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Formerly Utilized Sites Remedial Action Program (FUSRAP)
Contract No. DE-AC05-81OR20722

MAYWOOD INTERIM STORAGE SITE ANNUAL SITE ENVIRONMENTAL REPORT

Maywood, New Jersey

Calendar Year 1988

April 1989

Bechtel National, Inc.

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MAYWOOD INTERIM STORAGE SITE

ANNUAL SITE ENVIRONMENTAL REPORT

CALENDAR YEAR 1988

APRIL 1989

Prepared for

UNITED STATES DEPARTMENT OF ENERGY

OAK RIDGE OPERATIONS OFFICE

Under Contract No. DE-AC05-81OR20722

By

Bechtel National, Inc.

P. O. Box 350

Oak Ridge, Tennessee

Bechtel Job No. 14501

ABSTRACT

During 1988, the environmental monitoring program, begun in 1984, was continued at the Maywood Interim Storage Site (MISS), a U.S. Department of Energy (DOE) facility located in the Borough of Maywood and the Township of Rochelle Park, New Jersey. The MISS is currently used for storage of soils contaminated with low-level radioactivity.

The MISS is part of the Formerly Utilized Sites Remedial Action Program (FUSRAP), a DOE program to identify and decontaminate or otherwise control sites where residual radioactive materials (exceeding current guidelines) remain from the early years of the nation's atomic energy program or from commercial operations causing conditions that Congress has mandated DOE to remedy. As part of the decontamination research and development project authorized by Congress under the 1984 Energy and Water Development Appropriations Act, remedial action is being conducted at this site and at vicinity properties by Bechtel National, Inc. (BNI), project management contractor for FUSRAP. The environmental monitoring program is also carried out by BNI.

The monitoring program at the MISS measures thoron and radon concentrations in air; external gamma radiation levels; and thorium, uranium, and radium concentrations in surface water, groundwater, and sediment.

The radiation dose was calculated for a hypothetical maximally exposed individual to verify that the site is in compliance with the DOE radiation protection standard (100 mrem/yr) and to assess its potential effects on public health. Based on the conservative scenario described in this report, this hypothetical individual receives an annual external exposure approximately equivalent to 1 percent of the DOE radiation protection standard. This exposure is less than a person receives during a round-trip flight from New York to Los Angeles (because of the greater amounts of cosmic

radiation present at higher altitudes). Cumulative dose to the population within an 80-km (50-mi) radius of the MISS that results from radioactive materials present at the site is indistinguishable from the dose the same population receives from naturally occurring radioactive sources.

Results of the 1988 monitoring show that the MISS is in compliance with the DOE radiation protection standard and with applicable permit requirements specified by the New Jersey Department of Environmental Protection Division groundwater permit No. NJ0054500.

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1.0 INTRODUCTION

This report presents the findings of the environmental monitoring program conducted at the U.S. Department of Energy's (DOE) Maywood Interim Storage Site (MISS) during calendar year 1988. Environmental monitoring began at the MISS in 1984. As part of the research and development decontamination program authorized by Congress under the 1984 Energy and Water Development Appropriations Act, Bechtel National, Inc. (BNI) is conducting remedial action at the site and at vicinity properties. The work is being performed as part of the DOE Formerly Utilized Sites Remedial Action Program (FUSRAP).

1.1 LOCATION AND DESCRIPTION

The MISS is located in the Borough of Maywood and the Township of Rochelle Park, in Bergen County, New Jersey, approximately 19.2 km (12 mi) north-northwest of downtown Manhattan (New York City) and 20.8 km (13 mi) northeast of Newark, New Jersey (Figures 1-1 and 1-2). Figure 1-3 is an aerial photograph of the site. The MISS is bounded by New Jersey Route 17 on the west, a railroad line on the northeast, and commercial/industrial areas on the south and east. The site occupies 4.7 ha (11.7 acres) of a 12-ha (30-acre) property owned by the Stepan Company (formerly Maywood Chemical Works). The MISS is fenced. The Stepan Company property is also enclosed by a fence and is currently used for chemical processing activities.

Site activities are conducted in a manner designed to preclude the migration of contaminants from the MISS via groundwater or surface water. During construction, pollution control measures include the use of prudent engineering controls, such as installation of sedimentation barriers in excavation areas and treatment of impounded surface water prior to discharge, in accordance with New Jersey Department of Environmental Protection (NJDEP) requirements.

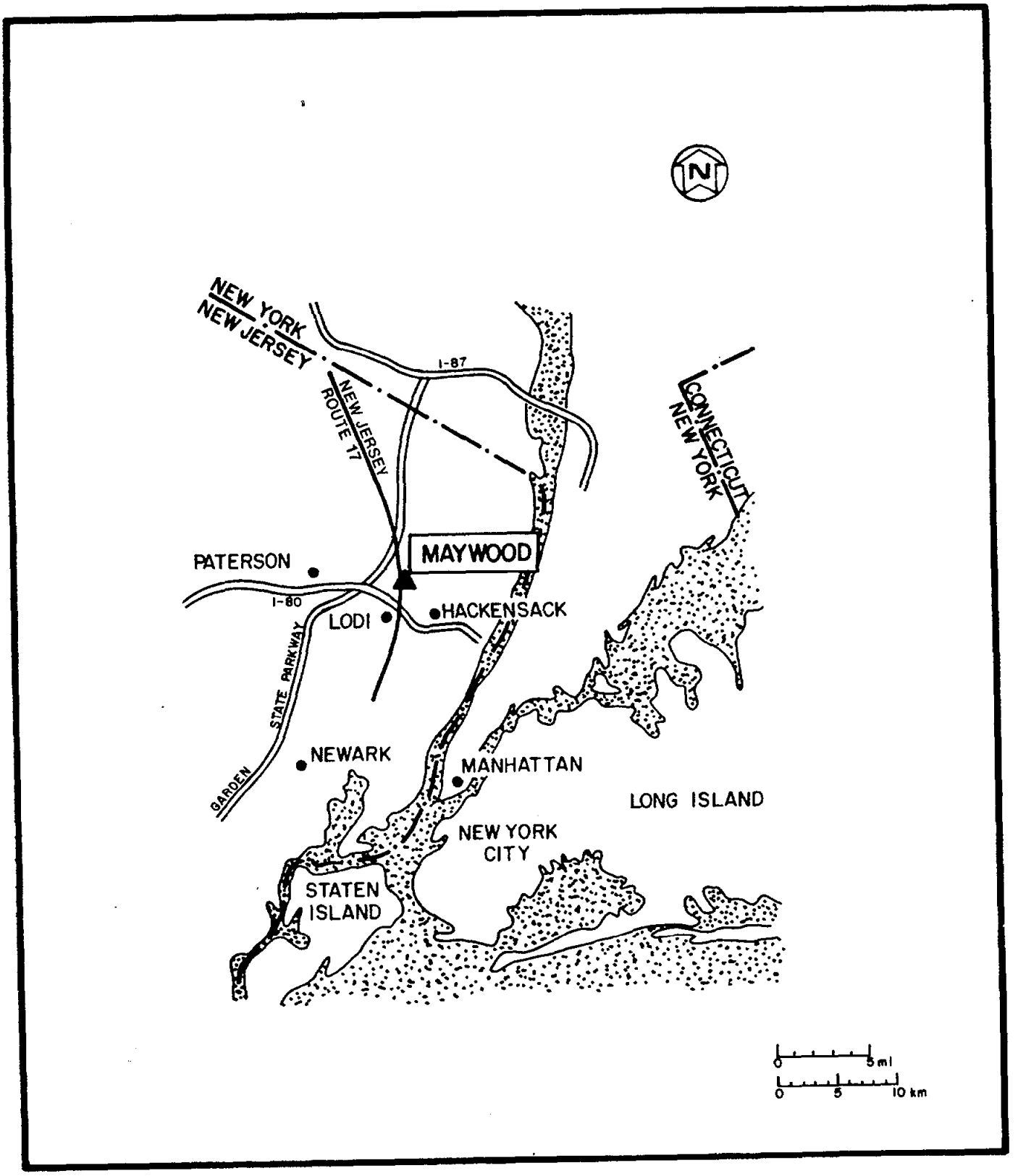

FIGURE 1-1 LOCATION OF MAYWOOD, NEW JERSEY

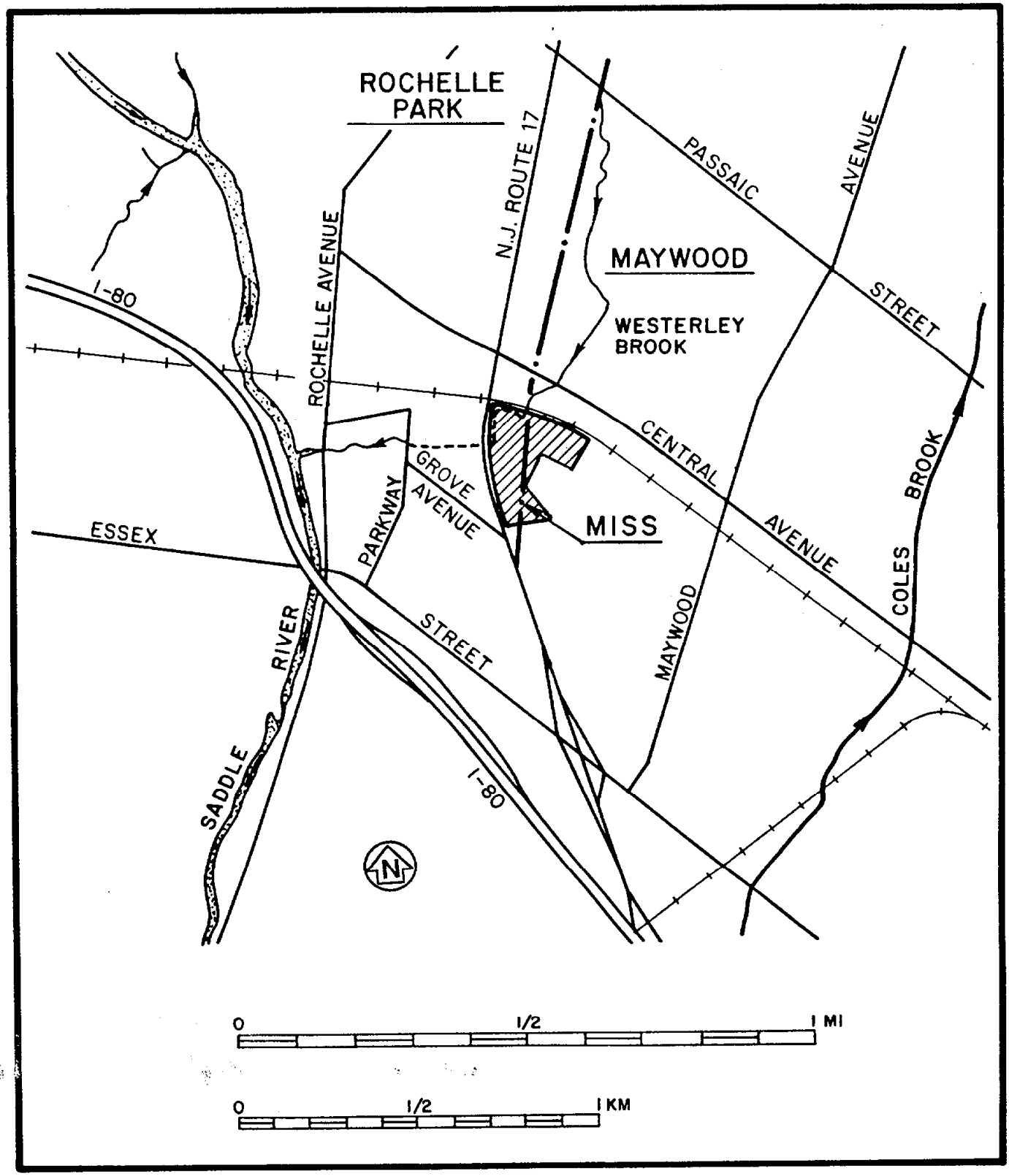

FIGURE 1-2 LOCATION OF THE MISS

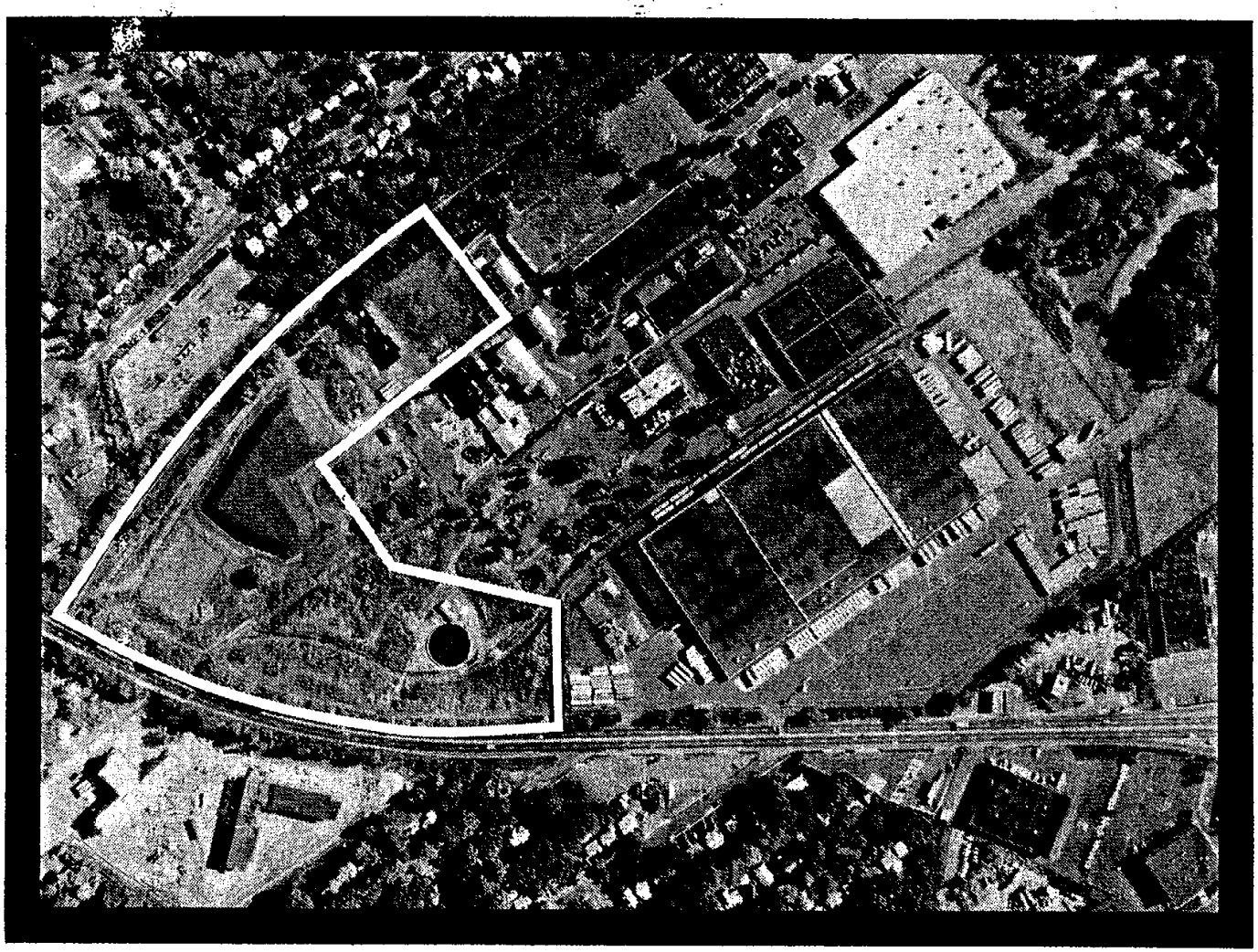

FIGURE 1-3 AERIAL VIEW OF THE MISS AND ITS VICINITY

The MISS is located within the glaciated section of the Piedmont Plateau of north-central New Jersey (Ref. 1). The terrain is generally level with intermittent shallow ditches and slight mounds (Ref. 2). The MISS slopes gently toward the Saddle River, which is located west of the site (Figure 1-2). It is underlain by sedimentary sandstone, mudstone, and siltstone of the Brunswick formation (Refs. 3 and 4). The bedrock lies close to the surface and is overlain by 1 to 4.5 m (3 to 15 ft) of weathered bedrock and unconsolidated glacial deposits of clay, silt, sand, and gravel. The depth of the glacial deposits varies considerably in the vicinity of the site. In addition, fill materials consisting primarily of soil and building rubble were placed on the site during its many years of industrial use (Ref. 3).

The MISS is located within the Saddle River drainage basin (Figure 1-2), approximately 0.8 km (0.5 mi) east of the Saddle River (a tributary of the Passaic River) and approximately 1.6 km (1 mi) west of the drainage divide lying between the Hackensack River and the Saddle River (Ref. 3). The MISS is poorly drained. Rainwater runoff from the MISS empties into the Saddle River via Westerley Brook. The brook flows under the site through a concrete storm drain, passes under New Jersey Route 17, and eventually empties into the Saddle River. Neither the Saddle River nor Westerley Brook is used as a source of drinking water (Ref. 5).

The groundwater table is generally shallow, lying 2.1 to 3 m (7 to 10 ft) below the ground surface (Ref. 3). Groundwater in the Maywood area is available primarily from a bedrock aquifer and from unconsolidated surficial deposits; the former is generally considered to be the more significant groundwater resource. The wells that draw from the unconsolidated surficial deposits generally have low yields and are used for domestic purposes. However, some wells located in areas with thicker surficial deposits of stratified glacial drift have high yields and have been developed for industrial and public uses.

The average frequency of precipitation in New Jersey is 120 days/yr; the mean annual precipitation is approximately 122 cm (48 in.), with an average annual snowfall of 74 cm (29.1 in.) As shown in Figure 1-4, winds in the area blow predominantly from the southwest at a mean speed of 16.3 km/h (10.2 mph) (Refs. 6 and 7).

The 1980 populations for Maywood and Rochelle Park were approximately 9,900 and 5,600, respectively, a decline from 11,000 and 6,400 in 1970. The 1970 and 1980 populations of Bergen County were approximately 898,000 and 845,000, respectively. The population of Bergen County is expected to increase over the next 20 years (Ref. 1).

Generalized land uses in the vicinity of the MISS are shown in Figure 1-5. The areas adjacent to the site are zoned primarily for limited commercial, light industrial, or single-family residential use. With the exception of one house located on the eastern border of the Stepan Company property, the areas to the east and south of the site are used for industrial and restricted commercial purposes. The New York, Susquehanna and Western Railroad runs along the northern border of the MISS.

1.2 SITE HISTORY

The MISS was established to provide an interim storage site for residual radioactive material found in the vicinity of the former Maywood Chemical Works. From 1916 through 1956, Maywood Chemical Works processed monazite sand (thorium ore) for use in manufacturing industrial products such as mantles for gas lanterns. During that time, slurry containing process wastes from the thorium operations was pumped to diked areas west of the plant. Some of these process wastes were removed from the Maywood Chemical Works and used as mulch and fill on nearby properties, thereby contaminating them. Some of the material migrated off-site via natural drainage formerly provided by Lodi Brook. In 1932, New Jersey Route 17 was built through this disposal area (Figure 1-2).

