Formerly Utilized Sites Remedial Action Program (FUSRAP)
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NEW BRUNSWICK SITE ANNUAL ENVIRONMENTAL REPORT FOR CALENDAR YEAR 1991

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NEW BRUNSWICK SITE
ANNUAL ENVIRONMENTAL REPORT
FOR CALENDAR YEAR 1991
NEW BRUNSWICK, NEW JERSEY

SEPTEMBER 1992

Prepared for

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

By

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EXECUTIVE SUMMARY

This document describes the environmental monitoring program at the New Brunswick Site (NBS) and surrounding area, implementation of the program, and monitoring results for 1991. The site, near New Brunswick, New Jersey, is a 5.6-acre vacant, fenced, and grass-covered area. Environmental monitoring of NBS began in 1981 when the site was part of the U.S. Department of Energy's (DOE) Surplus Facilities Management Program. In 1990 responsibility for NBS was transferred to the Formerly Utilized Sites Remedial Action Program (FUSRAP). FUSRAP is a DOE program 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 monitoring program at NBS includes sampling networks for radon and thoron in air; external gamma radiation exposure; and radium-226, radium-228, thorium-228, thorium-230, thorium-232, americium-241, cesium-137, plutonium-239, and total uranium in surface water, sediment, and groundwater. Several nonradiological parameters are also measured in groundwater, surface water, and sediments.

Monitoring results are compared with applicable Environmental Protection Agency standards, DOE derived concentration guides, dose limits, and other requirements in DOE orders. Environmental standards are established to protect public health and the environment.

Results of environmental monitoring during 1991 indicate that all concentrations of contaminants of concern were well below applicable criteria. The potential radiation dose calculated for a hypothetical maximally exposed individual is 0.1 mrem (milliroentgen equivalent man) per year, which is less than an individual would receive while traveling in an airplane at 12,000 meters (39,000 feet) for one hour.

During 1991, there were no routine or nonroutine releases from the site; it was in compliance with applicable regulations for releases from the site. Site activities were limited to environmental monitoring and site maintenance.

As part of the ongoing environmental monitoring program at the site, the adequacy of existing monitoring activities is assessed annually. Results of this assessment are used to identify any necessary changes in the scope of the monitoring program. Such changes may result from changing site conditions, changing regulatory requirements, or newly identified data needs to support the remedy selection process being conducted for the site. Additionally, as monitoring data are accumulated, decisions may be made to adjust monitoring requirements. Future annual site environmental reports will reflect any changes to the routine monitoring program.

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ACRONYMS

AEC	Atomic Energy Commission
ANL	Argonne National Laboratory
BNAE	base/neutral and acid extractable
BNI	Bechtel National, Inc.
CAA	Clean Air Act
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
EE/CA	engineering evaluation/cost analysis
EPA	Environmental Protection Agency
FUSRAP	Formerly Utilized Sites Remedial Action Program
MSD	matrix spike duplicate
NBL	New Brunswick Laboratory
NBS	New Brunswick Site
NEPA	National Environmental Policy Act
NESHAPS	National Emission Standards for Hazardous Air Pollutants
NJDEPE	New Jersey Department of Environmental Protection and Energy
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
PARCC	precision, accuracy, representativeness, comparability, and completeness
QA	quality assurance

ACRONYMS
(continued)

QAPmP	quality assurance program plan
QC	quality control
RCRA	Resource Conservation and Recovery Act
RPD	relative percent difference
SRM	standard reference material
TETLD	tissue-equivalent thermoluminescent dosimeter
TMA/E	Thermo Analytical/Eberline
TPQ	threshold planning quantity
TSCA	Toxic Substances Control Act
VOC	volatile organic compound

UNITS OF MEASURE

Bq	becquerel
C	Celsius
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
rem	roentgen equivalent man
Sv	sievert
yr	year

1.0 INTRODUCTION

Environmental monitoring of the U.S. Department of Energy's (DOE) New Brunswick Site (NBS) and surrounding area began in 1981. This document describes the environmental monitoring program, implementation of the program, monitoring results for 1991, and special occurrences (if any) during 1991 and the first quarter of 1992.

1.1 DOE INVOLVEMENT

Environmental monitoring of NBS began in 1981 when the site was part of DOE's Surplus Facilities Management Program. In 1990 responsibility for NBS was transferred to the Formerly Utilized Sites Remedial Action Program (FUSRAP). FUSRAP is a DOE program to 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.

1.2 SITE DESCRIPTION

NBS occupies 2.3 ha (5.6 acres) in Middlesex County, approximately 48 km (30 mi) southwest of New York City, 95 km (60 mi) northeast of Philadelphia, and approximately 3.2 km (2 mi) southwest of downtown New Brunswick, New Jersey (Figure 1-1).

Figure 1-2 shows a plan view of NBS before decommissioning and decontamination activities were conducted. The site now consists of three of the original building pads and a parking area, but no buildings remain. The NBS property is fenced to restrict public access. The vacant, grass-covered site is in an urban, industrialized setting.

1.3 SITE HISTORY

Before 1948 the New Brunswick Laboratory (NBL) was used by a manufacturing company under contract to the U.S. Navy to build

Figure 1-1
Location of NBS

SOURCE: Modified from ANL 1990.

Figure 1-2
 Plan View of NBS Before Decommissioning
 and Decontamination Activities

naval pumps. In 1948 the Atomic Energy Commission (AEC) acquired the NBL property, modified existing structures, and added new ones. The site consisted of the main building, a plutonium laboratory complex, a hot cell, and nine support structures.

In 1949 AEC renovated and equipped the main building as a general nuclear chemistry laboratory for performing standards assays of nuclear and other materials used in AEC reactor and weapons programs. Several other projects grew out of this original assay work. The laboratory conducted spectrochemical analyses of lithium, magnesium, beryllium, zirconium, and other materials used in operating nuclear reactors.

NBL also conducted pilot projects to develop methods for thorium extraction and green salt (uranium tetrafluoride) production. In addition, a small-scale pilot plant was used to recycle borated products, in which impure forms of boron, such as borax powder (sodium tetraborate), were distilled and purified to yield pure boron.

In 1951 NBL began work on pilot-scale extraction of high-purity thorium from thorium ore and scrap. Aqueous mixtures of the finely powdered, thorium-containing raw material were treated in columns and tanks; organic solvents were used to remove thorium metal.

During its 29 years of operation, NBL provided a variety of services that utilized nuclear materials such as thorium and uranium ores, high-purity plutonium, and americium and uranium enriched with uranium-233 and uranium-235. There were contamination incidents, and liquid waste containing various radionuclides was discharged into the sanitary sewer system as permitted by AEC criteria in effect at that time.

In 1960, 510 m³ (18,000 ft³) of soil contaminated with Belgian-Congo pitchblende was transferred to the NBL site from the Middlesex Municipal Landfill (another New Jersey FUSRAP site). The contaminated soil was mixed with clean soil, resulting in a total volume of 3,100 m³ (110,000 ft³) that was used as fill on an unused railroad spur.

The assay work and associated activities continued until 1977, when the laboratory transferred its activities to Argonne National

Laboratory (ANL). Remedial action activities (decommissioning and preliminary decontamination) were initiated at the site in 1978 under the direction of the DOE Surplus Facilities Management Program. During a second remedial action phase completed in 1983, the structures and sewer lines were removed, and contaminated materials were transported offsite for disposal. Approximately 340 m³ (12,000 ft³) of radioactively contaminated soil from the site was placed near the pitchblende-contaminated soil on the railroad spur.

1.4 LAND USE

Land use in the vicinity of NBS is predominantly commercial and residential with some forest and meadow land (Figure 1-3). The property is bordered by Highway 91 to the north, a railroad and vacant area to the south, and commercial property to the east and west.

There is no residential housing within a 0.4-km (0.25-mi) radius of the site. The 1980 residential population within 1.6 km (1 mi) of the site boundary was estimated at 29,572 (ANL 1990). The total population of the area within an 80-km (50-mi) radius of NBS is approximately 15 million.

1.5 CLIMATE

Table 1-1 is a summary of climatological data from the National Oceanic and Atmospheric Administration (NOAA) for the Newark vicinity for 1991. Temperature extremes ranged from 13° to 39°C (9° to 102°F). Average wind speeds ranged from 12.9 to 18.0 km/h (8.0 to 11.2 mph), and the predominant resultant wind direction was from the west.

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Figure 1-3
Generalized Land Use in the Vicinity of NBS

Table 1-1
Summary of Climatological Data for
the Newark Vicinity, 1991

Month	Temperature (°F)			Total Precip (in.)	Wind	
	Min	Max	Avg		Avg Speed (mph)	Resultant Direction
January	9	55	33.6	3.72	9.7	W
February	15	69	38.6	1.81	10.4	W
March	24	77	44.4	5.49	11.2	W
April	34	88	54.8	3.91	10.6	W
May	46	93	68.9	4.80	9.8	NW
June	53	97	74.2	2.95	9.7	NW
July	65	102	77.9	5.21	8.0	W
August	62	96	77.7	5.63	9.1	NW
September	44	95	68.0	3.24	9.0	NW
October	39	82	58.3	1.29	9.2	N
November	27	73	47.6	2.04	9.6	NW
December	14	65	38.8	3.67	10.6	W

Source: NOAA 1992.

2.0 SUMMARY OF ENVIRONMENTAL COMPLIANCE

The primary regulatory guidelines and limits are given in the DOE orders and are authorized by six federal acts: the Clean Air Act (CAA); the Clean Water Act (CWA); the Resource Conservation and Recovery Act (RCRA); the Toxic Substances Control Act (TSCA); the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA); and the National Environmental Policy Act (NEPA).

The following summaries describe compliance requirements as they existed in 1991 and first quarter 1992, as well as anticipated regulatory requirements that may affect the site in the future.

2.1 PRIMARY REGULATORY GUIDELINES

DOE Orders for Radionuclide Releases

Site releases must comply with specific DOE orders [5400 series and DOE Order 5820.2A, "Radioactive Waste Management" (DOE 1988a)] that establish quantitative limits, derived concentration guides (DCGs), and dose limits for radiological releases from DOE facilities. The applicable guidelines and dose limits are presented in Appendix A. For Environmental Protection Agency (EPA) permitting purposes, DOE orders are treated as legal requirements, and releases of source, special nuclear, and by-product material in compliance with DOE orders at its facilities are considered "federally permitted actions" (54 FR 22524).

A review of environmental monitoring results for calendar year 1991 shows that NBS was in compliance with all applicable radionuclide release standards in DOE orders. Detailed monitoring results for radionuclides are presented in Section 4.0.

Clean Air Act and National Emission Standards for Hazardous Air Pollutants

The primary federal statute governing air emissions is the CAA. The only potential source of air emissions from NBS is radionuclide emissions from contaminated soil. NBS is not required to have any

state or federal air permits, pursuant to the authority of CERCLA Section 121. Although NBS is a nonoperating DOE facility, Subpart Q of the National Emission Standards for Hazardous Air Pollutants (NESHAPs) is applicable (DOE 1990a). Compliance with the EPA-approved strategy for radon monitoring was attained and maintained in 1991.

Subpart H has been determined to not apply to NBS because the contaminated soil is technically only a diffuse or fugitive emission source, not a point source as defined by the NESHAPs regulations. However, compliance with the non-radon radionuclide standard in Subpart H of NESHAPs is maintained by evaluating the site using the computer model AIRDOS (Version 3.0) approved by EPA. This evaluation was completed, and the information was submitted to EPA in the form of a draft Memorandum of Understanding between DOE and EPA for compliance with NESHAPs and by agreement with EPA Region II.

Clean Water Act

Pollutants discharged to waters of the United States are regulated under the federal CWA.

Unchannelized stormwater flow is the only potential discharge to surface water. On November 16, 1990, EPA promulgated its federal program for the control of stormwater discharges from sites associated with industrial activity, including sites containing waste. New Jersey is an authorized state for implementation of the federal program, and permit applications will be due to the New Jersey Department of Environmental Protection and Energy (NJDEPE) Bureau of Industrial Discharge Permits by October 1, 1992. DOE is evaluating whether a permit application is required for NBS because knowledge of present site conditions indicates that there is no point-source flow of stormwater to any receiving water body that would require a permit.

Resource Conservation and Recovery Act

RCRA is the principal federal statute governing the management of hazardous waste. Neither RCRA-regulated wastes nor radioactive wastes containing RCRA-regulated wastes are known to be present at the site. Characterization activities scheduled for 1992 include sampling to confirm this.

Toxic Substances Control Act

The most common toxic substances regulated by TSCA are polychlorinated biphenyls and asbestos. TSCA-regulated waste has not been detected at the site.

Comprehensive Environmental Response, Compensation, and Liability Act

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

Remediation of the site is being managed pursuant to the authority delegated to DOE by Executive Order 12580 because wastes containing radionuclides are defined as hazardous substances under CERCLA. Any potential regulatory conflicts regarding removal action decisions will be resolved upon completion of an engineering evaluation/cost analysis (EE/CA) in fiscal year 1994. After the EE/CA is completed, the remedial design will be prepared for the remedial action selected.

National Environmental Policy Act

Documentation to justify a categorical exclusion for environmental monitoring and surveillance activities was prepared in 1991 and approved in 1992. Information on environmental assessments is provided in Subsection 2.3.

Other Major Environmental Statutes and Executive Orders

In addition to the aforementioned DOE orders and statutes, several other major environmental statutes have been reviewed for applicability. For example, the Federal Insecticide, Fungicide, and Rodenticide Act; the Endangered Species Act; the Safe Drinking Water Act; and the National Historic Preservation Act have all been found to impose no current requirements on NBS. In addition, Executive Orders 11988 ("Floodplain Management") and 11990 ("Protection of Wetlands") and state laws and regulations have been reviewed for applicability. NBS is in compliance with all applicable environmental statutes, regulations, and executive orders.

