Formerly Utilized Sites Remedial Action Program (FUSRAP)
Contract No. DE-AC05-91OR21949

MIDDLESEX SAMPLING PLANT
ENVIRONMENTAL REPORT
FOR CALENDAR YEAR 1992

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Middlesex, New Jersey

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**MIDDLESEX SAMPLING PLANT
ENVIRONMENTAL REPORT
FOR CALENDAR YEAR 1992**

**239 MOUNTAIN AVENUE
MIDDLESEX, NEW JERSEY**

MAY 1993

Prepared for

**United States Department of Energy
Oak Ridge Operations Office
Under Contract No. DE-AC05-91OR21949**

By

Bechtel National, Inc.

Oak Ridge, Tennessee

Bechtel Job No. 14501

MASTER

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EXECUTIVE SUMMARY

This report describes the environmental surveillance program at the Middlesex Sampling Plant (MSP) and provides the results for 1992. The site, in the Borough of Middlesex, New Jersey, is a 3.9-ha (9.6-acre), fenced area and includes four buildings and two storage piles that contain 50,800 m³ (66,400 yd³) of radioactive and mixed hazardous waste. More than 70 percent of the MSP site is paved with asphalt.

The MSP facility was established in 1943 by the Manhattan Engineer District (MED) to sample, store, and/or ship uranium, thorium, and beryllium ores. In 1955 the Atomic Energy Commission (AEC), successor to MED, terminated the operation and later used the site for storage and limited sampling of thorium residues. In 1967 AEC activities ceased, onsite structures were decontaminated, and the site was certified for unrestricted use under criteria applicable at that time. In 1980 the U.S. Department of Energy (DOE) initiated a multiphase remedial action project to clean up several vicinity properties onto which contamination from the plant had migrated. Material from these properties was consolidated into the storage piles onsite.

Environmental surveillance of MSP began in 1980 when Congress added the site to DOE's Formerly Utilized Sites Remedial Action Program (FUSRAP). FUSRAP was established to identify and decontaminate or otherwise control sites where residual radioactive materials remain from the early years of the nation's atomic energy program or from commercial operations causing conditions that Congress has authorized DOE to remedy.

The environmental surveillance program at MSP includes sampling networks for radon and thoron in air; external gamma radiation exposure; and radium-226, radium-228, thorium-230, thorium-232, and total uranium in surface water, sediment, and groundwater. Additionally, chemical analyses are performed to detect metals and organic compounds in surface water and groundwater and metals in sediments. This program assists in fulfilling the DOE policy of measuring and monitoring effluents from DOE activities and calculating hypothetical doses.

Monitoring results are compared with applicable U.S. Environmental Protection Agency (EPA) and state standards, DOE derived concentration guides (DCGs), dose limits, and other DOE requirements to determine the compliance status and the need for mitigative actions.

Based on a very conservative but plausible scenario, the potential radiation dose calculated for a resident in a home 30 m (100 ft) from the site would be about 0.3 mrem/yr (3×10^{-3} mSv/yr). This is less than one would receive from watching a color television set [less than 1 mrem/yr (1×10^{-2} mSv/yr)] or from heating a home and cooking with natural gas [2 mrem/yr (2×10^{-2} mSv/yr)]. The radiological dose to the total population is essentially zero.

Results from 1992 environmental surveillance and additional special sampling performed in 1990 and 1991 indicate the presence of radioactive contamination (exceeding DOE FUSRAP soil guidelines) in sediments in the drainage ditch adjacent to MSP. The impacts are being assessed to determine the level of environmental documentation required to support cleanup of the contaminated sediments in the ditch. After these assessments are completed, the appropriate actions will be taken to remedy the offsite contamination. An evaluation regarding the need for future cleanup will be performed. Lead was detected in several wells, and barium, chromium, and nickel were detected in one well at concentrations exceeding New Jersey Groundwater Quality Standards (NJGQS) for Class II-A waters and EPA Safe Drinking Water Act (SDWA) maximum contaminant levels (MCLs). Site activities in 1992 included environmental surveillance, site maintenance, and additional sampling onsite and offsite to determine the source of the elevated radionuclide concentrations in the drainage ditch. A permit application was submitted to the New Jersey Department of Environmental Protection and Energy (NJDEPE) to address the discharge of stormwater from MSP to the ditch.

The complete environmental report is distributed to representatives of federal, state, and local agencies and to individuals who have requested copies. The report is also available to the media.

COMPLIANCE SUMMARY

The primary regulatory guidelines, limits, and DOE requirements for environmental monitoring originate in the following federal acts: the Clean Air Act (CAA); the Clean Water Act (CWA); the SDWA; the Resource Conservation and Recovery Act (RCRA); the Toxic Substances Control Act (TSCA); the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA); the National Environmental Policy Act (NEPA); and the National Historic Preservation Act (NHPA).

Environmental remediation of MSP is being conducted in accordance with CERCLA, the protocol for remediating low-level radioactive contamination at FUSRAP sites, and applicable DOE requirements authorized by the Atomic Energy Act. The following summaries identify applicable or relevant and appropriate requirements (ARARs) as they existed in 1992 and the first quarter of 1993, define the status of compliance with the referenced requirements, and forecast the regulatory changes that may affect the site in the near future.

PRIMARY REGULATORY GUIDELINES

DOE Requirements for Radionuclide Releases

Site releases comply with specific DOE requirements that establish quantitative limits, DCGs, and dose limits for radiological releases from DOE facilities. Results of environmental monitoring indicate the presence of radionuclides in sediments in the drainage ditch adjacent to MSP at levels above DOE soil guidelines (because no sediment guidelines exist, soil guidelines are used for comparison).

Clean Air Act and National Emission Standards for Hazardous Air Pollutants

The primary federal statute governing air emissions is the CAA. Potential sources of air emissions from MSP are radionuclide emissions from the waste piles and onsite soils that are mostly covered by asphalt. Although CERCLA exempts MSP from requiring federal or

state air permits, MSP is required to comply with Subpart H ("National Emission Standards for Emissions of Radionuclides Other Than Radon from Department of Energy Facilities") and Subpart Q ("National Emission Standards for Radon Emissions from Department of Energy Facilities") of the National Emission Standards for Hazardous Air Pollutants (NESHAPs).

In 1992 compliance with the radon emission standard of Subpart Q was evaluated by monitoring radon flux emissions semiannually in accordance with EPA procedures. The resulting data were submitted to EPA, and MSP is in compliance with the radon emission standard.

In 1992 compliance with the emission standard for other radionuclides under Subpart H was evaluated using the EPA Clean Air Act Assessment Package-1988 (CAP-88) PC computer model. An annual report is due to EPA on June 30, 1993, and calculations performed indicate that the site is in compliance with Subpart H.

In addition, in spring 1993, one of the covered storage piles at MSP was recapped; a new cover was laid over the existing cover. The planned work was evaluated for compliance with applicable emission standards, and EPA has been informed of the work.

NESHAPs Subpart M contains the "National Asbestos Emission Standards." Asbestos is present on pipes in the processing building, and when the asbestos is removed, compliance with Subpart M and state asbestos standards will be required.

Clean Water Act

Pollutants discharged to waters of the United States are regulated under the CWA through regulations promulgated and implemented by the State of New Jersey.

On January 19, 1990, a permit application for surface water discharge was submitted to NJDEPE. On October 1, 1992, a second permit application was submitted for MSP to comply with federal stormwater regulations. NJDEPE has appended the 1992 application to the 1990 application but has not yet made a determination about them.

Safe Drinking Water Act

The SDWA was enacted by Congress in 1974 to regulate drinking water systems, provide for the protection of aquifers, and require EPA to establish primary drinking water regulations for contaminants that can cause adverse public health effects. The regulations established by EPA for drinking water systems include both mandatory levels (MCLs) and nonenforceable health goals [maximum contaminant level goals (MCLGs)] for regulated contaminants in drinking water.

Under the 1986 Superfund Amendments and Reauthorization Act, drinking water MCLs and MCLGs for regulated contaminants are ARARs that CERCLA cleanups are to meet for groundwater or surface water that is a current or potential source of drinking water. New Jersey is responsible for primary enforcement of federal drinking water regulations, and federal and state standards for regulated radionuclides in groundwater and surface water are identical.

In addition, New Jersey, unlike EPA, has established standards for contaminants in groundwater. These standards, revised in February 1993, also establish numerical criteria for regulated radionuclides in groundwater that are the same as federal and state SDWA standards. Under CERCLA, state groundwater standards that are more stringent than federal standards are ARARs to be attained in site remediation.

To determine whether the radionuclide and chemical concentrations in site groundwater met federal and state groundwater quality standards, the 1992 groundwater analysis results were compared with the federal SDWA MCLs, SDWA non-zero MCLGs, and the newly enacted NJGQS. During 1992 the NJGQS and/or SDWA MCLs and MCLGs for barium, beryllium, chromium, nickel, and 1,2,4-trichlorobenzene were exceeded in groundwater

samples from one well, and the standards for lead were exceeded in three wells. In addition, the concentrations of aluminum, iron, and manganese in groundwater exceeded NJGQS in all samples (except manganese in well 11), suggesting that background levels for these constituents in the vicinity of the site may be above NJGQS. The remaining 1992 groundwater sample results met the standards. Groundwater contamination will be discussed in the environmental documentation being prepared for site remediation.

Resource Conservation and Recovery Act

RCRA is the principal federal statute governing the management of hazardous waste. In compliance with solid waste testing requirements, soil samples were taken from the two waste piles at MSP and analyzed for toxicity. The pile, which contains waste from the 1984 cleanup of the nearby Middlesex Municipal Landfill, exhibits the RCRA characteristic of toxicity because of elevated levels of lead in the pile. Because MSP is being remediated pursuant to CERCLA, no RCRA permit for the storage pile is required; however, compliance with the substantive provisions of RCRA and with New Jersey groundwater and surface water standards is being reevaluated because of the presence of an RCRA-regulated contaminant. These elevated levels will also be considered when DOE evaluates cleanup alternatives for the site. As required by CERCLA, cleanup alternatives will comply with all applicable or relevant and appropriate environmental laws.

Toxic Substances Control Act

The most common toxic substances regulated by TSCA are polychlorinated biphenyls (PCBs) and asbestos. PCB waste has not been detected at MSP, but a small quantity of asbestos is present around piping in the processing building. When implementing remedial actions, FUSRAP will comply with the handling and notification provisions mandated by federal EPA and New Jersey regulations.

Comprehensive Environmental Response, Compensation, and Liability Act

CERCLA and the National Oil and Hazardous Substances Pollution Contingency Plan are the primary sources of federal regulatory authority for remedial action at MSP.

A review of environmental monitoring results for 1992 indicates the presence of radionuclides in sediments in the drainage ditch adjacent to MSP at levels exceeding DOE guidelines for residual radioactivity in soil. These elevated values were identified during characterization activities and will be factored into the decision-making process for selecting a final remedy for the site. Plans are under way to conduct a removal action at MSP to excavate the contaminated sediment in the ditch. As required under CERCLA, the removal action will be documented in an engineering evaluation/cost analysis (EE/CA) report that will be made available for public review when finalized. The level of NEPA documentation that will be required is being evaluated.

Onsite activities are being conducted in accordance with CERCLA provisions to comply with the substantive provisions of federal and state permitting regulations and the applicable or relevant and appropriate provisions of other regulations.

National Environmental Policy Act

During 1992, compliance with NEPA was achieved by the approval of categorical exclusions for ongoing environmental monitoring, surveillance, and maintenance activities at MSP. A categorical exclusion is a category of actions, defined by 40 CFR 1508, that would not normally require an environmental assessment (EA) or an environmental impact statement. The initiation of remedial action will require the preparation of an EA, which will be integrated into the EE/CA, consistent with DOE policy.

National Historic Preservation Act

The Office of New Jersey Heritage is evaluating MSP to identify cultural resources. Any information required by this office will be submitted accordingly. FUSRAP is actively

committed to managing cultural resources that may be affected by environmental restoration activities. The FUSRAP cultural resource management program ensures that the early stages of project planning provide for a thorough consideration of the potential effects of environmental restoration activities on any cultural resources that may be located on FUSRAP sites. Consultation with state historical preservation officers, Native American groups, and local historians is ongoing to identify cultural resources that may be eligible for nomination to the National Register of Historic Places in accordance with requirements of Section 106 of the NHPA.

To date, the FUSRAP cultural resource management program has not identified any historic properties, such as districts, sites, buildings, and structures, at any of the FUSRAP sites that are currently undergoing environmental restoration.

Other Major Environmental Statutes and Executive Orders

In addition to DOE requirements and statutes, several other major environmental statutes have been reviewed for applicability as information about the site is developed. For example, the Federal Insecticide, Fungicide, and Rodenticide Act and the Endangered Species Act have been found to impose no current requirements on MSP. In addition, Executive Orders 11988 ("Floodplain Management") and 11990 ("Protection of Wetlands") and state laws and regulations have been reviewed for applicability. Applicable environmental statutes, regulations, and executive orders are reviewed regularly to maintain continual regulatory compliance at MSP.

APPLICABLE ENVIRONMENTAL PERMITS

As stated previously in the CWA section, a stormwater discharge permit application was submitted pursuant to National Pollutant Discharge Elimination System regulations before the regulatory deadline of October 1, 1992.

SUMMARY OF REGULATORY COMPLIANCE IN CALENDAR YEAR 1993 (FIRST QUARTER)

Routine site maintenance, surveillance, and environmental surveillance continued during the first quarter of 1993, as did review of potentially applicable regulations for their impact on the site. Compliance issues currently being addressed include metals in excess of SDWA standards and NJGQS.

Plans are under way to clean up the ditch at the Middlesex site; these plans are being evaluated to ensure compliance with federal and state wetlands and floodplain requirements and with groundwater and surface water quality criteria. Compliance with federal and state emission standards has also been evaluated for the planned pile cover replacement activity.

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ACRONYMS

AEC	Atomic Energy Commission
ARAR	applicable or relevant and appropriate requirement
BGS	below ground surface
BNI	Bechtel National, Inc.
CAA	Clean Air Act
CAP88	Clean Air Act Assessment Package - 1988
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
CWA	Clean Water Act
DCG	derived concentration guide
DOE	Department of Energy
DQO	data quality objective
EA	environmental assessment
EE/CA	engineering evaluation/cost analysis
EPA	Environmental Protection Agency
FUSRAP	Formerly Utilized Sites Remedial Action Program
MCL	maximum contaminant level
MCLG	maximum contaminant level goal
MED	Manhattan Engineer District
MML	Middlesex Municipal Landfill
MS	matrix spike
MSD	matrix spike duplicate
MSL	mean sea level

ACRONYMS

(continued)

MSP	Middlesex Sampling Plant
NESHAPs	National Emission Standards for Hazardous Air Pollutants
NHPA	National Historic Preservation Act
NJGQS	New Jersey Groundwater Quality Standards
NOAA	National Oceanic and Atmospheric Administration
PARCC	precision, accuracy, representativeness, comparability, and completeness
PCB	polychlorinated biphenyl
QA	quality assurance
QC	quality control
RCRA	Resource Conservation and Recovery Act
RPD	relative percent difference
SDWA	Safe Drinking Water Act
TETLD	tissue-equivalent thermoluminescent dosimeter
TOC	total organic carbon
TOX	total organic halides
TPH	total petroleum hydrocarbon
TSCA	Toxic Substances Control Act

UNITS OF MEASURE

Bq	becquerel
C	Celsius
cm	centimeter
F	Fahrenheit
ft	foot
ft msl	feet above mean sea level
g	gram
h	hour
ha	hectare
in.	inch
kg	kilogram
km	kilometer
L	liter
m	meter
μ Ci	microcurie
μ g	microgram
mg	milligram
mi	mile
ml	milliliter
mph	miles per hour
mR	milliroentgen
mrem	millirem
mSv	millisievert
pCi	picocurie
ppb	parts per billion
ppm	parts per million
rem	roentgen equivalent man
Sv	sievert
yd	yard
yr	year

Between 1968 and 1980, the site was used by the General Services Administration and then by the Department of the Navy as a U.S. Marine Corps reserve training center. In 1980 custody of MSP was returned to DOE, which then initiated remedial action to clean up vicinity properties that had become contaminated by contaminant migration during earlier years of operation.

