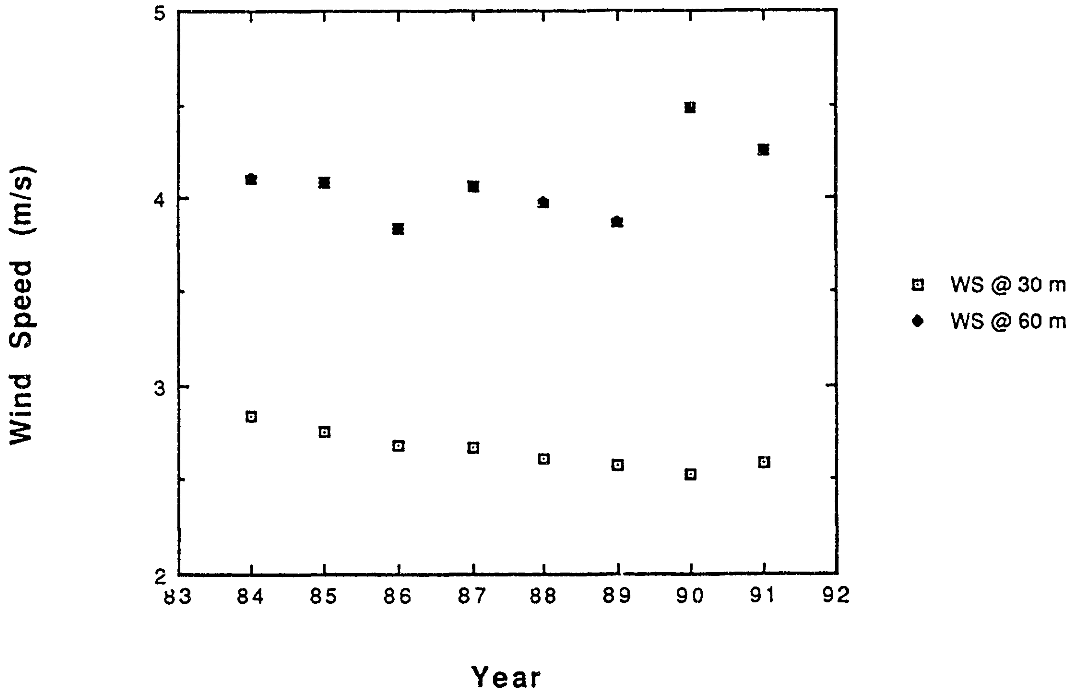


Figure 10.

Comparison of Monthly Average Wind Speed between 1984 and 1990 at 30 m Elevation

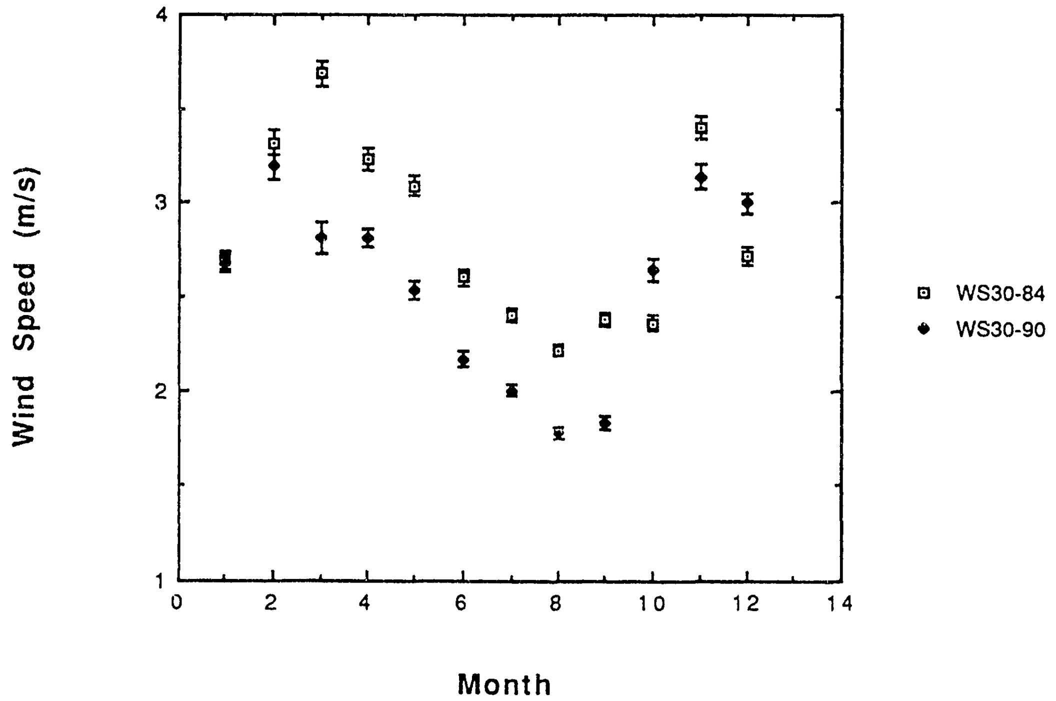


Figure 11. Aerial View of the Forrestal Campus

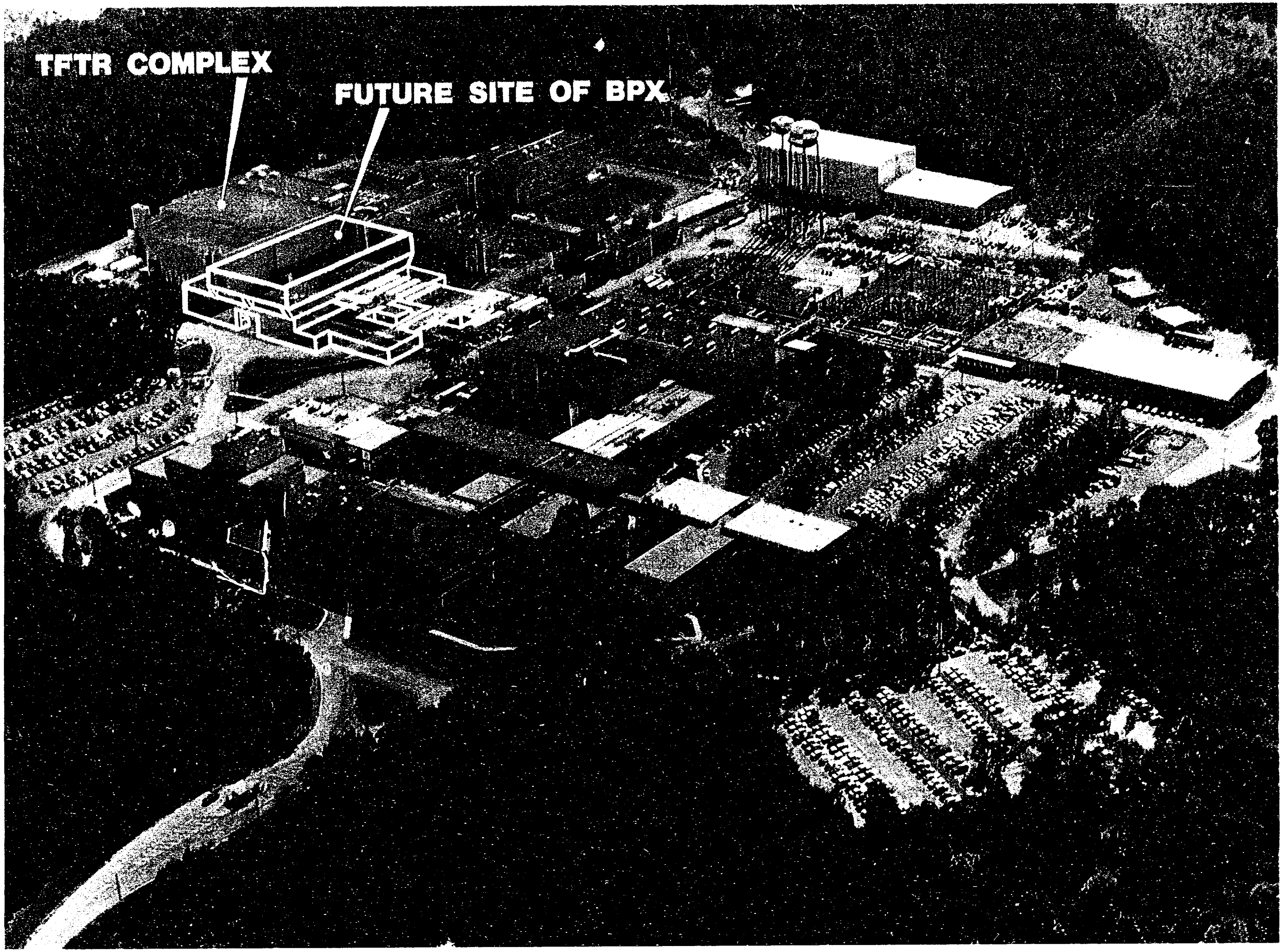


Figure 12. C- and D-Sites of the Forrestal Campus, PPPL

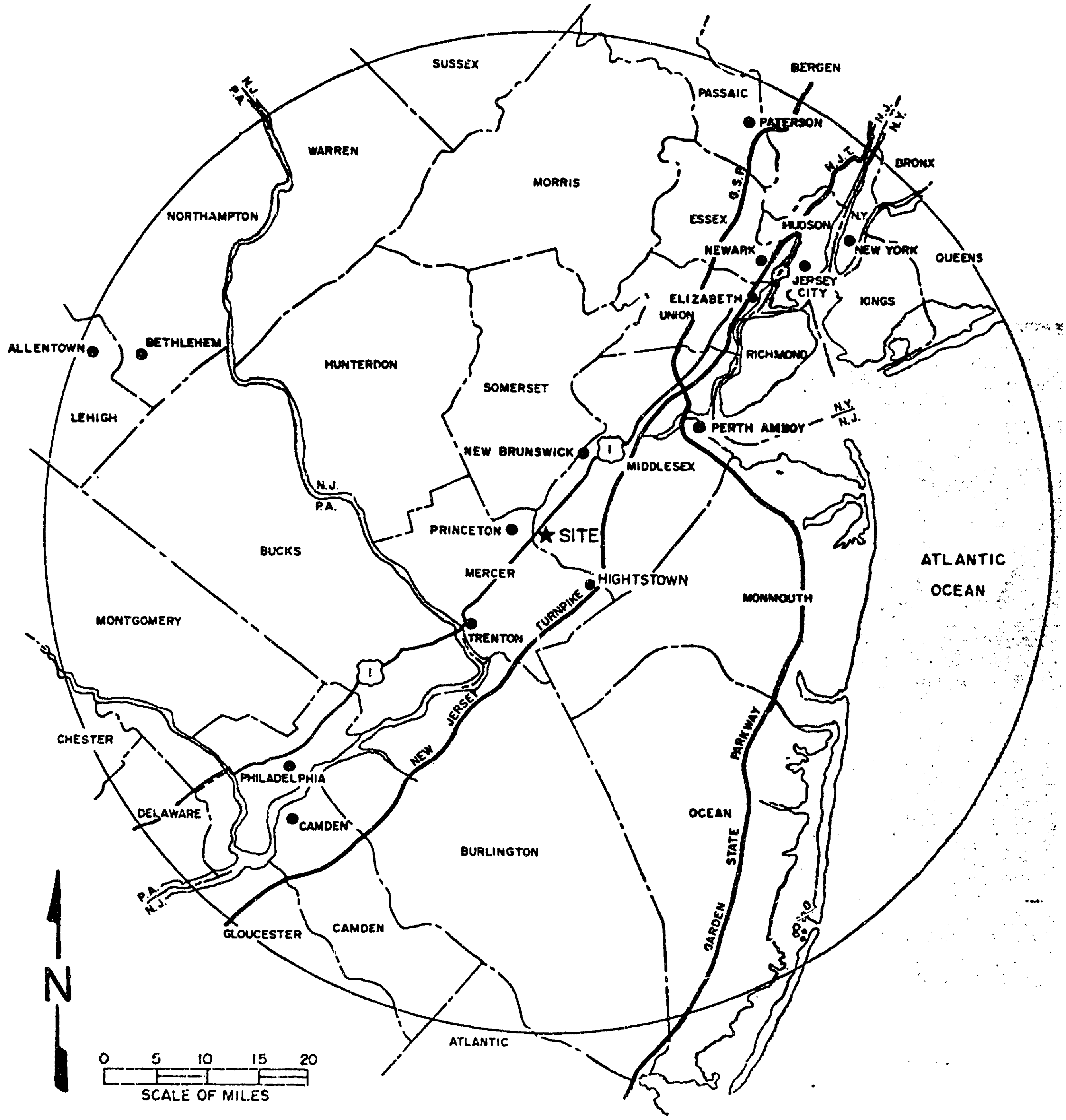


Figure 13. 80 km (50-mile) Radius of PPPL Site

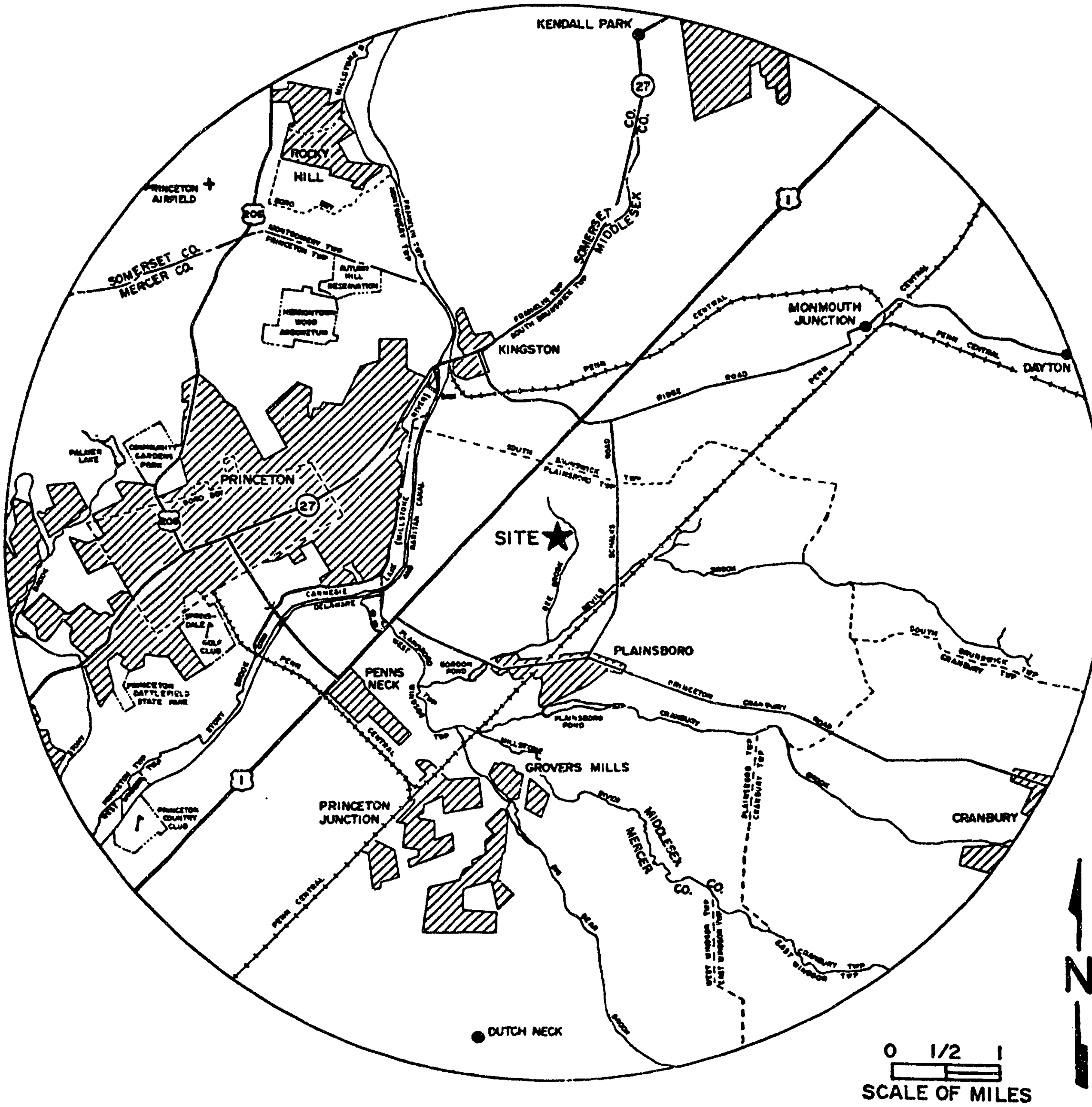


Figure 14. Immediate Site Vicinity (5-Mile Radius)