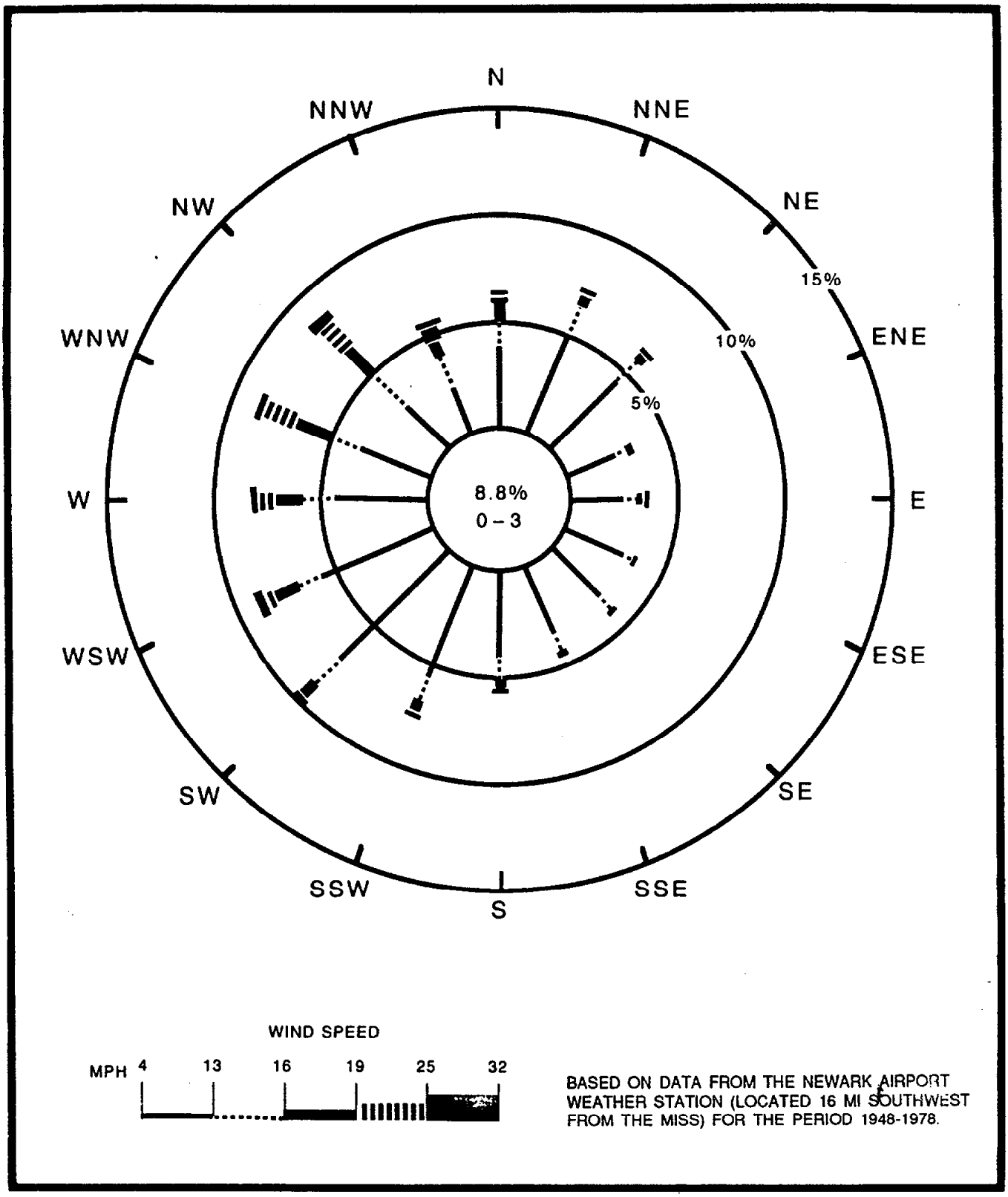

FIGURE 1-4 ANNUAL WIND ROSE FOR THE MISS

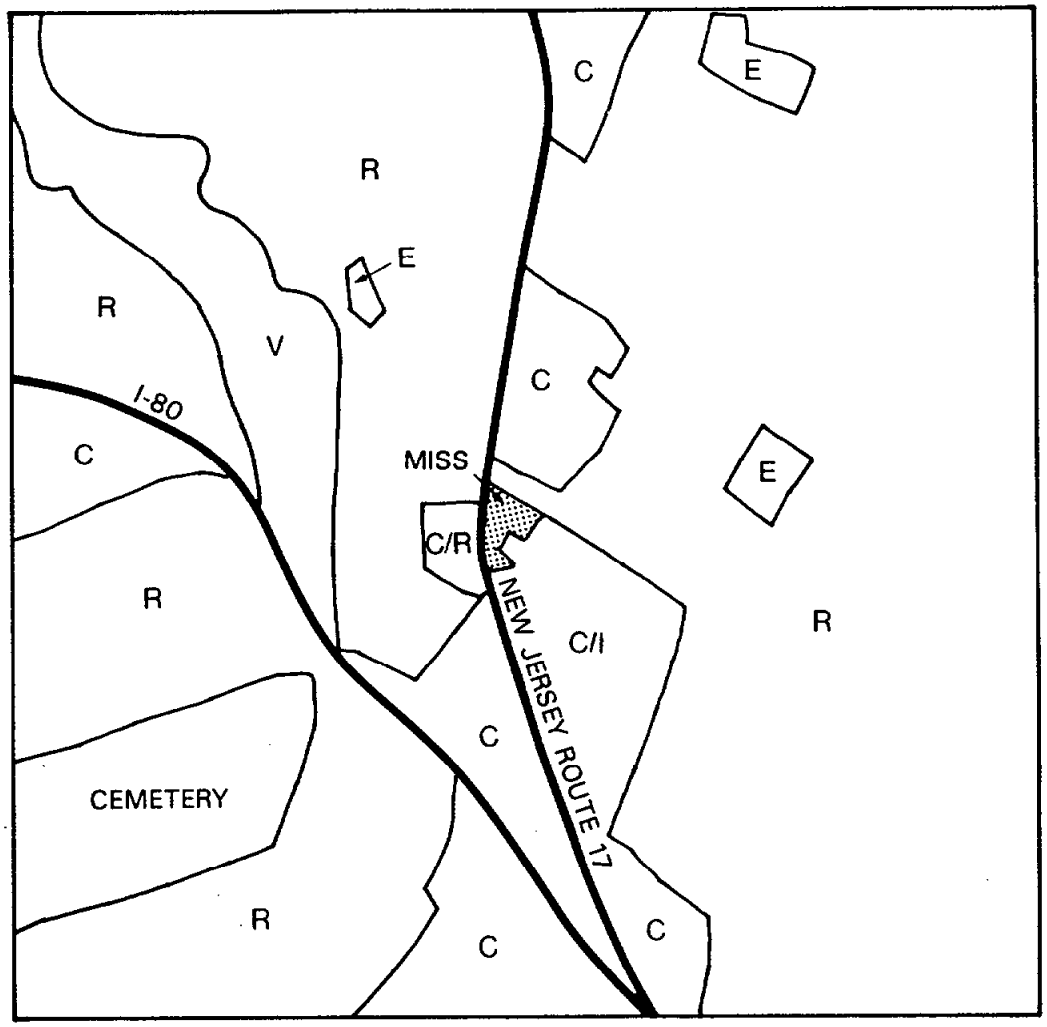

FIGURE 1-5 GENERALIZED LAND USE IN THE VICINITY OF THE MISS

In 1954, the Atomic Energy Commission (AEC) issued License R-103 to the Maywood Chemical Works, thereby allowing it to continue to possess, process, manufacture, and distribute radioactive materials under the auspices of the Atomic Energy Act of 1954 (Ref. 8). Maywood Chemical Works was sold to the Stepan Company in 1959.

In 1961, the Stepan Company was issued an AEC radioactive materials license (STC-130) (Ref. 8). Based on AEC inspections and information related to the Ballod property on the west side of Route 17, the Stepan Company agreed to take remedial action. The cleanup was begun in 1963. In 1966, 6,392 m^3 (8,360 yd^3) of waste was removed from the area east of Route 17 and buried on-site at Burial Site No. 1, which is now overlain by grass. In 1967, 1,570 m^3 (2,053 yd^3) of waste was removed from the same general area and buried on-site at Burial Site No. 2, which is now a parking lot. In 1968 the Stepan Company obtained permission from the AEC to transfer an additional 6,576 m^3 (8,600 yd^3) of waste from the south end of the Ballod property and bury it on-site at Burial Site No. 3, an area where a warehouse was later built (Ref. 8). Figure 1-6 shows the approximate locations of these burial sites. An area formerly occupied by thorium processing facilities is known to be contaminated (Ref. 3).

At the request of the Stepan Company, a radiological survey of the south end of the Ballod property west of Route 17 was conducted by the AEC in 1968. Based on the findings of that survey, clearance was granted for release of the property (Ref. 8). At the time of the survey, the AEC was not aware that unexcavated waste materials were present in the northeast corner of the property. In 1968 this portion of the Stepan Company property was sold to a private citizen, who later sold it to the current owners, Ballod and Associates (Ref. 8).

In 1980 the U.S. Nuclear Regulatory Commission (NRC) was notified that elevated readings were obtained on the Ballod and Associates property (Ref. 8). This information prompted the NRC to request a

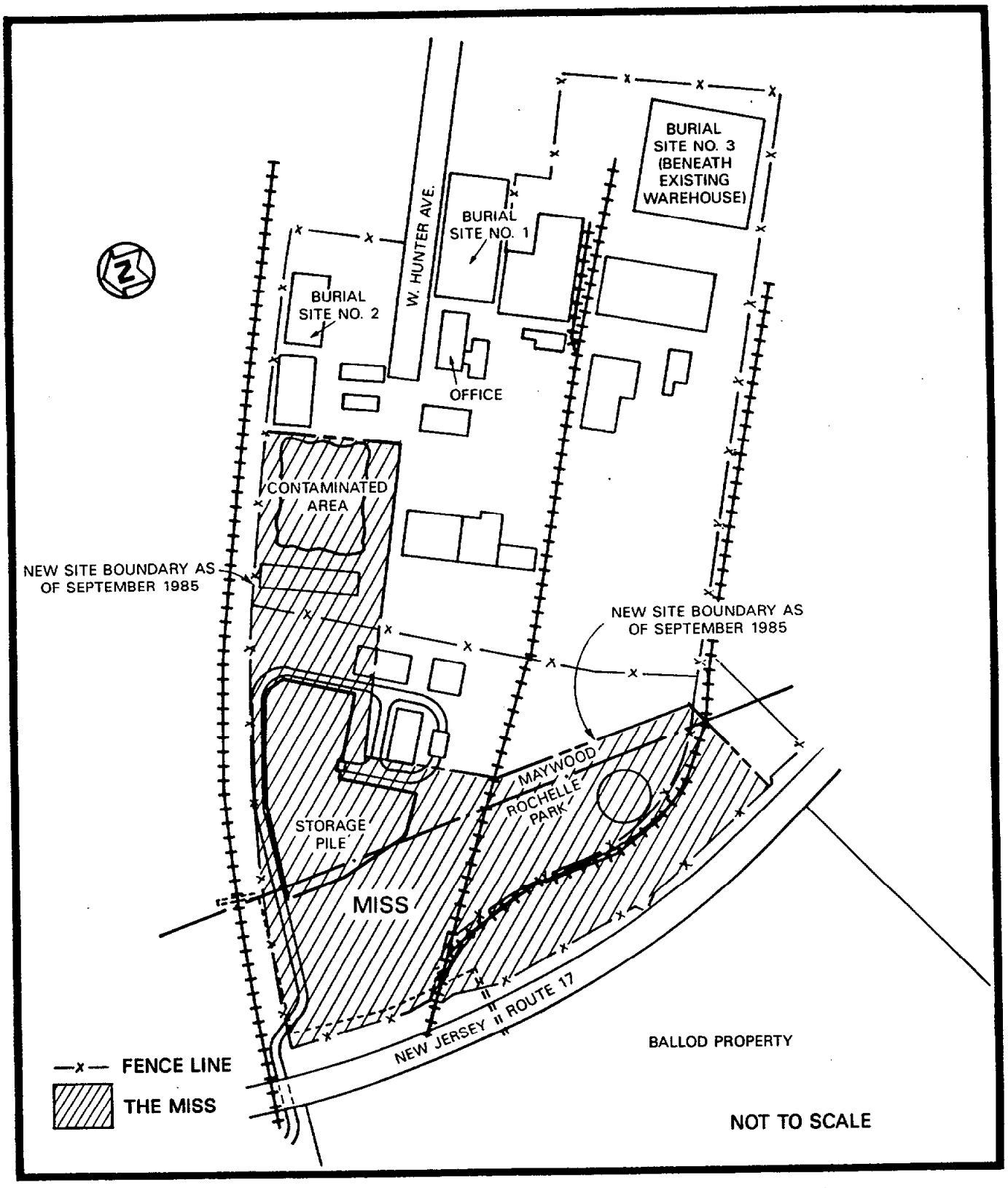

FIGURE 1-6 BURIAL SITE LOCATIONS ON THE STEPAN COMPANY PROPERTY

comprehensive survey to assess the radiological condition of the property. The survey was performed by Oak Ridge Associated Universities (ORAU) with the assistance of a representative from the Region I office of the NRC in February 1981 (Ref. 2).

The NRC also requested that an aerial radiological survey of the Stepan Company site, the Ballod and Associates property, and the surrounding area be conducted. This survey, which was conducted by EG&G in January 1981, resulted in the discovery of other anomalies (readings distinctly higher than those of surrounding areas) (Ref. 9). Elevated gamma readings (greater than the local background level) were detected directly over the Stepan Company chemical plant, as well as immediately to the west and south of the plant. Two other points of elevated background gamma radiation were detected approximately 0.8 km (0.5 mi) from the center of the plant: one to the northeast and the other to the south. Followup ground surveys were performed to determine the nature of these anomalies. These surveys identified contaminated residential properties on Davison and Latham streets.

In 1984, Oak Ridge National Laboratory (ORNL) surveyed the Lodi area with a mobile van (Ref. 10). Eight residential properties were found to be contaminated with thorium-232; additional properties were found to be contaminated with radium-226 and uranium. The presence of radium-226 and uranium appears to be associated with the presence of natural uranium ore.

In 1984, DOE negotiated an agreement with the Stepan Company for access to a 4.7-ha (11.7-acre) portion of the Stepan Company property on which to establish the MISS, pending execution of an agreement to transfer ownership of the site to DOE. Development of the storage site commenced, and contaminated materials removed from 17 vicinity properties in Maywood and Rochelle Park were brought to the site in 1984. In 1985, remedial action was conducted at eight residential properties in the Borough of Lodi and at the Ballod property in Rochelle Park. In September 1985, ownership of the MISS property was transferred to DOE.

Radiological characterization surveys were conducted in 1986 on the Sears property and adjoining commercial properties southeast of the MISS; on the New York, Susquehanna and Western Railroad property adjoining the northern boundary of the MISS; on a portion of Route 17; and on the north Ballod property. Radiological surveys of the following Lodi properties were also conducted in 1986: 1 commercial, 1 state-owned, 26 residential, and 1 municipal. Remedial action is planned for certain of these properties.

In 1987, several radiological surveys were conducted at residential, commercial, and municipal properties in Lodi. In addition, in late 1987, a layer of clean fill material was placed along the MISS boundary to reduce elevated levels of radon and external gamma radiation resulting from disturbance of the soil cover during the 1986 characterization activities. Also in 1987, several groundwater monitoring wells were installed on the Stepan property and adjacent properties to monitor the shallow groundwater system and deep aquifer. These wells, along with those added in the summer of 1988 on the MISS, the railroad, and Grove Street properties, are used to provide data on groundwater flow and quality. Data from the 1988 wells will be presented in the 1989 monitoring report.

There are no continuing commercial or industrial activities at the MISS; therefore, no radioactive effluents exist at the site.

1.3 HYDROGEOLOGICAL CHARACTERISTICS OF THE SITE

This section presents data on the hydrogeology at the MISS. The data and interpretations are based on groundwater levels measured in calendar year 1988. Groundwater monitoring wells (Figure 1-7) were installed at the MISS site in late 1984 through early 1985 (Ref. 11). Additional monitoring wells were installed during 1987 and 1988 in the properties surrounding the MISS (Ref. 12). A summary of construction information for wells sampled for this report is shown in Table 1-1. An example of construction details from Ref. 11 is included as Appendix E.

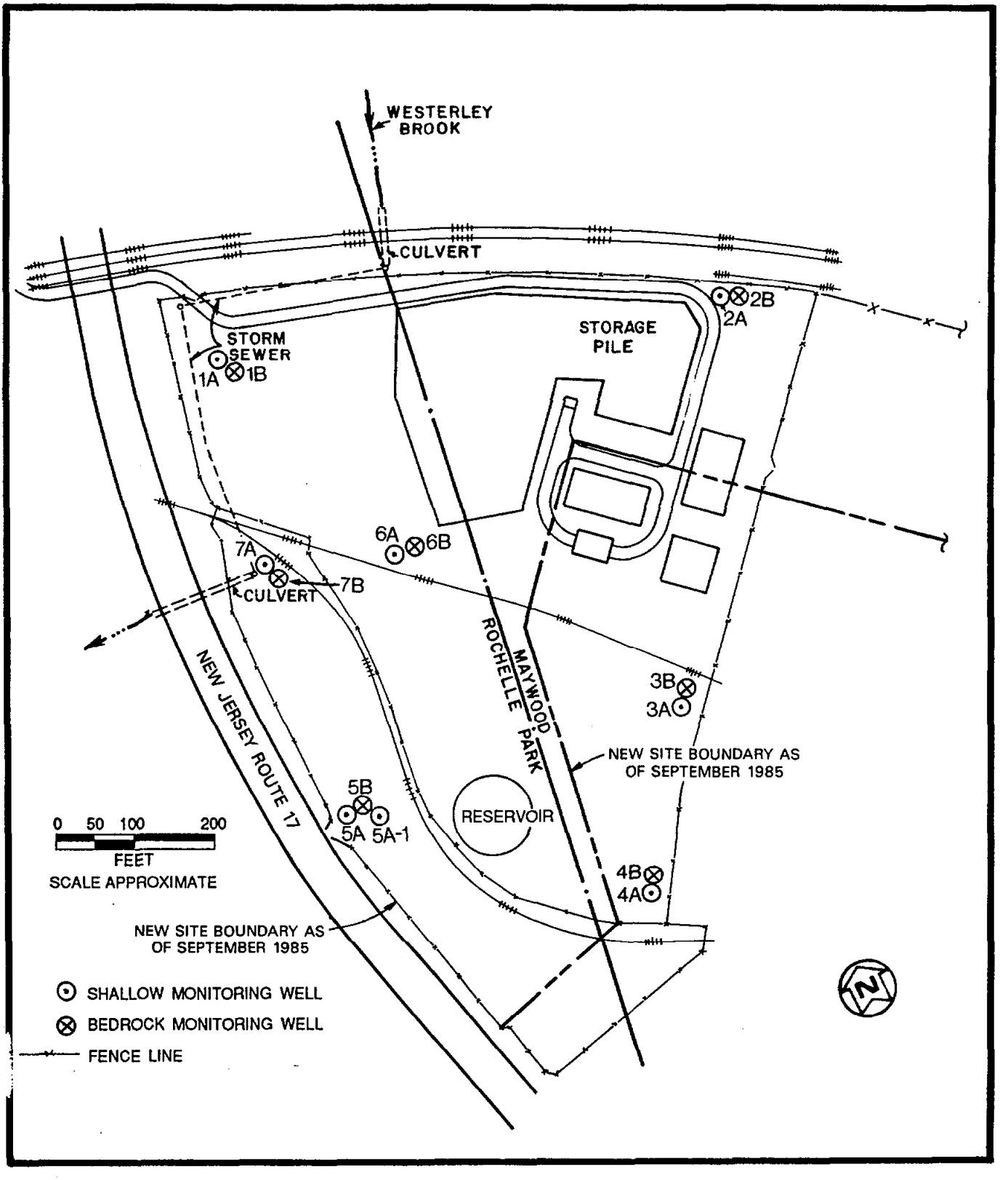

FIGURE 1-7 LOCATIONS OF GROUNDWATER MONITORING WELLS AT THE MISS

TABLE 1-1

MISS SHALLOW AND DEEP MONITORING WELL CONSTRUCTION SUMMARY

Well Number[a]	Completion Date	Total Depth [m (ft)]	Monitored Interval Below Ground [m-m (ft-ft)]	Construction Material
MISS-1A	Nov. 1984	3.7 (12.0)	1.2-3.5 (4.0-11.4)	PVC[b]
MISS-1B	Nov. 1984	16.3 (53.5)	7.0-16.3 (23.0-53.5);[c] Open hole	Steel
MISS-2A	Oct. 1984	6.1 (20.0)	1.5-5.7 (5.0-18.9)	PVC
MISS-2B	Nov. 1984	17.8 (58.5)	8.7-17.8 (28.5-58.5);[c] Open hole	Steel
MISS-3A	Oct. 1984	4.6 (15.0)	1.5-3.9 (5.0-12.7)	PVC
MISS-3B	Nov. 1984	15.2 (50.0)	6.1-15.2 (20.0-50.0);[c] Open hole	Steel
MISS-4A	Oct. 1984	3.0 (10.0)	1.1-2.9 (3.8-9.7)	PVC
MISS-4B	Nov. 1984	14.3 (47.0)	5.2-14.3 (17.0-47.0);[c] Open hole	Steel
MISS-5A	Nov. 1984	4.6 (15.0)	3.0-4.5 (10.0-14.6)	PVC
MISS-5A1	Nov. 1984	2.4 (8.0)	0.8-2.4 (2.5-8.0)	PVC
MISS-5B	Nov. 1984	16.8 (55.0)	7.6-16.8 (25.0-55.0);[c] Open hole	Steel
MISS-6A	Oct. 1984	4.9 (16.0)	1.5-4.6 (5.0-15.2)	PVC
MISS-6B	Nov. 1984	16.2 (53.0)	7.0-16.2 (23.0-53.0);[c] Open hole	Steel
MISS-7A	Nov. 1984	3.5 (11.5)	0.8-2.9 (2.5-9.6)	PVC
MISS-7B	Nov. 1984	14.9 (49.0)	5.8-14.9 (19.0-49.0);[c] Open hole	Steel
B38W04B[d]	Sept. 1987	11.1 (36.3)	4.0-8.4 (13.2-27.7)	Stainless Steel

[a]Shallow wells are designed with an "A"; deep wells are designated with a "B".

[b]PVC - polyvinyl chloride.

[c]Carbon steel casing extends through overburden and 2 ft into bedrock; monitored interval is an 8-cm- (3.0-in.-) diameter open hole in bedrock.

[d]Located at Stepan Company, approximately 61 m (200 ft) east of MISS wells 3A and 3B.

The two groundwater systems monitored are designated "shallow" and "bedrock" (Ref. 11). Monitoring wells installed in the shallow system are referred to as "A" wells, and those in the bedrock system are referred to as "B" wells. Further background information on site geology, hydrogeology, and well installation methods can be found in Refs. 11 and 12.

Groundwater levels at the MISS site were measured with an electric downhole probe water level indicator. In 1988, water level measurements at all of the wells were taken weekly.

1.3.1 Shallow Groundwater System

The potentiometric surface of the shallow groundwater system is approximately 1.2 to 3.7 m (4 to 12 ft) below ground surface. (Potentiometric surface is defined as the level to which water will rise in tightly cased wells. Delineation of the potentiometric surface of an aquifer indicates groundwater slope and flow direction.) Wells in this zone are screened in unconsolidated materials at depths of 0.9 to 5.2 m (3 to 17 ft). Groundwater level measurements taken in 1988 for each well are shown as hydrographs (Figures 1-8 and 1-9). No hydrograph is given for Well 1A because it was dry throughout 1988.

Precipitation records were not available for the MISS site, but the records of precipitation collected at the Middlesex Sampling Plant (MSP), which is located approximately 48.3 km (30 mi) southwest, are presented with the hydrographs in Figures 1-8 and 1-9.

