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NIAGARA FALLS STORAGE SITE
ANNUAL ENVIRONMENTAL REPORT
FOR CALENDAR YEAR 1990

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EXECUTIVE SUMMARY

Environmental monitoring of the U.S. Department of Energy's (DOE) Niagara Falls Storage Site (NFSS) and surrounding area began in 1981. NFSS is part of the Formerly Utilized Sites Remedial Action Program (FUSRAP), 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.

It is DOE policy to conduct operations in an environmentally safe and sound manner that provides protection of human health and the environment. To that end, DOE is committed to incorporating national environmental protection and restoration programs, minimizing risks to the public and the environment, and addressing potential environmental hazards before they pose a threat to public welfare or environmental quality.

Environmental monitoring programs have been established at DOE-managed sites to confirm adherence to DOE environmental protection policies; to determine the effects of site operations on human health and the environment; and to ensure compliance with legal and regulatory requirements imposed by federal, state, and local agencies. Environmental monitoring programs are determined on a site-specific basis to reflect facility characteristics, applicable regulations, hazard potential, quantities and concentrations of materials released, extent and use of affected land and water, and local public interest or concern.

Environmental monitoring systems at NFSS include sampling networks for radon concentrations in air; external gamma radiation exposure; and total uranium and radium-226 concentrations in surface water, sediments, and groundwater. Additionally, several nonradiological parameters are routinely measured in groundwater.

Monitoring results are compared with applicable Environmental Protection Agency (EPA) standards; federal, state, and local applicable or relevant and appropriate requirements (ARARs); and/or DOE derived concentration guidelines (DCGs). Environmental

standards, ARARs, and DCGs are established to protect public health and the environment and reduce negative environmental impacts.

During 1990, the average ambient air radon concentration (including background) at NFSS ranged from 0.3 to 0.7 pCi/L (0.01 to 0.03 Bq/L); the maximum at any location for any quarter was 1.6 pCi/L (0.06 Bq/L). No quarterly level or annual average exceeded the DOE interim storage site guideline of 3.0 pCi/L at the boundary. Radon flux measurements were collected to demonstrate that the site is in compliance with the radon flux limit of 20 pCi/m²/s set forth in 40 CFR Part 61, Subpart Q. The average radon flux rate for the Interim Waste Containment Facility (IWCF) was 0.9 pCi/m²/s (0.03 Bq/m²/s); the two small storage piles averaged 0.02 pCi/m²/s (7E-4 Bq/m²/s). (Note: 1E-n = 1 x 10⁻ⁿ.)

The average on-site external gamma radiation exposure level was 69 mR/yr; the average at the property line was 68 mR/yr (including background). The average background radiation level in the area was 66 mR/yr.

Average annual concentrations of radium-226 and total uranium in surface water ranged from 0.4E-9 to 0.9E-9 μ Ci/ml (0.02 to 0.03 Bq/L) and from 5E-9 to 9E-9 μ Ci/ml (0.2 to 0.3 Bq/L), respectively. Both were well below the applicable DOE DCGs of 100E-9 and 600E-9 μ Ci/ml for radium-226 and total uranium, respectively. Average annual concentrations of radium-226 and total uranium in sediment ranged from 0.8 to 1.4 pCi/g (0.03 to 0.052 Bq/g) and from 1.6 to 3.7 pCi/g (0.059 to 0.14 Bq/g), respectively. Annual average radium-226 and total uranium concentrations in groundwater from wells around the IWCF ranged from 0.02E-9 to 1.7E-9 μ Ci/ml (0.0007 to 0.063 Bq/L) and from 3E-9 to 31E-9 μ Ci/ml (0.1 to 1.2 Bq/L), respectively.

Routine analyses of groundwater samples from NFSS included the indicator parameters total organic carbon, total organic halides, pH, and specific conductivity. In addition, analyses were performed for 34 metals. During the second quarter, groundwater was analyzed for the presence of priority pollutant organics

(34 volatile and 65 semivolatile or extractable compounds). Concentrations of potential chemical contaminants in downgradient wells were essentially no different than those in upgradient wells.

To verify that the site is in compliance with the DOE radiation protection standard of 100 mrem/yr and to assess its potential effect on public health, the potential radiation dose was calculated for a hypothetical maximally exposed individual. Based on the conservative scenario described in this report, this hypothetical individual would receive an annual exposure approximately equivalent to 0.44 mrem/yr (4.4 μ Sv/yr). The cumulative dose to the population within an 80-km (50-mi) radius of NFSS resulting from materials present at the site was calculated to be 0.3 person-rem/yr (0.003 person-Sv/yr) for an estimated population of 227,000 individuals. This is a very small collective population dose compared with the collective population dose of $1.5E+4$ person-rem/yr ($1.5E+2$ person-Sv/yr) received by the general public within 80 km (50 mi) of the site from background gamma radiation.

To verify that the site is in compliance with 40 CFR Part 61, Subpart H, the EPA-approved AIRDOS computer model was used to calculate the dose to a hypothetical maximally exposed individual due to airborne radionuclides transported from the site. The calculated dose was 0.34 mrem/yr (0.0034 mSv/yr), well below the 10 mrem/yr limit specified in the regulation.

During 1990, site activities included maintenance of contaminated soils in the storage piles, a limited chemical characterization, and installation of three wells. NFSS was in compliance with all applicable DOE orders and federal and state regulations, as has been the case since 1984, when the environmental monitoring program and remedial action began.

CONTENTS

	<u>Page</u>
Figures	viii
Tables	ix
Acronyms	xi
Units of Measure	xiii
1.0 INTRODUCTION	1
1.1 DOE INVOLVEMENT	1
1.2 SITE HISTORY	1
1.3 SITE DESCRIPTION	2
1.4 LAND USE	2
1.5 CLIMATE	7
2.0 SUMMARY OF ENVIRONMENTAL COMPLIANCE	9
2.1 PRIMARY REGULATORY GUIDELINES	9
2.2 APPLICABLE ENVIRONMENTAL PERMITS	14
2.3 ENVIRONMENTAL IMPACT STATEMENTS AND ENVIRONMENTAL ASSESSMENTS	14
2.4 SUMMARY OF COMPLIANCE IN CALENDAR YEAR 1991 (FIRST QUARTER)	15
3.0 ENVIRONMENTAL PROGRAM INFORMATION	16
3.1 SUMMARY OF ENVIRONMENTAL MONITORING PROGRAM	16
3.1.1 Environmental Monitoring Requirements	16
3.1.2 Monitoring Networks	17
3.1.3 Summary of Environmental Monitoring Data	18
3.2 APPLICABLE ENVIRONMENTAL PERMITS	20
3.3 ENVIRONMENTAL IMPACT STATEMENTS AND ENVIRONMENTAL ASSESSMENTS	21
3.4 SUMMARY OF ENVIRONMENTAL ACTIVITIES	21
3.5 SELF-ASSESSMENTS	23
4.0 RADIOLOGICAL ENVIRONMENTAL PROGRAM	24
4.1 ENVIRONMENTAL MONITORING FOR RADIOLOGICAL CONTAMINANTS	25
4.1.1 Radon Monitoring	25
4.1.2 External Gamma Exposure Monitoring	32
4.1.3 Surface Water Monitoring	39
4.1.4 Sediment Monitoring	44
4.1.5 Groundwater Monitoring	46
4.2 POTENTIAL DOSE TO THE PUBLIC	56
4.2.1 Maximally Exposed Individual	60
4.2.2 General Population	63
5.0 NONRADIOLOGICAL ENVIRONMENTAL PROGRAM	66
6.0 GROUNDWATER PROTECTION PROGRAM	92
6.1 HYDROGEOLOGICAL CHARACTERISTICS	92
6.1.1 Site Hydrogeology	92
6.1.2 Groundwater Quality and Usage	93
6.2 GROUNDWATER MONITORING	94
6.2.1 Methods	94
6.2.2 Results and Conclusions	94

CONTENTS
(continued)

	<u>Page</u>
7.0 QUALITY ASSURANCE	108
REFERENCES	113
APPENDIX A METHODOLOGY FOR STATISTICAL ANALYSIS OF DATA .	A-1
APPENDIX B POPULATION EXPOSURE METHODOLOGY	B-1
APPENDIX C ENVIRONMENTAL STANDARDS	C-1
APPENDIX D PARAMETERS FOR ANALYSIS	D-1
APPENDIX E SAMPLE OBSERVATION WELL CONSTRUCTION LOGS AND HYDROGRAPHS SHOWING WATER LEVEL ELEVATIONS . .	E-1
APPENDIX F RADIATION IN THE ENVIRONMENT	F-1
APPENDIX G CONVERSION FACTORS	G-1
APPENDIX H CLEAN AIR ACT COMPLIANCE REPORT FOR NIAGARA FALLS STORAGE SITE	H-1
APPENDIX I DISTRIBUTION LIST FOR NIAGARA FALLS STORAGE SITE ENVIRONMENTAL REPORT FOR CALENDAR YEAR 1990	I-1

FIGURES

<u>Figure</u>	<u>Title</u>	<u>Page</u>
1-1	Location of Niagara Falls Storage Site	3
1-2	Present Configuration of NFSS	4
1-3	Aerial View of the NFSS Interim Waste Containment Facility	5
1-4	Generalized Land Use in the Vicinity of NFSS . .	6
4-1	On-Site and Fenceline Radon and External Gamma Radiation Monitoring Locations	26
4-2	Off-Site Surface Water, Sediment, Radon, and External Gamma Radiation Monitoring Locations . .	27
4-3	External Gamma Radiation Exposure Rates	37
4-4	On-Site Surface Water and Sediment Sampling Locations	40
4-5	Groundwater Wells Monitored for Radiological and Chemical Contamination in 1990	49
6-1	Wells Used for Water Level Measurements in 1990	95
6-2	Potentiometric Map of Upper Groundwater System (2/2/90)	99
6-3	Potentiometric Map of Upper Groundwater System (3/5/90)	100
6-4	Potentiometric Map of Upper Groundwater System (6/12/90)	101
6-5	Potentiometric Map of Upper Groundwater System (12/4/90)	102
6-6	Potentiometric Map of Lower Groundwater System (2/2/90)	104
6-7	Potentiometric Map of Lower Groundwater System (3/5/90)	105
6-8	Potentiometric Map of Lower Groundwater System (6/12/90)	106
6-9	Potentiometric Map of Lower Groundwater System (12/4/90)	107

TABLES

<u>Table</u>	<u>Title</u>	<u>Page</u>
1-1	Summary of Climatological Data for 1990 for Buffalo, New York, and Vicinity	8
3-1	Summary of Gross Alpha and Gross Beta Results for NFSS, 1990	22
4-1	Concentrations of Radon at NFSS, 1990.	29
4-2	Trend Analysis for Concentrations of Radon at NFSS, 1986-1990	31
4-3	External Gamma Radiation Levels at NFSS, 1990.	34
4-4	Trend Analysis for External Gamma Radiation Levels at NFSS, 1986-1990	38
4-5	Concentrations of Total Uranium and Radium-226 in Surface Water at NFSS, 1990	42
4-6	Trend Analysis for Total Uranium and Radium-226 Concentrations in Surface Water at NFSS, 1986-1990.	43
4-7	Concentrations of Total Uranium and Radium-226 in Sediment at NFSS, 1990	45
4-8	Trend Analysis for Total Uranium and Radium-226 Concentrations in Sediment at NFSS, 1986-1990	47
4-9	Concentrations of Radium-226 in Groundwater at NFSS, 1990	51
4-10	Concentrations of Radium-226 in Groundwater in the Vicinity of the IWCF, 1990	53
4-11	Concentrations of Total Uranium in Groundwater at NFSS, 1990	54
4-12	Concentrations of Total Uranium in Groundwater in the Vicinity of the IWCF, 1990	57
4-13	Trend Analysis for Concentrations of Total Uranium in Groundwater at NFSS, 1986-1990	58
4-14	Trend Analysis for Concentrations of Radium-226 in Groundwater at NFSS, 1986-1990	59

TABLES
(continued)

<u>Table</u>	<u>Title</u>	<u>Page</u>
4-15	Summary of Calculated Doses for NFSS, 1990 . . .	61
4-16	Maximum Effective Dose to the General Public from NFSS, 1990	64
5-1	Reporting Limits for Chemical Analyses at NFSS During Second Quarter 1990	68
5-2	Analytical Results for Indicator Parameters in Groundwater at NFSS, 1990	72
5-3	Concentrations of Total Organic Carbon and Total Organic Halides in Groundwater at NFSS, 1990 . .	76
5-4	Concentrations of Metals Detected in Groundwater at NFSS, 1990	79
5-5	Concentrations of Volatile and Semivolatile Organic Compounds Detected in Groundwater at NFSS, 1990	85
5-6	Analytical Results for Indicator Parameters in Groundwater from the Vicinity of the IWCF, 1990 .	87
5-7	Concentrations of Total Organic Carbon and Total Organic Halides in Groundwater from the Vicinity of the IWCF, 1990	89
6-1	NFSS Monitoring Well Construction Summary	96
7-1	Summary Comparison of Water Sample Results . . . (EPA and TMA/E)	110
7-2	Summary Comparison of Air, Soil, and Water Sample Results (EML and TMA/E)	111

ACRONYMS

AEC	Atomic Energy Commission
ARAR	applicable or relevant and appropriate requirement
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
CX	categorical exclusion
DCG	derived concentration guideline
DOE	Department of Energy
EIS	environmental impact statement
EPA	Environmental Protection Agency
FR	Federal Register
FUSRAP	Formerly Utilized Sites Remedial Action Program
IWCF	Interim Waste Containment Facility
LOOW	Lake Ontario Ordnance Works
MED	Manhattan Engineer District
MSL	mean sea level
NEPA	National Environmental Policy Act
NESHAPs	National Emission Standards for Hazardous Air Pollutants
NFSS	Niagara Falls Storage Site
NPDES	National Pollutant Discharge Elimination System
NYCRR	New York Compilation of Rules and Regulations
NYSDEC	New York State Departments of Environmental Conservation

ACRONYMS

(continued)

PCB	polychlorinated biphenyl
QA	quality assurance
QC	quality control
RCRA	Resource Conservation and Recovery Act
ROD	record of decision
SARA	Superfund Amendments and Reauthorization Act
TCL	Target Compound List
TETLD	tissue-equivalent thermoluminescent dosimeter
TMA/E	Thermo Analytical/Eberline
TOC	total organic carbon
TOX	total organic halides
TSCA	Toxic Substances Control Act
USC	United States Code

UNITS OF MEASURE

Bq	becquerel
C	Celsius
cm	centimeter
F	Fahrenheit
ft	foot
ft MSL	feet above mean sea level
g	gram
h	hour
ha	hectare
in.	inch
km	kilometer
L	liter
m	meter
μ Ci	microcurie
μ g	microgram
mg	milligram
mi	mile
ml	milliliter
mm	millimeter
mph	miles per hour
mR	milliroentgen
mrem	millirem
mSv	millisievert
pCi	picocurie
s	second
Sv	sievert
yr	year

1.0 INTRODUCTION

Environmental monitoring of the U.S. Department of Energy's (DOE) Niagara Falls Storage Site (NFSS) and surrounding area began in 1981. This document describes the environmental monitoring program, the program's implementation, and the monitoring results for 1990.

1.1 DOE INVOLVEMENT

NFSS is part of the Formerly Utilized Sites Remedial Action Program (FUSRAP), 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 HISTORY

The history of NFSS goes back to World War II, when the Manhattan Engineer District (MED), predecessor to the Atomic Energy Commission (AEC), used part of the Army's Lake Ontario Ordnance Works (LOOW) as a transshipment and storage site for radioactive materials. The site was also used for enriching nonradioactive boron-10 (1954 through 1958 and 1964 through 1971). The site's primary use, however, was for storage of radioactive residues produced as a by-product of uranium production (1944 to present). As a result of storage operations, portions of the former LOOW (other than the present NFSS) became contaminated when some of the radioactive materials stored at NFSS migrated due to erosion, chiefly through drainage ditches.

Today, NFSS consists of 77 ha (191 acres) of the LOOW's original 3,040 ha (7,570 acres). Radiological surveys and characterization of NFSS were performed in 1979 and 1980, and radiological surveys of vicinity properties were conducted from 1981 to 1985. Remediation on vicinity properties began in 1981 and

continued until 1986. Remediation at NFSS began in 1982 and continued until 1986. Contaminated materials moved between 1981 and 1986 (including K-65 material resulting from uranium extraction) were stored in the Interim Waste Containment Facility (IWCF), a clay-lined, clay-capped storage pile. At present, all areas of residual radioactivity on the site have been remediated except for one localized [100-m² (1,100-ft²)] area suspected to be mixed radiological/chemical contamination. A chemical characterization of the site conducted in 1990 identified no chemical constituents of concern.

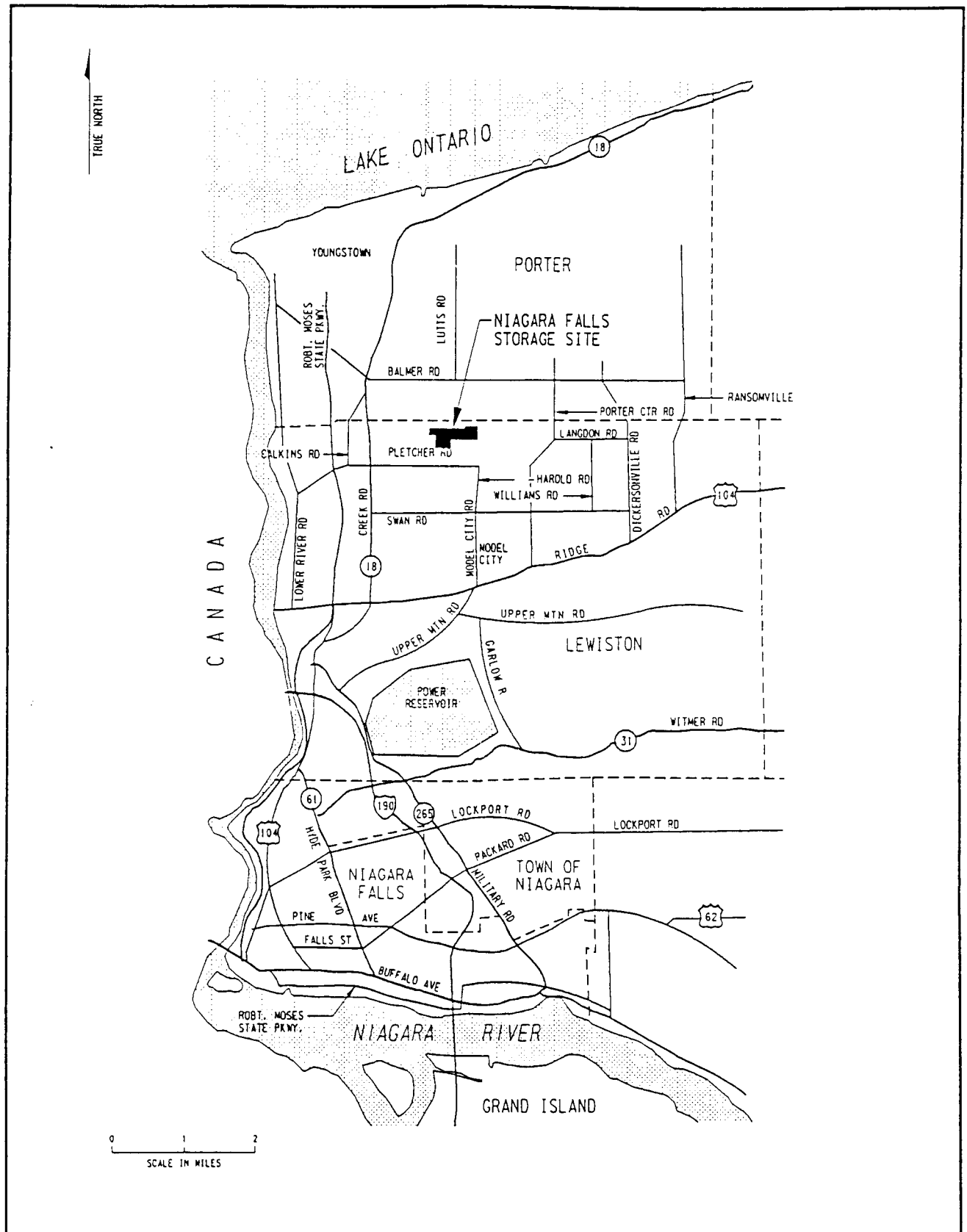
In addition to the IWCF, there are two small interim storage piles for materials generated during remedial action on isolated areas of residual contamination during the fall of 1989. Current plans call for the two interim storage piles to be consolidated into the IWCF. Also stored at the site are 60 drums of radioactively contaminated material that will be consolidated into the IWCF in 1991.

1.3 SITE DESCRIPTION

NFSS is in northwestern New York within the township of Lewiston (Niagara County) (Figure 1-1). The NFSS property includes a three-story building (Building 401) with three adjacent silos, an office building, and a small storage shed (Figure 1-2). No effluents are generated. The IWCF, which covers approximately 4 ha (10 acres), is shown in Figure 1-3. The property is entirely fenced and public access is restricted.

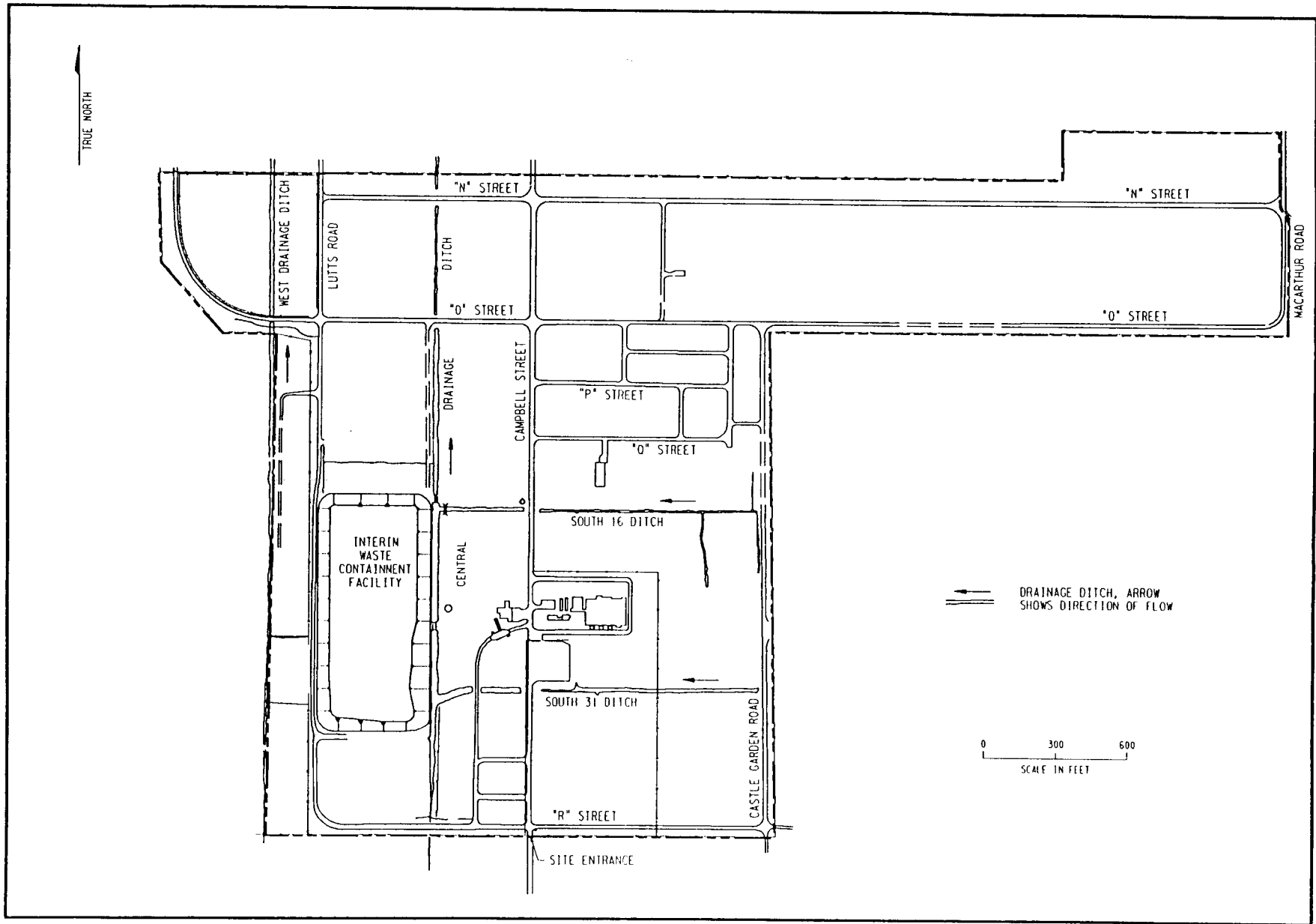
1.4 LAND USE

As shown in Figure 1-4, land use in the vicinity of the site is predominantly rural. The site is bordered by a chemical waste disposal facility (C.W.M. Chemical Services) to the north, a solid waste disposal facility (Modern Disposal) on the east and south, and a Niagara Mohawk Power Corporation right-of-way to the west.



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Figure 1-1
Location of Niagara Falls Storage Site



202F037.DGN G160

Figure 1-2
Present Configuration of NFSS

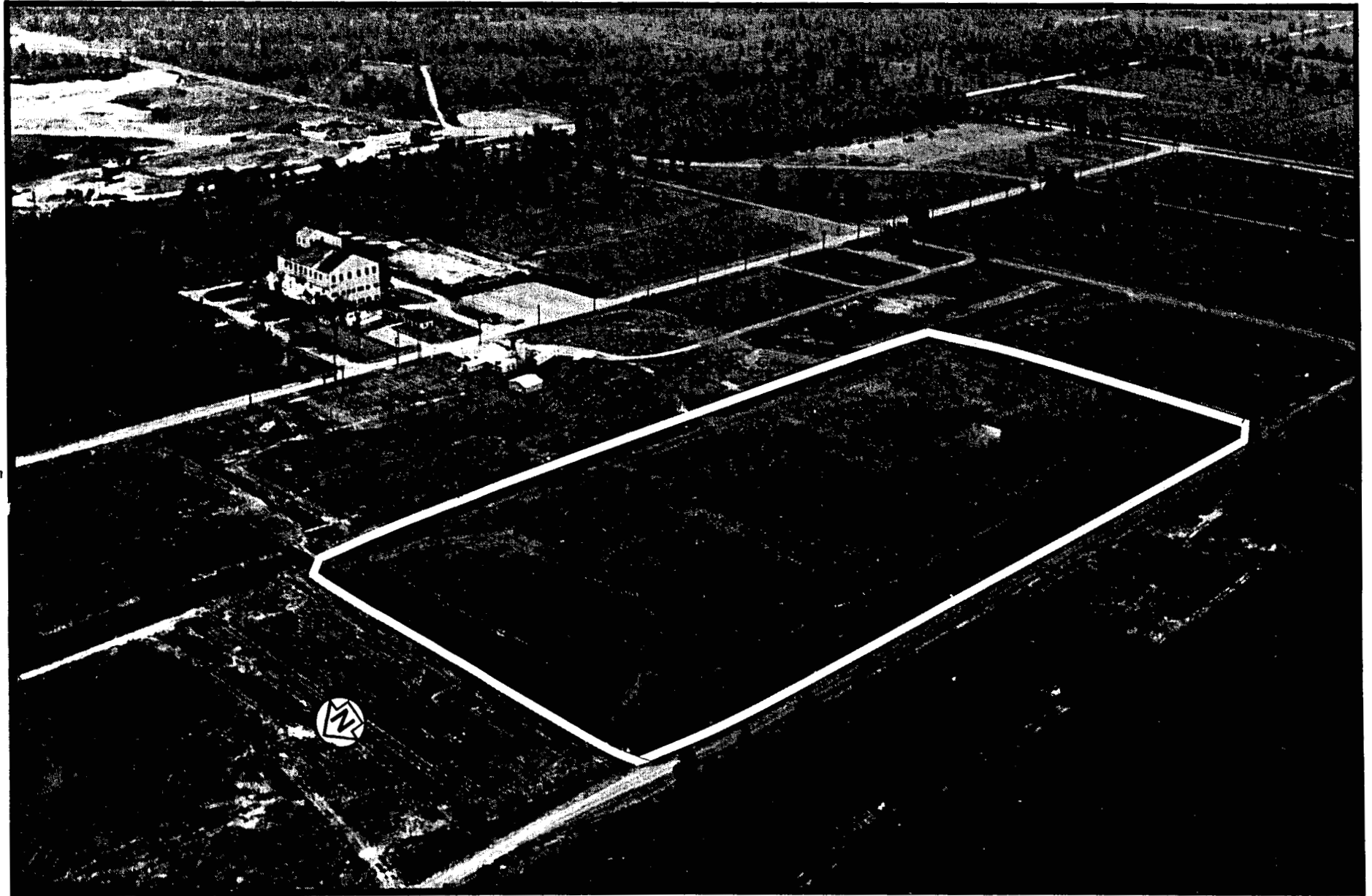
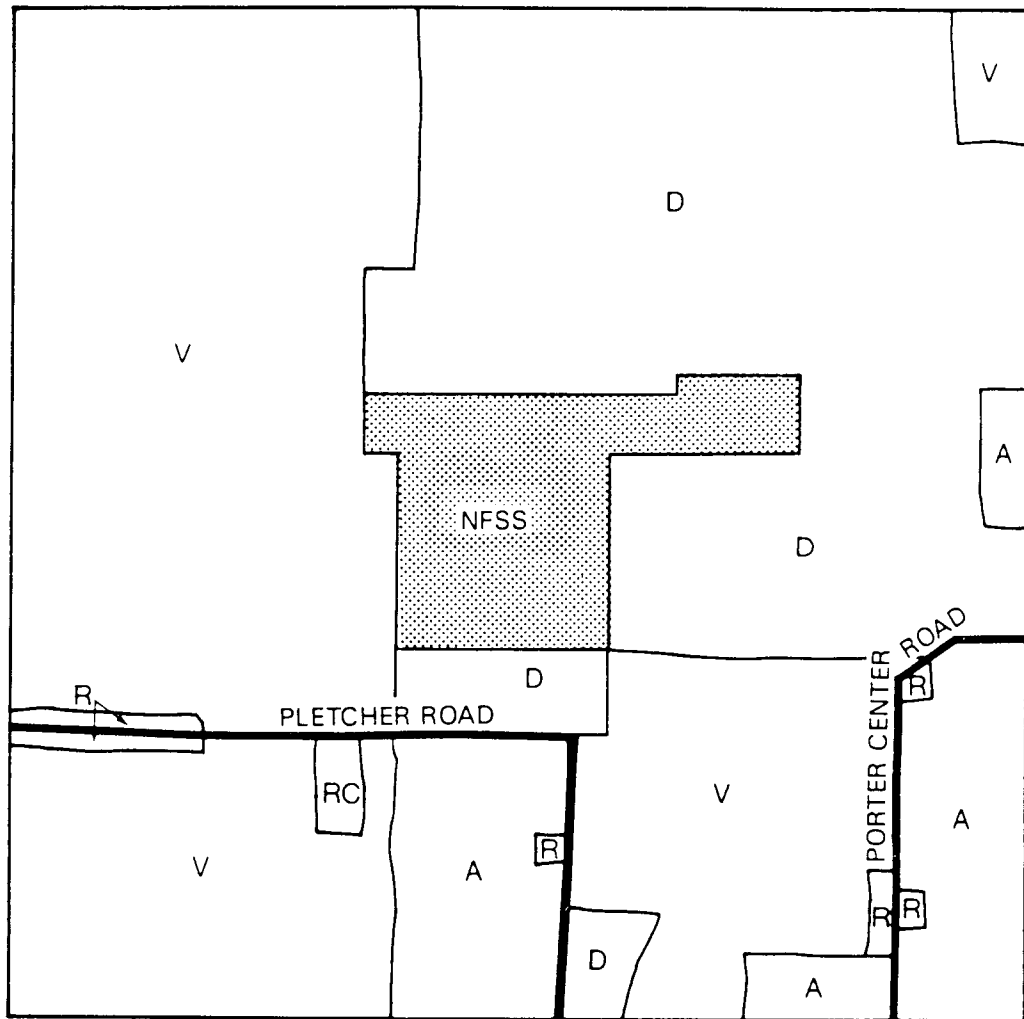


Figure 1-3
Aerial View of the NFSS Interim Waste Containment Facility



BASED ON AERIAL PHOTOGRAPHS, SITE VISITS, AND USGS TOPOGRAPHIC MAP, 1:24000 SCALE, RANSOMVILLE QUADRANGLE, (PHOTO REVISED 1980)

R RESIDENTIAL
 RC RECREATIONAL
 A AGRICULTURAL

D WASTE DISPOSAL
 V VACANT



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

The principal sources of potable water in the NFSS area are Lake Erie (65 percent), the Niagara River (25 percent), and groundwater (10 percent); approximately 90 percent of the population of Lewiston uses the first two sources. Surface water discharges from the site via the Central Drainage Ditch, which empties into Fourmile Creek, which discharges into Lake Ontario [approximately 6 km (4 mi) north of NFSS].

The nearest residential areas are approximately 1.1 km (0.68 mi) southwest of the site; the residences are primarily single-family dwellings. The total population of the area lying within an 80-km (50-mi) radius of NFSS is in excess of 250,000, based on a population of 227,000 for Niagara County.