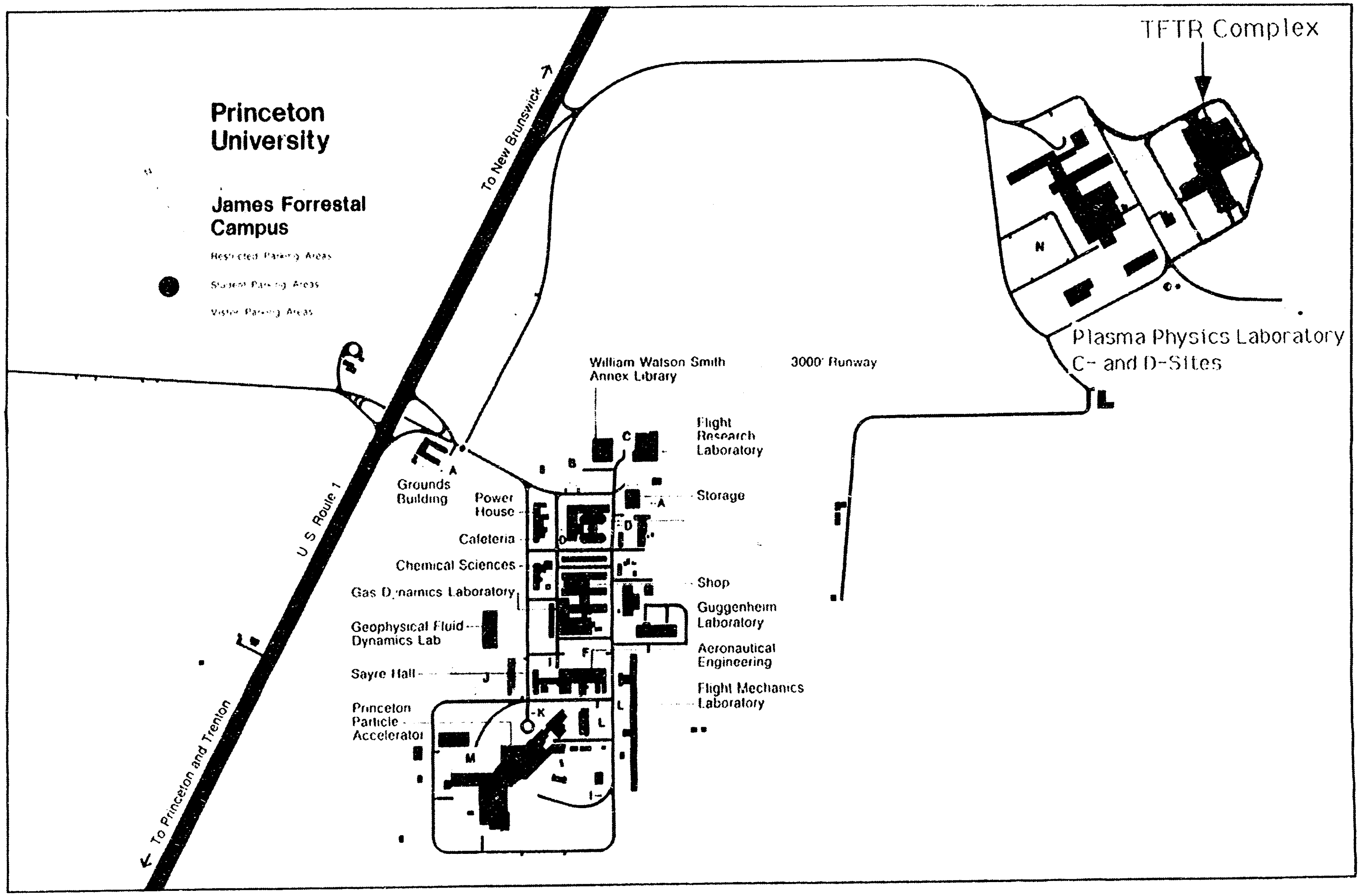
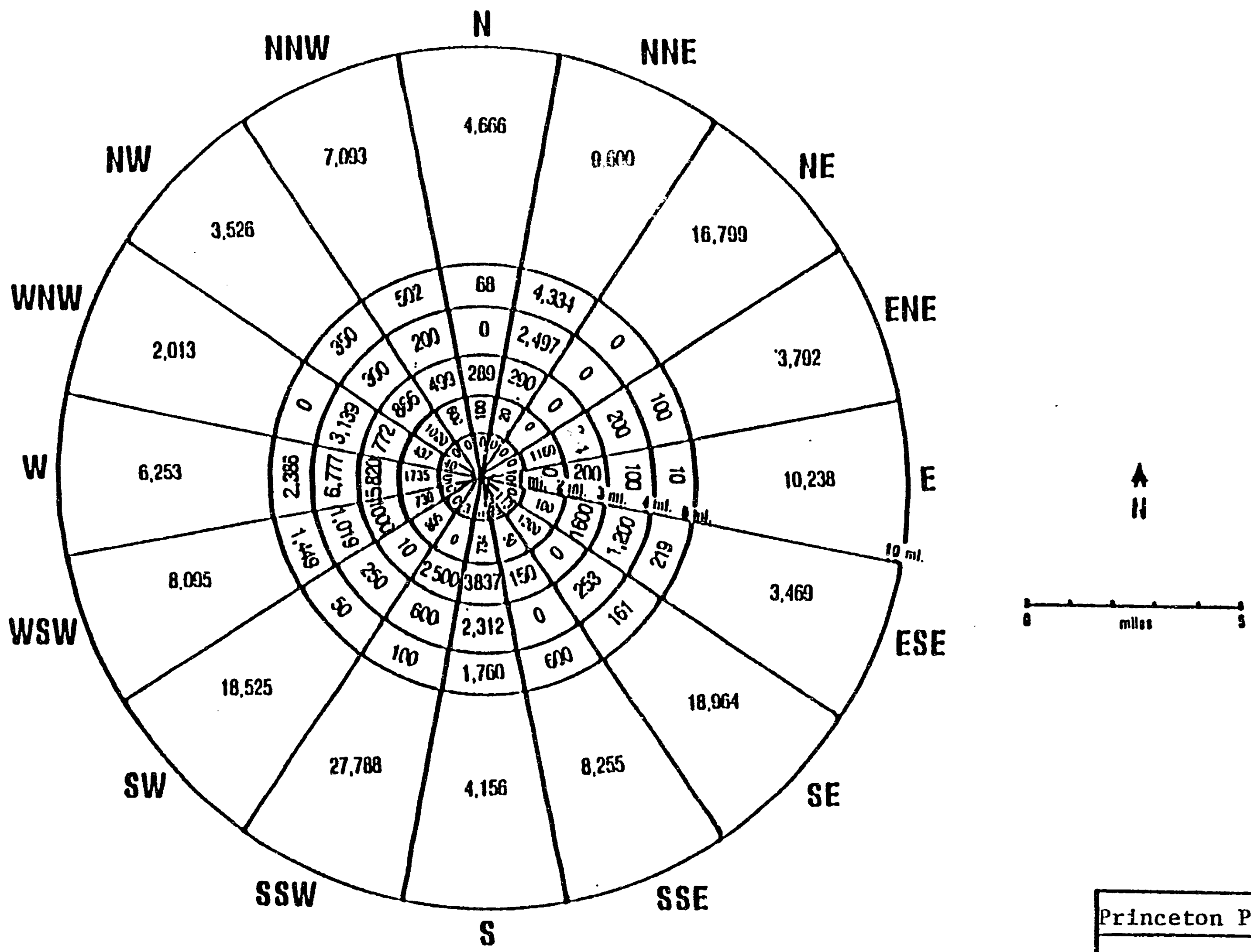


Figure 15. Layout of the James Forrestal Campus
Princeton University, Princeton, New Jersey