The hydrographs for the shallow groundwater system show seasonal fluctuations in groundwater levels from well to well. During the winter months, groundwater levels change slowly or not at all; they did not seem to react to the precipitation except in March. This behavior may have been because the ground was frozen or precipitation was in the form of snow, with a brief thaw in March. From late May through December, the water levels generally reacted to heavy precipitation by rising and then falling over a period of 3

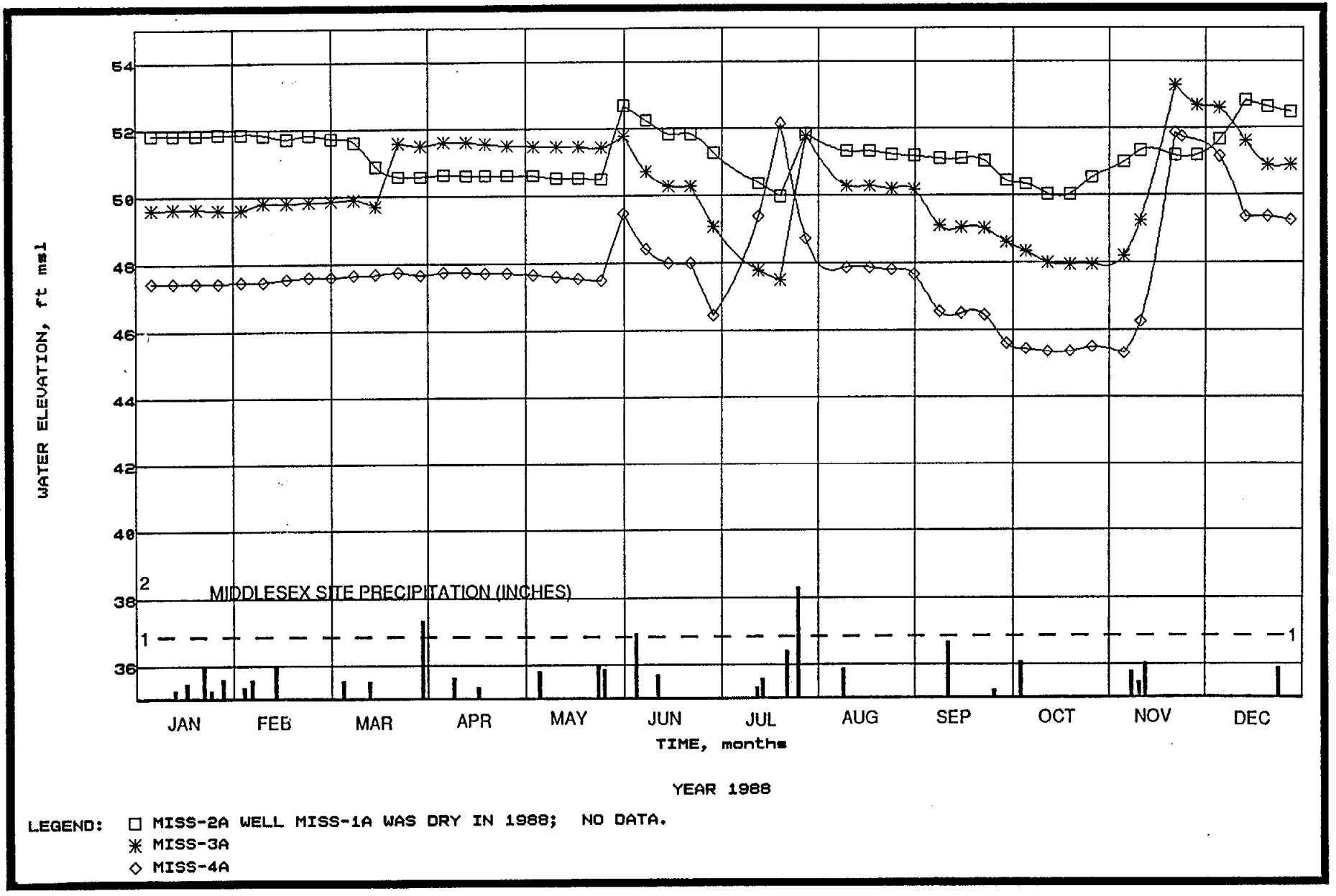

FIGURE 1-8 HYDROGRAPHS OF MISS SHALLOW WELLS 2A, 3A, AND 4A

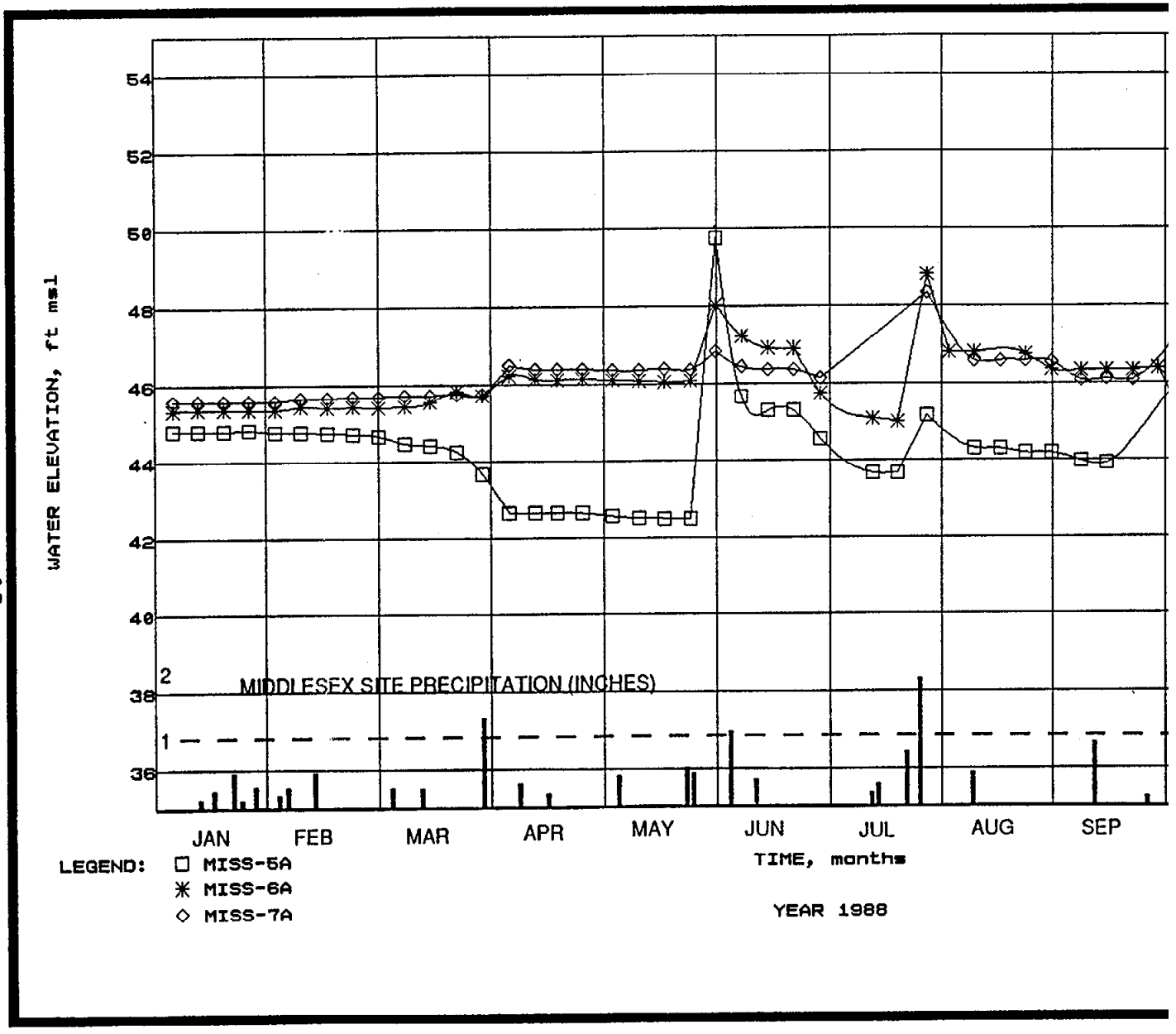

FIGURE 1-9 HYDROGRAPHS OF MISS SHALLOW WEL 5A, 6A, AND 7A

to 4 weeks. When the wells did not show reaction to precipitation, it may have been because the precipitation at MSP differed from that at the MISS.

The correlation of water level patterns between the wells is fair. The behavior of water levels in Wells 2A and 5A is least like those of the other shallow wells. The variations of water level trends for the wells may be due to variations in the hydraulic conductivity of the screened intervals.

The slope and flow direction of the shallow groundwater system were determined using shallow well potentiometric surface maps. Two of these maps (Figures 1-10 and 1-11), one prepared using March data and the other prepared using August data, show the minimal seasonal variation in the shallow groundwater system. The general flow direction is from east to west for both dates. The contours suggest that the potentiometric surface is approximately parallel to the regional surface topography (Ref. 12, p. 32). The slope for both potentiometric surfaces is similar (0.01).

1.3.2 Bedrock Groundwater System

The potentiometric surface of the bedrock groundwater system is from 2.1 to 5.2 m (7 to 17 ft) below the ground surface. The bedrock wells are open holes (no screen or filter pack), below a steel surface casing set through the overburden, emplaced with a cement grout seal in the top of the Brunswick formation and have depths of 5.2 to 18 m (17 to 59 ft).

Hydrographs of the bedrock groundwater system (Figures 1-12 and 1-13) show a seasonal variation similar to that of the shallow groundwater system, but there is better correlation of water levels from well to well. Precipitation records for the MSP site are also shown with the hydrographs in Figures 1-12 and 1-13.

Like those of the shallow groundwater system, the bedrock groundwater system water levels show little fluctuation through the

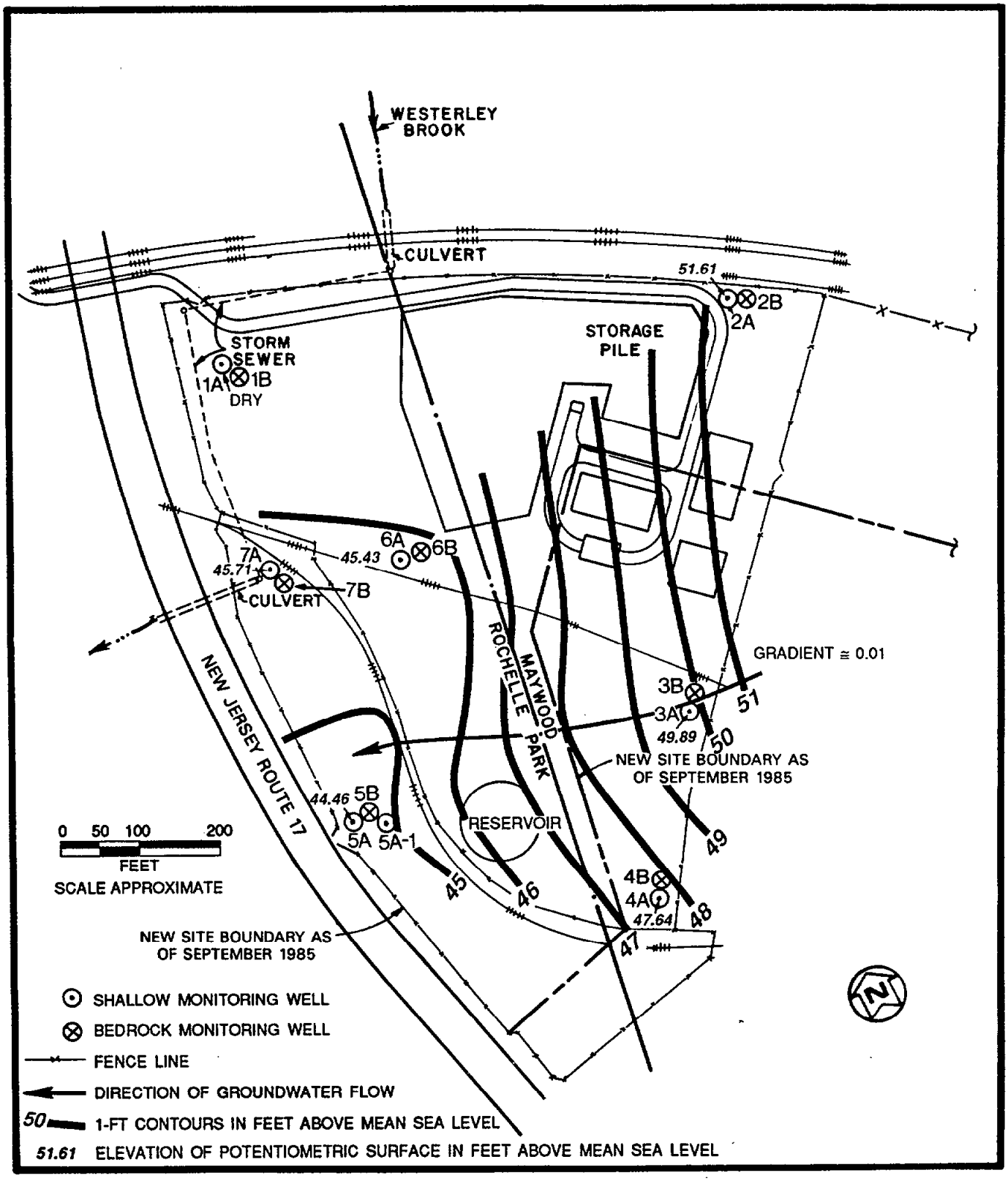

FIGURE 1-10 POTENTIOMETRIC SURFACE MAP FOR MISS SHALLOW GROUNDWATER SYSTEM (3/9/88)

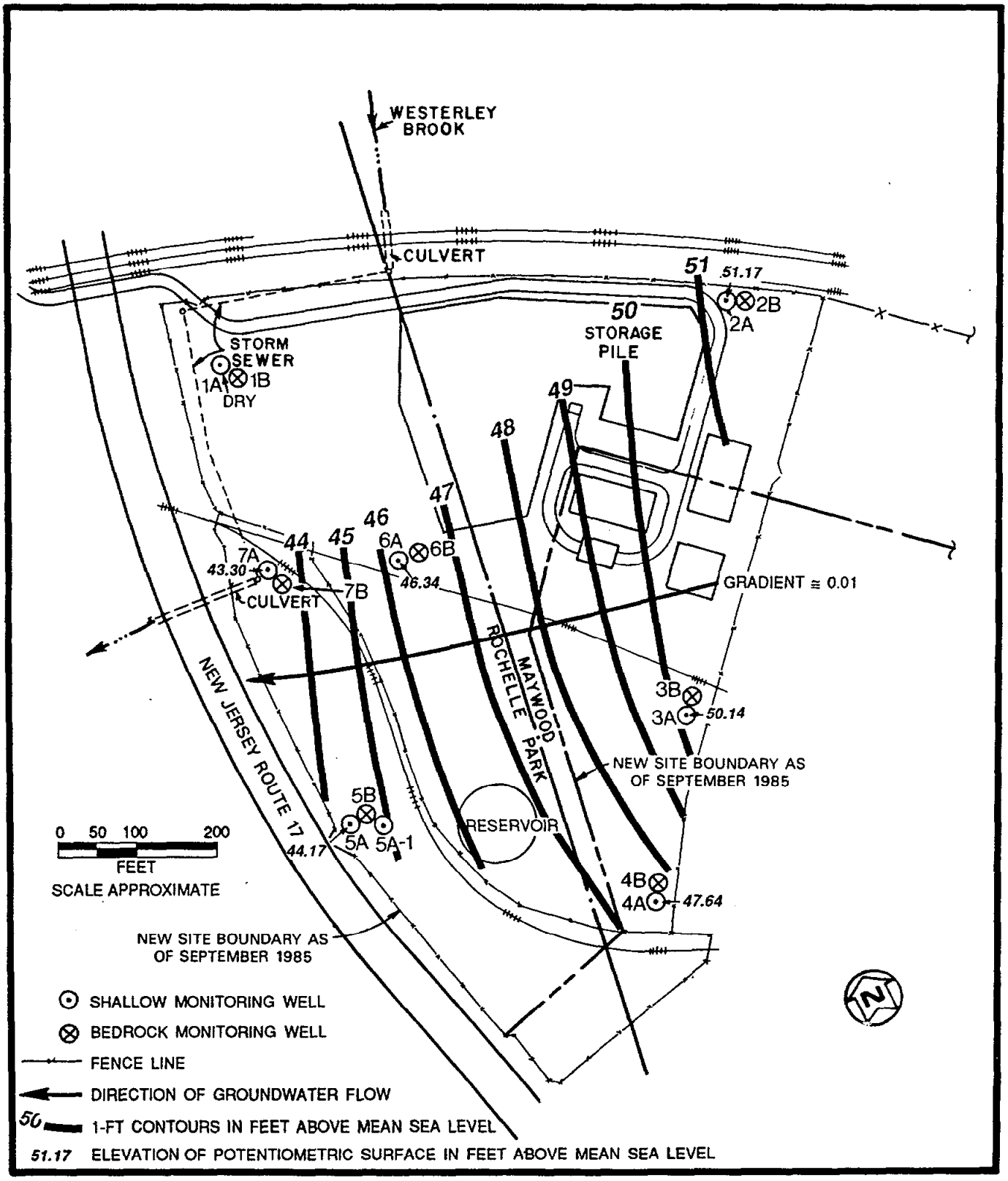

FIGURE 1-11 POTENTIOMETRIC SURFACE MAP FOR MISS SHALLOW GROUNDWATER SYSTEM (8/31/88)