The Middlesex Municipal Landfill (MML), an MSP vicinity property established in the mid-1940s, began to receive soil contaminated with pitchblende (high-grade uranium ore) in 1948, which was placed over existing fill at MML. By 1974 solid waste disposal had ceased at MML. Early radiological surveys indicated that 0.2 ha (0.5 acre) of MML required remediation; in 1984 approximately 12,000 m³ (16,000 yd³) of contaminated soil was returned to MSP for interim storage. Later investigations showed the contaminated area to be 1.2 ha (3.0 acres). By 1986, 23,900 m³ (31,200 yd³) of contaminated soil had been returned to MSP for interim storage, which marked the completion of the remedial action at vicinity properties.

1.2 REGIONAL DEMOGRAPHY

As shown in Figure 1-4, land use in the vicinity of MSP is predominantly industrial/residential with some forest and meadow land. The property is bordered by the Lehigh Valley Railroad to the north, vacant land to the south, residential and commercial property to the east, and a salvage yard to the west.

The nearest residential areas are adjacent to the eastern side of the site; the residences are primarily mixed single- and multiple-family dwellings. The distance to the nearest residence is approximately 30 m (100 ft). The total population of the area within an 80-km (50-mi) radius of MSP is approximately 15 million.

1.0 INTRODUCTION

Environmental monitoring of the U.S. Department of Energy's (DOE) Middlesex Sampling Plant (MSP) began in 1980. This document describes the environmental surveillance program, the results for 1992, and the compliance status of the site.

Environmental monitoring of MSP began when it was placed in DOE's Formerly Utilized Sites Remedial Action Program (FUSRAP). FUSRAP was established to identify and decontaminate or otherwise control sites where residual radioactive materials remain from the early years of the nation's atomic energy program or from commercial operations causing conditions that Congress has authorized DOE to remedy.

1.1 SITE DESCRIPTION

MSP occupies approximately 3.9 ha (9.6 acres) in north-central New Jersey within the Borough of Middlesex (Middlesex County) (Figure 1-1). The MSP property includes four buildings, a sediment settling basin, and two storage piles that contain a total of 50,800 m³ (66,400 yd³) of contaminated soil (Figure 1-2). More than 70 percent of the property is paved with asphalt. The site is currently used for interim storage of radioactively contaminated soil and hazardous waste as defined by the Resource Conservation and Recovery Act. The hazardous waste is in the form of contaminated soils contained in one of the two storage piles. The site is entirely fenced, and public access is restricted. Figure 1-3 is an aerial photograph of the site.

The MSP facility was established in 1943 by the Manhattan Engineer District (MED) to sample, store, and/or ship uranium, thorium, and beryllium ores. In 1955 the Atomic Energy Commission (AEC), successor to MED, terminated the operation and later used the site for storage and limited sampling of thorium residues. In 1967 AEC activities ceased, onsite structures were decontaminated, and the site was certified for use without radiological restrictions under criteria applicable at that time.

1.3 HYDROGEOLOGIC SETTING

1.3.1 Geology

MSP is underlain by the Passaic Formation of the Brunswick Group, Newark Supergroup, as defined by the nomenclature of Lyttle and Epstein (1987). The Passaic Formation in the local area is composed of interbedded dark, dull, red fissile shale and massive siltstone with occasional lenticular strata of well-sorted sandstone. The bedrock unit in the site area consists of the shale portion of the Passaic Formation and is moderately to highly fractured. The formation is horizontally bedded, and fracture frequency decreases with depth. Bedrock at the site occurs at depths of approximately 0.9 to 2 m (3 to 7 ft) [elevation of 13.4 to 16.5 m (44 to 54 ft) above mean sea level (MSL)]. The upper portion of the bedrock is weathered, grading downward into competent rock. Overlying the weathered bedrock unit is a thin [0.9 to 2 m (3 to 7 ft) thick] layer of unconsolidated sediments. The natural materials in this section are composed primarily of poorly sorted, silty, sandy clay and clayey, silty, fine- to medium-grained sand.

1.3.2 Surface Water

The site slopes gently, and approximately 70 percent of the surface is covered by asphalt and the waste storage piles. The remainder of the site is covered with grass and gravel. Rainfall runoff from the waste storage piles is diverted into a settling basin located along the southern site boundary. The settling basin is connected to an outfall near the center of the southern property line. Runoff from the areas outside the piles also drains to the outfall, which discharges into a drainage ditch conveying surface water offsite to Main Stream south of the site.

1.3.3 Groundwater

The site is underlain by the shale portion of the Passaic Formation, which is used for domestic, municipal, and industrial water supply in Middlesex County. In general, the formation has low primary porosity. Groundwater flow in the aquifer is controlled by

secondary porosity associated with fractures and joints in the formation. Groundwater flow across the site is from north to south toward a small drainage ditch south of the site. Water level data indicate that the gradient is 0.01. Groundwater underlying the site is very shallow, ranging in depth from 0.03 to 2.4 m (0.1 to 8 ft) below the surface. Hydrographs are presented in Appendix A.

The Passaic Formation in the local area, which is used as a source of water for municipal and industrial supply, is classified as a II-A water supply source under Environmental Protection Agency (EPA) criteria.

Water Supply

The principal sources of potable water in the MSP area are wells and surface water from the Raritan River. Many wells are located within 4.8 km (3 mi) of MSP, a public well field (Sebrings Mill) is about 2 km (1.3 mi) northwest, and a surface water intake is about 4.8 km (3 mi) downstream of the site. Nearly all the water supply for the Borough of Middlesex comes from these sources.

1.4 CLIMATE

Climatological data from the National Oceanic and Atmospheric Administration (NOAA) for the Newark vicinity for 1992 (measured at the Newark Airport) show that temperature extremes ranged from -12° to 36°C (10° to 97°F). Average wind speeds ranged from 14 to 18.4 km/h (8.7 to 11.4 mph), and the predominant resultant wind direction was from the west (NOAA 1993).

The minimum monthly precipitation [1.85 cm (0.73 in.)] occurred in October 1992, the maximum [12.8 cm (5.02 in.)] occurred in November 1992, and the average for 1992 was 7.77 cm (3.06 in.).

FIGURES FOR SECTION 1.0

Figure 1-1
Location of MSP

Figure 1-2
Plan View of MSP

118 R39F 004.DGN

Figure 1-3 Aerial View of MSP

BASED ON AERIAL PHOTOGRAPHS, SITE VISITS, AND USGS TOPOGRAPHIC MAPS, 1:24000 SCALE, PLAINFIELD NJ QUADRANGLE, (PHOTO REVISED 1981) AND BOUND BROOK, (PHOTO REVISED 1970)

R RESIDENTIAL	C/I COMMERCIAL/INDUSTRIAL
C COMMERCIAL	T/I TRANSPORTATION/INDUSTRIAL
C/R MIXED COMMERCIAL/RESIDENTIAL	V VACANT
P PUBLIC	E EDUCATIONAL

0 0.5 MI
0 0.8 KM

Figure 1-4
Generalized Land Use in the Vicinity of MSP

2.0 ENVIRONMENTAL PROGRAM INFORMATION

2.1 PERMIT ACTIVITIES

This section of the report describes programmatic activities conducted at MSP other than those conducted as part of routine environmental monitoring. The environmental program information discussed in this section includes descriptions of the following:

- Permit-driven activities at MSP
- Emissions monitoring other than routine environmental surveillance
- Environmental documentation activities
- Significant environmental activities at the site
- Environmental awareness activities such as employee education programs to help promote waste minimization at the site
- Self-assessment activities

Information regarding routine environmental surveillance at the site is provided in Section 3.0.

A permit application for stormwater discharge was initially submitted to the New Jersey Department of Environmental Protection and Energy on January 19, 1990. Supplementary information was submitted on October 1, 1992 (DOE 1992). Based on the present knowledge of site conditions and the onsite permitting exemption accorded under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) to sites that conduct onsite remedial action activities, no other permits are required. DOE must, however, meet all substantive requirements of those permits that would affect the site.

2.2 EMISSIONS MONITORING RESULTS

No reports were required under Section 313 of the Emergency Preparedness and Community Right-to-Know Act. FUSRAP sites were not subject to toxic chemical release reporting provisions under 40 CFR 372.22 in 1992.

However, FUSRAP evaluates and inventories toxic chemicals maintained onsite. Chemicals such as nitric acid are used at FUSRAP sites for sampling and other purposes, but the quantities of such chemicals stored onsite are well below threshold planning quantities.

2.3 ENVIRONMENTAL DOCUMENTATION

Environmental documentation for the site consists of categorical exclusions under the National Environmental Policy Act for routine site maintenance and environmental monitoring.

2.4 SIGNIFICANT ENVIRONMENTAL ACTIVITIES

2.4.1 Special Studies

Data for a limited number of sediment samples collected to assist in site characterization will be published in next year's environmental report. The samples were collected during fall 1992 from several onsite locations and from the drainage ditch that receives site surface water runoff. The samples were collected to identify the source(s) of radionuclides that are apparently migrating from the site into the ditch. Information regarding the nature and extent of this contamination can be found in Subsection 3.2 and the 1991 environmental report for MSP (BNI 1992b).

2.4.2 Environmental Monitoring Changes

The environmental surveillance programs at FUSRAP sites are periodically evaluated and revised on the basis of individual site conditions, program objectives, and data results. Revisions can consist of the number of sample collection points, frequency of sample collection, and parameters analyzed. Details of changes and rationales supporting the current program design can be found in the MSP environmental monitoring plan (BNI 1991). This section summarizes changes in the MSP environmental surveillance program from 1991 to 1992.

Surface Water and Sediment

Sampling locations and frequency remained the same in 1992 as they were in 1991. However, the number of chemical analyses performed was reduced (BNI 1991). Analyses for nitrate, sulfate, chloride, and phosphate were conducted in 1991 to support data requirements for the remedial investigation/feasibility study. Because the results were generally consistent and below applicable guidelines and because the data requirements have been met, these analyses are no longer performed. Analyses for certain metals and organic compounds are performed annually.

Groundwater

The groundwater monitoring network consists of 19 wells from which samples were collected and analyzed quarterly from 1980 to 1991 for radiological and chemical constituents. Based on these results and results of a comprehensive suite of analyses conducted in 1991, the scope of the surveillance program was reduced to annual sampling of seven wells. The spectrum of radiological analyses was unchanged; the number of chemical analyses was slightly reduced in the same manner and for the same reason as described for the surface water and sediment changes.

External Gamma Radiation

Based on previous years' monitoring results, the number of monitoring locations was reduced from 27 in 1991 to 19 in 1992, which still provides adequate surveillance. In addition, the locations were moved from areas primarily onsite, surrounding the piles, to fenceline locations to better assess potential doses to the public.

Radon/Thoron

Based on the low concentrations observed in previous years, the number of radon/thoron monitoring stations was reduced from 27 to 19, which still maintains adequate coverage. These stations are situated at the external gamma radiation monitoring locations.

2.4.3 Remedial Actions

No remedial action activities were conducted during the reporting period.

2.5 ENVIRONMENTAL AWARENESS ACTIVITIES

FUSRAP is committed to minimizing the generation of waste at FUSRAP sites by using source reduction, material substitution, and recycling.

Pollution prevention awareness is promoted and various waste minimization techniques are implemented as part of continuing employee training and awareness programs to reduce waste and meet the requirements for quality, safety, and environmental compliance. No hazardous waste minimization certifications or waste reduction reports for waste generators were required during this reporting period.

Site workers must complete a 40-h hazardous waste training program before beginning work and an 8-h refresher program every year thereafter to comply with Occupational Safety and Health Administration requirements in 29 CFR 1910.120. During their first three days onsite, workers also attend site-specific training sessions. Additional training includes, but is not limited to, fire extinguisher training, respirator training, self-contained breathing apparatus training, and weekly safety meetings.

2.6 SELF-ASSESSMENTS

A self-assessment was conducted in late December 1992; however, the assessment report has not been completed yet and, therefore, the results cannot be incorporated into this environmental report. The assessment results will be included in the 1993 environmental report.

A formalized self-assessment approach for all FUSRAP sites was approved on April 22, 1993, specifically addressing self-assessment activities for the program during the remainder of fiscal year 1993 and fiscal year 1994.

3.0 MONITORING NETWORKS AND RESULTS

MSP is not an active site and produces no processing effluents. The only possibility for contamination to be released from the site would be through contaminant migration. The adequacy of existing monitoring activities is assessed annually, and the results are used to identify the need for changes in the program. These may result from changing site conditions or regulatory requirements or from newly identified data needs to support the remedy selection process for the site. Additionally, as monitoring data are accumulated, decisions may be made to adjust monitoring requirements. Future site environmental reports will reflect these changes.

Based on knowledge of contaminants historically present at MSP, environmental monitoring in 1992 included sampling and analysis for:

- Radon and thoron concentrations in air
- External gamma radiation exposure
- Selected inorganic and organic chemicals and radium-226, radium-228, thorium-230, thorium-232, and total uranium concentrations in groundwater, surface water, and sediments

Readers not familiar with radiation units may benefit from reviewing Appendix B before proceeding.

The monitoring systems included onsite, site boundary, and offsite stations to provide sufficient information on the potential effects of the site on human health and the environment. The analytical methods performed for each parameter in each matrix are listed in Appendix C.

This section of the report contains sampling results and yearly averages, where applicable. The methodology for evaluating the data is provided in Appendix D. The results are compared with standards listed in Appendix E.

3.1 AIR MONITORING

3.1.1 Radon/Thoron

One of the potential pathways of radiation exposure from the uranium-238 decay series is the inhalation of the radioactive gas radon-222 and its associated decay products. Radon-222 has a short half-life (3.8 days), which is the time it takes for half of the activity to decay. When the gaseous radon decays, it forms a radioactive particulate (solid) that attaches itself to very small dust particles that can also be inhaled. Similarly, in the thorium-232 decay series, inhalation of the radioactive gas radon-220 (or thoron) and its associated decay products is a potential pathway for radiation exposure. The half-life of thoron is very short (55 seconds), and its associated decay products are also radioactive solids that attach themselves to particles. Both radon and thoron decay by the emission of alpha particles that travel only a very short distance in air (about one inch) before losing their energy and ability to contribute a radiation dose to an individual.

Because radon and thoron are gaseous and subsequently decay to products that attach themselves to very small, easily dispersible particles, they are very mobile in air and are diluted and dissipated very quickly in the environment.

Radon and thoron are monitored quarterly at MSP to evaluate compliance with environmental regulations and to aid in the determination of the potential dose to the maximally exposed member of the general public. The monitoring locations are shown in Figures 3-1 and 3-2.

As shown in Tables 3-1 and 3-2, all boundary monitoring locations yielded 1992 annual average results that were essentially the same as background. In 1992 and the preceding five years, only one of the average radon boundary concentrations (Station 4 in 1991) exceeded the derived concentration guide (DCG) of 3.0×10^{-9} $\mu\text{Ci/ml}$ (0.1 Bq/L). This occurrence is considered an anomaly and is not a true indication of the annual average concentration actually present. Thoron levels measured since 1991 have remained similarly low. No other trends are indicated. Radon and thoron concentrations onsite are elevated because monitoring

was conducted within the poorly ventilated process building, which was constructed on contaminated soils.