2.2 APPLICABLE ENVIRONMENTAL PERMITS

NBS must meet all applicable permit conditions even though no permit applications are required. Although CERCLA Section 121 provides the statutory authority for an exemption to permitting requirements for onsite CERCLA remedial actions, the CWA permit under the National Pollutant Discharge Elimination System (NPDES) does not exempt CERCLA remedial actions. Therefore, a stormwater discharge permit application for NBS may be submitted to NJDEPE by the regulatory deadline of October 1, 1992, after a determination is made on the nature of stormwater flow to any receiving waters.

2.3 ENVIRONMENTAL IMPACT STATEMENTS AND ENVIRONMENTAL ASSESSMENTS

The preparation of an environmental assessment may be required to complete remedial action activities at the site. Characterization activities scheduled for 1992 will provide information on the extent of remediation that will be required.

2.4 SUMMARY OF REGULATORY COMPLIANCE IN CALENDAR YEAR 1992 (FIRST QUARTER)

During the first quarter of calendar year 1992, the site was in full regulatory compliance, as it was during 1991. Environmental monitoring continued, as did review of potentially applicable regulations for their impact on the site. DOE is evaluating whether a stormwater permit will be required for the site, and a stormwater sampling effort is being developed to support the permit application, if required. Redevelopment and performance testing of site groundwater monitoring wells are being planned, and site characterization activities are scheduled to commence in summer 1992.

3.0 ENVIRONMENTAL PROGRAM INFORMATION

Routine monitoring for radiation, radioactive materials, and chemical substances at NBS is used to document compliance with appropriate standards, provide the public with information, provide a historical record for year-to-year comparisons, and identify environmental impacts. The environmental monitoring program assists in fulfilling the DOE policy of protecting public health and the environment and mitigating environmental impacts.

The objectives of this report are to:

- Describe efforts to control stored pollutants until future remediation
- Describe the environmental monitoring program
- Report radiological and nonradiological conditions of the site and surrounding areas during 1991
- Provide comparison of monitoring results and applicable regulations and DOE orders (see Appendix A)

To ensure that the environmental monitoring data are of sufficient quality to meet these objectives, all personnel involved in sampling are trained in site-specific requirements and sampling techniques. This training is conducted before each sampling event begins and is followed up by a "lessons learned" analysis after sampling is completed. The environmental monitoring group supervisor is responsible for ensuring that all Oak Ridge support staff and site support personnel are properly trained.

The primary audience for the environmental monitoring results includes the general public; property owners; news media; community interest groups; technical staffs of federal, state, and local government agencies; and regulatory personnel.

3.1 SUMMARY OF ENVIRONMENTAL MONITORING PROGRAM

3.1.1 Environmental Monitoring Requirements

Requirements for environmental monitoring of radioactive materials are found in the DOE orders (5400 series) dealing with radiation protection of the public and the environment. These requirements include the monitoring of radionuclides in groundwater, surface water, and sediment at all applicable DOE sites. Requirements for environmental monitoring of airborne pollutants (radon and other radionuclides) are found in NESHAPs. Requirements for environmental monitoring of nonradiological parameters are found in DOE Order 5400.1 (DOE 1988b). Nonradiological parameters were monitored to obtain baseline information on groundwater, surface water, and sediment quality.

3.1.2 Monitoring Networks

The environmental monitoring networks at NBS are as follows:

- All monitoring stations, except for the surface water and sediment sampling locations, are onsite and accessible only to employees and authorized visitors.
- Background stations are located offsite in areas considered to be uncontaminated. Measured background values are compared with site values to determine compliance with DOE orders.

3.2 SUMMARY OF SPECIAL ENVIRONMENTAL ACTIVITIES

In support of onsite characterization of NBS, groundwater, surface water, and sediment samples collected during the first three quarters of 1991 were analyzed for rare earths and mobile ions. No rare earths were detected, and all mobile ion concentrations were low, reflecting ambient conditions.

3.3 SELF-ASSESSMENTS

During April 1991, Bechtel National, Inc. (BNI), the project management contractor for FUSRAP, conducted a self-assessment of the environmental monitoring activities at the site. Findings from this self-assessment focused on monitoring techniques, field documentation of monitoring events, and agreement between sampling practices and stated procedures. As a result of this assessment, corrective actions were developed and have been implemented.

An action remaining open from 1990 assessments was to develop environmental monitoring plans [required by DOE Order 5400.1 (DOE 1988b)] to document the rationale for the environmental monitoring networks at FUSRAP sites. These plans were published in November 1991.

Any deficiencies identified in self-assessments are processed through the corrective action process established by BNI. Depending on the nature of the deficiency, a corrective action request, nonconformance report, or observation report is used to document the deficiency and begin the corrective action process. The method of identification, documentation, and final corrective action enables the information to be retained and improvements incorporated into the program.

4.0 RADIOLOGICAL ENVIRONMENTAL PROGRAM

NBS is not an active site and produces no processing effluents. The only possibility for contamination to be released from the site would be through migration.

Based on knowledge of contaminants historically present at NBS, radiological environmental monitoring in 1991 included sampling for:

- Radon and thoron concentrations in air
- External gamma radiation exposure
- Radium-228, radium-226, thorium-232, thorium-228, thorium-230, cesium-137, americium-241, plutonium-239, and total uranium concentrations in surface water, sediment, and groundwater

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 on each matrix are provided in Appendix B.

This section of the report contains the quarterly radiological data for each sampling point and yearly averages, where applicable. The methodology for calculating the averages is provided in Appendix C. Although monitoring at NBS was initiated in 1981, sampling media, techniques, and sample analyses performed for 1991 monitoring differed from those in previous years; these changes preclude the presentation of trend information. The differences in programs resulted from the transfer of site responsibility from DOE-Chicago Field Office to DOE-Oak Ridge Field Office and from the Surplus Facilities Management Program to FUSRAP in September 1990.

All quarterly data are reported as received from the laboratory; all calculated values have been rounded off using standard rules for significant figures. Where appropriate, data are presented using powers of ten (e.g., $0.32 = 3.2 \times 10^{-1}$). Some

of the quarterly results are reported using a "less than" (<) sign. This notation is used to denote specific sample results that are below the limit of sensitivity of the analytical method, based on a statistical analysis of parameters. For computing annual averages, quarterly values reported as less than a given limit of sensitivity are considered equal to that limit.

The following subsections discuss the radiological monitoring program, results for 1991, and any possible radioactive contaminant migration indicated by the results.

4.1 ENVIRONMENTAL MONITORING FOR RADIOACTIVE CONTAMINANTS

4.1.1 Radon and Thoron Monitoring

One potential pathway of radiation exposure from the uranium-238 decay series arises from inhalation of the short-lived radionuclides, radon (radon-222) and radon daughter products. Thoron (radon-220), is the short-lived gaseous decay product of the thorium-232 decay series. Radon and thoron are radioactive (alpha-particle-emitting) gases that are very mobile in air. Radon and thoron monitoring is conducted at NBS to measure their concentrations at the site boundary and to demonstrate compliance with environmental regulations. Radon and thoron monitoring locations are shown in Figure 4-1.

Data and discussion

No annual average radon concentrations were higher than the DCG of 3.0×10^{-9} $\mu\text{Ci/ml}$ (0.11 Bq/L) (see Table 4-1). As shown in Table 4-2, all monitoring locations for thoron yielded annual average results that were essentially the same as background.

4.1.2 External Gamma Radiation Exposure Monitoring

External gamma radiation exposure rates are measured as part of the routine environmental monitoring program to confirm that direct

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Figure 4-1
Radon, Thoron, and External Gamma
Radiation Monitoring Locations at NBS

Table 4-1
Average Concentrations^{a,b} of Radon
at NBS, 1991

Page 1 of 2

Sampling Location ^c	Quarter ^d			Avg
	2	3	4	

(Concentrations are in 10^{-9} $\mu\text{Ci/ml}$)

Site Boundary

1	2.3	<0.3	0.5	1
2	<0.5	<0.3	0.5	0.4
3	0.5	<0.3	1.0	0.6
4	<0.5	<0.3	0.7	0.5
5	<0.5	<0.3	0.7	0.5
6	<0.5	<0.3	0.6	0.5
7	<0.5	<0.3	0.6	0.6
8	<0.5	<0.3	0.6	0.5
9	0.5	<0.3	0.5	0.4
10	0.7	<0.3	0.6	0.5
11	0.6	<0.3	0.6	0.5
12	0.7	<0.3	0.6	0.5
13	<0.5	<0.3	0.5	0.4
14	<0.5	<0.3	0.5	0.4
15	<0.5	<0.3	0.7	0.5
16	0.5	<0.3	0.8	0.5
17	0.6	<0.3	0.6	0.5
18	<0.5	<0.3	0.6	0.5
19	0.5	<0.3	0.7	0.5
20	<0.5	<0.3	0.8	0.5
21	<0.5	<0.3	0.5	0.4
22	0.5	<0.3	0.6	0.5
23	0.7	<0.3	1.0	0.7
24	0.7	<0.3	0.8	0.6

Onsite

25	<0.5	<0.3	0.9	0.6
26	0.6	<0.3	0.7	0.5
27	0.8	<0.3	0.7	0.6
28	<0.5	<0.3	0.8	0.5

Background

29 ^e	0.7	<0.3	0.9	0.6

Table 4-1
(continued)

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

^bBackground has not been subtracted from the boundary and onsite readings. Concentrations at some stations were below those at background stations.

^cSampling locations are shown in Figure 4-1.

^dRadon monitoring began during the second quarter of 1991.

^eLocated at 658 Leone Street, Woodbridge, N.J., approximately 21 km (13 mi) northeast of NBS.

Table 4-2
Average Concentrations^{a,b} of Thoron
at NBS, 1991

Page 1 of 2

Sampling Location ^c	Quarter ^d			Avg
	2	3	4	
(Concentrations are in 10 ⁻⁹ µCi/ml)				
Site Boundary				
1	1.0	0	0.6	0.5
2	0	0	0	0
3	0	0	0	0
4	0	0	0.2	0.1
5	0.3	0	0.4	0.2
6	0.3	0.1	0.5	0.3
7	0.1	0.1	0.2	0.1
8	0.2	0	0.3	0.2
9	0	0	0	0
10	0.6	0.5	0.9	0.7
11	0	0	0.1	0.1
12	0	0	0.2	0.1
13	0.4	0	0.1	0.2
14	0	0.1	0.7	0.3
15	0	0.1	0.2	0.1
16	0	0	0	0
17	0.2	0.4	0.4	0.3
18	0.3	0	0.2	0.2
19	0.1	0	0.4	0.2
20	0.2	0	0.1	0.1
21	0	0	0.4	0.1
22	0	0	0	0
23	0	0	0	0
24	0	0.1	0	0.1
Onsite				
25	0.2	0.1	0.3	0.2
26	0	0.1	0	0.1
27	0	0	0.4	0.1
28	0.2	0	0	0.1
Background				
29 ^e	0	0	0	0

Table 4-2
(continued)

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^a1 x 10⁻⁹ µCi/ml is equivalent to 0.037 Bq/L. The DCG for thoron is being assessed by DOE; until this review has been completed and new guidelines have been issued, the DCG for radon (3.0 x 10⁻⁹ µCi/ml) can be used for comparison.

^bBackground has not been subtracted from the boundary and onsite readings. Concentrations at some stations were below those at background stations.

^cSampling locations are shown in Figure 4-1.

^dThoron monitoring began during the second quarter of 1991.

^eLocated at 658 Leone Street, Woodbridge, N.J., approximately 21 km (13 mi) northeast of NBS.

radiation from NBS 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 70 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 less than the background rates measured some distance from the site, and rates onsite could be lower than at the boundary.

For comparison, Figure 4-2 shows the annual average external gamma radiation exposure rates for locations onsite, at the site boundary, and across the nation. Based on these data, the radioactive waste stored at NBS 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.

Data and discussion

External gamma radiation monitoring was initiated at NBS in January 1991 with the placement of TETLDs at the locations shown in Figure 4-1. The dosimeters were removed and analyzed in January 1992, yielding the average 1991 exposures that are listed in Table 4-3. The annual average exposure rate at NBS was 90 mR/yr onsite and 10 mR/yr at the site boundary; these values do not include a measured background value of 72 mR/yr. Information on public exposure can be found in Subsection 4.3.

Note: The DOE guideline for external gamma radiation exposure is 100 mrem/yr above background level (DOE 1990b). 1 mrem is approximately equivalent to 1 mR.

(a) Source: Martin Marietta Energy Systems, Inc., 1989.

Background

Figure 4-2
External Gamma Radiation Exposure Rates

Table 4-3
Average External Gamma Radiation Exposure Rates^a
at NBS, 1991

Page 1 of 2

Sampling Location ^b	1991 Average
(Rates are in mR/yr)	
Site Boundary (measured background subtracted) ^c	
1	0 ^d
2	0
3	0
4	13
5	21
6	8
7	3
8	0
9	1
10	57
11	10
12	14
13	19
14	22
15	-- ^e
16	12
17	15
18	22
19	8
20	1
21	20
22	-- ^e
23	5
24	<u>2</u>
Average	10
Onsite (measured background subtracted) ^c	
25	-- ^e
26	2
27	228
28	<u>52</u>
Average	90
Background	
29 ^f	72

Table 4-3
(continued)

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^aDosimeters have been in place for 1 yr. The DOE guideline is 100 mrem/yr above background. 1 mrem is approximately equivalent to 1 mR.

^bSampling locations are shown in Figure 4-1.