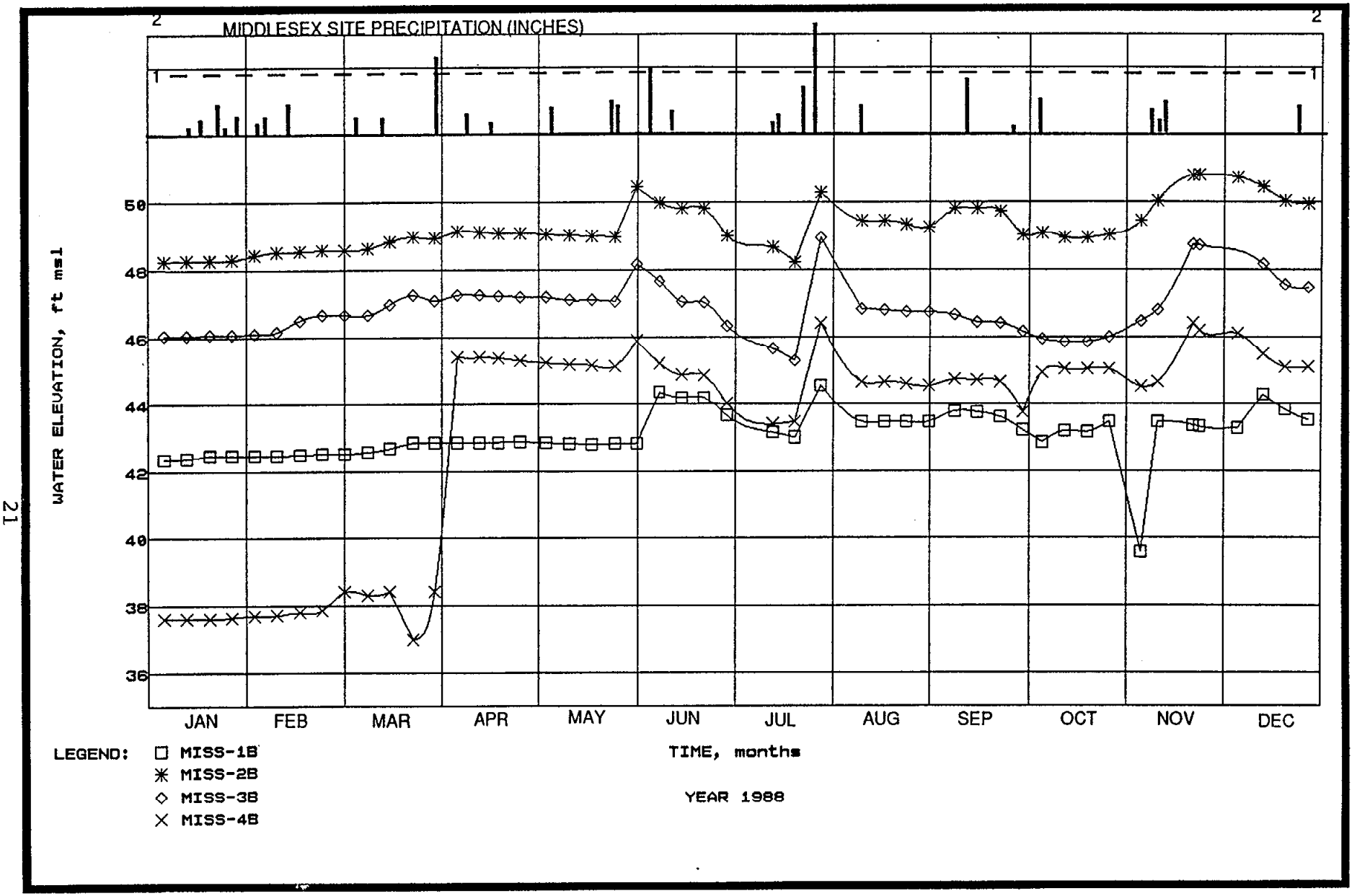

FIGURE 1-12 HYDROGRAPHS OF MISS BEDROCK WELLS 1B, 2B, 3B, AND 4B

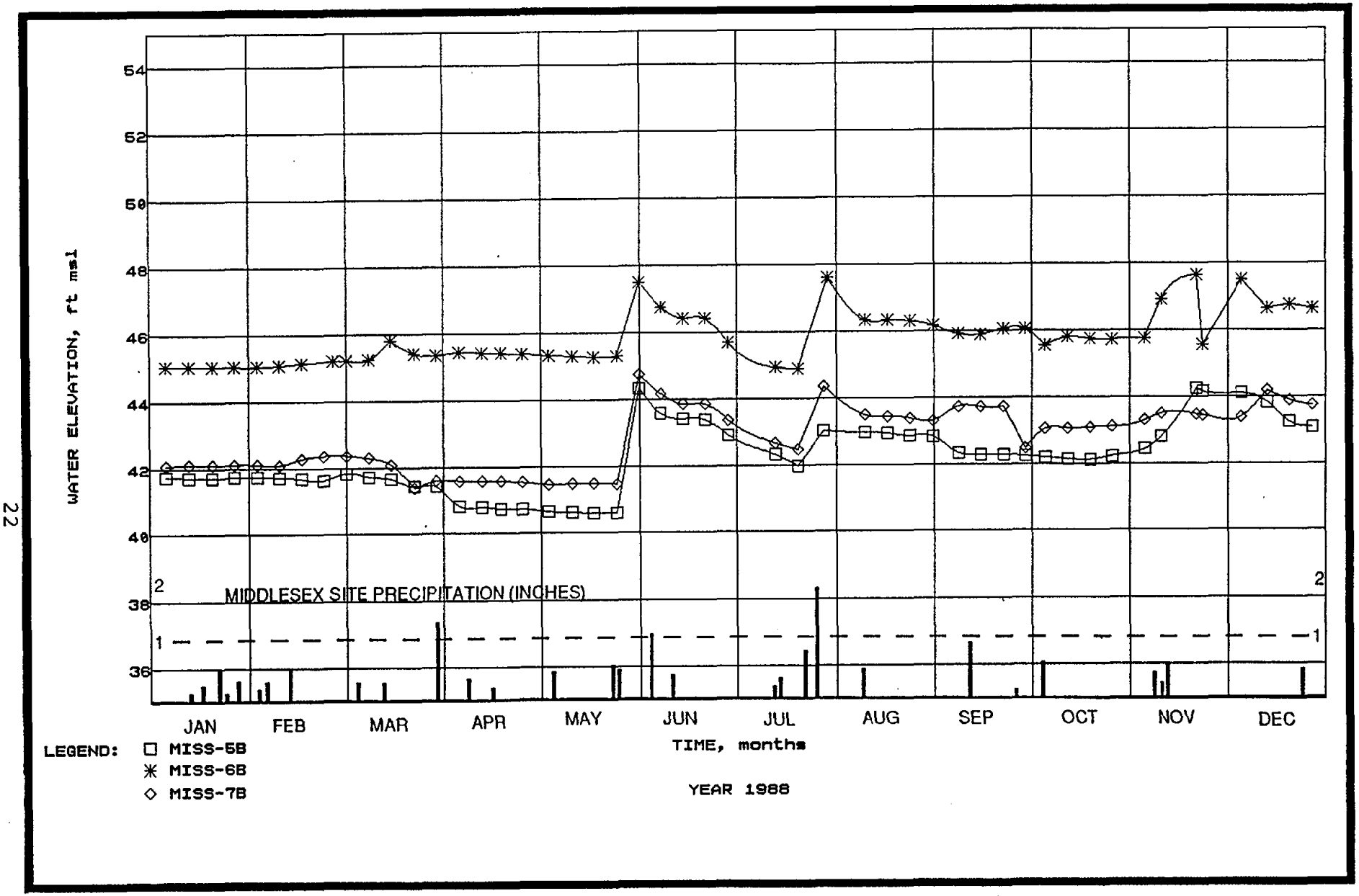

FIGURE 1-13 HYDROGRAPHS OF MISS BEDROCK WELLS 5B, 6B, AND 7B

winter months when the ground is presumably frozen. Some response of the water levels to precipitation events can be seen after late May. Well 4B displayed a rapid rise in water level during the presumed late March thaw. The effect of this change in water level becomes evident in comparing the difference in slope and flow direction on the potentiometric surface maps for dates before and after the event (Figures 1-14 and 1-15).

The slopes and flow directions for the bedrock groundwater system were determined from potentiometric surface maps (Figures 1-14 and 1-15), which show little or no seasonal variation in the slopes and flow directions. Both maps show the groundwater flow direction from Well 2B to the west and to the south, with a slope of approximately 0.01. Figure 1-14 shows the effect of the low winter water levels in Well 4B. The resulting slope of 0.03 between 4B and 3B for that date does not change the general flow direction trend.

1.3.3 Discussion

The shallow and bedrock groundwater systems at the MISS site appear to have consistent slopes and flow directions throughout the year.

Potentiometric surface elevations, slopes, and flow directions for the two groundwater systems vary only slightly. Sufficient head differences exist between the shallow and bedrock well pairs to continue to monitor and describe the groundwater occurrence at the MISS site as two groundwater systems.

1.3.4 Conclusions

- The potentiometric surface of the shallow groundwater system is consistently 0.9 to 5.2 m (3 to 17 ft) below ground surface, depending upon location on the site. Groundwater flows from east to west with a slope of 0.01.
- The potentiometric surface of the bedrock groundwater system is consistently 2.1 to 5.2 m (7 to 17 ft) below ground surface, depending upon location on the site. Groundwater flow is away from the Well-2B area to the west and south with a slope of 0.01.

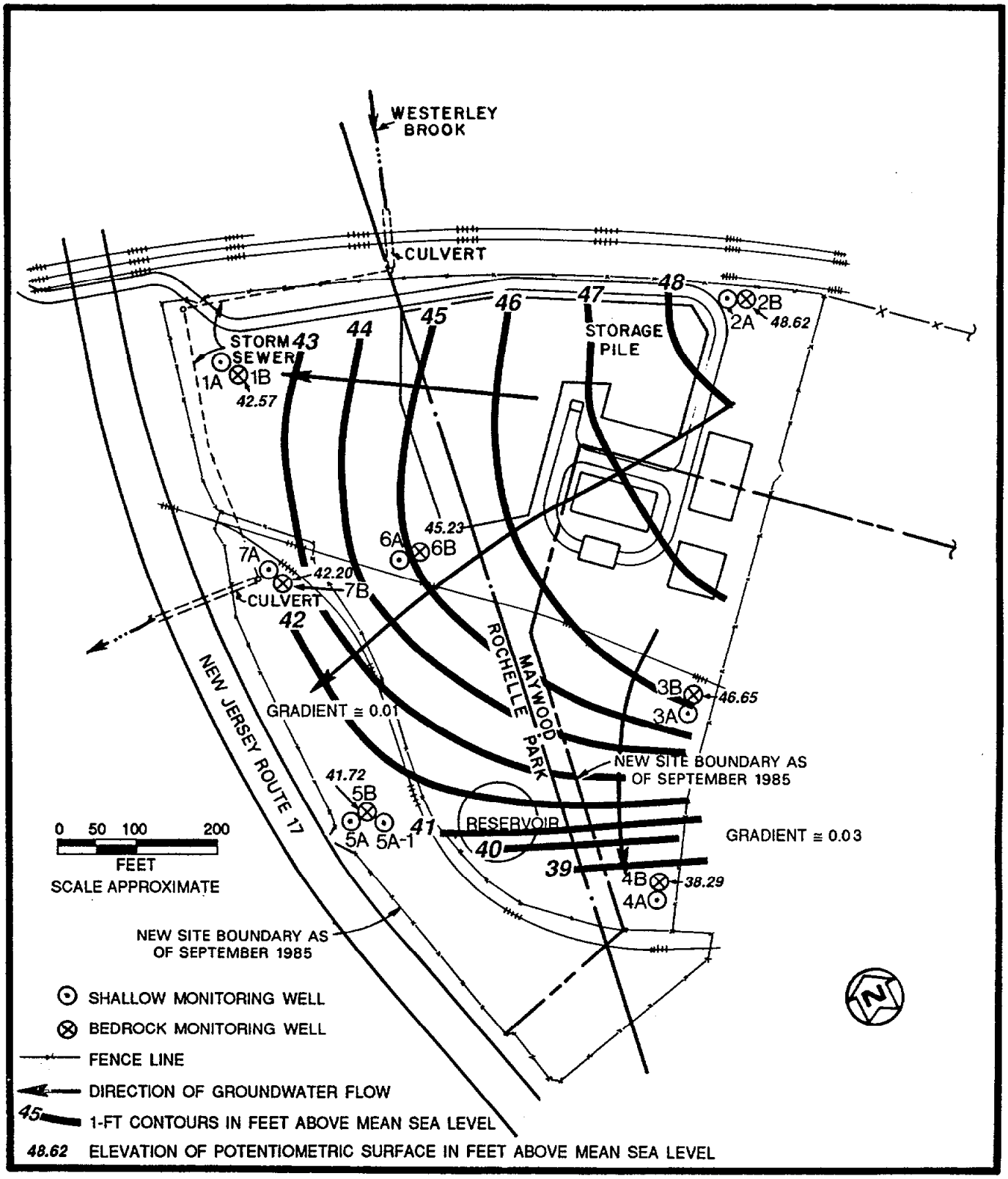

FIGURE 1-14 POTENTIOMETRIC SURFACE MAP OF THE MISS BEDROCK GROUNDWATER SYSTEM (3/9/88)

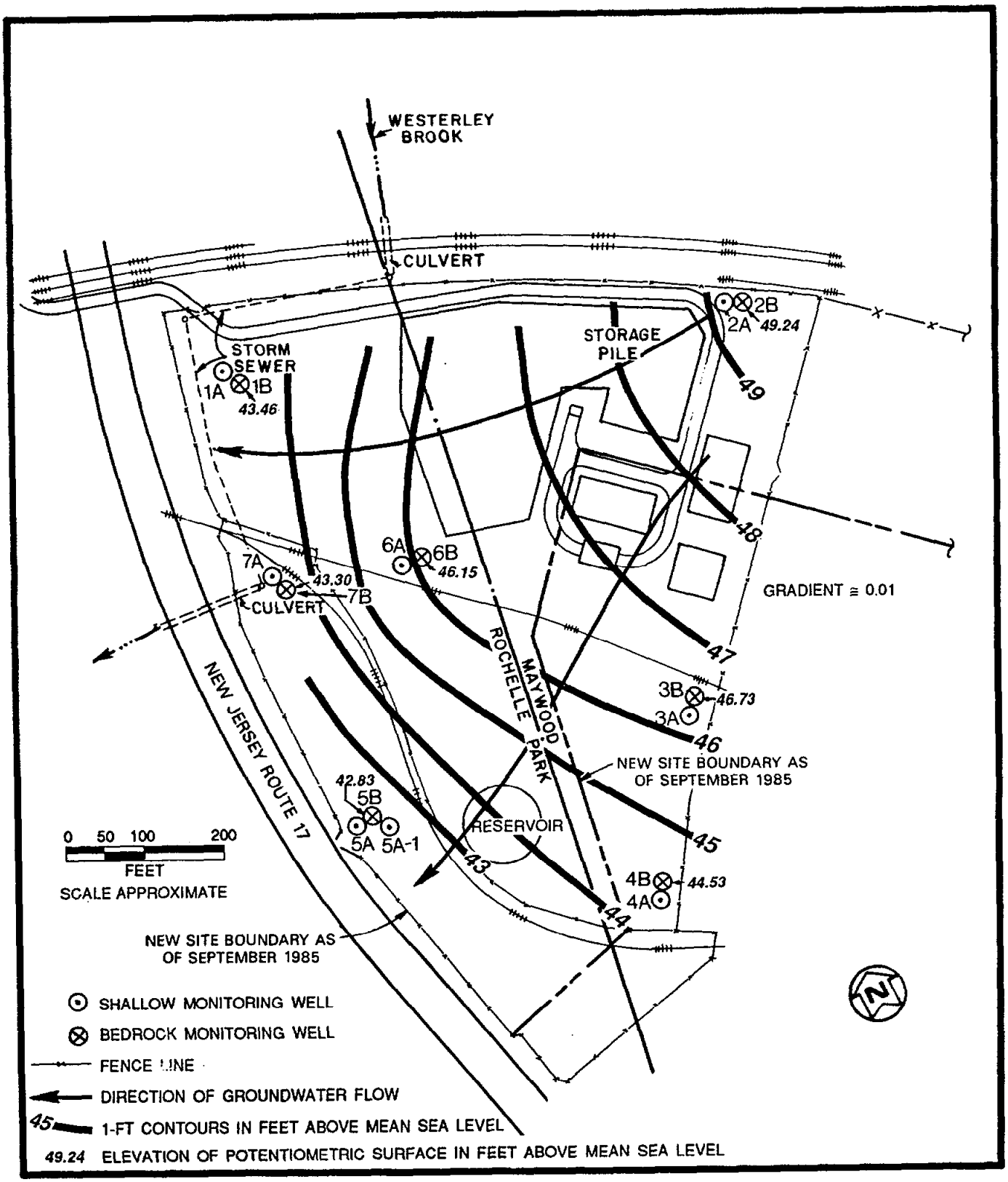

FIGURE 1-15 POTENTIOMETRIC SURFACE MAP OF THE MISS BEDROCK GROUNDWATER SYSTEM (8/31/88)

- Based on potentiometric surface elevation differences between wells in pairs and gradient direction differences between the two systems, the MISS bedrock groundwater system is apparently separated from the shallow system.

2.0 SUMMARY OF MONITORING RESULTS

The environmental monitoring program at the MISS, which began in 1984, was continued during 1988. The program includes sampling and analysis of air, water, and sediments and measurement of external gamma radiation levels to verify compliance with the DOE radiation protection standard of 100 mrem/yr (Ref. 13). The potential radiation dose that might be received by the maximally exposed individual was calculated to determine the degree of compliance with the radiation protection standard.

Annual average concentrations of radon (including background) ranged from 4×10^{-10} to 7.4×10^{-9} μCi/ml (0.4 to 7.4 pCi/l) (Table 3-1). The average background radon concentration for the MISS was 3×10^{-10} μCi/ml (0.3 pCi/l). Thoron concentrations (including background) ranged from 1×10^{-10} μCi/ml (0.1 pCi/l) to 6.4×10^{-9} μCi/ml (6.4 pCi/l) (Table 3-1). The average background thoron concentration for the MISS was less than the minimum detectable limit. A detailed discussion of 1988 radon and thoron concentrations is provided in Subsection 3.1.

Radon and thoron concentrations at the MISS generally decreased from 1984 to 1985 and increased again in 1987. Concentrations of both radionuclides decreased slightly in 1988, but the decrease is not statistically significant (see Subsection 3.6.1) (Refs. 14-17). The 1987 rise in radon and thoron levels coincided with a drought in the northeastern United States and is thought to result from these dry conditions. A similar rise occurred at background monitoring stations in 1987. Since the dry conditions moderated in 1988, a minor decrease in radon and thoron levels occurred during that year.

Annual average external gamma radiation levels measured at the MISS ranged from 16 to 317 mR/yr above background (Table 3-2). The maximum was measured in an area of known contamination with no

significant occupancy factor (Ref. 3). These rates may be compared with the external gamma radiation levels from natural radiation in the vicinity of the MISS, which averaged 78 mR/yr. External radiation levels are discussed in Subsection 3.2. Average external gamma radiation levels decreased sharply from 1984 to 1988 (see Subsection 3.6.2) (Refs. 14 and 15).

In surface waters (Subsection 3.3.1), measured concentrations of uranium in 1988 were equal to or slightly higher than concentrations measured upstream of the site. Concentrations of radium-226 and thorium-232 were equal to or slightly below those measured at the upstream location. Concentrations of uranium, thorium-232, and radium-226 remained stable from 1984 through 1988.

In groundwater at the MISS (Subsection 3.3.2), the highest annual average concentration of uranium in 1988 was 8.4×10^{-9} μCi/ml (8.4 pCi/l). The highest annual average concentration of thorium-232 was 1.6×10^{-9} μCi/ml (1.6 pCi/l); for radium-226 it was 2.8×10^{-9} μCi/ml (2.8 pCi/l). Concentrations of radionuclides in surface water and groundwater may be compared with the levels of radioactivity in the commonly consumed liquids listed in Appendix D.

Concentrations of uranium, radium-226, and thorium-232 in groundwater have remained essentially unchanged since groundwater monitoring began in 1985 (see Subsection 3.6.4) (Ref. 15).

The highest annual average concentrations of total uranium, radium-226, and thorium-232 in sediments (Subsection 3.4) were 1.6 pCi/g, 0.5 pCi/g, and 0.4 pCi/g, respectively. Average concentrations of these radionuclides at the MISS may be compared with the levels of radioactivity in phosphate fertilizers listed in Appendix D.

Calculations were made of the radiological dose received by a hypothetical maximally exposed individual (Subsection 3.5.1). This hypothetical individual is one who is assumed to be adjacent to the

site and who, when all potential routes of exposure are considered, receives the greatest dose. Exposure to external gamma radiation was the exposure pathway quantified because it is the only feasibly significant pathway. The maximum exposure this individual would receive is approximately 1 mR/yr above background. Because 1 mR is approximately equivalent to 1 mrem, this exposure is approximately equivalent to 1 percent of the DOE radiation protection standard.

The cumulative dose to the population within an 80-km (50-mi) radius of the MISS that results from radioactive materials present at the site is indistinguishable from the dose that the same population receives from naturally occurring radioactive sources.

Analytical results for chemical sampling are summarized in Section 4.1.

Results of the 1988 monitoring show that the MISS is in compliance with the DOE radiation protection standard.

3.0 DATA COLLECTION, ANALYSIS, AND EVALUATION

This section provides the results of 1988 environmental monitoring at the MISS (Ref. 18) and includes descriptions of the sampling, monitoring, and analytical procedures. Calculations were made to determine the estimated maximum possible radiation dose based on environmental conditions, measurements recorded, and evaluation of potential exposure pathways.

Data are presented in summary tables by sample category. Summaries of data include minimum and maximum values recorded, number of data points collected, and average annual values. The average value for a given sampling location is the average of individual results for that sampling location. Individual sources of error (e.g., analytical error, sampling error) were not estimated. The "less than" (<) notation is used to denote sample analysis results that are below the limit of sensitivity of the analytical method, based on a statistical analysis of parameters. In computing the averages, where no more than one value is less than the limit of sensitivity of the analytical method, that value is considered to be equal to the limit of sensitivity, and the average value is reported without the "less than" notation.

During 1988, the routine environmental monitoring program for the MISS included measurement of radon and thoron concentrations and of external gamma radiation levels, sampling of surface water and sediments, and sampling of groundwater monitoring wells on the site.

Tables 3-9 through 3-12 show trends in radon and thoron concentrations, external gamma radiation levels, and radionuclide concentrations in surface water and groundwater at the MISS. These tables list annual averages for each monitoring location for 1984 through 1988 to allow for comparisons of data and identification of trends in monitoring results (see Subsection 3.6).

3.1 RADON MONITORING

Two forms of radon are present at the MISS. The more common form, radon-222, is part of the natural uranium decay chain. The other form, radon-220, is part of the natural thorium decay chain. To distinguish between these two forms of radon, the term thoron (the common name for radon-220) will be used in this report.

Radon detectors are maintained on-site near the storage pile and at approximately equal intervals along the site perimeter. One of the detectors is designated for quality control. The locations of the radon monitors are shown in Figure 3-1.

Radon and thoron concentrations are determined using monitors purchased from the Terradex Corporation. These devices (Terradex Type F and Type M Track-Etch) consist of an alpha-sensitive film contained in a small plastic cup covered by a membrane through which radon and/or thoron can diffuse. Radon and/or thoron will diffuse through the membrane (in or out of the cup) when a concentration gradient exists; therefore, they will equilibrate with radon and/or thoron in the outside air. Alpha particles from the radioactive decay of radon and/or thoron and their daughters in the cup create tiny tracks when they collide with the film. When returned to Terradex for processing, the films are placed in a caustic etching solution to enlarge the tracks. Under strong magnification, the tracks can be counted. The number of tracks per unit area (i.e., tracks/mm^2) is related through calibration to the concentration of thoron and/or radon in air. Fresh Track-Etch monitors are obtained from Terradex each quarter. Site personnel place these units in each sampling location and return the exposed monitors to Terradex for analysis.