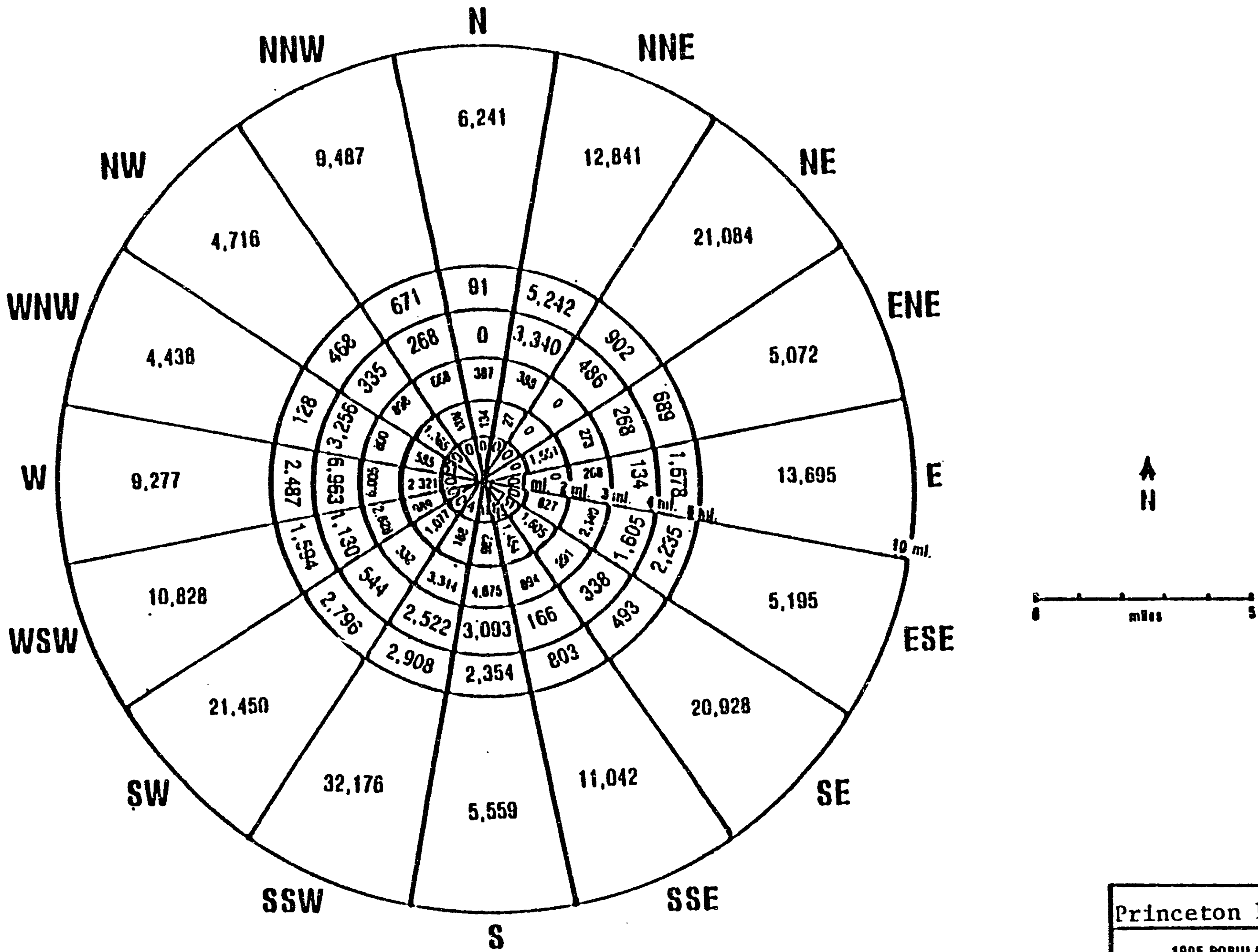


Princeton Plasma Physics

1985 POPULATION ESTIMATES WITHIN ANNULAR SECTORS 0 - 10 MILES

Figure 16

*Taken from Be87a

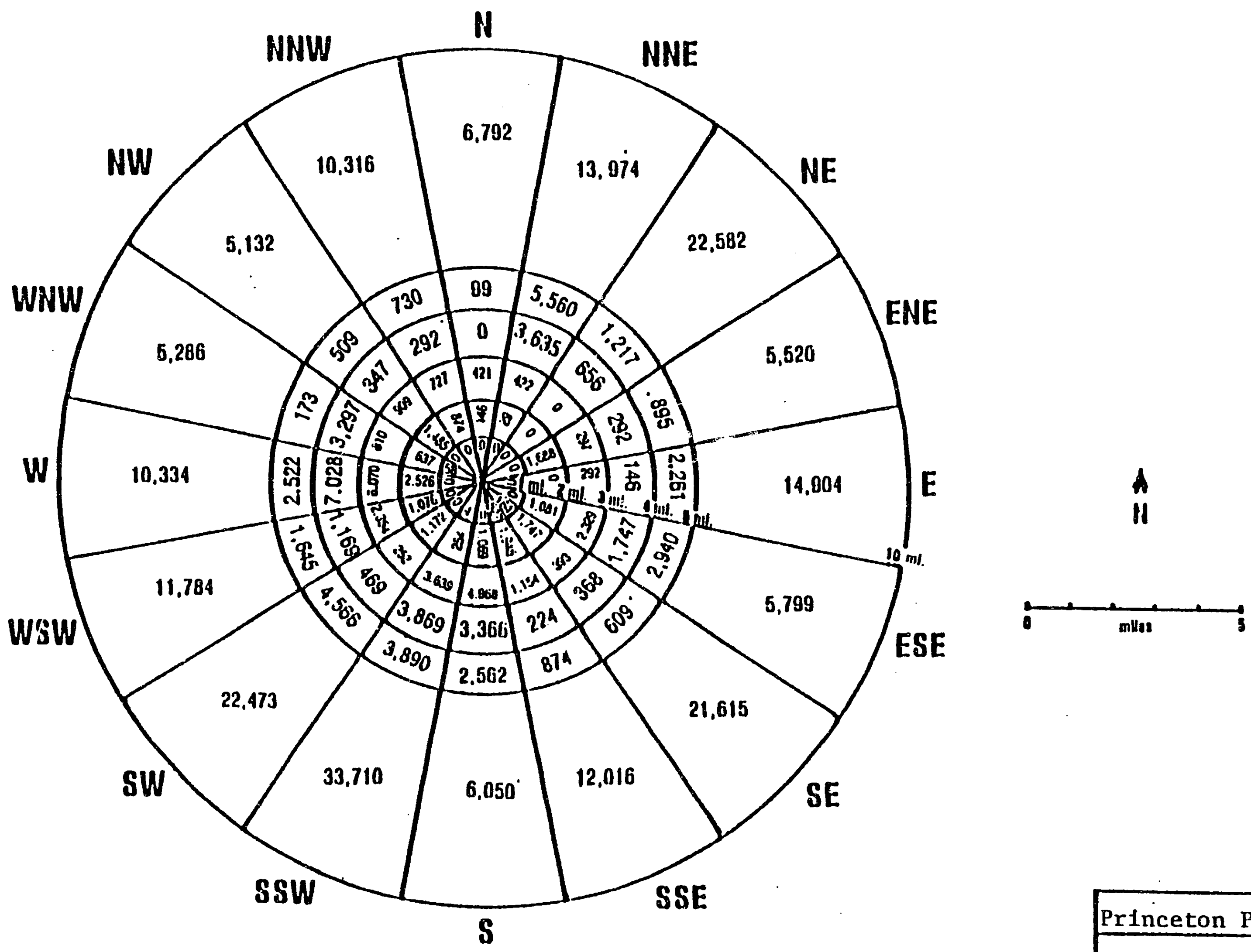


Princeton Plasma Physics

1995 POPULATION PROJECTIONS
WITHIN ANNULAR SECTORS
0 - 10 MILES

Figure 17

*Taken from Be87a

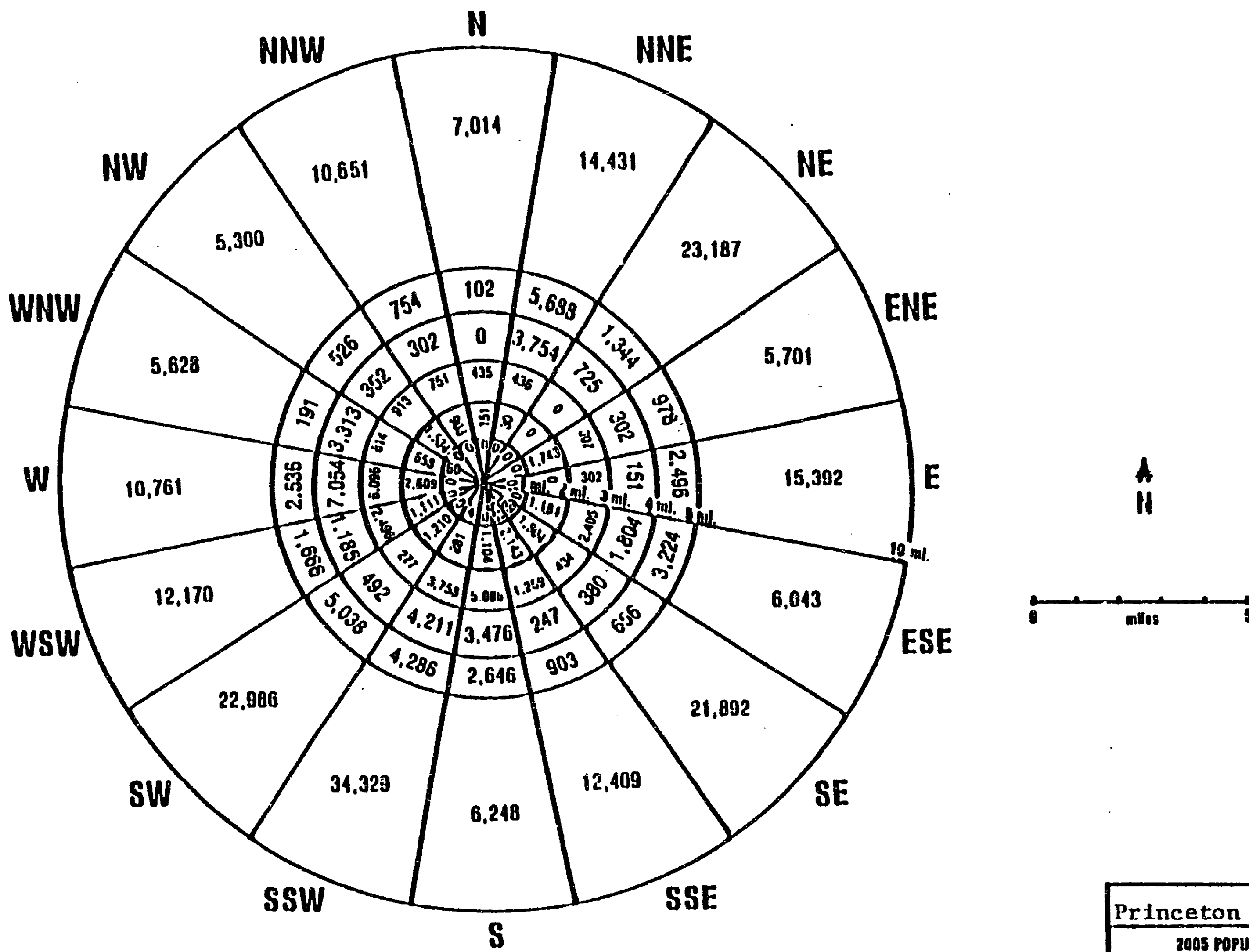


Princeton Plasma Physics

2000 POPULATION PROJECTIONS WITHIN ANNULAR SECTORS 0 - 10 MILES

Figure 18

*Taken from Be87a

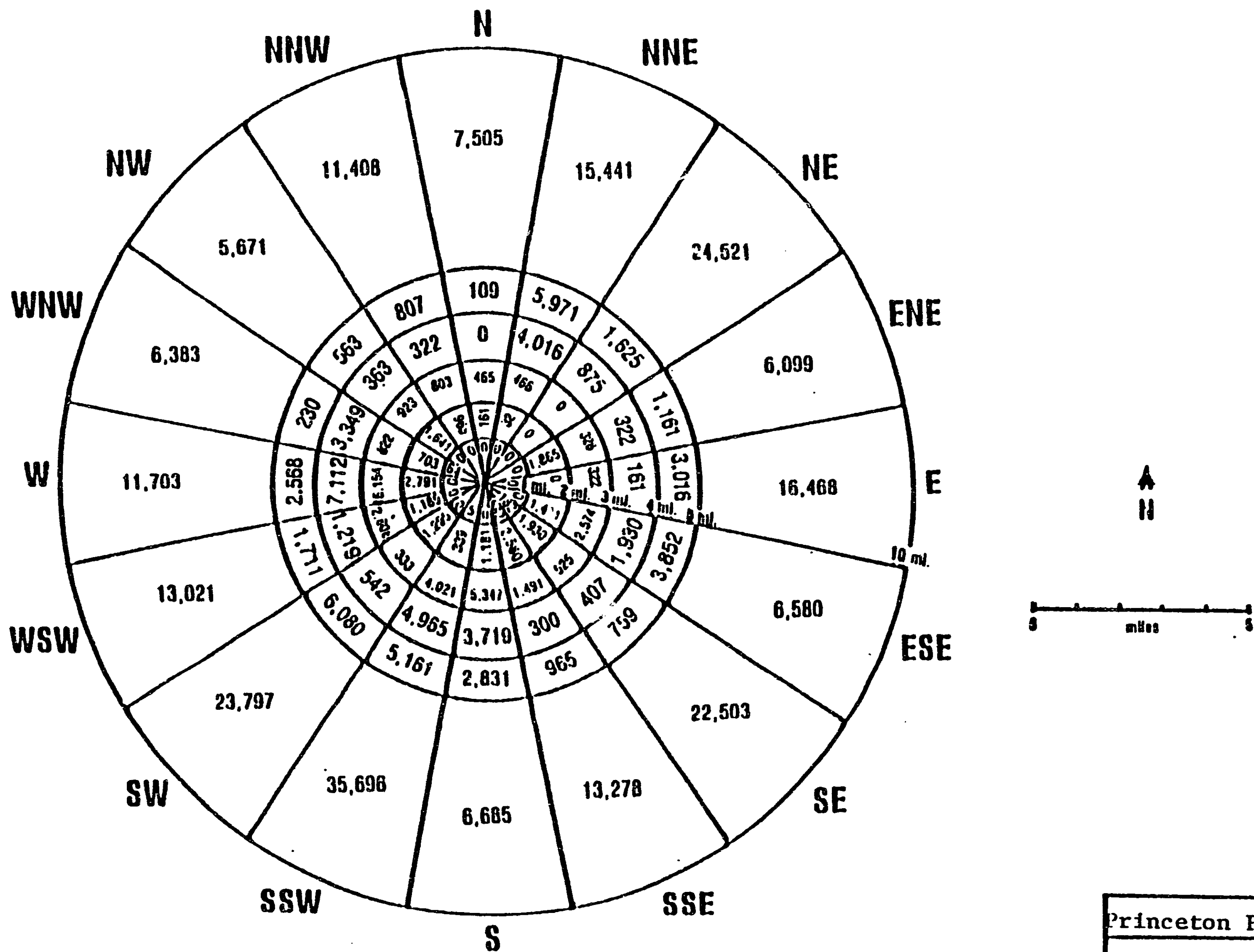


Princeton Plasma Physics

2005 POPULATION PROJECTIONS WITHIN ANNULAR SECTORS 0 - 10 MILES

Figure 19

*Taken from Be87a

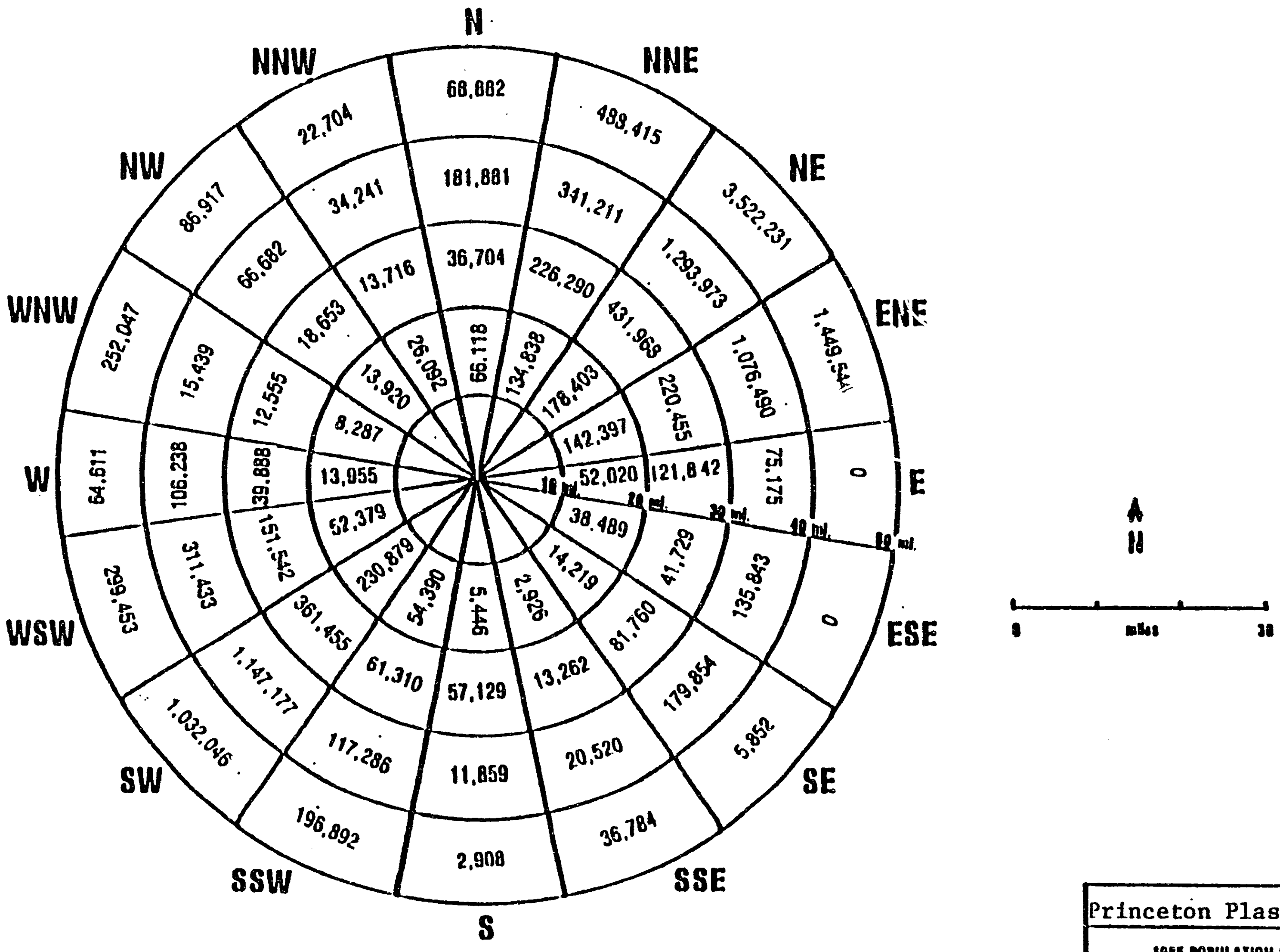