^cAverage annual measured background of 72 mR/yr has been subtracted from boundary and onsite readings.

^dA zero indicates that the measured value was not distinguishable from background levels.

^eDetector lost in processing.

^fLocated at 658 Leone Street, Woodbridge, N.J., approximately 21 km (13 mi) northeast of NBS.

4.1.3 Surface Water Monitoring

Surface water monitoring is conducted to ensure compliance with environmental regulations and to determine whether runoff from NBS contributes to surface water contamination in the area. Surface water monitoring locations are shown in Figure 4-3.

Data and discussion

Table 4-4 presents 1991 concentrations of total uranium, radium-226, radium-228, thorium-228, thorium-230, thorium-232, americium-241, plutonium-239, and cesium-137 in surface water. As shown in Table 4-4, all concentrations are well below the respective DCGs; contaminants do not appear to be migrating offsite via surface water.

4.1.4 Sediment Monitoring

Sediment monitoring is conducted to determine whether contaminants are collecting in onsite and/or offsite sediments and to ensure compliance with environmental regulations. Sediment sampling locations are shown in Figure 4-3.

Data and discussion

Table 4-5 presents 1991 concentrations of total uranium, radium-226, radium-228, thorium-228, thorium-230, thorium-232, americium-241, plutonium-239, and cesium-137 in sediment. Currently, there are no DCGs for radionuclides in sediment; therefore, applicable concentrations have been compared with FUSRAP soil guidelines, which are listed in Appendix A (there are no guidelines for total uranium, thorium-228, americium-241, cesium-137, and plutonium-239). The results show that all radionuclide concentrations detected in sediment samples were very low and well below the applicable guidelines. These low results are to be expected, given the low radionuclide concentrations

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Figure 4-3
 Surface Water and Sediment Sampling Locations
 in the Vicinity of NBS

Table 4-4
Concentrations^{a,b} of Radionuclides in
Surface Water in the Vicinity
of NBS, 1991

Page 1 of 2

Sampling Location ^c	Quarter ^d		Avg
	3	4	

(Concentrations are in 10^{-9} $\mu\text{Ci/ml}$)

Total Uranium^e

3	<0.35	0.81	0.6
4	<0.25	0.79	0.5

Radium-226

3	0.23	0.10	0.16
4	0.13	0.30	0.22

Radium-228

3	<1.87	<0.47	1
4	<2.21	<0.47	1

Thorium-228

3	<0.05	<0.78	0.4
4	<0.19	<0.77	0.5

Thorium-230

3	<0.05	<0.78	0.4
4	<0.19	<0.79	0.5

Thorium-232

3	<0.05	<0.78	<0.4
4	<0.19	<0.79	<0.5

Americium-241

3	<0.06	<0.79	0.4
4	<0.09	<0.68	0.4

Plutonium-239

3	<0.05	<0.34	0.2
4	<0.04	<0.12	0.08

Table 4-4
(continued)

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Sampling Location ^c	Quarter ^d		Avg
	3	4	
Cesium-137			
3	<1.27	-- ^f	--
4	<1.34	-- ^f	--

^a1 x 10⁻⁹ µCi/ml is equivalent to 0.037 Bq/L. The DCGs are as follows: for total uranium, 600 x 10⁻⁹ µCi/ml; for radium-226 and radium-228, 100 x 10⁻⁹ µCi/ml; for thorium-228, 400 x 10⁻⁹ µCi/ml; for thorium-230, 300 x 10⁻⁹ µCi/ml; for thorium-232, 50 x 10⁻⁹ µCi/ml; for americium-241 and plutonium-239, 30 x 10⁻⁹ µCi/ml; and for cesium-137, 3,000 x 10⁻⁹ µCi/ml.

^bMeasured background has not been subtracted.

^cSampling locations are shown in Figure 4-3.

^dSurface water sampling at NBS was initiated in the third quarter of 1991.

^eTotal uranium concentrations were determined by using fluorometric analysis during the third quarter and kinetic phosphorescence analysis during the fourth quarter.

^fAmount of surface water collected was insufficient for analysis.

Table 4-5
Concentrations^{a,b} of Radionuclides in
Sediment in the Vicinity
of NBS, 1991

Page 1 of 2

Sampling Location ^c	Quarter ^d		Avg
	3	4	

(Concentrations are in pCi/g)

Total Uranium^e

3	4.54	2.09	3.3
4	3.18	2.64	2.9

Radium-226

3	0.37	<0.40	0.4
4	0.47	0.31	0.39

Radium-228

3	<0.70	<0.64	0.6
4	<0.60	<0.50	0.8

Thorium-228

3	<0.74	<0.76	0.4
4	<0.37	<0.16	0.3

Thorium-230

3	1.10	<0.95	1
4	0.88	1.12	1.0

Thorium-232

3	<0.70	0.65	0.7
4	<0.60	1.34	1

Americium-241

3	<0.30	2.32	1
4	<0.30	1.76	1

Plutonium-239

3	<0.07	<0.24	0.2
4	<0.03	<0.20	0.1

Table 4-5
(continued)

Page 2 of 2

Sampling Location ^c	Quarter ^d		Avg
	3	4	
Cesium-137			
3	<0.10	<0.11	0.1
4	<0.11	<0.12	0.1

^a1 pCi/g is equivalent to 0.037 Bq/g. There are no DOE guidelines for total uranium, thorium-228, americium-241, plutonium-239, and cesium-137; the FUSRAP soil guideline for radium-226, radium-228, thorium-230, and thorium-232 is 5 pCi/g.

^bMeasured background has not been subtracted.

^cSampling locations are shown in Figure 4-3.

^dSediment sampling at NBS was initiated in the third quarter of 1991.

^eTotal uranium concentrations were determined by using fluorometric analysis during the third quarter and kinetic phosphorescence analysis during the fourth quarter.

detected in surface water samples, and further indicate the apparent lack of contaminant migration from NBS via surface water or sediment transport.

4.1.5 Groundwater Monitoring

Groundwater monitoring is conducted to provide information on potential migration of contaminants through the groundwater system and to ensure compliance with environmental regulations. Groundwater monitoring locations are shown in Figure 4-4.

Data and discussion

Table 4-6 presents 1991 concentrations of total uranium, radium-226, radium-228, thorium-228, thorium-230, thorium-232, americium-241, plutonium-239, and cesium-137 in groundwater. As shown in Table 4-6, all concentrations are well below the respective DCGs.

However, groundwater samples taken from well L, which is in an area known to contain pitchblende-contaminated soils, had concentrations of total uranium and thorium-230 that were slightly above the concentrations in other onsite wells. The well did not contain enough water for sampling during the third and fourth quarters.

4.2 UNPLANNED RADIOACTIVE RELEASES

No unplanned radioactive releases occurred at NBS in 1991.

4.3 POTENTIAL DOSE TO THE PUBLIC

This section contains information on exposures to the general public and a hypothetical maximally exposed individual from the radioactive materials at NBS. As expected for a relatively stable site such as NBS, all calculated doses are below the DOE guidelines.

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Figure 4-4
Groundwater Sampling Locations at NBS

Table 4-6
Concentrations^{a,b} of Radionuclides
in Groundwater at NBS, 1991

Page 1 of 5

Sampling Location ^c	Quarter				Avg
	1	2	3	4	

(Concentrations are in 10^{-9} $\mu\text{Ci/ml}$)

Total Uranium^d

A	0.4	-- ^e	1.6	<1.58	1
B	0.3	0.48	2.15	<1.14	1
C	<0.3	-- ^e	1.46	<0.60	0.8
D	0.8	0.81	1.47	<0.99	1.0
E	0.3	0.49	0.5	<1.99	0.8
F	0.6	0.56	0.38	<0.77	0.6
G	0.5	0.78	2.69	<1.78	1
H	0.7	-- ^e	1.9	<0.86	1
I	<0.3	<0.31	-- ^f	-- ^f	0.3
J	<0.4	0.5	-- ^f	-- ^f	0.5
K	3.3	1.9	2.67	<1.15	2
L	4.4	11.5	-- ^f	-- ^f	8.0
M	<0.8	0.7	-- ^f	-- ^f	0.8

Radium-226

A	0.5	0.50	0.48	2.3	1
B	1.7	1.60	0.65	4.5	2.1
C	1.9	1.40	0.3	1.9	1
D	0.2	1.00	0.78	0.2	0.6
E	0.4	0.70	<1.15	0.7	0.7
F	0.4	0.30	<1.07	0.6	0.6
G	2.1	2.00	2.61	4.8	2.9
H	0.4	1.10	1.20	0.6	0.8
I	0.2	0.50	-- ^f	-- ^f	0.4
J	0.3	0.70	-- ^f	-- ^f	0.5
K	0.4	0.67	0.43	8.0	2
L	1.6	2.70	-- ^f	-- ^f	2.2
M	0.8	<0.20	-- ^f	-- ^f	0.5

Radium-228

A	<1.0	<3.5	<2.97	0.5	2
B	1.1	<2.6	<4.38	<0.5	2
C	<1.1	<2.5	-- ^e	<0.5	1
D	<1.1	<8.3	<2.65	<0.5	3

Table 4-6
(continued)

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Sampling Location ^c	Quarter				Avg
	1	2	3	4	

Radium-228 (cont'd)					
E	<1.0	<2.9	14.10	<0.5	5
F	<1.1	<2.0	<8.12	<0.5	3
G	1.6	<1.9	<2.89	<0.5	2
H	<1.1	<8.7	<3.66	<0.5	4
I	<0.9	<10.0	-- ^f	-- ^f	6
J	<1.0	<4.7	-- ^f	-- ^f	3
K	<1.1	<7.6	<4.31	<0.5	3
L	<3.7	<6.7	-- ^f	-- ^f	5
M	<3.7	<4.8	-- ^f	-- ^f	4

Thorium-228					
A	<0.1	0.07	<0.05	<0.77	0.3
B	<0.1	<0.20	<0.06	<0.77	0.3
C	0.1	<0.07	<0.21	<0.79	0.3
D	<0.1	0.07	<0.06	<0.77	0.3
E	<0.1	<0.10	0.06	<0.78	0.3
F	<0.1	0.20	0.10	<0.80	0.3
G	0.2	<0.10	0.09	<0.79	0.3
H	<0.1	0.07	<0.09	<0.77	0.3
I	<0.1	0.07	-- ^f	-- ^f	0.1
J	<0.1	0.11	-- ^f	-- ^f	0.1
L	<0.1	<0.04	<0.03	<0.78	0.1
M	0.1	<0.03	-- ^f	-- ^f	0.1

Thorium-230					
A	0.1	<0.05	<0.04	<0.77	0.3
B	0.1	<0.20	<0.05	<0.77	0.3
C	0.1	<0.07	<0.27	<0.79	0.3
D	0.1	0.06	0.04	<0.77	0.2
E	0.1	<0.10	<0.06	<0.78	0.3
F	0.1	0.28	<0.09	<0.80	0.4
G	<0.01	<0.20	0.09	<0.79	0.3
H	0.1	<0.05	<0.04	<0.77	0.2
I	<0.1	<0.04	-- ^f	-- ^f	0.1
J	<0.1	<0.13	-- ^f	-- ^f	0.1
K	<0.1	<0.04	0.07	<0.78	0.2

Table 4-6
(continued)

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Sampling Location ^c	Quarter				Avg
	1	2	3	4	

Thorium-230 (cont'd)					
L	0.9	5.60	--- ^f	--- ^f	3.3
M	0.1	0.21	--- ^f	--- ^f	0.2

Thorium-232					
A	<0.1	0.07	<0.05	<0.77	0.3
B	<0.1	<0.2	<0.06	<0.77	0.3
C	0.1	<0.07	<0.21	<0.79	0.3
D	<0.1	0.07	<0.05	<0.77	0.3
E	<0.1	<0.09	0.06	<0.78	0.3
F	<0.1	<0.20	0.10	<0.80	0.3
G	0.2	<0.10	0.09	<0.79	0.3
H	<0.1	0.07	<0.09	<0.77	0.3
I	<0.1	0.07	--- ^f	--- ^f	0.3
J	<0.1	0.11	--- ^f	--- ^f	0.1
K	<0.1	<0.04	<0.03	<0.78	0.1
L	0.1	0.33	--- ^f	--- ^f	0.2
M	0.1	<0.03	--- ^f	--- ^f	0.2

Americium-241					
A	0.1	<0.33	<0.15	<0.49	0.3
B	<0.1	<0.30	0.22	<0.71	0.3
C	<0.1	<0.12	<0.26	<0.12	0.2
D	<0.1	<0.17	<0.07	<0.33	0.2
E	<0.1	<0.50	0.05	<0.54	0.3
F	<0.2	<0.17	<0.20	<0.64	0.3
G	<0.4	<0.06	<0.12	<0.62	0.3
H	<0.1	<0.18	<0.11	<0.40	0.2
I	0.1	<0.20	--- ^f	--- ^f	0.2
J	<0.1	<0.12	--- ^f	--- ^f	0.1
K	<0.2	<0.30	<0.15	<0.11	0.2
L	0.1	<0.15	--- ^f	--- ^f	0.1
M	<0.1	<0.10	--- ^f	--- ^f	0.1

Table 4-6
(continued)

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Sampling Location ^c	Quarter				Avg
	1	2	3	4	
Plutonium-239					
A	0.1	<0.06	<0.06	<0.14	0.1
B	<0.1	<0.20	<0.20	<0.81	0.3
C	<0.1	<0.05	<0.12	<0.73	0.3
D	<0.1	<0.04	<0.04	<0.57	0.2
E	<0.1	<0.10	<0.05	2.01	0.6
F	0.1	<0.05	<0.06	<0.60	0.2
G	0.2	<0.05	<0.17	<0.20	0.2
H	<0.1	<0.39	<0.23	<0.23	0.2
I	<0.1	<0.10	--- ^f	--- ^f	0.1
J	0.1	<0.06	--- ^f	--- ^f	0.1
K	<0.1	<0.10	<0.08	<0.68	0.2
L	<0.1	<0.33	--- ^f	--- ^f	0.2
M	0.1	<0.05	--- ^f	--- ^f	0.1
Cesium-137					
A	<0.8	<3.0	<1.29	<5.48	3
B	<1.1	<2.9	<1.18	<5.95	3
C	<0.9	<3.9	<1.14	<3.1	2
D	<0.9	<2.0	<1.29	<5.41	2
E	<0.9	<2.6	<1.21	<4.87	2
F	<0.9	<4.8	<1.00	3.08	2
G	<0.9	<3.3	<1.32	<5.23	3
H	<1.0	<3.0	<1.40	<5.82	3
I	<0.8	<3.4	--- ^f	--- ^f	2
J	<1.4	<2.5	--- ^f	--- ^f	2
K	<0.8	<3.5	1.30	<2.58	2
L	<1.1	<2.5	--- ^f	--- ^f	2
M	<0.8	<2.3	--- ^f	--- ^f	2

^a1 x 10⁻⁹ μCi/ml is equivalent to 0.037 Bq/L. The DCGs are as follows: for total uranium, 600 x 10⁻⁹ μCi/ml; for radium-226 and radium-228, 100 x 10⁻⁹ μCi/ml; for thorium-228, 400 x 10⁻⁹ μCi/ml; for thorium-230, 300 x 10⁻⁹ μCi/ml; for thorium-232, 50 x 10⁻⁹ μCi/ml; for americium-241 and plutonium-239, 30 x 10⁻⁹ μCi/ml; and for cesium-137, 3,000 x 10⁻⁹ μCi/ml.