1.5 CLIMATE

Table 1-1 is a summary of 1990 climatological data from the National Oceanic and Atmospheric Administration for the Buffalo/Niagara Falls area. Temperature extremes ranged from -17°C (2°F) to 35°C (94°F). Average wind speed ranged from 13 to 24 km/h (8.2 to 15 mph), predominantly from the southwest (BNI 1991).

TABLE 1-1
SUMMARY OF CLIMATOLOGICAL DATA FOR 1990
FOR BUFFALO, NEW YORK, AND VICINITY

Month	Temperature (°F)			Total Precip (in.)	Avg Wind Speed (mph)	Resultant Wind Direction
	Min	Max	Avg			
January	13	55	33.4	2.69	14.5	SW
February	2	60	29.3	5.9	12.4	W
March	7	79	36.9	1.5	11.6	W
April	24	94	48.5	5.22	11.7	W
May	36	79	54.9	6.08	11.7	SW
June	43	90	66.7	3.55	11.7	SW
July	50	91	71.4	3.14	9.7	W
August	55	88	70.4	3.25	8.2	S
September	40	86	61.7	3.65	9.4	SW
October	27	81	52.5	4.59	11.0	SW
November	22	72	43.4	2.61	13.7	SW
December	7	61	34.4	8.71	13.0	SW

Source: BNI 1991.

2.0 SUMMARY OF ENVIRONMENTAL COMPLIANCE

Throughout its history, NFSS has been subject to evolving federal and state environmental regulations. The primary regulatory guidelines and limits are given in the DOE orders and 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) as amended by the Superfund Amendments and Reauthorization Act (SARA); and the National Environmental Policy Act (NEPA)]. The following summaries describe compliance requirements as they existed in 1990, as well as anticipated future regulatory requirements that could affect the site.

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 1988)] that establish quantitative limits, derived concentration guidelines (DCGs), and dose limits for radiological releases from DOE facilities. For Environmental Protection Agency (EPA) permitting purposes, DOE orders are treated as legal requirements, and remedial action activities conducted by DOE at its facilities are considered "federally permitted actions" [54 Federal Register (FR) 22524].

A review of environmental monitoring results for calendar year 1990 shows that NFSS was in compliance with all applicable radionuclide release standards and DOE orders. Section 4.0 presents the results of the environmental monitoring program for radiological contaminants.

Clean Air Act and National Emissions Standards for Hazardous Air Pollutants

The primary federal statute governing air emissions is the CAA [42 United States Code (USC) 7401 et seq.], as amended. Federal regulations governing air emissions are contained in 40 Code of Federal Regulations (CFR) Parts 50 through 87 and 29 CFR Part 1910.

NFSS has no point sources for radionuclide air emissions and does not require any state or federal air permits. Because NFSS is a nonoperating facility and the interim storage piles were not modified in 1990, only Subpart Q of National Emission Standards for Hazardous Air Pollutants (NESHAPs) was applicable (DOE 1990a). If the piles had been modified during 1990, Subpart A would also be applicable.

Compliance with the non-radon radionuclide standard in Subpart H has been determined by evaluating the site using the computer model AIRDOS approved by EPA. Results from the model indicate that NFSS is in compliance with Subpart H. Subpart Q of NESHAPs expressly applies to NFSS per 40 CFR Section 61.190. A strategy for determining compliance with the radon flux standard in Subpart Q was approved by EPA in 1990, and compliance with the strategy was attained and maintained in 1990. Radon flux results collected to demonstrate compliance with Subpart Q are provided in Subsection 4.1.1 of this report.

Because EPA Region II has determined that the requirements imposed by the radionuclide NESHAPs are applicable during remedial actions, procedures for complying with Subpart Q will continue to be implemented when remedial activities begin.

NESHAPs Subpart M contains the National Asbestos Emission Standards. Asbestos from the roof of Building 410 (which has been demolished) is buried in an on-site asbestos burial area. Because long-term storage is planned for this waste, Subpart M would be applicable only if DOE decided to excavate the asbestos. Asbestos is also present in Building 401, as well as in siding on other buildings. Subpart M will be applicable for all asbestos removal activities.

On November 20, 1990, EPA promulgated new emission standards for asbestos. Significant changes include increased reporting requirements for demolition or renovation of buildings containing asbestos. Although these provisions did not affect reporting obligations for 1990, changes in reporting are anticipated for 1991.

Clean Water Act

Waters discharged to navigable waters of the United States are regulated under the federal CWA, as amended (33 USC 1251 et seq.), and its associated EPA regulations (40 CFR Parts 122, 136, 403, and 405 through 471). New York has enacted its own Water Pollution Control Law, which is found in the New York Environmental Conservation Law, Article 17. New York Water Pollution Control Regulations are found in the New York Compilation of Rules and Regulations (NYCRR), Chapter V, Subpart D.

On February 2, 1990, DOE submitted an informal National Pollutant Discharge Elimination System (NPDES) stormwater discharge permit application for NFSS to the New York State Department of Environmental Conservation (NYSDEC). However, on November 16, 1990, EPA promulgated changes to its stormwater regulation provisions. Although these provisions did not affect reporting obligations for 1990, significant changes in compliance reporting and monitoring are anticipated for 1991. DOE is evaluating whether a stormwater discharge permit will be required for NFSS; in the interim, a plan is being developed for compliance with the regulation by the deadline of November 18, 1991. The plan will include a data collection methodology for all applicable regulatory parameters referenced in the regulation. Should DOE determine that NFSS is not subject to this regulation, the informal permit application will be withdrawn.

Resource Conservation and Recovery Act

RCRA (40 USC 6901 et seq.) is the principal federal statute governing the management of hazardous waste. EPA regulations for implementing RCRA are contained in 40 CFR Parts 260 through 271.

New York is an authorized state for implementation of RCRA; state RCRA requirements can be found in the New York Environmental Conservation Law, Article 27. New York's hazardous waste regulations are contained in NYCRR, Parts 370 through 474.

Neither EPA RCRA-regulated wastes nor radioactive wastes containing EPA RCRA-regulated wastes have been detected at NFSS. However, the State of New York regulates polychlorinated biphenyls (PCBs) as hazardous waste. Absent generation of EPA RCRA-regulated waste in any sampling or monitoring process, it is anticipated that state hazardous waste regulations will remain inapplicable given that all PCB waste has been manifested and shipped off site (ORNL 1990).

Toxic Substances Control Act

The toxic substances regulated by TSCA (15 USC 2601 et seq.) are PCBs and asbestos. Like RCRA requirements, TSCA requirements will have to be met in remedial actions where they are applicable and relevant or appropriate.

PCB management involves monitoring of in-service equipment; storage and disposal of equipment removed from service; cleanup and management of spill residues; and recordkeeping and reporting. EPA regulations regarding the production, use, storage, handling, and disposal of PCBs are codified in 40 CFR Part 761. New York regulations governing the management of PCBs are found in 6 NYCRR 371.4(e). Under New York regulation, seven categories of wastes containing PCBs are listed hazardous wastes; therefore, PCB waste at NFSS is regulated under both TSCA and the state RCRA program.

All remaining PCB-contaminated materials stored at NFSS were shipped off site for disposal during the first quarter of 1990. Two PCB-contaminated transformers and one barrel of PCB-contaminated clothing were properly manifested and shipped for disposal on January 13, 1990; a certificate of disposal has been received. The remaining PCB transformer at the site was drained, flushed, and refilled with new oil in November 1989. The

PCB-contaminated waste was properly manifested and shipped for disposal in accordance with TSCA requirements on November 7, 1989.

As noted, asbestos is present at NFSS. However, because long-term storage of the asbestos waste in the on-site landfill is planned, it is anticipated that NESHAPs provisions regulating asbestos will remain limited to the notification of any future landowner.

Comprehensive Environmental Response, Compensation, and Liability Act

CERCLA (42 USC 9601 et seq.) as amended by SARA is the primary source of statutory authority for the remediation of sites contaminated with hazardous substances. However, any further remedial activities will be managed under NEPA authority because the record of decision (ROD) was placed in the Administrative Record in 1986 before SARA made CERCLA applicable to federal facilities.

National Environmental Policy Act

Compliance with NEPA (42 USC 4321 et seq.) was accomplished through the use of action description memoranda with corresponding memoranda-to-file and an environmental impact statement (EIS). An EIS was issued in 1986 to evaluate long-term disposition of NFSS. Consistent with the ROD, DOE has chosen long-term, in-place management of the waste pile. Because remediation of the site and construction of the waste pile were completed before the effective date of SARA, the 1986 reauthorization of CERCLA (42 USC 9601 et seq.), the cleanup decision was based on NEPA and designed to meet the goal of protecting human health and the environment.

On November 2, 1990, DOE proposed to amend its NEPA guidelines. Among the proposed revisions is an expansion of the list of categorical exclusions (CXs). A categorical exclusion is a class of actions that normally do not require the preparation of either an EIS or environmental assessment. One CX concerns site characterization and environmental monitoring under CERCLA and

RCRA. The adoption of the amended guidelines may significantly reduce DOE's reporting burden under NEPA in 1991. The CX used as an example has been available for use since publication in the Federal Register on September 7, 1990.

In 1990, documentation to justify CXs for certain FUSRAP activities was completed and submitted to DOE for approval. The CXs were prepared for environmental monitoring activities, chemical characterization work, and a well removal program.

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 the NFSS site. In addition, Executive Orders 11988 ("Floodplain Management") and 11990 ("Protection of Wetlands") and state laws and regulations have been reviewed for applicability and compliance. NFSS is in compliance with, or not subject to, all applicable environmental statutes, regulations, and executive orders.

2.2 APPLICABLE ENVIRONMENTAL PERMITS

As noted, an informal stormwater permit has been submitted to NYSDEC. DOE is evaluating the need for a stormwater discharge permit for NFSS in the context of the November 16, 1990, stormwater regulations. Should NFSS be subject to the regulations, a formal permit application will be submitted by the regulatory deadline of November 18, 1991.

2.3 ENVIRONMENTAL IMPACT STATEMENTS AND ENVIRONMENTAL ASSESSMENTS

As stated, an EIS was completed and incorporated into the Administrative Record in 1986. In 1990, documentation to justify

CXs for three site activities was completed and submitted to DOE for approval. The CXs were prepared for environmental monitoring activities, chemical characterization work, and a well removal program.

2.4 SUMMARY OF COMPLIANCE IN CALENDAR YEAR 1991 (FIRST QUARTER)

During the first quarter of calendar year 1991, the facility remained in full regulatory compliance. The discovery of underground storage tanks at NFSS during the first quarter of 1991 has been the only change in the regulatory status of the site. At the present time, plans are being developed for sampling and eventually remediating the storage tanks. Environmental monitoring continues, as does review of potentially applicable regulations.

3.0 ENVIRONMENTAL PROGRAM INFORMATION

Routine monitoring for radiation, radioactive materials, and chemical substances on and off NFSS 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 reducing negative environmental impacts.

The objectives of this report are to:

- Highlight significant programs and efforts
- Describe the environmental monitoring program
- Report 1990 radiological and nonradiological conditions of the site and surrounding areas
- Provide comparison of monitoring results and applicable regulations
- Provide trend analyses, where applicable, to indicate increases or decreases in environmental impact
- Provide detailed information on the input and assumptions used in all dose calculations

The primary audience for the environmental monitoring results includes the general public; property owners; 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 in air, surface water, sediment, and groundwater are found in the DOE orders dealing with radiation protection of the public and the environment. Requirements for environmental

monitoring of airborne pollutants are found in NESHAPs; non-radon radionuclide and radon monitoring are required by NESHAPs. Requirements for environmental monitoring of nonradiological parameters are found in DOE Order 5400.1 (DOE 1989). Nonradiological parameters were monitored to obtain information on groundwater quality.

3.1.2 Monitoring Networks

The following common criteria were used in establishing the environmental monitoring networks at NFSS:

- There are 46 radon and gamma radiation monitoring stations (18 on site, 19 at the property line, and 9 off site). All radon and gamma exposure rate monitoring stations, except background stations, are on site and accessible only to employees and authorized visitors. Some radon and gamma exposure rate stations are located on or near the DOE property line to allow determination of exposure at the "fenceline" as required by DOE orders. Background stations are located off site in areas known to be uncontaminated.
- There are 5 surface water monitoring locations [3 on site (1 upstream) and 2 off site downstream].
- There are 5 sediment monitoring locations [3 on site (1 upstream) and 2 off site downstream].
- NFSS has a total of 47 groundwater monitoring locations; monitoring the IWCF is the overriding consideration. The two groundwater systems beneath the IWCF are independent of each other and flow in different directions. Therefore, one upgradient and five downgradient wells for each groundwater system were chosen for separate discussion and evaluation.

3.1.3 Summary of Environmental Monitoring Data

Radon

Annual average radon concentrations ranged from 0.3 to 0.7 pCi/L (0.01 to 0.03 Bq/L), including an average background level of 0.3 pCi/L (0.01 Bq/L). All quarterly radon concentrations were well below the DOE guideline of 3.0 pCi/L; the maximum quarterly radon concentration was 1.6 pCi/L (0.06 Bq/L). Monitoring was not conducted for thoron because this radioactive gas has a very short half-life and would decay before it could migrate from the IWCF. Detailed information on radon monitoring data can be found in Subsection 4.1.1.

Additionally, radon flux measurements were collected to demonstrate that the site was in compliance with the radon flux limit of 20 pCi/m²/s set forth in 40 CFR Part 61, Subpart Q. The average radon flux rate for the IWCF was 0.9 pCi/m²/s (0.03 Bq/m²/s); the two small storage piles averaged 0.02 pCi/m²/s (7E-4 Bq/m²/s).

External gamma radiation exposure

The annual average gamma radiation exposure level was 3 mR/yr on site and 2 mR/yr at the property line, excluding an average background level of 66 mR/yr (Subsection 4.1.2). If continuous exposure by an individual is assumed, the dose received by the individual would be approximately 3 percent of the DOE radiation protection standard (100 mrem/yr above background) (1 mR/yr is approximately equal to 1 mrem/yr).

Surface water

Quarterly surface water sampling was performed at the South 31 and Central drainage ditches to determine concentrations of radium-226 and total uranium (Subsection 4.1.3). Average annual concentrations of radium-226 and total uranium in surface water

ranged from 0.4E-9 to 0.9E-9 $\mu\text{Ci/ml}$ (0.02 to 0.03 Bq/L) and from 5E-9 to 9E-9 $\mu\text{Ci/ml}$ (0.02 to 0.3 Bq/L), respectively. Radionuclide concentrations at downstream sampling locations were slightly greater than upstream (background) concentrations, but the maximum radium-226 concentration at any location was 0.9 percent of the DOE DCG for radium-226 (100 pCi/L). The maximum total level at any location was 1.5 percent of the DOE DCG for uranium (600 pCi/L).

Sediment

Sediment samples were collected quarterly, in conjunction with surface water samples, as a check for buildup of radium-226 and total uranium concentrations (Subsection 4.1.4). Average annual concentrations of radium-226 and total uranium in sediment ranged from 0.8 to 1.4 pCi/g (0.03 to 0.052 Bq/g) and from 1.6 to 3.7 pCi/g (0.059 to 0.14 Bq/g), respectively. Radionuclide concentrations at downstream sampling locations were comparable to upstream (background) concentrations. For comparison, these concentrations are much less than the levels of radioactivity in phosphate fertilizers listed in Appendix F. There are currently no guidelines for radionuclides in sediment, but neither radium-226 nor total uranium levels were near the DOE soil guidelines (Appendix C).

Groundwater

Quarterly groundwater samples were analyzed for radium-226 and total uranium; chemical parameters analyzed include pH, specific conductivity, total organic carbon (TOC), total organic halides (TOX), and metals.

Of primary concern at NFSS is migration of contaminants from the IWCF via groundwater. Therefore, discussion of groundwater monitoring is concentrated on the area surrounding the IWCF. Because of the different flow patterns in the two groundwater systems monitored, they are discussed separately. In the upper groundwater system, well OW-14B is upgradient, and downgradient

ranges from northeast to southeast; wells OW-8B, OW-9B, OW-10B, OW-11B, and OW-12B are downgradient (see Section 6.0). In the lower groundwater system, well OW-12A is upgradient, and the gradient generally is to the northwest; downgradient wells for the lower groundwater system are OW-3A, OW-4A, OW-5A, OW-14A, and OW-15A.

Results from groundwater samples at NFSS were generally consistent with previous data and did not reveal any new contamination. An unusually high TOC value (294 mg/L) was recorded for the second-quarter sampling period for well OW-5A (lower groundwater system). Because the average value for the other three quarters was 4.1 mg/L (max = 6.1 mg/L), the high value is believed to be the result of a data transfer error.

Groundwater monitoring results indicate that the only difference in upgradient (background) and downgradient groundwater around the IWCF is in the upper groundwater system, where water from downgradient wells exhibits a slightly higher total uranium content-- $4.3E-9$ $\mu\text{Ci/ml}$ (0.16 Bq/L) upgradient versus an average of $15E-9$ $\mu\text{Ci/ml}$ (0.55 Bq/L) for the five downgradient wells. All wells are far below the DOE DCG of $600E-9$ $\mu\text{Ci/ml}$ (22 Bq/L).

Priority pollutant organic levels (volatile and semivolatile compounds) were typical of those in normal groundwater (New York Water Classifications and Quality Standards, 10 NYCRR 609), except for some laboratory solvents and phthalate that were also found in laboratory blanks (Subsection 5.1).

Upgradient and downgradient groundwater metal concentrations were comparable. Fourth-quarter values for some metals are high relative to those of the first three quarters because the fourth-quarter values were for total metals and the previous three quarters' values were for dissolved metals only (Subsection 5.1).

3.2 APPLICABLE ENVIRONMENTAL PERMITS

No environmental permits are currently required for NFSS. As noted in Section 2.0, DOE is evaluating the need for a stormwater discharge permit for NFSS. Should such a permit be required, an

application will be submitted by the regulatory deadline of November 18, 1991.

3.3 ENVIRONMENTAL IMPACT STATEMENTS AND ENVIRONMENTAL ASSESSMENTS

As stated in Section 2.0, an EIS was completed and incorporated into the Administrative Record in 1986. Documentation to justify CXs for three site activities was completed in 1990 and submitted to DOE for approval. The CXs were prepared for environmental monitoring activities, chemical characterization work, and a well removal program.

3.4 SUMMARY OF ENVIRONMENTAL ACTIVITIES

During 1990, the environmental activities at NFSS consisted of performing the environmental monitoring described in Sections 4.0 and 5.0 and conducting a limited chemical characterization of the site. Results of this chemical characterization are scheduled for publication in 1991.

A one-time sampling effort was conducted during the fourth quarter to study gross alpha and gross beta concentrations in 20 percent of the surface water, sediment, and groundwater samples (Table 3-1). This program was designed to evaluate the need to expand the isotopic analyses currently performed.

The sum of the discrete radionuclide results (total uranium and radium) is also included in Table 3-1 for comparison. In general, the gross alpha and gross beta results should not be the same as the summation of the isotopic results because there are short-lived daughters in the uranium decay chain that are not included in the primary analyses and there are naturally occurring radionuclides, such as potassium-40, that would also be included in the gross alpha and beta results. Based on the results provided in Table 3-1, there are some large discrepancies between the gross alpha and beta results and the isotopic results for some of the

TABLE 3-1
SUMMARY OF GROSS ALPHA AND GROSS BETA
RESULTS FOR NFSS, 1990

Sampling Location ^a	Gross Alpha	Gross Beta	Sum of Isotopic Results
<u>Surface Water^b</u>			
11	26	16	18
<u>Sediment^c</u>			
11	26	24	5.6
<u>Groundwater^b</u>			
OW-3A	16	9	4
OW-3B	24	8	12
OW-5A	24	16	4
OW-5B	14	13	7
OW-12A	9	18	4
OW-12B	33	18	11
OW-15A	51	210	4
OW-15B	22	21	6
BH-61	7	38	3

^aSampling locations are shown in Figures 4-4 and 4-5.

^bConcentrations are given in E-9 $\mu\text{Ci/ml}$. Note: 1E-9 $\mu\text{Ci/ml}$ is equivalent to 0.037 Bq/L.

^cConcentrations are given in pCi/g. Note: 1 pCi/g is equivalent to 0.037 Bq/L).

sediment and groundwater sampling locations (especially groundwater locations OW-3A, OW-5A, and OW-15A). Because the groundwater locations are wells installed in the lower groundwater system, the source of the contamination is most likely potassium-40 and/or natural thorium. That these results indicate contamination migrating from the IWCF is unlikely because (1) results for the primary radionuclides in the IWCF (total uranium and radium) are very low and (2) contamination in the lower groundwater system and not in the upper groundwater system is not probable. Samples collected from the sediment and groundwater locations with elevated gross alpha and beta results will be analyzed for potassium-40 and isotopic thorium during at least one quarter in 1991 to determine the cause of these elevated levels.

3.5 SELF-ASSESSMENTS

During 1990, DOE conducted two major self-assessments of the FUSRAP environmental monitoring program: one in June by the Oak Ridge Operations Environmental Protection Division, the second in November by the DOE Headquarters Office of Environmental Audits. Findings from these two self-assessments focused on monitoring techniques, field documentation of monitoring events, and planning for environmental monitoring locations and events. As a result of the June assessment, corrective actions were developed and implemented before the next quarter's environmental monitoring. Actions remaining consist of developing environmental monitoring plans [required by DOE Order 5400.1 (DOE 1990b)] to document the logic behind the environmental monitoring networks for FUSRAP sites. Work on these plans is currently under way; they are scheduled to be published by December 1991.

4.0 RADIOLOGICAL ENVIRONMENTAL PROGRAM

NFSS is not currently an active site; therefore, the only "effluents" originating from the site would be the result of contaminant migration.

Radiological environmental monitoring for 1990 at NFSS included sampling for:

- radon concentrations in air
- on-site external gamma radiation exposure
- radium-226 and total uranium concentrations in surface water, sediment, and groundwater

The monitoring systems include on-site, property-line, and off-site sampling locations to provide sufficient information on the site's potential effects on human health and the environment.

The information contained in this section of the report includes the quarterly radiological data for each sampling point, yearly averages, and trend information. The methodologies for calculating the averages and standard deviations are provided in Appendix A.

Some of the quarterly results are reported using a "less than" (<) sign. This notation is used to denote specific sample analysis results that are below the limit of sensitivity of the analytical method, based on a statistical analysis of parameters. When computing annual averages, quarterly values reported as less than a given limit of sensitivity are considered equal to that limit of sensitivity. Additionally, all quarterly data are reported as received from the laboratory; however, the reported averages, standard deviations, and expected ranges are reported using the smallest number of significant figures from the quarterly data (e.g., 3.2 and 32 both have two significant figures). Some of the data are reported using scientific notation and the exponent has been identified by E (e.g., $1E-9 = 1 \times 10^{-9}$).

The following subsections discuss the monitoring program and any possible contaminant migration indicated by the results.

4.1 ENVIRONMENTAL MONITORING FOR RADIOLOGICAL CONTAMINANTS

4.1.1 Radon Monitoring

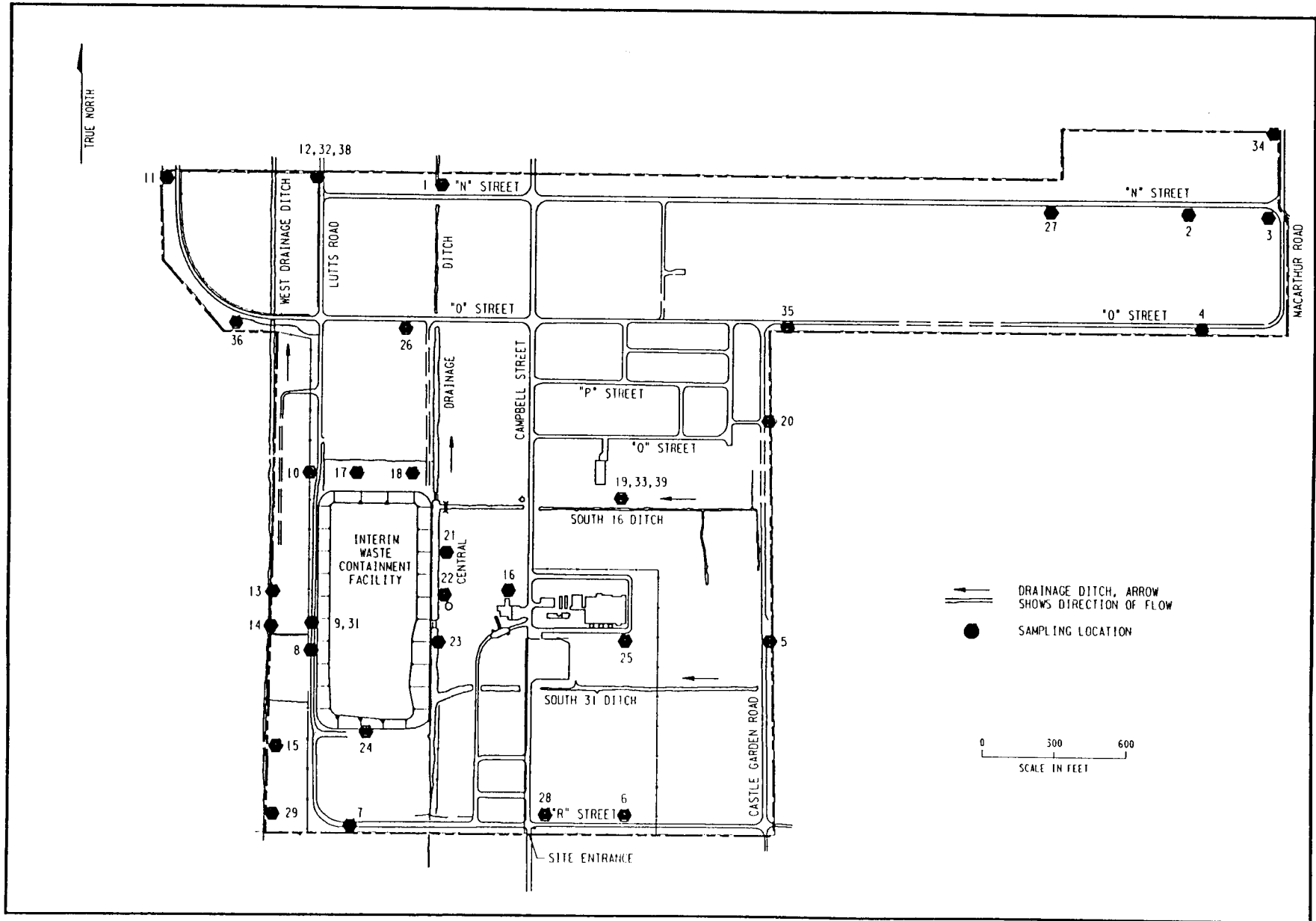
The major radiation exposure from the uranium-238 series occurs through inhalation of the short-lived radon and radon daughter products. Radon is a radioactive (alpha-emitting) gas that is very mobile in air. Radon monitoring is conducted to confirm that NFSS is not significantly adding to the natural radon background levels and to ensure compliance with environmental regulations.

Program description

Radon concentrations were obtained quarterly using monitoring devices that consist of an alpha-sensitive film contained in a small plastic two-piece cup. Radon diffuses through a seam or membrane (depending on the manufacturer of the detector) of the cup until the radon concentrations inside and outside the cup reach equilibrium. Alpha particles from the radioactive decay of radon and its daughters in the cup create tiny tracks when they collide with the film. After they are collected, the films are placed in a caustic etching solution to enlarge the tracks; under strong magnification, the tracks are counted. The number of tracks per unit area (i.e., tracks/mm²) is converted through calibration to the radon concentration in air.

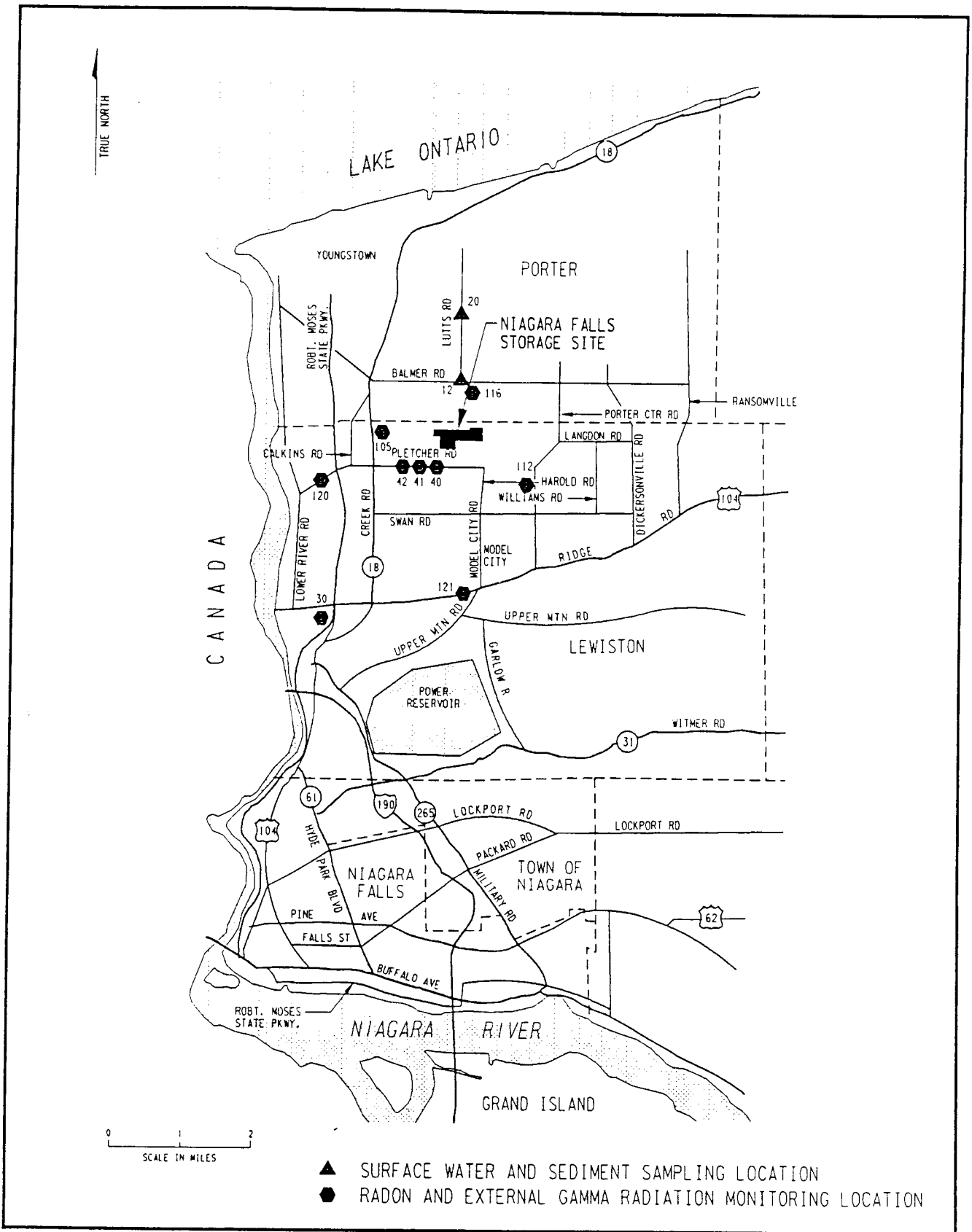
Radon detectors are maintained at 18 on-site, 19 property-line, and 9 off-site (background) locations, as shown in Figures 4-1 and 4-2. Detectors are spaced along the site boundary to ensure adequate detection capability under most atmospheric conditions.

To determine the radon flux from the IWCF, 180 charcoal canisters were placed on the storage pile. Five charcoal canisters were placed on each of the interim storage piles. The canisters remained on the piles for 24 hours and were then collected, sealed, and shipped for analysis. No major weather event that might conceivably have affected the sampling occurred either within three days prior to or during the sampling event. Because radon is a



202F035.DGN C100

Figure 4-1
On-Site and Fenceline Radon and External Gamma Radiation Monitoring Locations



202F036.DGN GIGO F2

Figure 4-2
Off-Site Surface Water, Sediment, Radon, and External Gamma Radiation
Monitoring Locations

gas, rain or snow could inhibit the normal flux rate and cause the resulting measurements to be lower than average.

Data and discussion

The maximum ambient air radon concentration detected on site was 1.6 pCi/L (0.059 Bq/L) (including background), at location 24. The annual average radon concentration on site, including background, ranged from 0.3 to 0.7 pCi/L (0.01 to 0.03 Bq/L). Annual average radon concentrations at the property line ranged from 0.3 to 0.4 pCi/L (0.01 to 0.02 Bq/L). No quarterly level or annual average was higher than the DOE interim storage site guideline of 3.0 pCi/L. The quarterly radon concentrations measured in 1990 are shown in Table 4-1.

The radon results from the IWCF showed an average flux rate of 0.09 pCi/m²/s (3E-3 Bq/m²/s) with minimum and maximum levels of 0.02 and 0.58 pCi/m²/s (7E-4 and 22E-3 Bq/m²/s). These results demonstrate that the IWCF is in compliance with the limit of 20 pCi/m²/s set forth in 40 CFR Part 61, Subpart Q. The standard (20 pCi/m²/s) is an averaged value. The two smaller interim storage piles were also determined to be in compliance with the regulation; their average flux rate was 0.02 pCi/m²/s (7E-4 Bq/m²/s).