Princeton Plasma Physics

2010 POPULATION PROJECTIONS
WITHIN ANNULAR SECTORS
0 - 10 MILES

Figure 20

*Taken from Be87a

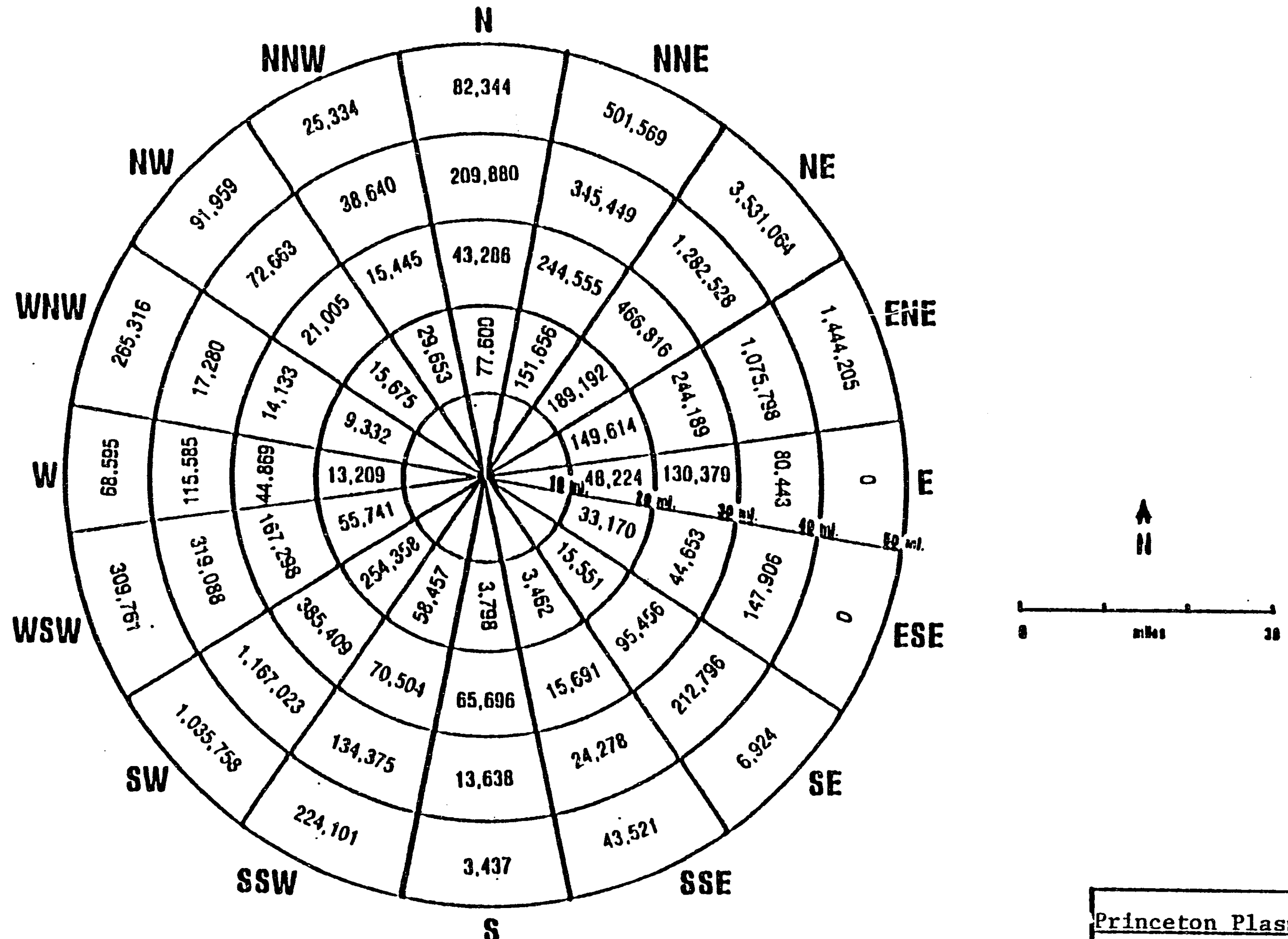


Princeton Plasma Physics

1986 POPULATION ESTIMATES
WITHIN ANNULAR SECTORS
10 - 50 MILES

Figure 21

*Taken from Be87a

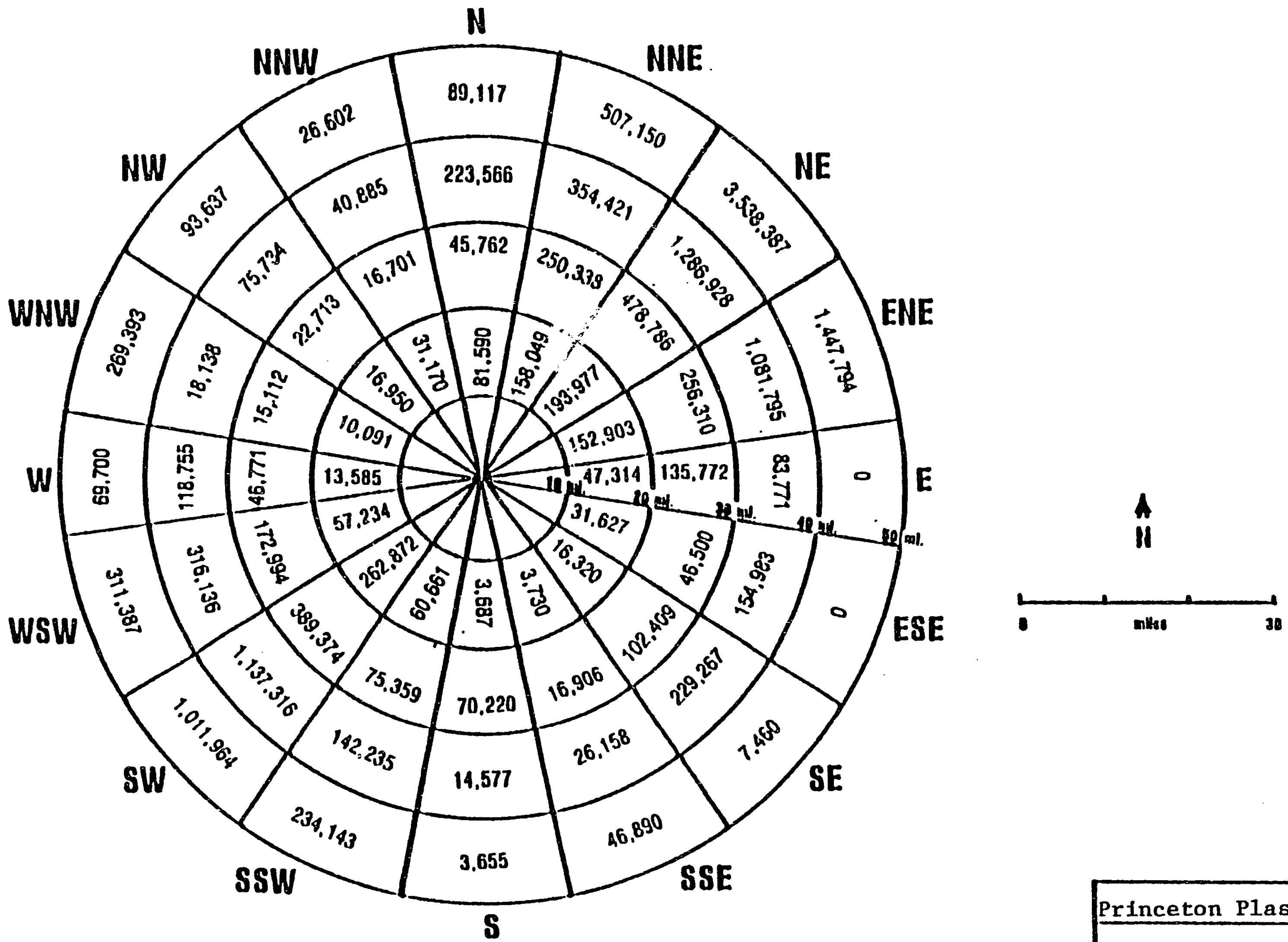


Princeton Plasma Physics

1995 POPULATION ESTIMATES WITHIN ANNULAR SECTORS 10 - 50 MILES

Figure 22

*Taken from Be87/a

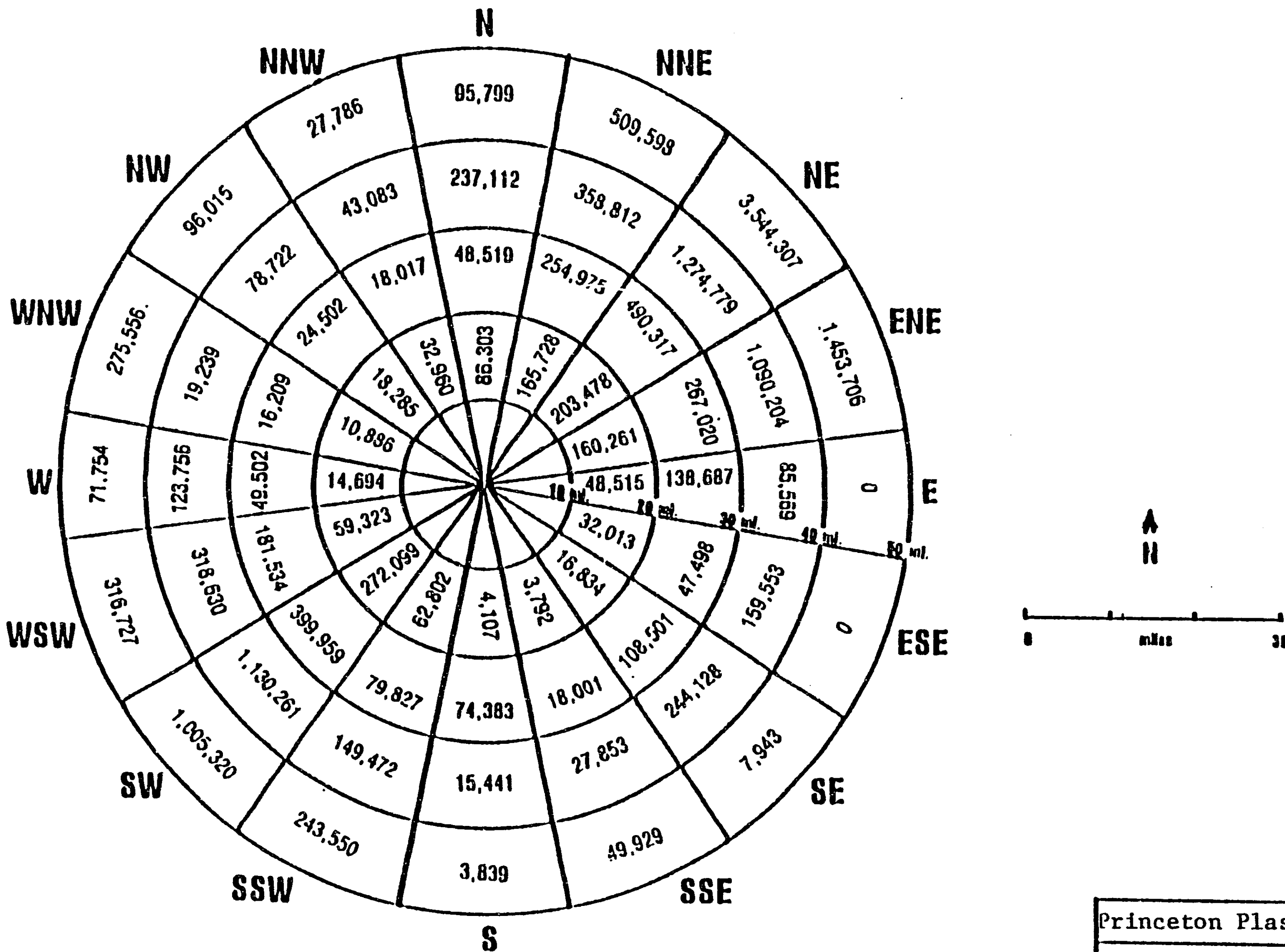


Princeton Plasma Physics

2000 POPULATION ESTIMATES WITHIN ANNULAR SECTORS 10 - 50 MILES

Figure 23

*Taken from Be87a

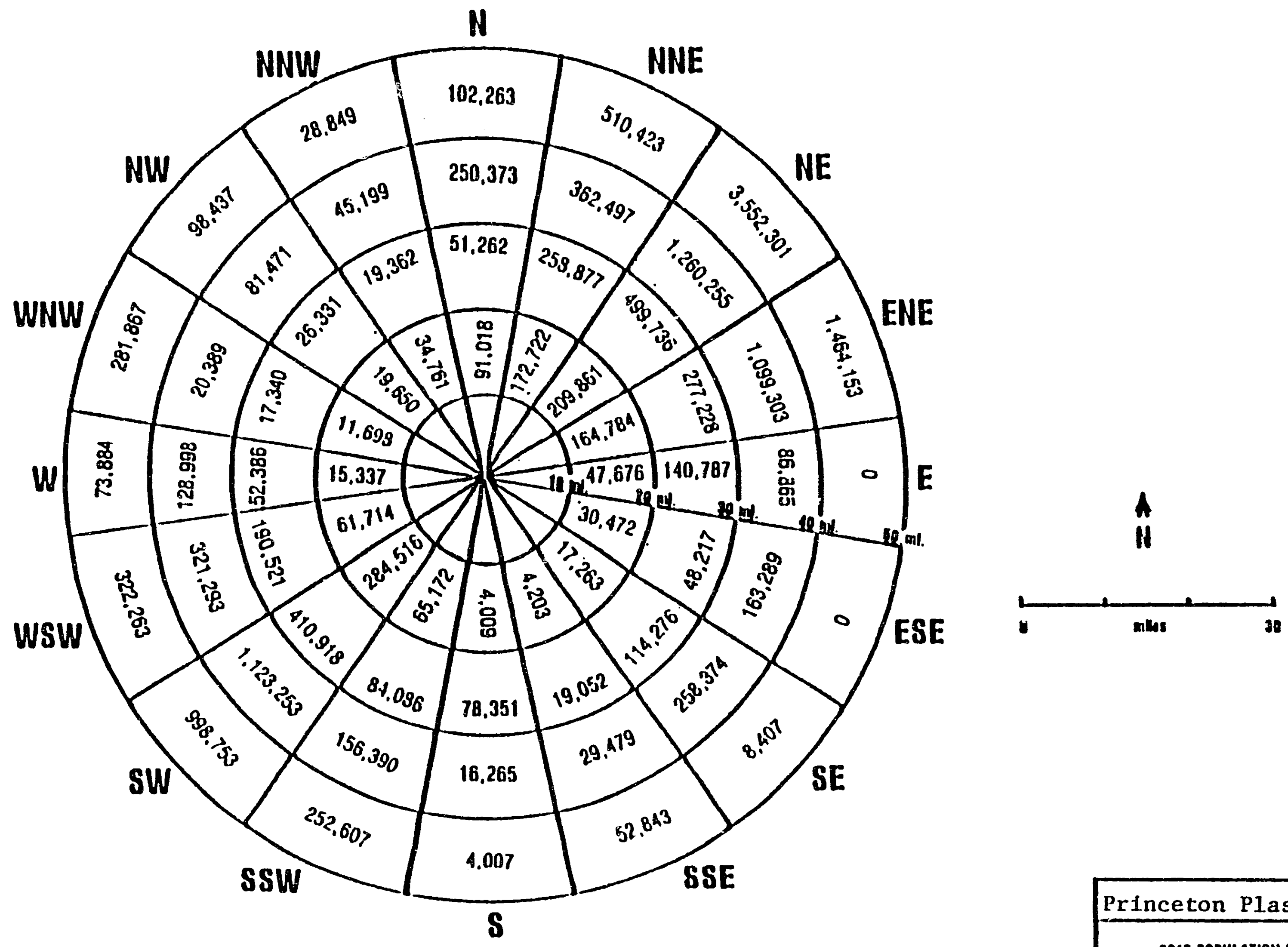


Princeton Plasma Physics

2005 POPULATION ESTIMATES