^bMeasured background has not been subtracted.

Table 4-6
(continued)

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^cSampling locations are shown in Figure 4-4.

^dTotal uranium concentrations were determined by using fluorometric analysis during the first three quarters and by kinetic phosphorescence analysis during the fourth quarter.

^eSample volume was insufficient to complete all analyses.

^fWater in well was insufficient for sampling.

Doses to the general public 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.

To assess the potential health effects from the materials stored at NBS, radiological exposure pathways were evaluated and radiation doses were calculated for a hypothetical maximally exposed individual and for the population within 80 km (50 mi) of the site. The combined effects from all pathways (surface water, groundwater, air, and direct gamma radiation) from all DOE sources were then compared with the DOE guidelines. All doses presented in this section are estimated and do not represent actual doses. A summary is provided in Table 4-7.

4.2.1 Hypothetical Maximally Exposed Individual

Direct gamma radiation pathway

The hypothetical maximally exposed individual is assumed to work 40 hours per week at a facility 15 m (50 ft) from the southeastern fenceline of the site. This is a realistic approach because the closest business to the site is a factory located approximately 15 m (50 ft) from the southeastern fenceline. The calculated dose does not account for any shielding provided by the facility.

The calculated yearly dose to this individual was determined by using the average of the annual average exposure rates for the TETLDs along this fenceline (locations 4 and 5). Using this average (17 mR/yr above background; see Table 4-3), the dose received by the hypothetical maximally exposed individual from exposure to direct gamma radiation was calculated to be 0.1 mrem/yr

Table 4-7
Summary of Calculated Doses^a for NBS, 1991

Exposure Pathway	Dose to Hypothetical Maximally Exposed Individual (mrem/yr) ^b	Collective Dose for Population Within 80 km of Site (person-rem/yr) ^b
Direct gamma radiation ^c	0.1	-- ^d
Drinking Water	-- ^d	-- ^d
Ingestion	-- ^d	-- ^d
Air immersion	-- ^d	-- ^d
Inhalation ^e	<u>1.5 x 10⁻⁴</u>	<u>0.04</u>
Total	0.1 ^f	0.04
Background ^g	72	1 x 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 background.

^dExposures from this pathway are negligible.

^eCalculated using EPA's AIRDOS model (Version 3.0). Based on the AIRDOS PC user manual, the 50-yr effective dose equivalent factors were used to determine the committed effective dose equivalent to various critical organs. Therefore, the "mrem/yr" unit of effective dose equivalent from internal deposition of radionuclides should be interpreted as the "50-yr" committed dose equivalent based on total radiological particulate intake for a given year.

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

^gDirect gamma radiation exposure only.

^hCalculated by the following: (72 mrem/yr) (15 x 10⁶ people).

(0.001 mSv/yr), well below the DOE guideline of 100 mrem/yr. This dose was determined using the equation given in Appendix D for this pathway.

Drinking water pathway

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

Because there are no wells in the immediate vicinity of the site that are used for drinking water, groundwater is not a credible exposure pathway; therefore, the dose contribution from this pathway to the hypothetical maximally exposed individual was not calculated. There was also no credible exposure from surface water because radionuclide concentrations downstream of NBS are extremely low.

Air pathway (ingestion, air immersion, inhalation)

The hypothetical maximally exposed individual is assumed to work adjacent to and live near the site throughout the year. Air doses determined using Version 3.0 of EPA's AIRDOS model were found to be negligible [0.00015 mrem/yr (1.5×10^{-6} mSv/yr)]. This dose is well below the 10-mrem/yr (0.1-mSv/yr) limit given in 40 CFR Part 61, Subpart H. The 1991 AIRDOS compliance report is provided in Appendix E.

Total dose

The total dose for the hypothetical 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 1991 and the effective dose equivalent due to total external direct gamma

radiation measured at the fenceline in 1991. When these doses are added together, the total dose is 0.1 mrem/yr (0.001 mSv/yr) for the hypothetical maximally exposed individual. This dose is less than the dose an individual would receive from a one-hour flight at 12,000 m (39,000 ft) (Appendix F).

4.2.2 Population Dose

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

Direct gamma radiation pathway

NBS is located in an industrial area and thus is remote from the general population. Distance from the site to the nearest residential areas and the presence of intervening structures reduce direct gamma radiation exposure from NBS (see Table 4-8). Therefore, it is assumed that there is no detectable collective exposure to the general population.

Drinking water pathway

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

Air (ingestion, air immersion, inhalation)

The AIRDOS model provides an effective dose equivalent for contaminants transported via the air pathway at different distances from the site (Table 4-8). The collective dose for the general population within 80 km (50 mi) of NBS was calculated using this effective dose equivalent and the population density. The calculated collective population dose was 0.04 person-rem/yr (0.0004 person-Sv/yr).

Table 4-8
Maximum Effective Dose to the General Public
from NBS, 1991

Distance from the Site (m) (inner radius) (outer radius)	Effective Dose Equivalent (mrem/yr) ^{a, b}	Population Dose (person-rem/yr) ^{c, d}
0 - 1,000	1.7×10^{-4} *	2.1×10^{-3}
1,000 - 3,000	1.8×10^{-5}	1.8×10^{-3}
3,000 - 10,000	2.8×10^{-6}	3.1×10^{-3}
10,000 - 100,000	4.4×10^{-7}	<u>3.4×10^{-2}</u>
	Total dose	0.04

^aTo be conservative, the effective dose equivalent used for each range was that for the distance closest to the site. The DCG is 100 mrem above background for effective dose equivalent in a year.

^bValues were obtained using AIRDOS (Appendix E).

^cA population density of 10,000 persons/mi² (3,900 persons/km²) was used in the calculation.

^dCalculated using:

Population dose = [population density] [π (outer radius)² - π (inner radius)²] [effective dose equivalent].

*Effective dose equivalent for 300 m.

Total population dose

The total population dose is the sum of the doses from all exposure pathways. Because the only pathway with any potential contribution to the collective population dose is the air, the total population dose is equal to the dose calculated for it [0.04 person-rem/yr (0.0004 person-Sv/yr)].

5.0 NONRADIOLOGICAL ENVIRONMENTAL PROGRAM

The environmental monitoring program at NBS includes surface water, sediment, and groundwater monitoring for nonradiological parameters. Samples were collected from the same locations that were used for radiological sampling (see Figures 4-3 and 4-4).

Surface water and groundwater samples were analyzed for the indicator parameters total organic carbon, total organic halides, pH, and specific conductivity; mobile ions; organic compounds; and metals. Sediments were analyzed for metals. The indicator parameters are not addressed in this report because they are only gross indicators of ambient water quality; the parameters indicate that the groundwater and surface water associated with NBS is of a quality that might be expected in an area of mixed residential/commercial establishments.

Nonradiological parameters are monitored as specified by EPA requirements; DOE directives; and federal, state, and local statutes, regulations, and requirements applicable to DOE.

NBS is not an active site; therefore, the only "effluents" from the site would be contaminants that migrate by routes such as infiltration into groundwater, surface water runoff, or suspension and dispersion into the air.

Tables 5-1 and 5-2 give laboratory detection limits for the metals and volatile and semivolatile organic compound analyses performed on samples from NBS. Several metals identified at the site (e.g., calcium, potassium, sodium, magnesium, and manganese) were not considered because of the variability in their relative abundance in undisturbed soils and their common occurrence in the earth's crust.

The following subsections discuss the nonradiological monitoring program, results for 1991, and any possible contaminant migration indicated by the results. As was the case with radiological monitoring, the differences between the environmental monitoring program in 1991 and in previous years preclude the presentation of trend information.

Table 5-1
Laboratory Detection Limits for Organic Chemical
Analyses of Surface Water and Groundwater at NBS
During Third Quarter 1991

Page 1 of 3

Compound	Laboratory Detection Limit ($\mu\text{g/L}$)
Volatile Organic Compounds	
Chloromethane	10
Bromomethane	10
Vinyl chloride	10
Chloroethane	10
Methylene chloride	3
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
Trichloroethene	5
Dibromochloromethane	5
1,1,2-Trichloroethane	5
Benzene	5
trans-1,3-Dichloropropene	5
Bromoform	5
4-Methyl-1,2-pentanone	10
2-Hexanone	10
Tetrachloroethene	5
1,1,2,2-Tetrachloroethane	5
Toluene	5
Chlorobenzene	5
Ethylbenzene	5
Styrene	5
Xylene (total)	5

Table 5-1
(continued)

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

Table 5-1
(continued)

Page 3 of 3

Compound	Laboratory Detection Limit (µg/L)
Semivolatile Organic Compounds (cont'd)	
4-Nitroaniline	50
4,6-Dinitro-2-methylphenol	50
N-Nitrosodiphenylamine (1)	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

Table 5-2
Laboratory Detection Limits for Metals Analyses of
Surface Water, Sediment, and Groundwater
at NBS

Analyte	Laboratory Detection Limit for Sediment (mg/kg)	Laboratory Detection Limit for Water (µg/L)
Aluminum	40	200
Antimony	12	60
Arsenic		
(ICPAES ^a scan)	100	500
(Atomic absorption)	2	10
Barium	40	200
Beryllium	1	5
Boron	20	100
Cadmium	1	5
Calcium	1,000	5,000
Chromium	2	10
Cobalt	10	50
Copper	5	25
Iron	20	100
Lead		
(ICPAES scan)	100	500
(Atomic absorption)	1	5
Lithium	20	100
Magnesium	1,000	5,000
Manganese	3	15
Molybdenum	20	100
Nickel	8	40
Potassium	1,000	5,000
Selenium		
(ICPAES scan)	100	500
(Atomic absorption)	1	5
Silver	2	10
Sodium	1,000	5,000
Thallium		
(ICPAES scan)	100	500
(Atomic absorption)	2	10
Vanadium	10	50
Zinc	4	20

^aICPAES - Inductively coupled plasma atomic emission spectrophotometry.

5.1 SURFACE WATER MONITORING

Nonradiological surface water monitoring is conducted to determine whether runoff from NBS contributes to surface water contamination in the area. No volatile or semivolatile organic compounds were detected in surface water. As shown in Table 5-3, the metals boron, iron, and zinc were detected in surface water downgradient of NBS. However, there is no regular surface water flow across NBS, and the site is located in a heavily populated and industrialized area; therefore, results most likely reflect the ambient quality of surface water runoff in the area.

5.2 SEDIMENT MONITORING

Sediment monitoring was conducted to assess whether nonradiological contaminants are collecting in onsite or offsite sediments. Table 5-4 lists the concentrations of metals detected in sediments. Although the sampling results show the presence of several metals, the contribution of NBS to these concentrations is uncertain. Because there is no regular surface water flow across the site and it is covered with vegetation, the contribution, if any, is likely very small; therefore, the results reflect the typical condition of sediments in the area.

5.3 GROUNDWATER MONITORING

Groundwater monitoring was conducted to provide information on potential migration of nonradiological contaminants through the groundwater system and to ensure compliance with environmental standards. Table 5-5 lists the concentrations of metals detected in groundwater. Overall, the metals and concentrations detected were fairly consistent across the site, reflecting conditions typical of heavily populated and industrialized areas. An exception to this was the detection of lead, chromium, and copper in well L during the third quarter; this well is in an area known

Table 5-3
Concentrations of Metals in Surface Water
at NBS, 1991

Sampling Location ^a	Metal	Quarter ^b		Avg
		3	4	
(Concentrations are in µg/L)				
3	Boron	506	324	415
	Iron	2,790	2,420	2,605
	Zinc	-- ^c	22	21
4	Boron	3,920	195	2,058
	Iron	282	756	519

^aSampling locations are shown in Figure 4-3.

^bSurface water sampling was initiated in the third quarter of 1991.

^cNot detected above the detection limit; the limit is used in calculating the annual average.