3.1.2 External Gamma Radiation

External gamma radiation exposure rates are measured as part of the routine environmental surveillance program to confirm that direct radiation from MSP is not significantly increasing radiation levels above natural background and to ensure compliance with environmental regulations.

Although the tissue-equivalent thermoluminescent dosimeters (TETLDs) used for monitoring are state-of-the-art, the dosimeter accuracy is approximately ± 10 percent at exposure rates between 100 and 1,000 mR/yr and ± 25 percent at rates between 0 and 100 mR/yr.

The external gamma radiation background value is not constant for a given location or from one location to another, even over a short time, because the value is affected by a combination of both natural terrestrial and cosmic radiation sources and factors such as the location of the dosimeter in relation to surface rock outcrops, stone or concrete structures, or highly mineralized soil. Dosimeters are also influenced by site altitude, annual barometric pressure cycles, and the occurrence and frequency of solar flare activity (Eisenbud 1987). Thus, external gamma radiation exposure rates at the boundary could be lower than the background rates measured some distance from the site, and rates onsite could be lower than at the boundary.

Results for external gamma radiation monitoring in 1992 are provided in Table 3-3. Results from 1987 through 1991 are included to aid in the identification of trends. As the table shows, 1992 results for the site boundary locations are all low; the annual average rate was 13 mR/yr above the measured background. None of the measurements exceeded the DOE guideline of 100 mrem/yr (1 mSv/yr) above background (1 mR of external gamma radiation is equal to a dose of 1 mrem). Generally, the measured exposure rates in 1992 were lower than in previous years because many of the detector locations were moved to the

site boundary, farther away from the interim storage piles. Although these location changes preclude the identification of any trends in exposure rates between 1992 and previous years, the results demonstrate how exposure rates decrease rapidly as distance from a source is increased; the new locations provide better data for dose calculations. Information on public exposure can be found in Section 4.0. Elevated results at onsite location 6 are a result of its proximity to the interim storage pile.

For comparison, Table 3-4 shows the annual average external gamma radiation exposure rates at the site boundary, in the vicinity of the site, and across the nation. Based on these data, contaminated soil stored at MSP does not present a threat to the public from external gamma radiation exposure because the rates are so low and access to the material is restricted.

3.2 SURFACE WATER AND SEDIMENT MONITORING

Surface water and sediment samples were collected quarterly at six locations (Figure 3-3). Location 4 is upstream to monitor background conditions; locations 1, 2, 2A, and 3 are downstream to determine the effect of runoff from the site on surface waters and sediments in the vicinity; and location 5 is onsite in the settling basin. Sampling location 2 was replaced with 2A in the third quarter of 1992 because of recurring sample retrieval problems created by the presence of large gravels used to prevent erosion.

The 1992 surface water and sediment samples were analyzed quarterly for radium-226, radium-228, thorium-230, thorium-232, and total uranium, and annually (in June) for total petroleum hydrocarbons (TPH) and the 25 metals listed in Appendix C, Tables C-1 and C-2. In addition, surface water samples were analyzed for organic compounds and indicator parameters [i.e., pH, specific conductance, total organic halides (TOX), and total organic carbon (TOC)].

3.2.1 Surface Water Results

Table 3-5 presents annual average results of radiological analyses for 1992 and the past five years. Although total uranium and radium-226 concentrations at location 1 exceed background (measured at location 4), they are still well below DOE DCGs and do not pose a health threat. The rise in the annual average radium-226 concentration at location 1 over previous years' results is a result of one elevated measurement [$77.8 \times 10^{-9} \mu\text{Ci/ml}$ (2.9 Bq/L)] obtained in the fourth quarter. This may be an anomaly because no activities that might disturb the stability of the contaminants onsite occurred in 1992. Radium-228, thorium-230, and thorium-232 concentrations were all low and well below DOE guidelines.

Analyses for chemical constituents in surface water detected no pesticides, polychlorinated biphenyls (PCBs), or volatile or semivolatile organic compounds above the detection limits. Results of analyses for indicator parameters are given in Table 3-6. TOC and TPH results are all low, with no meaningful differences between the upstream and downstream sampling results. TOX results are also fairly low, although results from locations 5 (in the settling basin) and 1 (immediately downstream of the site) are higher than results for the upstream sample. The TOX concentrations in samples farther downstream are comparable to the concentration found at the upstream sampling location. As Table 3-7 shows, no metals were detected above existing EPA drinking water standards or New Jersey surface water quality criteria.

3.2.2 Sediment Results

Table 3-8 presents annual average results of radiological analyses of sediments for 1992 and the past five years. There are no DOE DCGs for radionuclides in sediment; therefore, concentrations of radium and thorium isotopes in sediment have been compared with FUSRAP soil guidelines, which are listed in Appendix E. A site-specific guideline has not been established for uranium.

Table 3-8 shows that elevated concentrations (above background measured at location 4) of total uranium, radium, and thorium are present in samples from locations downstream of

MSP. To better determine the nature and extent of the elevated concentrations, a special study was performed in which additional sediment samples were collected downstream of the plant outfall. The results of this study, which are summarized in the 1991 environmental report (BNI 1992b), indicate that contaminated sediments are migrating offsite, and radium-226 and thorium-232 concentrations in some areas of the drainage ditch exceed the FUSRAP guideline of 5.0 pCi/g above background in surface soil.

The ditch will be cleaned up in accordance with CERCLA, and an engineering evaluation/cost analysis will be prepared to develop and evaluate cleanup alternatives. This document will be made available to the public for review and comment before any cleanup activities begin. Efforts are under way to determine the area(s) from which the contaminants are migrating. A silt fence to stop further migration has been designed but will not be constructed until a wetlands assessment investigation is completed for the vacant land adjacent to the ditch.

Sediment samples collected in the third quarter from all five monitoring locations were analyzed for TPH; results are given in Table 3-9. Concentrations were greatest at location 1 just downstream of the settling basin and at location 5 in the settling basin. The results for location 1 are also influenced by stormwater discharges from neighboring upstream properties where activities such as truck maintenance and automobile salvage are performed. Spills of oil, lubricants, and fuel could be contributing to the TPH result at that location. The other three sediment sampling locations show considerable variation in the concentration of TPH (25 to 870 mg/kg), with the location upstream of MSP having the highest concentration. These results indicate that there is considerable variation in the ambient concentrations of TPH in the vicinity of MSP. Although TPH concentrations in sediment increase just downstream of MSP, the urban environment contributing to this location makes contributions from MSP indistinguishable from contributions from other properties.

Sediment samples collected in the third quarter from all five monitoring locations were analyzed for metals; results are given in Table 3-10. The metals most frequently detected were aluminum, arsenic, chromium, copper, iron, lead, and zinc. Location 2A, 0.4 km (0.25 mi) downstream of MSP, and location 5, in the settling basin, generally had the highest

concentrations; location 1, immediately downstream of the settling basin, generally had the lowest or next-to-lowest concentrations. These results indicate that the settling basin may be collecting metals in sediment from MSP and adjacent properties and preventing the migration of metals through the surface water system. The increase in metal concentrations at location 2A may be a result of water runoff into Main Stream (unaffected by MSP runoff).

3.3 GROUNDWATER MONITORING

Groundwater monitoring was conducted to detect potential contaminants in the shallow groundwater and to ensure compliance with environmental regulations.

3.3.1 Monitoring Well Network

The existing groundwater monitoring network consists of 19 wells, which were installed during 1980 and 1981 primarily along the perimeter of the site (Figure 3-4). Most of these wells have been monitored for radiological and chemical constituents since 1985.

Conclusions from these results (1985-1991) are summarized as follows:

- Detected concentrations of radionuclides were all below DOE DCGs
- Total metals concentrations were generally low, but there were some erratic elevated concentrations that may have reflected excess sample turbidity
- Detected dissolved metals concentrations were within the range of background concentrations
- Volatile and semivolatile organic compounds were typically not detected; the only consistently detected compound was trichloroethene, (at concentrations between 18 and 66 $\mu\text{g/L}$) in well 21D
- Pesticides and PCBs were not detected

Based on these results, the scope of the DOE environmental surveillance program was reduced in 1992; the revised scope included collection of samples from fewer wells and a reduction in sampling frequency from quarterly to annually.

Monitoring in 1992 included collection of groundwater samples from seven wells: upgradient well 1 and downgradient wells 4, 5, 9, 11, 14, and 21S. Because of slow recovery, well 1 was not sampled, and well 20S was substituted for well 5. All the wells sampled are completed in the upper 3 to 4.6 m (10 to 15 ft) of the stratigraphic section (Appendix A, Table A-1). The samples were collected in October 1992 and analyzed for radionuclides, total metals, volatile and semivolatile organic compounds, pesticides, and PCBs.

3.3.2 Results

Table 3-11 presents the 1991 and 1992 analytical results for total uranium, radium-226, and thorium-232. Average annual concentrations of total uranium and radium-226 from 1987 through 1991 are presented in Table 3-12. Results for all the onsite shallow wells are included in the table for comparison.

As shown in Table 3-11, the highest detected total uranium concentration was measured in the sample from well 11 at $187 \times 10^{-9} \mu\text{Ci/ml}$ (7 Bq/L). Uranium concentrations in the other samples ranged from approximately 0.7×10^{-9} to $13 \times 10^{-9} \mu\text{Ci/ml}$ (0.03 to 0.48 Bq/L). Historically, the highest uranium concentrations have been detected in wells 5 and 11, with average annual concentrations from 20×10^{-9} to $192 \times 10^{-9} \mu\text{Ci/ml}$ (0.74 to 7.1 Bq/L) (Table 3-12). The 1992 results for radium-226 ranged from approximately $0.3 \times 10^{-9} \mu\text{Ci/ml}$ (0.01 Bq/L) in well 20S to $4.6 \times 10^{-9} \mu\text{Ci/ml}$ (0.17 Bq/L) in well 4. Detected concentrations of thorium-232 were very low, ranging from 0.04×10^{-9} to $0.35 \times 10^{-9} \mu\text{Ci/ml}$ (1.5×10^{-3} to 13×10^{-3} Bq/L). These concentrations are within the range of previous results. All radiological results were below DOE DCGs of $600 \times 10^{-9} \mu\text{Ci/ml}$ for total uranium, $100 \times 10^{-9} \mu\text{Ci/ml}$ for radium-226, and $50 \times 10^{-9} \mu\text{Ci/ml}$ for thorium-232.

Results of the 1992 total metals analyses are presented in Table 3-13. EPA Safe Drinking Water Act (SDWA) maximum contaminant levels (MCLs), maximum contaminant level goals (MCLGs), and New Jersey Groundwater Quality Standards (NJGQS) (7 NJAC 9-6) for Class II-A waters are included in the table for comparison. As shown in Table 3-13, aluminum, iron, and manganese concentrations in the groundwater samples are above NJGQS in samples from all wells (except manganese in well 11), suggesting that background levels for these constituents in the vicinity of the site may be above NJGQS. These metals are common constituents of soils and are not considered indicative of contamination from site activities. Other constituents with levels that exceeded SDWA MCLs, MCLGs, or NJGQS include lead in three wells (9, 11, and 14) at concentrations of approximately 19, 70, and 17 $\mu\text{g/L}$, respectively, and concentrations of barium (3,250 $\mu\text{g/L}$), beryllium (18.2 $\mu\text{g/L}$), chromium (274 $\mu\text{g/L}$), and nickel (458 $\mu\text{g/L}$) in well 4. Well 4 was sampled once during 1991 and exhibited substantially lower metals concentrations than in 1992. This difference may be the result of suspended sediment in the sample. The remaining sample results were below SDWA MCLs, MCLGs, and/or NJGQS.

Results of the TOX, TOC, and TPH analyses are presented in Table 3-14. These results indicate slightly elevated concentrations of TOX in wells 4 and 21S; however, while volatile and semivolatile organic analyses identified two organic compounds [acetone (16 $\mu\text{g/L}$) and trichlorobenzene (75 $\mu\text{g/L}$)] at detectable concentrations in well 4, no organic compounds were detected in well 21S (Table 3-14). The concentration of 1,2,4-trichlorobenzene in well 4 exceeded the SDWA MCL and the NJGQS. No other organic compounds including pesticides and PCBs were detected in the groundwater samples collected during 1992.

FIGURES FOR SECTION 3.0

Figure 3-1
Radon/Thoron and External Gamma Radiation
Monitoring Locations at MSP (1991)

Figure 3-2
Radon/Thoron and External Gamma Radiation
Monitoring Locations at MSP (1992)

Figure 3-3
Surface Water and Sediment Sampling Locations in the Vicinity of MSP

Figure 3-4
Well Locations at MSP

TABLES FOR SECTION 3.0

Table 3-1
Trend Analysis for Radon Concentrations^{a,b}
at MSP, 1987-1992

Page 1 of 2

Sampling Location ^c	Average Annual Concentration					Average Annual Concentration
	1987	1988	1989	1990	1991	1992
(Concentrations are in 10^{-9} μ Ci/ml)						
Site Boundary						
2	1.0	0.3	0.4	0.6	1	0.4
4	0.8	0.7	1.8	1.3	5	0.4
5	0.8	0.6	0.4	0.5	0.5	0.4
7	0.9	0.3	0.4	0.7	0.9	0.4
8	0.6	0.3	0.4	0.4	0.5	0.4
11	1.0	0.3	0.4	0.9	1	0.4
12	0.4	0.5	0.4	0.6	0.9	0.4
13	1.4	0.4	0.4	1.0	0.9	0.4
14	0.9	0.4	0.4	0.5	1	0.4
15	0.3	0.4	0.6	0.6	0.8	0.4
16 ^d	0.8	0.3	0.5	0.6	1	--
17	0.7	0.4	0.5	0.8	1	0.4
18	1.0	0.6	0.4	1.1	1	0.4
19 ^d	1.3	0.4	0.6	1.0	1	--
Onsite						
1	--	--	--	1.4	1	1.4
3 ^e	--	--	--	16.2	10	15.2
6	--	--	--	4.6	4	0.8
9 ^d	0.8	0.7	--	0.7	0.6	--
10 ^d	0.7	0.4	0.4	0.7	0.8	--
21 ^e	--	--	--	18.9	18.7	14.0
Quality Control						
20 ^f	1.5	0.5	0.5	0.9	1	0.4
22 ^g	1.6	0.3	0.4	1.4	0.7	--
23 ^g	--	--	--	0.5	1	--
24 ^h	--	--	--	15.4	19.6	13.9
31 ^{d,h}	--	--	--	21.3	17.5	--
Background						
MML-4 ⁱ	0.9	0.4	0.4	1.2	2.5	0.4
29 ^j	1.2	0.3	0.4	0.5	1.1	0.4

Source for 1987-1991 data: BNI 1992b.

Table 3-1

(continued)

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^a $1 \times 10^{-9} \mu\text{Ci/ml} = 1 \text{ pCi/L} = 0.037 \text{ Bq/L}$. The DOE guideline is $3.0 \times 10^{-9} \mu\text{Ci/ml}$ above background.

^bMeasured background has not been subtracted from the boundary and onsite readings.

^cSampling locations are shown in Figures 3-1 and 3-2.

^dSampling location deleted from 1992 monitoring program.

^eLocated inside processing building.

^fQuality control for station 18.

^gQuality control for station 15. Deleted from program in 1992.

^hQuality control for station 21.

ⁱLocated at Middlesex Municipal Landfill, Mountain Avenue, Middlesex, N.J., 0.8 km (0.5 mi) northwest of MSP.