WITHIN ANNULAR SECTORS
10 - 50 MILES

Figure 24

*Taken from Be87a



Princeton Plasma Physics

2010 POPULATION ESTIMATES
WITHIN ANNULAR SECTORS
10 - 50 MILES

Figure 25

*Taken from Be87a

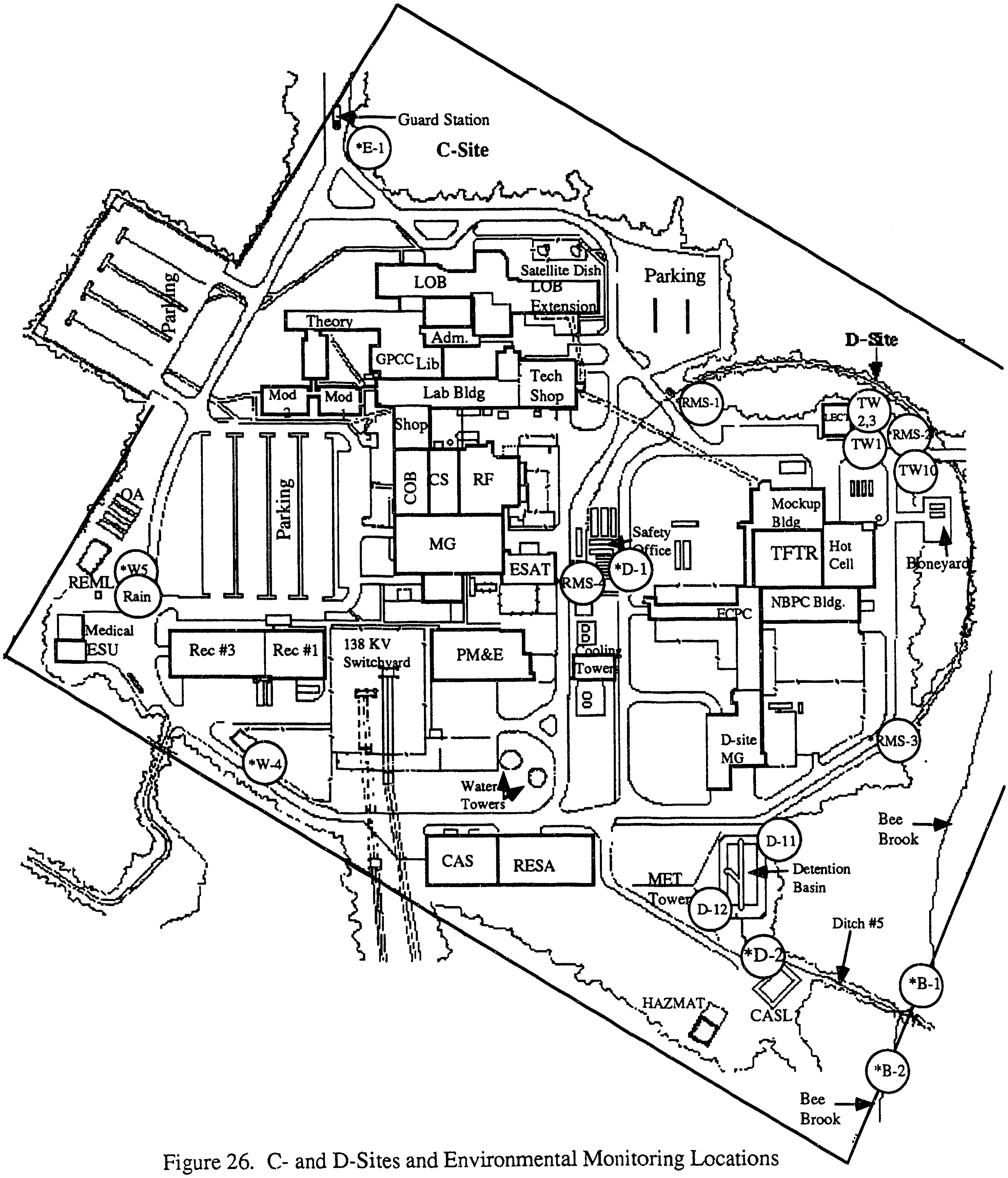


Figure 26. C- and D-Sites and Environmental Monitoring Locations

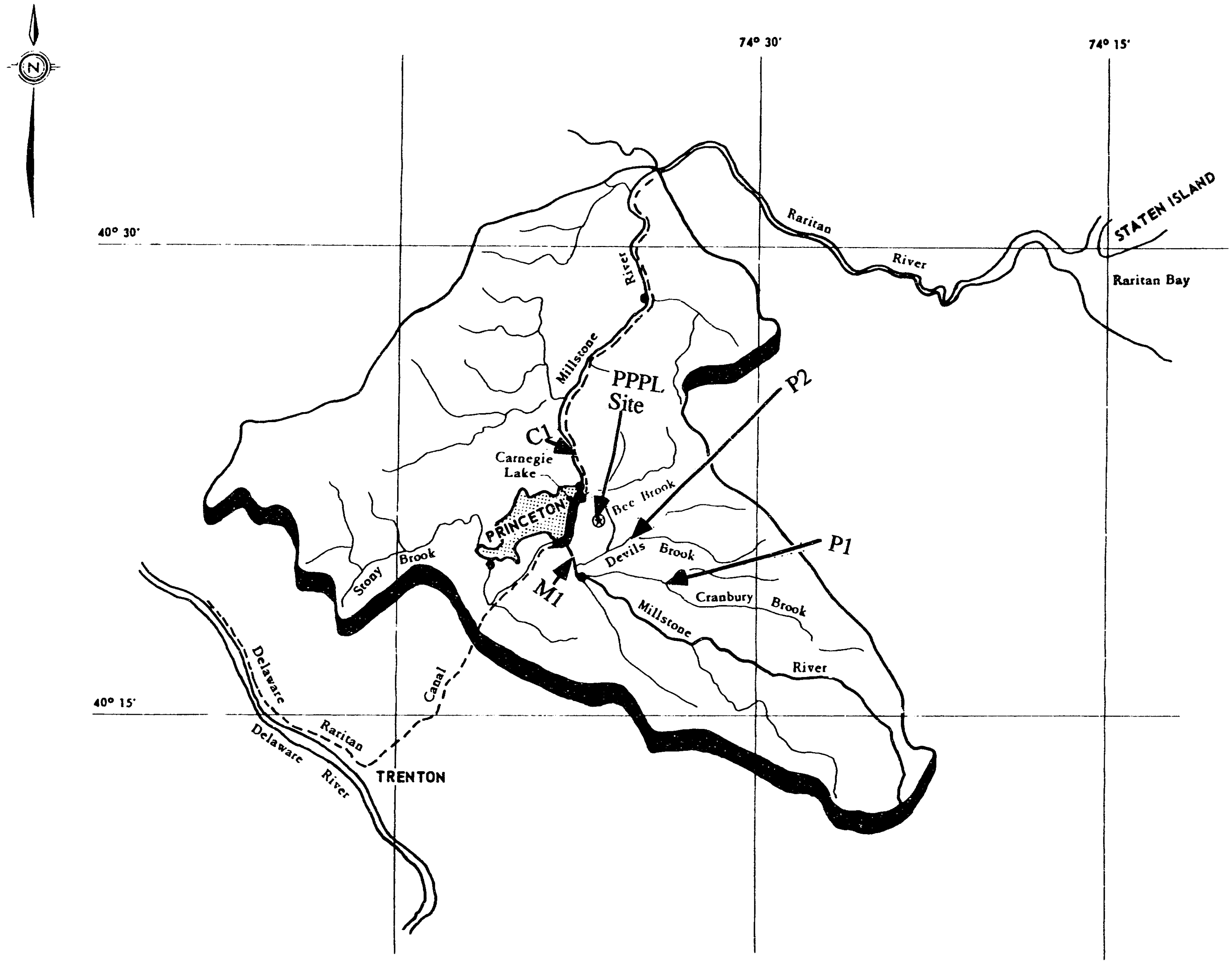


Figure 27. Millstone River Basin Offsite Water Sample Locations

Figure 28.

1991 TFTR Stack Tritium

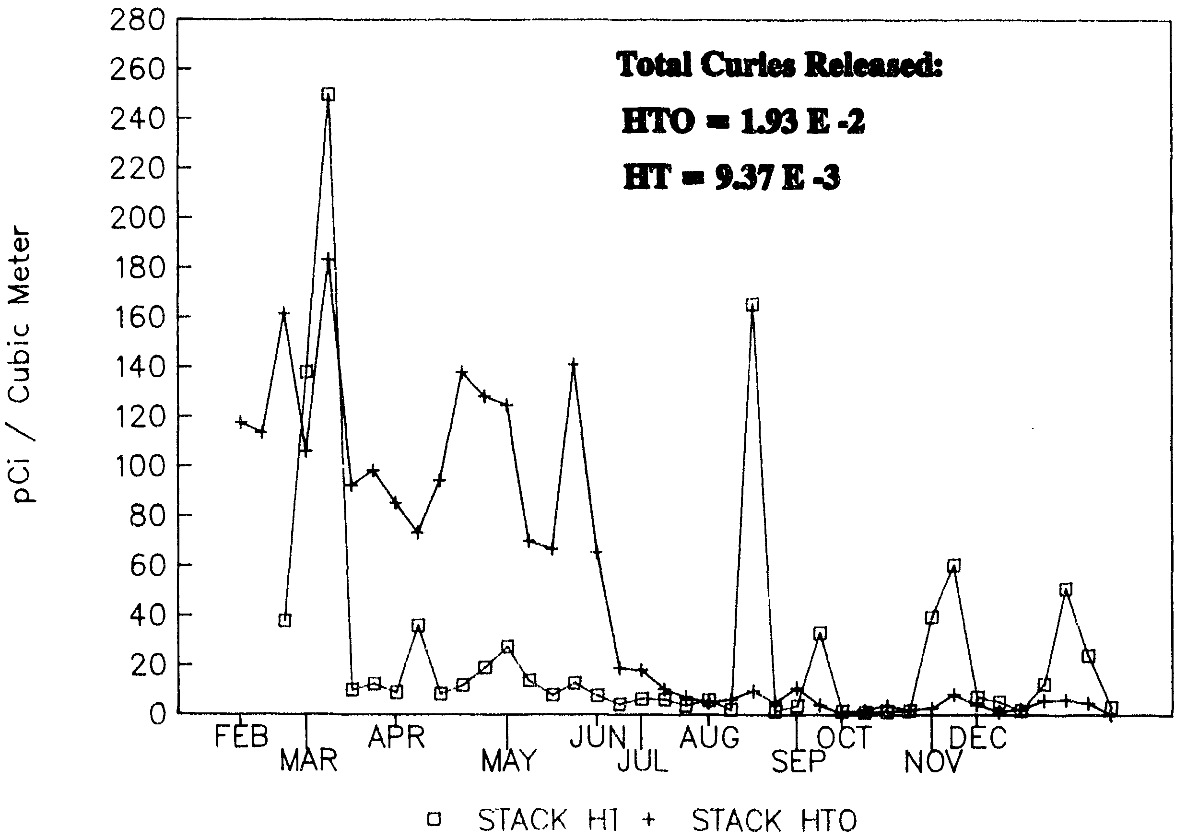


Figure 29. 1991 Air Tritium (HTO)

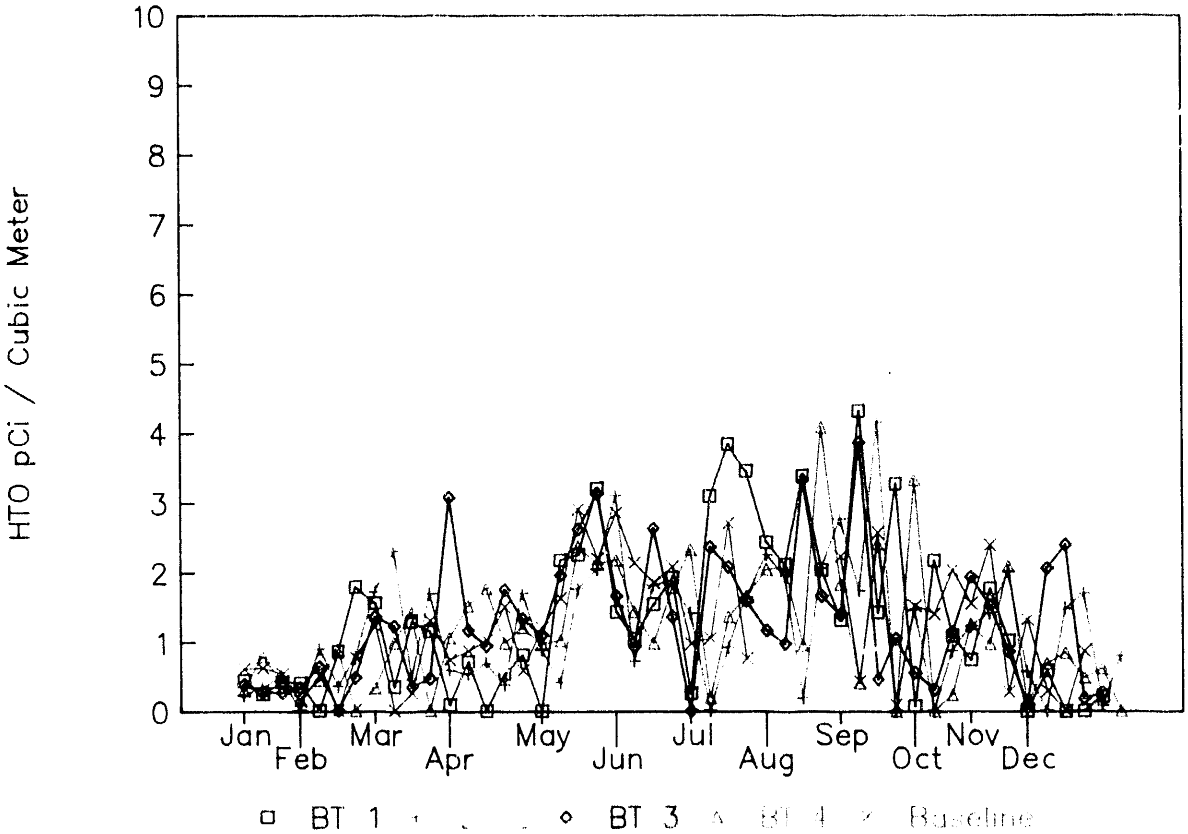


Figure 30. 1991 Air Tritium (HT)

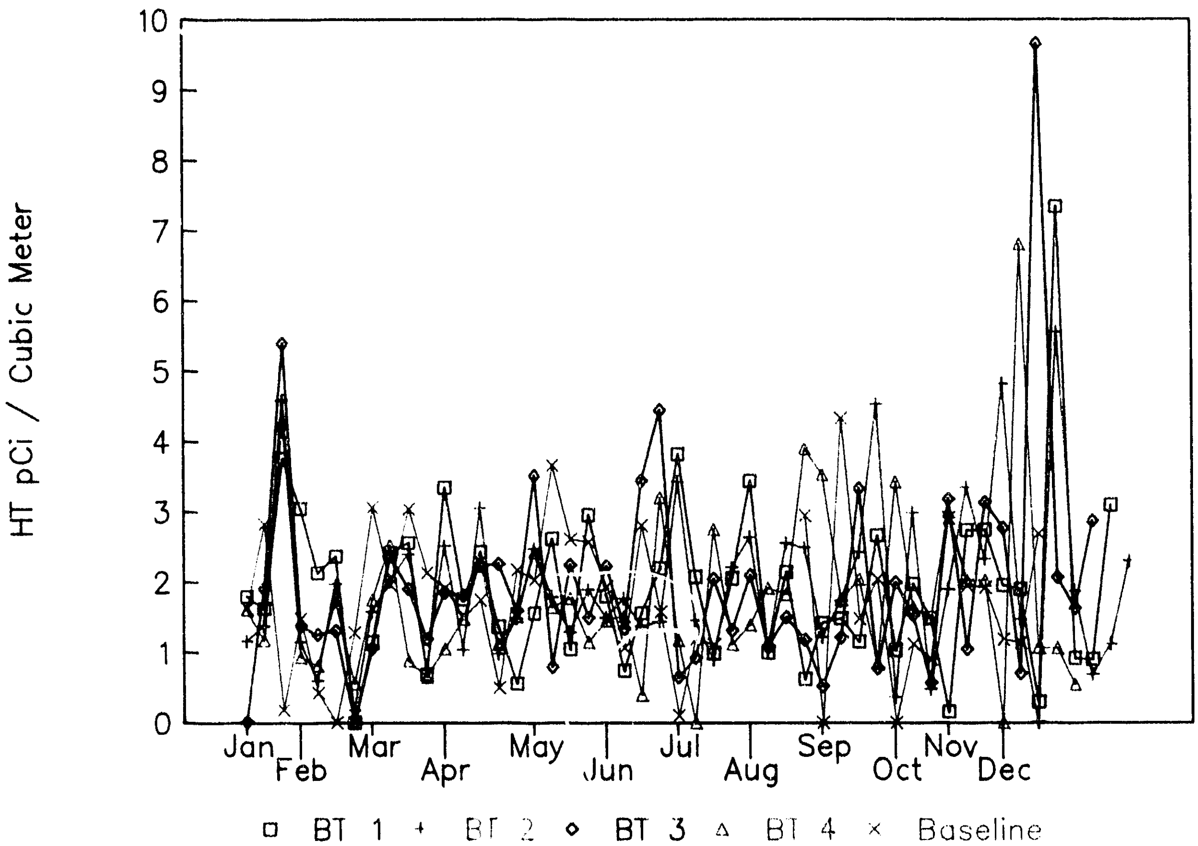
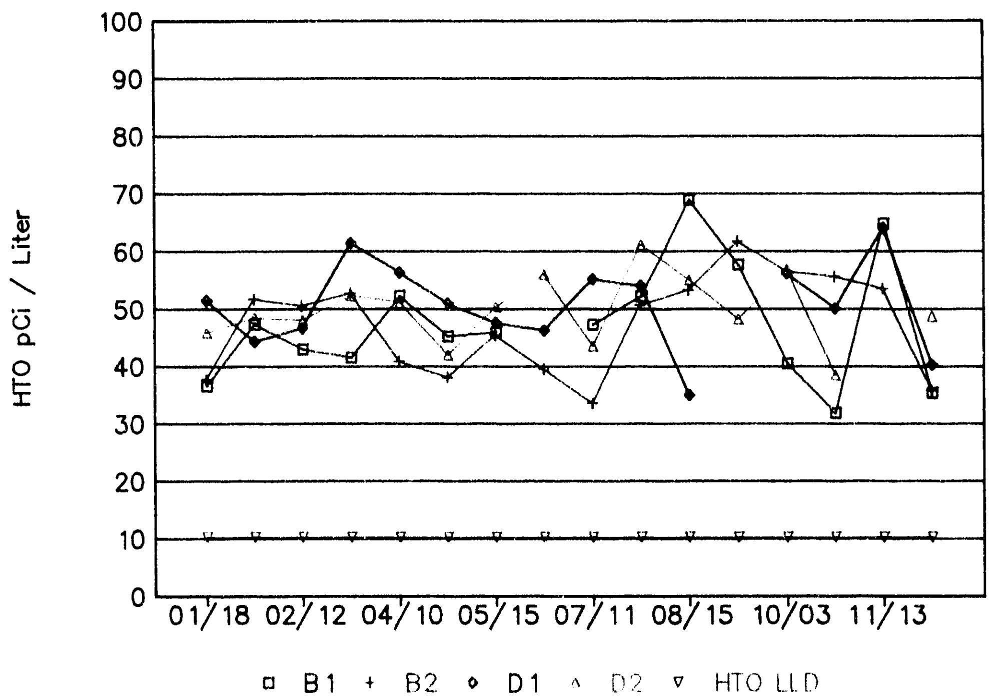


Figure 31.