Table 5-4
Concentrations of Metals in Sediment
at NBS, 1991

Sampling Location ^a	Metal	Quarter ^b		Avg
		3	4	
(Concentrations are in $\mu\text{g/kg}$)				
3	Aluminum	2,660	4,610	3,635
	Boron	-- ^c	99.3	90.5
	Chromium	13.3	31.4	22.4
	Copper	79.4	106	92.7
	Iron	12,600	17,500	15,050
	Lead	205.0	285	245
	Nickel	26.6	36.5	31.6
	Vanadium			13.5
	Zinc	164.0	236	200
4	Aluminum	1,870	6,240	4,053
	Barium	63.9	71.3	67.6
	Chromium	16.1	18.4	17.2
	Copper	83.7	62.4	73.7
	Iron	7,960	14,000	10,980
	Lead	80.8	58.9	69.8
	Nickel	12.8	17.8	15.3
	Vanadium	-- ^c	-- ^c	23.6
	Zinc	182	126	154

^aSampling locations are shown in Figure 4-3.

^bSediment sampling was initiated in the third quarter of 1991.

^cNot detected above the detection limit; the limit is used in calculating the annual average.

Table 5-5
Concentrations of Metals in Groundwater at NBS, 1991

Page 1 of 2

Sampling Location ^a	Metal	Quarter				Avg ^b
		1	2	3	4	
(Concentrations are in µg/L)						
A	Silver	-- ^c	13.5	-- ^c	-- ^c	10.8
	Barium	-- ^c	296	270	253	255
	Boron	105	-- ^c	-- ^c	-- ^c	101
	Iron	319	10,200	6,630	2,060	4,802
	Zinc	-- ^c	-- ^c	93.4	-- ^c	38.4
B	Silver	-- ^c	11.1	-- ^c	-- ^c	10.3
	Barium	262	309	262	240	268
	Iron	7,320	12,300	7,140	4,530	7,823
	Zinc	-- ^c	-- ^c	92.0	-- ^c	38
C	Silver	-- ^c	13.0	-- ^c	-- ^c	10.8
	Aluminum	219	-- ^c	-- ^c	-- ^c	205
	Barium	398	354	385	360	374
	Iron	1,480	1,040	2,770	1,070	1,590
	Zinc	-- ^c	30.5	178.0	-- ^c	62
D	Silver	-- ^c	13.2	-- ^c	-- ^c	10.8
	Aluminum	-- ^c	489	-- ^c	-- ^c	272
	Barium	269	286	252	-- ^c	252
	Iron	10,500	7,020	3,940	415	5,469
	Zinc	-- ^c	43.7	37.6	-- ^c	30
E	Silver	-- ^c	11.2	-- ^c	-- ^c	10.3
	Barium	-- ^c	224	228	-- ^c	213
	Iron	893	3,220	4,000	865	2,245
	Zinc	-- ^c	25.2	189.0	-- ^c	63.6
F	Aluminum	-- ^c	-- ^c	601	324	331.23
	Barium	-- ^c	256	466	350	318
	Iron	-- ^c	217	988	584	472
G	Aluminum	314	1,140	1,850	-- ^c	876
	Barium	236	321	469	290	329
	Copper	-- ^c	48.6	88.6	28.2	47.6
	Iron	662	2,270	3,470	562	1,741
	Zinc	-- ^c	20.3	134.0	-- ^c	49
H	Silver	-- ^c	13.2	-- ^c	-- ^c	10.8
	Aluminum	-- ^c	940	700	390	558
	Iron	440	8,130	9,170	3,210	5,238
	Barium	-- ^c	-- ^c	227	-- ^c	207
	Zinc	-- ^c	33.0	194.0	20.1	69

Table 5-5
(continued)

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Sampling Location ^a	Metal	Quarter				Avg ^b
		1	2	3	4	
I ^d	Silver	-- ^c	12.8	-- ^c	--	10.9
	Aluminum	-- ^c	209	405	--	271
	Copper	-- ^c	-- ^c	26.0	--	25.3
	Iron	410	612	1,290	--	771
	Zinc	-- ^c	24.7	24.5	--	23
J ^e	Aluminum	-- ^c	200	-- ^c	-- ^c	200
	Iron	226	6,140	-- ^c	-- ^c	3,138
	Zinc	-- ^c	68.3	-- ^c	-- ^c	44
	Copper	-- ^c	39.3	-- ^c	-- ^c	32.2
K	Iron	611	5,470	4,360	3,060	3,375
	Zinc	-- ^c	20.2	20.9	-- ^c	20
L	Aluminum	-- ^c	587	6,940	-- ^c	2,576
	Barium	-- ^c	-- ^c	251	-- ^c	251
	Boron	-- ^c	128	-- ^c	-- ^c	109
	Zinc	-- ^c	131.0	131.0	-- ^c	44
	Iron	-- ^c	2,460	38,300	-- ^c	13,620
	Lead	-- ^c	-- ^c	230	-- ^c	138
	Chromium	-- ^c	-- ^c	13.9	-- ^c	11.3
	Copper	-- ^c	-- ^c	79.5	-- ^c	43.2
M	Aluminum	-- ^c	518	-- ^c	-- ^c	359
	Iron	-- ^c	3,630	-- ^c	-- ^c	1,865
	Zinc	-- ^c	26.0	-- ^c	-- ^c	23

^aSampling locations are shown in Figure 4-4.

^bWhen analytical results are below detection limits, the limits are used in calculating annual averages.

^cNot detected above the detection limit.

^dWell did not recover sufficiently to sample after purging during fourth quarter.

^eWell did not recover sufficiently to sample after purging during third and fourth quarters.

to contain pitchblende-contaminated soils. Silver was also detected, but the analytical results may be false because of matrix effects on the analytical method used (see Subsection 7.3.2).

5.4 NATIONAL POLLUTANT DISCHARGE ELIMINATION SYSTEM

A permit application to comply with the EPA NPDES requirements may be completed in 1992. Stormwater discharges will be sampled in the third quarter of 1992 to support the application, if required.

5.5 OTHER EMISSIONS MONITORING

NBS is not an active site; therefore there are no emissions, other than those already discussed, to monitor.

5.6 ENVIRONMENTAL OCCURRENCES

No unplanned releases occurred at NBS in 1991.

5.7 SARA TITLE III REPORTING

No reports under Section 313 of the Emergency Preparedness and Community Right-to-Know Act were filed during 1991. FUSRAP sites were not subject to toxic chemical release reporting provisions under 40 CFR 372.22 in 1991. However, in accordance with the spirit and language of DOE Order 5400.1, FUSRAP evaluates and inventories toxic chemicals used onsite to ensure that no threshold planning quantities (TPQs) are exceeded.

Toxic chemicals, such as nitric acid, are used at FUSRAP sites for sampling and other purposes. However, the quantities of such chemicals stored onsite are well below TPQs. If a TPQ is exceeded at a site, the Toxic Chemical Release Inventory Reporting Form (Form R) under 40 CFR 372.85 will be filed with EPA.

6.0 GROUNDWATER PROTECTION PROGRAM

6.1 HYDROGEOLOGIC CHARACTERISTICS

NBS is located in the Triassic Lowlands section of the Piedmont Physiographic Province (Geraghty and Miller 1976). The site lies within the geologic structure known as the Newark Basin, which trends from southwest to northeast across central New Jersey. The Newark Basin is underlain by a thick sequence of Late Triassic clastic sedimentary rocks (the Newark Group) and interlayered with Triassic basalt and diabase. NBS is near the contact of the Brunswick Formation and the unconsolidated sediments of the Atlantic Coastal Plain Physiographic Province. The Raritan Formation, representing the coastal plain deposits, is located approximately 5 km (3.1 mi) southeast of the site.

The NBS area is underlain by the Brunswick Formation, of the Newark Group, which contains dark, dull, red fissile shale interbedded with massive siltstone and occasional lenticular strata of sorted sandstone and conglomerate. The Brunswick Formation is overlain by a thin veneer of unconsolidated sediments consisting of glacial sediments, residual soils, and man-made fill.

The Brunswick 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. The aquifer properties are typically highly variable. Well yields depend on the frequency and size of fractures and partings intercepted by the wells.

Observations of core samples provided the following stratigraphic information (ANL 1984). Three types of materials are present at the site: unweathered bedrock, weathered bedrock, and overburden. The bedrock consists of the shale portion of the Triassic Brunswick Formation and is a reddish-brown, soft rock that is moderately to highly fractured. The formation is horizontally bedded and becomes less fractured with increasing depth. The weathered bedrock consists of a clay layer formed by weathering of

the upper portion of the shale. This weathered shale is a reddish-brown, soft to very soft clay containing sand-sized fragments of less-weathered shale. The overburden can be divided into an upper unit consisting of gray and brown silty, sandy clay with a high organic content and an underlying unit consisting of reddish-brown clayey, silty, fine- to medium-grained sand.

The existing groundwater monitoring well network was installed by ANL. In September 1981, ten wells (A through J) were installed at the site. The water level data collected from November 1981 through November 1983 indicated groundwater flow to the northwest and seasonal fluctuations in water levels of up to 0.9 m (3 ft) within individual wells (ANL 1984). During May 1984, well D was replaced with well D', and three additional wells (K, L, and M) were installed. Water level data from 1984 through mid-1989 indicated flow to the northwest and a hydraulic gradient of 0.02 to 0.03. From mid-1989 through 1990, water level data indicated a flatter hydraulic gradient in the southeastern part of the site.

6.2 GROUNDWATER MONITORING

During 1991, the shallow groundwater underlying NBS was monitored quarterly for the presence of radioactive and chemical contamination, and water levels were measured biweekly. Sections 4.0 and 5.0 of this report present the results of the radiological and chemical monitoring; this section describes the hydrogeologic results.

6.2.1 Methods

The hydrogeologic interpretations are based on water level measurements from 13 monitoring wells at NBS. These data were used to determine seasonal fluctuations, groundwater flow directions, and hydraulic gradient. Borehole logs for the monitoring wells were not available during preparation of this document; therefore, the materials in which the wells are completed are not known. Well depths range from 4 to 7 m (13 to 23 ft) below ground surface, and screened intervals are generally 3 to 4.6 m (10 to 15 ft) in

length. The wells are assumed to be completed in the overburden and weathered bedrock; however, the wells may extend into competent bedrock. Monitoring well locations are shown in Figure 6-1, and well completion data are summarized in Table 6-1.

6.2.2 Results and Conclusions

Depths to water ranged from 0.02 to 3 m (0.08 to 10 ft) below ground surface in January 1991 and from 1.9 to 5.2 m (6.3 to 16.9 ft) below ground surface in September 1991. Water level measurements during 1991 show that water level fluctuations ranged from 0.9 to 2.7 m (3 to 9 ft) (Appendix G).

As shown on the hydrographs, water levels start to rise in late November and early December, are highest from January through early May, and are 0.6 to 2.1 m (2 to 7 ft) lower from May through November.

The general trend in groundwater elevations in most of the wells appears to be the same, and the relationship among the wells is relatively consistent throughout the year. With the exception of wells C and I, the water level elevations shown in the hydrographs range from approximately 27.4 to 29.9 m (90 to 98 ft) above mean sea level. Water level elevations in well C are approximately 0.6 to 2.1 m (2 to 7 ft) lower than in the other wells, and the elevations in well I are generally 0.6 to 1.5 m (2 to 5 ft) higher. The low levels in well I (in July, August, October, and November) are attributed to slow recovery after purging and sampling and probably indicate lower-permeability materials in this area.

Water level elevation contours for January and September 1991 are presented in Figures 6-2 and 6-3. Water level elevations in wells to the southeast indicate that the water table is relatively flat in this area. In the northern part of the site, the data indicate flow toward the north-northwest; the hydraulic gradient is approximately 0.03 to 0.04 in January (Figure 6-2) and approximately 0.02 in September (Figure 6-3).

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Figure 6-1
Well Locations at NBS

Table 6-1
NBS Monitoring Well Construction Summary

Well Number ^a	Completion Date	<u>Total Depth</u> [m (ft)]		<u>Screened Interval</u> <u>Below Ground</u>		Construction Material ^b
				[m - m (ft - ft)]		
A	1981	5.79	(19.0)	5.46 -	0.88 (17.9 - 2.9)	4-in. PVC
B	1981	4.57	(15.0)	4.57 -	1.52 (15.0 - 5.0)	4-in. PVC
C	1981	5.52	(18.1)	5.52 -	10.06 (18.1 - 3.3)	4-in. PVC
D ^c	1984	7.01	(23.0)	7.01 -	2.19 (23.0 - 7.2)	4-in. PVC
E	1981	4.57	(15.0)	4.57 -	1.52 (15.0 - 5.0)	4-in. PVC
F	1981	4.21	(13.8)	4.21 -	1.16 (13.8 - 3.8)	4-in. PVC
G	1981	3.96	(13.0)	3.96 -	0.91 (13.0 - 3.0)	4-in. PVC
H	1981	4.51	(14.8)	4.51 -	15.2 (14.8 - 5.0)	4-in. PVC
I	1981	6.16	(20.2)	6.16 -	1.52 (20.2 - 5.0)	4-in. PVC
J	1981	5.88	(19.3)	5.88 -	1.52 (19.3 - 5.0)	4-in. PVC
K	1984	6.16	(20.2)	6.16 -	1.58 (20.2 - 5.2)	4-in. PVC
L	1984	6.77	(22.2)	6.77 -	3.66 (22.2 - 12.0)	4-in. PVC
M	1984	5.91	(19.4)	5.91 -	3.05 (19.4 - 10.0)	4-in. PVC

Source: ANL 1984.

^aWell locations are shown in Figure 6-1.

^bPVC = polyvinyl chloride.