^jLocated at 658 Leone Street, Woodbridge, N.J., approximately 18.5 km (11.5 mi) east of MSP.

Table 3-2
Average Concentrations^{a,b} of Thoron
at MSP, 1991-1992

Page 1 of 2

Sampling Location ^c	Average	
	1991	1992

(Concentrations are in 10^{-9} μ Ci/ml)

Site Boundary

2	0.1	0.1
4	0.2	0.1
5	0.2	0.1
7	0	0.1
8	0.1	0.1
11	0.1	0.1
12	0.2	0.1
13	0	0.2
14	0	0.1
15	0.1	0.1
16 ^d	0.1	--
17	0.1	0
18	0.9	0.1
19 ^d	0.1	--

Onsite

1	1	0.5
3 ^e	3.4	2.7
6	1	0.4
9 ^d	0	--
10 ^d	0.1	--
21 ^e	2	0

Quality Control

20 ^f	0.1	0.1
22 ^g	0.1	--
23 ^g	0.1	--
24 ^h	1	1.9
31 ^{d,h}	2	--

Background

MML-4 ⁱ	0.1	0.1
29 ^j	0	0

Table 3-2

(continued)

Page 2 of 2

Source for 1991 data: BNI 1992b.

^a $1 \times 10^{-9} \mu\text{Ci/ml} = 1 \text{ pCi/L} = 0.037 \text{ Bq/L}$.
The DCG is $3.0 \times 10^{-9} \mu\text{Ci/ml}$.

^bMeasured background has not been subtracted from the boundary and onsite readings.

^cSampling locations are shown in Figures 3-1 and 3-2.

^dSampling location deleted from 1992 monitoring program.

^eLocated inside processing building.

^fQuality control for station 18.

^gQuality control for station 15. Deleted from program in 1992.

^hQuality control for station 21.

ⁱLocated at Middlesex Municipal Landfill, Mountain Avenue, Middlesex, N.J., 0.8 km (0.5 mi) northwest of MSP.

^jLocated at 658 Leone Street, Woodbridge, N.J., approximately 18.5 km (11.5 mi) east of MSP.

Table 3-3
Annual Average External Gamma Radiation Exposure
Rates^a at MSP, 1987-1992

Page 1 of 2

Sampling Location ^b	Average Annual Rate					Average Annual Rate
	1987	1988	1989	1990	1991	1992
(Rates are in mR/yr)						
Site Boundary (measured background subtracted)^c						
2	60	112	86	77	76	27
4	31	48	20	35	35	0
5	99	115	55	67	73	25
7	17	25	14	23	19	7
8	23	65	48	59	68	26
11	94	155	125	136	157	4
12	55	142	90	101	120	9
13	40	61	51	60	63	2
14	19	32	16	28	30	14
15	27	50	35	51	54	8
16 ^d	17	34	36	42	48	--
17	13	31	20	23	28	6
18	14	21	15	26	24	24
19 ^d	13	28	20	47	32	--
Onsite (measured background subtracted)^c						
1	--	--	--	9	9	9
3 ^e	--	--	--	51	55	55
6	--	--	--	121	128	290
9 ^d	--	--	--	88	97	--
10 ^d	44	115	66	86	93	--
21 ^e	--	--	--	98	99	99
Background						
29 ^f	71	90	76	68	72	85
MML-4 ^g	--	--	--	--	--	73

Source for 1987-1991 data: BNI 1992b.

Table 3-3

(continued)

Page 2 of 2

^aThe DOE guideline is 100 mrem/yr above background. 1 mR is approximately equivalent to 1 mrem. To obtain mSv, multiply mrem by 0.01.

^bSampling locations are shown in Figures 3-1 and 3-2. Note that locations previously surrounding storage piles were moved to the fenceline in 1992 to better assess potential public doses.

^cMeasured background has been subtracted from readings at boundary and onsite stations.

^dSampling location deleted from 1992 monitoring program.

^eLocated inside processing building.

^fLocated at 658 Leone Street, Woodbridge, N.J., approximately 18.5 km (11.5 mi) east of MSP.

^gLocated at Middlesex Municipal Landfill, Mountain Avenue, Middlesex, N.J., 0.8 km (0.5 mi) northwest of MSP.

Table 3-4
External Gamma Radiation Exposure
Rates for Comparison

Location	Average Rate (mR/yr)
MSP boundary (1992)	92
MSP vicinity (1992)	79
U.S. background ^a	103
Grand Central Station ^b	525
Statue of Liberty base ^b	325

^aShleien 1989.

^bAppendix B.

Table 3-5
Concentrations^{a,b} of Total Uranium, Radium-226, Radium-228, Thorium-230,
and Thorium-232 in Surface Water in the Vicinity of MSP, 1987-1992

Page 1 of 2

Sampling Location ^c	Average Annual Concentration					Average Annual Concentration
	1987	1988	1989	1990	1991	1992
(Concentrations are in 10 ⁻⁹ µCi/ml)						
Total Uranium						
1	54	47	34	60	39	53
2	5	3	3	3	2	2
2A ^d						7
3	3	4	5	3	3	1
4 ^e	3	3	3	3	3	1
5	3	4	3	4		2
Radium-226						
1	1.7	2.0	1.7	2.8	3.6	26.9
2	0.7	0.3	0.6	0.3	0.6	1.6
2A ^d						2.0
3	0.6	0.2	0.6	0.5	0.6	1.3
4 ^e	0.7	0.2	1.0	0.4	0.4	0.5
5	0.7	0.3	0.7	0.8	1.0	1.6
Radium-228^f						
1						4.5
2						2.2
2A ^d						2.6
3						2.3
4 ^e						2.7
5						2.5
Thorium-230^f						
1						2.9
2						0.8
2A ^d						2.4
3						0.3
4 ^e						0.5
5						0.7
Thorium-232^f						
1						0.9
2						0.6
2A ^d						1.3
3						0.2
4 ^e						0.2
5						0.2

Source for 1987-1991 data: BNI 1992b.

Table 3-5

(continued)

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^a $1 \times 10^{-9} \mu\text{Ci/ml} = 1 \text{ pCi/L} = 0.037 \text{ Bq/L}$. The DCGs are as follows: for total uranium, $600 \times 10^{-9} \mu\text{Ci/ml}$; for radium-226 and radium-228, $100 \times 10^{-9} \mu\text{Ci/ml}$; for thorium-230, $300 \times 10^{-9} \mu\text{Ci/ml}$; for thorium-232, $50 \times 10^{-9} \mu\text{Ci/ml}$.

^bMeasured background has not been subtracted.

^cSampling locations are shown in Figure 3-3.

^dLocation 2A replaced location 2 in the third quarter of 1992; therefore, location 2 results are for the first and second quarters, and location 2A results are for the third and fourth quarters.

^eUpstream monitoring location.

^fAnalysis began in 1992.

Table 3-6
Concentrations of TOC, TOX, and TPH
in Surface Water in the Vicinity of MSP, 1992

Sampling Location ^a	Parameter	Concentration ^b	Detection Limit ^c
1	TOC	3.8	0.5
	TOX	161.0	10.0
	TPH	1.0 ^d	1.0
2A	TOC	5.2	0.5
	TOX	71.7	5.0
	TPH	1.0 ^d	1.0
3	TOC	5.3	0.5
	TOX	29.9	5.0
	TPH	1.0 ^d	1.0
4	TOC	3.3	0.5
	TOX	55.0	5.0
	TPH	1.0 ^d	1.0
5	TOC	4.5	0.5
	TOX	185.0	20.0
	TPH	1.0 ^d	1.0

^aSampling locations are shown in Figure 3-3.

^bTOC and TPH concentrations are in mg/L (ppm), and TOX concentrations are in $\mu\text{g/L}$ (ppb).

^cDetection limits can vary because of dilution ratios.

^dNot detected above detection limit. Value reported is the detection limit.

Table 3-7
Concentrations of Metals and Major Ions in Surface Water
in the Vicinity of MSP, 1992

Parameters	Sampling Location ^a					SDWA MCL ^b	NJSWQC ^c
	1	2A	3	4	5		
(Concentrations are in µg/L)							
Metals (total)							
Aluminum	460	200 ^d	200 ^d	200 ^d	200 ^d		
Antimony	60 ^d	60 ^d	60 ^d	60 ^d	60 ^d		
Arsenic	10 ^d	10 ^d	10 ^d	10 ^d	10 ^d	50	50
Barium	200 ^d	200 ^d	200 ^d	200 ^d	200 ^d	2,000	1000
Beryllium	5 ^d	5 ^d	5 ^d	5 ^d	5 ^d		
Boron	327	162	138	144	100		
Cadmium	5 ^d	5 ^d	5 ^d	5 ^d	5 ^d	5	10
Chromium	10 ^d	10 ^d	10 ^d	10 ^d	10 ^d	100	50
Cobalt	50 ^d	50 ^d	50 ^d	50 ^d	50 ^d		
Copper	25 ^d	25 ^d	25 ^d	25 ^d	25 ^d	1,300	
Iron	1,220	468	474	173	270		
Lead	13.5	3 ^d	3 ^d	3 ^d	5	15	50
Manganese	330	139	86.3	28.5	93.9		
Molybdenum	100 ^d	100 ^d	100 ^d	100 ^d	100 ^d		
Nitrogen	40 ^d	40 ^d	40 ^d	40 ^d	40 ^d		
Selenium	5 ^d	5 ^d	5 ^d	5 ^d	5 ^d	50	10
Silver	10 ^d	10 ^d	10 ^d	10 ^d	10 ^d		50
Thallium	10 ^d	10 ^d	10 ^d	10 ^d	10 ^d		
Vanadium	50 ^d	50 ^d	50 ^d	50 ^d	50 ^d		
Zinc	275	38.9	21.3	20 ^d	79.7		
Major Ions (total)							
Calcium	30,300	21,400	20,400	23,500	7,640		
Magnesium	9,870	5,810	5,460	6,760	5,000 ^d		
Potassium	5,000 ^d	5,000 ^d	5,000 ^d	5,000 ^d	5,000 ^d		
Sodium	16,900	12,300	11,900	12,600	5,000 ^d		

^aSampling locations are shown in Figure 3-3.

^bSDWA MCL - Safe Drinking Water Act maximum contaminant level.

^cNJSWQC - New Jersey Surface Water Quality Criteria.

^dNot detected above the detection limit. Value reported is the detection limit.

Table 3-8
Concentrations^{a,b} of Total Uranium, Radium-226, Radium-228,
Thorium-230, and Thorium-232 in Sediment
in the Vicinity of MSP, 1987-1992

Page 1 of 2

Sampling Location ^c	Average Annual Concentration					Average Annual Concentration
	1987	1988	1989	1990	1991	1992
(Concentrations are in pCi/g)						
Total Uranium						
1	12.8	7.1	13.5	10.6	26.0	24.1
2	-- ^d	6.0	31.8	3.7	-- ^e	10.7
2A ^f						10.3
3	5.8	9.7	12.6	1.5	9.7	5.6
4 ^g	2.1	7.8	2.8	0.7	3.0	3.2
5	-- ^d	2.6	3.4	8.5	14.0	21.1
Radium-226						
1	6.8	5.0	6.4	6.0	16.0	4.3
2	-- ^d	1.9	15.2	1.9	-- ^e	1.6
2A ^f						2.3
3	0.7	3.9	5.4	0.8	2.7	0.9
4 ^g	0.7	2.0	1.0	0.7	1.0	0.7
5	-- ^d	2.3	1.8	5.3	8.0	6.8
Radium-228^h						
1						1.4
2						2.1
2A ^f						3.0
3						1.0
4 ^g						1.3
5						1.8
Thorium-230^h						
1						4.1
2						1.8
2A ^f						1.3
3						1.2
4 ^g						0.8
5						6.8
Thorium-232^h						
1						1.1
2						0.7
2A ^f						2.0
3						0.8
4 ^g						0.9
5						1.4

Table 3-8

(continued)

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Source for 1987-1991 data: BNI 1992b.

^a1 pCi/g is equivalent to 0.037 Bq/g. The FUSRAP soil concentration guideline for radium and thorium is 5 pCi/g above background. There is no guideline for total uranium.

^bMeasured background has not been subtracted.

^cSampling locations are shown in Figure 3-3.

^dSediment sample was not obtained because no sediment was present.

^eSediment sample was not obtained because of placement of rip-rap.

^fLocation 2A replaced location 2 in the third quarter of 1992; therefore, location 2 results are for the first and second quarters, and location 2A results are for the third and fourth quarters.

^gUpstream monitoring location.

^hAnalysis began in 1992.

Table 3-9
Concentrations of TPH in Sediment
in the Vicinity of MSP, 1992

Sampling Location ^a	TPH (mg/kg)	Detection Limit
1	2,700	200
2A	310	18
3	25	5.4
4 ^b	870	12
5	1,400	47

^aSampling locations are shown in Figure 3-3.

^bUpstream sampling location.

Table 3-10
Concentrations of Metals and Major Ions in Sediments
in the Vicinity of MSP, 1992

Parameters ^a	Sampling Location ^b				
	1	2A	3	4	5
Metals (total)					
Aluminum	3,820	16,800	9,170	6,870	12,300
Antimony	23.8 ^c	70.6 ^c	15.7 ^c	24.7 ^c	25.1 ^c
Arsenic	6.8	14.6	2.9	4.5 ^c	49.2
Barium	79.3 ^c	235 ^c	109	96.6	101
Beryllium	2 ^c	5.9 ^c	1.3 ^c	2.1 ^c	2.1 ^c
Boron	39.6 ^c	118 ^c	26.1 ^c	41.2 ^c	41.9
Cadmium	2 ^c	5.9 ^c	1.3 ^c	2.1 ^c	6.7
Chromium	11.4	44	21.4	19.1	61.1
Cobalt	19.8 ^c	58.8 ^c	13 ^c	20.6 ^c	20.9 ^c
Copper	46.9	161	12.8	74.3	235
Iron	9,610	34,600	19,800	15,700	25,600
Lead	179	238	23.9	53.4	440
Manganese	262	998	190	361	387
Molybdenum	39.6	118 ^c	26.1 ^c	41.2 ^c	41.9
Nitrogen	15.9 ^c	55.8	17.5	22	39.9
Selenium	2 ^c	5.5 ^c	1.3 ^c	2.2 ^c	2.2 ^c
Silver	4 ^c	11.8 ^c	2.6 ^c	4.1 ^c	4.2 ^c
Thallium	4 ^c	11.1 ^c	2.6 ^c	4.5 ^c	4.4 ^c
Vanadium	19.8 ^c	58.8 ^c	34.1	31.6	40.5
Zinc	714	773	63.7	212	1,540
Major Ions (total)					
Calcium	1,980 ^c	5,880 ^c	1,300 ^c	4,890	3,000
Magnesium	2,350	6,470	3,390	3,700	4,830
Potassium	1,980 ^c	5,880 ^c	1,330 ^c	2,060 ^c	2,100 ^c
Sodium	1,980 ^c	5,880 ^c	1,300 ^c	2,060 ^c	2,100 ^c

^aAll chemicals are total.

^bSampling locations are shown in Figure 3-3.

^cNot detected above the detection limit. Value reported is the detection limit.