Trends

A comparison of annual average radon concentrations measured at the site boundary and background locations from 1986 through 1990 is presented in Table 4-2. The monitoring stations located on the property line were chosen for the trend analysis because the radon levels measured at these locations best represent the potential levels of exposure to the public. Background stations were not established at the Lewiston Town Hall and the Lewiston Water Pollution Control Center (locations 121 and 120, respectively) until April 1988. Although the other background stations were established before 1986, only location 30 was part of the

TABLE 4-1
 CONCENTRATIONS^{a,b} OF RADON
 AT NFSS, 1990

Page 1 of 2

Sampling Location ^c	Quarter				Min	Max	Avg
	1	2	3	4			
Property Line							
1	<0.4	<0.3	<0.3	<0.3	0.3	0.4	0.3
3	<0.4	<0.3	<0.3	<0.3	0.3	0.4	0.3
4	<0.4	<0.3	<0.3	<0.3	0.3	0.4	0.3
5	0.4	-- ^d	<0.3	<0.3	0.3	0.4	0.3
6	0.5	<0.3	<0.3	<0.3	0.3	0.5	0.4
7	0.4	<0.3	<0.3	<0.3	0.3	0.4	0.3
11	0.7	<0.3	<0.3	<0.3	0.3	0.7	0.4
12	0.4	<0.3	<0.3	<0.3	0.3	0.4	0.3
13	0.4	<0.3	<0.3	<0.3	0.3	0.4	0.3
14	0.8	0.3	<0.3	<0.3	0.3	0.8	0.4
15	0.5	<0.3	<0.3	<0.3	0.3	0.5	0.4
20	0.4	<0.3	<0.3	<0.3	0.3	0.4	0.3
28	0.6	<0.3	<0.3	<0.3	0.3	0.6	0.4
29	0.6	<0.3	<0.3	<0.3	0.3	0.6	0.4
34	<0.4	<0.3	<0.3	<0.3	0.3	0.4	0.3
35	0.6	<0.3	<0.3	<0.3	0.3	0.6	0.4
36	<0.4	<0.3	<0.3	<0.3	0.3	0.4	0.3
38	<0.4	<0.3	<0.3	<0.3	0.3	0.4	0.3
Quality Control							
32 ^e	<0.4	<0.3	<0.3	<0.3	0.3	0.4	0.3
On Site							
2	0.4	<0.3	-- ^d	<0.3	0.3	0.4	0.3
8	0.4	<0.3	<0.3	<0.3	0.3	0.4	0.3
9	<0.4	<0.3	<0.3	<0.3	0.3	0.4	0.3
10	0.5	<0.3	<0.3	<0.3	0.3	0.5	0.4
16	1.1	0.4	0.4	0.6	0.4	1.1	0.6
17	0.4	<0.3	<0.3	<0.3	0.3	0.4	0.3
18	1.2	<0.3	<0.3	<0.3	0.3	1.2	0.5
19	0.7	<0.3	<0.3	<0.3	0.3	0.7	0.4
21	<0.4	<0.3	<0.3	<0.3	0.3	0.4	0.3
22	0.4	<0.3	<0.3	<0.3	0.3	0.4	0.3
23	0.6	<0.3	<0.3	<0.3	0.3	0.6	0.4
24	<0.4	<0.3	1.6	<0.3	0.3	1.6	0.7
25	<0.4	<0.3	<0.3	<0.3	0.3	0.4	0.3
26	0.8	<0.3	<0.3	<0.3	0.3	0.8	0.4
27	<0.4	<0.3	<0.3	<0.3	0.3	0.4	0.3
39	<0.4	<0.3	<0.3	<0.3	0.3	0.4	0.3

TABLE 4-1
(continued)

Page 2 of 2

Sampling Location ^c	Quarter				Min	Max	Avg
	1	2	3	4			
Quality Control							
31 ^f	<0.4	<0.3	<0.3	<0.3	0.3	0.4	0.3
33 ^g	<0.4	<0.3	-- ^d	<0.3	0.3	0.4	0.3
Background							
30	0.6	<0.3	<0.3	<0.3	0.3	0.6	0.4
40	0.6	<0.3	<0.3	<0.3	0.3	0.6	0.3
41	<0.4	<0.3	<0.3	<0.3	0.3	0.4	0.3
42	0.4	<0.3	<0.3	<0.3	0.3	0.4	0.3
105	<0.4	<0.3	<0.3	<0.3	0.3	0.4	0.3
112	0.8	<0.3	<0.3	<0.3	0.3	0.8	0.4
116	<0.4	<0.3	<0.3	<0.3	0.3	0.4	0.3
121	<0.4	<0.3	<0.3	<0.3	0.3	0.4	0.3
120	<0.4	-- ^d	<0.3	<0.3	0.3	0.4	0.3

^aConcentrations are given in pCi/L. Note: 1 pCi/L is equivalent to 0.037 Bq/L.

^bBackground has not been subtracted from the reported values. Note: Concentrations at some stations were below values at background stations.

^cSampling locations are shown in Figures 4-1 and 4-2.

^dDamaged foil; no reading possible.

^eStation 32 is a quality control for station 12.

^fStation 31 is a quality control for station 9.

^gStation 33 is a quality control for station 19.

TABLE 4-2

TREND ANALYSIS FOR CONCENTRATIONS^{a,b} OF RADON AT NFSS, 1986-1990

Sampling Location ^c	Annual Average Concentration					Average Value	Standard Deviation	Expected Range ^d
	1986	1987	1988	1989	1990			
1	0.3	0.2	0.5	0.4	0.3	0.3	0.1	0.1 - 0.5
3	0.3	0.3	0.2	0.4	0.3	0.3	0.06	0.2 - 0.4
4	0.3	0.4	0.2	0.4	0.3	0.3	0.07	0.2 - 0.4
5	0.3	0.2	0.5	0.7	0.3	0.4	0.2	0 - 0.8
6	0.2	0.2	0.4	0.4	0.4	0.3	0.1	0.1 - 0.5
7	0.2	0.3	0.4	0.8	0.3	0.4	0.2	0 - 0.8
11	0.4	0.2	0.2	0.4	0.4	0.3	0.1	0.1 - 0.5
12	0.2	0.3	0.3	0.5	0.3	0.3	0.1	0.1 - 0.5
13	0.4	0.1	0.5	0.7	0.3	0.4	0.2	0 - 0.8
14	0.8	0.4	0.3	0.5	0.4	0.5	0.2	0.1 - 0.9
15	0.3	0.2	0.3	0.4	0.4	0.3	0.07	0.2 - 0.4
20	0.2	0.2	0.5	0.4	0.3	0.3	0.1	0.1 - 0.5
28	0.3	0.2	0.3	0.5	0.4	0.3	0.1	0.1 - 0.5
29	0.4	0.3	0.3	0.8	0.7	0.5	0.2	0.1 - 0.9
32	0.3	0.3	0.3	0.6	0.3	0.4	0.1	0.2 - 0.6
34	0.3	0.8	0.2	0.5	0.3	0.4	0.2	0 - 0.8
35	0.2	0.2	0.5	0.4	0.4	0.3	0.1	0.1 - 0.5
36	0.3	0.2	0.3	0.4	0.3	0.3	0.06	0.2 - 0.4
Background								
30	0.3	0.3	0.6	1.4	0.4	0.6	0.4	0 - 1
120 ^e	--	--	0.5	0.5	0.3	0.4	0.09	0.2 - 0.6
121 ^e	--	--	0.5	0.4	0.3	0.4	0.08	0.2 - 0.6

NOTE: Sources for 1986-1989 data are the annual site environmental reports for those years (BNI 1987, 1988a, 1989, 1990).

^aConcentrations are given in units of pCi/L. Note: 1 pCi/L is equivalent to 0.037 Bq/L.

^bMeasured background has not been subtracted.

^cSampling locations are shown in Figures 4-1 and 4-2.

^dAverage value ± 2 standard deviations.

^eStation established in April 1988.

environmental monitoring program. The expected values shown in Table 4-2 are based on the calculation of standard deviation of the yearly mean. The expected range provides a rough check on whether there are any trends present in the data. If the range varies a great deal from location to location, or if a station consistently falls outside the expected range, then a trend could be present. As Table 4-2 shows, radon concentrations at the NFSS site boundary are low, have not fluctuated notably, and approximate background levels for the area.

4.1.2 External Gamma Exposure Monitoring

External gamma radiation levels are measured as part of the routine environmental monitoring program to confirm that direct radiation around NFSS does not differ from natural background radiation levels and to ensure compliance with environmental regulations.

Program description

Since 1988, the external gamma radiation monitoring system has used tissue-equivalent thermoluminescent dosimeters (TETLDs) to provide realistic values of radiation dose to the tissues of the body. When exposed to penetrating radiation (such as gamma or cosmic radiation), thermoluminescent materials absorb and store a portion of the energy. If the material is heated, the stored energy is released as light; the light is used to calculate an equivalent dose.

Each dosimetry station contains a minimum of four dosimeters. One dosimeter in each station will have been exposed for a full year at the end of each quarter, at which time the fully exposed dosimeter is exchanged with a new dosimeter. Each dosimeter contains five individual lithium fluoride chips preselected on the basis of having a reproducibility of ± 3 percent across a series of laboratory exposures. The responses are averaged, and the average value is then corrected for the shielding effect of the shelter

housing (approximately 8 percent). The corrected value is then converted to milliroentgen per year (mR/yr). (In determining exposure one mR/yr is approximately equal to one mrem/yr.)

External gamma radiation levels are measured at 18 on-site, 19 property-line, and 9 off-site locations. Three of the detectors are on the perimeter of the former location of the tower used to store K-65 residues. All gamma radiation detector locations correspond to the radon detector locations shown in Figures 4-1 and 4-2.

Data and discussion

Although TETLDs are state of the art, the dosimeter accuracy is approximately ± 10 percent at levels between 100 and 1,000 mR/yr and ± 25 percent at radiation levels in the range of 70 mR/yr. Therefore, for the low levels that are being monitored at NFSS (in the 70 mR/yr range), there can be seemingly large differences resulting from inaccuracies of detection and the processing system.

The results of external gamma radiation monitoring are presented in Table 4-3. For each quarter, an average of the background levels measured was subtracted from the site boundary measurements to provide an estimate of radiation levels resulting from residual materials at the site.

The annual average gamma radiation exposure level was 3 mR/yr on site and 2 mR/yr at the property line, excluding a background level of 66 mR/yr. The highest annual average external gamma radiation level at the property line, excluding background, was 7 mR/yr (location 5).

The background radiation level for a given location is not a constant because the value is affected by a combination of both natural terrestrial and cosmic radiation sources and by factors such as the location of the detector in relation to surface rock outcrops, stone or concrete structures, or highly mineralized soil. Detectors are also influenced by site altitude, annual barometric pressure cycles, and the occurrence and frequency of solar flare activity (Eisenbud 1987).

TABLE 4-3
EXTERNAL GAMMA RADIATION LEVELS^{a,b} AT NFSS, 1990

Page 1 of 2

Sampling Location ^c	Quarter				Average
	1	2	3	4	
Property Line					
1	1	1	3	0 ^d	1
3	0 ^d	3	0 ^d	0	1
4	2	0 ^d	1	0 ^d	1
5	7	7	13	2	7
6	0 ^d	0 ^d	0 ^d	0 ^d	0
7	2	0 ^d	7	0 ^d	2
11	0 ^d	0 ^d	0 ^d	0 ^d	0
12	0 ^d	1	0 ^d	0 ^d	0
13	0 ^d	0 ^d	1	0 ^d	0
14	8	0 ^d	8	0 ^d	4
15	0 ^d	0 ^d	5	1	2
20	7	0 ^d	14	1	6
28	0 ^d	6	6	3	4
29	0 ^d	0 ^d	2	0 ^d	1
34	0 ^d	0 ^d	0 ^d	0 ^d	0 ^d
35	4	4	3	0 ^d	3
36	0 ^d	0 ^d	3	— ^f	1
38	0 ^d	0 ^d	0 ^d	0 ^d	0
				Average	2
Quality Control					
32 ^e	0 ^d	2	0 ^d	0 ^d	1
On Site					
2	0 ^d	4	6	0 ^d	3
8	6	20 ^d	22	20	20
9	0 ^d	0 ^d	1	0 ^d	0
10	0 ^d	0 ^d	4	0 ^d	1
16	0 ^d	0 ^d	0 ^d	0 ^d	0
17	5	26	5	0 ^d	9
18	7	6	9	0 ^d	6
19	0 ^d	2	1	0 ^d	1
21	0 ^d	1	12	7	5
22	10	1	4	9	6
23	2	1	0 ^d	1	1
24	0 ^d	0 ^d	0 ^d	0 ^d	0
25	0 ^d	0 ^d	0 ^d	0 ^d	0
26	0 ^d	0 ^d	5	0 ^d	1
27	0 ^d	0 ^d	0 ^d	0 ^d	0
39	0 ^d	0 ^d	0 ^d	0 ^d	0
				Average	3

TABLE 4-3

(continued)

Page 2 of 2

Sampling Location ^c	Quarter				Average
	1	2	3	4	
Quality Control					
31 ^g	0 ^d	1	4	3	2
33 ^h	0 ^d	0 ^d	0 ^d	0 ^d	0
Background					
30	54	57	52	-- ^f	54
40	73	69	58	69	67
41	72	65	59	66	66
42	75	62	59	67	66
105	57	62	52	67	60
112	60	63	60	62	61
116	62	66	30	61	55
120	85	86	66	84	80
121	84	79	78	92	<u>83</u>
				Average	66

^aLevels are given in units of mR/yr. Dosimeters evaluated each quarter have been in place for 1 year.

^bMeasured background has been subtracted from the readings taken at the site boundary and on-site locations.

^cSampling locations are shown in Figures 4-1 and 4-2.

^dThe measured value was not distinguishable from background.

^eStation 32 is a quality control for station 12.

^fNo data available.

^gStation 31 is a quality control for station 9.

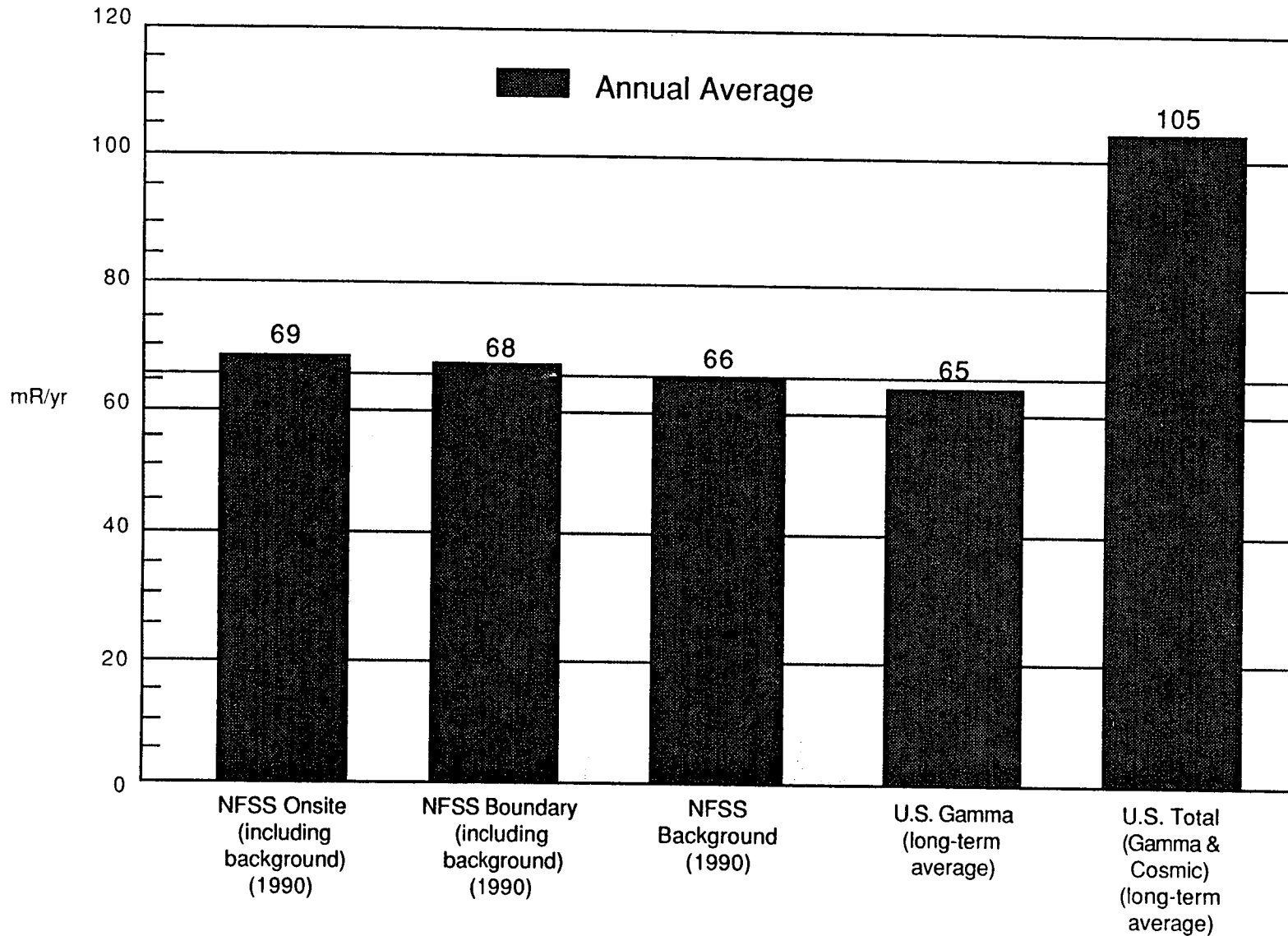
^hStation 33 is a quality control for station 19.

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

For comparison, Figure 4-3 shows the average annual external radiation levels for locations on site, at the site boundary, off site, and the nation.

Trends

Average external gamma exposure levels measured at the site boundary and background locations from 1986 through 1990 are presented in Table 4-4. The monitoring stations located on the property line were chosen for trend analysis because the exposure levels measured at these locations indicate the potential levels of exposure to the public. Background stations were not established at the Lewiston Town Hall and the Lewiston Water Pollution Control Center (locations 121 and 120; respectively) until April 1988. Therefore, data from these locations were not available until the second quarter of 1989. Although the other background stations were established prior to 1986, only location 30 was a part of the environmental monitoring program. The expected values shown in Table 4-4 are based on the calculation of standard deviation of the yearly mean. The expected range provides a rough check on whether there are any trends present in the data. If the range varies a great deal from location to location, or if a station consistently falls outside the expected range, then a trend could be present. As shown in Table 4-4, levels of external gamma exposure have not changed noticeably over the last five years. The lower values measured in 1989 and 1990 are probably due to a change in the manufacturer of the detectors. There has been no significant work at the site for the past two years that would notably decrease the gamma radiation.



The DOE guideline for external gamma exposure is 100 mrem/yr above background level (DOE 1990b). Note: 1 mrem is approximately equivalent to 1 mR.
Source: Martin Marietta Energy Systems, Inc., 1989. *Portsmouth Gaseous Diffusion Plant Site Environmental Report for 1988*, ES/ESH-8/V4, Oak Ridge, Tenn.

Figure 4-3
External Gamma Radiation Exposure Rates

TABLE 4-4

TREND ANALYSIS FOR EXTERNAL GAMMA RADIATION LEVELS^{a,b} AT NFSS, 1986-1990

Sampling Location ^c	Annual Average Level					Average Value	Standard Deviation	Expected Range ^d
	1986	1987	1988	1989	1990			
1	16	11	11	0 ^e	1	8	6	0 - 20
3	4	11	9	0	1	5	4	0 - 10
4	14	13	7	0	1	7	6	0 - 20
5	14	16	22	2	7	10	7	0 - 20
6	8	3	16	0	0	5	6	0 - 20
7	8	11	7	2	2	6	4	0 - 10
11	4	2	5	0	0	2	2	0 - 6
12	2	6	8	0	0	3	3	0 - 9
13	0	0	6	1	0	1	2	0 - 5
14	3	7	14	0	4	6	5	0 - 20
15	6	6	14	3	2	6	4	0 - 10
20	26	24	23	8	6	20	9	2 - 40
28	14	14	10	2	4	9	5	0 - 20
29	0	0	10	0	1	2	4	0 - 10
32 ^f	6	5	8	0	1	4	3	0 - 10
34	6	8	3	0	0	3	3	0 - 9
35	15	14	14	1	3	9	6	0 - 20
36	5	16	10	0	1	6	6	0 - 20
Background								
30	69	64	71	61	54	64	6.1	52 - 76
120 ^g	--	--	--	83	80	82	1.5	79 - 85
121 ^g	--	--	--	87	83	85	2.0	81 - 89

NOTE: Sources for 1986-1989 data are the annual site environmental reports for those years (BNI 1987, 1988a, 1989, 1990).

^aLevels are given in units of mR/yr.

^bMeasured background has been subtracted from the readings taken at the site boundary and on-site sampling stations.

^cSampling locations are shown in Figures 4-1 and 4-2.

^dAverage value ± 2 standard deviations.

^eAll zero values represent a measurement that was equal to or less than the measured background value.

^fStation 32 is a quality control for station 12.

^gStation established in April 1988.

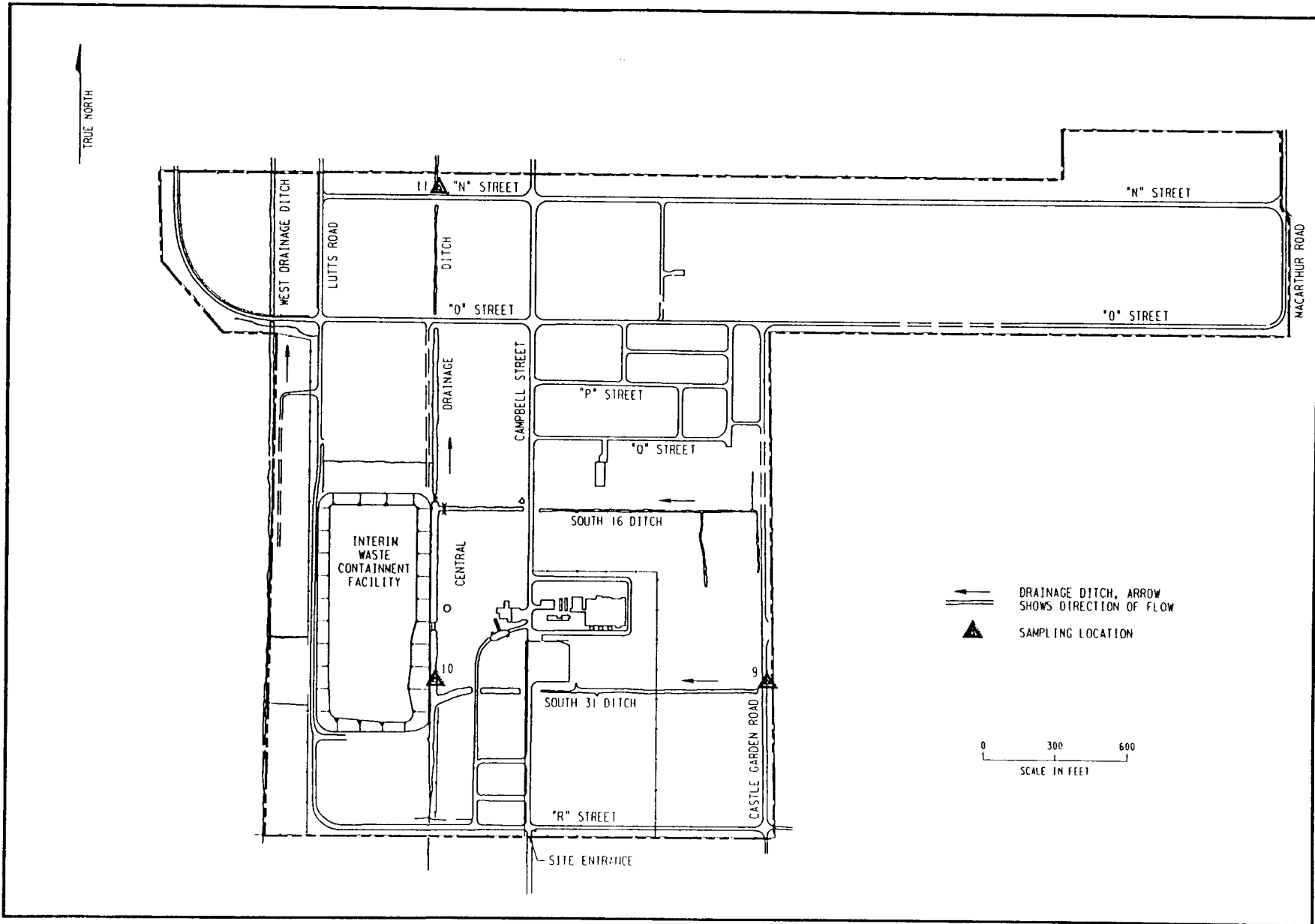
4.1.3 Surface Water Monitoring

Surface water monitoring is conducted to determine whether on-site surface water is contaminated, to ensure compliance with environmental regulations, and to determine whether runoff from NFSS contributes to surface water contamination in the area.

Program description

Surface water samples were collected quarterly at sampling locations established on the basis of potential contaminant migration and discharge routes from the site. On-site sampling locations for surface water (9, 10, and 11) are shown in Figure 4-4; off-site locations (12 and 20) are shown in Figure 4-2. Location 9 is an upstream background location established at the South 31 Ditch in October 1988. Locations 12 and 20 are 1.6 and 3.2 km (1 and 2 mi) downstream, respectively, from the northern boundary of NFSS. Because surface water runoff from the site discharges via the Central Drainage Ditch, all sampling locations except location 9 were placed along that ditch. Sampling of water supplied by a local municipal water system upstream of NFSS was suspended in 1986 because data from previous years indicated no total uranium or radium-226 concentrations discernibly different from background levels in these waters.

Surface water samples were analyzed for total uranium and radium-226. Total uranium in surface water is typically measured using the global change fluorometric method, which is a very sensitive and dependable method for determining trace concentrations of uranium. The first step is to dispense a measured aliquot (typically 0.1 ml) of sample onto a flux pellet made of sodium fluoride (98 percent) and lithium fluoride (2 percent). After the pellet is dried, the uranium is fused to the pellet by a rotary fusion burner for 5 to 10 minutes. After cooling, the fluorescence of the fused pellet is measured by a fluorimeter; the measured fluorescence is directly proportional to the concentration of total uranium in the sample as compared with spikes, standards, and blanks.



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Figure 4-4
On-Site Surface Water and Sediment Sampling Locations

Radium-226 concentrations are determined by radon emanation. The method for detecting radon consists of precipitating radium-226 as sulfate and transferring the treated sulfate to a radon bubbler, where radon is allowed to come to equilibrium with its radium-226 parent. The radon is then withdrawn into a scintillation cell and counted by the gross alpha technique. The quantity of radon detected in this manner is directly proportional to the quantity of radium-226 originally present in the sample.

Data and discussion

Table 4-5 presents 1990 concentrations of total uranium and radium-226 in surface water. Annual average concentrations of total uranium ranged from $5E-9$ to $9E-9$ $\mu\text{Ci/ml}$ (0.2 to 0.33 Bq/L) at on-site (upstream) locations and $8E-9$ to $9E-9$ $\mu\text{Ci/ml}$ (0.3 to 0.33 Bq/L) at off-site (downstream) locations. Annual average background was $7E-9$ $\mu\text{Ci/ml}$ (0.3 Bq/L). Total uranium concentrations were well below the DCG of $600E-9$ $\mu\text{Ci/ml}$.

The annual average concentration of radium-226 was $0.4E-9$ $\mu\text{Ci/ml}$ (0.02 Bq/L) at on-site locations and $0.7E-9$ to $0.9E-9$ $\mu\text{Ci/ml}$ (0.26 to 0.3 Bq/L) at off-site (downstream) locations. Annual average background was $0.5E-9$ $\mu\text{Ci/ml}$ (0.02 Bq/L). Radium-226 concentrations were well below the DCG of 100 pCi/L.

Trends

Comparisons of annual average radionuclide concentrations measured from 1986 through 1990 are presented in Table 4-6. The expected value ranges shown are based on calculation of the standard deviation of the yearly mean. The expected range provides a rough check on whether there are any trends present in the data. If the range varies a great deal from location to location, or if a station consistently falls outside the expected range, then a trend could be present.

TABLE 4-5
 CONCENTRATIONS^a OF TOTAL URANIUM AND RADIUM-226
 IN SURFACE WATER AT NFSS, 1990

Sampling Location ^b	Quarter				Min	Max	Avg
	1	2	3	4			
Total Uranium							
9 ^c	4	3	11	9	3	11	7
10	6	3	4	7	3	7	5
11	7	6	5	18	5	18	9
12 ^d	9	3	11	12	3	12	9
20 ^d	9	3	12	6	3	12	8
Radium-226							
9 ^c	0.3	0.7	0.7	0.3	0.3	0.7	0.5
10	0.1	0.5	0.9	0.3	0.1	0.9	0.4
11	0.6	0.4	0.4	0.2	0.2	0.6	0.4
12 ^d	0.3	0.2	2.8	0.3	0.2	2.8	0.9
20 ^d	0.3	0.2	2.0	0.2	0.2	2.0	0.7

^aConcentrations are given in units of E-9 $\mu\text{Ci/ml}$.

Note: E-9 $\mu\text{Ci/ml}$ is equivalent to 0.037 Bq/L.

^bSampling locations are shown in Figures 4-2 and 4-4.

^cLocation 9 serves as a background sampling station.

^dOff-site, downstream sampling station.

TABLE 4-6
TREND ANALYSIS FOR TOTAL URANIUM AND RADIUM-226
CONCENTRATIONS^a IN SURFACE WATER AT NFSS, 1986-1990

Sampling Location ^b	Annual Average Concentration					Average Value	Standard Deviation	Expected Range ^c
	1986	1987	1988	1989	1990			
Total Uranium								
9 ^d	--	--	8	9	7	8	0.8	6 - 10
10	8	6	7	21	5	9	6	0 - 20
11	5	14	10	16	9	10	4	2 - 20
12 ^e	4	5	6	10	9	7	2	3 - 10
20 ^e	5	6	7	4	8	6	1	4 - 8
Radium-226								
9 ^d	--	--	0.2	1.5	0.5	0.7	0.6	0 - 2
10	0.2	0.2	0.2	0.6	0.5	0.3	0.2	0 - 0.7
11	0.3	1.8	1	2.5	0.4	1	0.8	0 - 3
12 ^e	0.3	0.3	0.3	0.6	0.9	0.5	0.2	0.1 - 0.9
20 ^e	0.4	0.3	1	0.5	0.7	0.6	0.3	0 - 1

NOTE: Data sources for 1986-1989 are the annual environmental reports for those (BNI 1987, 1988a, 1989, 1990).

^aConcentrations are given in units of E-9 $\mu\text{Ci}/\text{ml}$. Note: E-9 $\mu\text{Ci}/\text{ml}$ is equivalent to 0.037 Bq/L.

^bSampling locations are shown in Figures 4-2 and 4-4.

^cAverage value ± 2 standard deviations.

^dLocation 9 serves as a background sampling station. This station was established in October 1988 at the South 31 Ditch; thus, data for 1988 represent one quarter's results, and not an annual average.

^eOff-site, downstream sampling location.

As shown in the table, results for 1990 fell within the expected range of values. Concentrations of total uranium and radium-226 remain fairly consistent and close to background.

4.1.4 Sediment Monitoring

Sediment monitoring is conducted to determine whether contaminants are collecting in on-site and/or off-site sediments and to ensure compliance with environmental regulations.

Program description

Sediment samples were collected quarterly at surface water sampling locations where sediment is present. On-site sampling locations (9, 10, and 11) are shown in Figure 4-4; downstream, off-site locations (12 and 20) are shown in Figure 4-2. Downstream locations were established to determine the effect of the site on the sediments in the vicinity. Location 9 is a background location established at the South 31 Ditch in October 1988.

Sediment samples were analyzed for total uranium and radium-226. Isotopic uranium and radium-226 were eluted in solution, organically extracted, electroplated to a stainless steel disc, and counted by alpha spectrometry. Total uranium concentrations were calculated by summing the results for isotopic uranium.

Currently, there are no DCGs for radionuclides in sediment; therefore, sediment concentrations are compared with FUSRAP soil guidelines (Appendix C).

Data and discussion

Table 4-7 presents 1990 concentrations of total uranium and radium-226 in sediment at NFSS. Annual average concentrations of total uranium ranged from 1.8 to 2.5 pCi/g (0.067 to 0.093 Bq/g) at on-site locations and 1.6 to 1.7 pCi/g (0.059 to 0.063 Bq/g) at

TABLE 4-7
 CONCENTRATIONS^a OF TOTAL URANIUM AND RADIUM-226
 IN SEDIMENT AT NFSS, 1990

Sampling Location ^b	Quarter				Min	Max	Avg
	1	2	3	4			
Total Uranium							
9 ^c	1.6	3.3	5.1	4.6	1.6	5.1	3.7
10	1.3	2.1	1.6	2.1	1.3	2.1	1.8
11	1.2	1.7	3.5	3.6	1.2	3.6	2.5
12 ^d	1.7	1.4	1.6	2.1	1.4	2.1	1.7
20 ^d	1.1	1.5	1.8	2.0	1.1	2.0	1.6
Radium-226							
9 ^c	1.4	1.5	0.8	1.9	0.8	1.9	1
10	0.7	0.9	0.5	1.0	0.5	1.0	0.8
11	1.0	1.3	0.7	2.0	0.7	2.0	1
12 ^d	0.9	0.7	0.4	1.0	0.4	1.0	0.8
20 ^d	0.7	1.0	0.6	1.7	0.6	1.7	1

^aConcentrations are given in units of pCi/g. Note: 1 pCi/g is equivalent to 0.037 Bq/g.