^cWell D' is a replacement well for well D.

144 R14F004.DGN

Figure 6-2
Potentiometric Surface Map of NBS (1/22/91)

144 R14F005.DGN

Figure 6-3
Potentiometric Surface Map of NBS (9/25/91)

7.0 QUALITY ASSURANCE

7.1 INTRODUCTION

This section summarizes the quality assurance (QA) assessment of environmental surveillance activities at NBS, which were conducted to ensure that onsite contamination is not posing a threat to human health and the environment. Based on this criterion, the overall data quality objective (DQO) for the environmental monitoring program is to provide data of a sufficient quality to allow reliable detection and quantification of any potential release of contaminated material from NBS.

7.2 PROCEDURES

The Quality Assurance Program Plan for the U.S. DOE FUSRAP (QAPmP) (BNI 1990) addresses the quality requirements for all work being performed as part of FUSRAP. In addition, all subcontractors adhere to or implement a QA system that is compatible with the program. The objectives of the QAPmP are to maintain quality through a system of planned work operations and to verify the preservation of quality standards through a system of checks and reviews.

Established QA procedures are detailed in project procedures and instructions and an instruction guide and are implemented for all field sampling activities. Sampling methodology and techniques are consistent with the methods detailed in A Compendium of Superfund Field Operations Methods (EPA 1987). Laboratory QA procedures, which have been reviewed by BNI, are implemented to control applicable laboratory activities. In addition, various activities (such as data reviews, calculations, and evaluations) are conducted to monitor the information being generated and to prevent or identify quality problems. Quality control (QC) sample requirements, data use information, and QA/QC procedures are provided in project instruction guides.

7.3 QUALITY ASSURANCE SUMMARY

QA/QC activities are an integral part of environmental monitoring activities at NBS. The quality of the data collected for the 1991 monitoring program is considered to be appropriate for these reporting purposes.

The QA/QC program implemented at NBS satisfies the 1991 requirements of DOE Orders 5400.1, 5400.5, and 5700.6B. The programmatic controls in place during the 1991 environmental monitoring program are discussed in the project instruction guide.

The specific methods and formulas used to evaluate the QA/QC program are described in an internal BNI QA document for annual site environmental reports; the QA document also discusses the requirements of precision, accuracy, representativeness, comparability, and completeness (PARCC). This subsection summarizes the results of the QA/QC program at NBS.

7.3.1 Data Usability

To determine data usability, the analytes of interest for NBS were evaluated for the PARCC parameters; Table 7-1 lists each analyte and indicates whether it meets these and other parameters. The following analytes have been determined to satisfy all elements of the PARCC parameters:

- Radium-226 in sediments
- Radium-228 in sediments
- Thorium-230 in sediments
- Total uranium in sediments
- Americium-241 in surface water and sediments

Other analytes were also evaluated, and certain elements did not fully meet PARCC requirements or could not be completely evaluated because some QC data were not retrievable. Corrective actions were initiated for all identified data deficiencies and nonconformances. As part of the ongoing FUSRAP QA program,

Table 7-1
Data Usability Summary

ANALYTE	PRECISION	ACCURACY	REPRESENTATIVENESS	COMPLETENESS	COMPARABILITY	QUANTITATIVE	QUALITATIVE	DQO ¹
Metals	2	3	4	YES ⁵	6	7	YES	YES
Volatile organic compounds	2	3	4	8	6	7	YES	YES
Semivolatile organic compounds	2	3	4	8	6	7	YES	YES
Radium-226	2	YES	YES	YES	YES	YES	YES	YES
Radium-228	2	YES	YES	YES	6	YES	YES	YES
Thorium-228	2	3	4	YES	6	7	YES	YES
Thorium-230	2	YES	YES	YES	6	YES	YES	YES
Thorium-232	2	3	4	YES	6	7	YES	YES
Total uranium	2	YES	YES	YES	YES	YES	YES	YES
Cesium-137	2	3	4	YES	6	7	YES	YES
Plutonium-239	2	3	4	YES	6	7	YES	YES
Americium-241	YES	YES	YES	YES	YES	YES	YES	YES
Thoron	2	3	4	YES	6	7	YES	YES
External gamma radiation	2	3	4	8	6	7	YES	YES
Radon	2	YES	YES	YES	6	7	YES	YES

Further information on any of the PARCC parameters can be found in the corresponding summaries of the text.

- 1 The data quality objective for the environmental monitoring program is to detect and quantify any release from NBS that could be potentially harmful to human health and the environment.
- 2 Insufficient field duplicate and/or laboratory duplicate data were reported for this parameter. In addition, no matrix spike duplicate information was reported for organic analyses.
- 3 Accuracy goal was not met or could not be assessed because of insufficient laboratory standard reference materials and blank data and/or insufficient field (rinse) blank data. In addition, no matrix spike information was reported for any of the organic analyses.
- 4 Representativeness goal was not met or could not be assessed because of insufficient laboratory blank information and/or insufficient field (rinse) blank information for this parameter.
- 5 The term "Yes" indicates that data are usable based on the analyses of the indicated PARCC parameters.
- 6 Comparability factor could not be calculated because precision and accuracy data were unreported or insufficient to meet the 80-percent goal.
- 7 Data do not meet quantitative goals because the variation associated with those values could not be adequately assessed.
- 8 Completeness could not be assessed because no information was reported for this parameter.

appropriate actions have been implemented including root-cause analyses and procedure development and revision.

Results of the evaluation indicate that the data quality for the following analytes did meet the intended end use. After a thorough review of all site information (including non-QC data), the results were determined to be of sufficient quality to achieve reliable detection and quantification of any potential release of contaminated material from NBS.

- Metals in groundwater, surface water, and sediments
- Volatile organic compounds (VOCs) in groundwater and surface water
- Semivolatile organic [base/neutral and acid extractable (BNAE)] compounds in groundwater and surface water
- Radium-226 in groundwater and surface water
- Radium-228 in groundwater and surface water
- Thorium-228 in groundwater, surface water, and sediments
- Thorium-230 in groundwater and surface water
- Thorium-232 in groundwater, surface water, and sediments
- Total uranium in groundwater and surface water
- Radon in air
- Thoron in air
- External gamma radiation in air
- Cesium-137 in groundwater and sediments
- Plutonium-239 in groundwater, surface water, and sediments
- Americium-241 in groundwater

7.3.2 Precision

The precision goal of 80 percent, as measured by analytical results for matrix spike duplicates (MSDs) and field and laboratory duplicates, was met for metals in groundwater at NBS. This goal indicates that a minimum of 80 percent of the QC results fell within acceptable ranges. Other chemical analytes did not meet the goal because of insufficient or unreported laboratory and field duplicate information. In addition, no information was reported for volatiles or semivolatiles in groundwater or surface water.

Minimal variability was introduced by field sampling for metals, based on the information available for field and laboratory duplicates. MSD groundwater samples (which measure analytical variability) analyzed for silver, calcium, magnesium, and sodium (in the second quarter) exceeded the analytical method's established criteria for acceptable variation. Sediment samples analyzed for calcium (in the third quarter) and lead (in the fourth quarter) also exceeded these criteria. MSD values that exceed control limits may indicate that a matrix effect was present at the site and interfered with the analytical determination of variation. The program's evaluation of the data usability indicated that the data met their intended end use.

The precision goal of 80 percent was met for radium-226, radium-228, thorium-228, thorium-230, thorium-232, and total uranium in sediments and for americium-241 in surface water and sediments. For all other radiological analytes of concern at NBS, QC data for field and/or laboratory duplicates were incomplete or unreported. Lack of precision information for these analytes does not affect the usability of the data.

Radiological QC data indicate that some degree of variability was present. A high degree of variability was seen in field duplicate results as measured by relative percent differences (RPDs); however, the RPDs were calculated from a limited data population. (As more data become available, the statistical reliability of these values increases, control limits may become tighter, and data more accurately reflect true site conditions.) The radiological methods used have no defined criteria for RPD values near the method detection limits; therefore, sampling variation cannot be quantitatively separated from laboratory variation. Because the laboratory precision criterion has not been established, the calculated upper control limit from the field duplicates (the mean plus three standard deviations) was used as the standard of data quality.

Values for radiological sediment analyses are considered qualitative because no field duplicate samples were taken and, consequently, total variability could not be quantified. Qualitative data are useful for estimating the approximate

concentration or activity of an analyte, but the amount of variation associated with the data remains unknown.

Data from the FUSRAP radiological laboratory's monthly QC reports indicate that the following analytes met the overall laboratory duplicate requirements for precision: radium-226, radium-228, thorium-228, thorium-230, thorium-232, total uranium, and americium-241. The remaining analytes could not be assessed or did not meet the precision goal because QC data for them were incomplete or not reported. Data for these analytes are considered qualitative; however, the DQOs for precision have been met.

7.3.3 Accuracy

The accuracy goal of 80 percent was not met for any chemical analytes of concern at NBS because of insufficient information on laboratory (method) blanks for metal analytes and unreported data for organic analytes. Control limits were statistically established from the data population for metals in groundwater. Blank contamination was detected in samples analyzed for metals in the second, third, and fourth quarters. Some associated concentrations could not be assessed to determine whether they had exceeded these control limits.

The accuracy goal was met for radium-226, radium-228, thorium-230, thorium-232, total uranium, and americium-241 in surface water and sediments and for radon in air. All other radiological analytes of concern at NBS did not meet the accuracy objective because field blanks, laboratory (method) blanks, and/or standard reference material (SRM) data were insufficient or not reported. However, the QA program has determined that the values associated with these radiological analytes were sufficient for the intended end use of the data.

Evaluation of radiological accuracy was limited because it was based on the total reported results for all FUSRAP sites where environmental monitoring was conducted in 1991. Laboratory QC data were summarized in a monthly report that provided an overall assessment of the laboratory's performance for that period.

Because of the summary nature of the reports, NBS QC data may be more accurate than actually reported.

7.3.4 Representativeness

The 80-percent goal for representativeness was not met for the chemical analytes of concern because of incomplete data on laboratory (method) blanks and holding times for metals and unreported data for organics. The following analytes met the goal: radium-226, radium-228, thorium-230, total uranium, and americium-241 in surface water and sediments and for radon in air. The remaining radiological analytes could not be assessed because the laboratory (method) blank and field blank information used in this QC assessment to calculate representativeness was not reported or not required. Lack of representativeness information for these analytes does not affect the usability of the data.

7.3.5 Completeness

The completeness goal of 80 percent was met for all metals and radiological analytes in all matrices except for total uranium in groundwater. Representativeness could not be assessed for organics because no information was reported. Thoron and radon monitoring satisfied the completeness goal; however, because no data were reported for external gamma radiation, its completeness could not be assessed.

7.3.6 Comparability

The established comparability goal of 80 percent (as calculated by evaluation of precision and accuracy) was not met for any of the chemical analytes of concern at NBS because of insufficient or unreported information. NBS data met the program's comparability requirements for radium-226, radium-228, thorium-230, thorium-232, total uranium, and americium-241 in surface water and sediments. The remaining radiological analytes did not attain the goal of

80 percent because comparability cannot be assessed when data for precision and/or accuracy are unavailable.

7.4 PROGRAMMATIC FACTORS

FUSRAP has established specific requirements in the areas of qualifications and training of personnel, data management and recordkeeping, chain-of-custody procedures, audits, performance reporting, independent data verification, and laboratory certification. These topics are covered in more detail in the program QA/QC document.

7.5 DOE LABORATORY QUALITY ASSESSMENT PROGRAM FOR RADIOACTIVE MATERIAL

Results of the radiological laboratory's participation in the DOE Environmental Measurements Laboratory Quality Assessment Program are presented in Table 7-2. The range of ratios presented has been determined to satisfy the requirements of the quality assessment program for radioactive materials.