Table 3-11
Concentrations^{a,b} of Total Uranium, Radium-226, and
Thorium-232 in Groundwater at MSP, 1991-1992

Page 1 of 2

Well No. ^c	Quarter 1991				1991 Average ^d	1992
	1	2	3	4		

(Concentrations are in 10^{-9} μ Ci/ml)

Total Uranium^e

1	NS ^f	NS	NS	NS	NA ^g	NS
3	<3.4	<3.4	<3.4	0.6	2.7	NS
4	8.7	NS	NS	NS	8.7	12.52
5	27.1	67.7	NS	69.9	54.9	NS
9	<3.4	3.6	4.1	2.2	3.3	4.87
11	23.7	21.0	125.9	24.8	48.9	187.29
12	7.5	27.8	29.1	NS	21.5	NS
13	<3.4	NS	4.7	NS	4.0	NS
14	<3.4	3.4	3.4	0.8	2.8	2.44
15	NS	NS	10.8	NS	10.8	NS
20S	<3.4	<3.4	<3.4	0.4	2.7	0.73
21S	0.8	<3.4	<3.4	1.2	2.2	0.95

Radium-226

1	NS	NS	NS	NS	NA	NS
3	0.5	3.9	3.6	0.3	2.1	NS
4	5.7	NS	NS	NS	5.7	4.60
5	0.5	1.1	NS	2.5	1.4	NS
9	0.7	2.5	2.0	2.1	1.8	3.80
11	1.6	2.3	2.4	0.1	1.6	2.40
12	1.6	3.0	5.1	NS	3.2	NS
13	0.4	NS	0.3	NS	0.4	NS
14	0.3	1.1	0.3	<0.1	0.5	0.35
15	NS	NS	1.9	NS	1.9	NS
20S	0.4	0.2	0.1	0.1	0.2	0.29
21S	0.4	0.2	2.8	0.4	1	0.53

Table 3-11

(continued)

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Well No. ^c	Quarter 1991				1991 Average ^d	1992
	1	2	3	4		
Thorium-232						
1	NS	NS	NS	NS	NA	NS
3	0.5	1.9	1.8	<0.3	1.1	NS
4	1.9	NS	NS	NS	1.9	0.18
5	<0.1	<0.03	NS	1.3	0.5	NS
9	<0.1	<0.1	<0.1	<0.2	0.1	0.04
11	0.4	1.4	0.2	0.2	0.6	0.20
12	1.1	2.8	2.5	NS	2.1	NS
13	0.2	NS	1.1	NS	0.7	NS
14	0.7	2.7	0.5	<0.4	1	0.35
15	NS	NS	2.3	NS	2.3	NS
20S	<0.1	<0.1	<0.1	<0.1	0.1	0.00
21S	<0.2	<0.2	<0.1	<0.1	0.2	0.06

^a $1 \times 10^{-9} \mu\text{Ci/ml} = 0.037 \text{ Bq/L} = 1 \text{ pCi/L}$. The DCGs for total uranium, radium-226, and thorium-232 are $600 \times 10^{-9} \mu\text{Ci/ml}$, $100 \times 10^{-9} \mu\text{Ci/ml}$, and $50 \times 10^{-9} \mu\text{Ci/ml}$, respectively.

^bMeasured background has not been subtracted.

^cSampling locations are shown in Figure 3-4.

^dResults reported as "less than" (<) are used as absolute numbers for the calculation of averages.

^eTotal uranium concentrations were determined by using fluorometric analysis during the first three quarters of 1991 and by kinetic phosphorescence analysis during the fourth quarter of 1991 and in 1992.

^fNS = no sample collected.

^gNA = not applicable.

Table 3-12
Trend Analysis for Total Uranium and Radium-226 Concentrations^{a,b}
in Groundwater at MSP, 1987-1992

Page 1 of 2

Well No. ^c	Average Concentration					Concentration
	1987	1988	1989	1990	1991	1992

(Concentrations are in 10^{-9} μ Ci/ml)

Total Uranium^d

1	3	12	4	6	NS ^e	NS
3	1	3	3	3	2.7	NS
4	1	7	6	5	8.7	12.5
5	82	192	131	123	54.9	NS
9	2	5	4	13	3.3	4.9
11	20	67	42	41	48.9	187.3
12	1	7	7	10	21.5	NS
13	3	5	3	7	4	NS
14	3	NS	4	NS	2.8	2.4
15	3	4	4	5	10.8	NS
20S	1	4	2	3	2.7	0.7
21S	0.4	2	1	3	2.2	0.9

Radium-226

1	0.3	0.3	0.9	0.5	NS	NS
3	0.3	1.2	1.6	0.9	2.1	NS
4	0.4	2.0	2.1	1.2	5.7	4.6
5	0.6	2.4	2.4	0.3	1.4	NS
9	0.8	2.8	7.0	2.4	1.8	3.8
11	0.5	4.1	4.7	2.2	1.6	2.4
12	0.3	2.3	2.2	2.3	3.2	NS
13	0.4	0.3	0.7	0.3	0.4	NS
14	0.1	NS	1.0	NS	0.5	0.4
15	0.3	0.4	0.8	0.5	1.9	NS
20S	0.3	1.1	0.7	0.5	0.2	0.3
21S	0.4	0.7	0.9	0.6	1.0	0.5

Sources for 1987-1991 data: BNI 1992b.

Table 3-12

(continued)

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^a $1 \times 10^{-9} \mu\text{Ci/ml} = 0.037 \text{ Bq/L} = 1 \text{ pCi/L}$. The DCGs for total uranium and radium-226 are 600×10^{-9} and $100 \times 10^{-9} \mu\text{Ci/ml}$, respectively.

^bMeasured background has not been subtracted.

^cSampling locations are shown in Figure 3-4.

^dTotal uranium concentrations were determined by using fluorometric analysis during 1987 through 1990 and the first three quarters of 1991 and by kinetic phosphorescence analysis during the fourth quarter of 1991 and in 1992.

^eNS = no sample collected.

Table 3-13
Concentrations of Metals and Major Ions in Groundwater at MSP, 1992

Parameter ^a	Sampling Location ^b						SDWA MCL ^c	SDWA MCLG ^d	NJGQS ^e
	Well 4 10/23/92	Well 9 10/27/92	Well 11 10/26/92	Well 14 10/28/92	Well 20S 10/30/92	Well 21S 10/28/92			
(Concentrations are in µg/L)									
Metals									
Aluminum	162,000.0	988.0	1,470.0	12,800.0	211.0	474.0	-	-	200
Antimony	60.0UR ^{f,g}	60.0U	60.0U	60.0U	60.0U	60.0U	6	6	20
Arsenic	2.0U	3.9J ^h	5.0J	2.6	2.0U	2.0U	50	-	8
Barium	3,250.0	149.0	55.1	252.0	129.0	77.7	2,000	2,000	2,000
Beryllium	18.2	1.0U	1.0U	1.0U	1.0U	1.0U	4	4	20
Boron	146.0	684.0	82.2	274.0	184.0	417.0	-	-	-
Cadmium	7.0U	7.0U	7.0U	7.0U	7.0U	7.0U	5	5	4
Chromium	274.0J	9.0U	9.0U	19.7	9.0U	9.0U	100	100	100
Cobalt	216.0	9.0U	9.0U	14.7	9.0U	9.0U	-	-	-
Copper	246.0	25.0	13.5	24.8	8.0U	12.5	1,300	1,300	1,000
Iron	205,000.0	20,900.0	1,920.0	13,800.0J	1,050.0	578.0J	-	-	300
Lead	8.7	19.4J	70.4J	16.7	2.0U	2.0U	15	0	10
Manganese	11,300.0	1,140.0J	40.9	3,230.0	730.0	744.0	-	-	50
Molybdenum	145.0J	19.5	8.9	10.5	5.0U	5.0U	-	-	-
Nickel	458.0	20.0U	20.0U	25.6	20.0U	25.9	100 ^j	100 ^j	100
Selenium	9.3	2.0U	2.0UR	2.0U	2.0UJ	2.0U	50	-	50
Silver	10.0U	10.0U	10.0U	10.0U	10.0U	10.0U	-	-	-
Thallium	2.0U	2.0U	2.0UR	2.0U	2.0UJ	2.0U	2 ⁱ	0.5 ⁱ	10
Vanadium	276.0	8.0U	8.0U	24.9	8.0U	8.0U	-	-	-
Zinc	2,180.0	76.2	57.5	170.0	17.8	33.0	-	-	5,000
Major Ions									
Calcium	57,900.0	67,500.0J	23,400.0	33,900.0	14,400.0	25,700.0	-	-	-
Magnesium	100,000.0	23,500.0	6,300.0	13,200.0	4,800.0	6,110.0	-	-	-
Potassium	26,700.0J	5,220.0	3,120.0	3,740.0	1,340.0U	1,840.0	-	-	-
Sodium	19,700.0	24,300.0	13,300.0	9,490.0	12,600.0	23,900.0	-	-	50,000

^aResults reflect total concentrations in unfiltered samples.

^bSampling locations are shown in Figure 3-4.

^cSDWA MCL - Safe Drinking Water Act maximum contaminant level.

^dSDWA MCLG - Safe Drinking Water Act maximum contaminant level goal.

^eNJGQS - New Jersey Groundwater Quality Standards (7 NJAC 9-6).

^fU - Not detected above the detection limit. Value reported is the detection limit.

^gR - Rejected value.

^hJ - Estimated value.

ⁱEffective 1994.

Table 3-14
Concentrations of Organics Detected in Groundwater at MSP, 1992

Parameter	Sampling Location ^a						SDWA MCL ^b	SDWA MCLG ^c	NJGQS ^d
	Well 4	Well 9	Well 11	Well 14	Well 20S	Well 21S			
TOX (µg/L) ^e	139	21.2	20 U ^f	5 UJ ^g	8.8	69.3 J	-	-	-
TOC (mg/L) ^h	4.5	15.6	3.5 J	8	1.9	7.8 J	-	-	-
TPH (mg/L)	1 U	1.2	1 U	1 UJ	1 U	1 U	-	-	-
Acetone (µg/L)	16	10 U	10 U	10 U	10 U	10 U	-	-	700
1,2,4-Trichlorobenzene (µg/L)	75	10 U	10 U	10 U	10 U	10 U	70	70	9

^aSampling locations are shown in Figure 3-4.

^bSDWA MCL - Safe Drinking Water Act maximum contaminant level.

^cSDWA MCLG - Safe Drinking Water Act maximum contaminant level goal.

^dNJGQS - New Jersey Groundwater Quality Standards.

^eµg/L = ppb.

^fU - Analyte was not detected above the detection limit. Value reported is the detection limit.

^gJ - Estimated value.

^hmg/L = ppm.

4.0 ESTIMATED DOSE

The information in Section 3.0 was evaluated as described in Appendix F to estimate the potential radiation doses to the general public and to a maximally exposed individual from the radioactive material at MSP. This material consists primarily of pitchblende-contaminated soil (see Subsection 1.1). Pitchblende is a naturally occurring ore containing primarily isotopes of radium, uranium, and thorium.

To assess the potential health effects from the materials stored at MSP, internal and external radiation exposures were considered for the maximally exposed individual and the general public within 80 km (50 mi) of the site.

Doses can come from either external or internal exposures. Exposures to radiation from radionuclides outside the body are called external exposures; exposures to radiation from radionuclides deposited inside the body are called internal exposures. The distinction is important because external exposures occur only when a person is near the external radionuclides, but internal exposures continue as long as the radionuclides reside in the body.

External exposure results from direct gamma radiation from the radioactive materials in the storage pile and in surface and subsurface soils at the site. External exposure is determined by calculations performed on data obtained from the TETLD monitoring program.

To determine internal exposures to the maximally exposed individual and the general population within 80 km (50 mi), realistic and complete pathways by which radioactive materials could enter individuals must be identified. A complete internal exposure pathway must contain each of the following elements:

- A contaminant source and a mechanism by which the contaminant is released into the environment

- An environmental transport mechanism (i.e., a mechanism that disperses the contaminant into the surrounding environment)
- A location where human contact (a human receptor) with the contaminant is possible
- A route of entry that would enable the contaminant to enter the human receptor's body

If any of these four elements is not present, or could not conceivably be present in the future, the exposure pathway is not considered realistic, and no evaluation of exposure from this pathway is performed. Because of the inaccessibility of the contaminated material at the site and the lack of a drinking water well within 1.6 km (1 mi) of the site, the only complete exposure pathways would be from direct gamma radiation and from radon and thoron (and their associated decay products). These pathways would be the only contributors to the potential dose to the maximally exposed individual. All doses presented in this section are estimated and do not represent actual doses. A summary is provided in Table 4-1.

4.1 MAXIMALLY EXPOSED INDIVIDUAL

4.1.1 Direct Gamma Radiation Pathway

The maximally exposed individual is assumed to spend 100 percent of his or her time at a residence 30 m (100 ft) from the eastern boundary of the site.

The calculated yearly dose to this individual was determined by using the average of the annual average exposure rates for the TETLDs along the fenceline near the closest residence (locations 7, 12, 14, and 15). Using this average [9.5 mR/yr ($9.5 \times 10^{-2} \text{ mSv/yr}$) above background; see Table 3-3], the dose to the maximally exposed individual from exposure to direct gamma radiation was calculated to be 0.3 mrem/yr ($3 \times 10^{-3} \text{ mSv/yr}$), well below the DOE guideline of 100 mrem/yr . This dose was determined using the equation for this pathway given in Appendix F.

4.1.2 Drinking Water Pathway

Only one water pathway, either groundwater or surface water, is used to determine the committed dose to the maximally exposed individual (see Appendix F). This individual would obtain 100 percent of his or her drinking water from either surface water or groundwater in the vicinity of the site.

Concentrations of total uranium and the radium and thorium isotopes in onsite groundwater are compared with DOE standards (DCGs). These standards reflect the concentration of a radionuclide in water that, if ingested for one year, would result in an effective dose equivalent of 100 mrem (1 mSv). All the radionuclides were well below these standards. Because nearby municipal wells are upgradient of the site, groundwater is not a credible, complete exposure pathway; therefore, the dose contribution of these radionuclides to the maximally exposed individual was not calculated. There is also no credible, complete exposure pathway from surface water because radionuclide concentrations at both upstream and downstream locations on Main Stream are essentially equivalent, and the stream is not used as a drinking water source.

4.1.3 Air Pathway (Ingestion, Air Immersion, Inhalation)

To calculate a conservative dose to the maximally exposed individual, the individual was assumed to reside 30 m (100 ft) from the site. Air doses determined using EPA's Clean Air Act Assessment Package-1988 (CAP88) PC computer model were found to be negligible.

4.1.4 Total Dose

The total dose for the maximally exposed individual is the sum of the 50-yr committed effective dose equivalent and the external effective dose equivalent, based on the total estimated radioactive particulates released in 1992 and the effective dose equivalent from total external direct gamma radiation measured at the fenceline in 1992.

The total dose is the sum of the doses calculated for each exposure pathway, 0.3 mrem/yr (0.003 mSv/yr), which is virtually indistinguishable from background.

4.2 GENERAL POPULATION

The collective dose to the general population living within 80 km (50 mi) of the site was also calculated.

4.2.1 Direct Gamma Radiation Pathway

MSP is located in an area with both industrial and residential land uses. Distance from the site to the nearest residential areas and the presence of intervening structures reduce direct gamma radiation exposure from MSP. Additionally, monitoring results show that site perimeter radiation exposure rates are barely detectable above background rates. Therefore, it is assumed that there is no detectable exposure to the general population.

4.2.2 Drinking Water Pathway

Because the radionuclides found in groundwater and surface water were present at low concentrations and no credible, complete exposure scenario was identified for the maximally exposed individual, the collective population dose from drinking water is also negligible.

4.2.3 Air Pathway (Ingestion, Air Immersion, Inhalation)

The CAP88-PC model provides an effective dose equivalent for contaminants transported through the atmospheric pathway at different distances from the site. Based on these effective dose equivalents and the population density, the collective dose for the general population within 80 km (50 mi) of the site was calculated to be negligible compared with the dose from natural background.

4.2.4 Total Population Dose

The total population dose is the sum of the doses from all exposure pathways. Because the exposures from all pathways are negligible, the total population dose is also negligible.