Table 3-1 lists thoron and radon concentrations (including background) recorded at the MISS in 1988. Annual average concentrations of thoron ranged from 1×10^{-10} µCi/ml (0.1 pCi/l) to 6.4×10^{-9} µCi/ml (6.4 pCi/l). The average background

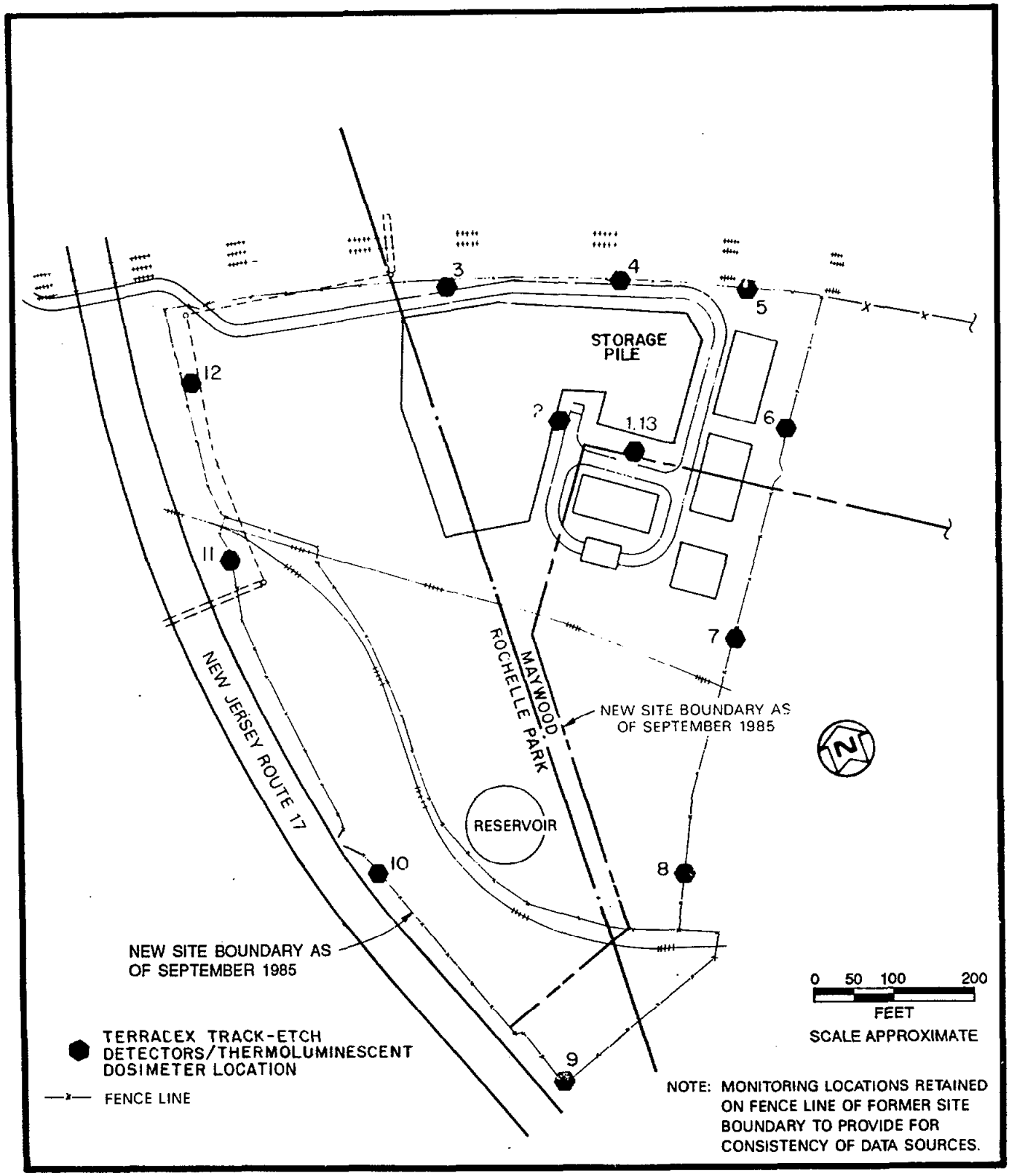

FIGURE 3-1 RADON AND EXTERNAL GAMMA RADIATION MONITORING LOCATIONS AT THE MISS

TABLE 3-1

CONCENTRATIONS OF THORON AND RADON AT THE MISS, 1988

Sampling Location[a]	Number of Measurements	Concentration (10^{-9} µCi/ml)[b,c] Minimum	Maximum	Average
Thoron (Rn-220)				
1[d]	3[d]	<MDL[e]	0.6	0.4
2	4	0.1	0.7	0.5
3	4	<MDL	0.4	0.2
4	4	<MDL	5.1	1.4
5	4	0.5	11.2	6.4
6	4	<MDL	2.6	1.0
7	4	<MDL	0.9	0.3
8	4	<MDL	0.5	0.1
9	4	<MDL	0.6	0.2
10	4	0.1	0.9	0.5
11	4	0.2	0.5	0.4
12	4	<MDL	1.6	0.6
13[f]	4	<MDL	0.2	0.1
Background[g]				
14[h]	4	<MDL	<MDL	<MDL
Radon (Rn-222)				
1	4	0.3	1.1	0.6
2	4	0.5	1.2	0.9
3	4	0.3	0.9	0.6
4	4	0.3	5.4	1.9
5	4	1.0	14.1	7.4
6[e]	4	0.5	3.4	1.4
7	4	0.3	1.3	0.8
8	4	0.1	0.9	0.4
9	4	0.3	0.9	0.5
10	4	0.4	1.3	1.0
11	4	0.5	1.1	0.8
12	4	0.3	1.9	1.1
13[f]	4	0.3	0.5	0.4
Background[g]				
14[h]	4	0.2	0.3	0.3

[a]Sampling locations are shown in Figure 3-1.

[b]1 x 10^{-9} µCi/ml is equivalent to 1 pCi/l.

[c]All results include background.

[d]Detector was damaged.

TABLE 3-1
(continued)

[e]No detectable thoron (radon-220), or less than minimum detectable limit (MDL).

[f]Location 13 is a quality control for Location 1.

[g]Additional background locations were established in January 1989 at the Rochelle Park Post Office and the Rochelle Park Fire Station, both of which are approximately 0.8 km (0.5 mi) south of the MISS. Data from these locations will be presented in the 1989 environmental report.

[h]Located at the Department of Health, Paterson, NJ, approximately 22 km (14 mi) west of the MISS.

concentration, as measured at Location 14 (the Department of Health in Paterson, New Jersey), was less than the minimum detectable limit.

Annual average concentrations of radon-222 ranged from 3.0×10^{-10} to 7.4×10^{-9} μCi/ml (0.3 pCi/l to 7.4 pCi/l). The 1988 average background radon concentration, as measured at Location 14, was 3.0×10^{-10} μCi/ml (0.3 pCi/l).

In January 1989, additional background locations for radon and thoron were established at the Rochelle Park Fire Station and the Rochelle Park Post Office. Data from these locations will be presented in the 1989 environmental report.

For a comparison of radon and thoron concentrations measured at the MISS from 1984-1988, see Subsection 3.6.1.

3.2 EXTERNAL GAMMA RADIATION LEVELS

External gamma radiation levels were measured at 12 monitoring locations. Ten of the locations are spaced at approximately equal intervals on the site boundary, and the other two are on the perimeter of the on-site storage pile. All locations correspond to the radon detector locations shown in Figure 3-1. Sampling locations were selected to monitor radiation levels at the site boundary and in the area adjacent to the contaminated storage pile.

External gamma radiation levels are measured using lithium fluoride (LiF) thermoluminescent dosimeters (TLDs). Beginning in 1988, the system of measurement utilizes tissue-equivalent dosimeters to provide values that are more realistic in terms of radiation dose to the tissues of the body at a depth of 1 cm. This dosimetry system offers advantages in accuracy and sensitivity that were not available with the system used previously.

Each dosimetry station contains a minimum of four dosimeters, which are exchanged after one year of accumulated exposure. For example,

a dosimeter placed in the station in October 1987 would be removed in October 1988. Each dosimeter contains five individual LiF chips (each group of which was preselected on the basis of having a reproducibility of $\pm$3 percent across a series of laboratory exposures), the responses of which are averaged. Analysis is performed by Thermo Analytical/Eberline (TMA/E). The average value is then corrected for the shielding effect of the shelter housing (approximately 8 percent) and for the effect of fade.

Fade is the loss of dose information brought about by environmental effects, primarily high summer temperatures. Fade is determined by collocating dosimeters that have been exposed to a known level of radiation (called a spike) before they are placed at a minimum of two stations, generally on the eastern and western boundaries of a site. The fade factor can be determined by subtracting the station radiation value from the fade control dosimeter followed by dividing by the known spike level. The corrected value is then converted to milliroentgen per year by dividing by the number of days of exposure and subsequently multiplying by 365 days.

Some differences in external gamma radiation values may be noted in the 1988 data in comparison with the 1987 values. The current measurement system is more sensitive to low radiation levels and more accurate in its resolution than the system used previously. Therefore, some stations that previously demonstrated no measurable external gamma radiation value in excess of background now exhibit a small measurable value. Similarly, at some other stations values are higher or lower because of the improved method of measurement, not because of deterioration of site conditions or remedial action.

Monitoring results for external gamma radiation are presented in Table 3-2. The average background radiation level for the MISS area (78 mR/yr) has been subtracted from the radiation levels in Table 3-2 to provide an estimate of the effect of the site on measured radiation levels at the site boundary. Of the seven locations (on the northern and western boundaries of the site) to which members of the public might have access, but which have no

TABLE 3-2

EXTERNAL GAMMA RADIATION LEVELS AT THE MISS, 1988

Sampling Location[a]	Number of Measurements	Radiation Level (mR/yr)[b] Minimum	Maximum	Average
Boundary				
3	4	9	36	21
4	4	61	138	109
5	4	142	238	186
6	4	69	106	85
7	4	8	27	16
8	4	13	64	30
9	3[d]	17	49	32
10[e]	4	245	398	317
11	4	47	77	59
12	4	84	118	106
On-Site				
1	4	30	48	40
2	4	40	69	52
13[f]	4	28	48	39
Background[g]				
14[h]	4	66	85	78

[a]Sampling locations are shown in Figure 3-1.

[b]Measured background radiation has been subtracted from external gamma radiation levels measured at the site boundary and at on-site locations.

[c]Measurement was less than or equal to the measured background value.

[d]Detector was removed in error during the first quarter.

[e]Location 10 is in an area of known contamination (Ref. 3).

[f]Location 13 is a quality control for Location 1.

[g]Additional background locations were established in April 1988 at the Rochelle Park Post Office and the Rochelle Park Fire Station, both of which are approximately 0.8 km (0.5 mi) south of the MISS. No data are presented for this year because the TLDs have not yet been in place for 1 year; data will be presented in the 1989 environmental report.

[h]Station 14 is located at the Department of Health, Paterson, NJ, approximately 22 km (14 mi) west of the MISS.

significant occupancy factor, the highest average external gamma radiation level was recorded at Location 10 (near State Route 17), an area known to be contaminated before DOE acquired the property (Ref. 3).

In April 1988, additional background locations were established at the Rochelle Park Fire Station and the Rochelle Park Post Office. Because of the measurement system operating parameters, the six months of exposure time on the TLDs is not representative of the yearly fluctuations in the background. These fluctuations occur because of seasonal weather variations. These locations will be fully reported in the 1989 environmental report.

The background external gamma radiation value for a given location is not a static constant. Because the background value is a combination of both natural terrestrial sources and cosmic radiation sources, factors such as the location of the detector in relation to surface rock outcrops, stone or concrete structures, or highly mineralized soil can affect the value measured. Independent of the placement of the detector at the Earth's surface are the factors of site altitude, annual barometric pressure cycles, and the occurrence and frequency of solar flare activity (Ref. 19).

Because of these factors, the background radiation level is not constant from one location to another even over a short time. Thus it is not abnormal for some stations at the boundary of a site to have an external gamma radiation value less than the background level measured some distance from the site.

For comparisons of external gamma radiation levels measured from 1984 through 1988, see Subsection 3.6.2.

3.3 WATER SAMPLING

During 1988, quarterly sampling was performed to determine the concentrations of total uranium, thorium-232, and radium-226 in surface water and groundwater at both on-site and off-site

locations. Surface water sampling locations are shown in Figure 3-2, and groundwater sampling locations are shown in Figure 1-7.

3.3.1 Surface Water

Surface water sampling locations were established on the Saddle River (Location 1) and on Westerley Brook (Locations 2, 3, and 4). Location 4 was formerly accessible by way of a manhole that is now welded shut and is therefore no longer accessible. Locations 5 and 6 were established on the Ballod property west of the MISS.

Because no standing water was present at Locations 5 and 6 during 1988 quarterly sampling, no surface water samples could be obtained from these locations. Surface water collection locations were selected based on migration potential and discharge routes from the site. Because surface water runoff from the site discharges via underground Westerley Brook, samples were collected both upstream (Location 3) and downstream (Locations 1 and 2) of the site.

Nominal 1-liter (0.26-gal) grab samples were collected to fill a 4-liter (1-gal) container. The samples were analyzed by TMA/E for total uranium, thorium-232, and dissolved radium-226. The concentration of total uranium was determined by a fluorometric method. Radium-226 concentrations in water were determined by radon emanation. (This method consists of precipitating radium as a sulfate and transferring the treated sulfate to a radon bubbler, where radon-222 is allowed to come to equilibrium with its radium-226 parent. The radon-222 gas is then withdrawn into a scintillation cell and counted by the gross alpha technique. The quantity of radon-222 detected in this manner is directly proportional to the quantity of radium-226 originally present in the sample.) Thorium-232 was eluted in solution, electrodeposited on stainless steel discs, and counted by alpha spectrometry.

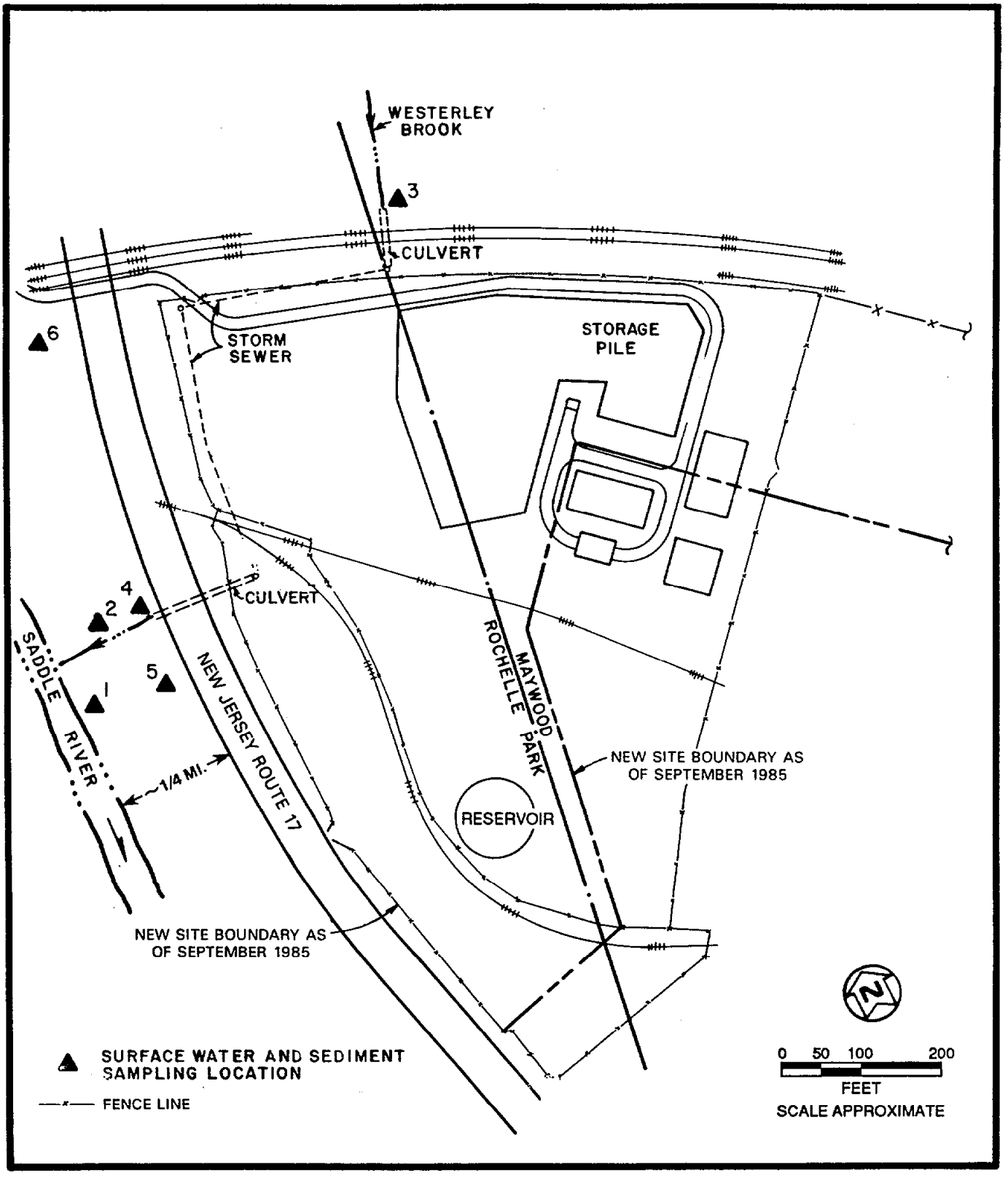

FIGURE 3-2 SURFACE WATER AND SEDIMENT SAMPLING LOCATIONS IN THE VICINITY OF THE MISS

Analysis results are presented in Table 3-3. The annual average concentrations of total uranium in surface water ranged from 3×10^{-9} to 4.3×10^{-9} μCi/ml (3.0 to 4.3 pCi/l). The annual average concentrations of radium-226 in surface water ranged from 3×10^{-10} to 4×10^{-10} μCi/ml (0.3 to 0.4 pCi/l). Annual average thorium-232 concentrations in all cases were less than or equal to the limit of sensitivity of the analytical method, which is 1×10^{-10} μCi/ml (0.1 pCi/l). Thorium-232 concentrations were the same upstream and downstream. These values may be compared with the levels of radioactivity in the commonly consumed liquids listed in Appendix D to this report.

For a comparison of radionuclide concentrations measured in surface water from 1984 through 1988, see Subsection 3.6.3.

3.3.2 Groundwater

During 1988, groundwater samples were collected quarterly from 15 on-site wells at 7 locations (see Figure 1-7). Monitoring wells designated "A" are shallow [approximately 0.9 to 5.2 m (3 to 17 ft) below ground]; "B" wells extend into the Brunswick formation bedrock aquifer [approximately 5.2 to 18 m (17 to 59 ft) below ground]. Groundwater flows from the northeast to the southwest in both the overburden and the bedrock aquifer; therefore, Wells 2A and 2B represent groundwater quality upgradient of the contaminated waste pile. All other wells are downgradient monitoring locations. Well locations were selected on the basis of available geohydrological data.

After the wells had been pumped dry and allowed to recover or three casing volumes had been removed, grab samples were collected and analyzed by TMA/E for total uranium, thorium-232, and radium-226 by the same methods described in Subsection 3.3.1.

TABLE 3-3

CONCENTRATIONS OF TOTAL URANIUM, RADIUM-226,
AND THORIUM-232 IN SURFACE WATER AT THE MISS, 1988

Sampling Location[a]	Number of Samples	Concentration (10^{-9} µCi/ml)[b,c] Minimum	Maximum	Average[d]
Total Uranium				
1	4	<3.0	5.3	3.0
2	4	3.0	6.0	4.3
3	4	<3.0	5.3	3.8
Radium-226				
1	4	0.1	0.6	0.4
2	4	0.1	0.6	0.3
3	4	0.1	0.7	0.3
Thorium-232				
1	4	<0.1	<0.1	<0.1
2	4	<0.1	<0.1	<0.1
3	4	<0.1	0.1	0.1

[a]Sampling locations are shown in Figure 3-2. Location 3 is upstream of the MISS and represents background. No water was available at sampling Locations 5 and 6. Location 4 is no longer accessible.

[b]All results include background.

[c]1 x 10^{-9} µCi/ml is equivalent to 1 pCi/l.

[d]Where no more than one value is less than the limit of sensitivity of the analytical method, values are considered equal to the limit of sensitivity, and the average value is reported without the notation "less than."

Analysis results are presented in Tables 3-4, 3-5, and 3-6. Annual average total uranium concentrations ranged from 7×10^{-10} to 8.4×10^{-9} μCi/ml (0.7 to 8.4 pCi/l). Average thorium-232 concentrations ranged from $<2 \times 10^{-10}$ to 1.6×10^{-9} μCi/ml (<0.2 to 1.6 pCi/l). Average radium-226 concentrations ranged from 7×10^{-10} to 2.8×10^{-9} μCi/ml (0.7 to 2.8 pCi/l). These concentrations may be compared with the levels of radioactivity in the commonly consumed liquids listed in Appendix D. For a comparison of radionuclide concentrations measured in groundwater at the MISS from 1985 through 1988, see Subsection 3.6.4.

3.4 SEDIMENT SAMPLING

Sediment samples that consisted of composites weighing approximately 500 g (1.1 lb) were obtained at surface water sampling locations where sediment was present (see Figure 3-2). The rationale for selection of the individual sampling locations is given in Subsection 3.3.1. Samples were analyzed by TMA/E for isotopic uranium, radium-226, and thorium-232. The concentrations of isotopic uranium and thorium-232 were determined by alpha spectrometry after the uranium and thorium-232 had been leached, extracted, and electroplated on metal substrates. Radium-226 concentrations were determined by the radon emanation method described in Subsection 3.3.1.

The results of isotopic uranium analyses (based on dry weight) are presented in Table 3-7. Results of analyses for total uranium showed concentrations ranging from 1.0 pCi/g to 1.6 pCi/g. The isotopic uranium concentrations were summed to estimate the total uranium concentrations shown in Table 3-7.

Analysis results for radium-226 (based on dry weight) are presented in Table 3-8. Results for radium-226 showed concentrations ranging from 0.4 to 0.5 pCi/g. Results for thorium-232 (based on dry weight) are also presented in Table 3-8. Average annual

TABLE 3-4

CONCENTRATIONS OF TOTAL URANIUM IN GROUNDWATER AT THE MISS, 1988

Sampling Location[a]	Number of Samples	Concentration (10^{-9} µCi/ml)[b] Minimum	Maximum	Average[c]
1B	4	1.6	3.5	2.4
2A	4	0.9	2.0	1.4
2B	4	0.6	0.9	0.8
3A	3[d]	0.9	2.0	1.5
3B	4	0.9	1.6	1.3
4A	2[e]	2.7	5.1	3.9
4B	4	0.6	0.8	0.7
5B	4	0.6	0.9	0.7
6A	2[f]	4.5	12.2	8.4
6B	4	0.8	1.4	1.1
7B	4	4.1	7.8	6.3
Background				
B38W04B[g]	3	0.6	1.2	0.8

[a]Sampling locations are shown in Figure 1-7. Wells 1A, 5A, 5A-1, and 7A were dry during all sampling periods and are therefore not listed.

[b]1 x 10^{-9} µCi/ml is equivalent to 1 pCi/l.

[c]Where no more than one value is less than the limit of sensitivity of the analytical method, values are considered equal to the limit of sensitivity, and the average value is reported without the notation "less than."

[d]Well dry in the third quarter.

[e]Well was dry in the third and fourth quarters.

[f]Well was dry in the first and fourth quarters.

[g]Located at Stepan Company, approximately 61 m (200 ft) east of MISS wells 3A and 3B. Well was added to the monitoring program in April 1988 to represent background.