^bSampling locations are shown in Figures 4-2 and 4-4.

^cLocation 9 serves as an upstream sampling station.

^dOff-site, downstream sampling location.

offsite (downstream) locations. The annual average value for the upstream location was 3.7 pCi/g (0.14 Bq/g). The higher value at location 9 (the upstream location) is probably due to residual radioactivity (below guidelines) remaining from previous remedial action activities. Total uranium concentrations were close to background throughout the year and below the FUSRAP soil guidelines established for NFSS of 90 pCi/g.

Annual average concentrations of radium-226 ranged from 0.8 to 1.0 pCi/g (0.03 to 0.04 Bq/g) at on-site locations and 0.8 to 1.0 pCi/g (0.03 to 0.04 Bq/g) at off-site (downstream) locations. Annual average background was 1 pCi/g (0.04 Bq/g). Radium-226 levels were close to background throughout the year and below the FUSRAP soil guidelines listed in Appendix C.

Trends

Comparisons of annual average radionuclide concentrations measured from 1986 through 1990 are presented in Table 4-8. The expected value ranges shown are based upon the calculation of standard deviation of the yearly mean. The expected range provides a rough check to see if there are any trends present in the data. If the range varies a great deal from location to location, or if a station consistently falls outside the expected range, then a trend could be present. All average annual concentrations for radionuclides in sediment for 1990 fell within the expected ranges. Total uranium and radium-226 concentrations have remained fairly consistent over the past five years.

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.

TABLE 4-8
TRENDS ANALYSIS FOR TOTAL URANIUM AND RADIUM-226
CONCENTRATIONS^a IN SEDIMENT AT NFSS, 1986-1990

Sampling Location ^b	Annual Average Concentration					Average Value	Standard Deviation	Expected Range ^c
	1986	1987	1988	1989	1990			
Total Uranium								
9 ^d	--	--	2	2.6	3.7	3	0.7	2 - 4
10	-- ^e	1.8	2.7	8.8	1.8	3.8	2.9	0 - 9.6
11	1.4	2	1.5	2.1	2.5	2	0.40	1.1 - 2.7
12 ^f	1.9	1.3	1.9	1.4	1.7	1.6	0.25	1.1 - 2.1
20 ^f	1.4	1.5	1.8	1.5	1.6	1.6	0.14	1.3 - 1.9
Radium-226								
9 ^d	--	--	1.3	1	1	1	0.2	0.6 - 1
10	-- ^e	0.8	0.8	1.8	0.8	1	0.4	0.2 - 2
11	1.1	1.3	1	1.7	1	1	0.3	0.4 - 1.6
12 ^f	1	0.5	1.3	0.8	0.8	0.9	0.3	0.3 - 2
20 ^f	0.6	0.8	0.9	0.8	1	0.8	0.1	0.6 - 1

NOTE: Source for 1986-1989 data are the annual site environmental reports for those years (BNI 1987, 1988a, 1989, 1990).

^aConcentrations are given in units of pCi/g. Note: 1 pCi/g is equivalent to 0.037 Bq/g.

^bSampling locations are shown in Figures 4-2 and 4-4.

^cAverage value ± 2 standard deviations.

^dLocation established in October 1988; thus, data for 1988 represent one quarter's results, and not an annual average.

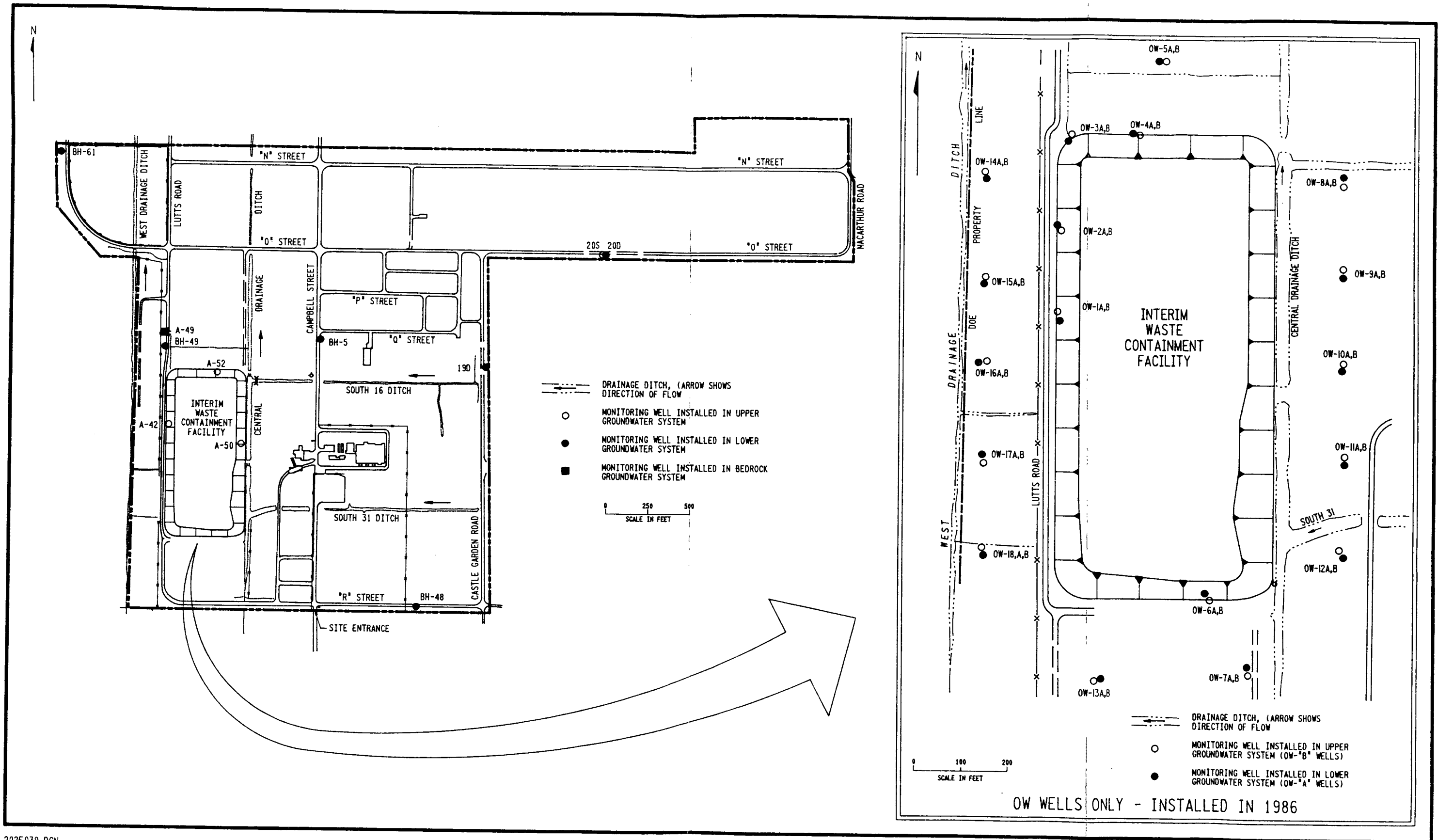
^eWater level too high to collect sample.

^fOff-site, downstream sampling location.

Program description

The monitoring well system is designed to provide sufficient coverage of both upgradient and downgradient conditions. Sampling locations were selected based on the inventory of radioactive materials in various areas of the site and available hydrogeological data. Site sampling locations are BH-48, to establish background conditions; on site (BH-5, BH-49, A-42, A-49, A-50, A-52); and normal downgradient (BH-61), to determine the effects of the site on groundwater in the vicinity (Figure 4-5). Wells with the prefix "A" and suffix "S" are in the upper groundwater system; those with the prefix "BH" and suffix "D" are in the lower system. However, most of the monitoring wells are located near the IWCF. In late 1986, 36 wells ("OW" wells in Figure 4-5) were installed along the IWCF perimeter to monitor groundwater in the vicinity of the storage facility more closely. These wells were added to the environmental monitoring program in April 1987. "OW" wells with the suffix "A" are in the lower groundwater system; those with the suffix "B" are in the upper system. To provide specific information on possible contaminant movement from the pile, special attention is given the "OW" wells. The two groundwater systems monitored by these wells are discussed separately, and focused attention is given to the wells around the IWCF. Well OW-14B is the upgradient well for monitoring the upper groundwater system around the IWCF; the gradient ranges from northeast to southeast. Wells OW-8B, OW-9B, OW-10B, OW-11B, and OW-12B are downgradient wells for the upper system. Well OW-12A is the upgradient well for the lower system; the gradient is generally to the northwest. Wells OW-3A, OW-4A, OW-5A, OW-14A, and OW-15A are the downgradient wells for the lower system (see Section 6.0).

Wells A-42A, A-50, and A-52 are also near the IWCF; however, these wells are not considered as part of the IWCF monitoring system because they were installed prior to the completion of the IWCF cap. Well A-42 is completed in a sand lens of unknown extent. Due to elevated uranium values in well A-42, its chemical,



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Figure 4-5
Groundwater Wells Monitored for Radiological and Chemical Contamination in 1990

radiological, and hydrogeological behavior was investigated in December 1988. Results indicate that the sand lens in which this well is completed is not in good hydraulic connection with the zones of completion of adjacent wells. Additionally, results of a sequential sampling program conducted in 1989 indicate that radioactive contamination in well A-42 is probably associated with contaminated soils in or near the well.

Three new wells (19D, 20S, and 20D) were added to the environmental monitoring program in June 1990 and first sampled in October 1990. These wells were added to monitor groundwater near the NFSS/Modern Disposal landfill boundary for chemicals.

Quarterly groundwater samples were analyzed for radium-226 and total uranium in the same manner as surface water samples.

Data and discussion

Radium-226 concentrations in groundwater samples are presented in Table 4-9. The annual average concentrations of radium-226 in background well BH-48 and normal downgradient well BH-61 were $0.7E-9$ $\mu\text{Ci/ml}$ (0.03 Bq/L) and $0.4E-9$ $\mu\text{Ci/ml}$ (0.1 Bq/L), respectively. Average annual concentrations for the remaining on-site wells (excluding the "OW" wells) ranged from $0.3E-9$ to $2E-9$ $\mu\text{Ci/ml}$ (0.01 to 0.07 Bq/L). Annual average concentrations for the wells monitoring the IWCF area ranged from $0.2E-9$ to $0.8E-9$ $\mu\text{Ci/ml}$ (0.01 to 0.03 Bq/L). There were no differences in upgradient and downgradient values in the upper or lower groundwater systems for IWCF area wells (Table 4-10). Radium-226 concentrations were all below the DCG of $100E-9$ $\mu\text{Ci/ml}$.

Total uranium concentrations in groundwater samples are presented in Table 4-11. Annual average concentrations of total uranium in site upgradient (BH-48) and downgradient (BH-61) locations were $3E-9$ $\mu\text{Ci/ml}$ (0.1 Bq/L). Average annual concentrations for the remaining on-site wells (excluding the "OW" wells) ranged from $3E-9$ to $76E-9$ $\mu\text{Ci/ml}$ (0.1 to 2.8 Bq/L), with the elevated value of $76E-9$ $\mu\text{Ci/ml}$ (2.8 Bq/L) found in well A-42.

TABLE 4-9
 CONCENTRATIONS^a OF RADIUM-226
 IN GROUNDWATER AT NFSS, 1990

Page 1 of 2

Sampling Location ^b	Quarter				Min	Max	Avg
	1	2	3	4			
OW-1A	0.3	0.2	0.5	0.2	0.2	0.5	0.3
OW-1B	0.2	0.4	0.6	0.1	0.1	0.6	0.3
OW-2A	0.2	0.2	0.5	0.3	0.2	0.5	0.3
OW-2B	0.1	0.1	0.4	0.1	0.1	0.4	0.2
OW-3A	0.3	0.3	0.4	0.3	0.3	0.4	0.3
OW-3B	0.2	0.3	0.4	0.2	0.2	0.4	0.3
OW-4A	0.3	0.3	0.6	0.1	0.1	0.6	0.3
OW-4B	0.2	0.4	0.6	0.1	0.1	0.6	0.3
OW-5A	0.3	0.3	0.8	0.8	0.3	0.8	0.6
OW-5B	0.4	0.5	0.6	0.4	0.4	0.6	0.5
OW-6A	0.2	0.1	0.6	0.1	0.1	0.6	0.3
OW-6B	0.3	0.2	0.3	0.1	0.1	0.3	0.2
OW-7A	0.2	0.5	0.8	0.2	0.2	0.8	0.4
OW-7B	0.2	0.2	0.3	0.5	0.2	0.5	0.3
OW-8A	0.3	0.1	0.7	0.7	0.1	0.7	0.5
OW-8B	0.2	0.3	0.5	0.1	0.1	0.5	0.3
OW-9A	0.2	0.3	0.5	0.1	0.1	0.5	0.3
OW-9B	0.3	0.2	0.4	ND ^c	0.2	0.4	0.3
OW-10A	0.2	0.2	0.3	0.1	0.1	0.3	0.2
OW-10B	0.3	0.2	0.3	0.2	0.2	0.3	0.3
OW-11A	0.4	0.3	0.6	0.3	0.3	0.6	0.4
OW-11B	0.3	0.2	0.3	0.4	0.2	0.4	0.3
OW-12A	0.4	0.3	0.4	0.3	0.3	0.4	0.4
OW-12B	0.2	0.2	0.9	0.4	0.2	0.9	0.4
OW-13A	0.3	0.4	0.4	0.4	0.3	0.4	0.4
OW-13B	0.2	1.1	1.0	0.8	0.2	1.1	0.8
OW-14A	0.2	0.2	0.3	0.2	0.2	0.3	0.2
OW-14B	0.1	0.3	0.7	0.7	0.1	0.7	0.5
OW-15A	0.3	0.3	0.7	0.9	0.3	0.9	0.5
OW-15B	0.2	0.1	0.9	0.4	0.1	0.9	0.4
OW-16A	0.3	0.1	0.7	0.3	0.1	0.7	0.4
OW-16B	0.1	0.2	1.7	0.3	0.1	1.7	0.6
OW-17A	0.1	0.2	0.6	0.3	0.1	0.6	0.3
OW-17B	0.3	0.2	0.7	0.2	0.2	0.7	0.4
OW-18A	0.2	0.4	0.9	0.7	0.2	0.9	0.6
OW-18B	0.2	0.3	0.5	0.4	0.2	0.5	0.4
BH-5	0.3	0.3	0.6	0.4	0.3	0.6	0.4
BH-48 ^d	0.6	0.6	1.0	0.5	0.5	1.0	0.7
BH-61 ^e	0.3	0.3	0.6	0.2	0.2	0.6	0.4
A-42	0.7	1.1	1.5	0.3	0.3	1.5	0.9
A-49	ND	2.9	1.8	0.3	0.3	2.9	2
A-50	0.7	0.4	0.6	0.1	0.1	0.7	0.5

TABLE 4-9

(continued)

Page 2 of 2

Sampling Location ^b	Quarter				Min	Max	Avg
	1	2	3	4			
A-52	0.1	0.5	0.9	0.1	0.1	0.9	0.4
BH-49	ND	0.4	0.5	0.1	0.1	0.5	0.3
19D ^f	--	--	--	0.3	--	--	--
20S ^f	--	--	--	0.4	--	--	--
20D ^f	--	--	--	0.5	--	--	--

^aConcentrations are given in units of E-9 $\mu\text{Ci/ml}$.

Note: $1\text{E-}9 \mu\text{Ci/ml}$ is equivalent to 0.037 Bq/L .

^bSampling locations are shown in Figure 4-5.

^cND - No data available.

^dBackground well.

^eDowngradient well.

^fNew well; established June 1990.

TABLE 4-10
 CONCENTRATIONS^a OF RADIUM-226 IN GROUNDWATER IN
 THE VICINITY OF THE IWCF, 1990

Sampling Location ^b	Quarter				Min	Max	Avg
	1	2	3	4			
Upper Groundwater System							
Upgradient							
OW-14B	0.1	0.3	0.7	0.7	0.1	0.7	0.5
Downgradient							
OW-8B	0.2	0.3	0.5	0.1	0.1	0.5	0.3
OW-9B	0.3	0.2	0.4	ND ^c	0.2	0.4	0.3
OW-10B	0.3	0.2	0.3	0.2	0.2	0.3	0.3
OW-11B	0.3	0.2	0.3	0.4	0.2	0.4	0.3
OW-12B	0.2	0.2	0.9	0.4	0.2	0.9	<u>0.4</u>
Average							0.3
Lower Groundwater System							
Upgradient							
OW-12A	0.4	0.3	0.4	0.3	0.3	0.4	0.4
Downgradient							
OW-3A	0.3	0.3	0.4	0.3	0.3	0.4	0.3
OW-4A	0.3	0.3	0.6	0.1	0.1	0.6	0.3
OW-5A	0.3	0.3	0.8	0.8	0.3	0.8	0.6
OW-14A	0.2	0.2	0.3	0.2	0.2	0.3	0.2
OW-15A	0.3	0.3	0.7	0.9	0.3	0.9	<u>0.5</u>
Average							0.4

^aConcentrations are given in E-9 $\mu\text{Ci/ml}$. Note: $1\text{E-}9 \mu\text{Ci/ml}$ is equivalent to 0.037 Bq/L.

^bSampling locations are shown in Figure 4-5.

^cND - No data available.

TABLE 4-11
 CONCENTRATIONS^a OF TOTAL URANIUM
 IN GROUNDWATER AT NFSS, 1990

Page 1 of 2

Sampling Location ^b	Quarter				Min	Max	Avg
	1	2	3	4			
OW-1A	3	3	4	3	3	4	3
OW-1B	3	3	6	3	3	6	4
OW-2A	3	3	6	3	3	6	4
OW-2B	7	9	8	3	3	9	7
OW-3A	3	5	6	4	3	6	5
OW-3B	14	9	13	12	9	14	10
OW-4A	3	3	3	3	3	3	3
OW-4B	6	5	6	5	5	6	6
OW-5A	5	3	3	3	3	5	4
OW-5B	3	12	9	7	3	12	8
OW-6A	3	3	3	3	3	3	3
OW-6B	11	20	12	17	11	20	15
OW-7A	3	3	3	3	3	3	3
OW-7B	5	9	9	11	5	11	9
OW-8A	3	3	3	4	3	4	3
OW-8B	13	13	14	14	13	14	14
OW-9A	3	3	3	3	3	3	3
OW-9B	9	20	10	ND ^c	9	20	10
OW-10A	3	3	3	3	3	3	3
OW-10B	7	7	5	9	5	9	7
OW-11A	3	3	3	3	3	3	3
OW-11B	26	48	26	22	22	48	31
OW-12A	3	3	3	4	3	4	3
OW-12B	9	14	10	11	9	14	10
OW-13A	3	3	3	3	3	3	3
OW-13B	22	19	14	19	14	22	19
OW-14A	3	3	3	3	3	3	3
OW-14B	4	5	3	5	3	5	4
OW-15A	3	3	3	3	3	3	3
OW-15B	7	8	8	6	6	8	7
OW-16A	3	3	3	3	3	3	3
OW-16B	3	6	5	5	3	6	5
OW-17A	3	3	3	3	3	3	3
OW-17B	7	6	4	6	4	7	6
OW-18A	3	3	3	3	3	3	3
OW-18B	20	20	19	16	16	20	19
BH-5	3	3	3	3	3	3	3
BH-48 ^d	3	3	3	3	3	3	3
BH-61 ^e	3	3	3	3	3	3	3
A-42	78	101	66	57	57	101	76
A-49	ND	3	4	5	3	5	4
A-50	16	7	3	4	3	16	8

TABLE 4-11
(continued)

Page 2 of 2

Sampling Location ^b	Quarter				Min	Max	Avg
	1	2	3	4			
A-52	9	16	15	18	9	18	15
BH-49	ND	3	3	3	3	3	3
19D ^f	--	--	--	3	--	--	--
20S ^f	--	--	--	9	--	--	--
20D ^f	--	--	--	2	--	--	--

^aConcentrations are given in limits of E-9 $\mu\text{Ci/ml}$.
Note: $1\text{E-}9 \mu\text{Ci/ml}$ is equivalent to 0.037 Bq/L .

^bSampling locations are shown in Figure 4-5.

^cND - No data available.

^dBackground well.

^eDowngradient well.

^fNew well; established June 1990.

Annual average concentrations for the wells monitoring the IWCF area ranged from $3E-9$ to $31E-9$ $\mu\text{Ci/ml}$ (0.1 to 1.2 Bq/L). There were no significant differences in values for the background and downgradient wells in the lower groundwater system. However, average concentrations in downgradient wells monitoring the upper groundwater system were approximately four times that of the upgradient well (Table 4-12). As can be seen in the trend section, this is a steady state and the IWCF does not appear to be the source of the uranium. Total uranium concentrations were all below the DCG of $600E-9$ $\mu\text{Ci/ml}$ (22 Bq/L).

Trends

Comparisons of annual average radionuclide concentrations measured from 1986 (1987 for "OW" wells) through 1990 are presented in Tables 4-13 and 4-14. The expected value ranges shown are based on calculation of the standard deviation of the yearly mean. The expected range provides a rough check on whether there are any trends present in the data. If the range varies a great deal from location to location, or if a station consistently falls outside the expected range, then a trend could be present.

Concentrations of radium-226 and total uranium in groundwater at NFSS have remained basically stable, as can be seen by the small standard deviations and narrow ranges. The total uranium concentration in well A-42 has been consistently above that measured in the other wells. Historical records indicate that this well was installed in an area that had been radioactively contaminated.

4.2 POTENTIAL DOSE TO THE PUBLIC

This section contains information on exposures to the maximally exposed individual and the general public from radioactive materials at NFSS. As expected for a stable site like NFSS, all

TABLE 4-12
 CONCENTRATIONS^a OF TOTAL URANIUM IN GROUNDWATER IN
 THE VICINITY OF THE IWCF, 1990

Sampling Location ^b	Quarter				Min	Max	Avg
	1	2	3	4			
Upper Groundwater System							
Upgradient							
OW-14B	4	5	3	5	3	5	4
Downgradient							
OW-8B	13	13	14	14	13	14	14
OW-9B	9	20	10	ND ^c	9	20	10
OW-10B	7	7	5	9	5	9	7
OW-11B	26	48	26	22	22	48	31
OW-12B	9	14	10	11	9	14	<u>11</u>
						Average	15
Lower Groundwater System							
Upgradient							
OW-12A	3	3	3	4	3	4	3
Downgradient							
OW-3A	3	5	6	4	3	6	5
OW-4A	3	3	3	3	3	3	3
OW-5A	5	3	3	3	3	5	4
OW-14A	3	3	3	3	3	3	3
OW-15A	3	3	3	3	3	3	<u>3</u>
						Average	4

^aConcentrations are given in E-9 $\mu\text{Ci/ml}$. Note: $1\text{E-9 } \mu\text{Ci/ml}$ is equivalent to 0.037 Bq/L.

^bSampling locations are shown in Figure 4-5.

^cND - No data available.

TABLE 4-13
TREND ANALYSIS FOR CONCENTRATIONS^a OF TOTAL URANIUM
IN GROUNDWATER AT NFSS, 1986-1990

Sampling Location ^{b,c}	Annual Average Concentration					Average Value	Standard Deviation	Expected Range ^d
	1986	1987	1988	1989	1990			
OW-1A	--	4	3	4	3	4	0.5	3 - 5
OW-1B	--	4	5	8	4	5	2	1 - 9
OW-2A	--	3	3	4	4	4	0.5	3 - 5
OW-2B	--	5	8	9	7	7	2	3 - 10
OW-3A	--	3	4	8	5	5	2	1 - 9
OW-3B	--	10	14	17	10	13	3.4	6 - 20
OW-4A	--	3	3	3	3	3	0	3 - 3
OW-4B	--	6	7	7	6	7	0.5	6 - 8
OW-5A	--	3	4	4	4	4	0.4	3 - 5
OW-5B	--	11	10	12	8	10	2	6 - 14
OW-6A	--	3	3	3	3	3	0	3 - 3
OW-6B	--	15	14	13	15	14	0.8	12 - 16
OW-7A	--	8	10	10	3	9	0.8	7 - 11
OW-7B	--	3	5	3	9	4	0.9	2 - 6
OW-8A	--	3	3	5	3	4	0.9	2 - 6
OW-8B	--	17	20	20	14	18	2.5	13 - 23
OW-9A	--	3	4	5	3	4	0.8	2 - 6
OW-9B	--	14	20	20	10	17	3.3	10 - 24
OW-10A	--	5	4	3	3	4	0.8	2 - 6
OW-10B	--	3	6	7	7	6	2	2 - 10
OW-11A	--	3	4	3	3	3	0.4	2 - 4
OW-11B	--	36	28	32	31	32	2.9	26 - 38
OW-12A	--	3	5	7	3	5	2	1 - 9
OW-12B	--	15	14	10	10	12	3	4 - 16
OW-13A	--	3	4	3	3	3	0.4	2 - 4
OW-13B	--	14	17	17	19	17	1.8	13 - 21
OW-14A	--	4	4	3	3	4	0.5	3 - 5
OW-14B	--	5	7	6	4	6	1	4 - 8
OW-15A	--	3	4	3	3	3	0.4	2 - 4
OW-15B	--	6	7	14	7	9	3	3 - 20
OW-16A	--	3	5	3	3	4	0.8	2 - 6
OW-16B	--	6	7	11	5	7	2	3 - 10
OW-17A	--	3	4	4	3	4	0.5	3 - 5
OW-17B	--	7	8	8	6	7	0.8	5 - 9
OW-18A	--	3	4	5	3	5	2	1 - 9
OW-18B	--	14	18	19	19	17	2.1	13 - 21
BH-5	3	3	3	7	3	4	2	0 - 8
BH-48 ^e	5	4	3	5	3	4	0.9	2 - 6
BH-61 ^f	3	3	3	3	3	3	0	3 - 3
A-42	71	78	55	67	76	69	8.2	53 - 85
A-50	4	4	3	7	8	5	2	1 - 9
A-52	17	18	19	13	15	16	2.2	12 - 20

NOTE: Sources for 1986-1989 data are the annual site environmental reports for those years (BNI 1987, 1988a, 1989, 1990).

^aConcentrations are given in units of E-9 $\mu\text{Ci/ml}$. Note: 1E-9 $\mu\text{Ci/ml}$ is equivalent to 0.037 Bq/L.

^bSampling locations are shown in Figure 4-5. Sampling locations that no longer exist due to adjustments in the monitoring program or changes due to remedial actions are not reported in trend tables. Data from these locations would not be valid for comparison or trends.

^cAll "OW" wells were added to the program in 1987.

^dAverage value ± 2 standard deviations.

^eUpgradient well.

^fDowngradient well.

TABLE 4-14
TREND ANALYSIS FOR CONCENTRATIONS^a OF RADIUM-226
IN GROUNDWATER AT NFSS, 1986-1990

Sampling Location ^{b,c}	Annual Average Concentration					Average Value	Standard Deviation	Expected Range ^d
	1986	1987	1988	1989	1990			
OW-1A	--	0.4	0.4	0.6	0.3	0.4	0.1	0.2 - 0.6
OW-1B	--	0.2	0.4	0.7	0.3	0.4	0.2	0 - 0.8
OW-2A	--	0.2	0.4	0.4	0.3	0.3	0.08	0.1 - 0.5
OW-2B	--	0.2	0.4	0.3	0.2	0.3	0.08	0.1 - 0.5
OW-3A	--	0.1	0.4	0.5	0.3	0.3	0.2	0 - 0.7
OW-3B	--	0.1	0.5	0.7	0.3	0.4	0.2	0 - 0.8
OW-4A	--	0.2	0.4	0.5	0.3	0.4	0.1	0.2 - 0.6
OW-4B	--	0.2	0.3	0.5	0.3	0.3	0.1	0.1 - 0.5
OW-5A	--	0.2	0.4	0.4	0.6	0.4	0.1	0.2 - 0.6
OW-5B	--	0.2	0.7	0.7	0.5	0.5	0.2	0.1 - 0.9
OW-6A	--	0.2	0.4	0.5	0.3	0.4	0.1	0.2 - 0.6
OW-6B	--	0.2	0.5	0.5	0.2	0.4	0.2	0 - 0.8
OW-7A	--	0.2	0.5	1.0	0.4	0.5	0.3	0 - 1
OW-7B	--	0.2	0.4	0.5	0.3	0.4	0.1	0.2 - 0.6
OW-8A	--	0.2	0.5	0.6	0.5	0.5	0.2	0.1 - 0.8
OW-8B	--	0.2	0.8	0.6	0.3	0.5	0.2	0.1 - 0.9
OW-9A	--	0.2	0.4	0.5	0.3	0.4	0.1	0.2 - 0.6
OW-9B	--	0.2	0.7	0.9	0.3	0.5	0.3	0 - 1
OW-10A	--	0.3	0.3	0.4	0.2	0.3	0.07	0.2 - 0.4
OW-10B	--	0.2	0.3	0.3	0.3	0.3	0.04	0.2 - 0.4
OW-11A	--	0.2	0.6	0.8	0.4	0.5	0.2	0.1 - 0.9
OW-11B	--	0.1	0.5	0.4	0.3	0.3	0.2	0 - 0.7
OW-12A	--	0.2	0.5	0.5	0.4	0.4	0.1	0.2 - 0.6
OW-12B	--	0.2	0.6	0.5	0.4	0.4	0.2	0 - 0.8
OW-13A	--	0.2	0.5	0.6	0.4	0.4	0.2	0 - 0.8
OW-13B	--	0.2	0.7	0.7	0.8	0.6	0.2	0.2 - 1
OW-14A	--	0.2	0.5	0.3	0.2	0.3	0.1	0.1 - 0.5
OW-14B	--	0.5	0.8	1.0	0.5	0.7	0.2	0.3 - 1
OW-15A	--	0.3	0.5	0.4	0.5	0.4	0.08	0.2 - 0.6
OW-15B	--	0.2	0.6	0.8	0.4	0.5	0.2	0.1 - 0.9
OW-16A	--	0.2	0.4	0.5	0.4	0.4	0.1	0.2 - 0.6
OW-16B	--	0.2	0.8	0.7	0.6	0.6	0.2	0.2 - 1
OW-17A	--	0.2	0.5	0.3	0.3	0.3	0.1	0.1 - 0.5
OW-17B	--	0.2	0.3	0.4	0.4	0.3	0.08	0.1 - 0.5
OW-18A	--	0.3	0.5	0.3	0.5	0.4	0.1	0.2 - 0.6
OW-18B	--	0.4	0.4	0.8	0.4	0.5	0.2	0.1 - 0.9
BH-5	0.5	0.4	0.3	0.4	0.4	0.4	0.06	0.3 - 0.5
BH-48 ^e	0.5	0.5	0.7	0.7	0.7	0.6	0.1	0.4 - 0.8
BH-61 ^f	0.3	0.3	0.3	0.4	0.4	0.3	0.05	0.2 - 0.4
A-42	0.6	0.2	0.5	0.6	0.9	0.6	0.2	0.2 - 1
A-50	0.5	0.3	0.3	0.5	0.5	0.4	0.1	0.2 - 0.6
A-52	0.3	0.2	0.3	0.6	0.4	0.4	0.1	0.2 - 0.6

NOTE: Sources for 1986-1989 data are the annual site environmental reports for those years (BNI 1987, 1988a, 1989, 1990).

^aConcentrations are given in units of E-9 $\mu\text{Ci/ml}$. Note: $1\text{E-9 } \mu\text{Ci/ml}$ is equivalent to 0.037 Bq/L.

^bSampling locations are shown in Figure 4-5. Sampling locations that no longer exist due to adjustments in the monitoring program or changes due to remedial actions are not reported in trend tables. Data from these locations would not be valid for comparison or trends.

^cAll "OW" wells were added to the program in 1987.

^dAverage value ± 2 standard deviations.

^eBackground well.

^fDowngradient well.

calculated doses were well below the DOE guidelines. Doses to the general public can come from either external or internal exposures. Exposures to radiation outside the body are called external exposures; exposures to radiation from radionuclides deposited inside the body are called internal exposures. This distinction is important because external exposures occur only when a person is near the radionuclides, but internal exposures continue as long as the radionuclides reside in the body.

To assess the potential health effects of the material stored at NFSS, 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 effect from all the pathways from all DOE sources can then be compared with the DOE guidelines. The pathways considered are surface water, groundwater, air, and direct exposure. Exposures from radon and radon daughters are not considered in these calculations because radon exposure is controlled through compliance with boundary concentration requirements (Appendix B). All doses presented in this section are estimates and do not represent actual doses. A summary is provided in Table 4-15.

4.2.1 Maximally Exposed Individual

The hypothetical maximally exposed individual is assumed to be an individual who lives near the site and works at the Modern Disposal landfill adjacent to the eastern side of the site.

Direct exposure

The calculated yearly dose to the hypothetical worker at the landfill, calculated by using the equation in Appendix B for direct exposure, is 0.1 mrem/yr (0.001 mSv/yr), well below the DOE guideline of 100 mrem/yr. This approach is conservative because it is unlikely that an individual would work this close to the fence for an entire year.