TABLE FOR SECTION 4.0

Table 4-1
Summary of Calculated Doses^a for MSP, 1992

Exposure Pathway	Dose to Maximally Exposed Individual (mrem/yr) ^b	Collective Dose to Population Within 80 km of Site (person-rem/yr) ^b
Direct gamma radiation ^c	0.3	-- ^d
Drinking water	-- ^e	-- ^e
Air immersion	-- ^e	-- ^e
Inhalation ^c	-- ^d	-- ^d
Total ^f	0.3	-- ^d
Background ^g	79	1×10^6 ^h

^aDoes not include radon.

^b1 mrem/yr = 0.01 mSv/yr; 1 person-rem/yr = 0.01 person-Sv/yr.

^cDoes not include contribution from natural background.

^dExposures from this pathway are negligible.

^eNo realistic pathway.

^fThe DOE guideline for total exposure to an individual is 100 mrem/yr above background (DOE 1990).

^gDirect gamma radiation exposure only.

^hCalculated by the following: (79 mrem/yr) (15 × 10⁶ persons).

5.0 QUALITY ASSURANCE

5.1 INTRODUCTION

This section summarizes the quality assurance (QA) assessment of environmental activities at the site, which were conducted to ensure that onsite contamination does not pose a threat to human health and the environment. Using this criterion, the overall project data quality objective (DQO) for the environmental surveillance program is to provide data of sufficient quality to allow reliable detection and quantitation of potential release of contaminated material from the site. DQO requirements are assessed annually during review of the environmental monitoring plan (BNI 1991) and are updated based on historical information, trends identified, and changes in environmental regulations.

5.2 PROCEDURES

The *Quality Assurance Program Plan for the U.S. DOE FUSRAP* (BNI 1992a) addresses the quality requirements for work performed under FUSRAP. This plan requires all subcontractors to implement a compatible plan for QA or use the DOE plan. This is done to ensure compatibility with all requirements to maintain protection of human health and the environment.

QA procedures are detailed in project procedures and project instructions and are implemented for all field activities. Sampling techniques are derived from several documents, including *A Compendium of Superfund Field Operations Methods* (EPA 1987) and the EPA Region II QA manual. Laboratory QA procedures are derived from applicable EPA methods to ensure compatibility of the results. Also, activities such as data reviews, calculation checks, and data evaluations have been incorporated in procedures to monitor results and prevent or identify quality problems.

5.3 QUALITY ASSURANCE SUMMARY

QA/quality control (QC) activities are an integral part of all environmental monitoring activities at the site. The specific methods, definitions, and formulas used to evaluate the QA/QC program are described in the *Quality Assurance Document for Site Environmental Reports* (BNI 1993). This document also discusses, in detail, the precision, accuracy, representativeness, comparability, and completeness (PARCC) parameters. For informational purposes, brief definitions and explanations will be given throughout this section for terms and processes used during the QA/QC evaluation.

The QA/QC program satisfies the requirements of DOE Orders 5400.1, 5400.5, and 5700.6C (DOE 1988, 1990, 1991). The programmatic controls in place for the environmental surveillance program are discussed in project instruction guides.

5.3.1 Data Usability

To determine data usability, a verification process is used that evaluates items such as holding times and results for method blanks, spike recoveries, and duplicates. The information from this evaluation is then used to verify whether the data are of sufficient quality to provide a basis for making decisions about the site. During this process, two qualifiers are associated with the data if there is any question concerning their usability: 1) "J" - the data result is estimated and should be used with discretion, and 2) "R" - the data result is rejected and should not be used.

The data are then evaluated using the PARCC parameters to determine whether there is enough information to make decisions concerning the site. Any major problems encountered are documented as nonconformances and are tracked to ensure correction.

The results of the PARCC evaluation are presented as a percentage that met requirements. The formula used is:

$$\frac{\text{number of results that met EPA requirements}}{\text{total number of results}} \times 100 = \text{percent acceptable}$$

For Tables 5-1 to 5-5, a generic 80 percent has been used as an acceptable level. Representativeness and comparability cannot have a percentage applied; see Subsections 5.3.4 and 5.3.5 for definitions and discussions about the use of these two parameters.

5.3.2 Precision

Precision is defined as a measurement of the agreement of a set of replicate results among themselves without assumption of any prior information about the true result. Precision is assessed through the use of duplicate results or matrix spike (MS) and matrix spike duplicate (MSD) results. MSs and MSDs are usually used with organic analytes; inorganic analytes are generally run as a true duplicate and a single MS. Field duplicates are also used to assess field precision; results are presented separately from the laboratory duplicate results. EPA method limits are used to assess the results for both field and laboratory precision. Table 5-1 lists the results for laboratory precision. All results met the requirements for acceptability except for TPH. This failure was assessed during verification for associated sample impact.

Table 5-2 provides the results for field duplicates. Results for TOC and thorium-232 met the acceptable levels. Precision was not calculated for semivolatiles, volatiles, and pesticides/PCBs because there were no positive values for the samples. Metals, TOC, TPH, radium-226, radium-228, thorium-228, thorium-230, and total uranium all fell below the 80 percent precision level. Most of the failures were the result of the limited number of duplicates and the low level of the results. By comparison with the laboratory duplicates, TPH would be considered the only problem because this parameter failed both precision categories. The method used for TPH is not as precise as methods used for metals or other organic parameters; precision results are therefore affected.

Table 5-3 gives the results for laboratory radiochemical duplicates. All parameters met the 80 percent level. Radiochemical duplicate acceptance criteria are derived from the *Laboratory Data Validation Functional Guidelines for Evaluating Inorganic Analyses* (EPA 1988). The acceptable relative percent difference (RPD) derived from the guidelines is 20 percent for radiochemical precision.

5.3.3 Accuracy

Accuracy is defined as the nearness of a result or the mean of a set of results to the true, known, or reference value. The assessment of accuracy may be determined through standard reference materials, MSs, laboratory control samples, and surrogate spikes.

Table 5-4 gives the results for chemical spikes, all of which were above the 80 percent level. Results for radiological spikes, given in Table 5-5, were all within criteria. Radiological spike acceptance criteria are derived from the *Laboratory Data Validation Functional Guidelines for Evaluating Inorganic Analyses* (EPA 1988). The acceptable recovery range derived from the guidelines is 75 percent to 125 percent recovery for spiked analytes.

5.3.4 Representativeness

Field sampling and laboratory analytical representativeness expresses the degree to which the data accurately and precisely represent the matrix from which the samples were obtained. Representativeness generally expresses the extent to which the data generated define an environmental condition.

To ensure field sampling representativeness, several controls were used during sampling, including the use of dedicated sampling equipment and trip blanks for volatiles. The dedicated equipment ensures that no cross-contamination occurs between sampling locations. The trip blank for volatiles monitors for contamination from the time of sampling through the time of analysis.

To ensure representativeness in the laboratory, constraints are placed on analytical methodology. Method blanks are prepared for each parameter analyzed, both organic and inorganic, with an associated frequency of 1 per batch of no more than 20 samples. A method or preparation blank is used to determine whether contaminants are present in the laboratory that could have an impact on the samples associated with that method blank. The presence of contaminants can indicate the possibility for false positive results.

The possibility of false negative results can also be reduced through the use of sample preservatives and holding times. All samples were preserved at the time of sampling by adding required chemicals and/or using refrigeration. The use of preservatives limits biological and chemical degradation that would bias sample results.

Tables 5-6 and 5-7 list the contaminants analyzed and their concentrations detected in laboratory method blanks and trip blanks. The laboratory contamination was caused by common laboratory contaminants [acetone, methylene chloride, 4-methyl-2-pentanone, bis(2-ethylhexyl)phthalate, and di-n-butylphthalate], metals (boron, aluminum, iron, and zinc), and radium-228. EPA has recognized certain analytes as being present in the laboratory and expects some contamination. The rules governing these contaminants allow up to five times the quantitation limit of these analytes. The results for the common contaminants were below this requirement and do not pose a problem. The metal contamination was evaluated during verification and does not pose a significant problem. However, EPA does not recognize these metals as being common contaminants. The trip blank contamination was from methylene chloride, chloroform, and acetone. Because of the common laboratory contaminants and the low-level chloroform, the samples were not affected.

5.3.5 Comparability

Comparability expresses the confidence with which data are compared with each other, taking into account the use of equivalent instrumentation and methodology. The laboratories follow approved procedures that are consistent with industry-accepted practices, and comparability is maintained.

5.3.6 Completeness

Completeness measures the number of usable data resulting from the data collection activities compared with the total data possible. For environmental monitoring, all samples were taken as required in the instruction guide for usability; therefore, the sampling completeness was 100 percent. As defined in Subsection 5.3.1, usable data are those that have no qualifiers that cause them to be rejected. Table 5-8 summarizes the usability rate for each analyte; all of them met the completeness goal.

5.3.7 Interlaboratory Programs

The radiochemistry laboratory participates in the Environmental Measurements Laboratory's Quality Assessment Program, EPA's Cross Check Program, and the Nuclear Fuel Services' Interlab Quality Control Comparison. The chemical laboratory participates in EPA's water supply and water pollution programs, along with quarterly single-blind samples submitted by FUSRAP. Results for the above programs are submitted to FUSRAP. Repeated failure of an analyte for consecutive periods results in the suspension of that analyte until corrective actions have been taken. Table 5-9 provides the radiochemistry laboratory results from the DOE Quality Assessment Program. Table 5-10 gives the results from the EPA Intercomparison Program.

TABLES FOR SECTION 5.0

Table 5-1
Results for Laboratory Duplicates

Parameters	Percent Acceptable	Meets Established DQOs
Metals	90	Yes
TOX	100	Yes
TOC	100	Yes
TPH	75	No
Volatiles	100	Yes
Semivolatiles	94	Yes
Pesticides/PCBs	100	Yes

Table 5-2
Results for Field Duplicates^a

Parameters	Percent Acceptable	Meets Established DQOs
Metals	74	No
Semivolatiles	NC ^b	NC
Volatiles	NC	NC
Pesticides	NC	NC
TOC	100	Yes
TOX	50	No
TPH	50	No
Radium-226	33	No
Radium-228	33	No
Thorium-228	50	No
Thorium-230	50	No
Thorium-232	84	Yes
Total uranium	33	No

^aAcceptability based on 20 percent RPD for radiological analytes.

^bNC - not calculated because all duplicates were nondetectable.

Table 5-3
Results for Laboratory Radiochemical Duplicates^a

Parameters	Percent Acceptable	Meets Established DQOs
Radium-226	100	Yes
Radium-228	89	Yes
Thorium-228	100	Yes
Thorium-230	89	Yes
Thorium-232	100	Yes
Total uranium	100	Yes

^aAcceptability based on 20 percent RPD.

Table 5-4
Results for Chemical Spike Recoveries

Parameters	Percent Acceptable	Meets Established DQOs
Metals	81	Yes
TOX	100	Yes
TOC	100	Yes
TPH	87	Yes
Volatiles	100	Yes
Semivolatiles	98	Yes
Pesticides/PCBs	100	Yes

Table 5-5
Results for Radiological Spike Recoveries^a

Parameters	Percent Acceptable	Meets Established DQOs
Radium-226	100	Yes
Radium-228	92	Yes
Thorium-228	100	Yes
Thorium-230	100	Yes
Thorium-232	86	Yes
Total uranium	100	Yes

^aAcceptability based on a 75 - 125 percent recovery rate.

Table 5-6
Results for Laboratory Blanks

Analyte	Concentration
4-Methyl-2-pentanone	6 µg/L
Acetone	10 µg/L
Aluminum	57.6 µg/L
Bis(2-ethylhexyl)phthalate	4 µg/L
Boron	15.8 µg/L
Di-n-butylphthalate	3 µg/L
Iron	43.6 µg/L
Methylene chloride	7 µg/L
Zinc	8.1 µg/L
Radium-228	1 pCi/L

Table 5-7
Results for Trip Blanks

Analyte	Concentration
Methylene chloride	3 µg/l
Chloroform	1 µg/L
Acetone	12 µg/L

Table 5-8
Passability Rate for Each Analyte

Page 1 of 5

Parameters	Percent Acceptable	Meets Established DQOs
Metals		
Aluminum	100	Yes
Antimony	95	Yes
Arsenic	100	Yes
Barium	100	Yes
Beryllium	100	Yes
Boron	100	Yes
Cadmium	100	Yes
Calcium	100	Yes
Chromium	100	Yes
Cobalt	100	Yes
Copper	100	Yes
Iron	100	Yes
Molybdenum	100	Yes
Lead	100	Yes
Magnesium	95	Yes
Manganese	100	Yes
Nickel	100	Yes
Potassium	89	Yes
Selenium	95	Yes
Silver	100	Yes
Sodium	95	Yes
Thallium	95	Yes
Vanadium	100	Yes
Zinc	100	Yes
TOX	92	Yes
TOC	100	Yes
TPH	100	Yes
Volatiles		
Chloromethane	100	Yes
Bromomethane	100	Yes
Vinyl chloride	100	Yes
Chloroethane	100	Yes
Methylene chloride	100	Yes
Acetone	100	Yes

Table 5-8

(continued)

Page 2 of 5

Parameters	Percent Acceptable	Meets Established DQOs
Carbon disulfide	100	Yes
1,1-Dichloroethene	100	Yes
1,1-Dichloroethane	100	Yes
1,2-Dichloroethene (total)	100	Yes
Chloroform	100	Yes
1,2-Dichloroethane	100	Yes
2-Butanone	100	Yes
1,1,1-Trichloroethane	100	Yes
Carbon tetrachloride	100	Yes
Bromodichloromethane	100	Yes
1,2-Dichloropropane	100	Yes
cis-1,3-Dichloropropene	100	Yes
Trichloroethene	100	Yes
Dibromochloromethane	100	Yes
1,1,2-Trichloroethane	100	Yes
Benzene	100	Yes
trans-1,3-Dichloropropene	100	Yes
Bromoform	100	Yes
4-Methyl-2-pentanone	100	Yes
2-Hexanone	100	Yes
Tetrachloroethene	100	Yes
Toluene	100	Yes
1,1,2,2-Tetrachloroethane	100	Yes
Chlorobenzene	100	Yes
Ethyl benzene	100	Yes
Styrene	100	Yes
Xylenes (total)	100	Yes
2-Chloroethylvinylether	100	Yes
Acrolein	100	Yes
Acrylonitrile	100	Yes
Vinyl acetate	100	Yes
Semivolatiles		
Phenol	100	Yes
bis(2-Chloroethyl)ether	100	Yes
2-Chlorophenol	100	Yes
1,3-Dichlorobenzene	100	Yes
1,4-Dichlorobenzene	100	Yes

Table 5-8

(continued)

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Parameters	Percent Acceptable	Meets Established DQOs
1,2-Dichlorobenzene	100	Yes
2-Methylphenol	100	Yes
bis(2-Chloroisopropyl)ether	100	Yes
4-Methylphenol	100	Yes
N-Nitroso-di-n-propylamine	100	Yes
Hexachloroethane	100	Yes
Nitrobenzene	100	Yes
Isophorone	100	Yes
2-Nitrophenol	100	Yes
2,4-Dimethylphenol	100	Yes
bis(2-Chloroethoxy)methane	100	Yes
2,4-Dichlorophenol	100	Yes
1,2,4-Trichlorobenzene	100	Yes
Naphthalene	100	Yes
4-Chloroaniline	100	Yes
Hexachlorobutadiene	100	Yes
4-Chloro-3-methylphenol	100	Yes
2-Methylnaphthalene	100	Yes
Hexachlorocyclopentadiene	100	Yes
2,4,6-Trichlorophenol	100	Yes
2,4,5-Trichlorophenol	100	Yes
2-Chloronaphthalene	100	Yes
2-Nitroaniline	100	Yes
Dimethylphthalate	100	Yes
Acenaphthylene	100	Yes
2,6-Dinitrotoluene	100	Yes
3-Nitroaniline	100	Yes
Acenaphthene	100	Yes
2,4-Dinitrophenol	100	Yes
4-Nitrophenol	100	Yes
Dibenzofuran	100	Yes
2,4-Dinitrotoluene	100	Yes
Diethylphthalate	100	Yes
4-Chlorophenyl-phenyl ether	100	Yes
Fluorene	100	Yes
4-Nitroaniline	100	Yes
4,6-Dinitro-2-methylphenol	100	Yes
N-nitrosodiphenylamine	100	Yes
4-Bromophenyl-phenyl ether	100	Yes