1991 Surface Water HTO



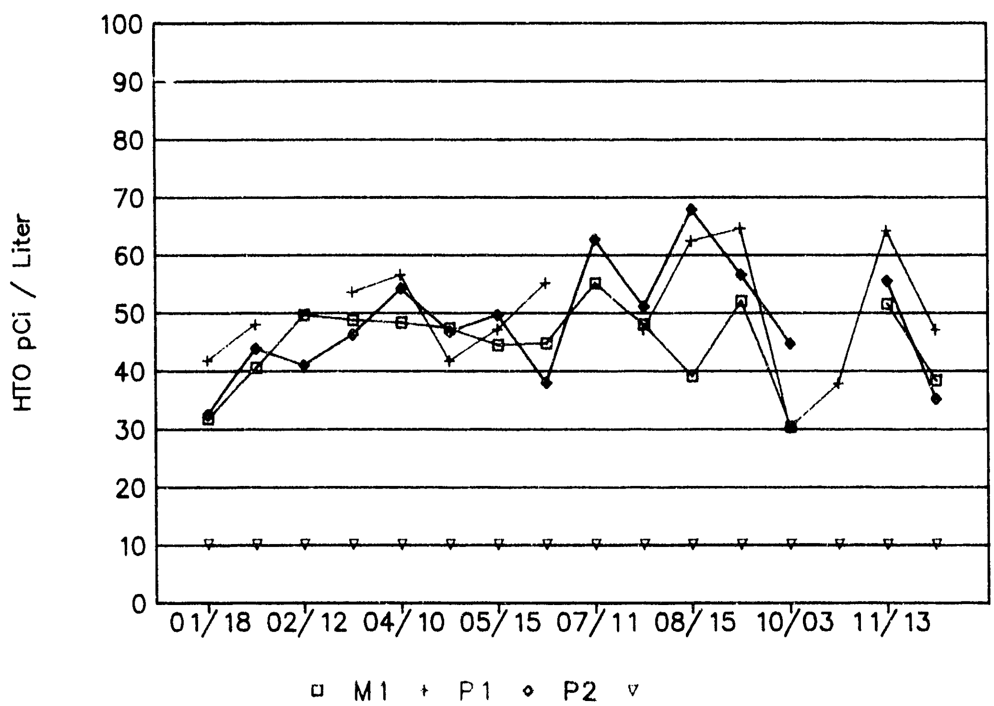


Figure 32. **1991 Precipitation & Rain Water HTO**

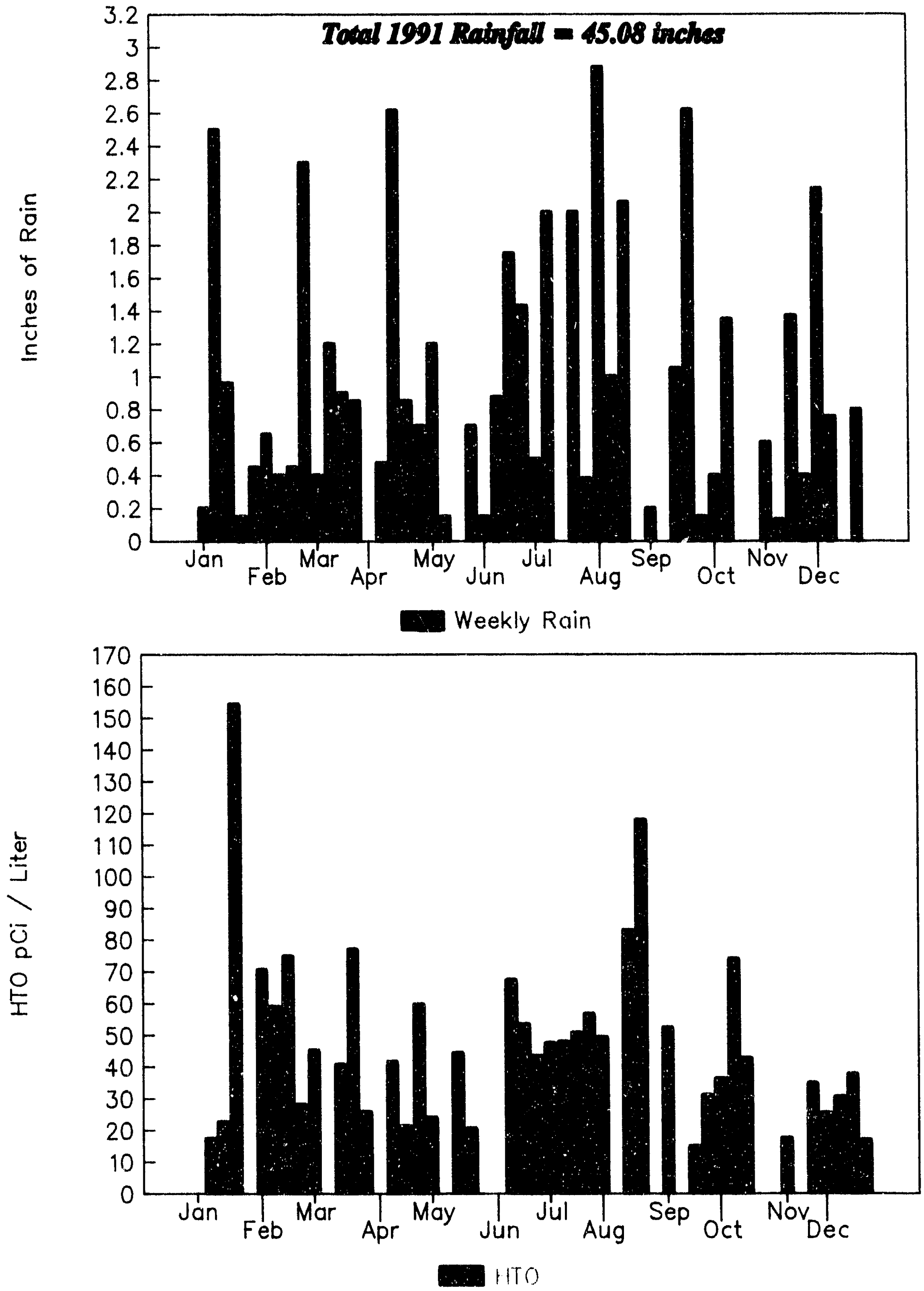
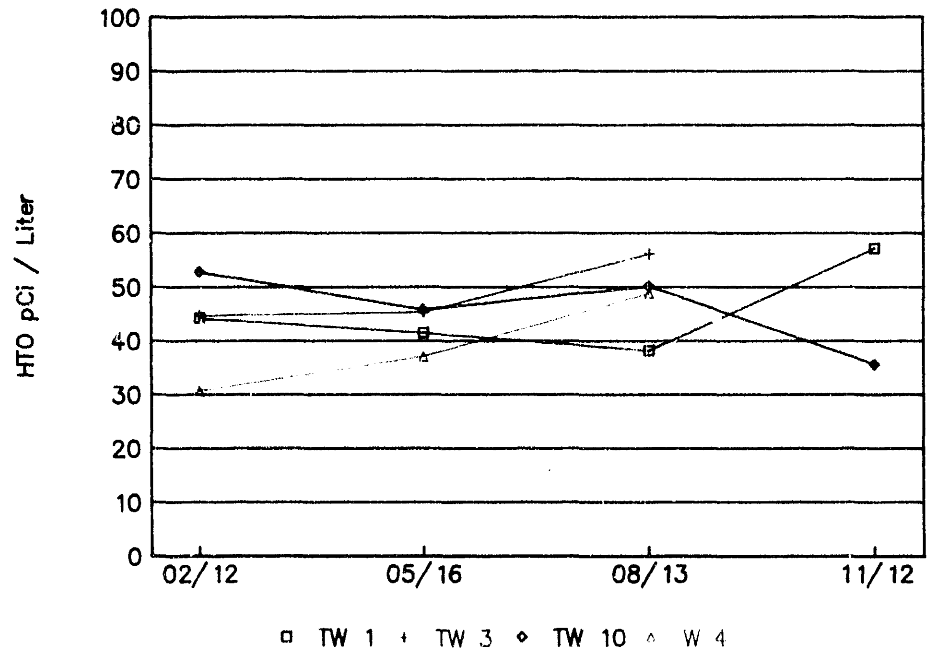


Figure 33. 1991 Ground (Well) Water HTO



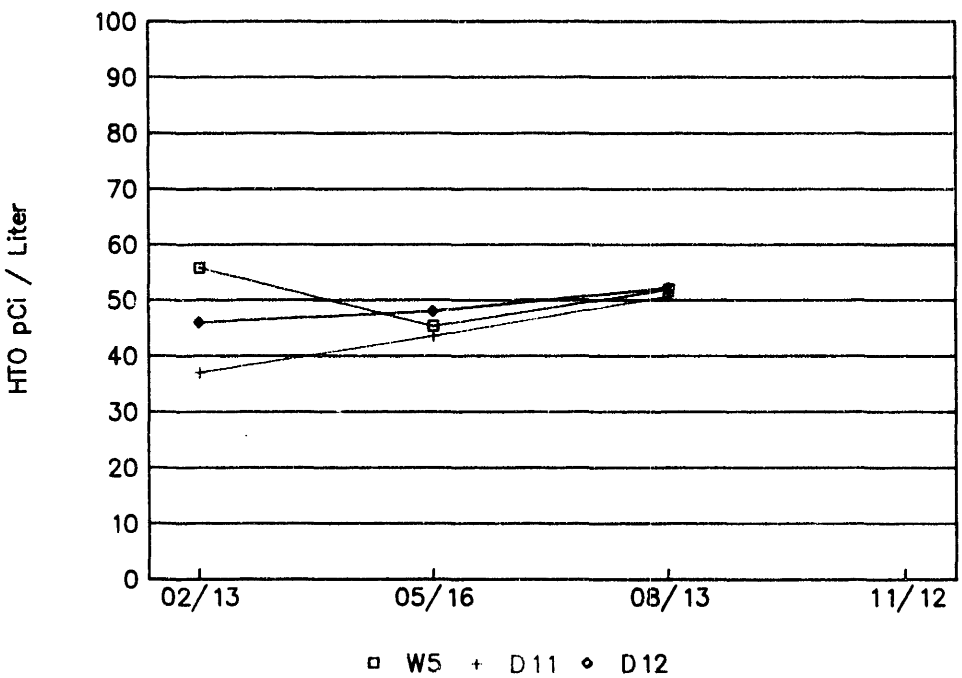


Figure 34.