Table 7-2
Results of the Quality Assessment Program, 1991

Page 1 of 2

Sample Type	Analysis	Results		Units	Ratio TMA/E:EML
		TMA/E ^a	EML ^b		
Air Filter	Be-7	63.1	53.0	Bq/filter	1.19
Air Filter	Mn-54	5.90	4.80	Bq/filter	1.23
Air Filter	Sr-90	0.914	0.789	Bq/filter	1.16
Air Filter	Cs-137	5.83	4.53	Bq/filter	1.29
Air Filter	Ce-144	67.3	52.2	Bq/filter	1.29
Air Filter	Pu-239	0.146	0.154	Bq/filter	0.948
Air Filter	Am-241	0.0940	0.101	Bq/filter	0.931
Air Filter	U-234	0.0514	0.0350	Bq/filter	1.47
Air Filter	U-238	0.0444	0.0350	Bq/filter	1.27
Soil	K-40	348	374	Bq/kg	0.931
Soil	Cs-137	154	150	Bq/kg	1.03
Soil	Pu-238	10.8	11.5	Bq/kg	0.939
Soil	Pu-239	3.27	3.40	Bq/kg	0.962
Soil	Am-241	1.48	1.76	Bq/kg	0.841
Soil	U-234	26.7	29.4	Bq/kg	0.908
Soil	U-238	23.0	30.0	Bq/kg	0.767
Vegetation	K-40	492	1150	Bq/kg	0.428
Vegetation	Sr-90	151	186	Bq/kg	0.812
Vegetation	Cs-137	74.4	67.6	Bq/kg	1.10
Vegetation	Pu-238	3.50	4.06	Bq/kg	0.862
Vegetation	Pu-239	0.962	1.40	Bq/kg	0.687
Vegetation	Am-241	0.608	0.829	Bq/kg	0.733
Water	H-3	321	361	Bq/L	0.889
Water	Mn-54	194	213	Bq/L	0.911
Water	Co-57	187	230	Bq/L	0.813
Water	Co-60	178	201	Bq/L	0.886
Water	Sr-90	8.53	8.63	Bq/L	0.988
Water	Cs-137	150	169	Bq/L	0.888
Water	Ce-144	33.2	35.1	Bq/L	0.946
Water	Pu-239	0.665	0.773	Bq/L	0.860
Water	Am-241	1.23	1.19	Bq/L	1.03
Water	U-234	0.236	0.219	Bq/L	1.08
Water	U-238	0.275	0.219	Bq/L	1.26
Air Filter	Be-7	74.7	53.8	Bq/filter	1.39
Air Filter	Mn-54	27.1	24.3	Bq/filter	1.12
Air Filter	Co-57	20.0	16.6	Bq/filter	1.20
Air Filter	Co-60	23.6	23.0	Bq/filter	1.03
Air Filter	Sr-90	0.773	0.663	Bq/filter	1.17
Air Filter	Cs-137	31.6	28.0	Bq/filter	1.13
Air Filter	Ce-144	54.5	50.8	Bq/filter	1.07
Air Filter	Pu-239	0.0704	0.0840	Bq/filter	0.838
Air Filter	Am-241	0.0858	0.104	Bq/filter	0.825
Air Filter	U-234	0.0518	0.0395	Bq/filter	1.31
Air Filter	U-238	0.0585	0.0388	Bq/filter	1.51
Soil	K-40	301	430	Bq/kg	0.700
Soil	Cs-137	240	312	Bq/kg	0.769

Table 7-2
(continued)

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Sample Type	Analysis	Results			Ratio TMA/E:EML
		TMA/E ^a	EML ^b	Units	
Soil	Pu-239	8.25	7.35	Bq/kg	1.12
Soil	Am-241	1.31	1.58	Bq/kg	0.829
Soil	U-234	25.3	28.9	Bq/kg	0.875
Soil	U-238	26.1	28.9	Bq/kg	0.903
Vegetation	K-40	819	992	Bq/kg	0.826
Vegetation	Sr-90	308	439	Bq/kg	0.702
Vegetation	Cs-137	11.7	27.1	Bq/kg	0.432 ^c
Vegetation	Pu-239	0.352	0.365	Bq/kg	0.964
Vegetation	Am-241	0.222	0.266	Bq/kg	0.835
Water	H-3	16.6	100	Bq/L	0.166 ^c
Water	Mn-54	91.2	103	Bq/L	0.885
Water	Co-57	154	166	Bq/L	0.928
Water	Co-60	261	291	Bq/L	0.897
Water	Sr-90	8.40	10.1	Bq/L	0.832
Water	Cs-137	42.8	46.0	Bq/L	0.930
Water	Ce-144	201	226	Bq/L	0.889
Water	Pu-239	0.519	0.510	Bq/L	1.02
Water	Am-241	0.620	0.570	Bq/L	1.09
Water	U-234	0.426	0.462	Bq/L	0.922
Water	U-238	0.485	0.478	Bq/L	1.01

^aTMA/E - ThermoAnalytical/Eberline, the radiological analysis subcontractor for FUSRAP.

^bEML - the DOE Environmental Measurements Laboratory.

^cCorrective action request has been issued.

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APPENDIX A
ENVIRONMENTAL STANDARDS

ENVIRONMENTAL STANDARDS

The DOE long-term radiation protection standard of 100 mrem/yr (1 mSv/yr) in excess of background level includes exposure from all pathways except medical treatments and exposures from radon (DOE 1990b). Evaluation of exposure pathways and resulting dose calculations are based on assumptions such as the use of occupancy factors in determining dose due to external gamma radiation; subtraction of background concentrations of radionuclides in air, water, and soil before calculating dose; closer review of water use, using the data that most closely 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

As referenced in Section 2.0, 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 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
" 232	2E-4	5E-8	--	7E-15	1E-14
Uranium-234	2E-3	5E-6	--	--	9E-14
" 235	2E-3	5E-6	--	--	1E-13
" 238	2E-3	6E-6	--	--	1E-13
Radon-222 ^d	3E-9	3E-9	--	--	3E-9
" 220 ^d	3E-9	3E-9	--	--	3E-9

^aF1 is defined as the gastrointestinal tract absorption factor. This 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 for releases from DOE facilities.

SOIL GUIDELINES*

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

<u>Radionuclide</u>	<u>Soil Concentration (pCi/g) Above Background</u>
Radium-226	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.
Radium-228	
Thorium-230	
Thorium-232	
Other Radionuclides	Soil guidelines will be calculated on a site-specific basis using the DOE manual developed for this use.

*Source: U.S. Department of Energy, "Guidelines for Residual
Radioactive Material at Formerly Utilized Sites Remedial Action
Program and Surplus Facilities Management Program Sites,"
Revision 2, March 1987.

APPENDIX B
PARAMETERS FOR ANALYSIS

Parameters for Analysis at NBS, 1991

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Medium	Parameter	Technique
Groundwater	Total uranium	Fluorometric
	Radium-226	Emanation
	Radium-228	Beta liquid scintillation
	Thorium-232	Gamma spectrometry
	Plutonium-239	Alpha spectroscopy
	Cesium-137	Beta proportional counting
	Americium-241	Alpha spectroscopy
	Total organic halides	Carbonaceous analyzer
	Total organic carbon	Coulometric determination
	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, mercury, selenium, thallium	Atomic absorption (AA) spectrophotometry
	Specific conductivity	Electrometric
	pH	Electrometric
	Volatile compounds	Gas chromatography/ mass spectroscopy
	Semivolatile compounds	Gas chromatography/ mass spectroscopy
Surface water	Total uranium	Fluorometric
	Radium-226	Emanation
	Radium-228	Beta liquid scintillation
	Thorium-232	Gamma spectrometry
	Plutonium-239	Alpha spectroscopy
	Cesium-137	Beta proportional counting
	Americium-241	Alpha spectroscopy
	Total organic halides	Carbonaceous analyzer
	Total organic carbon	Coulometric determination
	Mobile ions	Colorimetric determination

Parameters for Analysis at NBS, 1991
(continued)

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Medium	Parameter	Technique
Surface Water (cont'd)	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, mercury, selenium, thallium	Atomic absorption (AA) spectrophotometry
	Specific conductivity	Electrometric
	pH	Electrometric
	Volatile compounds	Gas chromatography/ mass spectroscopy
	Semivolatile compounds	Gas chromatography/ mass spectroscopy
	Total uranium	Alpha spectrometry
	Radium-226	Gamma spectrometry
Sediment	Radium-228	Gamma spectrometry
	Thorium-232	Gamma spectrometry
	Plutonium-239	Alpha spectroscopy
	Cesium-137	Beta proportional counting
	Americium-241	Alpha 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, mercury, selenium, thallium	Atomic absorption (AA) spectrophotometry
	Radon-222	Track-etch
Air	Radon-220	Track-etch
	External gamma radiation	Thermoluminescence

*Air samples are cumulative; all others are grab samples.

APPENDIX C
METHODOLOGY FOR STATISTICAL
ANALYSIS OF DATA

**METHODOLOGY FOR STATISTICAL
ANALYSIS OF DATA**

Average annual concentrations are calculated by averaging the results of all four quarters of sampling. When possible, sampling results are compiled in computer spreadsheets and the average values are calculated for all quarters of data.

Thorium-230 Results (pCi/L)

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

Average annual 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 is given below.

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 were data for all four quarters.

$$37 \div 4 = 9.25$$

Because there are two single-digit numbers (5 and 7), the result is rounded to 9 (number of significant figures is 1). 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 D
POPULATION EXPOSURE METHODOLOGY

POPULATION EXPOSURE METHODOLOGY

DOSE CALCULATION METHODOLOGY

DOE Order 5400.5 requires that the impacts of the 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 a hypothetical maximally exposed individual and the general population and comparing this dose with DOE guidelines. This appendix describes the methodology used to calculate the doses given in Subsection 4.2.

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 are 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 sources 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 maximally exposed individual.

Contamination transported via the atmospheric pathway takes the form of contaminated particulates or dust and can provide a

potential dose only when it is inhaled. Doses from radon are intentionally excluded; radon exposure is controlled through compliance with boundary concentration requirements.

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

Primary Radionuclides of Concern

The primary radionuclides of concern for these calculations 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 less than one year are included with the parent radionuclide. Table D-1 lists the pertinent radionuclides, 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 hypothetical maximally exposed individual. The dose from direct gamma radiation exposure is determined by using data collected through the tissue-equivalent thermoluminescent dosimeter (TETLD) program (described in Section 4.0). 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, it is assumed that the hypothetical maximally exposed individual works 40 hours per week at a facility 15 m (50 ft) from the southeastern fenceline of the site.

Table D-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: Radiological Health Handbook (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.

The dose to the hypothetical 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 (3 ft) from the fenceline, the exposure at 15 m (50 ft) from the fenceline can be calculated by using the following equation (Cember 1983).

$$\text{Exposure at 15 m} = (\text{Exposure at 1.6 m}) \times \frac{h_1}{h_2} \times \frac{\tan^{-1} (L/h_2)}{\tan^{-1} (L/h_1)}$$

where: h_1 = TETLD distance from the fenceline [1 m (3 ft)]
 h_2 = Hypothetical maximally exposed individual's distance from the fenceline [15 m (50 ft)]
 L = The length of the southeastern fenceline between stations 4 and 5 [17 m (56 ft)]

The exposure rate at 1 m (3 ft) can be calculated by taking the average of the results from the two detectors along this portion of the fenceline (4 and 5). The average exposure rate for these detectors was 17 mR/yr above background. Using the formula above, the exposure rate at 15 m (50 ft) is approximately 0.1 mR/yr. Because 1 mR/yr is approximately equal to 1 mrem/yr (1E-2 mSv/yr), the resulting dose would be 0.1 mrem/yr (1E-3 mSv/yr) assuming exposure over a 40-hour work week. This exposure scenario does not account for shielding provided by the facility.

Surface water pathway

Exposures from contaminants in surface water are important in calculating the dose to both the hypothetical maximally exposed individual and the nearby population. The data used to support the surface water dose calculation consist of measurements of concentrations of contaminants in surface water at the site and of the amount of dilution provided by tributaries or rivers between

the site and the point of intake. Thus, the dose to the individual can be calculated by the following:

$$D_s = \sum_{i=1}^N C_i \times (F_s + F_i) \times U_a \times DCF_i$$

where: D_s = Committed effective dose from surface water
 C_i = Concentration of the i^{th} radionuclide in surface water at the site
 F_s = Average annual flow of surface water from the site
 F_i = Average flow of surface water at the point of intake
 U_a = Annual consumption of liquid (approx. 730 L/yr)
 DCF_i = Dose conversion factor for the i^{th} radionuclide

To determine the dose to the population, the same equation would be used, and the dose would be multiplied by the population group served by the drinking water supply. It is important to note that for the population dose, the intake point is probably not the same as that for the hypothetical maximally exposed individual.

The approach outlined above for the surface water pathway does not account for radionuclides settling out or for any municipal water treatment.

Groundwater pathway

Exposures from contaminants in groundwater are important in calculating the dose to both the hypothetical maximally exposed individual and the nearby population. The data used to support the groundwater dose calculations consist of measurements of the concentration of the contaminants in groundwater and an estimate of the dilution that occurs between the measurement location and the intake point. The dose for the individual can be calculated by using the following equation:

$$D_{gw} = \sum_{i=1}^N (C_i) \times (D) \times (U_a) \times (DCF_i)$$

where: D_{gw} = Committed effective dose from groundwater
 C_i = Concentration of the i^{th} radionuclide in groundwater at the site
 D = Estimated dilution factor
 U_a = Annual consumption of water (approx. 730 L/yr)
 DCF_i = Dose conversion factor for the i^{th} radionuclide

To determine the dose to the population, the same equation would be used, and the dose would be multiplied by the population group served by the drinking water supply. It is important to note that the population intake point is usually different from that of the hypothetical maximally exposed individual.

The approach given above for the groundwater pathway does not account for any water treatment.

Air pathway (ingestion, air immersion, inhalation)

The doses to the hypothetical maximally exposed individual and the general public from particulate radionuclides transported via the air pathway are calculated using EPA's computer model AIRDOS; results are provided in Subsection 4.2.

The release of particulates was calculated using a model for wind erosion because there were no other mechanisms for releasing particulates from the site. The wind erosion model used was taken from the DOE "Remedial Action Priority System Mathematical Formulation." The input into the model consisted of site-specific average soil concentrations, local meteorological data (Section 1.0), and areas of contamination.

The site was modeled as three areas: the filled railroad spur area known to contain pitchblende-contaminated soil, a localized contaminated area near the midpoint of the southeastern fenceline, and an area near the center of the site that is suspected to be contaminated.

The average particle size for the soil at NBS is estimated at 0.05 mm for determining the emission factor for windblown material. This greatly overestimates the fraction of the airborne material that is respirable because most particles greater than 0.01 mm in diameter either would not be inhaled or would be quickly removed. Nevertheless, to provide a conservative calculation, all airborne particles were assumed to be respirable with an activity median aerodynamic diameter of 0.001 mm. Because the calculated dose was a small fraction of the NESHAPs standard of 10 mrem/yr, no effort was made to estimate the fraction of the airborne material that would be in the respirable range. Other assumptions used in the model were that the contamination at the site is 99 percent covered by vegetation and that there are very few mechanical disturbances at the site each month.