TABLE 3-5

CONCENTRATIONS OF THORIUM-232 IN GROUNDWATER AT THE MISS, 1988

Sampling Location[a]	Number of Samples	Concentration (10^{-9} µCi/ml)[b] Minimum	Maximum	Average[c]
1B	4	<0.2	<0.4	<0.3
2A	4	0.2	0.7	0.4
2B	4	<0.2	<0.3	<0.3
3A	3[d]	0.4	1.1	0.7
3B	4	<0.2	<0.4	<0.3
4A	2[e]	1.2	1.9	1.6
4B	4	<0.2	0.2	<0.2
5B	4	<0.2	<0.2	<0.2
6A	2[f]	<0.2	<0.2	<0.2
6B	4	<0.2	0.3	0.3
7B	4	<0.2	0.3	<0.3
Background				
B38W04B[g]	3	<0.2	<0.2	<0.2

[a]Sampling locations are shown in Figure 1-7. Wells 1A, 5A, 5A-1, and 7A were dry during all sampling periods and are therefore not listed.

[b]1 x 10^{-9} µCi/ml is equivalent to 1 pCi/l.

[c]Where no more than one value is less than the limit of sensitivity of the analytical method, values are considered equal to the limit of sensitivity, and the average value is reported without the notation "less than."

[d]Well was dry in the third quarter.

[e]Well was dry in the third and fourth quarters.

[f]Well was dry in the first and fourth quarters.

[g]Located at Stepan Company, approximately 61 m (200 ft) east of MISS wells 3A and 3B. Well was added to the monitoring program in April 1988 to represent background.

TABLE 3-6

CONCENTRATIONS OF RADIUM-226 IN GROUNDWATER AT THE MISS, 1988

Sampling Location[a]	Number of Samples	Concentration (10^{-9} µCi/ml)[b] Minimum	Maximum	Average[c]
1B	4	0.7	1.0	0.9
2A	4	0.9	1.2	1.0
2B	4	0.5	0.9	0.7
3A	3[d]	0.9	1.3	1.2
3B	4	0.4	1.2	0.8
4A	2[e]	2.7	2.9	2.8
4B	4	1.1	1.8	1.4
5B	4	0.3	0.9	0.7
6A	2[f]	1.7	2.2	2.0
6B	4	0.4	1.0	0.7
7B	4	0.6	4.3	1.5
Background				
B38W04B[g]	3	0.7	1.3	1.0

[a]Sampling locations are shown in Figure 1-7. Wells 1A, 5A, 5A-1, and 7A were dry during all sampling periods and are therefore not listed.

[b]1 x 10^{-9} µCi/ml is equivalent to 1 pCi/l.

[c]Where no more than one value is less than the limit of sensitivity of the analytical method, values are considered equal to the limit of sensitivity, and the average value is reported without the notation "less than."

[d]Well was dry in the third quarter.

[e]Well was dry in the third and fourth quarters.

[f]Well was dry in the first and fourth quarters.

[g]Located at Stepan Company, approximately 61 m (200 ft) east of MISS wells 3A and 3B. Well was added to the monitoring program in April 1988 to represent background.

TABLE 3-7

CONCENTRATIONS OF URANIUM IN SEDIMENT IN THE VICINITY OF THE MISS, 1988

Sampling Location[a]	Number of Samples	Concentration [pCi/g (dry)] Minimum	Maximum	Average
Uranium-234				
1	4	0.3	1.5	0.7
2	4	0.3	0.8	0.6
3	3[b]	0.3	0.6	0.4
Uranium-235				
1	4	<0.1	<0.1	<0.1
2	4	<0.1	<0.1	<0.1
3	3[b]	<0.1	<0.1	<0.1
Uranium-238				
1	4	0.3	1.4	0.8
2	4	0.3	0.6	0.5
3	3[b]	0.4	0.8	0.5
Total Uranium[c]				
1	4	0.7	3.0	1.6
2	4	0.7	1.5	1.2
3	3[b]	0.8	1.5	1.0

[a]Sampling locations shown in Figure 3-2. Location 3 is upstream of the MISS and represents background. No sediment was available at sampling Locations 5 and 6. Location 4 is no longer accessible.

[b]Location was frozen during the first quarter.

[c]Total uranium was determined by summing concentrations of all three isotopes.

TABLE 3-8

CONCENTRATIONS OF RADIUM-226 AND THORIUM-232 IN SEDIMENT IN THE VICINITY OF THE MISS, 1988

Sampling Location[a]	Number of Samples	Concentration [pCi/g (dry)] Minimum	Maximum	Average
Radium-226				
1	4	0.3	0.6	0.4
2	4	0.3	0.6	0.5
3	3[b]	0.3	0.5	0.4
Thorium-232				
1	4	0.2	0.6	0.4
2	4	0.3	0.5	0.4
3	3[b]	0.2	0.4	0.3

[a]Sampling locations are shown in Figure 3-2. Location 3 is upstream of the MISS and represents background. No sediment was available at sampling locations 5 and 6. Location 4 is no longer accessible.

[b]Location was frozen during the first quarter.

concentrations of thorium-232 ranged from 0.3 to 0.4 pCi/ml. These concentrations may be compared with the levels of radioactivity in phosphate fertilizers listed in Appendix D.

3.5 RADIATION DOSE

To assess the potential health effects of the radioactive materials stored at the MISS, radiological exposure pathways were evaluated to calculate the dose to a hypothetical maximally exposed individual. This individual is one who is assumed to be adjacent to the site and who, when all potential routes of exposure are considered, receives the greatest dose. An evaluation of potential pathways (exposure to external gamma radiation, ingestion of water, and inhalation of radon) indicates that external gamma radiation is the only feasibly significant exposure mode.

The dose from ingesting groundwater or surface water from sources on the MISS was not calculated because it was considered unrealistic that ingestion of this water would occur. The MISS is fenced and locked, and security is well maintained, so a member of the public could only consume water on the site by trespassing on the property. Furthermore, the trespasser would have to be equipped with a means of removing the well cap (which is locked) and a power source, a pump, and a hose.

Radon concentrations measured at the boundary of the MISS were within the normal variations associated with background measurements. Given the amount of time that the hypothetical maximally exposed individual would spend near these locations, the dose from radon inhalation would be indistinguishable from that received from background concentrations. Consequently, this pathway would not contribute additional dose to the hypothetical maximally exposed individual and was not considered in the dose calculations presented in Subsection 3.5.1. Measured radon and thoron concentrations are discussed fully in Subsection 3.1.

3.5.1 Dose to the Maximally Exposed Individual

To identify the maximally exposed individual in the vicinity of the MISS who would receive the highest dose from on-site radioactive materials, the dose from exposure to external gamma radiation was calculated at various monitoring locations that could be accessible to the public. These doses were then reviewed with regard to land use and occupancy factors for areas adjacent to the monitoring points.

Residents of homes on Central Avenue north of the site boundary would receive exposures equivalent to background for the area because of the distance of these homes from the site. The highest annual average external gamma radiation levels at the MISS boundary in 1988 were measured along the western side of the site, with an average value of 129 mR/yr at monitoring Locations 9 through 12. Therefore, the highest overall exposure from external gamma radiation would be received by an individual walking at a speed of 4.8 km/h (3 mph) along the western boundary of the site twice a day, 365 days/yr, spending 8 min/day (48.7 h/yr) in the area. This maximally exposed individual would receive an exposure of less than 1 mR/yr above background. This scenario is, however, highly conservative because it is unlikely that any individual would spend so much time at this location. A more realistic assessment of the use of the site would demonstrate that the incremental dose is less than 1 mrem/yr. Because 1 mR is approximately equivalent to 1 mrem, this exposure is approximately equivalent to 1 percent of the DOE radiation protection standard of 100 mrem/yr and is less than the exposure a person receives during a flight between New York and Los Angeles through the increased cosmic radiation present at higher altitudes.

3.5.2 Dose to the Population in the Vicinity of the MISS

The dose to the population represents the conceptual cumulative radiation dose to all residents within an 80-km (50-mi) radius of a given site. This calculated dose includes contributions from all

potential pathways. For the MISS, these pathways are direct exposure to gamma radiation, inhalation of radon, and ingestion of radioactively contaminated water.

The contribution to the population dose made by gamma radiation from on-site radioactive materials is too small to be measured; gamma radiation levels decrease rapidly as distance from the source of contamination increases. For example, if the external gamma radiation level at a distance of 1 m (3 ft) from a small-area radioactive source were 100 mR/yr, the external radiation level at a distance of 6.3 m (21 ft) from the source would be indistinguishable from naturally occurring background radiation. Similarly, radon is known to dissipate rapidly as distance from the radon source increases (Ref. 20). Therefore, radon exposure from on-site sources does not contribute significantly to population dose.

On the basis of radionuclide concentrations measured in water leaving the site, it also appears that there is no predictable pathway by which ingestion of water could result in a significant dose to the population. As water migrates farther from the source, radionuclide concentrations are further reduced, thereby lowering potential doses to even less significant levels.

The cumulative dose to the population within an 80-km (50-mi) radius of the MISS that results from radioactive materials present at the site is indistinguishable from the dose the same population receives from naturally occurring radioactive sources.

3.6 TRENDS

The environmental monitoring program at the MISS was established to allow an annual assessment of the environmental conditions at the site, provide a historical record for comparisons from year to year, and permit detection of trends over time. In the following subsections, 1988 annual averages for each monitoring location for radon and thoron, external gamma radiation, and uranium, radium-226, and thorium-232 in surface water and groundwater are compared with

results for 1984 through 1987. As the environmental monitoring program continues at the MISS and more data are collected, comparisons and analyses of trends will become more valid.

3.6.1 Radon

Table 3-9 lists annual average concentrations of radon and thoron for each monitored location for the period 1984 through 1988. The 1988 radon and thoron concentrations at the MISS are statistically similar to those in 1987. The concentrations of both radionuclides decreased in 1985 and rose in 1987. The 1987 rise in radon and thoron levels coincided with a drought in the northeastern United States and is thought to result from this climatic effect. A similar rise occurred in 1986 at background monitoring stations and at other FUSRAP sites within 50 miles of the MISS site. Dry conditions moderated in 1988, resulting in a minor decrease in general radon and thoron levels when compared with 1987 levels.

Statistical analyses conducted to compare annual average concentrations of radon and thoron over the period 1984-1988 indicate that the only statistically significant variation in average concentrations applies to 1985 as compared with subsequent years. No other statistically significant variances occurred during this period. Based on available data, it appears that the lowest radon and thoron levels at the MISS were recorded in 1985.

For each year the monitoring program has been in effect, significant differences in radionuclide concentrations have existed between respective monitoring stations. Most notable are the levels measured at Locations 5 and 10 (see Figure 3-1), both of which are near areas of known contamination that are scheduled for remedial action. Disturbances of the surface soil cover near these locations during characterization activities in 1986 may be responsible for the rise in radon levels that began in 1986 and continued, with some climatic moderation, in 1987. The placement in 1987 of clean fill material along the site boundary near these locations has reduced radon concentrations.

TABLE 3-9

ANNUAL AVERAGE CONCENTRATIONS OF THORON AND RADON AT THE MISS, 1984-1988[a]

Sampling Location[b]	Concentration (10^{-9} µCi/ml)[c,d,e] 1984	1985	1986	1987	1988
Thoron (Rn-220)					
1	8.1	0.5	<MDL	0.2	0.4
2	2.1	0.6	<MDL	0.3	0.5
3	2.1	0.3	0.1	0.4	0.2
4	1.4	0.5	<MDL	<MDL	1.4
5	9.9	3.2	9.2	9.2	6.4
6	1.1	1.0	0.6	1.3	1.0
7	0.2	0.3	<MDL	0.5	0.3
8	0.6	0.02	0.07	0.4	0.1
9	<MDL	0.2	<MDL	0.1	0.2
10	2.1	2.7	6.0	4.0	0.5
11	<MDL	0.2	0.04	0.1	0.4
12	1.4	1.2	1.7	1.7	0.6
13[f]	1.2	2.9	0.6	0.2	0.1
Background[g]					
14[h]	<MDL	0.1	0.4	0.3	<MDL
Radon (Rn-222)					
1	0.9	0.3	0.6	0.7	0.6
2	0.8	0.2	1.2	1.2	0.9
3	0.9	0.3	1.2	1.5	0.6
4	0.8	0.4	1.6	1.1	1.9
5	1.3	0.5	9.9	9.7	7.4
6	1.2	0.2	1.9	2.4	1.4
7	0.9	0.2	0.9	1.1	0.8
8	0.6	0.3	0.8	1.0	0.4
9	1.0	0.2	0.9	1.1	0.5
10	0.8	0.4	6.5	4.9	1.0
11	2.7	0.2	1.3	0.8	0.8
12	1.4	0.2	2.6	2.3	1.1
13	0.7	0.3	1.2	1.1	0.4
Background[g]					
14[h]	1.3	0.4	1.0	0.8	0.3

[a]Sources for 1984, 1985, 1986, and 1987 data are the annual site environmental reports for those years (Refs. 14-17).

[b]Sampling locations shown in Figure 3-1.

[c]1 x 10^{-9} µCi/ml is equivalent to 1 pCi/l.

TABLE 3-9

(continued)

[d]All results include background.

[e]MDL means minimum detectable limit.

[f]Location 13 is a quality control for Location 1.

[g]Additional background detectors were established in January 1989 at the Rochelle Park Post Office and the Rochelle Park Fire Station, both of which are located approximately 0.8 km (0.5 mi) south of the MISS. Data from these detectors will be reported in the 1989 environmental report.

[h]Background detector located at the Department of Health, Paterson, NJ, approximately 22 km (14 mi) west of the MISS.

To determine the impact of radon and thoron levels at the MISS as measured at the site boundary, statistical analyses were conducted to compare radon and thoron levels at upwind Locations 12, 11, 10, and 9 with levels at downwind Locations 4, 5, 6, and 7. It was determined that at most of the downwind locations there was no significant statistical difference between the annual average values for each group. This indicates that radon emanation at the MISS has not had a measurable, statistically significant impact on air quality at the site boundary during the past five years.

3.6.2 External Gamma Radiation Levels

As shown in Table 3-10, external gamma radiation levels have remained stable with the exception of Locations 4, 5, 6, 9, and 10. These locations are where radiologically clean fill was emplaced in August 1987 in an attempt to shield the site boundary within 10 m (30 ft) of the site fence. Radiation levels dropped significantly at Location 10 as a result of this shielding. The decrease at Location 9 was more modest and was not statistically significant.

At the other locations (4, 5, and 6), net radiation levels increased as compared with 1987 values. It is known that no additional radioactive materials were placed at the MISS during the period of exposure; thus the increase was most likely the result of factors relating to the spatial location and geometry of the source of radiation and of the attempted shielding. Because detectors are located on the boundary of the MISS, any shielding placed on the site side of the fence would be ineffective for sources located outside the fence. Measurements made with a directional radiation detector in April and November 1987 confirmed that a fraction of the source as seen at these locations lies outside the site perimeter fence. Shields consisting of earth berms approximately 1.5 m (5 ft) high are located from 0.5 to 1 m back from the fence line from approximately the area of Station 6 along the fence to the area of Station 4. Such a configuration would scatter radiation coming from outside the site perimeter back toward the detector and could account for the increases observed at these locations.

TABLE 3-10

ANNUAL AVERAGE EXTERNAL GAMMA RADIATION LEVELS AT THE MISS, 1984-1988[a]

Sampling Location[b]	Radiation Level (mR/yr)[c]				
	1984	1985	1986	1987	1988
Boundary					
3	196	27	38	29	21
4	182	130	91	69	109
5	368	272	172	121	186
6	287	106	83	67	85
7	147	15	24	36	16
8	148	15	18	37	30
9	176	38	23	39	32
10[d]	759	627	496	521	317
11	90	57	50	61	59
12	208	180	88	79	106
On-Site					
1	91	48	41	36	40
2	89	50	51	43	52
13[e]	80	46	35	33	39
Background[f]					
14[g]	-[g]	108	63	58	78

[a]Sources for 1984, 1985, 1986, and 1987 data are the annual site environmental reports for those years (Refs. 14-17).

[b]Sampling locations are shown in Figure 3-1.

[c]Measured background has been subtracted at on-site and boundary locations.

[d]Location 10 is in an area of known contamination (Ref. 3).

[e]Location 13 is a quality control for Location 1.

[f]Additional background locations were established in April 1988 at the Rochelle Park Post Office and the Rochelle Park Fire Station, both of which are approximately 0.8 km (0.5 mi) south of the MISS. No values are reported this year because the TLDs have not yet had a full year of exposure. Data for these locations will be presented in the 1989 environmental report.

[g]Background detector located at the Department of Health, Paterson, NJ, approximately 22 km (14 mi) west of the MISS.

3.6.3 Surface Water

Concentrations of uranium, radium-226, and thorium-232 in surface water remained stable at the MISS. As shown in Table 3-11, no significant changes occurred in these levels from 1984 through 1988.

3.6.4 Groundwater

Groundwater monitoring has been conducted at the MISS since 1985. Table 3-12 lists the annual average concentrations of the three radionuclides of primary concern at each monitoring well location. Concentrations of thorium-232 and radium-226 remained stable from 1985 through 1988. Uranium concentrations have not exhibited a definite trend in either the shallow wells (designated with the letter "A") or the deep wells (designated with the letter "B"), because differences from year to year have not been statistically significant. In addition, because the analytical method was changed from fluorometry to alpha spectrometry in 1986, no meaningful trend for uranium in groundwater can be identified. Because the alpha spectrometry method is more precise, very slight changes that would be unnoticeable using fluorometry are more easily detected.

Generally, higher concentrations of uranium are found in the shallow monitoring wells located within the site boundary. These wells are located within the disturbed zone (see Subsection 3.6.1) and capture primarily soil water (as distinguished from water produced from an aquifer). Typically, these wells produce only limited quantities of water and are often dry during periods when rainfall is minimal.

Uranium, thorium-232, and radium-226 concentrations in the deeper wells that are drilled to bedrock to monitor the available groundwater on the site have remained relatively constant from 1985 through 1988.

TABLE 3-11

ANNUAL AVERAGE CONCENTRATIONS OF TOTAL URANIUM, RADIUM-226, AND THORIUM-232 IN SURFACE WATER AT THE MISS, 1984-1988[a]

Sampling Location[b]	Concentration (10^{-9} µCi/ml)[c,d]				
	1984	1985	1986	1987	1988
Total Uranium					
1	3.0	<3.0	<3.0	<3.0	3.0
2	3.0	<3.0	<3.0	<3.0	4.3
3[e]	3.0	<3.0	<3.0	<3.0	3.8
Radium-226					
1	0.4	0.2	0.4	0.4	0.4
2	0.2	0.4	0.4	0.2	0.3
3[e]	0.7	0.4	0.6	0.3	0.3
Thorium-232					
1	0.4	0.2	<0.1	<0.1	<0.1
2	0.5	0.1	0.1	<0.1	<0.1
3[e]	0.4	0.1	0.1	<0.1	0.1

[a]Sources for 1984, 1985, 1986, and 1987 data are the annual site environmental reports for those years (Refs. 14-17).

[b]Sampling locations shown in Figure 3-2. Locations 4, 5, and 6 are not reported because there were no data for these locations for 1986-1988, and only very limited data for prior years.

[c]1 x 10^{-9} µCi/ml is equivalent to 1 pCi/l.

[d]All results include background.

[e]Location is upstream of the MISS and represents background.

TABLE 3-12

ANNUAL AVERAGE CONCENTRATIONS OF TOTAL URANIUM, RADIUM-226, AND THORIUM-232 IN GROUNDWATER AT THE MISS, 1985-1988[a]

Sampling Location[b]	Concentration (10^{-9} µCi/ml)[c] 1985	1986	1987	1988
Total Uranium				
1A	27.0	-[d]	-[d]	-[d]
1B	<3.0	1.6	3.3	2.4
2A	3.0	0.6	2.4	1.4
2B	12.0	0.5	2.1	0.8
3A	<3.0	0.6	2.0	1.5
3B	<3.0	0.3	3.3	1.3
4A	<3.0	-[d]	-[d]	3.9
4B	<3.0	0.5	2.0	0.7
5A	63.0	100.0	98.8	-[d]
5A-1	-[d]	-[d]	-[d]	-[d]
5B	<3.0	0.3	1.5	0.7
6A	9.0	8.4	12.1	8.4
6B	5.0	0.8	2.2	1.1
7A	-[d]	-[d]	15.9	-[d]
7B	12.0	4.7	5.0	6.3
Background				
B38W04B[e]	-[e]	-[e]	-[e]	0.8
Radium-226				
1A	0.1	-[d]	-[d]	-[d]
1B	0.6	0.6	0.4	0.9
2A	0.4	0.5	0.4	1.0
2B	0.3	1.5	0.4	0.7
3A	0.4	0.6	0.6	1.2
3B	0.3	0.5	0.3	0.8
4A	0.4	-[d]	-[d]	2.8
4B	0.3	0.4	0.5	1.4
5A	0.2	0.6	0.8	-[d]
5A-1	-[d]	-[d]	-[d]	-[d]
5B	0.3	0.2	0.3	0.7
6A	0.2	0.4	0.5	2.0
6B	0.4	0.5	0.3	0.7
7A	-[d]	-[d]	0.1	-[d]
7B	0.3	0.4	0.3	1.5
Background				
B38W04B[e]	-[e]	-[e]	-[e]	1.0

TABLE 3-12

(continued)

Page 2 of 2

Sampling Location[b]	Concentration (10^{-9} µCi/ml)[c] 1985	1986	1987	1988
Thorium-232				
1A	0.1	-[d]	-[d]	-[d]
1B	<0.1	<0.2	<0.3	<0.3
2A	0.3	<0.2	<0.1	0.4
2B	<0.2	<0.2	<0.1	<0.3
3A	<0.1	<0.2	<0.1	0.7
3B	<0.2	<0.1	<0.2	<0.3
4A	<0.1	-[d]	-[d]	1.6
4B	<0.1	<0.1	<0.1	<0.2
5A	<0.1	0.3	0.3	-[d]
5A-1	-[d]	-[d]	-[d]	-[d]
5B	<0.2	<0.1	<0.1	<0.2
6A	<0.2	0.1	0.3	<0.2
6B	<0.3	<0.2	<0.1	0.3
7A	-[d]	-[d]	<0.1	-[d]
7B	<0.2	<0.2	<0.1	<0.3
Background				
B38W04B[e]	-[e]	-[e]	-[e]	<0.2

[a]Sources for 1985, 1986, and 1987 data are the annual site environmental reports for those years (Refs. 15-17).