1991 Elizabethtown City Water Tritium (HTO) Concentrations

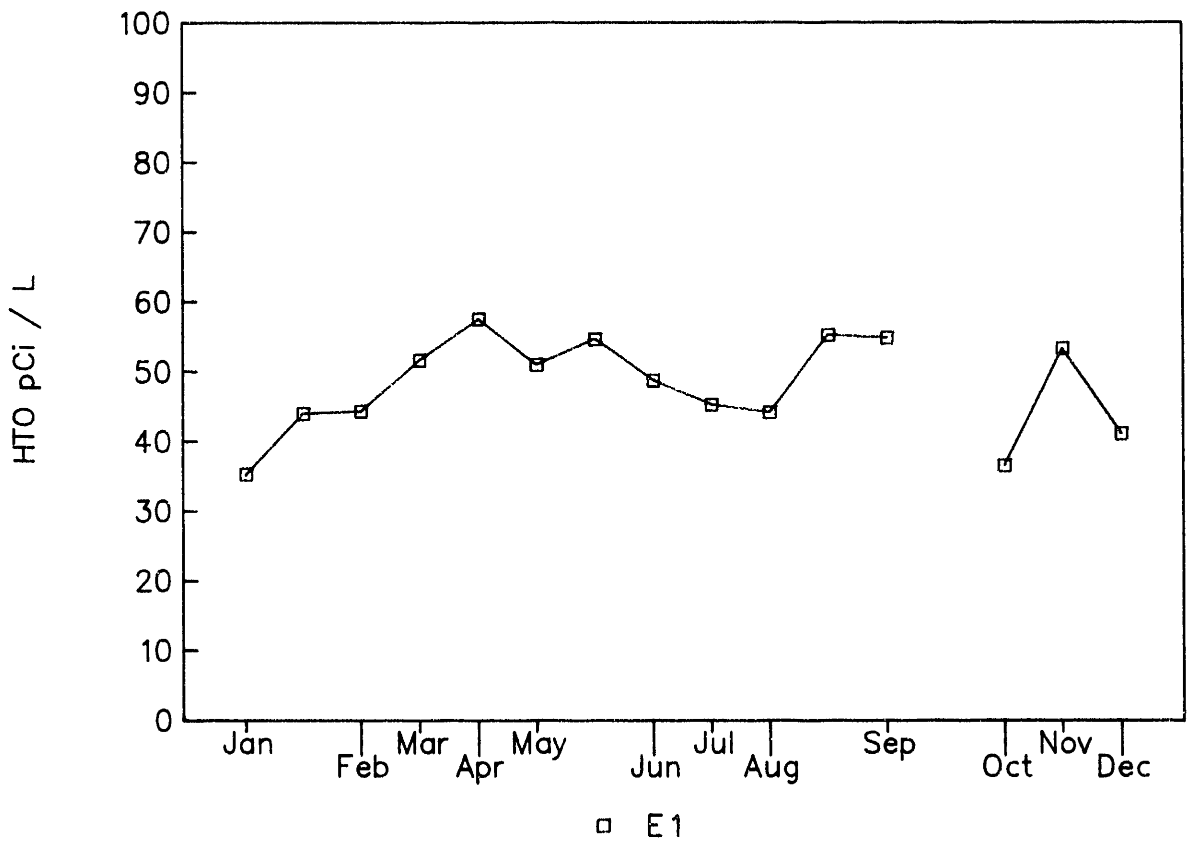


Figure 35. **1991 Tritium (HTO) in Biota**

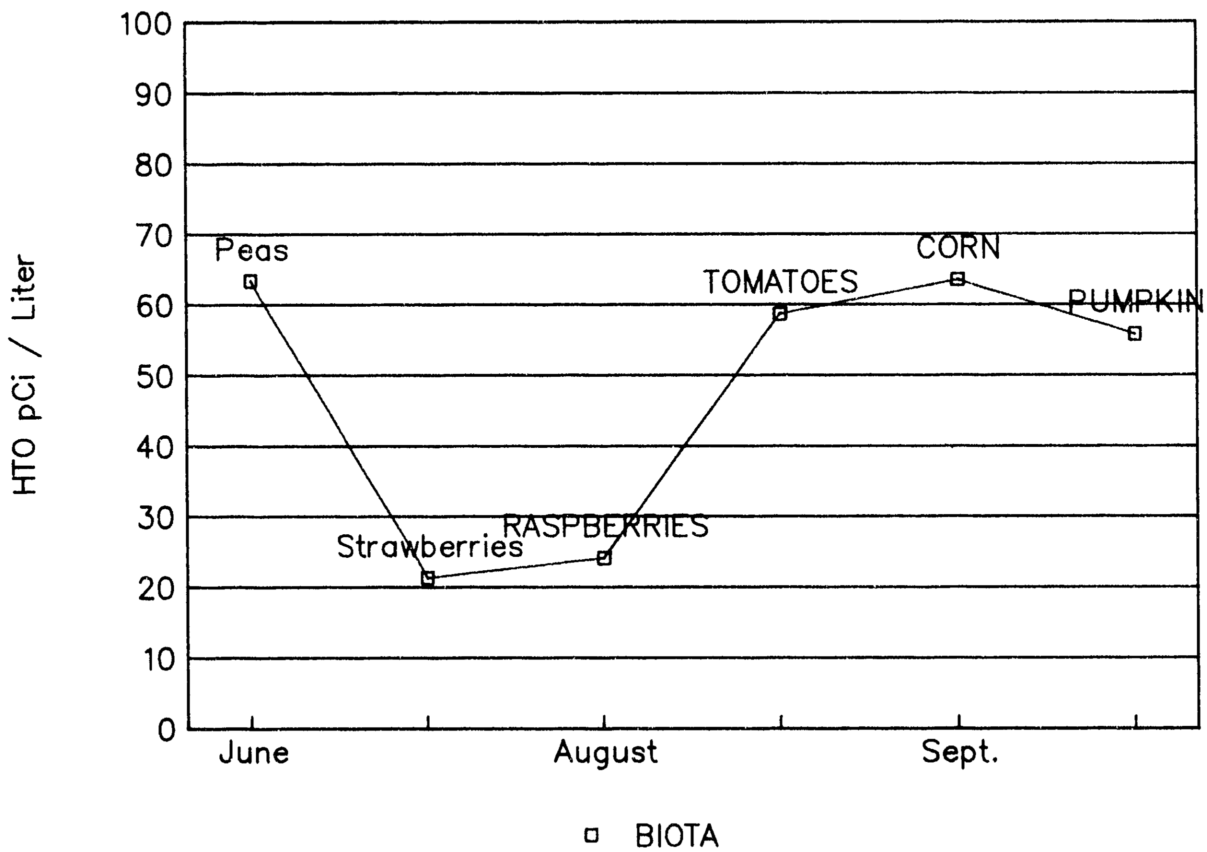
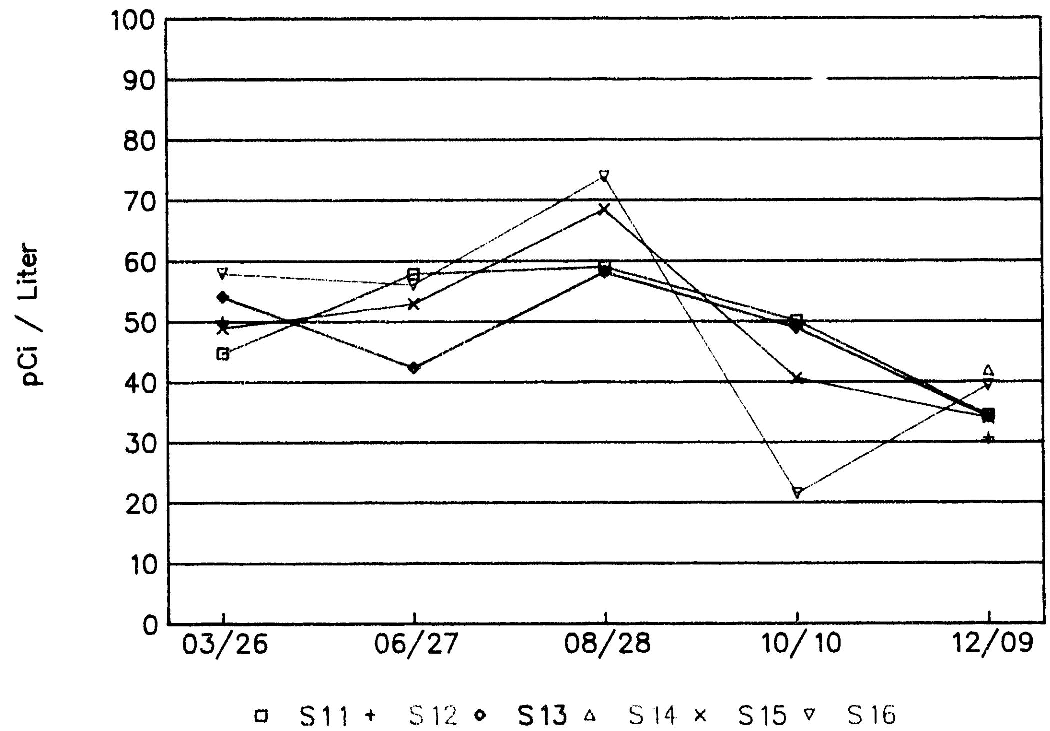
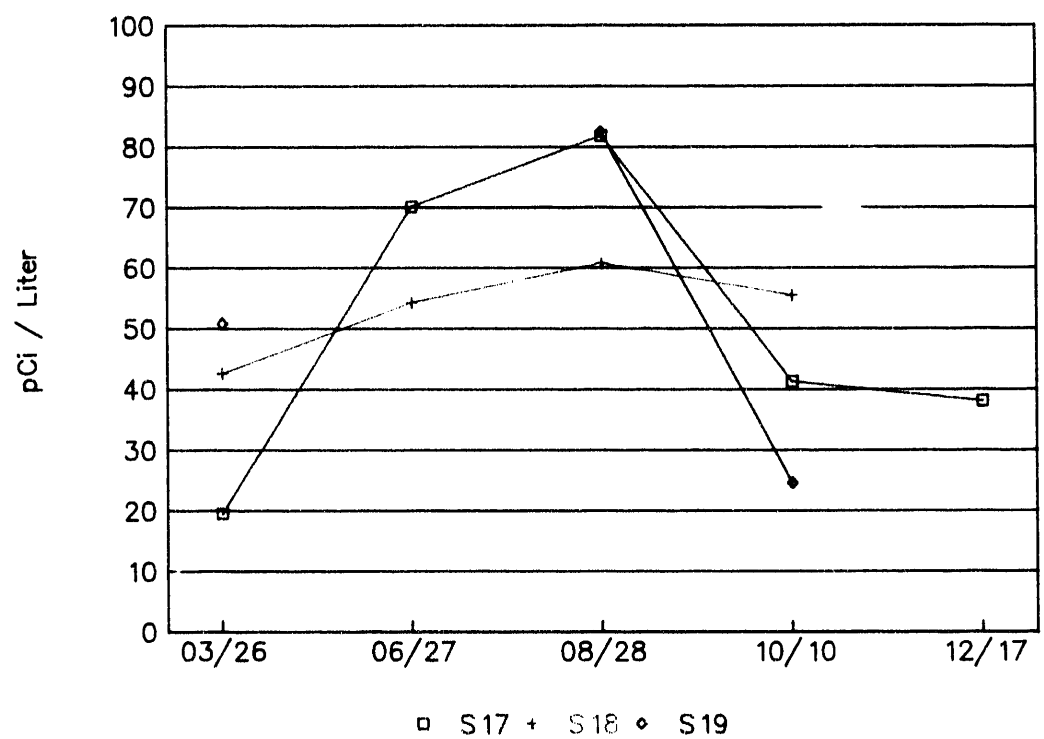


Figure 36. **1991 Soil Tritium (HTO & HT)**





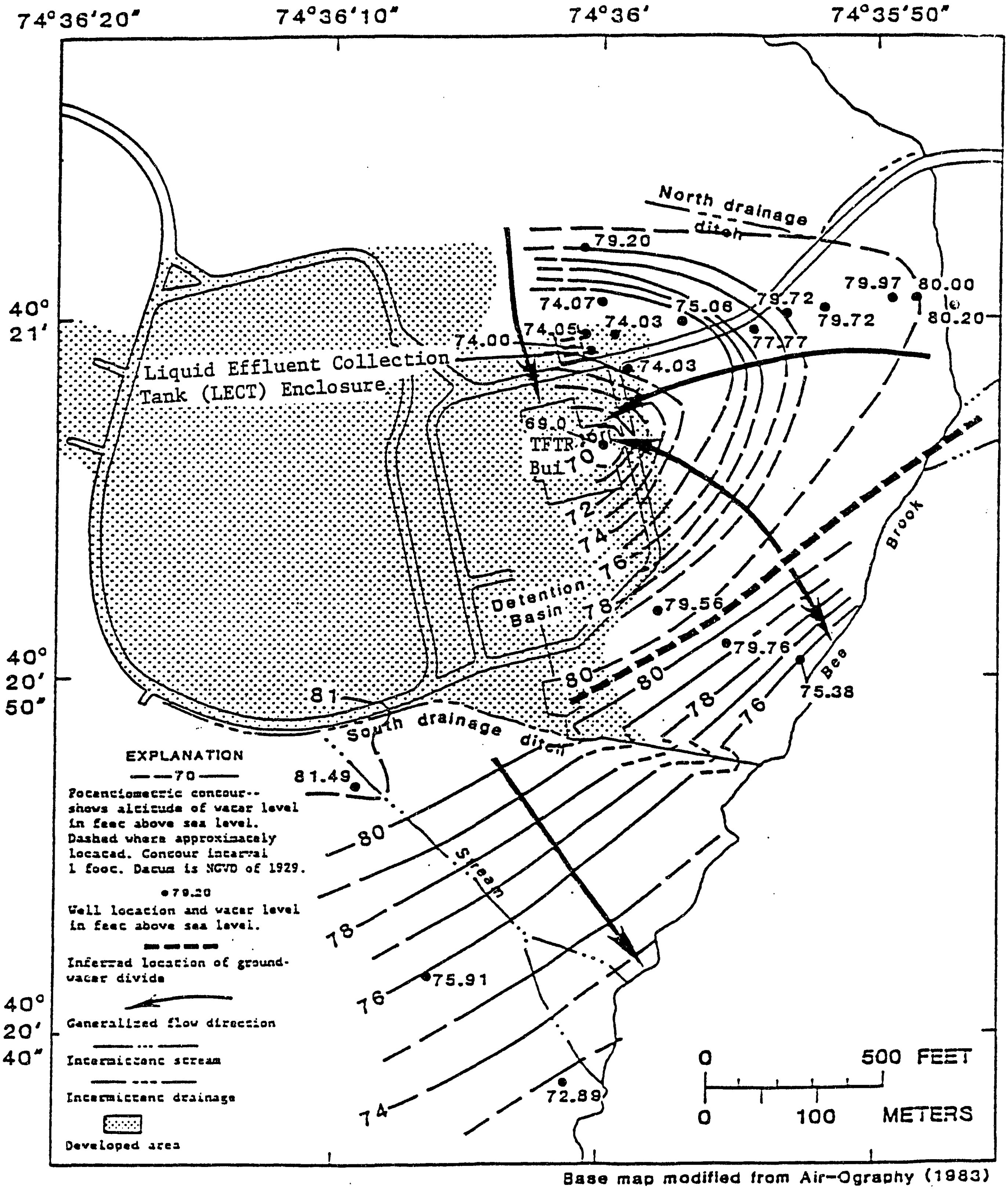


Figure 37. Potentiometric surface of the bedrock aquifer, October 30, 1986. (Taken from Le87)

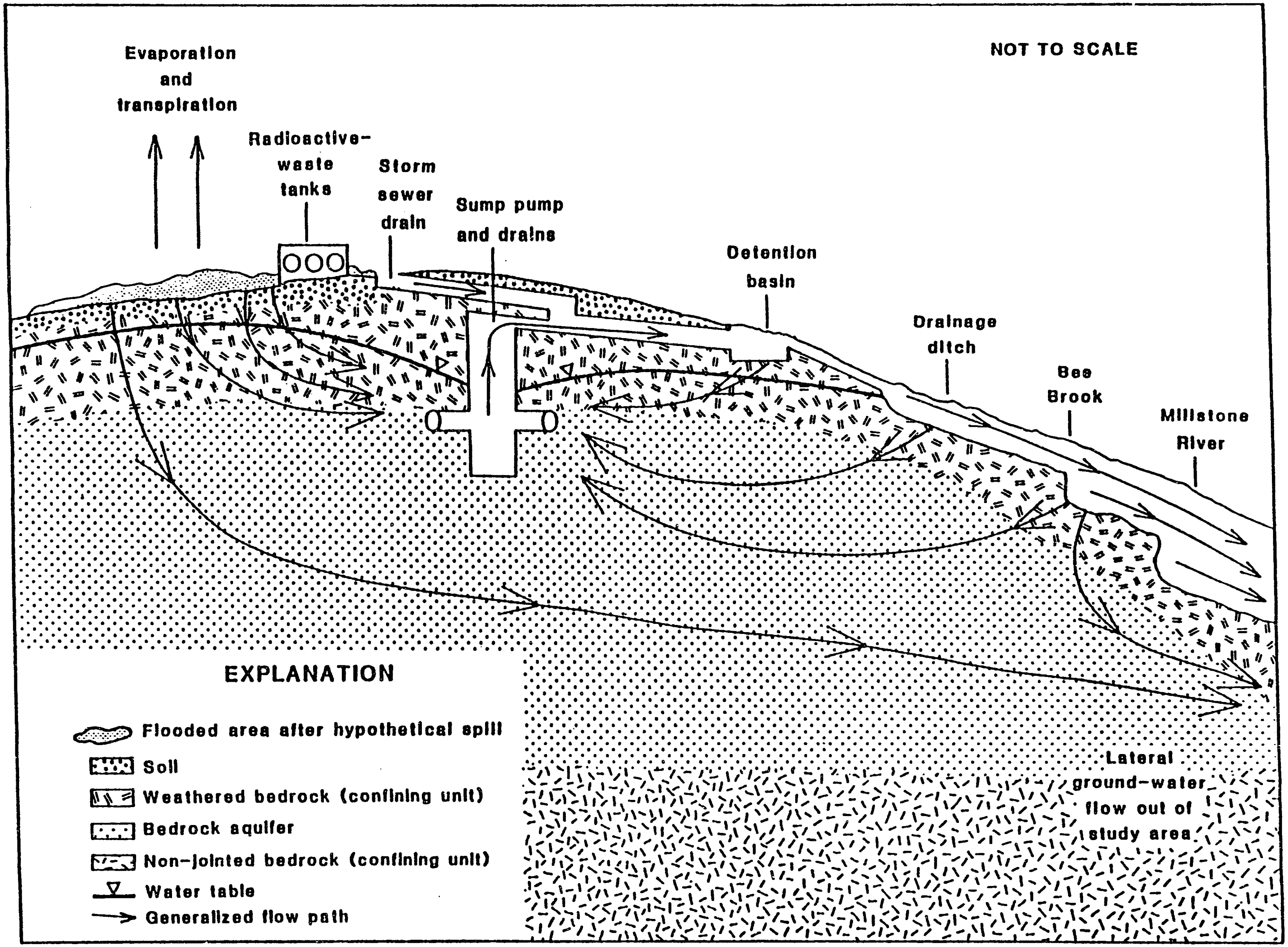


Figure 38. Schematic representation of hydrogeologic framework and potential flow paths of spilled water. (Taken from Le87).