APPENDIX E
CLEAN AIR ACT COMPLIANCE REPORT
FOR NEW BRUNSWICK SITE

40 CFR Part 61
National Emission Standards
for Hazardous Air Pollutants

CLEAN AIR ACT COMPLIANCE REPORT
(Version 3.0 November 1989)

Facility: New Brunswick Laboratory
Address:

New Brunswick, NJ.
Annual Assessment for Year: 1991
Date Submitted: 5/ 4/92

Comments: Input data is taken from calculation
144-CV-07

Prepared By:

Name: Bechtel National Inc.
Title: FUSRAP
Phone #: (615) 576-1699

Prepared for:
U.S. Environmental Protection Agency
Office of Radiation Programs
Washington, D.C. 20460

CLEAN AIR ACT COMPLIANCE REPORT

5/ 4/92 4:27 PM

Facility: New Brunswick Laboratory

Address:

City: New Brunswick

State: NJ

Comments: Input data is taken from calculation 144-CV-07

Year: 1991

Dose Equivalent Rates to Nearby Individuals (mrem/year)

Effective
Dose Equivalent

0.0002

Highest Organ
Dose is to
LUNGS

0.0013

-----EMISSION INFORMATION-----

Radio-nuclide	Class	Amad	Area #1 (Ci/y)	Area #2 (Ci/y)	Area #3 (Ci/y)
U-238	Y	1.0	1.2E-07	2.5E-08	2.5E-08
U-235	Y	1.0	5.5E-08	1.1E-08	1.1E-08
RA-226	Y	1.0	1.4E-08	2.9E-09	2.9E-09
Total Area (m**2)			8.6E+02	1.7E+02	1.7E+02

-----SITE INFORMATION-----

Wind Data	NY_NY.WND	Temperature (C)	13
Food Source	LOCAL	Rainfall (cm/y)	117
Distance to Individuals (m)	300	Lid Height (m)	1000

*NOTE: The results of this computer model are dose estimates.
They are only to be used for the purpose of determining
compliance and reporting per 40 CFR 61.93 and 40 CFR 61.94.

ORGAN DOSE TO THE MAXIMALLY EXPOSED INDIVIDUAL

ORGAN	DOSE EQUIVALENT RATE TO THE ORGAN (mrem/y)
-----	-----
GONADS	2.3E-06
BREAST	2.5E-06
RED MARROW	1.5E-05
LUNGS	1.3E-03
THYROID	2.3E-06
ENDOSTEUM	1.9E-04
REMAINDER	1.6E-05
EFFECTIVE	1.7E-04

New Brunswick

5/ 4/92 4:27 PM

DOSE TO THE MAXIMALLY EXPOSED INDIVIDUAL
BY PATHWAY FOR ALL RADIONUCLIDES

	EFFECTIVE DOSE EQUIVALENT (mrem/y) -----	DOSE EQUIVALENT TO THE ORGAN WITH THE HIGHEST DOSE LUNGS (mrem/y) -----
INGESTION	1.2E-05	6.8E-07
INHALATION	1.5E-04	1.3E-03
AIR IMMERSION	3.5E-11	3.0E-11
GROUND SURFACE	1.0E-06	8.6E-07
	-----	-----
TOTAL:	1.7E-04	1.3E-03

New Brunswick

5/ 4/92 4:27 PM

DOSE TO THE MAXIMALLY EXPOSED INDIVIDUAL
BY RADIONUCLIDE FOR ALL PATHWAYS

RADIONUCLIDE	EFFECTIVE DOSE EQUIVALENT (mrem/y)	DOSE EQUIVALENT TO THE ORGAN WITH THE HIGHEST DOSE LUNGS (mrem/y)
U-238	1.0E-04	8.0E-04
U-235	5.0E-05	3.8E-04
RA-226	1.4E-05	1.1E-04
TOTAL :	1.7E-04	1.3E-03

New Brunswick

EFFECTIVE DOSE EQUIVALENT AS A FUNCTION
OF DISTANCE IN THE DIRECTIONS OF THE
MAXIMALLY EXPOSED INDIVIDUAL FOR
ALL RADIONUCLIDES AND ALL PATHWAYS

DIRECTION : NORTH

DISTANCE (meters)	EFFECTIVE DOSE EQUIVALENT (mrem/y)
-----	-----
300	1.7E-04
1000	1.8E-05
3000	2.8E-06
10000	4.4E-07
80000	1.7E-08

New Brunswick

EFFECTIVE DOSE EQUIVALENT AS A FUNCTION
OF ALL DISTANCES AND ALL DIRECTIONS FOR ALL
RADIONUCLIDES AND ALL PATHWAYS

DIRECTIONS:	N	NNE	NE	ENE	E	ESE	SE	SSE
DISTANCE (METERS):								
300	1.7E-04	8.7E-05	1.1E-04	9.3E-05	9.2E-05	1.1E-04	9.8E-05	8.1E-05
1000	1.8E-05	9.0E-06	1.1E-05	9.7E-06	9.8E-06	1.2E-05	1.0E-05	8.6E-06
3000	2.8E-06	1.4E-06	1.8E-06	1.5E-06	1.5E-06	1.8E-06	1.6E-06	1.3E-06
10000	4.4E-07	2.2E-07	2.8E-07	2.4E-07	2.5E-07	2.9E-07	2.6E-07	2.2E-07
80000	1.7E-08	8.1E-09	1.2E-08	9.1E-09	1.0E-08	1.3E-08	1.1E-08	9.2E-09

	S	SSW	SW	WSW	W	WNW	NW	NNW
DISTANCE (METERS):								
300	1.0E-04	8.7E-05	1.1E-04	1.1E-04	8.0E-05	2.9E-05	3.6E-05	3.9E-05
1000	1.1E-05	9.0E-06	1.2E-05	1.1E-05	8.3E-06	3.0E-06	3.7E-06	4.1E-06
3000	1.7E-06	1.4E-06	1.8E-06	1.8E-06	1.3E-06	4.6E-07	5.8E-07	6.5E-07
10000	2.7E-07	2.2E-07	2.9E-07	2.8E-07	2.0E-07	7.0E-08	9.1E-08	1.0E-07
80000	1.1E-08	8.4E-09	1.1E-08	1.1E-08	6.8E-09	2.2E-09	3.1E-09	3.8E-09

New Brunswick

METEOROLOGICAL AND PLANT INFORMATION SUPPLIED TO PROGRAM----

AVERAGE VERTICAL TEMPERATURE GRADIENT OF THE AIR (DEG K/METER)

IN STABILITY CLASS E	0.0728
IN STABILITY CLASS F	0.1090
IN STABILITY CLASS G	0.1455

PLUME DEPLETION AND DEPOSITION PARAMETERS

NUCLIDE	GRAVITATIONAL FALL VELOCITY (METERS/SEC)	DEPOSITION VELOCITY (METERS/SEC)	SCAVENGING COEFFICIENT (1/SEC)	EFFECTIVE DECAY CONSTANT IN PLUME (PER DAY)
U-238	0.000	0.00180	0.117E-04	0.000E+00
U-235	0.000	0.00180	0.117E-04	0.000E+00
RA-226	0.000	0.00180	0.117E-04	0.000E+00

FREQUENCY OF ATMOSPHERIC STABILITY CLASSES FOR EACH DIRECTION

SECTOR	FRACTION OF TIME IN EACH STABILITY CLASS						
	A	B	C	D	E	F	G
N	0.0010	0.0182	0.0904	0.7125	0.1196	0.0582	0.0000
NNW	0.0024	0.0094	0.0816	0.7012	0.1351	0.0702	0.0000
NW	0.0000	0.0236	0.0652	0.7089	0.1201	0.0821	0.0000
WNW	0.0041	0.0290	0.0552	0.7164	0.1180	0.0773	0.0000
W	0.0073	0.0483	0.0633	0.6566	0.1207	0.1038	0.0000
WSW	0.0038	0.0511	0.1443	0.6704	0.0751	0.0553	0.0000
SW	0.0014	0.0524	0.1438	0.6385	0.0894	0.0745	0.0000
SSW	0.0025	0.0369	0.0828	0.5869	0.1806	0.1102	0.0000
S	0.0043	0.0405	0.1038	0.6184	0.1602	0.0729	0.0000
SSE	0.0034	0.0611	0.1002	0.6674	0.1317	0.0362	0.0000
SE	0.0014	0.0375	0.0909	0.7152	0.1066	0.0485	0.0000
ESE	0.0012	0.0312	0.0817	0.6978	0.1387	0.0495	0.0000
E	0.0000	0.0225	0.0860	0.7281	0.1236	0.0398	0.0000
ENE	0.0027	0.0202	0.1118	0.6490	0.1488	0.0675	0.0000
NE	0.0000	0.0168	0.1093	0.6148	0.1938	0.0654	0.0000
NNE	0.0013	0.0129	0.0638	0.6073	0.1963	0.1184	0.0000

FREQUENCIES OF WIND DIRECTIONS AND RECIPROCAL-AVERAGED WIND SPEEDS

WIND TOWARD	FREQUENCY	WIND SPEEDS FOR EACH STABILITY CLASS (METERS/SEC)						
		A	B	C	D	E	F	G
N	0.121	0.77	2.58	4.45	5.03	3.36	1.53	0.00
NNW	0.024	2.57	2.88	4.58	4.22	3.33	1.58	0.00
NW	0.020	0.00	2.23	2.82	3.90	3.03	1.40	0.00
WNW	0.014	0.77	1.93	2.65	3.72	2.93	1.13	0.00
W	0.040	1.31	2.20	2.96	3.58	3.09	1.47	0.00
WSW	0.079	1.66	2.37	3.75	4.52	2.96	1.64	0.00
SW	0.076	2.57	2.52	3.60	4.82	3.39	1.57	0.00
SSW	0.047	1.19	2.10	2.76	4.35	3.67	1.65	0.00
S	0.071	2.39	1.57	3.48	5.34	3.87	1.66	0.00
SSE	0.070	2.34	2.27	3.56	5.70	3.98	1.46	0.00
SE	0.085	1.19	1.78	3.43	6.36	3.95	1.61	0.00
ESE	0.093	2.57	2.09	3.95	6.18	3.88	1.70	0.00
E	0.080	0.00	1.82	4.03	6.11	3.76	1.44	0.00
ENE	0.063	1.41	2.21	4.11	5.18	3.79	1.41	0.00
NE	0.072	0.00	2.16	3.93	4.78	3.73	1.75	0.00
NNE	0.045	2.57	1.50	4.16	4.49	3.40	1.58	0.00

FREQUENCIES OF WIND DIRECTIONS AND TRUE-AVERAGE WIND SPEEDS

WIND TOWARD	FREQUENCY	WIND SPEEDS FOR EACH STABILITY CLASS (METERS/SEC)						
		A	B	C	D	E	F	G
N	0.121	0.77	3.34	5.34	5.68	3.60	2.05	0.00
NNW	0.024	2.57	3.04	4.95	5.01	3.57	2.09	0.00
NW	0.020	0.00	3.00	3.83	4.65	3.23	1.93	0.00
WNW	0.014	0.77	2.53	3.56	4.69	3.11	1.59	0.00
W	0.040	1.83	2.97	3.45	4.58	3.30	1.99	0.00
WSW	0.079	2.15	3.13	4.10	5.61	3.14	2.13	0.00
SW	0.076	2.57	3.30	4.08	5.75	3.63	2.08	0.00
SSW	0.047	1.67	2.83	3.66	5.38	3.88	2.14	0.00
S	0.071	2.51	2.43	4.06	6.18	4.04	2.15	0.00
SSE	0.070	2.50	3.00	4.23	6.60	4.12	1.98	0.00
SE	0.085	1.67	2.71	4.08	7.14	4.10	2.11	0.00
ESE	0.093	2.57	3.01	4.44	6.98	4.05	2.18	0.00
E	0.080	0.00	2.77	4.45	6.76	3.96	1.97	0.00
ENE	0.063	1.94	3.11	4.60	5.89	3.98	1.93	0.00
NE	0.072	0.00	3.05	4.60	5.44	3.93	2.21	0.00
NNE	0.045	2.57	2.76	4.93	5.33	3.64	2.09	0.00

APPENDIX F
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

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

Porcelain Dentures

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

International Nuclear Weapons Test Fallout from pre-1980 atmospheric tests

(average for a U.S. citizen) ..... 1 mrem/year

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PERSPECTIVE: 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

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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

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 G
HYDROGRAPHS SHOWING WATER LEVEL ELEVATIONS

1-9

WATER ELEVATION, ftamsl

LEGEND:

- A
- * B
- ◇ C
- × D

G-2

8-9

WATER ELEVATION, ftamsl

LEGEND: □ I

1991

FUSRAP PROJECT

HYDROGRAPH FOR NBS

BECHTEL JOB 14501-144

G-4

APPENDIX H
CONVERSION FACTORS

Table H-1
Conversion Factors

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1 yr	=	8,760 h
1 L	=	1,000 ml
1 μ Ci	=	1,000,000 pCi
1 pCi	=	0.000001 μ Ci
0.037 Bq/L	=	10^{-9} μ Ci/ml = 1 pCi/L
0.037 Bq/L	=	0.000000001 μ Ci/ml
1 μ Ci/ml	=	1,000,000,000 pCi/L
$1E^{-6}$ = 1E-6 = 1E-06	=	0.000001 = 1×10^{-6}
$1E^{-7}$ = 1E-7 = 1E-07	=	0.0000001 = 1×10^{-7}
$1E^{-8}$ = 1E-8 = 1E-08	=	0.00000001 = 1×10^{-8}
$1E^{-9}$ = 1E-9 = 1E-09	=	0.000000001 = 1×10^{-9}
$1E^{-10}$ = 1E-10	=	0.0000000001 = 1×10^{-10}

APPENDIX I
DISTRIBUTION LIST FOR NEW BRUNSWICK SITE
ANNUAL ENVIRONMENTAL REPORT FOR CALENDAR YEAR 1991

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