[b]Sampling locations are shown in Figure 1-7.

[c]1 x 10^{-9} µCi/ml is equivalent to 1 pCi/l.

[d]Shallow well to monitor groundwater in unconsolidated material. These wells typically do not contain water.

[e]Location at Stepan Company, approximately 61 m (200 ft) east of MISS wells 3A and 3B. Well was added to the monitoring program in April 1988 to represent background.

4.0 RELATED ACTIVITIES AND SPECIAL STUDIES

4.1 RELATED ACTIVITIES

During calendar year 1988, site operations were conducted under Emergency Groundwater Permit No. NJ0054500, issued by the NJDEP, Water Resources Division, pending processing of the routine permit application. The New Jersey Pollutant Discharge Elimination System (NJPDES) regulates interim storage of waste at the MISS with the objective of preventing contamination of the groundwater. As such, the emergency permit prohibits discharges of water to groundwater. One of the NJPDES permit conditions requires the installation of groundwater monitoring wells at the MISS, which was completed during 1985.

Several groundwater monitoring wells installed at the Stepan property in 1987 to monitor the shallow groundwater system and deep aquifer and others added in the fall of 1988 on the railroad and Grove Street properties are used to provide data on groundwater flow and quality.

In accordance with permit requirements, chemical analyses were performed on samples collected from the groundwater monitoring wells shown in Figure 1-7. Monitoring wells 1A, 5A, 5A-1, and 7A were dry during all sampling periods. Wells designated "A" are shallow (approximately 10 ft below ground); "B" wells extend into the Brunswick formation bedrock aquifer [approximately 5.2 to 18 m (17 to 59 ft) below ground]. Groundwater flows from east to west in the shallow aquifer and from the northeast to the southwest in both the overburden and the bedrock aquifer; therefore, Wells 2A and 2B represent groundwater quality upgradient from the contaminated waste pile.

As required by permit number NJ0054500, groundwater samples from the MISS were analyzed for various parameters. Samples are analyzed quarterly for pH, total organic carbon (TOC), total organic halides

(TOX), and specific conductance. Analyses are performed annually for New Jersey priority pollutants. Table 4-1 lists analytical results for indicator parameters and chemical contaminants detected in groundwater at the MISS. Numerous other chemical contaminants for which analyses were completed under the permit requirements were not detected in any of the groundwater samples (see Table 4-2).

The highest concentration of TOX was measured in Well 5B, and the highest concentration of TOC was observed in Well 2A. Benzene was observed in one deep well (Well 2B).

A detectable concentration of contaminants was found in several of the shallow (overburden) wells (Wells 3A, 4A, and 6A). The appearance of bis(2-ethylhexyl) phthalate in 1988 in samples from Wells 2B, 3A, 3B, 5B, and 7B is currently considered to be a laboratory artifact. The appearance of acetone in samples from Wells 1B and 2B and methylene chloride in samples from Wells 1B, 3B, 4A, 4B, 5B, 6A, 6B, and 7B appears to be a sampling contaminant. Contaminants appeared in the laboratory blanks and in the field blank, respectively. No definitive conclusions can be drawn concerning the source of other contaminants observed at the MISS. Measurement of water level and water quality continues to provide additional information on groundwater gradient and flow directions.

Analysis results indicate that the groundwater at the MISS contains chemical contamination. The TOX and TOC concentrations measured at the MISS since the inception of monitoring for chemical contaminants in 1986 indicate that mobile organic chemicals are being transported via the groundwater. No noticeable trend has been demonstrated for either pH or specific conductance.

Although the presence of these contaminants would not be expected in pristine groundwater, their occurrence at trace levels is not unusual in groundwater underlying areas with a long history of industrial use. Comparison of the concentrations detected with maximum contaminant levels (MCLs) promulgated under the Safe

TABLE 4-1

ANALYSIS RESULTS FOR INDICATOR PARAMETERS AND CHEMICAL CONTAMINANTS IN GROUNDWATER AT THE MISS, 1988[a]

Parameter	Sampling Location (Monitoring Well Number)										
	1B	2A[b]	2B[b]	3A	3B	4A	4B	5B	6A	6B	7B
pH (Standard Units)	7.1-7.4	7.0-7.2	7.2-8.0	5.3-7.6	6.1-6.4	4.7-5.3	7.1-7.2	7.2-8.4	6.8-7.0	8.2-8.9	7.2-8.5
Total Organic Carbon (mg/l)	2.5-36.5	21.7-115	22.4-70.1	3.8-7.7	3.5-6.8	5.7-6.0	15.3-19.3	8.2-11.9	6.3-8.8	5.9-9.0	3.4-14.5
Total Organic Halide (µg/l)	ND-82[c]	24-260	ND-130	21-45	23-70	28-29	ND-150	ND-430	12-32	ND-78	ND-330
Specific Conductance (µmhos/cm)	788-896	4700-6990	1090-9750	720-831	1230-2720	1440-1730	1450-1660	2330-3590	2560-2690	2410-3670	4810-7720
Bis(2-Ethylhexyl)Phthalate (µg/l)	ND	ND	15	11	13	ND	ND	35	ND	ND	11
Methylene Chloride (µg/l)	10	ND	ND	ND	6	10	32	7	8	8	9
Acetone (µg/l)	12	ND	18	ND	ND	ND	ND	ND	ND	ND	ND
Benzene (µg/l)	ND	ND	62	ND	ND	ND	ND	ND	ND	ND	ND
Tetrachloroethene (µg/l)	17	ND	ND	ND	ND	ND	ND	ND	ND	ND	77
1,2-Dichloroethylene (µg/l)	ND	ND	ND	ND	ND	ND	26	ND	ND	ND	7
1,1,1-Trichloroethane (µg/l)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	5
Trichloroethylene (µg/l)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	5

[a]Does not include parameters for which concentrations were below the limit of sensitivity of the analytical method used.

[b]Upgradient well.

[c]ND - No detectable concentration.

TABLE 4-2

CHEMICAL CONTAMINANTS NOT DETECTED IN GROUNDWATER AT MISS, 1988[a]

Acrolein	4-Bromophenyl Phenyl Ether	Pyrene
Acrylonitrile	Butylbenzyl Phthalate	2-Chlorophenol
Bromoform	2-Chloronaphthalene	2,4-Dichlorophenol
Carbon Tetrachloride	4-Chlorophenyl Phenyl Ether	2,4-Dimethylphenol
Chlorobenzene	4-Chloroaniline	2,4-Dinitrophenol
Chlorodibromomethane	4-Chloro-3-Methylphenol	2-Nitrophenol
Chloroethane	Chrysene	4-Nitrophenol
Chloroform	Dibenzo(a,h)Anthracene	Pentachlorophenol
2-Chloroethyl Vinyl Ether	Dibenzofuran	Phenol
Dichlorobromomethane	Di-n-butyl Phthalate	2,4,5-Trichlorophenol
1,3-Dichloropropylene	Di-n-octyl Phthalate	2,4,6-Trichlorophenol
1,1-Dichloroethylene	1,2-Dichlorobenzene	Aldrin
1,1-Dichloroethane	1,3-Dichlorobenzene	BHC, Alpha
1,2-Dichloroethane	1,4-Dichlorobenzene	BHC, Beta
1,2-Dichloropropane	3,3-Dichlorobenzidine	BHC, Gamma
1,3-Dichloropropene	Diethyl Phthalate	BHC, Delta
Ethylbenzene	Dimethyl Phthalate	Alpha Chlordane
Methyl Bromide	2,4-Dinitrotoluene	Beta Chlordane
Methyl Chloride	2,6-Dinitrotoluene	Dieldrin
Toluene	4,6-Dinitro-2-Methylphenol	Endosulfan, I
Total Xylenes	Fluoranthene	Endosulfan, II
Styrene	Fluorene	Endosulfan Sulfate
1,1,2,2-Tetrachloroethane	Hexachlorobenzene	Endrin
Trichlorofluoromethane	Hexachlorobutadiene	Endrin Ketone
1,1,2-Trichloroethane	Hexachloroethane	Heptachlor
Vinyl Chloride	Hexachlorocyclopentadiene	Heptachlor Epoxide
Anthracene	Indeno(1,2,3-cd)Pyrene	4,4'-DDT
Acenaphthene	Isophorone	4,4'-DDE
Acenaphthylene	2-Methylnapthalene	4,4'-DDD
Benzo(a)Anthracene	2-Methylphenol	Methoxychlor
Benzo(k)Fluoranthene	4-Methylphenol	PCB 1016
Benzo(a)Pyrene	Naphthalene	PCB 1221
Benzo(g,h,i)Perylene	Nitrobenzene	PCB 1232
Benzyl Alcohol	2-Nitroaniline	PCB 1242
Benzoic Acid	3-Nitroaniline	PCB 1248
Bis(2-chloroethyl)Ether	4-Nitroaniline	PCB 1254
Bis(2-chloroethoxy)Methane	N-Nitrosodi-n-Propylamine	PCB 1260
Bis(2-chloroisopropyl)Ether	Phenanthrene	Toxaphene

[a]Analysis for the parameters required to meet NJDEP permit requirements.

Drinking Water Act indicates that water beneath the MISS would require treatment before it could be used as a public drinking water supply. The contaminants present do not exceed MCLs by more than a factor of 20, and some are present at concentrations at or below relevant MCLs. It should be noted that MCLs are enforceable standards when applied at a point of use and are not applicable to in situ groundwater contamination.

4.2 SPECIAL STUDIES

There were no special studies performed in relation to the MISS in 1988.

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APPENDIX A
QUALITY ASSURANCE

APPENDIX A
QUALITY ASSURANCE

A comprehensive quality assurance (QA) program was maintained to ensure that the data collected were representative of actual concentrations in the environment. First, extensive environmental data were obtained to prevent reliance on only a few results that might not be representative of the existing range of concentrations. Second, current monitoring data were compared with historical data for each environmental medium to ensure that deviations from previous conditions were identified and evaluated. Third, samples at all locations were collected using published procedures to ensure consistency in sample collection. Fourth, each analytical laboratory verified the quality of the data by conducting a continuing program of analytical quality control (QC), participating in interlaboratory cross-checks, performing replicate analyses, and splitting samples with other recognized laboratories. Fifth, chain-of-custody procedures were implemented to maintain traceability of samples and corresponding analytical results. This program ensures that the monitoring data can be used to evaluate accurately the environmental effects of site operations.

The majority of the routine radioanalyses for the FUSRAP Environmental Monitoring Program were performed under subcontract by TMA/E, Albuquerque, New Mexico. This laboratory maintained an internal quality assurance program that involved routine calibration of counting instruments, source and background counts, routine yield determinations of radiochemical procedures, and replicate analyses to check precision. The accuracy of radionuclide determination was ensured through the use of standards traceable to the National Bureau of Standards, when available. The laboratory also participated in the Environmental Protection Agency's (EPA) Laboratory Intercomparison Studies Program. In this program, samples of different environmental media (water, milk, air filters, soil, foodstuffs, and tissue ash) containing one or more radionuclides in known amounts were prepared and distributed

to the participating laboratories. After the samples were analyzed, the results were forwarded to EPA for comparison with known values and with the results from other laboratories. This program enabled the laboratory to regularly evaluate the accuracy of its analyses and take corrective action if needed.

Interlaboratory comparison of the TLD results was provided by participation in the International Environmental Dosimeter Project sponsored jointly by the DOE, the Nuclear Regulatory Commission, and the EPA. Table A-1 summarizes results of the EPA comparison studies for water samples.

To ensure the accuracy of dose calculations, all computed doses were double-checked by the originator and by an independent third party who also checked all input data and assumptions used in the calculations.

Chemical analyses were performed under subcontract by Weston Analytical Laboratory, Lionsville, Pennsylvania. Weston's standard practices manual was reviewed and accepted by BNI. The laboratory maintains an internal QA program that involves the following.

For inorganic analyses, the program includes:

- Initial calibration and calibration verification
- Continuing calibration verification
- Reagent blank analyses
- Matrix spike analyses
- Duplicate sample analyses
- Laboratory control sample analyses

TABLE A-1

SUMMARY COMPARISON OF WATER SAMPLE RESULTS

(EPA and TMA/E)

Analysis and Sample Date	Value (pCi/l) EPA	Value (pCi/l) TMA/E	Ratio (TMA/E:EPA)
Alpha			
1/88	28.0 ± 7.0	40.0 ± 2.0	1.43
2/88	4.00 ± 5.00	3.33 ± 0.60	0.83
5/88	6.0 ± 5.0	5.3 ± 0.6	0.88
7/88	46.0 ± 11.0	53.3 ± 2.9	1.16
8/88	15.0 ± 5.0	12.7 ± 0.6	0.85
11/88	8.00 ± 5.00	7.00 ± 1.00	0.88
Beta			
1/88	72.0 ± 5.0	90.0 ± 4.0	1.25
2/88	8.00 ± 5.00	9.30 ± 0.6	1.16
5/88	13.0 ± 5.0	16.3 ± 0.6	1.25
7/88	57.0 ± 5.0	69.7 ± 2.9	1.22
8/88	4.0 ± 5.0	5.0 ± 1.0	1.25
11/88	10.00 ± 5.00	10.00 ± 1.00	1.00
Ra-226			
1/88	4.80 ± 0.72	4.70 ± 0.26	0.98
1/88	4.80 ± 0.72	4.53 ± 0.15	0.94
5/88	7.60 ± 1.14	7.27 ± 0.25	0.96
7/88	6.40 ± 0.96	6.37 ± 0.59	1.00
8/88	10.0 ± 1.51	9.90 ± 0.53	0.99
11/88	8.40 ± 1.30	8.53 ± 0.15	1.02
Ra-228			
1/88	5.30 ± 0.80	4.35 ± 1.4	0.82
1/88	3.60 ± 0.54	4.60 ± 0.95	1.28
5/88	7.70 ± 1.16	8.73 ± 0.5	1.13
7/88	5.60 ± 0.84	6.50 ± 0.10	1.16
8/88	12.40 ± 1.86	14.80 ± 0.72	1.19
11/88	5.40 ± 0.80	5.33 ± 0.35	0.99
U (Natural)			
1/88	3.0 ± 6.0	3.33 ± 0.58	1.11
4/88	3.0 ± 6.0	3.7 ± 0.6	1.23
7/88	6.00 ± 6.00	6.33 ± 0.58	1.06
10/88	6.0 ± 6.0	7.0 ± 0.0	1.17

APPENDIX B
ENVIRONMENTAL STANDARDS

APPENDIX B
ENVIRONMENTAL STANDARDS

The DOE long-term radiation protection standard of 100 mrem/yr above background level includes exposure from all pathways except medical treatments (Ref. 13). Evaluation of exposure pathways and resulting dose calculations is based on assumptions such as occupancy factors in determining the dose from external gamma radiation; subtraction of background concentrations of radionuclides in air, water, and soil before calculating dose; closer review of water use, using the data that most closely represents actual exposure conditions rather than maximum values as applicable; and using average consumption rates of food and water per individual rather than maximums. Use of such assumptions will result in calculated doses that more accurately reflect the exposure potential from site activities.

TABLE B-1

CONVERSION FACTORS

1 year	=	8,760 hours
1 liter	=	1,000 ml
1 mR	=	1 mrem
1 mrem	=	1,000 μR
100 mrem/yr	=	11.4 μR/h (assuming 8,760 hours of exposure per year)
1 μCi	=	1,000,000 pCi
1 pCi	=	0.000001 μCi
1 pCi/l	=	10^{-9} μCi/ml
1 pCi/l	=	0.000000001 μCi/ml
1 μCi/ml	=	1,000,000,000 pCi/l
10^{-6}	=	0.000001
10^{-7}	=	0.0000001
10^{-8}	=	0.00000001
10^{-9}	=	0.000000001
10^{-10}	=	0.0000000001
7×10^{-10}	=	0.0000000007

APPENDIX C
ABBREVIATIONS

APPENDIX C
ABBREVIATIONS

cm	centimeter
cm/sec	centimeters per second
ft	foot
ft msl	feet above mean sea level
g	gram
gal	gallon
h	hour
ha	hectare
in.	inch
km	kilometer
km/h	kilometers per hour
lb	pound
m	meter
m^3	cubic meter
mg	milligram
mg/l	milligrams per liter
mi	mile
ml	milliliter
mph	miles per hour
mR	milliroentgen
mrem	millirem
mR/yr	milliroentgen per year
mrem/yr	millirem per year
µCi/ml	microcuries per milliliter
µg/l	micrograms per liter
µR/h	microroentgens per hour
pCi	picocurie
pCi/g	picocuries per gram
pCi/l	picocuries per liter
yd^3	cubic yard
yr	year

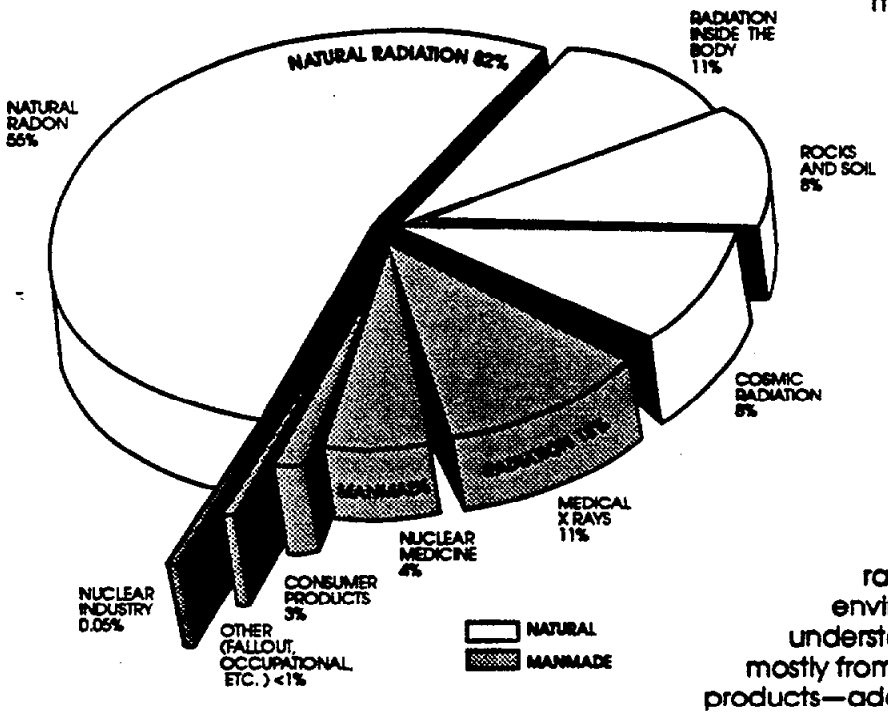
APPENDIX D
RADIATION IN THE ENVIRONMENT

Radiation in the Environment

Radiation is a natural part of our environment. When our planet was formed, radiation was present—and radiation surrounds it still. Natural radiation showers down from the distant reaches of the cosmos and continuously radiates from the rocks, soil, and water on the Earth itself.

During the last century, mankind has discovered radiation, how to use it, and how to control it. As a result, some manmade radiation has been added to the natural amounts present in our environment.

Sources of Radiation



Many materials—both natural and manmade—that we come into contact with in our everyday lives are radioactive. These materials are composed of atoms that release energetic particles or waves as they change into more stable forms. These particles and waves are referred to as *radiation*, and their emission as *radioactivity*.

As the chart on the left shows, most environmental radiation (82%) is from natural sources. By far the largest source is radon, an odorless, colorless gas given off by natural radium in the Earth's crust. While radon has always been present in the environment, its significance is better understood today. Manmade radiation—mostly from medical uses and consumer products—adds about eighteen percent to our total exposure.

TYPES OF IONIZING RADIATION

Radiation that has enough energy to disturb the electrical balance in the atoms of substances it passes through is called *ionizing radiation*. There are three basic forms of ionizing radiation.

Alpha

Alpha particles are the largest and slowest moving type of radiation. They are easily stopped by a sheet of paper or the skin. Alpha particles can move through the air only a few inches before being stopped by air molecules. However, alpha radiation is dangerous to sensitive tissue inside the body.

Beta

Beta particles are much smaller and faster moving than alpha particles. Beta particles pass through paper and can travel in the air for about 10 feet. However, they can be stopped by thin shielding such as a sheet of aluminum foil.

Gamma

Gamma radiation is a type of electromagnetic wave that travels at the speed of light. It takes a thick shield of steel, lead, or concrete to stop gamma rays. X rays and cosmic rays are similar to gamma radiation. X rays are produced by manmade devices; cosmic rays reach Earth from outer space.

Units of Measure

Radiation can be measured in a variety of ways. Typically, units of measure show either 1) the total amount of radioactivity present in a substance, or 2) the level of radiation being given off.

The radioactivity of a substance is measured in terms of the number of transformations (changes into more stable forms) per unit of time. The *curie* is the standard unit for this measurement and is based on the amount of radioactivity contained in 1 gram of radium. Numerically, 1 curie is equal to 37 billion transformations per second. The amounts of radioactivity that people normally work with are in the millicurie (one-thousandth of a curie) or microcurie (one-millionth of a curie) range. Levels of radioactivity in the environment are in the picocurie, or pCi (one-trillionth of a curie) range.