TABLE 4-15
SUMMARY OF CALCULATED DOSES^a FOR NFSS, 1990

Type	Dose to Hypothetical Maximally Exposed Individual (mrem/yr) ^b	Collective Dose for Population Within 80 km of Facility (person-rem/yr) ^b
Direct gamma radiation ^c	0.1	-- ^d
Drinking water	-- ^d	-- ^d
Ingestion	-- ^d	-- ^d
Air immersion	-- ^d	-- ^d
Inhalation ^h	<u>0.34</u>	<u>0.30</u>
Total	0.44	0.30
Background ^f	66	1.5E+4 ^g
DOE guideline ^h	100	-- ⁱ
Percent of guideline (excluding background)	0.44	-- ⁱ

^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.

^dContribution is negligible.

^eCalculated using EPA's AIRDOS model (Appendix B).

^fDirect gamma exposure only.

^gCalculated by the following: 66 mrem/yr x 2.3E+5 people.

^hNo DOE guideline.

ⁱSource: DOE 1990b.

Drinking water pathway

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

Concentrations of total uranium and radium-226 at discharge points downgradient of the site were determined by installing groundwater sampling wells in the vicinity of NFSS; no known drinking water wells are located within a 1.6-km (1-mi) radius of NFSS. For this analysis, the maximally exposed individual is assumed to be a farmer in the vicinity of the site who takes 100 percent of his drinking water from a well. Off-site groundwater sampling wells indicate radionuclide concentrations near or below background levels. Because of the low radionuclide concentrations found in groundwater monitoring wells in the vicinity of the site and the distance to any known drinking water wells, the dose commitment to the maximally exposed individual is negligible and was not calculated.

The downgradient surface water sources are Fourmile Creek and Lake Ontario. Drainage ditches leading from the site drain into these sources; however, these ditches generally contain little to no flowing water except during periods of significant rainfall. Sampling stations in the drainage ditches leading from NFSS to Fourmile Creek indicate radionuclide concentrations near or at background. Given the very low concentrations of radionuclides present in the surface water, the dose from surface water to the hypothetical maximally exposed individual was not calculated.

Air pathway

The maximally exposed individual would work in the Modern Disposal landfill adjacent to the eastern boundary of the site for one year. Air doses determined using EPA's AIRDOS model, version 3.0, were found to be negligible (0.34 mrem/yr), well below

the 10 mrem/yr limit given in 40 CFR Part 61, Subpart H, and the DOE 100 mrem/yr basic dose limit. The 1990 AIRDOS compliance report is provided in Appendix H.

Total dose

The total dose for the hypothetical maximally exposed individual would be the sum of the doses calculated for each exposure pathway. When these doses are added together, the total dose is 0.44 mrem/yr (0.0044 mSv/yr) for the hypothetical maximally exposed individual. The dose to the hypothetical maximally exposed individual is less than the dose a person receives during one flight from New York City to Los Angeles because of greater amounts of cosmic radiation at higher altitudes (Appendix F).

4.2.2 General Population

The collective dose to the general population living within 80 km (50 mi) of the site is calculated as follows.

Direct exposure

Distance from the site and intervening structures both reduce direct gamma exposure from NFSS (see Table 4-16). Therefore, it is safe to assume that there is no detectable exposure to the majority of the general public.

Drinking water pathway

No known drinking water wells are located within 1.6 km (1 mi) downgradient of the site (see Subsection 6.1.2). Because the hypothetical maximally exposed individual receives no significant dose commitment from radionuclides in drinking water, it is reasonable to assume that the general public would not receive a committed dose from radionuclides in the drinking water.

TABLE 4-16
 MAXIMUM EFFECTIVE DOSE TO THE GENERAL PUBLIC
 FROM NFSS, 1990

Distance from the Site (m)	Effective Dose Equivalent (mrem/yr) ^{a, b}	Population Dose (person-rem/yr) ^{c, d}
0 - 1,000	3.4E-1 ^e	0.013
1,000 - 3,000	4.1E-2	0.013
3,000 - 10,000	6.5E-2	0.023
10,000 - 80,000	1.0E-3	<u>0.25</u>
Total Dose		0.30

^aTo be conservative, the effective dose equivalent used for each range was that for the distance closest to the site. DOE DCG is 100 mrem/yr above background.

^bValues were obtained using AIRDOS (Appendix B).

^cA population density of 1.24E-5 person/m² was used in the calculation.

^dCalculated using:
 Population dose = population density x Π x [(outer radius)² - (inner radius)²] x effective dose equivalent.

^eEffective dose equivalent for 500 m.

Air pathway

The EPA AIRDOS model provides an effective dose equivalent for contaminants transported via the atmospheric pathway at different distances from the site (Table 4-16). The collective dose for the general population within 80 km (50 mi) of NFSS was calculated using these effective dose equivalents and the population density. The calculated dose to the general public within an 80-km (50-mi) radius of the site was 0.30 person-rem/yr (0.003 person-Sv/yr) (Table 4-16).

Total population dose

The total population dose is the sum of the doses from all exposure pathways. Because the only pathway with a potential major contribution to the collective population dose is the atmosphere, the total population dose is equal to that calculated for the atmospheric pathway [0.30 person-rem/yr (0.003 person-Sv/yr)].

5.0 NONRADIOLOGICAL ENVIRONMENTAL PROGRAM

Environmental monitoring systems at NFSS include groundwater monitoring for nonradiological parameters. Downgradient, upgradient, and on-site wells provide information on the site's potential effects on human health and the environment.

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

NFSS is not an active site; therefore, the only "effluents" would be contaminant migration. Based on site characterization, nonradiological contamination of the soil is not substantially different from background levels and does not pose a potential threat to human health or the environment via an airborne pathway (e.g., resuspension of soil) or a surface water pathway (e.g., runoff and/or collection in sediments).

Program description

Groundwater samples for chemical analysis were collected from the same locations as those in the radiological groundwater monitoring program (Figure 4-5). Sampling locations are BH-48, to establish background conditions; on site (BH-5, A-42, A-50, and A-52); and normal downgradient (BH-61), to determine the effects of the site on groundwater in the vicinity. Wells with the "A" prefix and "S" suffix are in the upper groundwater system; those with the "BH" prefix and "D" suffix are in the lower groundwater system.

Because possible movement of contaminants from the IWCF is of primary concern, emphasis is placed on monitoring results from groundwater around the storage area. In late 1986, 36 wells ("OW" wells in Figure 4-5) were installed along the IWCF perimeter to monitor for possible contaminant migration to the groundwater. Well OW-14B is the upgradient well for the upper groundwater system; the gradient generally ranges from east to southeast. Wells OW-8B, OW-9B, OW-10B, OW-11B, and OW-12B are downgradient monitoring points for the upper groundwater system. In the lower

groundwater system, well OW-12A is upgradient, and the gradient is generally to the northwest. Wells OW-3A, OW-4A, OW-5A, OW-14A, and OW-15A are downgradient monitoring points (see Section 6.0).

Quarterly groundwater samples were analyzed for indicator parameters and metals. In support of chemical characterization of NFSS, selected groundwater samples were also analyzed for priority pollutant volatile and semivolatile organic compounds during second-quarter sampling. Reporting limits for all chemical parameters are given in Table 5-1.

Indicator parameters monitored in groundwater at NFSS include specific conductance, pH, TOC, and TOX. These parameters provide information on the inorganic and organic composition of the groundwater and, over time, may indicate changes in groundwater composition. TOC measures the total organic content of the groundwater but is not specific to a contaminant. TOX measures organic compounds containing halogens (e.g., halogenated hydrocarbons).

Specific conductance and pH indicate changes in the inorganic composition of groundwater. Specific conductance measures the capacity of water to conduct an electrical current. Generally, conductivity increases with an elevated concentration of dissolved solids or salinity. Acidity or basicity of the water is expressed as pH. A change in pH affects the solubility and mobility of chemical contaminants in water.

A list of other chemical parameters analyzed for at NFSS is given in Table 5-1. Most volatile and semivolatile compounds are not normal constituents of groundwater; metal ions are normal constituents but can also be introduced as a result of previous waste management activities.

Data and discussion

As shown in Table 5-2, on-site annual averages for specific conductance ranged from 1,160 to 4,918 $\mu\text{mhos/cm}$, and annual averages for pH varied from 7.0 to 10.3 (strongly basic). Wells OW-13A, BH-5, and BH-49 (Figure 4-5) remained basic during the

TABLE 5-1
 REPORTING LIMITS FOR GROUNDWATER CHEMICAL ANALYSES
 AT NFSS DURING SECOND QUARTER 1990

Page 1 of 4

Analyte	Reporting Limit ($\mu\text{g/L}$)
Volatile Organic Compounds	
Chloromethane	10
Bromomethane	10
Vinyl chloride	10
Chloroethane	10
Methylene chloride	5
Acetone	10
Carbon disulfide	5
1,1-Dichloroethene	5
1,1-Dichloroethane	5
1,2-Dichloroethene (total)	5
Chloroform	5
1,2-Dichloroethane	5
2-Butanone	10
1,1,1-Trichloroethane	5
Carbon tetrachloride	5
Vinyl acetate	10
Bromodichloromethane	5
1,2-Dichloropropane	5
cis-1,3-dichloropropene	5
Trichloroethene	5
Dibromochloromethane	5
1,1,2-Trichloroethane	5
Benzene	5
trans-1,3-Dichloropropene	5
Bromoform	5
4-Methyl-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)

Page 2 of 4

Analyte	Reporting Limit ($\mu\text{g/L}$)
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 4

Analyte	Reporting Limit ($\mu\text{g/L}$)
4-Nitroaniline	50
4,6-Dinitro-2-methylphenol	50
N-Nitrosodiphenylamine	10
4-Bromophenyl-phenylether	10
Hexachlorobenzene	10
Pentachlorophenol	50
Phenanthrene	10
Anthracene	10
Di-n-Butylphthalate	10
Fluoranthene	10
Pyrene	10
Butylbenzylphthalate	10
3,3'-Dichlorobenzidine	20
Benzo(a)anthracene	10
Chrysene	10
bis(2-Ethylhexyl)phthalate	10
Di-n-Octyl phthalate	10
Benzo(b)fluoranthene	10
Benzo(k)fluoranthene	10
Benzo(a)pyrene	10
Indeno(1,2,3-cd)pyrene	10
Dibenzo(a,h)anthracene	10
Benzo(g,h,i)perylene	10

Organochlorine Pesticides and PCBs

Alpha-BHC	0.050
Beta-BHC	0.050
Delta-BHC	0.050
Gamma-BHC (Lindane)	0.050
Heptachlor	0.050
Aldrin	0.050
Heptachlor epoxide	0.050
Endosulfan I	0.050
Dieldrin	0.10
4,4'-DDE	0.10
Endrin	0.10
Endosulfan II	0.10
4,4'-DDD	0.10
Endosulfan sulfate	0.10
4,4'-DDT	0.10
Methoxychlor	0.50
Endrin ketone	0.10
Endrin aldehyde	0.10
Alpha-chlordane	0.50

TABLE 5-1
(continued)

Page 4 of 4

Analyte	Reporting Limit ($\mu\text{g/L}$)
Gamma-chlordane	0.50
Toxaphene	1.0
Aroclor-1016	0.50
Aroclor-1221	0.50
Aroclor-1232	0.50
Aroclor-1242	0.50
Aroclor-1248	0.50
Aroclor-1254	1.0
Aroclor-1260	1.0
Metals	
Aluminum ^a	200
Copper ^a	25.0
Iron ^a	100
Lead ^a	100
Manganese ^a	15.0
Mercury ^a	0.20
Vanadium ^a	50.0

^aAnalyzed during all four quarters.

TABLE 5-2
ANALYTICAL RESULTS FOR INDICATOR PARAMETERS
IN GROUNDWATER AT NFSS, 1990

Page 1 of 3

Sampling Location ^a	Quarter				Min	Max	Avg
	1	2	3	4			
Specific Conductance ($\mu\text{mhos/cm}$)							
OW-1A	1770	1670	1780	2198	1670	2198	1855
OW-1B	1140	1100	1180	1220	1100	1220	1160
OW-2A	1670	1670	2060	1858	1670	2060	1815
OW-2B	1570	2190	1550	1549	1549	2190	1715
OW-3A	2110	2150	2210	2209	2110	2210	2170
OW-3B	2020	2150	2310	2230	2020	2310	2178
OW-4A	1200	1280	1260	2130	1200	2130	1468
OW-4B	1220	1360	1290	1301	1220	1360	1293
OW-5A	1290	1280	1240	1324	1240	1324	1284
OW-5B	1540	1550	1550	1595	1500	1595	1546
OW-6A	1740	1840	1740	1970	1740	1970	1823
OW-6B	2160	2210	2130	2210	2130	2210	2178
OW-7A	1790	1790	1760	1925	1760	1925	1816
OW-7B	1900	1980	1890	1771	1771	1980	1885
OW-8A	2140	1950	2200	1974	1950	2200	2066
OW-8B	1660	1730	1800	934	934	1800	1530
OW-9A	1880	1640	1960	2050	1640	2050	1883
OW-9B	2210	2440	2540	2070	2070	2540	2315
OW-10A	1380	1320	1530	1364	1320	1530	1399
OW-10B	1250	1230	1240	1150	1150	1250	1218
OW-11A	1450	1670	1460	1540	1450	1670	1530
OW-11B	1520	1550	1600	1470	1470	1600	1535
OW-12A	1690	1680	1670	1670	1670	1690	1678
OW-12B	1530	1590	1560	1360	1360	1590	1510
OW-13A	1720	1530	1640	1832	1530	1832	1681
OW-13B	2260	2080	2280	2350	2080	2350	2243
OW-14A	2260	1680	1670	1807	1670	2260	1854
OW-14B	1280	1240	1330	1248	1240	1330	1275
OW-15A	2280	2180	2180	2222	2180	2280	2216
OW-15B	1690	1580	1600	1683	1580	1690	1638
OW-16A	2350	2300	2450	2480	2300	2480	2395
OW-16B	1190	1260	1240	1220	1190	1260	1228
OW-17A	2540	2450	2440	2272	2272	2540	2426
OW-17B	1620	1540	1540	1612	1540	1620	1578
OW-18A	1730	1950	2210	2218	1730	2218	2027
OW-18B	3310	3170	2650	2307	2307	3310	2859
BH-5	1280	1330	1120	1198	1120	1330	1232
BH-48 ^b	4950	4930	4780	5010	4780	5010	4918
BH-49	-- ^c	2060	1760	1674	1674	2060	1831
BH-61 ^d	1500	1570	1550	2450	1500	2450	1768

TABLE 5-2
(continued)

Page 2 of 3

Sampling Location ^a	Quarter				Min	Max	Avg
	1	2	3	4			
A-42	1340	1310	1310	1321	1310	1340	1320
A-49	-- ^c	1200	1340	1534	1200	1534	1358
A-50	1410	1660	1670	1890	1410	1890	1658
A-52	1290	1260	1400	1387	1260	1400	1334
19D ^e	--	--	--	2300	NA ^f	NA	NA
20S ^e	--	--	--	1188	NA	NA	NA
20D ^e	--	--	--	2010	NA	NA	NA
pH (standard units)							
OW-1A	9.1	9.9	8.3	7.2	7.2	9.9	8.6
OW-1B	8	7.7	7.5	6.7	6.7	8	8
OW-2A	8	8.2	7.5	6.8	6.8	8.2	8
OW-2B	7.4	7.2	7	6.5	6.5	7.4	7
OW-3A	7.4	7.3	7.4	6.6	6.6	7.4	7.2
OW-3B	7.5	7.4	7.3	6.4	6.4	7.5	7.2
OW-4A	8	7.8	7.7	7.4	7.4	8	8
OW-4B	8	7.6	7.3	6.4	6.4	8	7
OW-5A	8.1	8.4	7.8	7.1	7.1	8.4	7.9
OW-5B	7.7	7.7	7.3	6.8	6.8	7.7	7.4
OW-6A	7.6	7.6	7.6	7.4	7.4	7.6	7.6
OW-6B	7.2	7.2	7.1	7.3	7.1	7.3	7.2
OW-7A	7.3	7.1	7.4	7.6	7.1	7.6	7.4
OW-7B	7.6	7.6	7.5	6.7	6.7	7.6	7.4
OW-8A	8.1	7.4	7.3	7.1	7.1	8.1	7.5
OW-8B	7.7	7.1	7.3	7	7	7.7	7
OW-9A	7.8	7.5	7.6	7.5	7.5	7.8	7.6
OW-9B	7.9	7.3	7.2	7.2	7.2	7.9	7.4
OW-10A	8	7.9	7.8	7.9	7.8	8	8
OW-10B	7.6	7.2	7.3	7.2	7.2	7.6	7.3
OW-11A	8	7.5	7.4	6.8	6.8	8	7
OW-11B	7.8	7.6	7.6	7.1	7.1	7.8	7.5
OW-12A	7.7	7.4	7.4	7	7	7.7	7
OW-12B	7.7	7.4	7.3	7	7	7.7	7
OW-13A	10.7	10	9.3	8.4	8.4	10.7	9.6
OW-13B	7.6	7.4	7.2	7.1	7.1	7.6	7.3
OW-14A	7.8	7.8	7.4	7.1	7.1	7.8	7.5
OW-14B	7.4	8.1	7.2	6.8	6.8	8.1	7.4
OW-15A	7.7	7.5	7.8	7	7	7.8	7.5
OW-15B	7.4	7.4	7.4	6.8	6.8	7.4	7.3
OW-16A	7.6	7.4	7.5	6.8	6.8	7.6	7.3
OW-16B	7.4	7.6	7.3	6.7	6.7	7.6	7.3
OW-17A	7.8	7.8	7.5	6.9	6.9	7.8	7.5
OW-17B	7.6	7.4	7.4	6.6	6.6	7.6	7.3

TABLE 5-2
(continued)

Page 3 of 3

Sampling Location ^a	Quarter				Min	Max	Avg
	1	2	3	4			
pH (standard units) (cont'd)							
OW-18A	8	8.4	7.8	6.9	6.9	8.4	8
OW-18B	7.3	7.2	7.1	6.6	6.6	7.3	7.1
BH-5	11.5	7.7	11.5	10.5	7.7	11.5	10
BH-48	8.1	8.1	7.7	7.7	7.7	8.1	7.9
BH-49	-- ^c	7.8	11.4	10.4	7.8	11.4	9.9
BH-61	8.1	7.2	7.7	7.6	7.2	8.1	7.7
A-42	7.2	7	7.1	6.7	6.7	7.2	7
A-49	-- ^c	10.4	7.4	7.6	7.4	10.4	8.5
A-50	7.8	7.3	7.4	7	7	7.8	7
A-52	7.1	11.3	6.8	6.9	6.8	11.3	8.0
19D ^e	--	--	--	7.2	NA	NA	NA
20S ^e	--	--	--	7.4	NA	NA	NA
20D ^e	--	--	--	7.2	NA	NA	NA

^aSampling locations are shown in Figure 4-5.

^bBackground well.

^cNot sampled during first quarter.

^dDowngradient well.

^eWell installed in June 1990.

^fNA - Not applicable.

year, as has been the case in previous years. These three wells, all in the lower groundwater system, appear to owe their elevated pH to their location, since the other wells in the lower groundwater system do not exhibit these elevated values. As shown in Table 5-3, annual average TOC levels varied from 2.2 to 77 mg/L, and TOX levels ranged from below the detection limit (20 μ g/L) to 100 μ g/L.

Table 5-4 gives analytical results for metals detected in groundwater. A metal not detected in the well in any quarter is not listed in the table. It should be noted that the samples for the first three quarters were analyzed for filtered (dissolved) metals. Fourth-quarter samples were not filtered before analyses; therefore, some of these values are significantly higher than the results from the first three quarters because they include both dissolved and suspended metals. This programmatic change was made to determine if particulate contamination was migrating through groundwater. Concentrations of many of the contaminants were below the detection limit for the applicable analytical method. The only metal found in on-site wells but not in the background well was mercury, in very low concentrations and without regularity. Based on the low concentrations and the fact that mercury, was primarily detected in the lower groundwater system, the site does not appear to be contributing mercury to the groundwater. Concentrations of metals in the downgradient well were lower than those in the background well for every quarter. Comparison of metal concentrations in the downgradient well (BH-61) with site wells and the background well (BH-48) indicates that NFSS is having no impact on groundwater quality outside the NFSS boundary.

Table 5-5 lists volatile and semivolatile organic compounds detected in groundwater from selected wells at NFSS during second-quarter sampling. Analytical results indicate volatile/semivolatile contamination in NFSS groundwater to be well below regulated levels. The volatile organics methylene chloride and acetone and the semivolatile bis(2-ethylhexyl)phthalate were also

TABLE 5-3
 CONCENTRATIONS OF TOTAL ORGANIC CARBON
 AND TOTAL ORGANIC HALIDES IN GROUNDWATER AT NFSS, 1990

Page 1 of 3

Sampling Location ^a	Quarter				Min	Max	Avg
	1	2	3	4			
Total Organic Carbon (mg/L)							
OW-1A	7.3	27.2	1.5	2.6	1.5	27.2	9.7
OW-1B	7.4	3.9	1.2	1.6	1.2	7.4	3.5
OW-2A	8.2	2.9	1.9	2.6	1.9	8.2	3.9
OW-2B	10.9	26.2	1.3	3.2	1.3	26.2	10
OW-3A	7.3	2.9	1.6	2.8	1.6	7.3	3.7
OW-3B	13	4.8	2.2	1.9	1.9	13	5.5
OW-4A	11.5	2.3	1.4	1.8	1.4	11.5	4.3
OW-4B	4.9	2.5	1.6	2.8	1.6	4.9	3.0
OW-5A	6.1	294	2.7	3.4	2.7	294	77
OW-5B	8.6	89.5	1.9	2.2	1.9	89.5	26
OW-6A	4.4	6.7	2.3	7	2.3	7	5
OW-6B	5.1	8	3.4	74	3.4	74	20
OW-7A	3.8	6.5	2.9	4.2	2.9	6.5	4.4
OW-7B	6.5	6.6	2	6.1	2	6.6	5
OW-8A	3.6	1.9	3.5	1.7	1.7	3.6	2.7
OW-8B	5	10.6	3.9	3.6	3.6	10.6	6
OW-9A	8.3	1.9	1.4	8.7	1.4	8.7	5.1
OW-9B	13.7	20.4	2.1	3	2.1	20.4	10
OW-10A	6.6	3.3	1.3	2	1.3	6.6	3
OW-10B	2.7	3.8	1.4	1.9	1.4	3.8	2.5
OW-11A	6.2	9.8	1.6	1.9	1.6	9.8	4.9
OW-11B	10.5	5.4	1.4	1.9	1.4	10.5	4.8
OW-12A	7.2	7.4	3.6	2.9	2.9	7.4	5.3
OW-12B	5.3	3.6	2.4	2.6	2.4	5.3	3.5
OW-13A	7.2	5.1	2	20.8	2	20.8	9
OW-13B	4.5	17.3	3.1	3.4	3.1	17.3	7.1
OW-14A	2.6	1.7	1.9	2.7	1.7	2.7	2.2
OW-14B	2.6	6	1.5	1.9	1.5	6	3
OW-15A	2.9	2.6	2.6	2.3	2.3	2.9	2.6
OW-15B	1.9	24.3	1.5	2.4	1.5	24.3	7.5
OW-16A	5.3	3	1.9	2.5	1.9	5.3	3
OW-16B	2.3	25.9	1.5	2	1.5	25.9	8
OW-17A	3.6	37.2	1.6	2.1	1.6	37.2	11
OW-17B	10.7	16.3	1.9	2.4	1.9	16.3	7.8
OW-18A	5.1	3.2	1.8	3.4	1.8	5.1	3.4
OW-18B	8.8	5	3.1	3.4	3.1	8.8	5
BH-5	16.1	5.8	7.5	7.3	5.8	16.1	9.2
BH-48 ^b	3	5.5	1.8	0.95	0.95	5.5	3
BH-49	-- ^c	2.9	1.9	2.5	1.9	2.9	2.4
BH-61 ^d	4.9	6.2	2.3	1.4	1.4	6.2	3.7

TABLE 5-3
(continued)

Page 2 of 3

Sampling Location ^a	Quarter				Min	Max	Avg
	1	2	3	4			
A-42	17.1	13.9	4.1	2.2	2.2	17.1	9.3
A-49	-- ^c	4.5	1.4	1.6	1.4	4.5	2.5
A-50	6.3	3.8	3.6	1.9	1.9	6.3	3.9
A-52	8.3	3.3	13.8	2.7	2.7	13.8	7.0
19D ^e	--	--	--	2.9	NA ^f	NA	NA
20S ^e	--	--	--	2.2	NA	NA	NA
20D ^e	--	--	--	5.1	NA	NA	NA

Total Organic Halides ($\mu\text{g/L}$)

OW-1A	37	23	55	77	23	77	48
OW-1B	<20 ^b	<20	<20	64	20	64	31
OW-2A	83	96	66	120	66	120	91
OW-2B	<20	<20	<20	94	20	94	39
OW-3A	37	<20	<20	54	20	54	33
OW-3B	28	31	<20	33	20	33	28
OW-4A	<20	<20	25	76	20	76	35
OW-4B	74	<20	30	41	20	74	41
OW-5A	82	63	67	<20	20	82	58
OW-5B	<20	23	46	<20	20	46	27
OW-6A	21	140	<20	92	20	140	68
OW-6B	<20	22	27	120	20	120	47
OW-7A	26	<20	<20	55	20	55	30
OW-7B	<20	<20	53	31	20	53	31
OW-8A	<20	<20	32	57	20	57	32
OW-8B	<20	<20	68	<20	20	68	32
OW-9A	25	<20	<20	53	20	53	30
OW-9B	28	<20	43	<20	20	43	28
OW-10A	<20	<20	<20	31	20	31	23
OW-10B	25	<20	<20	<20	20	25	21
OW-11A	<20	<20	36	26	20	36	26
OW-11B	92	<20	88	35	20	92	59
OW-12A	27	<20	<20	<20	20	27	22
OW-12B	<20	<20	<20	23	20	23	21
OW-13A	55	<20	<20	62	20	62	39
OW-13B	<20	48	26	58	20	58	38
OW-14A	72	<20	68	130	20	130	73
OW-14B	<20	<20	<20	63	20	63	31
OW-15A	<20	120	150	87	20	150	94
OW-15B	<20	29	<20	<20	20	29	22
OW-16A	34	<20	<20	52	20	52	32
OW-16B	<20	<20	<20	<20	20	20	20
OW-17A	<20	<20	<20	110	20	110	43

TABLE 5-3
(continued)

Page 3 of 3

Sampling Location ^a	Quarter				Min	Max	Avg
	1	2	3	4			
Total Organic Halides (µg/L) (cont'd)							
OW-17B	<20	<20	43	22	20	43	26
OW-18A	<20	<20	39	64	20	64	36
OW-18B	100	<20	47	62	20	100	57
BH-5	48	<20	60	<20	20	60	37
BH-48 ^b	ND ^h	76	130	66	66	130	90
BH-49	-- ^c	98	<20	280	20	280	100
BH-61 ^d	130	96	<20	47	20	130	70
A-42	<20	<20	92	<20	20	92	38
A-49	-- ^c	100	<20	60	20	100	60
A-50	69	73	<20	77	20	77	60
A-52	<20	38	<20	37	20	38	29
19D ^e	--	--	--	110	NA	NA	NA
20S ^e	--	--	--	78	NA	NA	NA
20D ^e	--	--	--	62	NA	NA	NA

^aSampling locations are shown in Figure 4-5.

^bBackground well.

^cNot sampled during first quarter.

^dDowngradient well.

^eWell installed in June 1990.

^fNA - Not applicable.

^gThe detection limit for TOX was 20 µg/L.

^hND - No data.

TABLE 5-4
CONCENTRATIONS^a OF METALS DETECTED
IN GROUNDWATER AT NFSS, 1990

Page 1 of 6

Sampling Location ^b	Quarter				Min ^d	Max ^d	Avg ^d
	1	2	3	4 ^c			
<u>OW-1A</u>							
Aluminum	<200	<200	<200	5,500	<200	<200	<200
Iron	<100	<100	170	9,280	<100	170	123
Manganese	17.3	<15	22.5	361	<15	22.5	18
Vanadium	<50	<50	63.9	<50	<50	63.9	55
<u>OW-1B</u>							
Aluminum	<200	<200	<200	2,300	<200	<200	<200
Iron	<100	<100	<100	3,640	<100	<100	<100
Manganese	<15	<15	96.4	115	<15	96.4	42
Mercury	<0.2	<0.2	<0.2	0.3	<0.2	<0.2	<0.2
<u>OW-2A</u>							
Aluminum	<200	<200	309	4,900	<200	309	236
Iron	<100	<100	216	8,860	<100	216	139
Manganese	<15	<15	146	343	<15	146	59
Mercury	<0.2	<0.2	<0.2	0.3	<0.2	<0.2	<0.2
<u>OW-2B</u>							
Aluminum	<200	<200	494	241	<200	494	298
Iron	<100	<100	463	582	<100	463	221
Manganese	39.3	<15	158	169	<15	158	71
Vanadium	54.4	<50	<50	<50	<50	54.4	52
<u>OW-3A</u>							
Aluminum	<200	<200	<200	1,720	<200	<200	<200
Copper	25.7	34.4	<25	<25	<25	34.4	28
Iron	<100	<100	<100	3,530	<100	<100	<100
Manganese	155	91.6	128	239	91.6	155	124.9
Vanadium	56.3	<50	<50	<50	<50	56.3	52
<u>OW-3B</u>							
Aluminum	<200	<200	504	1,930	<200	504	301
Iron	<100	<100	550	7,780	<100	550	250
Manganese	28.4	<15	118	133	<15	118	54
<u>OW-4A</u>							
Aluminum	<200	<200	<200	2,520	<200	<200	<200
Iron	<100	<100	178	5,250	<100	178	126
Manganese	48.9	38.1	70.7	307	38.1	70.7	52.6
<u>OW-4B</u>							
Aluminum	<200	<200	230	3,780	<200	230	210
Iron	<100	<100	235	5,840	<100	235	145
Manganese	48.9	36.6	113	225	36.6	113	66.2

TABLE 5-4
(continued)

Page 2 of 6

Sampling Location ^b	Quarter				Min ^d	Max ^d	Avg ^d
	1	2	3	4 ^c			
<u>OW-5A</u>							
Aluminum	<200	<200	<200	36,400	<200	<200	<200
Copper	<25	<25	<25	71.9	<25	<25	<25
Iron	<100	<100	<100	64,000	<100	<100	<100
Manganese	46.0	38.9	97.7	1,930	38.9	97.7	60.9
Vanadium	<50	<50	<50	112	<50	<50	<50
<u>OW-5B</u>							
Aluminum	<200	<200	<200	7,580	<200	<200	<200
Copper	<25	<25	<25	50.6	<25	<25	<25
Iron	<100	<400	<100	12,700	<100	<100	<100
Manganese	<15	<15	65.4	375	<15	65.4	32
<u>OW-6A</u>							
Iron	<100	<100	<100	262	<100	<100	<100
Manganese	152	165	180	127	152	180	166
<u>OW-6B</u>							
Copper	25	81.8	<25	<25	<25	81.8	44
Iron	<100	<100	738	188	<100	738	313
Manganese	61.3	151	181	44.1	61.3	181	131
Vanadium	61.8	<50	<50	<50	<50	61.8	54
<u>OW-7A</u>							
Aluminum	<200	<200	319	4,360	<200	319	240
Iron	<100	<100	<100	7,950	<100	<100	<100
Manganese	<15	<15	39.5	353	<15	39.5	23
Vanadium	63.3	<50	<50	<50	<50	63.3	54
Mercury	<0.2	0.3	<0.2	<0.2	<0.2	0.3	0.2
<u>OW-7B</u>							
Aluminum	<200	<200	252	10,900	<200	252	217
Copper	<25	<25	<25	48.7	<25	<25	<25
Iron	<100	<100	237	20,900	<100	237	146
Manganese	115	89.3	204	781	89.3	204	136.1
Vanadium	50.9	<50	<50	55.2	<50	50.9	50
Mercury	<0.2	<0.2	<0.2	0.3	<0.2	<0.2	<0.2
<u>OW-8A</u>							
Aluminum	<200	<200	<200	1,200	<200	<200	<200
Copper	<25	<25	<25	51.9	<25	<25	<25
Iron	<100	<100	2,020	2,020	<100	2,020	740
Manganese	42.1	73.1	172	67.6	42.1	172.0	95.7
Vanadium	<50	<50	<50	139	<50	<50	<50

TABLE 5-4
(continued)