Table 5-8

(continued)

Page 4 of 5

Parameters	Percent Acceptable	Meets Established DQOs
Hexachlorobenzene	100	Yes
Pentachlorophenol	100	Yes
Phenanthrene	100	Yes
Anthracene	100	Yes
Butylbenzylphthalate	100	Yes
3,3'-Dichlorobenzidine	100	Yes
Benzo(a)anthracene	100	Yes
Di-n-butylphthalate	100	Yes
Fluoranthene	100	Yes
Pyrene	100	Yes
Chrysene	100	Yes
bis(2-Ethylhexyl)phthalate	100	Yes
Di-n-octylphthalate	100	Yes
Benzo(b)fluoranthene	100	Yes
Benzo(k)fluoranthene	100	Yes
Benzo(a)pyrene	100	Yes
Indeno(1,2,3-cd)pyrene	100	Yes
Dibenz(a,h)anthracene	100	Yes
Benzo(g,h,i)perylene	100	Yes
1,2-Diphenylhydrazine	100	Yes
Benzidine	100	Yes
Benzoic acid	100	Yes
Benzyl alcohol	100	Yes
N-nitrosodimethylamine	100	Yes
Pesticides/PCBs		
Alpha-BHC	100	Yes
Beta-BHC	100	Yes
Delta-BHC	100	Yes
Gamma-BHC (Lindane)	100	Yes
Heptachlor	100	Yes
Aldrin	100	Yes
Heptachlor epoxide	100	Yes
Endosulfan I	100	Yes
Dieldrin	100	Yes
4,4'-DDE	100	Yes
Endrin	100	Yes
Endosulfan II	100	Yes

Table 5-8

(continued)

Page 5 of 5

Parameters	Percent Acceptable	Meets Established DQOs
4,4'-DDD	100	Yes
Endosulfan sulfate	100	Yes
4,4'-DDT	100	Yes
Methoxychlor	100	Yes
Endrin ketone	100	Yes
Endrin aldehyde	100	Yes
Alpha chlordane	100	Yes
Gamma chlordane	100	Yes
Toxaphene	100	Yes
Aroclor 1016	100	Yes
Aroclor 1221	100	Yes
Aroclor 1232	100	Yes
Aroclor 1242	100	Yes
Aroclor 1248	100	Yes
Aroclor 1254	100	Yes
Aroclor 1260	100	Yes
Radiological		
Radium-226	100	Yes
Radium-228	100	Yes
Thorium-228	100	Yes
Thorium-230	100	Yes
Thorium-232	100	Yes
Total uranium	100	Yes

Table 5-9
Radiochemistry Laboratory Performance on DOE
Quality Assessment Program Samples, 1992

Sample Media	Radionuclides	Number of Results Reported	Number Within Control Limits
Air filters	Uranium (mass)	1	1
Soil	Potassium-40 Strontium-90 Cesium-137 Uranium (mass)	4	3
Vegetation	Potassium-40 Strontium-90 Cesium-137	3	3
Water	Tritium Manganese-54 Cobalt-60 Cesium-134 Cesium-137 Cerium-144 Plutonium-238 Plutonium-239 Americium-241 Uranium (mass)	10	9

Table 5-10
Radiochemistry Laboratory Performance on EPA
Intercomparison Program Samples, 1992

Sample Media	Radionuclides	Number of Results Reported	Number Within Control Limits
Water	Alpha Beta Zinc-65 Cobalt-60 Ruthenium-106 Cesium-134 Cesium-137 Barium-133	26	24
Water	Radium-226 Radium-228 Plutonium-239 Uranium (natural)	16	16
Water	Strontium-89 Strontium-90	7	6
Water	Tritium	2	2
Air filters	Alpha Beta Strontium-90 Cesium-137	7	5

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APPENDIX A Hydrogeologic Details

HYDROGEOLOGIC DETAILS

The Middlesex site is underlain by the Passaic Formation of the Brunswick Group, Newark Supergroup, as defined by the nomenclature of Lyttle and Epstein (1987). The Passaic Formation in the local area is composed of interbedded dark, dull, red fissile shale and massive siltstone with occasional lenticular strata of well-sorted sandstone. The bedrock unit in the site area consists of the shale portion of the Passaic Formation and is moderately to highly fractured. The formation is horizontally bedded, and fracture frequency decreases with depth. Bedrock at the site occurs at a depth of approximately 0.9 to 2 m (3 to 7 ft) [at an elevation of 13.4 to 16.5 m (44 to 54 ft) above MSL]. The upper portion of the bedrock is weathered, grading downward into competent rock. Overlying the weathered bedrock unit is a thin [0.9 to 2 m (3 to 7 ft) thick] layer of unconsolidated sediments. The natural materials in this section are composed primarily of poorly sorted, silty, sandy clay and clayey, silty, fine- to medium-grained sand.

The shale portion of the Passaic Formation is used for domestic, municipal, and industrial water supply in Middlesex County. Typically the formation has low primary porosity. Groundwater flow in the aquifer is controlled by secondary porosity associated with fractures and joints in the formation. Groundwater flow across the site is from north to south toward a small drainage ditch south of the site.

Two types of water-bearing material occur within 15.2 m (50 ft) of the ground surface: the red shale of the Brunswick Formation and the overlying unconsolidated sediments. The groundwater monitoring network includes wells completed in these materials. Monitoring well locations are shown in Figure A-1. In general, the deeper wells are completed in bedrock to a total depth of 15 m (50 ft), and the shallow wells are completed to a total depth of 3 m (10 ft). The shallow wells are completed in the unconsolidated sediments, in shallow bedrock, or across the unconsolidated sediment/bedrock interface. Three of the deep wells are open-hole completions with no documentation for the top of the open interval, and four of the deep wells are screened between 12 and 15 m (40 and 50 ft) below ground surface (BGS). Potentiometric levels in the deeper wells range from approximately 16.8 to 10.4 m (55 to 34 ft) above MSL. The elevation of the water table generally ranges from

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18 to 13.4 m (59 to 44 ft) above MSL. The depth to water in the shallow zone ranges from 0.03 to 2.4 m (0.1 to 8 ft) BGS.

Thirty-two boreholes were drilled in 1991. These boreholes provided adequate data to map the bedrock surface and the thickness of the unconsolidated sediments underlying the site (Figures A-2 and A-3, respectively). The general configuration of the bedrock surface has a strong influence on the groundwater flow direction and elevation. Further information on onsite geology, hydrogeology, and well installation methods can be found in Weston (1980).

Water level measurements from the shallow monitoring wells were used to prepare hydrographs and potentiometric surface maps that show hydrologic conditions at the site. The hydraulic gradient and flow direction in the MSP groundwater system were determined from maps showing: (1) potentiometric surfaces (water levels), (2) elevation of the approximate top of bedrock, and (3) thickness of the unconsolidated sediments. Potentiometric surface maps were prepared by plotting water level elevations for selected dates (representative of periods of maximum and minimum water level conditions) on a base map and contouring the values.

Potentiometric surface maps were not developed for the wells monitoring the deeper portion of the bedrock section. These potentiometric levels appear to reflect the variation in the well completions. Three of the deeper wells are open-hole completions, reflecting potentiometric levels averaged over the section, whereas four of the wells are screened from 12 to 15 m (40 to 50 ft) BGS, reflecting potentiometric levels from a more discrete zone. The potentiometric levels in the screened wells are generally several feet lower than those in the wells with open-hole completions.

Selected hydrographs showing water levels measured from 1989 through 1992 are shown in Figures A-4 through A-8. Information from the boreholes and the geologic potentiometric maps leads to the following conclusions:

- Flow at the site is north to south. Thus, well 1 is the upgradient location, and wells 14 and 15 are the downgradient locations. Samples from the upgradient well are used to establish background conditions, and samples from the downgradient wells are used to determine the effect of the site on groundwater quality in the immediate vicinity.
- Water levels measured in well 4A actually reflect shallow water table conditions; the well is not isolated in deep bedrock (as has been reported in the past).
- The water table can be adequately defined using measurements for water levels in wells completed in the shallow portion of the stratigraphic section.

The potentiometric surface maps are based on data from wells completed in the shallow portion of the stratigraphic section. The generalized hydraulic gradient is 0.01. Both the flow direction (see Figures A-9 and A-10) and hydraulic gradient are similar to those determined for the shallow system (BNI 1992b).

FIGURES FOR APPENDIX A

Figure A-1
Well Locations at MSP

Figure A-2
Contours on Top of Bedrock at MSP

Figure A-3
Isopach Map Showing Thickness of Sediments Above Bedrock at MSP

Figure A-4
Hydrograph for Wells 3 and 9

Figure A-5
Hydrograph for Well 3A

Figure A-6
Hydrograph for Wells 22D and 23D

Figure A-7
Hydrograph for Wells 14 and 15

Figure A-8
Hydrograph for Wells 12 and 13

Figure A-9
Potentiometric Surface Map for Shallow Wells (05/11/92)

Figure A-10
 Potentiometric Surface Map for Shallow Wells (08/10/92)

APPENDIX B 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.

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 in the *roentgen*. This is a relatively large unit, so measurements are often calculated in milliroentgen. 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 *gray*, 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
McAipe, 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 100.0 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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Radioactivity in Consumer Products. U.S. Nuclear Regulatory Commission, 1978.

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 (2.2×10^{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	2×10^{12} or 2 Trillion	2 Times the Annual Federal Budget	Nuclear Medicine Generator
1 Millicurie	mCi	2×10^9 or 2 Billion	Cost of a New Interstate Highway from Atlanta to San Francisco	Amount Used for a Brain or Liver Scan
1 Microcurie	μ Ci	2×10^6 or 2 Million	All-Star Baseball Player's Salary	Amount Used in Thyroid Tests
1 Nanocurie	nCi	2×10^3 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.

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.

APPENDIX C Parameters for Analysis

Table C-1
Parameters for Analysis at MSP, 1992

Page 1 of 2

Medium ^a	Parameter	Technique
Water	Total uranium	Kinetic phosphorescence analyzer
	Radium-226	Alpha spectrometry
	Radium-228	Beta liquid scintillation
	Thorium-230	Alpha spectrometry
	Thorium-232	Alpha spectrometry
	Total organic halides	Microcoulimetry
	Total organic carbon	Wet ultraviolet-aided persulfate oxidation
	Mobile ions	Colorimetric determination
	Total metals: aluminum, antimony, barium, beryllium, cadmium, calcium, chromium, cobalt, copper, iron, lanthanides, magnesium, manganese, molybdenum, nickel, potassium, silver, sodium, vanadium, zinc	Inductively coupled plasma atomic emission spectro- photometry (ICPAES)
	arsenic, lead, selenium, thallium	Atomic absorption (AA) spectrophotometry
	Specific conductivity	Electrometric
	pH	Electrometric
	Volatile compounds	Gas chromatography/mass spectroscopy
	Semivolatile compounds	Gas chromatography/mass spectroscopy
Sediment	Total uranium	Fluorometric
	Radium-226	Gamma spectroscopy
	Thorium-230	Alpha spectroscopy
	Radium-228	Beta scintillation

Table C-1

(continued)

Page 2 of 2

Medium ^a	Parameter	Technique
Sediment (cont'd)	Thorium-232	Gamma spectroscopy
	Total metals: aluminum, antimony, barium, beryllium, cadmium, calcium, chromium, cobalt, copper, iron, lanthanides, magnesium, manganese, molybdenum, nickel, potassium, silver, sodium, vanadium, zinc	Inductively coupled plasma atomic emission spectro- photometry (ICPAES)
	arsenic, lead, selenium, thallium	Atomic absorption (AA) spectrophotometry
Air	Radon-222	Track-etch
	Radon-220	Track-etch
	External gamma radiation	Thermoluminescence

^aAir samples are cumulative; all others are grab samples.

Sampling Methods and Detectors for Radon and Thoron

Radon and thoron concentrations are measured using an integrating alpha track etch detector that contains a piece of alpha-sensitive film enclosed in a small two-piece cup. The radioactive gases diffuse through a membrane of the cup until the concentrations inside the cup are in equilibrium with atmospheric concentrations. Different types of membranes are used to distinguish between radon and thoron; one permits both radon and thoron to diffuse into the cup, and one permits only radon to diffuse. Alpha particles from the radioactive decay of radon and thoron and their daughters create tiny tracks when they collide with the film. After they are collected, the films are placed in a caustic etching solution to enlarge the tracks; under strong magnification, the tracks are counted. The number of tracks per unit area is related through calibration to the radon concentration in air. For thoron measurements, both types of detectors are installed at the sampling location. The thoron level is then determined by subtracting the level measured by the radon detector from the level measured by the radon/thoron detector.