Levels of radiation are measured in various units. The level of gamma radiation in the air is measured by the *roentgen*. This is a relatively large unit, so measurements are often calculated in milliroentgens. Radiation absorbed by humans is measured in either *rad* or *rem*. The rem is the most descriptive because it measures the ability of the specific type of radiation to do damage to biological tissue. Again, typical measurements will often be in the millirem (mrem), or one-thousandth of a rem, range. In the international scientific community, absorbed dose and biological exposure are expressed in *grays* and *seiverts*. 1 gray (Gy) equals 100 rad. 1 seivert (Sv) equals 100 rem. On the average, Americans receive about 360 mrem of radiation a year. Most of this (97%) is from natural radiation and medical exposure. Specific examples of common sources of radiation are shown in the chart below.

Cosmic Radiation

Cosmic radiation is high-energy gamma radiation that originates in outer space and filters through our atmosphere.

Sea Level ..... 26 mrem/year
(Increases about 1/2 mrem for each additional 100 feet in elevation)
Atlanta, Georgia (1,050 feet)
..... 31 mrem/year
Denver, Colorado (5,300 feet)
..... 50 mrem/year
Minneapolis, Minnesota (815 feet)
..... 30 mrem/year
Salt Lake City, Utah (4,400 feet)
..... 46 mrem/year

Terrestrial Radiation

Terrestrial sources are naturally radioactive elements in the soil and water such as uranium, radium, and thorium. Average levels of these elements are 1 pCi/gram of soil.

United States (average) ..... 26 mrem/year
Denver, Colorado ..... 63 mrem/year
Nile Delta, Egypt ..... 350 mrem/year
Paris, France ..... 350 mrem/year
Coast of Kerala, India ..... 400 mrem/year
McAlpe, Brazil ..... 2,558 mrem/year
Pocos De Caldas, Brazil ..... 7,000 mrem/year

Buildings

Many building materials, especially granite, contain naturally radioactive elements.

U.S. Capitol Building ..... 85 mrem/year
Base of Statue of Liberty ..... 325 mrem/year
Grand Central Station ..... 525 mrem/year
The Vatican ..... 800 mrem/year

Radon

Radon levels in buildings vary, depending on geographic location, from 0.1 to 200 pCi/liter.

Average Indoor Radon Level ..... 1.5 pCi/liter
Occupational Working Limit ..... 200.0 pCi/liter

RADIATION IN THE ENVIRONMENT

Because the radioactivity of individual samples varies, the numbers given here are approximate or represent an average. They are shown to provide a perspective for concentrations and levels of radioactivity rather than dose.

mrem = millirem
pCi = picocurie

Food

Food contributes an average of 20 mrem/year, mostly from potassium-40, carbon-14, hydrogen-3, radium-226, and thorium-232.

Beer ..... 390 pCi/liter
Tap Water ..... 20 pCi/liter
Milk ..... 1,400 pCi/liter
Salad Oil ..... 4,900 pCi/liter
Whiskey ..... 1,200 pCi/liter
Brazil Nuts ..... 14 pCi/g
Bananas ..... 3 pCi/g
Flour ..... 0.14 pCi/g
Peanuts & Peanut Butter ..0.12 pCi/g
Tea ..... 0.40 pCi/g

Medical Treatment

The exposures from medical diagnosis vary widely according to the required procedure, the equipment and film used for x rays, and the skill of the operator.

Chest X Ray ..... 10 mrem
Dental X Ray,Each ..... 100 mrem

Consumer Goods

Cigarettes-two packs/day
(polonium-210) ..... 8,000 mrem/year
Color Television ..... <1 mrem/year
Gas Lantern Mantle
(thorium-232) ..... 2 mrem/year
Highway Construction ..... 4 mrem/year
Airplane Travel at 39,000 feet
(cosmic) ..... 0.5 mrem/hour
Natural Gas Heating and Cooking
(radon-222) ..... 2 mrem/year
Phosphate Fertilizers ..... 4 mrem/year

Natural Radioactivity in Florida Phosphate Fertilizers (in pCi/gram)

	Normal Superphosphate	Concentrated Superphosphate	Gypsum
Ra-226	21.3	21.0	33.0
U-238	20.1	58.0	6.0
Th-230	18.9	48.0	13.0
Th-232	0.6	1.3	0.3

Porcelain Dentures
(uranium) ..... 1,500 mrem/year
Radioluminescent Clock
(promethium-147) ..... <1 mrem/year
Smoke Detector
(americium-241) ..... 0.01 mrem/year

International Nuclear Weapons Test Fallout from pre-1980 atmospheric tests
(average for a U.S. citizen) ..... 1 mrem/year

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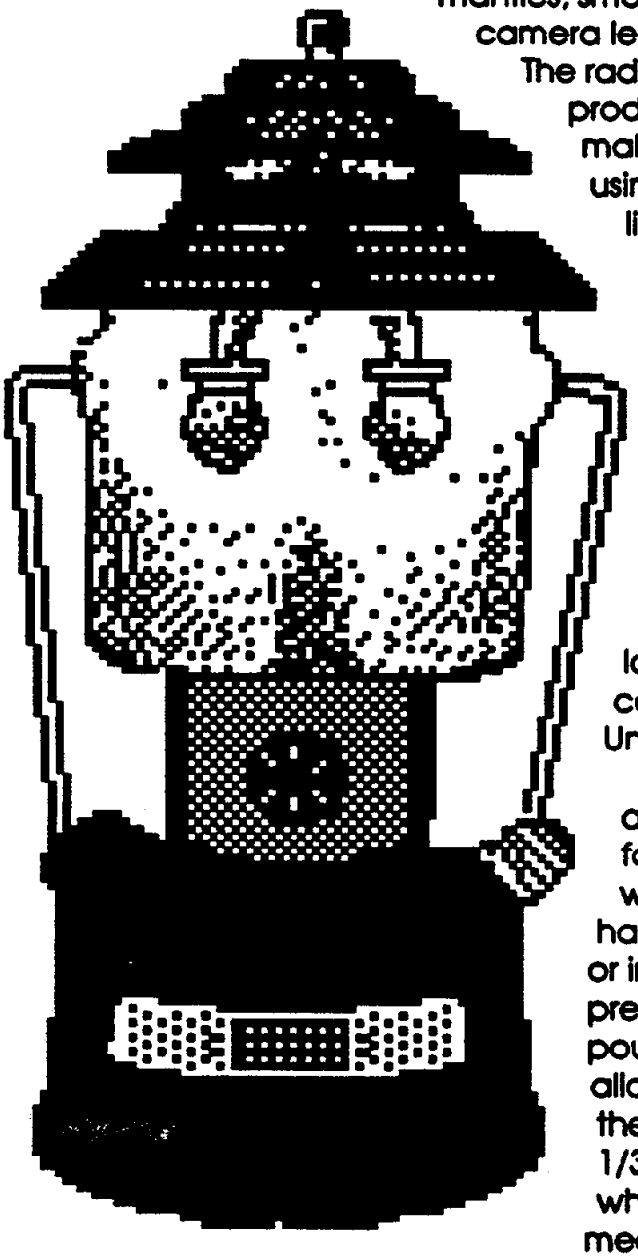
PERSPECTIVE: Radioactivity in Gas Lantern Mantles

Around the House

Many household products contain a small amount of radioactivity. Examples include gas lantern mantles, smoke detectors, dentures, camera lenses, and anti-static brushes. The radioactivity is added to the products either specifically to make them work, or as a result of using compounds of elements like thorium and uranium in producing them. The amount of radiation the products gives off is not considered significant. But with today's sensitive equipment, it can be detected.



Lanterns: In a New Light

About 20 million gas lantern mantles are used by campers each year in the United States.

Under today's standards, the amount of natural radioactivity found in a lantern mantle would require precautions in handling it at many Government or industry sites. The radioactivity present would contaminate 15 pounds of dirt to above allowable levels. This is because the average mantle contains 1/3 of a gram of thorium oxide, which has a specific activity (a measure of radioactivity) of approximately 100,000 picocuries per gram. The approximately 35,000 picocuries of radioactivity in the mantle would, if thrown onto the ground, be considered low-level radioactive contamination.

From information provided by W.L. Beck, Bechtel National, Inc.

PERSPECTIVE: How Big is a Picocurie?

The *curie* is a standard measure for the intensity of radioactivity contained in a sample of radioactive material. It was named after French scientists Marie and Pierre Curie for their landmark research into the nature of radioactivity.

The basis for the curie is the radioactivity of one gram of radium. Radium decays at a rate of about 2.2 trillion disintegrations ($2.2X10^{12}$) per minute. A *picocurie* is one trillionth of a curie. Thus, a picocurie represents 2.2 disintegrations per minute.

To put the relative size of one *trillionth* into perspective, consider that if the Earth were reduced to one trillionth of its diameter, the "pico earth" would be smaller in diameter than a speck of dust. In fact, it would be six times smaller than the thickness of a human hair.

The difference between the curie and the picocurie is so vast that other metric units are used between them. These are as follows:

Millicurie = $\frac{1}{1{,}000}$ **(one thousandth) of a curie**

Microcurie = $\frac{1}{1{,}000{,}000}$ **(one millionth) of a curie**

Nanocurie = $\frac{1}{1{,}000{,}000{,}000}$ **(one billionth) of a curie**

Picocurie = $\frac{1}{1{,}000{,}000{,}000{,}000}$ **(one trillionth) of a curie**

The following chart shows the relative differences between the units and gives analogies in dollars. It also gives examples of where these various amounts of radioactivity could typically be found. The number of disintegrations per minute has been rounded off for the chart.

UNIT OF RADIOACTIVITY	SYMBOL	DISINTEGRATIONS PER MINUTE	DOLLAR ANALOGY	EXAMPLES OF RADIOACTIVE MATERIALS
1 Curie	Ci	$2x10^{12}$ or 2 Trillion	2 Times the Annual Federal Budget	Nuclear Medicine Generator
1 Millicurie	mCi	$2x10^{9}$ or 2 Billion	Cost of a New Interstate Highway from Atlanta to San Francisco	Amount Used for a Brain or Liver Scan
1 Microcurie	µCi	$2x10^{6}$ or 2 Million	All-Star Baseball Player's Salary	Amount Used in Thyroid Tests
1 Nanocurie	nCi	$2x10^{3}$ or 2 Thousand	Annual Home Energy Costs	Consumer Products
1 Picocurie	pCi	2	Cost of a Hamburger and Coke	Background Environmental Levels

Chart provided by W.L. Beck, Bechtel National, Inc.

APPENDIX E

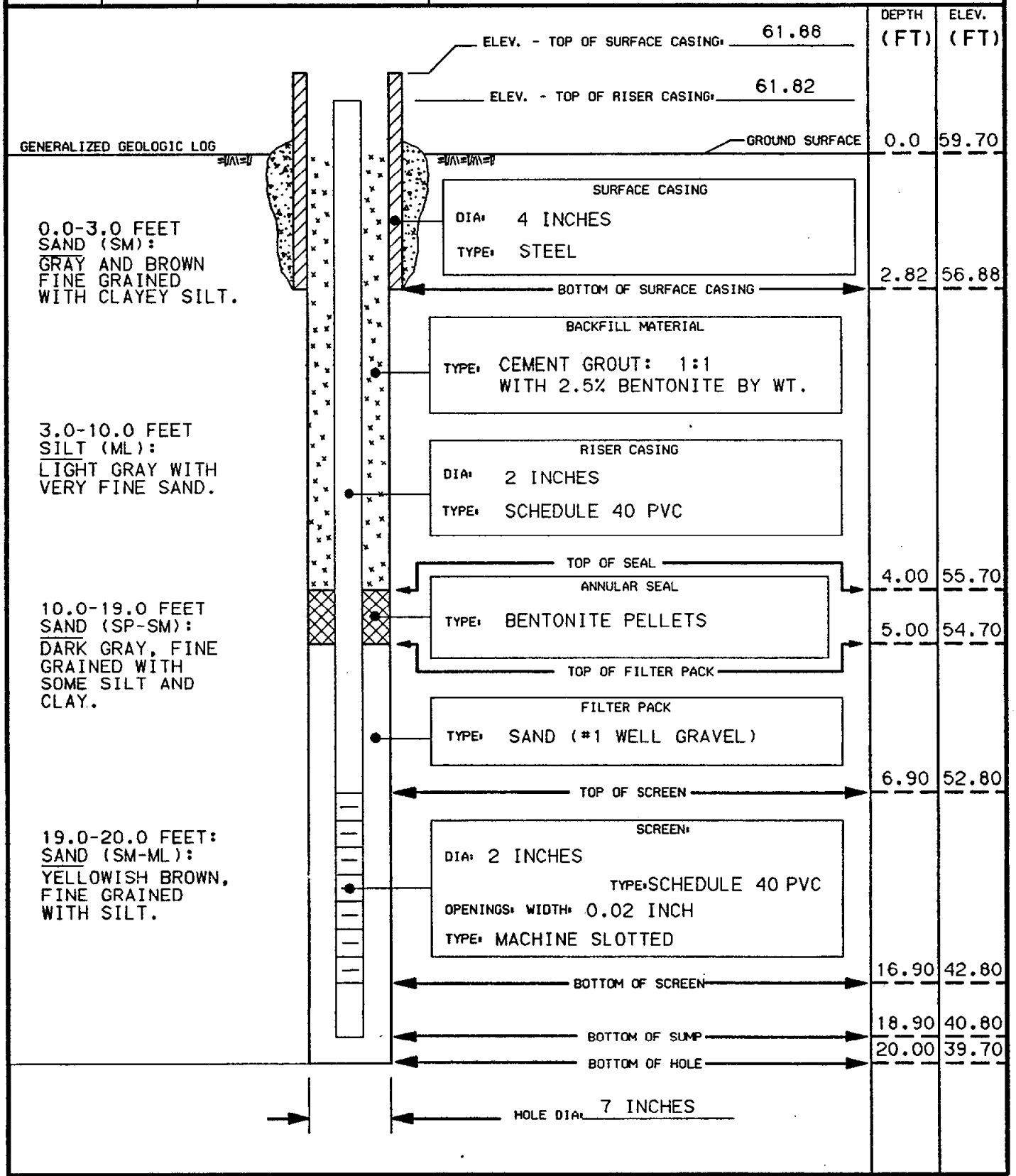
SAMPLE WELL CONSTRUCTION LOG

MONITORING WELL

PROJECT	WELL NO.
FUSRAP	MISS-2A

JOB NO.	SITE	COORDINATES (IN FEET)
14501	MAYWOOD I.S.S.	N 9973.36 E 9875.92

BEGUN	COMPLETED	PREPARED BY	REFERENCE POINT FOR MEASUREMENTS
10-29-84	10-30-84	R.H.NELSON	TOP OF RISER CASING



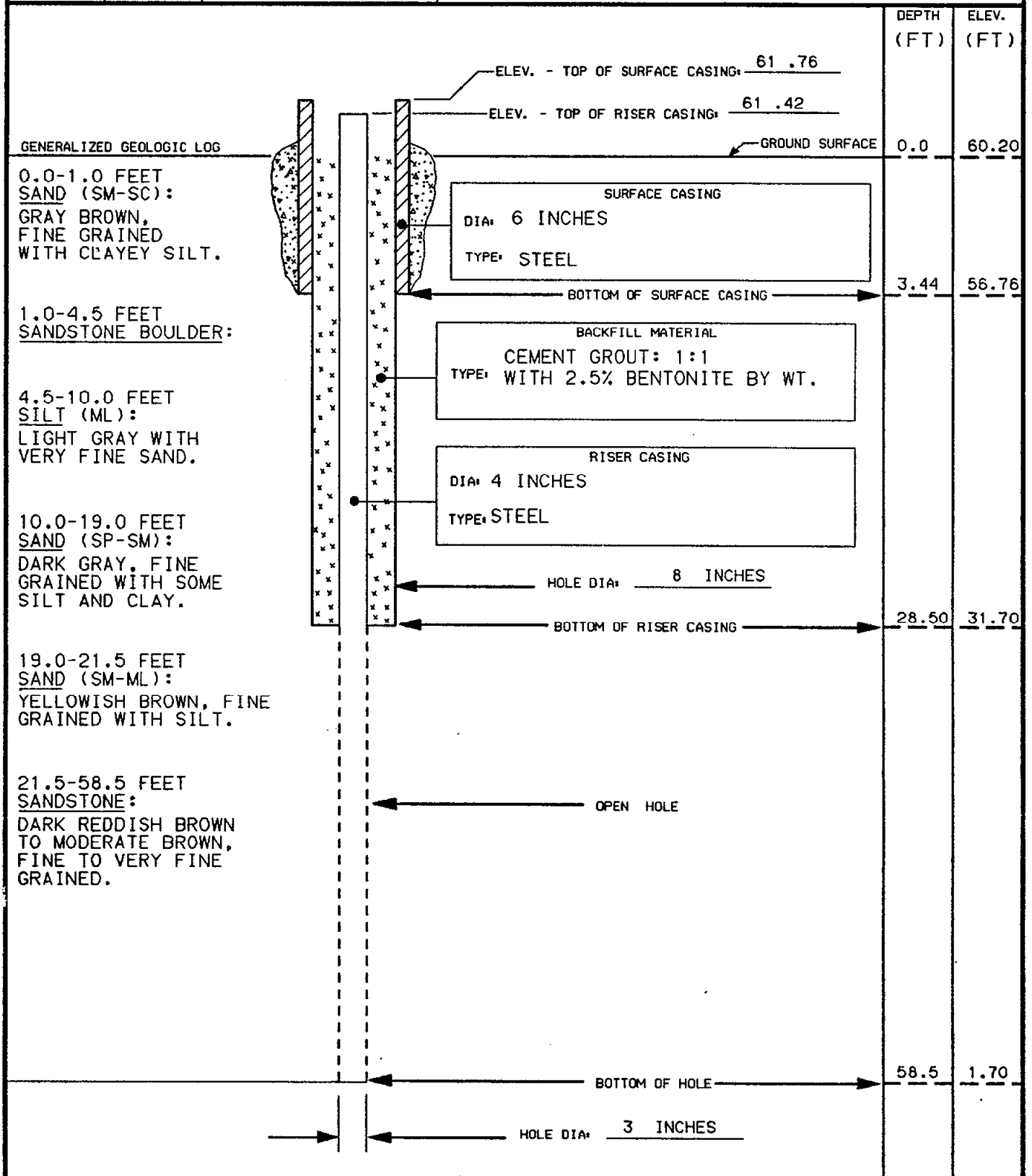
	DEPTH (FT)	ELEV. (FT)
GROUND SURFACE	0.0	59.70
BOTTOM OF SURFACE CASING	2.82	56.88
TOP OF SEAL	4.00	55.70
TOP OF FILTER PACK	5.00	54.70
TOP OF SCREEN	6.90	52.80
BOTTOM OF SCREEN	16.90	42.80
BOTTOM OF SUMP	18.90	40.80
BOTTOM OF HOLE	20.00	39.70

MONITORING WELL

PROJECT	WELL NO.
FUSRAP	MISS-2B

JOB NO.	SITE	COORDINATES (JOB-FEET)
14501	MAYWOOD I.S.S.	N 9962.48 E 9888.21

BEGUN	COMPLETED	PREPARED BY	REFERENCE POINT FOR MEASUREMENTS
10-29-84	11-12-84	R. H. NELSON	TOP OF RISER CASING



APPENDIX F

DISTRIBUTION LIST FOR MAYWOOD INTERIM STORAGE SITE ANNUAL SITE ENVIRONMENTAL REPORT

APPENDIX F

DISTRIBUTION LIST FOR MAYWOOD INTERIM STORAGE SITE

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Labor and Industry Building
John Fitch Plaza
Trenton, New Jersey 08625

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State of New Jersey
Department of Environmental Protection
Room 802, Labor and Industry Building
John Fitch Plaza CN-402
Trenton, New Jersey 08625

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Mr. Bob Stern
Radiation Decontamination Assessment
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State of New Jersey
Department of Environmental Protection
380 Scotch Road
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Mr. Jorge Berkowitz
State of New Jersey
Department of Environmental Protection
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Trenton, New Jersey 08625

Mr. E. Kaup
Bureau of Case Management and Enforcement
State of New Jersey
Department of Environmental Protection
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Trenton, New Jersey 08625

Mr. Frank Cosolito
Special Assistant to the Director
Division of Environmental Quality
State of New Jersey
Department of Environmental Protection
Room 1110, Labor and Industry Building
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Trenton, New Jersey 08625

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Borough of Maywood
459 Maywood Avenue
Maywood, New Jersey 07607

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Borough of Maywood
459 Maywood Avenue
Maywood, New Jersey 07607

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Rochelle Park, New Jersey 07662

Environmental Program Administrator
County of Bergen
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Mr. Wesley R. Van Pelt
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120 State Street
Hackensack, New Jersey 07601

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Maywood, New Jersey 07607

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Stepan Company
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Maywood, New Jersey 07607

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The laboratory for organic analyses conforms to QC procedures for the following:

- o GC/MS instrumentation for both volatile and semivolatile compound analysis
- o Initial multilevel calibration for each hazardous substance list (HSL) compound
- o Continuing calibration for each HSL compound
- o Addition of surrogate compounds to each sample and blanks for determining percent recovery information
- o Matrix spike analyses
- o Reagent blank analyses

Weston is currently an EPA-designated Contract Laboratory Program (CLP) laboratory for both organic and inorganic analyses. This requires passing EPA's blind performance evaluation testing each quarter. The technical specifications in BNI's subcontract with Weston specify QA/QC at, and in some cases beyond, the CLP level.

They participate in water studies to demonstrate technical competence for state drinking water certification programs. They also participate in water pollution studies to demonstrate technical competence for state wastewater certification programs. Currently, they participate in drinking water, wastewater, and/or hazardous waste certification programs. They are certified (or pending) in 35 such state programs. Continued certification hinges upon Weston's ability to pass the performance evaluation testing, and many of these tests are conducted semiannually.

Weston's QA program also includes an independent overview by their project QA coordinator and a corporate vice president who audits their program activities quarterly.

The FUSRAP sampling program was designed to provide for spikes, blanks, and QC duplicate sampling. Samples are tracked by chain-of-custody procecdures to maintain traceability.