Page 3 of 6

Sampling Location ^b	Quarter				Min ^d	Max ^d	Avg ^d
	1	2	3	4 ^c			
<u>OW-9B</u>							
Aluminum	<200	<200	<200	16,000	<200	<200	<200
Copper	<25	<25	<25	65.4	<25	<25	<25
Iron	<100	104	<100	24,800	<100	104	101
Manganese	59.2	17.9	213	521	17.9	213	96.7
Vanadium	59.2	<50	<50	70.4	<50	59.2	53
<u>OW-10A</u>							
Aluminum	<200	<200	<200	774	<200	<200	<200
Iron	<100	<100	<100	1,320	<100	<100	<100
Manganese	41.1	23.4	67.3	61.2	23.4	67.3	43.9
<u>OW-10B</u>							
Aluminum	<200	<200	<200	655	<200	<200	<200
Iron	<100	<100	162	1,380	<100	162	121
Manganese	19.6	21.9	<15	136	<15	21.9	19
<u>OW-11A</u>							
Aluminum	<200	<200	<200	1,090	<200	<200	<200
Copper	<25	149	<25	<25	<25	149	66
Iron	<100	<100	<100	2,170	<100	<100	<100
Manganese	<15	<15	200	136	<15	200	77
<u>OW-11B</u>							
Aluminum	<200	<200	<200	14,700	<200	<200	<200
Copper	<25	<25	<25	86.9	<25	<25	<25
Iron	<100	<100	<100	27,700	<100	<100	<100
Manganese	193	97.6	180	1,150	97.6	193	157
Vanadium	<50	<50	<50	65.7	<50	<50	<50
<u>OW-12A</u>							
Aluminum	<200	<200	<200	974	<200	<200	<200
Iron	259	2,510	138	4,780	138	2,510	969
Manganese	392	163	<15	212	<15	392	190
<u>OW-12B</u>							
Aluminum	<200	<200	<200	15,700	<200	<200	<200
Copper	<25	<25	<25	45.1	<25	<25	<25
Iron	<100	<100	<100	22,500	<100	<100	<100
Manganese	21.5	<15	78.1	439	<15	78.1	38
Vanadium	51.3	<50	<50	50.7	<50	51.3	50
<u>OW-13A</u>							
Aluminum	<200	<200	<200	295	<200	<200	<200
Iron	<100	<100	<100	677	<100	<100	<100
Manganese	<15	<15	<15	34.9	<15	<15	<15
Mercury	<0.2	<0.2	0.3	<0.2	<0.2	0.3	0.2

TABLE 5-4
(continued)

Page 4 of 6

Sampling Location ^b	Quarter				Min ^d	Max ^d	Avg ^d
	1	2	3	4 ^c			
<u>OW-13B</u>							
Aluminum	<200	<200	<200	13,300	<200	<200	<200
Copper	<25	<25	<25	55.4	<25	<25	<25
Iron	<100	<100	<100	25,400	<100	<100	<100
Manganese	<15	<15	17.3	839	<15	17.3	16
Vanadium	86.5	<50	<50	58.8	<50	86.5	62
<u>OW-14A</u>							
Aluminum	<200	<200	<200	2,730	<200	<200	<200
Copper	<25	<25	<25	25	<25	<25	<25
Iron	<100	<100	<100	4,490	<100	<100	<100
Manganese	136	122	141	304	122	141	133
Vanadium	58.8	<50	<50	<50	<50	58.8	53
<u>OW-14B</u>							
Aluminum	<200	<200	<200	47,000	<200	<200	<200
Copper	<25	<25	<25	175	<25	<25	<25
Iron	<100	240	<100	76,300	<100	240	147
Manganese	28.8	22.3	46.8	1,770	22.3	46.8	32.6
Vanadium	60.8	<50	94.1	<50	<50	94.1	68
<u>OW-15A</u>							
Aluminum	<200	<200	342	12,700	<200	342	247
Copper	<25	<25	<25	56.1	<25	<25	<25
Iron	<100	<100	296	24,800	<100	<296	165
Manganese	40.3	123	194	1,830	40.3	194	119.1
Vanadium	60.8	<50	<50	<50	<50	60.8	54
<u>OW-15B</u>							
Aluminum	<200	<200	<200	8,360	<200	<200	<200
Copper	<25	<25	<25	52.8	<25	<25	<25
Iron	<100	<100	132	14,000	<100	132	111
Manganese	<15	19.8	40.4	388	<15	40.4	25
Vanadium	63.8	<50	<50	<50	<50	63.8	55
<u>OW-16A</u>							
Aluminum	<200	<200	<200	952	<200	<200	<200
Iron	<100	<100	306	2,410	<100	306	169
Manganese	47.9	16.0	60.6	102	16.0	60.6	41.5
Vanadium	66.7	<50	<50	<50	<50	66.7	56
<u>OW-16B</u>							
Aluminum	<200	<200	<200	7,970	<200	<200	<200
Copper	<25	<25	<25	49	<25	<25	<25
Iron	<100	<100	<100	13,200	<100	<100	<100
Manganese	111	183	338	749	111	338	211

TABLE 5-4
(continued)

Page 5 of 6

Sampling Location ^b	Quarter				Min ^d	Max ^d	Avg ^d
	1	2	3	4 ^c			
<u>OW-17A</u>							
Aluminum	<200	<200	<200	1,070	<200	<200	<200
Iron	<100	<100	400	2,220	<100	400	200
Manganese	80.5	84.9	240	271	80.5	240	135
Vanadium	56.3	<50	<50	<50	<50	56.3	52
<u>OW-17B</u>							
Aluminum	<200	<200	<200	4,110	<200	<200	<200
Iron	100	<100	<100	7,210	<100	100	100
Manganese	<15	<15	53.1	202	<15	53.1	28
Vanadium	64.7	<50	<50	<50	<50	64.7	55
<u>OW-18A</u>							
Aluminum	<200	<200	<200	1,640	<200	<200	<200
Iron	<100	<100	<100	3,100	<100	<100	<100
Manganese	86.3	29	277	305	29	277	130.8
Vanadium	58.8	<50	<50	<50	<50	58.8	53
<u>OW-18B</u>							
Aluminum	<200	<200	<200	21,100	<200	<200	<200
Copper	<25	<25	<25	84.9	<25	<25	<25
Iron	<100	<100	<100	36,400	<100	<100	<100
Manganese	<15	195	127	1,180	127	195	161
Vanadium	85	<50	<50	<50	<50	85	62
<u>19D^e</u>							
Iron	<100	<100	<100	206	<100	<100	<100
Manganese	<15	<15	<15	270	<15	<15	<15
<u>20D^e</u>							
Aluminum	<200	<200	<200	4,220	<200	<200	<200
Iron	<100	<100	<100	7,650	<100	<100	<100
Manganese	<15	<15	<15	451	<15	<15	<15
<u>20S^e</u>							
Aluminum	<200	<200	<200	11,600	<200	<200	<200
Copper	<25	<25	<25	27.5	<25	<25	<25
Iron	<100	<100	<100	19,500	<100	<100	<100
Manganese	<15	<15	<15	583	<15	<15	<15
<u>BH-5</u>							
Aluminum	538	319	386	638	319	538	414

TABLE 5-4
(continued)

Page 6 of 6

Sampling Location ^b	Quarter				Min ^d	Max ^d	Avg ^d
	1	2	3	4 ^e			
<u>BH-48</u>							
Aluminum	<200	<200	<200	469	<200	<200	<200
Copper	<25	<25	53.1	<25	<25	53.1	34
Iron	103	214	<100	1,190	<100	214	139
Manganese	734	682	639	753	639	734	685
Vanadium	91.9	65	<50	<50	<50	91.9	69
<u>BH-49^f</u>							
<u>BH-61</u>							
Aluminum	<200	<200	<200	200	<200	<200	<200
Iron	<100	<100	<100	633	<100	<100	<100
Manganese	24	64.4	37.7	181	24	64.4	42
<u>A-42</u>							
Iron	<100	<100	<100	293	<100	<100	<100
Manganese	132	120	577	152	120	577	276
Vanadium	55.8	<50	<50	<50	<50	55.8	52
<u>A-49</u>							
Iron	-- ^g	<100	271	613	<100	271	186
Manganese	-- ^g	<15	345	214	<15	345	180
<u>A-50</u>							
Aluminum	<200	<200	211	639	<200	211	204
Iron	<100	<100	217	1,410	<100	217	139
Manganese	<15	29.7	63.2	67.1	<15	63.2	36
Vanadium	<50	60.8	<50	<50	<50	60.8	54
<u>A-52</u>							
Aluminum	<200	<200	<200	12,300	<200	<200	<200
Copper	<25	<25	<25	89.5	<25	<25	<25
Iron	<100	<100	<100	21,300	<100	<100	<100
Manganese	724	490	589	1,240	490	724	601
Vanadium	61.8	<50	<50	<50	<50	61.8	54

^aConcentrations are given in $\mu\text{g/L}$.

^bSampling locations are shown in Figure 4-5.

^cTotal metals reported for fourth quarter.

^dMinimum, maximum, and average value for first three quarters only because in those quarters the samples were filtered.

^eWell installed in June 1990.

^fNo samples taken during first quarter and no metals detected at or above the reported limits in other quarters.

^gNot sampled in first quarter.

TABLE 5-5
 CONCENTRATIONS OF VOLATILE AND SEMIVOLATILE ORGANIC
 COMPOUNDS DETECTED^a IN GROUNDWATER AT NFSS, 1990

Sampling Location ^b	Compound	Concentration ^c ($\mu\text{g/L}$)
Volatile Compounds		
OW-13A	Acetone	71
OW-14B	Carbon disulfide	12
	Acetone	25 ^d
	Methylene chloride	5 ^d
BH-46	Acetone	13 ^d
BH-60	Methylene chloride	6 ^d
Semivolatile Compounds		
OW-5A	Bis(2-ethylhexyl)phthalate	45 ^d
OW-9B	Bis(2-ethylhexyl)phthalate	20 ^d
OW-13A	Bis(2-ethylhexyl)phthalate	14 ^d
OW-13B	Bis(2-ethylhexyl)phthalate	11 ^d
OW-14A	Bis(2-ethylhexyl)phthalate	22 ^d
OW-16A	Bis(2-ethylhexyl)phthalate	25 ^d
OW-16B	Bis(2-ethylhexyl)phthalate	13 ^d
BH-48	Bis(2-ethylhexyl)phthalate	17 ^d
BH-50	Bis(2-ethylhexyl)phthalate	19 ^d
BH-51	Bis(2-ethylhexyl)phthalate	22 ^d
BH-60	Bis(2-ethylhexyl)phthalate	13 ^d

^aSampling took place during second quarter of 1990.

^bSampling locations are shown in Figure 4-5.

^cOnly positive values are listed.

^dCompound was found in method blanks associated with sample.

found in the laboratory blanks. It is probable that their presence in the NFSS samples can be attributed to laboratory contamination.

These analytical results indicate that the groundwater at NFSS is generally of poor quality, which is typical of groundwater in this area.

In the IWCF area, the average annual mean specific conductance for the five downgradient wells in the upper groundwater system was slightly greater than for the upgradient well (1,622 versus 1,275 $\mu\text{mhos/cm}$). Because this parameter can vary so much from quarter to quarter and the observed mean is well within the range of observed values, there is probably no meaningful difference in upgradient versus downgradient values. In the lower groundwater system there was no meaningful difference in the upgradient and downgradient mean values (Table 5-6).

No significant differences in pH or TOC were observed between upgradient and downgradient wells in either groundwater system (Tables 5-6 and 5-7). A single well, OW-5A (lower groundwater system), exhibited an unusually high (for NFSS) TOC value (294 mg/L) during the second-quarter sampling period. This value resulted in an average yearly value of 76.6 mg/L, compared with an average of 3.2 mg/L for the remaining four downgradient wells. Because the average of the remaining three quarters' data for OW-5A was 4.1 mg/L (the maximum was 6.1 mg/L), there is a strong probability that some type of organic carbon was introduced into the sample during sampling. Results of upper groundwater system monitoring indicate no significant difference in upgradient and downgradient groundwater.

TOX values for IWCF-area wells indicate no difference between upgradient and downgradient wells in the upper groundwater system (Table 5-7). In the lower groundwater system, however, the annual average upgradient well result (30 $\mu\text{g/L}$) was slightly less than the mean of five downgradient wells (59 $\mu\text{g/L}$). Based on these relatively low values, there does not appear to be any discernible movement of halogenated hydrocarbons in either groundwater system.

TABLE 5-6
ANALYTICAL RESULTS FOR INDICATOR PARAMETERS
IN GROUNDWATER FROM THE VICINITY
OF THE IWCF, 1990

Page 1 of 2

Sampling Location ^a	Quarter				Min	Max	Avg
	1	2	3	4			
Specific Conductance (μmhos/cm)							
UPPER GROUNDWATER SYSTEM							
Upgradient							
OW-14B	1280	1240	1330	1248	1240	1330	1275
Downgradient							
OW-8B	1660	1730	1800	934	934	1800	1531
OW-9B	2210	2440	2540	2070	2070	2540	2315
OW-10B	1250	1230	1240	1150	1150	1250	1218
OW-11B	1520	1550	1600	1470	1470	1600	1535
OW-12B	1530	1590	1560	1360	1360	1590	<u>1510</u>
						Average	1622
LOWER GROUNDWATER SYSTEM							
Upgradient							
OW-12A	1690	1680	1670	1670	1670	1690	1678
Downgradient							
OW-3A	2110	2150	2210	2209	2110	2210	2170
OW-4A	1200	1280	1260	2130	1200	2130	1468
OW-5A	1290	1280	1240	1324	1240	1324	1284
OW-14A	2260	1680	1670	1807	1670	2260	1854
OW-15A	2280	2180	2180	2222	2180	2280	<u>2216</u>
						Average	1798

TABLE 5-6
(continued)

Page 2 of 2

Sampling Location ^a	Quarter				Min	Max	Avg
	1	2	3	4			
pH (standard units)							
UPPER GROUNDWATER SYSTEM							
Upgradient							
OW-14B	7.4	8.1	7.2	6.8	6.8	8.1	7.4
Downgradient							
OW-8B	7.7	7.1	7.3	7	7	7.7	7.3
OW-9B	7.9	7.3	7.2	7.2	7.2	7.9	7.4
OW-10B	7.6	7.2	7.3	7.2	7.2	7.6	7.3
OW-11B	7.8	7.6	7.6	7.1	7.1	7.8	7.5
OW-12B	7.7	7.4	7.3	7	7	7.7	<u>7.4</u>
						Average	7.4
LOWER GROUNDWATER SYSTEM							
Upgradient							
OW-12A	7.7	7.4	7.4	7	7	7.4	7
Downgradient							
OW-3A	7.4	7.3	7.4	6.6	6.6	7.4	7.2
OW-4A	8	7.8	7.7	7.4	7.4	8	7.7
OW-5A	8.1	8.4	7.8	7.1	7.1	8.4	7.9
OW-14A	7.8	7.8	7.4	7.1	7.1	7.8	7.5
OW-15A	7.7	7.5	7.8	7	7	7.8	<u>7.5</u>
						Average	7.6

^aSampling locations are shown in Figure 4-5.

TABLE 5-7
 CONCENTRATIONS OF TOTAL ORGANIC CARBON
 AND TOTAL ORGANIC HALIDES IN GROUNDWATER
 FROM THE VICINITY OF THE IWCF, 1990

Page 1 of 2

Sampling Location ^a	Quarter				Min	Max	Avg
	1	2	3	4			
Total Organic Carbon (mg/L)							
UPPER GROUNDWATER SYSTEM							
Upgradient							
OW-14B	2.6	6	1.5	1.9	1.5	6	3.0
Downgradient							
OW-8B	5	10.6	3.9	3.6	3.6	10.6	5.8
OW-9B	13.7	20.4	2.1	3	2.1	20.4	9.8
OW-10B	2.7	3.8	1.4	1.9	1.4	3.8	2.5
OW-11B	10.5	5.4	1.4	1.9	1.4	10.5	4.8
OW-12B	5.3	3.6	2.4	2.6	2.4	5.3	<u>3.5</u>
Average							5.3
LOWER GROUNDWATER SYSTEM							
Upgradient							
OW-12A	7.2	7.4	3.6	2.9	2.9	7.4	5.3
Downgradient							
OW-3A	7.3	2.9	1.6	2.8	1.6	7.3	3.7
OW-4A	11.5	2.3	1.4	1.8	1.4	11.5	4.3
OW-5A	6.1	294	2.7	3.4	2.7	294	76.6
OW-14A	2.6	1.7	1.9	2.7	1.7	2.7	2.2
OW-15A	2.9	2.6	2.6	2.3	2.3	2.9	<u>2.6</u>
Average							17.9

TABLE 5-7
(continued)

Page 2 of 2

Sampling Location ^a	Quarter				Min	Max	Avg
	1	2	3	4			
Total Organic Halides ($\mu\text{g/L}$)							
UPPER GROUNDWATER SYSTEM							
Upgradient							
OW-14B	<20	<20	<20	63	20	63	31
Downgradient							
OW-8B	<20	<20	68	<20	20	68	32
OW-9B	28	<20	43	<20	20	43	28
OW-10B	25	<20	<20	<20	20	25	21
OW-11B	92	<20	88	35	20	92	59
OW-12B	<20	<20	<20	23	20	23	<u>21</u>
						Average	32
LOWER GROUNDWATER SYSTEM							
Upgradient							
OW-12A	27	<20	<20	<20	20	27	22
Downgradient							
OW-3A	37	<20	<20	54	20	54	33
OW-4A	<20	<20	25	76	20	76	35
OW-5A	82	63	67	<20	20	82	58
OW-14A	72	<20	68	130	20	130	73
OW-15A	<20	120	150	87	20	150	<u>94</u>
						Average	59

^aSampling locations are shown in Figure 4-5.

Trends

Analyses of indicator parameters such as TOC and TOX are used as gross indicators for the presence of organic compounds. Because these parameters can fluctuate greatly between sampling events, trend analysis is not feasible or meaningful. If TOC and TOX analyses indicate the need for broader organic contaminant screening because of sustained elevated levels above 200 mg/L for TOC and 200 $\mu\text{g/L}$ for TOX for several quarters, an individual organic contaminant analysis will be performed.

The volatile and semivolatile organic compound data resulted from sampling performed during regular second-quarter monitoring in support of a chemical characterization of NFSS. Therefore, trend analysis is not applicable.

6.0 GROUNDWATER PROTECTION PROGRAM

6.1 HYDROGEOLOGICAL CHARACTERISTICS

6.1.1 Site Hydrogeology

NFSS lies within the Central Lowlands Physiographic Province, which is part of the Erie-Ontario Lowland and is characterized by topography developed on undeformed Paleozoic sedimentary rocks. The rocks occupy a broad basin sloping gently southward from the neighboring crystalline terranes of the Canadian Shield and the Adirondack Dome (Muller 1965). Regionally, a basement of gneiss has been found in wells ranging from approximately 610 to 914 m (2,000 to 3,000 ft) in depth (USCE 1973). The area was significantly modified by glaciers.

The site stratigraphy includes 12 to 15 m (40 to 50 ft) of unconsolidated deposits overlying a thick sequence of sedimentary rocks. These surficial deposits are glacially derived sediments that include glaciofluvial sands and gravel, dense tills, and glacial lacustrine clays. Lacustrine materials were deposited on the bottoms and along the shores of glacial and postglacial lakes. Beneath these deposits are shales, siltstones, and mudstones of the Ordovician Queenston Formation. Six major geologic units have been identified within the interval from 0 to 27 m (90 ft) below ground surface. In order of increasing depth, these units are surficial soils and fill, brown clay, gray clay, sand and gravel, red silt, and bedrock of the Queenston Formation.

Two types of water-bearing material occur within 30 m (100 ft) of the ground surface: the bedrock of the Queenston Formation, and select permeable zones within the overlying unconsolidated deposits. Wells in bedrock are screened at depths ranging from 12.2 to 27.5 m (40 to 90 ft). The water table in this zone occurs at depths of approximately 1.75 to 3.88 m (5.75 to 12.73 ft). Water-bearing zones within the unconsolidated deposits can be subdivided into two units: (1) the intermittent sand, gravel, and silt lenses found in the brown clay unit between elevations

91.5 and 96.6 m (300 and 317 ft) MSL (mean sea level) and (2) the sand and gravel unit immediately below the gray clay, typically between elevations of 82.3 and 91.4 m (270 and 300 ft) MSL. Although the lenses of gravel, sand, and silt in the brown clay unit are discontinuous, the sand zones are referred to as the upper groundwater system. The water table in this zone occurs at a depth of 0.45 to 4.32 m (1.48 to 14.15 ft). Wells in the upper groundwater system are screened at depths of 2.4 to 6.7 m (8 to 22 ft). The sand and gravel unit between the red silt and the gray clay is referred to as the lower groundwater system. Wells in the lower groundwater system are screened at depths of 6.1 to 14.4 m (20 to 47.2 ft). The potentiometric surface in the lower groundwater system occurs in the depth interval between 0.56 and 3.85 m (1.84 and 12.62 ft).

6.1.2 Groundwater Quality and Usage

Groundwater is used as a source of water for approximately 10 percent of the population in Niagara and Erie counties. The primary uses are for small domestic and farm supplies in rural areas. The dominant source of this water, the Lockport dolomite aquifer, is absent north of the Niagara escarpment, where NFSS is located. Wells in the vicinity of NFSS generally have a low yield and supply water of poor quality. In some places, the upper groundwater systems in the glacial deposits near NFSS are capable of supplying adequate groundwater for domestic use, although these sources may be depleted during dry seasons (DOE 1986).

A well canvass of the area within a 4.8-km (3-mi) radius of NFSS conducted in 1987 and 1988 yielded records for seven wells. Four of these wells were used to supply water for irrigation and one was used for domestic purposes. There is no available information on water usage for the other two wells. No private wells were reported for drinking purposes, but one of the wells drilled for irrigation reportedly is a source of water suitable for

drinking. No public water supply wells were found within the canvass area. Water needs for the area are usually met by county-supplied treated water from Lake Erie and from the Niagara River.

6.2 GROUNDWATER MONITORING

6.2.1 Methods

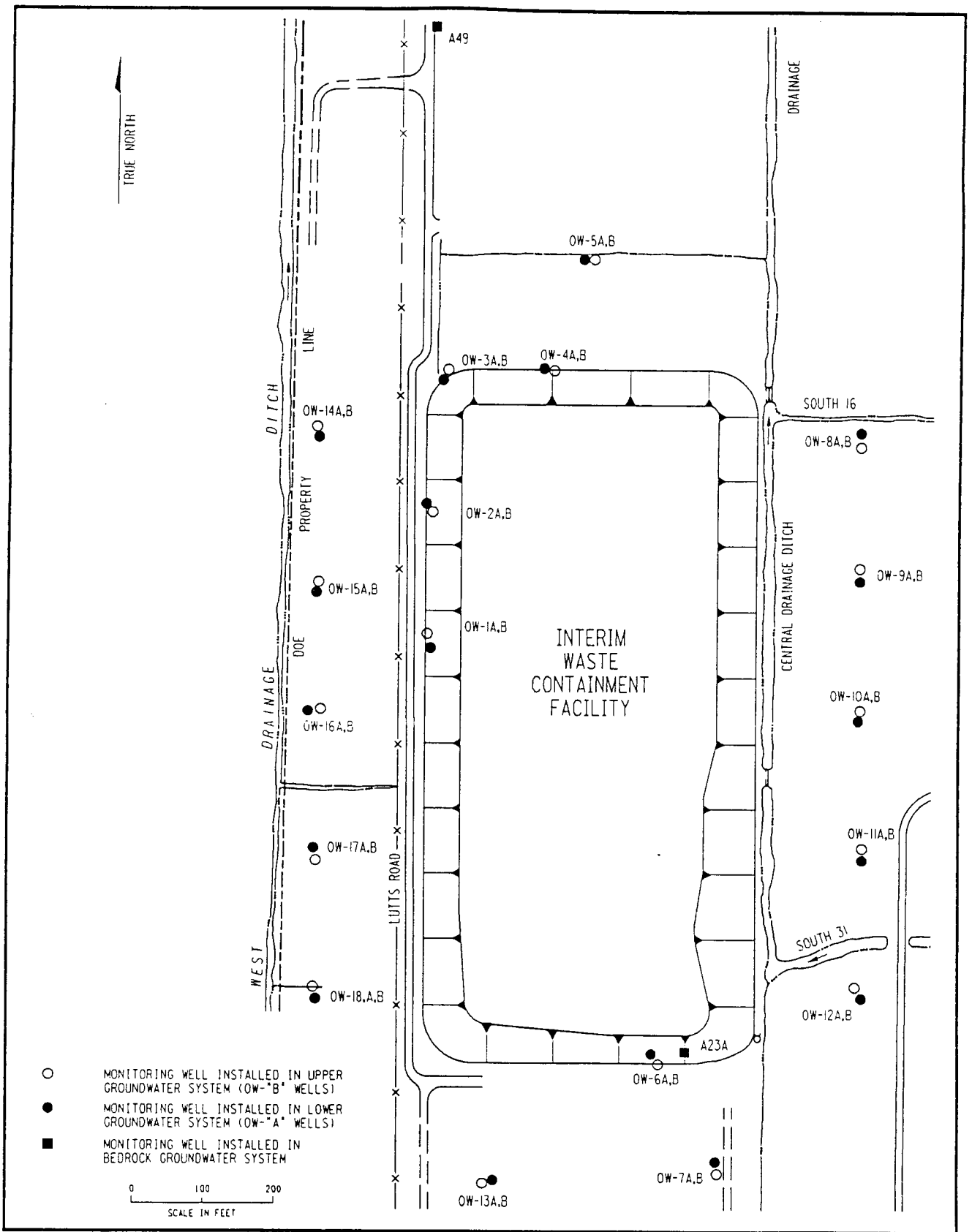
The hydrogeological interpretations presented here are based on groundwater levels measured in 48 monitoring wells in the general area of the IWCF during calendar year 1990 (Figure 6-1). Groundwater levels are measured weekly using an electric downhole probe water level indicator. A summary of well construction details is shown in Table 6-1. Examples of well construction details are provided in Appendix E. Further information on site geology, hydrogeology, and well installation methods can be found in BNI (1984, 1986, 1988b) and Acres American, Inc. (1981).

Water level measurements from monitoring wells are used to prepare two types of graphic exhibits (hydrographs and potentiometric surface maps) that show hydrogeological conditions. Hydrographs are line graphs that display changes in water levels for each monitoring well throughout the year (Appendix E). The NFSS hydrographs also include bar graphs of U.S. Weather Service precipitation records for the Niagara Falls area as an aid in evaluating the influence of precipitation on water level behavior.

The amount of slope (gradient) and flow direction of the NFSS groundwater systems are determined from potentiometric surface (water level) maps. These maps are prepared by plotting water level measurements for selected dates (to represent spring, summer, and winter) on base maps and contouring the values.

6.2.2 Results and Conclusions

The hydrographs prepared for the water levels measured in 1990 are shown in Appendix E. Conclusions derived from these



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Figure 6-1
Wells Used for Water Level Measurements in 1990

TABLE 6-1
NFSS MONITORING WELL CONSTRUCTION SUMMARY

Page 1 of 2

Well Number ^a	Completion Date	Total Depth [m (ft)]	Monitoring or Screened Interval Below Ground [m-m (ft-ft)]	Construction Material
<u>Wells Installed in Soil (Upper System)</u>				
A-42	Mar. 1983	6.86 (22.5)	3.17-6.86 (15.7-20.5)	PVC ^b
A-43	Mar. 1983	4.27 (14.0)	2.1-4.27(8.4-14.0)	PVC
A-45	Mar. 1983	6.10 (20.0)	2.4-6.10 (13.4-18.0)	PVC
A-50	Mar. 1983	7.01 (23.0)	3.05-6.71 (16.4-21.0)	PVC
A-52	Mar. 1983	4.58 (15.0)	1.8-4.58 (8.4-13.0)	PVC
OW-1B	Oct. 1986	5.18 (17.0)	3.14-4.67 (10.3-15.3)	316 Stainless Steel
OW-2B	Sept. 1986	6.10 (20.0)	4.11-5.64 (13.5-18.5)	316 Stainless Steel
OW-3B	Oct. 1986	4.88 (16.0)	2.9-4.42 (9.5-14.5)	316 Stainless Steel
OW-4B	Oct. 1986	5.18 (17.0)	3.11-4.63 (10.2-15.2)	316 Stainless Steel
OW-5B	Oct. 1986	5.18 (17.0)	2.9-4.42 (9.5-14.5)	316 Stainless Steel
OW-6B	Oct. 1986	5.18 (17.0)	3.14-4.67 (10.3-15.3)	316 Stainless Steel
OW-7B	Oct. 1986	3.97 (13.0)	1.9-3.45 (6.3-11.3)	316 Stainless Steel
OW-8B	Nov. 1986	3.66 (12.0)	1.7-3.20 (5.5-10.5)	316 Stainless Steel
OW-9B	Nov. 1986	4.45 (14.6)	2.5-4.03 (8.2-13.2)	316 Stainless Steel
OW-10B	Nov. 1986	8.85 (29.0)	5.28-8.42 (17.3-27.6)	316 Stainless Steel
OW-11B	Nov. 1986	4.88 (16.0)	2.3-3.81 (7.5-12.5)	316 Stainless Steel
OW-12B	Nov. 1986	3.66 (12.0)	1.8-3.29 (5.8-10.8)	316 Stainless Steel
OW-13B	Nov. 1986	4.27 (14.0)	2.2-3.72 (7.2-12.2)	316 Stainless Steel
OW-14B	Oct. 1986	4.64 (15.2)	2.6-4.12 (8.5-13.5)	316 Stainless Steel
OW-15B	Oct. 1986	3.66 (12.0)	1.7-3.26 (5.7-10.7)	316 Stainless Steel
OW-16B	Oct. 1986	3.97 (13.0)	2.1-3.63 (6.9-11.9)	316 Stainless Steel
OW-17B	Oct. 1986	5.18 (17.0)	3.20-4.73 (10.5-15.5)	316 Stainless Steel
OW-18B	Oct. 1986	5.06 (16.6)	3.11-4.64 (10.2-15.2)	316 Stainless Steel
<u>Wells Installed in Soil (Lower System)</u>				
BH-5	June 1981	15.9 (52.2)	7.3-14.4 (29.0-44.0)	PVC
BH-59	May 1981	12.4 (40.5)	7.0-11.5 (28.40-37.7)	PVC
BH-61	May 1981	14.0 (46.0)	7.3-12.7 (27.5-41.6)	PVC
BH-64	June 1981	14.9 (48.7)	8.5-13.1 (32.9-42.1)	PVC
BH-70	June 1981	13.7 (45.0)	6.1-12.2 (24.8-39.5)	PVC
OW-1A	Oct. 1986	14.3 (47.0)	10.6-13.7 (34.8-45.1)	316 Stainless Steel
OW-2A	Oct. 1986	14.0 (46.0)	10.3-13.4 (33.7-44.0)	316 Stainless Steel
OW-3A	Oct. 1986	12.8 (42.0)	9.9-11.4 (32.4-37.4)	316 Stainless Steel
OW-4A	Oct. 1986	12.4 (40.6)	8.6-11.7 (28.1-38.4)	316 Stainless Steel
OW-5A	Oct. 1986	13.5 (44.3)	9.8-12.8 (32.0-42.0)	316 Stainless Steel
OW-6A	Oct. 1986	12.3 (40.2)	8.6-11.7 (28.1-38.4)	316 Stainless Steel
OW-7A	Oct. 1986	12.1 (39.6)	8.5-11.7 (27.9-38.2)	316 Stainless Steel

TABLE 6-1
(continued)

Page 2 of 2

Well Number ^a	Completion Date	Total Depth [m (ft)]	Monitoring or Screened Interval Below Ground [m-m (ft-ft)]	Construction Material
OW-8A	Nov. 1986	13.6 (44.6)	10.0-13.1 (32.7-43.0)	316 Stainless Steel
OW-9A	Nov. 1986	12.5 (41.1)	8.7-11.9 (28.6-38.9)	316 Stainless Steel
OW-10A	Nov. 1986	12.3 (40.3)	10.2-11.7 (33.5-38.5)	316 Stainless Steel
OW-11A	Nov. 1986	11.4 (37.2)	7.7-10.8 (25.2-35.5)	316 Stainless Steel
OW-12A	Nov. 1986	11.7 (38.3)	7.6-12.1 (25.6-35.9)	316 Stainless Steel
OW-13A	Oct. 1986	12.5 (41.1)	9.0-13.2 (29.4-39.7)	316 Stainless Steel
OW-14A	Oct. 1986	13.7 (44.8)	10.1-13.2 (33.1-43.4)	316 Stainless Steel
OW-15A	Oct. 1986	13.9 (45.5)	11.9-13.4 (39.0-44.0)	316 Stainless Steel
OW-16A	Oct. 1986	13.8 (45.2)	9.9-13.0 (32.4-42.7)	316 Stainless Steel
OW-17A	Oct. 1986	13.0 (42.5)	9.2-12.3 (30.1-40.4)	316 Stainless Steel
OW-18A	Oct. 1986	14.6 (47.8)	10.9-14.0 (35.7-46.0)	316 Stainless Steel
<u>Wells Installed in Bedrock</u>				
A-23A	Mar. 1983	23.0 (78.5)	12.2-23.2 (62.1-71.3)	PVC
A-49	Mar. 1983	27.5 (90.0)	14.0-27.5 (75.8-85.0)	PVC

^aWell locations are shown in Figure 6-1.

^bPVC - polyvinyl chloride.

NOTE: Water level elevations for wells monitored in 1990 are shown as hydrographs in Appendix E.

hydrographs and from the potentiometric surface maps are presented in the following subsections.