Table C-2
Laboratory Detection Limits for Organic Chemical
Analyses of Groundwater at MSP
During Third Quarter, 1992

Page 1 of 4

Compound	Laboratory Detection Limit ^a (µg/L)
Volatile Organic Compounds	
Chloromethane	10
Bromomethane	10
Vinyl chloride	10
Chloroethane	10
Methylene chloride	5
Acetone	10
Carbon disulfide	5
1,1-Dichloroethene	5
1,1-Dichloroethane	5
1,2-Dichloroethene (total)	5
Chloroform	5
1,2-Dichloroethane	5
2-Butanone	10
1,1,1-Trichloroethane	5
Carbon tetrachloride	5
Vinyl acetate	10
Bromodichloromethane	5
1,2-Dichloropropane	5
cis-1,3-Dichloropropene	5
Trichloroethylene	5
Dibromochloromethane	5
1,1,2-Trichloroethane	5
Benzene	5
trans-1,3-Dichloropropene	5
2-Chloroethylvinylether	10
Bromoform	5
4-Methyl-1,2-pentanone	10
2-Hexanone	10
Tetrachloroethylene	5
1,1,2,2-Tetrachloroethane	5
Toluene	5
Chlorobenzene	5
Ethylbenzene	5

Table C-2

(continued)

Page 2 of 4

Compound	Laboratory Detection Limit ^a (µg/L)
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Semivolatile Organic Compounds

Styrene	5
Xylene (total)	5
Acrolein	10
Acrylonitrile	10
Phenol	10
bis(2-Chloroethyl)ether	10
2-Chlorophenol	10
1,3-Dichlorobenzene	10
1,4-Dichlorobenzene	10
Benzyl alcohol	10
1,2-Dichlorobenzene	10
2-Methylphenol	10
bis(2-Chloroisopropyl)ether	10
4-Methylphenol	10
N-Nitroso-di-n-propylamine	10
Hexachloroethane	10
Nitrobenzene	10
Isophorone	10
2-Nitrophenol	10
2,4-Dimethylphenol	10
Benzoic acid	50
bis(2-Chloroethoxy)methane	10
2,4-Dichlorophenol	10
1,2,4-Trichlorobenzene	10
Naphthalene	10
4-Chloroaniline	10
Hexachlorobutadiene	10
4-Chloro-3-methylphenol	10
2-Methylnaphthalene	10
Hexachlorocyclopentadiene	10
2,4,6-Trichlorophenol	10
2,4,5-Trichlorophenol	50
2-Chloronaphthalene	10
2-Nitroaniline	50
Dimethylphthalate	10
Acenaphthylene	10
2,6-Dinitrotoluene	10

Table C-2

(continued)

Page 3 of 4

Compound	Laboratory Detection Limit ^a (µg/L)
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Semivolatile Organic Compounds (cont'd)

3-Nitroaniline	50
Acenaphthene	10
2,4-Dinitrophenol	50
4-Nitrophenol	50
Dibenzofuran	10
2,4-Dinitrotoluene	10
Diethylphthalate	10
4-Chlorophenyl-phenylether	10
Fluorene	10
4-Nitroaniline	50
4,6-Dinitro-2-methylphenol	50
N-nitrosodiphenylamine	10
4-Bromophenyl-phenylether	10
Hexachlorobenzene	10
Pentachlorophenol	50
Phenanthrene	10
Anthracene	10
Di-n-butylphthalate	10
Fluoranthene	10
Pyrene	10
Butylbenzylphthalate	10
3,3'-Dichlorobenzidine	20
Benzo(a)anthracene	10
Chrysene	10
bis(2-Ethylhexyl)phthalate	10
Di-n-octyl phthalate	10
Benzo(b)fluoranthene	10
Benzo(k)fluoranthene	10
Benzo(a)pyrene	10
Indeno(1,2,3-cd)pyrene	10
Dibenzo(a,h)anthracene	10
Benzo(g,h,i)perylene	10
N-nitrosodimethylamine	10
Benzidine	50
1,2-Diphenylhydrazine	10

Table C-2

(continued)

Page 4 of 4

Compound	Laboratory Detection Limit ^a (µg/L)
PCBs	
Arochlor 1016	0.50
Arochlor 1221	0.50
Arochlor 1232	0.50
Arochlor 1242	0.50
Arochlor 1248	0.50
Arochlor 1254	1.00
Arochlor 1260	1.00
Pesticides	
Alpha-BHC	0.05
Beta-BHC	0.05
Delta-BHC	0.05
Gamma-BHC (Lindane)	0.05
Heptachlor	0.05
Aldrin	0.05
Heptachlor epoxide	0.05
Endosulfan I	0.05
Dieldrin	0.10
4,4'-DDE	0.10
Endrin	0.10
Endosulfan II	0.10
4,4'-DDD	0.10
Endosulfan sulfate	0.10
4,4'-DDT	0.10
Methoxychlor	0.50
Endrin ketone	0.10
Endrin aldehyde	0.10
Alpha chlordane	0.50
Gamma chlordane	0.50
Toxaphene	1.00

^aDetection limits can vary because of dilution ratios.

APPENDIX D Methodology for Statistical Analysis of Data

METHODOLOGY FOR STATISTICAL ANALYSIS OF DATA

Treatment of "Less than Zero" Values

Occasionally a radiological analytical value may be reported as a negative number. This is not a mistake, and the value does not represent "negative radioactivity." It is a result of the radiological measurement process produced by the subtraction of the background radiation measured by the instrument from the radiation measured in the sample. These results are essentially indistinguishable from zero.

Radioactive decay is a random phenomenon that can be described by a normal distribution (i.e., mean and standard deviation). When a sample contains radioactive elements at activities that are near instrument background, a single measurement of the sample can result in a negative value (when the instrument background is subtracted). If many measurements of the sample were taken and used to calculate the mean, this mean would be positive and would approximate the true radioactivity, however small, of the sample. In practice at FUSRAP sites, multiple measurements to calculate the mean activity of a sample near the instrument background are not necessary because the instrument background is typically several orders of magnitude lower than any DCGs.

Beginning with third quarter 1992 environmental monitoring, less-than-zero radiological values have been reported when they occur. This practice will be continued for all future environmental monitoring and will result in more accurate statistical analysis. For 1992 the result is that both negative values and values reported as less than a detection limit are used in the site environmental report. The negative values are used as reported in the statistical calculations. For values that are reported as less than the detection limit, the detection limit is used in the statistical calculations. The use of the detection limit is a conservative practice because it results in a high bias for the calculated mean.

Treatment of Rounding and Significant Figures

When calculations are made, the result can be no more accurate than the least accurate number in the data (i.e., the number with the least number of significant digits). Regardless of whether a number contains a decimal, the number of significant digits is the total number of digits starting with the left-most, non-zero digit and ending with the right-most digit (even if it is a zero). For example, 231, 230, and 23.0 each have three significant digits, while 0.05 and 5 each have one significant digit. Rounding is performed on final calculation results only, not on interim results.

Treatment of Annual Average Concentrations

Annual average concentrations are calculated by adding the results for the year and dividing by the number of quarters for which data have been taken and reported (usually four). An example follows.

Thorium-230 Results (pCi/L)

Sampling Location	Quarter			
	1	2	3	4
1	13	7	12	5

First, results reported for the year are added.

$$13 + 7 + 12 + 5 = 37$$

Next, the sum of all results is divided by the number of quarters for which data were taken and reported. In this example, there are data for all four quarters.

$$37 \div 4 = 9.25$$

Because there are two single-digit numbers (5 and 7) (the number of significant figures is 1), the result is rounded to 9. This value is entered into the average value column.

Thorium-230 Results (pCi/L)

Sampling Location	Quarter				Average Value
	1	2	3	4	
1	13	7	12	5	9

APPENDIX E Environmental Standards

ENVIRONMENTAL STANDARDS

The DOE long-term radiation protection standard of 100 mrem/yr (1 mSv/yr) in excess of the background level includes exposure from all pathways except medical treatments and exposures from radon (DOE 1990). Evaluation of exposure pathways and resulting dose calculations are based on assumptions such as the use of occupancy factors in determining dose from external gamma radiation; subtraction of background concentrations of radionuclides in air, water, and soil before calculating dose; closer review of water use; use of the data that most closely represent actual exposure conditions rather than maximum values, as applicable; and use of average consumption rates of food and water per individual rather than maximums. Use of such assumptions results in calculated doses that more accurately reflect the exposure potential from site activities.

DERIVED CONCENTRATION GUIDES

DOE orders provide the standards for radionuclide emissions from DOE facilities. DOE Order 5400.5, "Radiation Protection of the Public and the Environment," provides the procedures and requirements for radionuclide releases.

Applicable standards are found in Chapter III of DOE Order 5400.5 and are set as derived concentration guides (DCGs). A DCG is defined as the concentration of a radionuclide in air or water that, under conditions of continuous exposure to a single isotope for one year by one exposure mode (e.g., ingestion of water, inhalation), would result in an effective dose equivalent of 100 mrem. The following table provides reference values for conducting radiological environmental protection programs at operational DOE facilities and sites.

Radionuclide	F1 Value ^a	Ingested Water DCG ($\mu\text{Ci/ml}$) ^b	Inhaled Air DCGs ^c		
			D	W	Y
Radium-226	2E-1	1E-7	--	1E-12	--
Thorium-230	2E-4	3E-7	--	4E-14	5E-14
Thorium-232	2E-4	5E-8	--	7E-15	1E-14
Uranium-234	2E-3	5E-6	--	--	9E-14
Uranium-235	2E-3	5E-6	--	--	1E-13
Uranium-238	2E-3	6E-6	--	--	1E-13
Radon-222 ^d	3E-9	3E-9	--	--	3E-9
Radon-220 ^d	3E-9	3E-9	--	--	3E-9

^aF1 is defined as the gastrointestinal tract absorption factor, which measures the uptake fraction of ingestion of a radionuclide into the body.

^b1E-9 $\mu\text{Ci/ml}$ = 0.037 Bq/L = 1 pCi/L.

^cInhaled air DCGs are expressed as a function of time. D, W, and Y represent a measure of the time required for contaminants to be removed from the system (D represents 0.5 day; W represents 50 days; and Y represents 500 days).

^dDOE is reassessing the DCGs for radon. Until review is completed and new values issued, the values given in the chart above will be used.

SOIL GUIDELINES

Guidelines for residual radioactivity in soil established for FUSRAP are given below.

<u>Radionuclide</u>	<u>Soil Concentration (pCi/g) Above Background</u>
Radium-226 Radium-228 Thorium-230 Thorium-232	5 pCi/g, averaged over the first 15 cm of soil below the surface; 15 pCi/g when averaged over any 15-cm-thick soil layer below the surface layer.
Other radionuclides	Soil guidelines will be calculated on a site-specific basis using the DOE manual developed for this use.

Source: DOE 1987.

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POPULATION EXPOSURE METHODOLOGY

DOSE CALCULATION METHODOLOGY

DOE Order 5400.5 requires that the impacts of a site on both the hypothetical maximally exposed individual and the population within 80 km (50 mi) of the site be evaluated. For radioactive materials, this evaluation is usually conducted by calculating the dose received by the hypothetical individual and the general population and comparing this dose with DOE guidelines. This appendix describes the methodology used to calculate the doses discussed in Section 4.0.

PATHWAYS

The purpose of the dose calculation is to identify the potential routes or pathways that are available to transmit either radioactive material or ionizing radiation to the receptor. In general, the pathways are (1) direct exposure to gamma radiation, (2) atmospheric transport of radioactive material, (3) transport of radioactive material via surface water or groundwater, (4) bioaccumulation of radioactive materials in animals used as a food source, and (5) uptake of radioactive materials into plants used as a food source. For FUSRAP sites, the primary pathways may be direct gamma radiation and transport of radioactive materials by the atmosphere, groundwater, and surface water. The others are not considered primary pathways because FUSRAP sites are not located in areas where significant numbers of livestock are raised or foodstuffs are grown.

Gamma rays can travel until they expend all their energy in molecular or atomic interactions. In general, these distances are not very great, and the exposure pathway would affect only the hypothetical maximally exposed individual.

Contamination transported by the atmospheric pathway may take the form of contaminated particulates or dust and can provide a potential dose only when it is inhaled. Doses from radon are excluded in accordance with DOE Order 5400.5 II, 1.a(3) Application (02/08/90). Radon exposure is controlled through compliance with boundary concentration requirements.

Contamination can be transported in surface water when runoff from a rainfall event or some other source of overland flow carries contamination from a site to the surface water system. This contamination poses an exposure potential only when the surface water is used to provide municipal drinking water, to provide water for livestock, and/or to irrigate crops. Contamination can be transported via groundwater if contaminants migrate into the groundwater system.

Primary Radionuclides of Concern

The primary radionuclides of concern for these calculations at most FUSRAP sites are uranium-238, uranium-235, uranium-234, thorium-232, radium-226, and the daughter products (excluding radon). For several of the dose conversion factors used in these calculations, the contributions of the daughters with half-lives of less than one year are included with the parent radionuclide. Table F-1 lists the pertinent radionuclides common at FUSRAP sites, their half-lives, and dose conversion factors for ingestion.

DOSE CALCULATION METHOD

Direct Gamma Radiation Exposure

As previously indicated, direct gamma radiation exposure is important in calculating the dose to the maximally exposed individual. The dose from direct gamma radiation exposure is determined by using data collected through the tissue-equivalent thermoluminescent dosimeter (TETLD) program. These data provide a measure of the amount and energy (in units of mR/yr) of the ionizing radiation at 1 m (3 ft) above the ground. For the purposes of this report, the maximally exposed individual is assumed to live 30 m (100 ft) from the site and to spend 100 percent of his or her time at the residence.

The dose to the maximally exposed individual can be determined by assuming that the individual is exposed to a line source located along a segment of the southeastern fenceline. Because the average exposure rate is known from the TETLD program for a distance of 1 m

Table F-1
Radionuclides of Interest

Radionuclide	Half-life ^a	Dose Conversion Factor ^b for Ingestion (mrem/pCi)
Uranium-238	4.51E+9 years	2.5E-4
Thorium-234	24.1 days	-- ^c
Protactinium-234 m	1.17 minutes	-- ^c
Protactinium-234	6.75 hours	-- ^c
Uranium-234	2.47E+5 years	2.6E-4
Thorium-230	8.0E+4 years	5.3E-4
Radium-226	1602 years	1.1E-3
Uranium-235	7.1E+8 years	2.5E-4
Thorium-231	25.5 hours	-- ^d
Protactinium-231	3.25E+4 years	1.1E-2
Actinium-227	21.6 years	1.5E-2
Thorium-227	18.2 days	-- ^e
Radium-223	11.43 days	-- ^e
Thorium-232	1.41E+10 years	2.8E-3
Radium-228	6.7 years	1.2E-3
Actinium-228	6.13 hours	-- ^f
Thorium-228	1.91 years	7.5E-4

^aSource: HEW 1970.

^bSource: *Federal Guidance Report No. 11, Limiting Values of Radionuclide Intake and Air Concentrations and Dose Conversion Factors for Inhalation Submersion* (EPA-520/1-88-020) and *International Dose Conversion Factors for Calculation of Dose to the Public* (DOE/EH-0071).

^cIncluded in the uranium-238 dose conversion factor.

^dIncluded in the uranium-235 dose conversion factor.

^eIncluded in the actinium-227 dose conversion factor.

^fIncluded in the radium-228 dose conversion factor.

(3 ft) from the fenceline, the exposure at 30 m (100 ft) from the fenceline can be calculated by using the following equation (Cember 1983).

$$\text{Exposure at 30 m} = (\text{Exposure at 1 m}) \times \frac{h_1}{h_2} \times \frac{\tan^{-1}(L/h_2)}{\tan^{-1}(L/h_1)}$$

where: h_1 = TETLD distance from the fenceline [1 m (3 ft)]
 h_2 = Maximally exposed individual's distance from the fenceline [30 m (100 ft)]
 L = Half the length of the southeastern fenceline [114 m (375 ft)]

The exposure rate at 1 m (3 ft) can be calculated by taking the average of the results from the four detectors along this portion of the fenceline (stations 7, 12, 14 and 15). The average exposure rate for these detectors was 9.5 mR/yr above background. Using the formula above, the exposure rate at 30 m (100 ft) is approximately 0.3 mR/yr. Because 1 mR/yr is approximately equal to 1 mrem/yr (1E-2 mSv/yr), the resulting dose would be 0.3 mrem/yr (3E-3 mSv/yr).

Surface Water Pathway

Exposures from contaminants in surface water can be important in calculating the dose to both the maximally exposed individual and the nearby population. Because radionuclide concentrations in surface water samples taken from Main Stream upstream and downstream of its confluence with the MSP drainage ditch are essentially the same and because neither the ditch nor Main Stream is a drinking water source, significant exposures from the surface water ingestion pathway are not plausible.

Groundwater Pathway

Exposures from contaminants in groundwater that are part of a drinking water supply are important in calculating the dose to both the maximally exposed individual and the nearby population. The data used to support the groundwater dose calculations consist of

measurements of the concentrations of contaminants in groundwater and an estimate of the dilution that occurs between the measurement location and the intake point; however, the onsite shallow wells yield very low or nondetectable levels of radioactivity. Groundwater is therefore not a realistic or complete pathway.

Air Pathway (Ingestion, Air Immersion, Inhalation)

The doses to the maximally exposed individual and the general public from particulate radionuclides transported via the air pathway are calculated using EPA's computer model CAP88-PC.

The release of particulates would normally be calculated using a model for wind erosion because there are no other mechanisms for releasing particulates from the site; however, the site has a substantial asphalt and grass cover, which precludes wind erosion from being a credible pathway.

**APPENDIX G Distribution List for Middlesex Sampling Plant
Environmental Report for Calendar Year 1992**

**The Department of Energy distributes this report to local, state, and federal agencies;
U.S. Congress; the public; and the media (upon request).**

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