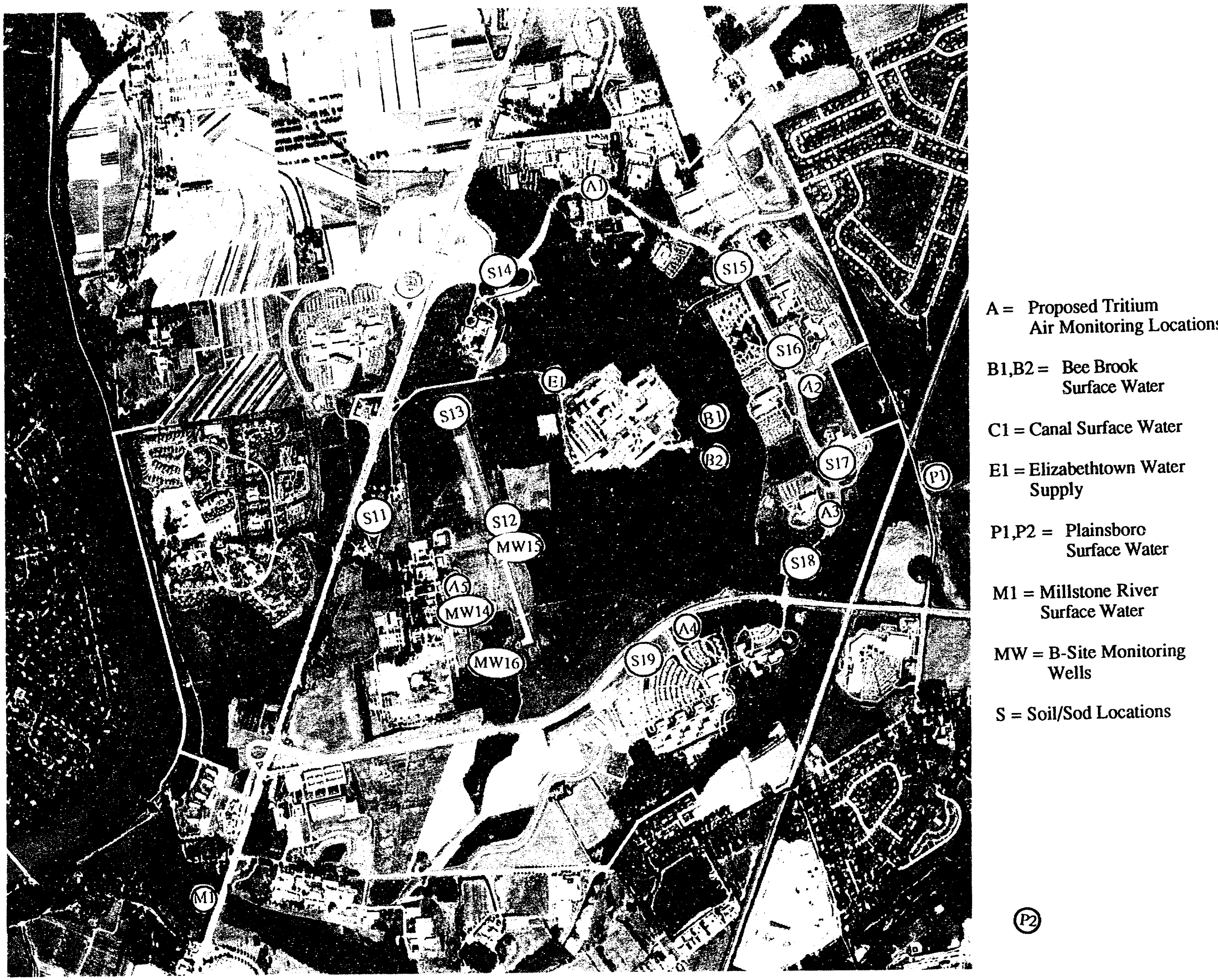


Figure 39. Off-Site Monitoring Locations

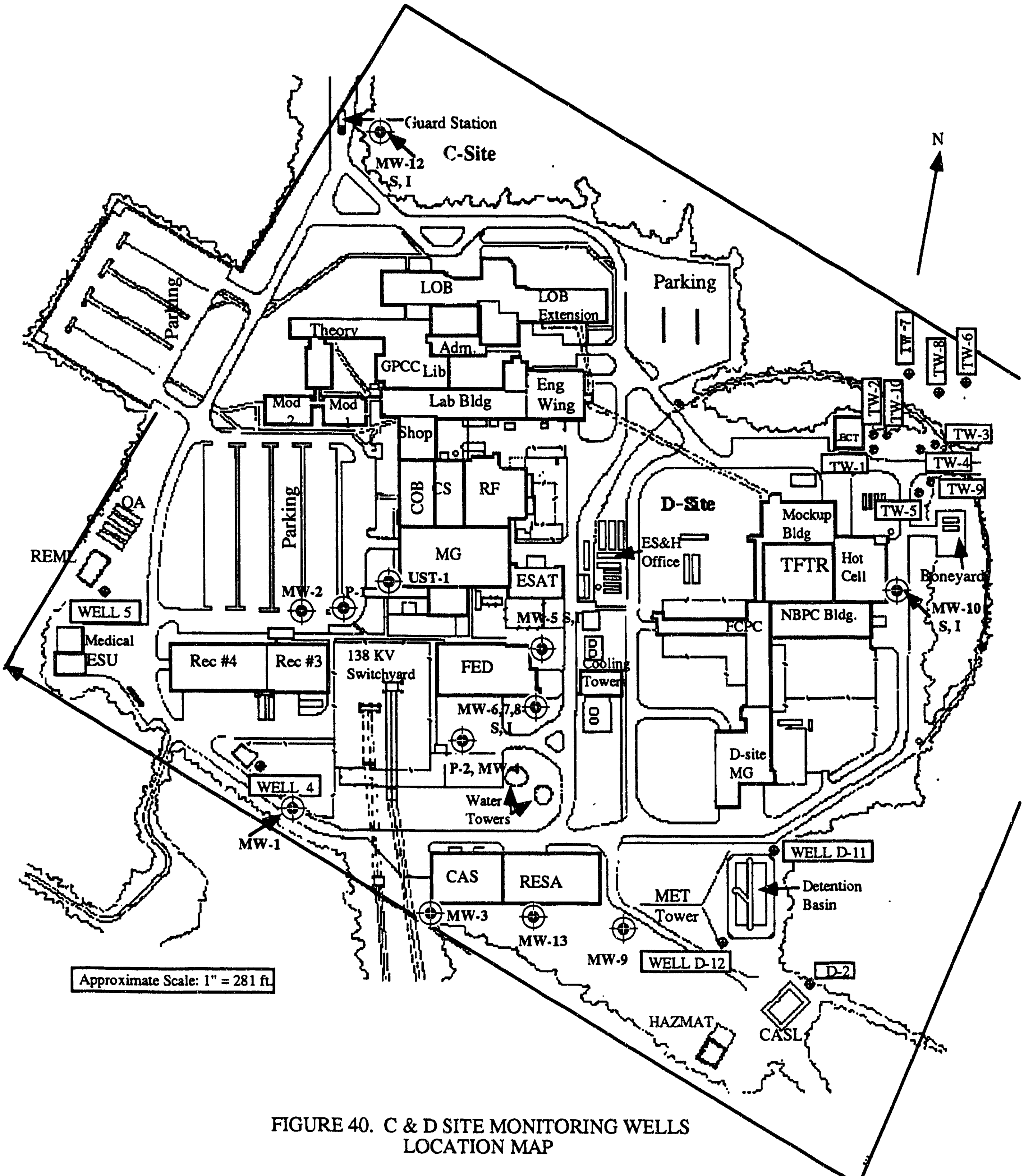


FIGURE 40. C & D SITE MONITORING WELLS LOCATION MAP

PRINCETON PLASMA PHYSICS LABORATORY (PPPL)

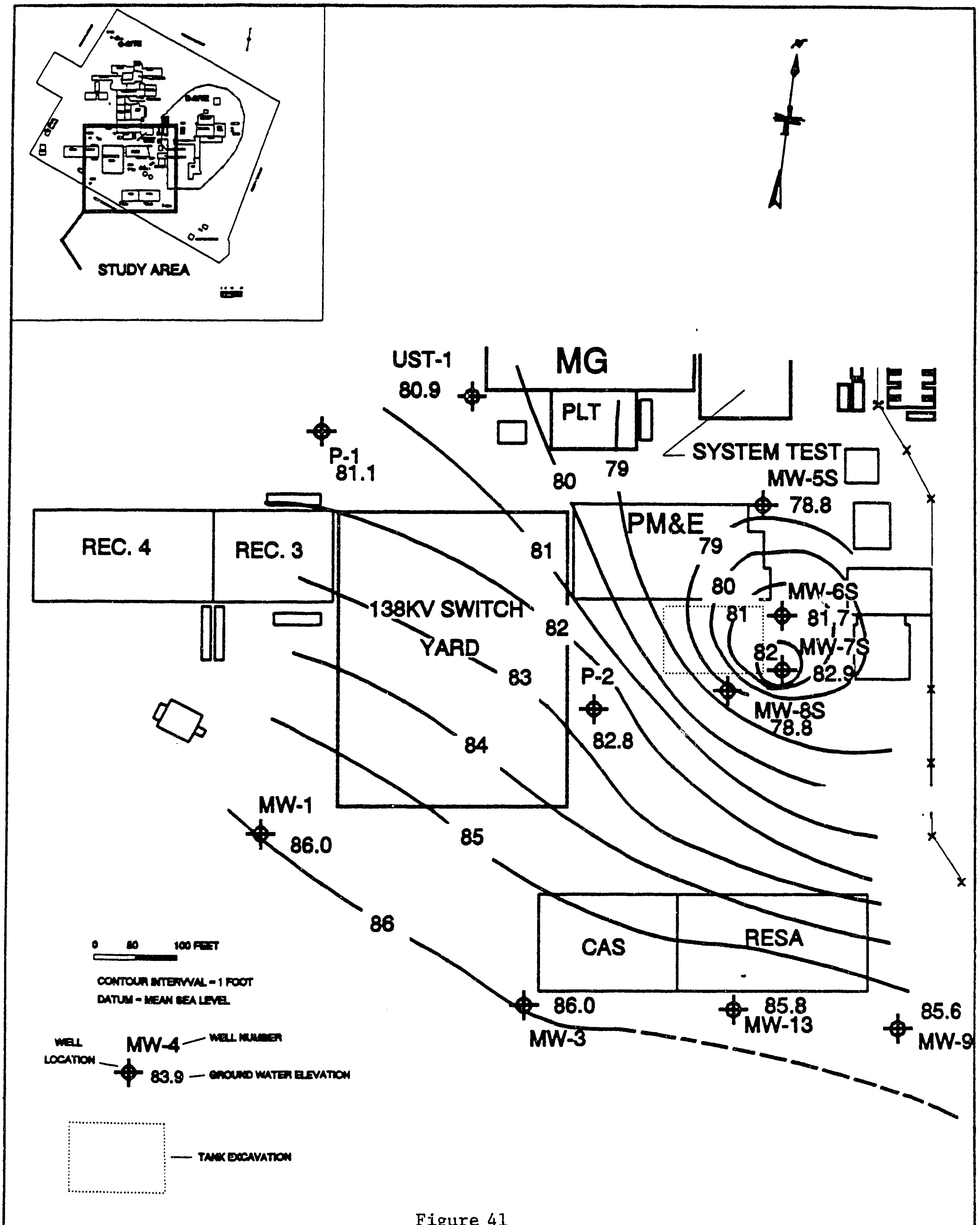


Figure 41

PRINCETON PLASMA PHYSICS LABORATORY
SHALLOW GROUND WATER
POTENTIOMETRIC MAP
JANUARY 13, 1992

Other Distribution

Argonne National Laboratory (R. Kolzow)
Brookhaven National Laboratory (J. Naidu)
CEBAF (C. Ficklen)
Congress (Sen. W. Bradley, Sen F. Lautenberg, Rep. C. Smith)
DOE Chicago Field Operations [3]
DOE Environmental Audit, EH-24 [2]
DOE Office of Environmental Guidance and Compliance, EH-23 [5]
DOE Office of Fusion Energy, ER-55
DOE Office of NEPA Project Assistance, EH-25 [2]
DOE Princeton Area Office (J. Balodis) [3]
EPA/HQ (William Gunther)
EPA/Region II
Fermilab (J. Don Cossairt)
Forrestal Development Center (R. Wolf)
General Atomics (R. Savercool)
Lawrence Livermore National Laboratory (E. B. Hooper, S. F. Eccles)
Los Alamos National Laboratory (W. E. Quinn)
Idaho National Engineering Laboratory (L. Calwallader, D. Holland)
Massachusetts Institute of Technology (C. Fiore)
Middlesex Health Department
NJDEPE, Bureau of Environmental Radiation (G. Nicholls)
NJDEPE, Bureau of Hazardous Waste Management
NJDEPE, Bureau of Planning & Site Assessment (L. Adams)
NJDEPE, Bureau of Groundwater Protection Abatement (G. Nicholas)
NJOEM, Division of Law & Public Safety (C. Williams)
Oak Ridge National Laboratory (J. Glowenika)
Omni-Environmental (M. Dimino)
Plainsboro Township (Glenn Carter) [2]
The Princeton Packet (W. Plump)
SAIC (M. McKenzie-Carter)
SSC (L. Coulson)
PPPL/Prin. Univ.:

H. L. Allen
J. Caruso
R. C. Davidson
J. De Looper
A. R. DeMec
H. Ende
V. Finley
G. Gettelfinger
J. D. Gilbert
R. Hawryluk
R. D. Holt
H. Howard
S. M. Iverson
C. Kircher
S. B. Larson
J. D. Levine
R. Kaeser
D. M. Meade
K. Norcross
R. Ortego
P. H. Rutherford
N. Sauthoff
J. A. Schmidt
E. D. Simon
J. Sinnis
W. Slavin
C. Smith
H. F. Sonnenchein [10]
R. A. P. Sissingh
J. R. Stencel
M. Viola
M. Wieczorek
M. Williams
E. H. Winkler

EXTERNAL DISTRIBUTION IN ADDITION TO UC-420

Dr. F. Paoloni, Univ. of Wollongong, AUSTRALIA
Prof. M.H. Brennan, Univ. of Sydney, AUSTRALIA
Plasma Research Lab., Australian Nat. Univ., AUSTRALIA
Prof. I.R. Jones, Flinders Univ, AUSTRALIA
Prof. F. Cap, Inst. for Theoretical Physics, AUSTRIA
Prof. M. Heindler, Institut für Theoretische Physik, AUSTRIA
Prof. M. Goossens, Astronomisch Instituut, BELGIUM
Ecole Royale Militaire, Lab. de Phy. Plasmas, BELGIUM
Commission-European, DG. XII-Fusion Prog., BELGIUM
Prof. R. Boucique, Rijksuniversiteit Gent, BELGIUM
Dr. P.H. Sakanaka, Instituto Fisica, BRAZIL
Instituto De Pesquisas Espaciais-INPE, BRAZIL
Documents Office, Atomic Energy of Canada Ltd., CANADA
Dr. M.P. Bachynski, MPB Technologies, Inc., CANADA
Dr. H.M. Skarsgard, Univ. of Saskatchewan, CANADA
Prof. J. Teichmann, Univ. of Montreal, CANADA
Prof. S.R. Sreenivasan, Univ. of Calgary, CANADA
Prof. T.W. Johnston, INRS-Energie, CANADA
Dr. R. Bolton, Centre canadien de fusion magnétique, CANADA
Dr. C.R. James,, Univ. of Alberta, CANADA
Dr. P. Lukac, Komenskeho Universzita, CZECHOSLOVAKIA
The Librarian, Culham Laboratory, ENGLAND
Library, R61, Rutherford Appleton Laboratory, ENGLAND
Mrs. S.A. Hutchinson, JET Library, ENGLAND
P. Mähönen, Univ. of Helsinki, FINLAND
C. Mouttet, Lab. de Physique des Milieux Ionisés, FRANCE
J. Radet, CEN/CADARACHE - Bat 506, FRANCE
Ms. C. Rinni, Univ. of Ioannina, GREECE
Dr. T. Mual, Academy Bibliographic Ser., HONG KONG
Preprint Library, Hungarian Academy of Sci., HUNGARY
Dr. B. Das Gupta, Saha Inst. of Nuclear Physics, INDIA
Dr. P. Kaw, Inst. for Plasma Research, INDIA
Dr. P. Rosenau, Israel Inst. of Technology, ISRAEL
Librarian, International Center for Theo Physics, ITALY
Miss C. De Palo, Associazione EURATOM-ENEA, ITALY
Dr. G. Grosso, Istituto di Fisica del Plasma, ITALY
Dr. H. Yamato, Toshiba Res & Devel Center, JAPAN
Prof. I. Kawakami, Atomic Energy Res.Inst., JAPAN
Prof. K. Nishikawa, Hiroshima Univ., JAPAN
Director, Japan Atomic Energy Research Inst., JAPAN
Prof. S. Itoh, Kyushu Univ., JAPAN
Data and Planning Center, Nagoya Univ., JAPAN
Prof. S. Tanaka, Kyoto Univ., JAPAN
Library, Kyoto Univ., JAPAN
Prof. N. Inoue, Univ. of Tokyo, JAPAN
S. Mori, Technical Advisor, JAERI, JAPAN
O. Mitarai, Kumamoto Inst. of Technology, JAPAN
H. Jeong, Korea Advanced Energy Research Inst., KOREA
Prof. D.I. Choi, The Korea Adv. Inst. of Sci. & Tech., KOREA
Prof. B.S. Liley, Univ. of Waikato, NEW ZEALAND
Inst. of Plasma Physics, PEOPLE'S REPUBLIC OF CHINA
Librarian, Inst. of Physics, PEOPLE'S REPUBLIC OF CHINA
Library, Tsinghua Univ., PEOPLE'S REPUBLIC OF CHINA
Z. Li, S.W. Inst Physics, PEOPLE'S REPUBLIC OF CHINA
Prof. J.A.C. Cabral, Instituto Superior Tecnico, PORTUGAL
Dr. O. Petrus, AL I CUZA Univ., ROMANIA
Dr. J. de Villiers, Fusion Studies, AEC, S. AFRICA
Prof. M.A. Hellberg, Univ. of Natal, S. AFRICA
C.I.E.M.A.T, Fusion Division Library, SPAIN
Dr. L. Stenflo, Univ. of UMEA, SWEDEN
Library, Royal Inst. of Technology, SWEDEN
Prof. H. Wilhelmson, Chalmers Univ. of Tech., SWEDEN
Centre Phys. Des Plasmas, Ecole Polytech, SWITZERLAND
Bibliotheek, Inst. Voor Plasma-Fysica, THE NETHERLANDS
M. Durgut, Vice Chairman, Middle East Tech. Univ., TURKEY
Dr. D.D. Ryutov, Siberian Branch of Academy of Sci., USSR
Dr. G.A. Eliseev, Kurchatov Inst., USSR
Librarian, The Ukr.SSR Academy of Sciences, USSR
Dr. L.M. Kovrizhnykh, Inst. of General Physics, USSR
Kernforschungsanlage GmbH, Zentralbibliothek, W. GERMANY
Bibliothek, Inst. Für Plasmaforschung, W. GERMANY
Prof. K. Schindler, Ruhr-Universität Bochum, W. GERMANY
Dr. F. Wagner, (ASDEX), Max-Planck-Institut, W. GERMANY
Librarian, Max-Planck-Institut, W. GERMANY
Prof. R.K. Janev, Inst. of Physics, YUGOSLAVIA

END

DATE FILMED

4 / 29 / 93