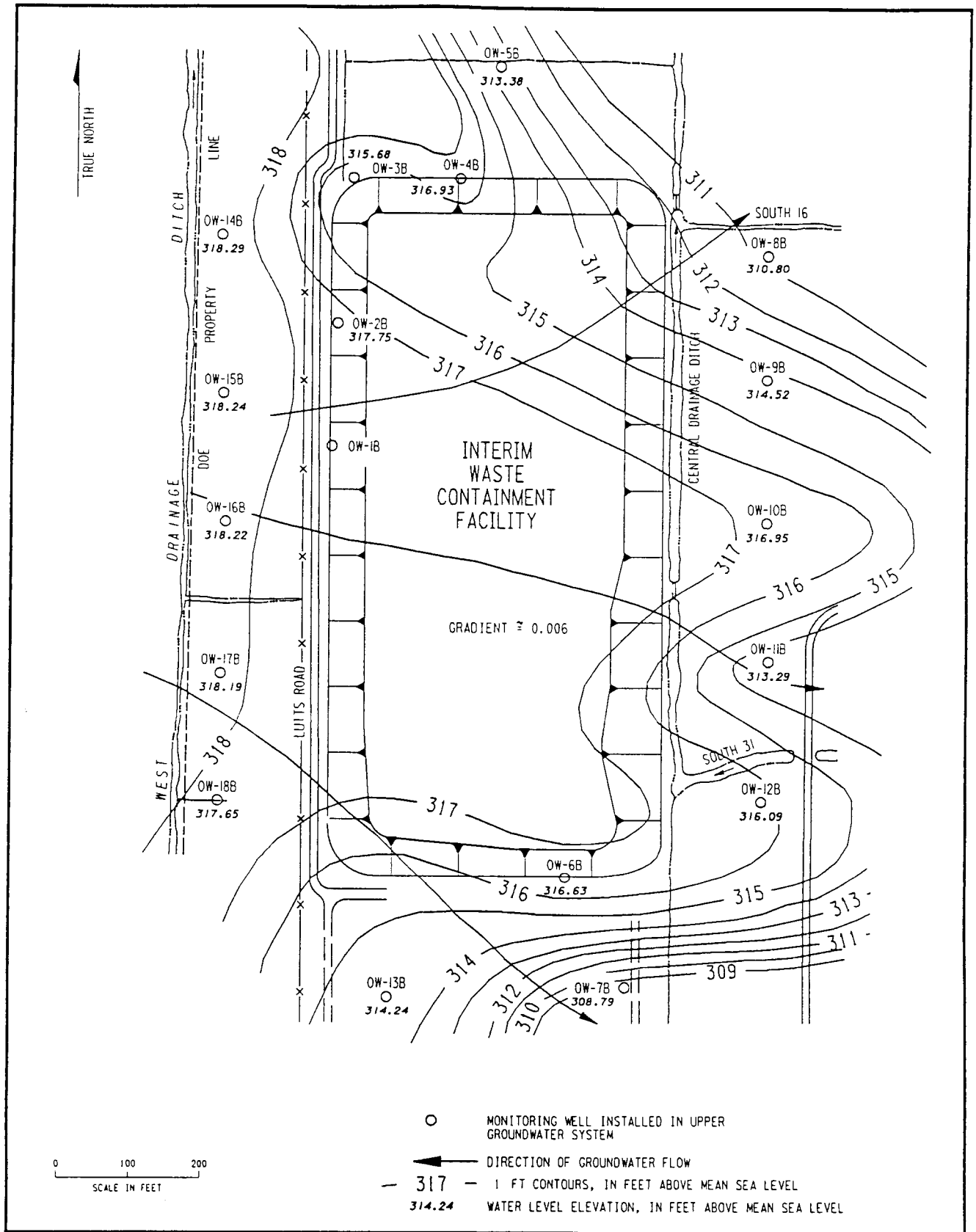
Upper groundwater system

Hydrographs of wells screened in the upper groundwater system show a definite seasonal variation of water levels. Water levels are highest in the early summer and lowest in the fall, which is similar to the seasonal fluctuations seen in 1989 (BNI 1990). Water levels in many of the wells do not appear to act similarly, and they also do not appear to be related to particular precipitation events.

The slope and flow direction of the upper groundwater system were determined from potentiometric surface maps (Figures 6-2, 6-3, 6-4, and 6-5). The dates plotted were representative of spring, summer, and winter. The general flow pattern at NFSS is to the west and northwest. However, potentiometric maps for the upper system show flow generally to the east, because of the influence of dewatering at the Modern Disposal landfill operation southeast of NFSS.

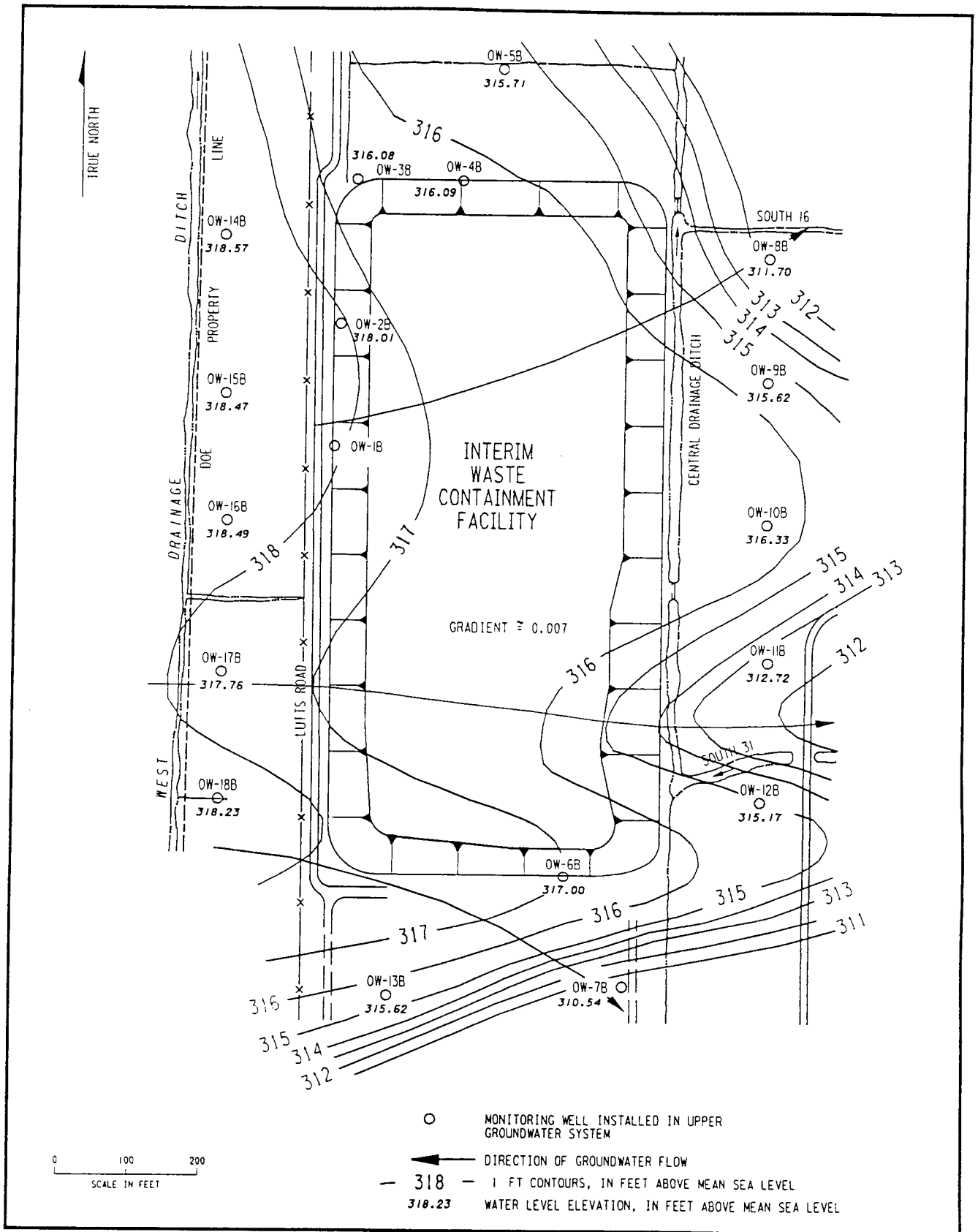
Lower and bedrock groundwater systems

The lower and bedrock groundwater systems are discussed as a single unit in this section because the two systems are hydraulically connected and have a similar flow gradient and direction (BNI 1990). Hydrographs of wells screened in the lower and bedrock groundwater systems show a definite seasonal variation in water levels. For the lower system, the water levels are highest in the summer [about 95.7 m (314 ft) above MSL] and lowest in the winter [about 94.8 m (311 ft) above MSL]. Water levels are about 1 m (3 ft) lower in the bedrock groundwater system. Seasonal fluctuation in water levels in 1990 was similar to that seen in 1989 (BNI 1990). Water levels in all of the wells except OW-4A appear to act similarly but do not appear to be related to precipitation events.



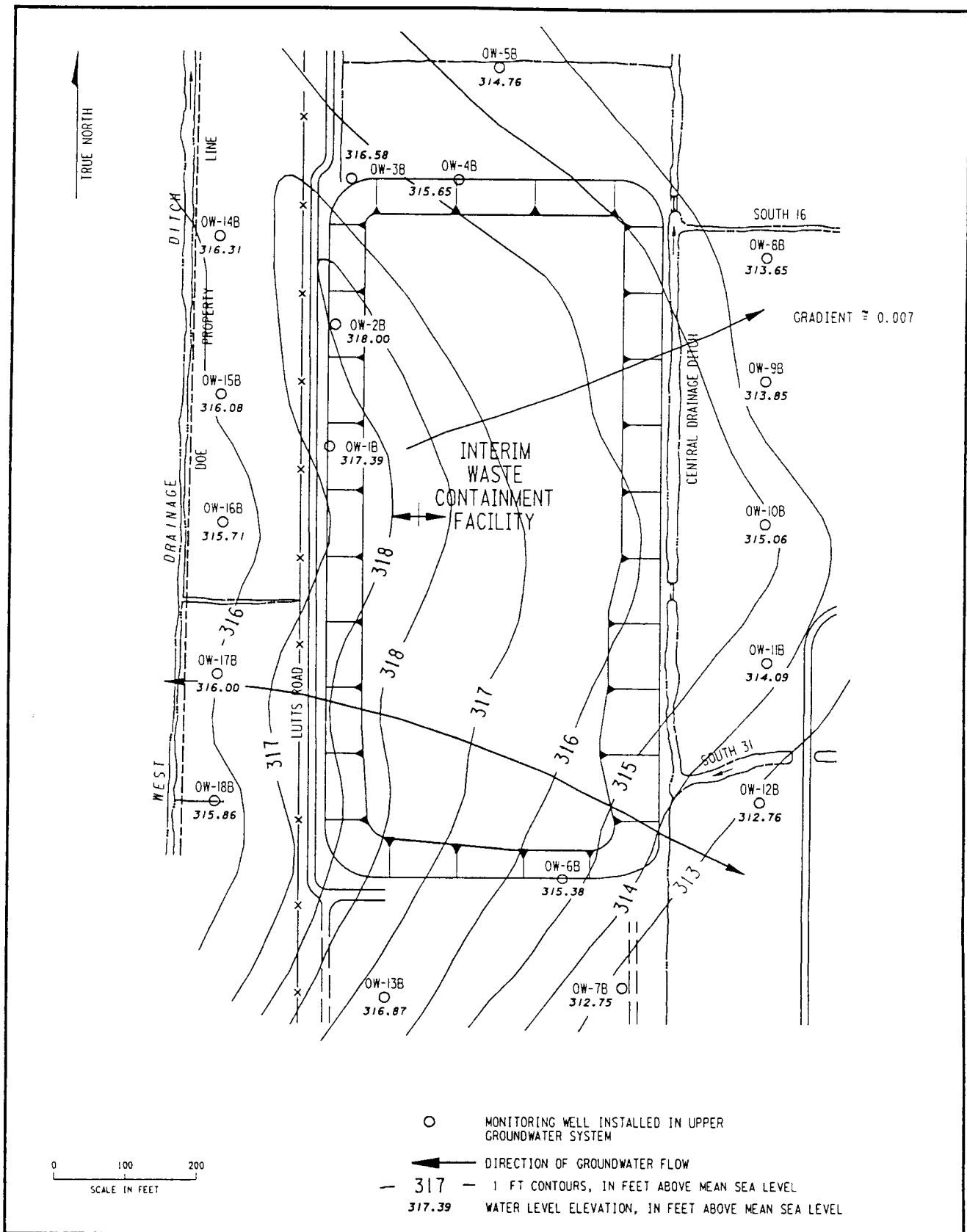
202F038.DGN F4

Figure 6-2
Potentiometric Map of Upper Groundwater System (2/2/90)



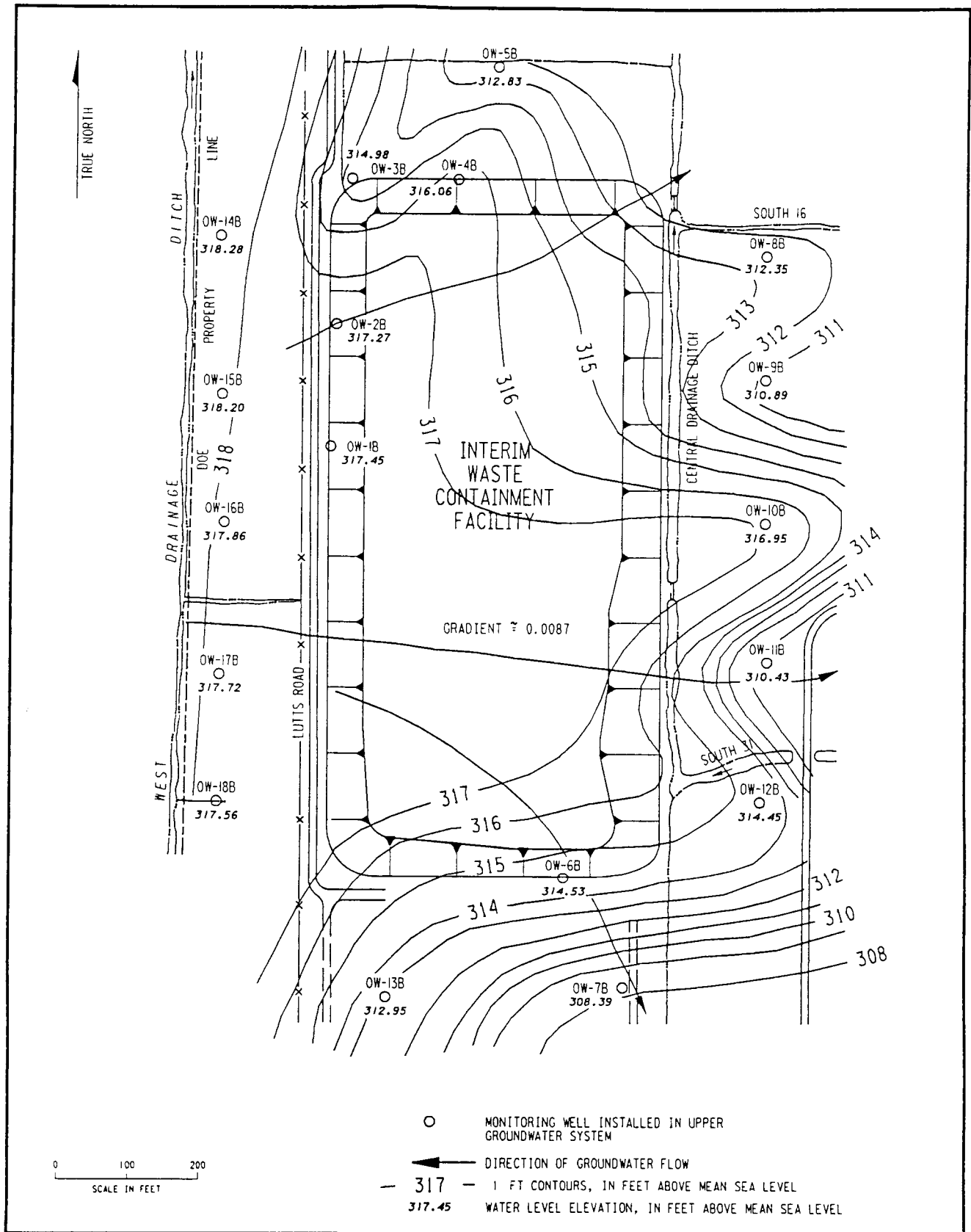
202F038.DGN F5

Figure 6-3
Potentiometric Map of Upper Groundwater System (3/5/90)



202F038.DGN F6

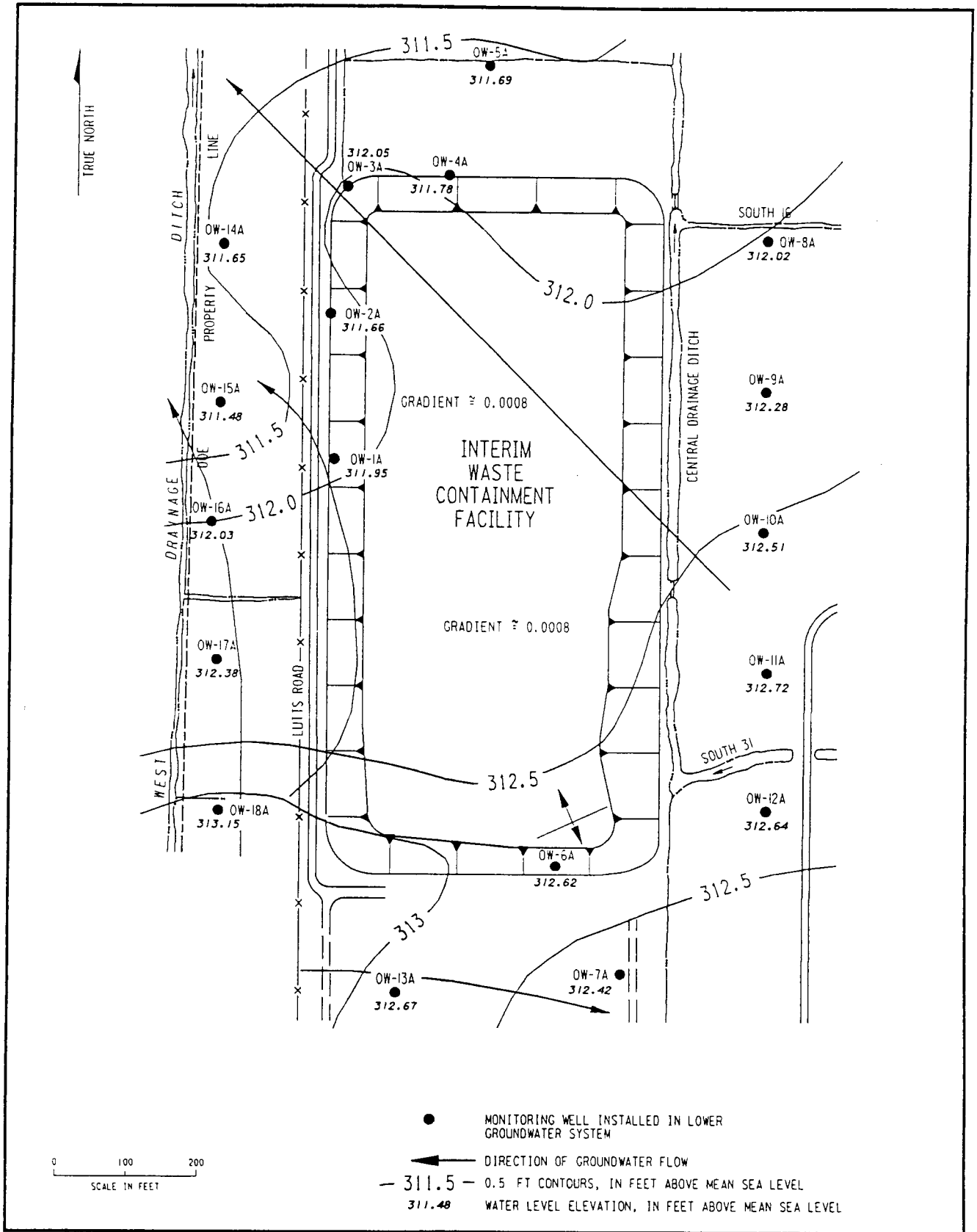
Figure 6-4
Potentiometric Map of Upper Groundwater System (6/12/90)



202F 038.DGN F7

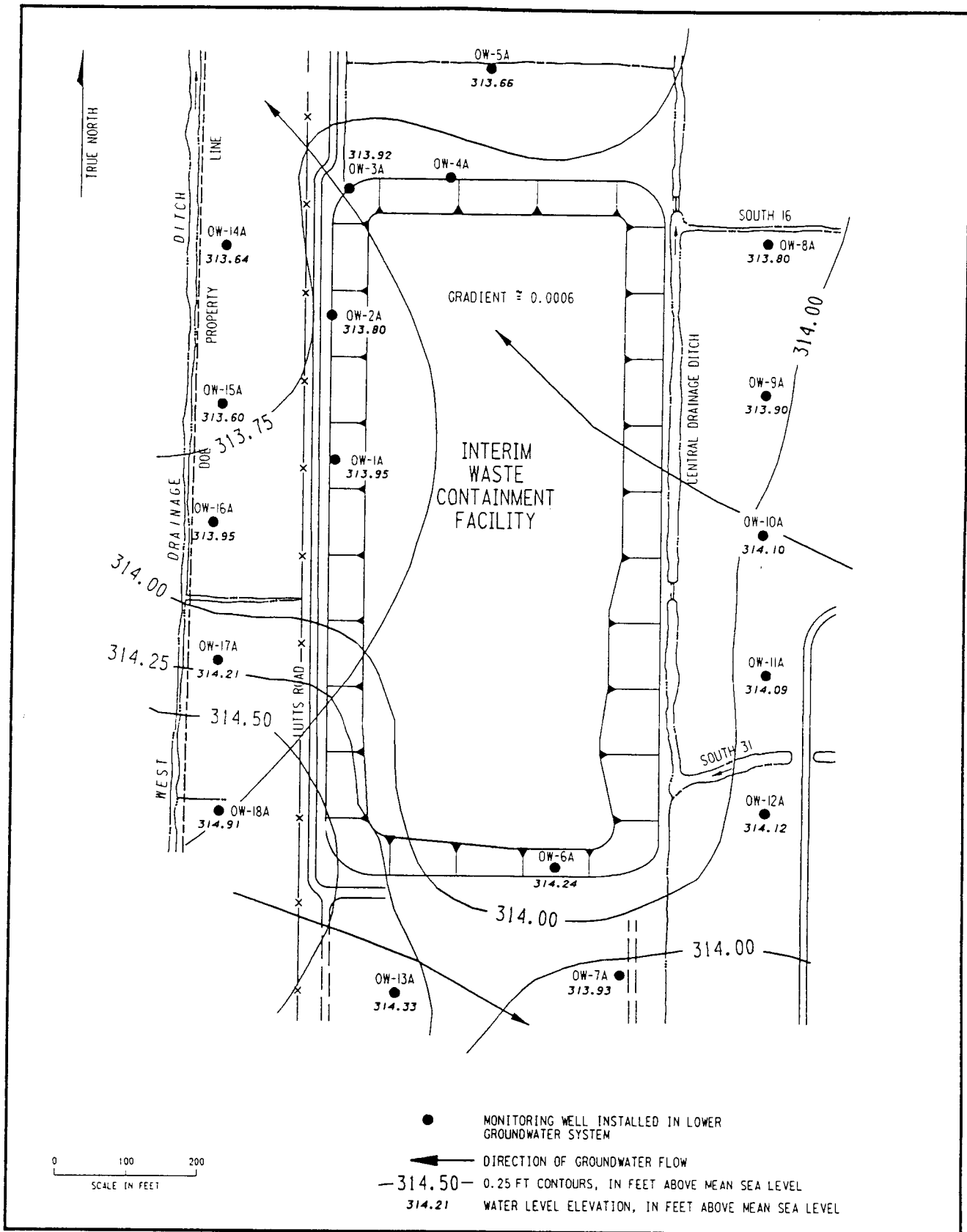
Figure 6-5
Potentiometric Map of Upper Groundwater System (12/4/90)

The slope and flow direction of the lower and bedrock groundwater systems were determined from potentiometric surface maps (Figures 6-6, 6-7, 6-8, and 6-9). The dates plotted were representative of spring, summer, and winter. The general flow pattern is to the northwest, as in 1989 (BNI 1990). However, some of the maps show a southeast flow below the southeastern corner of the pile. This represents early stages of the influence of dewatering at the Modern Disposal landfill southeast of NFSS. The effect of the dewatering operations is more pronounced in the upper groundwater system.



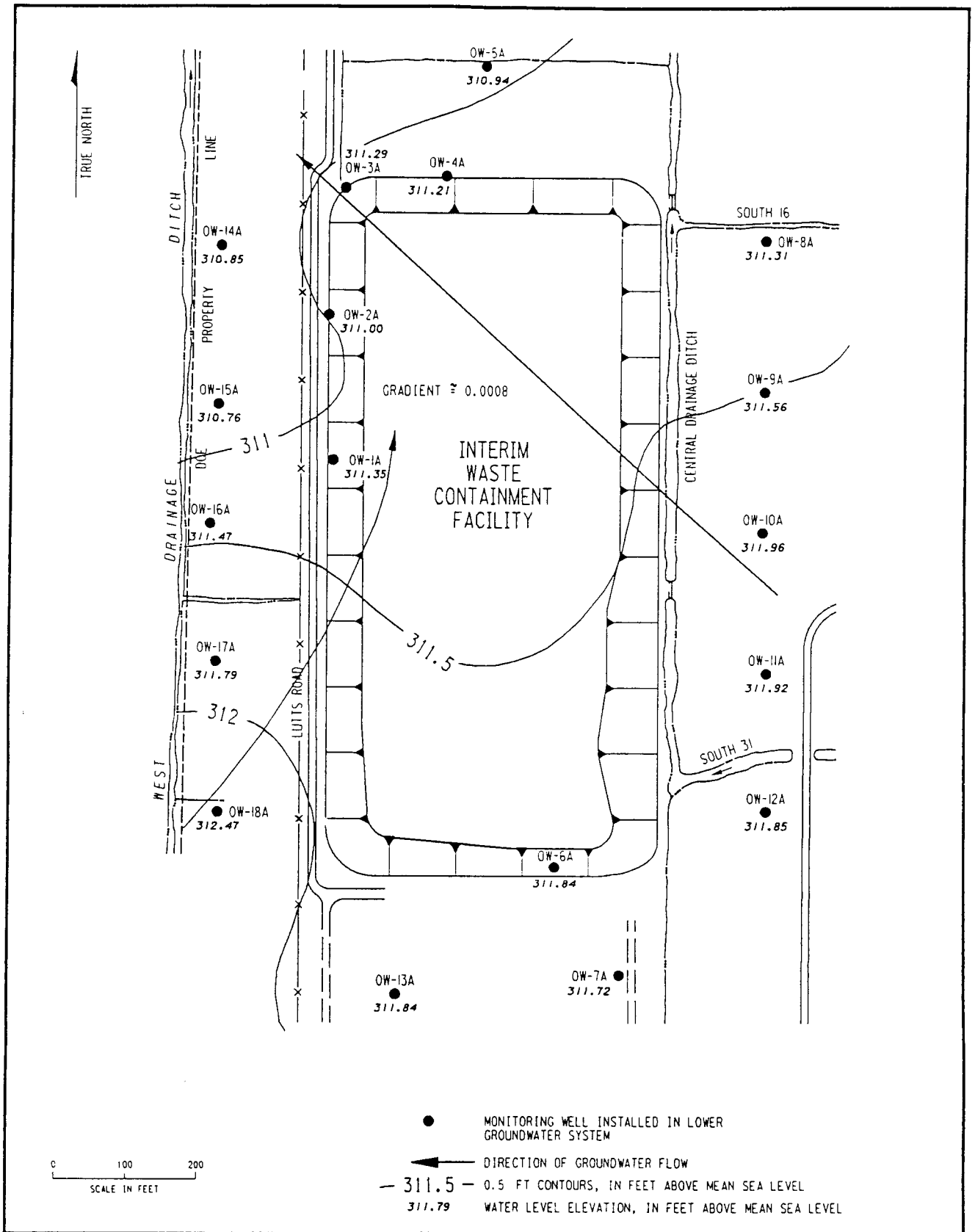
202F033.DGN F5

Figure 6-7
Potentiometric Map of Lower Groundwater System (3/5/90)



202F033.DGN F6

Figure 6-8
Potentiometric Map of Lower Groundwater System (6/12/90)



202F033.DGN F7

Figure 6-9
Potentiometric Map of Lower Groundwater System (12/4/90)

7.0 QUALITY ASSURANCE

A comprehensive quality assurance (QA) program involving sampling, data management, and analysis is maintained to ensure that the data reported are representative of actual concentrations in the environment. The QA program meets the requirements of DOE Order 5700.6B and ANSI/ASME NQA-1.

QA sampling requirements are ensured through the following:

- Samples at all locations are collected using established procedures as outlined in the FUSRAP Integrated Environmental Monitoring Instruction Guide, 191-00-IG-003
- The sampling program design provides for trip blanks, matrix spike and spike duplicates, field blanks (daily), and quality control (QC) duplicate sampling (minimum of 1 in 20)
- Chain-of-custody procedures are performed to maintain traceability of samples and corresponding analytical results

Data management QA is achieved through:

- Completion and recording of parameter-specific data review checklists for each analysis report
- Use of calculation sheets for documenting computations
- Double checking and concurrence on calculations
 - By the originator
 - By an independent, equally qualified second party
- Report preparation and presentations

System QA audits are conducted by Bechtel National, Inc. (BNI) FUSRAP project QA personnel to verify adherence to laboratory

procedures and to evaluate the appropriateness and effectiveness of the procedures. Audit team leaders and auditors are trained and certified in accordance with project procedures. Technical specialists participate as auditors under the direction of the audit team leader when warranted by the nature of the activities being audited. Audit reports are prepared for each audit conducted, and audit findings that require corrective action and followup are documented, tracked, and resolved, as verified by the project QA supervisor.

Routine radioanalyses are performed under subcontract by Thermo Analytical/Eberline (TMA/E), Albuquerque, New Mexico. This laboratory participates in the collaborative testing and interlaboratory comparison program with EPA at Las Vegas, Nevada. In this program, samples of various environmental media (water, milk, air filters, and soil) containing one or more radionuclides in known amounts are prepared and distributed to participating laboratories. After analysis, results are forwarded to EPA for comparison with known values and with the results from other laboratories. This program enables the laboratory to regularly evaluate the accuracy of its analyses and take corrective action, if needed. Table 7-1 summarizes results of the comparison studies for water samples. TMA/E also participates in the DOE Environmental Measurements Laboratory interlaboratory quality assessment program. This program consists of receiving and analyzing environmental samples (air filters, water, and soil) on a quarterly basis for specific radiochemical analyses (Table 7-2).

Interlaboratory comparison of the TETLD results is provided by participation in the International Environmental Dosimeter Project sponsored jointly by DOE, EPA, and the Nuclear Regulatory Commission. Additionally, in 1990 TMA/E successfully completed the analytical requirements for the DOE laboratory accreditation program for radiation monitoring devices.

Chemical analyses are performed under subcontract by Weston Analytical Laboratory, Lionsville, Pennsylvania. Weston's standard practices manual has been reviewed and accepted by BNI. Weston maintains an internal QA program and is audited by BNI FUSRAP

TABLE 7-1
 SUMMARY COMPARISON OF WATER SAMPLE RESULTS^{a,b}
 (EPA and TMA/E)

Analysis and Sample Date	Value (pCi/L) ^c		Ratio (TMA/E:EPA) ^d
	EPA	TMA/E	
<u>Alpha</u>			
1/90	12.0 ± 5.0	9.33 ± 1.5	0.78
4/90	90 ± 12.0	96 ± 12	1.07
5/90	22.0 ± 6.0	26.3 ± 2.3	1.20
9/90	10.0 ± 5.0	11.0 ± 1.0	1.10
<u>Beta</u>			
1/90	12.0 ± 5.0	11.7 ± 2.1	0.98
4/90	52.0 ± 5.0	46.0 ± 6.0	0.88
5/90	15.0 ± 5.0	15.0 ± 1.0	1.0
9/90	10.0 ± 5.0	11.0 ± 1.0	1.10
<u>Ra-226</u>			
3/90	4.9 ± 0.7	6.1 ± 0.4	1.24
4/90	5.0 ± 0.8	2.8 ± 0.1	0.56
7/90	12.1 ± 1.8	10.1 ± 0.1	0.84
9/90	12.1 ± 1.8	10.1 ± 0.1	0.84
<u>U (Natural)</u>			
3/90	4.0 ± 6.0	4.0 ± 0.0	1.0
4/90	20.0 ± 6.0	18.7 ± 1.5	0.94
7/90	20.8 ± 3.0	19.8 ± 1.1	0.95

^aResults from EPA Interlaboratory Comparison Program.

^bSamples were for comparison only and not site-specific.

^c1 pCi/L is equivalent to 0.037 Bq/L.

^dThis ratio can be used to determine the accuracy of TMA/E's analytical procedures.

TABLE 7-2
 SUMMARY COMPARISON OF AIR, SOIL, AND WATER SAMPLE RESULTS^{a,b}
 (EML and TMA/E)

Sample Type	Analysis (09/07/90)	Value		Ratio (TMA/E:EML) ^c
		EML	TMA/E	
Air (Bq/fil)	U-234	0.013	0.022 ± 0.012	1.69
Air (Bq/fil)	U-238	0.013	0.021 ± 0.012	1.62
Soil (Bq/kg)	U-234	28.3	23.9 ± 1.1	0.85
Soil (Bq/kg)	U-238	27.3	23.4 ± 1.0	0.86
Water (Bq/L)	U-234	0.236	0.232 ± 0.019	0.98
Water (Bq/L)	U-238	0.244	0.250 ± 0.041	1.03

^aResults from Environmental Measurements Laboratory Interlaboratory Quality Assessment Program.

^bSamples were for comparison only and not site-specific.

^cThis ratio can be used to determine the accuracy of TMA/E's analytical procedures.

personnel on a semiannual basis. The internal QA program involves the following for inorganic chemical analyses:

- Initial calibration and calibration verification
- Continuing calibration verification
- Reagent blank analyses
- Matrix spike analyses
- Duplicate sample analyses
- Laboratory control sample analyses
- Interlaboratory QA/QC

For organic chemical analyses the QA program involves:

- Gas chromatography/mass spectrometry instrumentation for both volatile and semivolatile compound analysis
- Initial multilevel calibration for each Target Compound List (TCL) compound
- Matrix spike analyses
- Reagent blank analyses
- Interlaboratory QA/QC
- Continuing calibration for each TCL compound
- Addition of surrogate compounds to each sample and blanks for determining percent recovery information

Currently, Weston participates in drinking water, wastewater, and/or hazardous waste certification programs and is certified (or pending) in 45 such state programs. Continuing certification hinges on Weston's ability to pass regular performance evaluation testing.

Weston's QA program also includes an independent overview by its project QA coordinator.

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APPENDIX A
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 minimum, maximum, and average values are calculated for all quarters of data.

Minimums and maximums are derived by comparing sampling results and determining the lowest and highest for the year. An example is given below.

Thorium-230 Results (pCi/L)

Sampling Location	Quarter				Minimum Value	Maximum Value
	1	2	3	4		
1	13	7	12	5	5	13

Because 5 pCi/L is less than any other result, it is entered into the minimum value column; 13 pCi/L, the greatest result reported, is entered into the maximum value column.

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

Expected concentration ranges are calculated to provide a basis for trend analysis of the data. These expected ranges are calculated by taking the average of the annual average concentrations for the past five years (when possible) and calculating a standard deviation for these data. The lower expected range is calculated by subtracting two standard deviations from the average value, and the upper range is calculated by adding two standard deviations to the average values. An example of these calculations is shown below.

Thorium-230 Results (pCi/L)

Sampling Location	Year					Average Value	Standard Deviation
	1986	1987	1988	1989	1990		
1	10	5	14	8	5	8	4

The formula for calculation of the standard deviation of a sample x_1, \dots, x_n is:

$$S = \sqrt{S^2} = \sqrt{\frac{\sum (x_i - \bar{x})^2}{n - 1}}$$

- Where S = Standard deviation
- x_i = Individual values
- \bar{x} = Average of values
- n = Number of values

n	x_i	\bar{x}	$(x_i - \bar{x})$	$(x_i - \bar{x})^2$
1	10	8.4	1.6	2.6
2	5	8.4	-3.4	11.56
3	14	8.4	5.6	31.36
4	8	8.4	-0.4	0.16
5	5	8.4	-3.4	11.56

$$\sum (x_i - \bar{x})^2 = 57.24$$

$$s = \sqrt{\frac{57.24}{5 - 1}} = \sqrt{\frac{57.24}{4}} = \sqrt{14.31} = 3.78,$$

which rounds to 4 because there is only one significant figure.

The calculation for the expected ranges for this example is shown below.

Lower expected range: $8 - 2(4) = 0$

Upper expected range: $8 + 2(4) = 20$ (rounded to one significant figure)

Annual average values for the current year are compared with these ranges to indicate a possible anomaly or trend. If a discernible trend is found from this comparison, the data are presented in the appropriate section of the report.

APPENDIX B
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 by 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 (the dose rate decrease proportionally to the inverse square of the distance from the source) 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 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 or 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-230, 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 B-1 lists the pertinent radionuclides, their half-lives, and dose conversion factors for ingestion.

DOSE CALCULATION METHOD

Direct Exposure

As previously indicated, direct exposure is only important in calculating the dose to the hypothetical maximally exposed individual. The dose from direct gamma exposure is determined by using data collected through the 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 1.6 m (5 ft) above the ground. For the purposes of this report, it is assumed that the maximally exposed individual works 40 hours per

TABLE B-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	4.47E+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

^aSource: Radiological Health Handbook (HEW 1970).

^bSource: Federal Guidance Report No. 11, Limiting Values of Radionuclide Intake and Air Concentration 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.

week at the Modern Disposal landfill southeast of the site at an average distance of 10 m (30 ft) from the site. This scenario was used because the nearest residence is 0.8 km (0.5 mi) from the site.

The dose to the maximally exposed individual can be determined by assuming that the individual is exposed to a line source located along the NFSS/landfill fenceline. Because the average exposure rate is known from the TETLD program for a distance of 1.6 m (5 ft) from the fenceline, the exposure at 10 m (30 ft) from the fenceline can be calculated by using the following equation (Cember 1983).

$$\text{Exposure at 10 m} = (\text{Exposure at 1.6 m}) \times \frac{h_1}{h_2} \times \frac{\tan^{-1}(L/h_2)}{\tan^{-1}(L/h_1)}$$

Where h_1 = TETLD distance from the fenceline [1.6 m (5 ft)]

h_2 = Maximally exposed individual's distance from the fenceline [10 m (30 ft)]

L = half of the length of the NFSS/landfill fenceline [700 m (2,100 ft)]

The exposure rate at 1.6 m (5 ft) can be calculated by taking the average of the results from the four detectors along this portion of the fenceline (4, 5, 20, and 35). The average exposure rate for these detectors was 4.25 mR/yr. Using the formula above, the exposure rate at 10 m (30 ft) is approximately 0.4 mR/yr. Because 1 mR/yr is approximately equal to 1 mrem/yr, the resulting dose would be 0.4 mrem/yr, assuming 24-h continuous residence. However, this is the dose for the entire year; to calculate the dose to a worker (8 h/day), the following equation must be used.

$$\text{Dose} = (\text{Dose at 10 m}) \times \frac{(40 \text{ h/wk})}{(7 \text{ days/wk} \times 24 \text{ h/day})} = 0.1 \text{ mrem/yr}$$

Therefore, the dose from direct gamma radiation to the hypothetical maximally exposed individual is 0.1 mrem/yr (0.001 mSv/yr).

This exposure scenario should provide a very conservative estimate of the dose from direct gamma exposure to the hypothetical maximally exposed individual.

Surface Water

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 intake. Thus, the dose to the maximally exposed 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 at the site
 F_i = Average flow of surface water at the 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 maximally exposed individual.

The approach outlined above should provide a very conservative dose calculation for the surface water pathway because it does not account for radionuclides settling out or for any municipal water treatment.

Groundwater

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 concentrations 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 maximally exposed 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 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 the population intake point is usually different from that of the maximally exposed individual.

The approach given above should provide a conservative dose calculation for the groundwater pathway because it does not account for any water treatment.

Atmospheric

The dose to the hypothetical maximally exposed individual from particulate radionuclides transported via the atmospheric pathway is calculated using EPA's computer model AIRDOS. Doses to the general public via this pathway are also calculated using AIRDOS results. 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 two areas: the interim storage piles and the remainder of the site. Assumptions used in the calculation model include: (1) an assumed particle size of 0.05 mm, (2) the pile cover is modeled as the contamination being 99 percent covered by vegetation, and (3) the site had very few mechanical disturbances per month.

APPENDIX C
ENVIRONMENTAL STANDARDS

ENVIRONMENTAL STANDARDS

The DOE long-term radiation protection standard of 100 mrem/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 using 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 GUIDELINES

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 guidelines (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 ($\mu\text{Ci/ml}$)	Inhaled Air DCGs ^b		
			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 ^c	3E-9	3E-9	--	--	3E-9
" 220 ^c	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.

^bInhaled 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).

^cDOE 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	
Total uranium (site-specific)	90 pCi/g for any 15-cm-thick soil layer
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.

POTENTIAL STATE ARARs

The following New York laws and regulations have been identified as potential ARARs for the management of NFSS. Where differences between state and federal requirements exist, the more restrictive requirements shall apply.

<u>Potential ARAR</u>	<u>Requirement</u>
New York Solid and Hazardous Waste Management Laws, New York Environmental Conservation Law (NYECL), Articles, 27, 71, and 72	Encourages development of economical projects and ensure protection of human health and the environment for the present and future collection, treatment, and management of solid and hazardous waste.
New York Hazardous Substances Bulk Storage Act 40 NYECL 672	Establishes legal requirements for all facilities storing hazardous substances.
New York Rules on Collection and Transport of Industrial Wastes, Title 6, New York Compilation of Rules and Regulations (NYCRR), Chapter 364	Establishes rules for collection, transport, and delivery of regulated waste.
New York General Hazardous Waste Management System Regulations, 6 NYCRR 370	Establishes general facility requirements for hazardous waste treatment, storage, and disposal facilities; similar to the federal RCRA regulations.
New York Identification of Hazardous Waste Regulation, 6 NYCRR 371	Identifies those solid wastes subject to regulation as hazardous waste.
New York Hazardous Waste Manifest System Regulations, 6 NYCRR 372	Establishes standards for generators; transporters; and treatment, storage, and disposal facilities for use of the manifest system and its recordkeeping requirements.

Potential ARAR

Requirement

New York Hazardous Waste Treatment, Storage and Disposal Facility Permitting Requirements, 6 NYCRR 373-1

Regulates and sets permit requirements for those hazardous waste management facilities that treat, store, or dispose of hazardous waste.

New York Final Status Standards for Owners and Operators of Hazardous Waste Treatment, Storage and Disposal Facilities, 6 NYCRR 373-2

Defines minimum state standards for acceptable management of hazardous waste.

New York Interim Status Standards for Owners and Operators of Hazardous Waste Facilities, 6 NYCRR 373-3

Establishes minimum state standards to define acceptable management of hazardous waste during interim status or until certification of final closure.

New York Standards for Managing Specific Hazardous Wastes and Hazardous Waste Management Facilities, 6 NYCRR 374

Contains requirements for generators and transporters of recyclable hazardous wastes identified by regulation.

New York Rules for Inactive Hazardous Waste Disposal Sites, 6 NYCRR 375

Provides for the administration of the Environmental Conservation Law, which implements inactive hazardous waste disposal site remedial programs.

New York Rules on Releases, Registration and Listing of Hazardous Substances, 6 NYCRR 595-7

Sets forth requirements for the reporting of releases, investigation, and corrective action for hazardous substance bulk storage facilities.

New York Wetlands Laws, 24 NYCRR 399

Sets forth legal requirements for preservation and protection of wetlands.

New York Environmental Conservation Law, Article 1

Sets out requirements, both procedural and substantive, to coordinate the environmental plans, functions, powers, and programs of the state to develop and manage its resources of water, land, and air to preserve them for present and future generations.

Potential ARAR

Requirement

New York Air Pollution Control Regulations, 6 NYCRR 200

Establishes rules for emissions of air pollutants; establishes permitting system and mandates procedures and control technologies for specific industries.

New York Environmental Quality Review Regulations 6 NYCRR 617

Contains provisions to implement to State Environmental Quality Review Act, which incorporates the consideration of environmental factors into the review and decision-making process of the state.

New York Ambient Air Quality Standards, 6 NYCRR 256

Promulgates air quality standards designed to protect the public from adverse health effects of air contamination.

New York Water Pollution Control Regulations, 6 NYCRR 608

Provides standards and a permitting system to prevent damage to the natural resources of the state.

New York Regulations on State Pollutant Discharge Elimination System 6 NYCRR 750

Promulgates regulations that prescribe procedures and standards for the State Pollutant Discharge Elimination System. These regulations include water quality standards and effluent limitations.

New York Water Classifications and Quality Standards, 10 NYCRR 609

Provides a use classification for all the waters of the state and sets forth standards of quality, effluent limitations, and criteria governing thermal discharges.

POTENTIAL FEDERAL ARARs

In addition to the federal regulations identified in Section 2.0, the following have been identified as potential ARARs.

Potential ARAR

Requirement

Occupational Safety and Health Administration General Industry Standards, 29 CFR 1910

Health and safety standards are established for hazardous waste operations, including limits for exposure to noise and certain hazardous materials.

Potential ARAR

Requirement

Occupational Safety and Health Administration Standards Hazardous Waste Operations and Emergency Response, 29 CFR 1910

General worker protection requirements are established, as are requirements for worker training and the development of emergency response plan and a safety and health program for employees. Procedures are established for hazardous waste operations, including decontamination of radioactive waste, shipping and transport, and container handling.

Health and Environmental Protection Standards for Uranium and Thorium Mill Tailings, 40 CFR 192

Contains limited permissible concentrations of radium, thorium, radon, and gamma radiation.

Radiation Protection for Occupational Workers, DOE Order 5480.11

Standards and program requirements are established for worker protection from ionizing radiation, including derived air concentration guides for inhalation and immersion. The basic dose limit of 100 mrem/yr also applies to any member of the public entering a controlled area.

Standards for Protection Against Radiation, 48 FR 20721

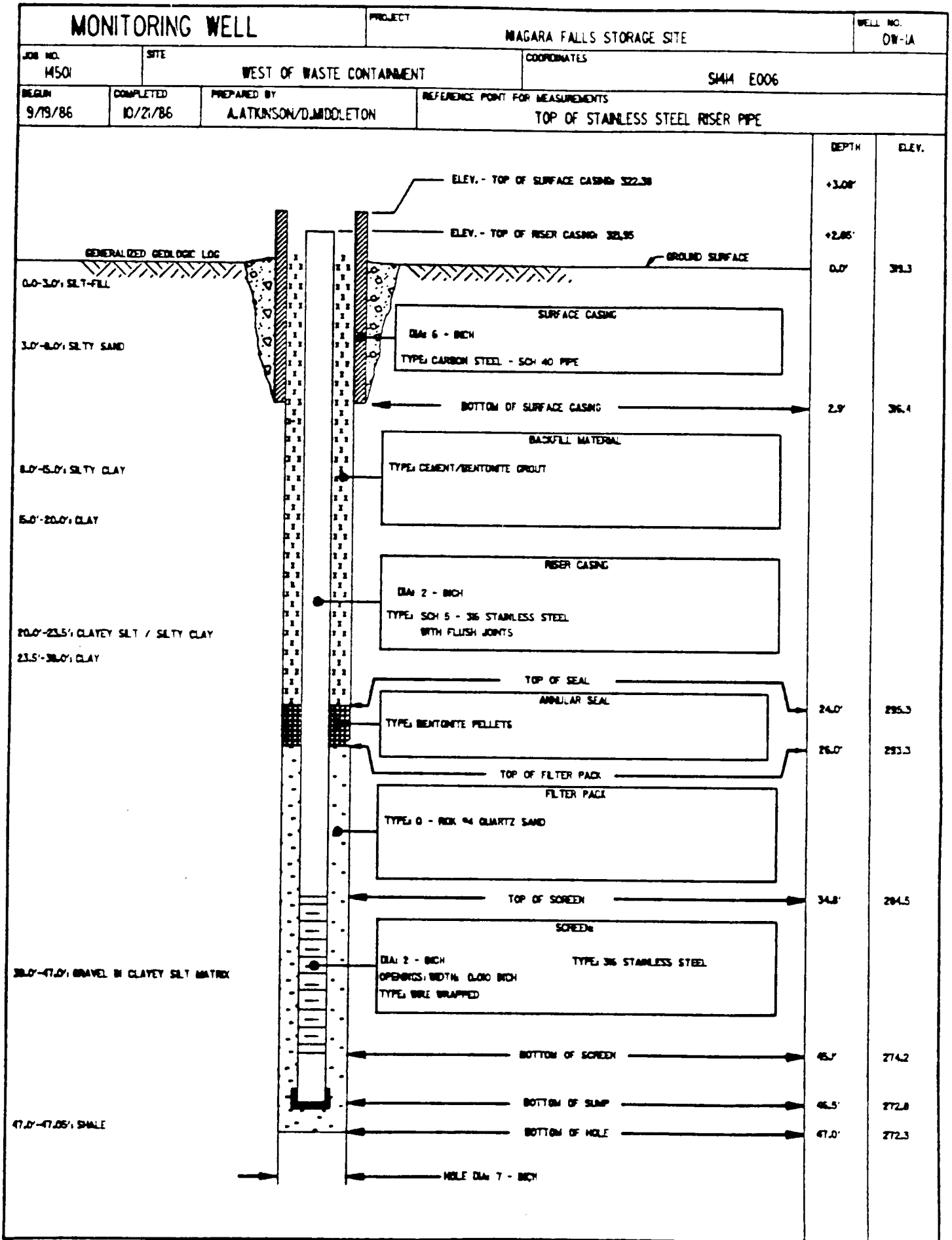
The standard for uranium-238 in inhaled air is $3E-12$ $\mu\text{Ci/ml}$ daily, $1E-12$ $\mu\text{Ci/ml}$ weekly; the standard for thorium-232 in inhaled air is $4E-15$ $\mu\text{Ci/ml}$ weekly and $8E-15$ $\mu\text{Ci/ml}$ yearly; the standard for thorium-230 in inhaled air is $2E-14$ $\mu\text{Ci/ml}$ yearly; and the standard for radium-226 in inhaled air is $9E-13$ $\mu\text{Ci/ml}$ weekly.

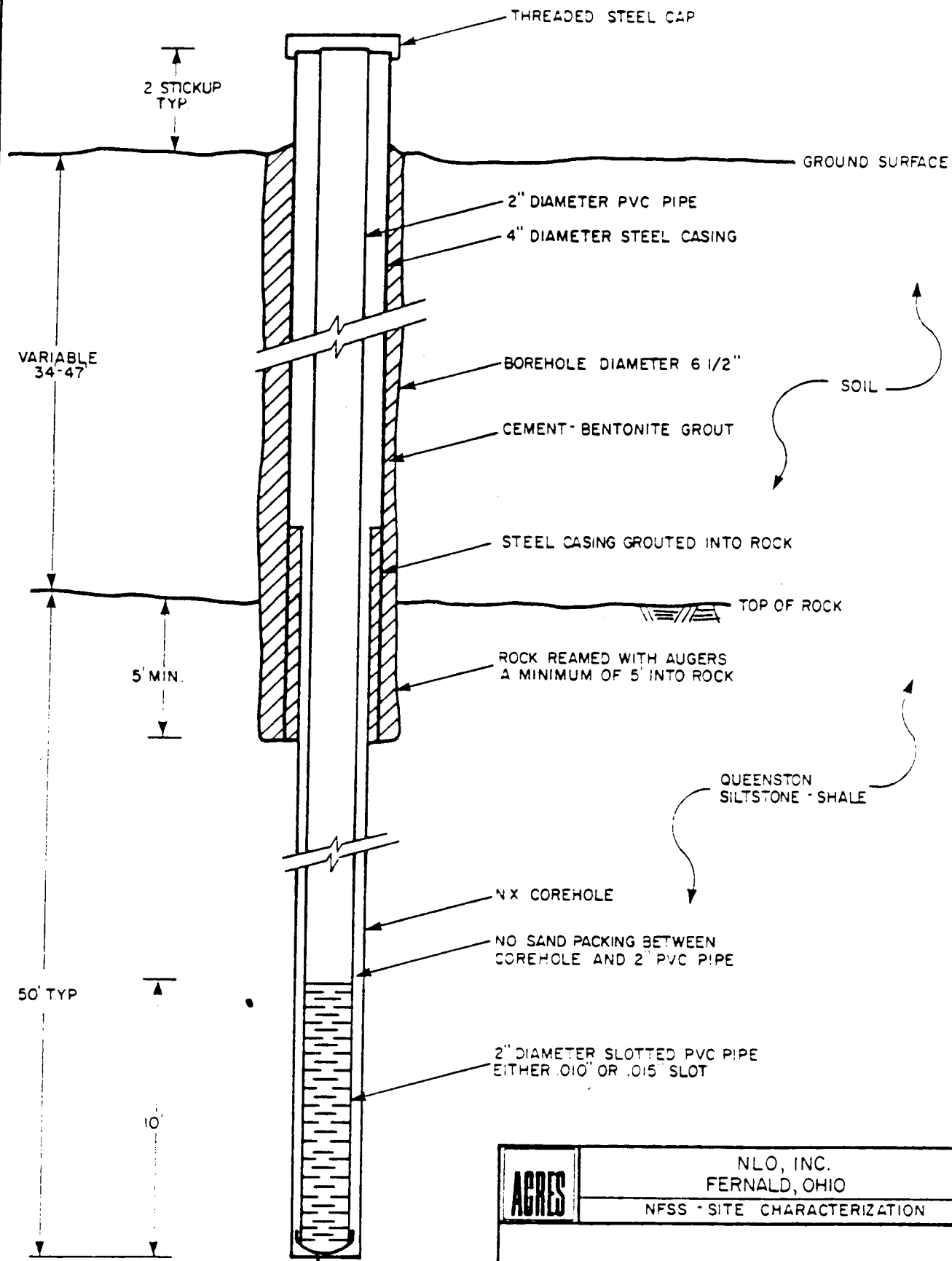
APPENDIX D
PARAMETERS FOR ANALYSIS

PARAMETERS FOR ANALYSIS AT NFSS, 1990

Medium	Parameter	Technique
Groundwater	Total uranium	Fluorometric
	Radium-226	Emanation
	Total organic halides (TOX)	Carbonaceous analyzer
	Total organic carbon (TOC)	Coulometric determination
	Total metals: aluminum, copper, iron, manganese, lead, vanadium	Inductively coupled plasma atomic emission spectrophotometry (ICPAES)
	Mercury	Atomic Absorption (AA) Spectrophotometry
	Specific conductance	Electrometric
	pH	Electrometric
Surface Water	Total uranium	Fluorometric
	Radium-226	Emanation
Sediment	Total uranium	Alpha spectrometry
	Radium-226	Gamma spectrometry
Air	Radon-222	Track-etch
	External gamma radiation	Thermoluminescence

APPENDIX E
SAMPLE OBSERVATION WELL CONSTRUCTION LOGS
AND HYDROGRAPHS SHOWING WATER LEVEL ELEVATIONS





AGRES	NLO, INC. FERNALD, OHIO
	NFSS - SITE CHARACTERIZATION
ROCK MONITORING WELL DESIGN	
<i>[Signature]</i>	SEPTEMBER 30, 198
P6254 07	DATE:



OBSERVATION WELL

PROJECT

FUSRAP/Niagara Falls Storage Site

WELL NO

A-23A

JOB NO
14501

SITE
NFSS

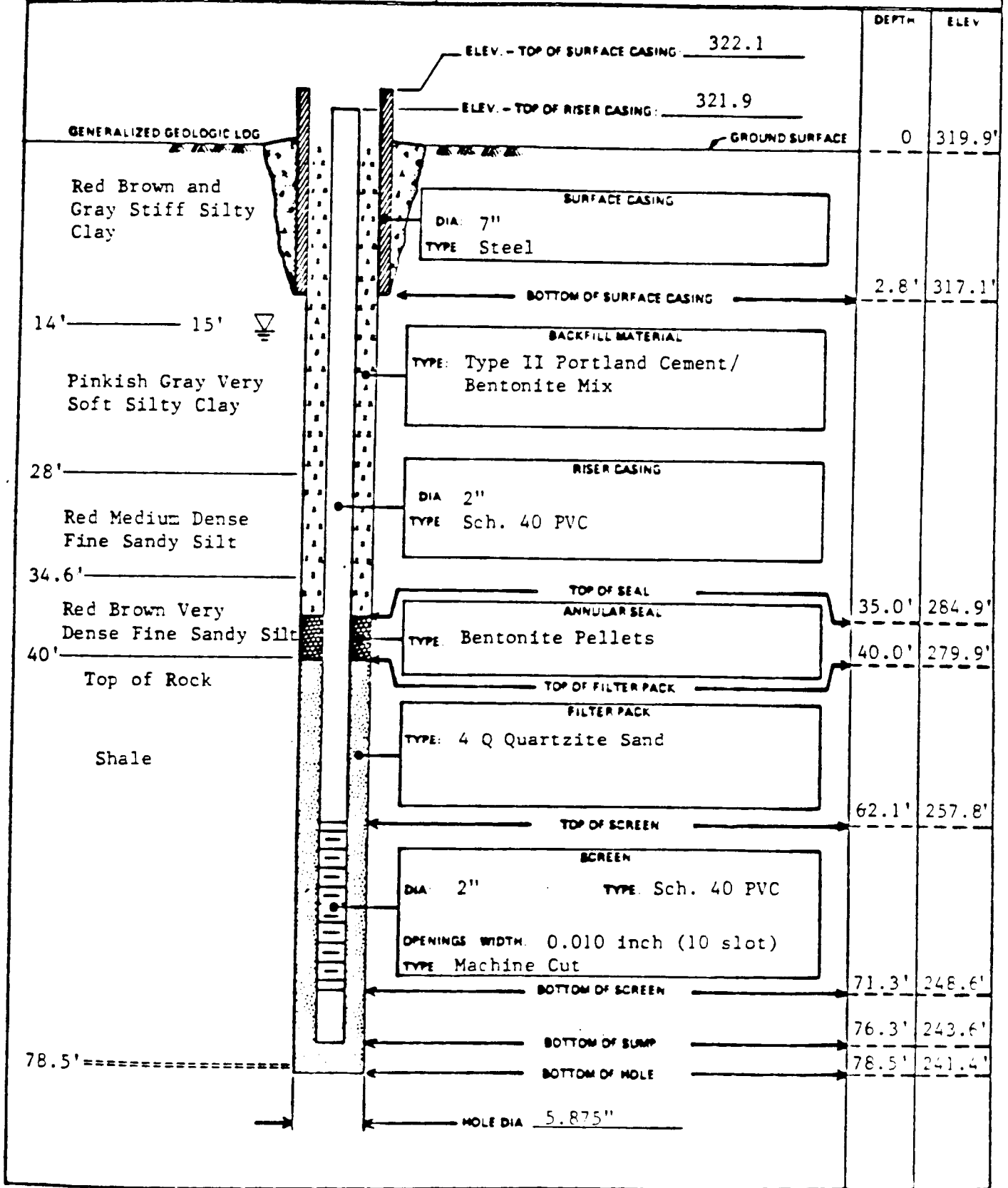
COORDINATES
S 1700.1 E 374.1

BEGUN
2/21/83

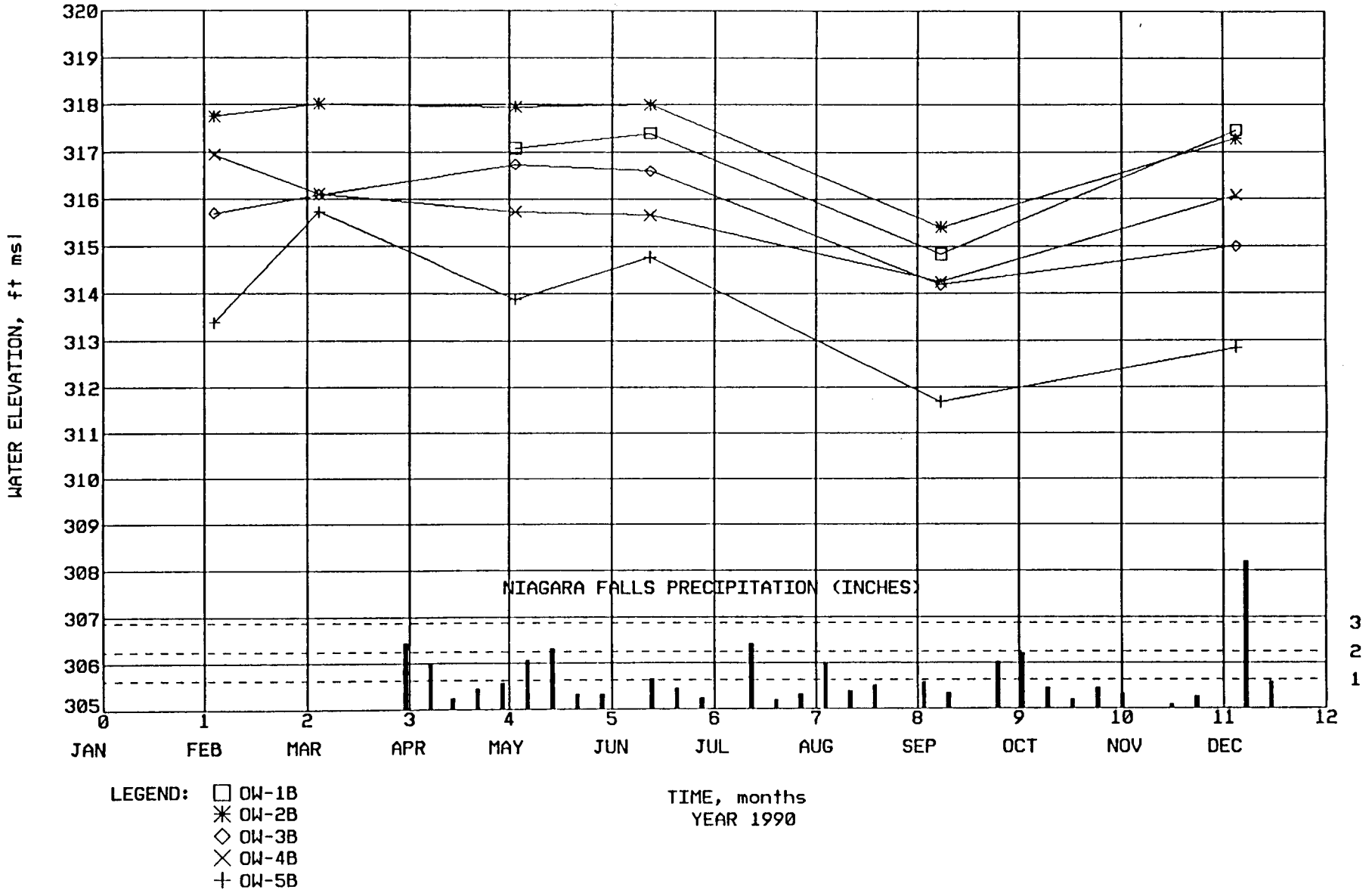
COMPLETED
3/2/83

PREPARED BY
D. Middleton

REFERENCE POINT FOR MEASUREMENTS
Ground Surface

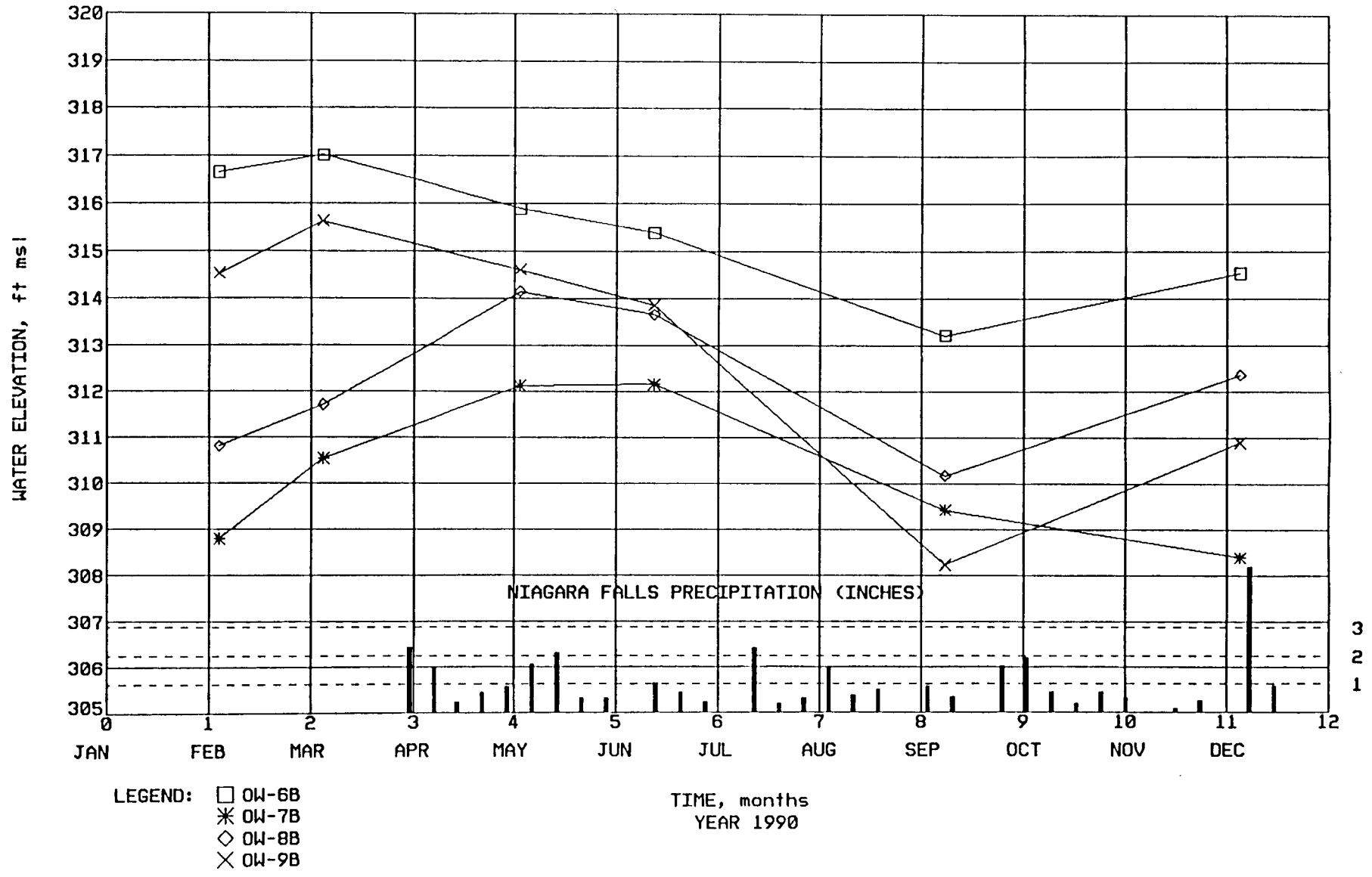


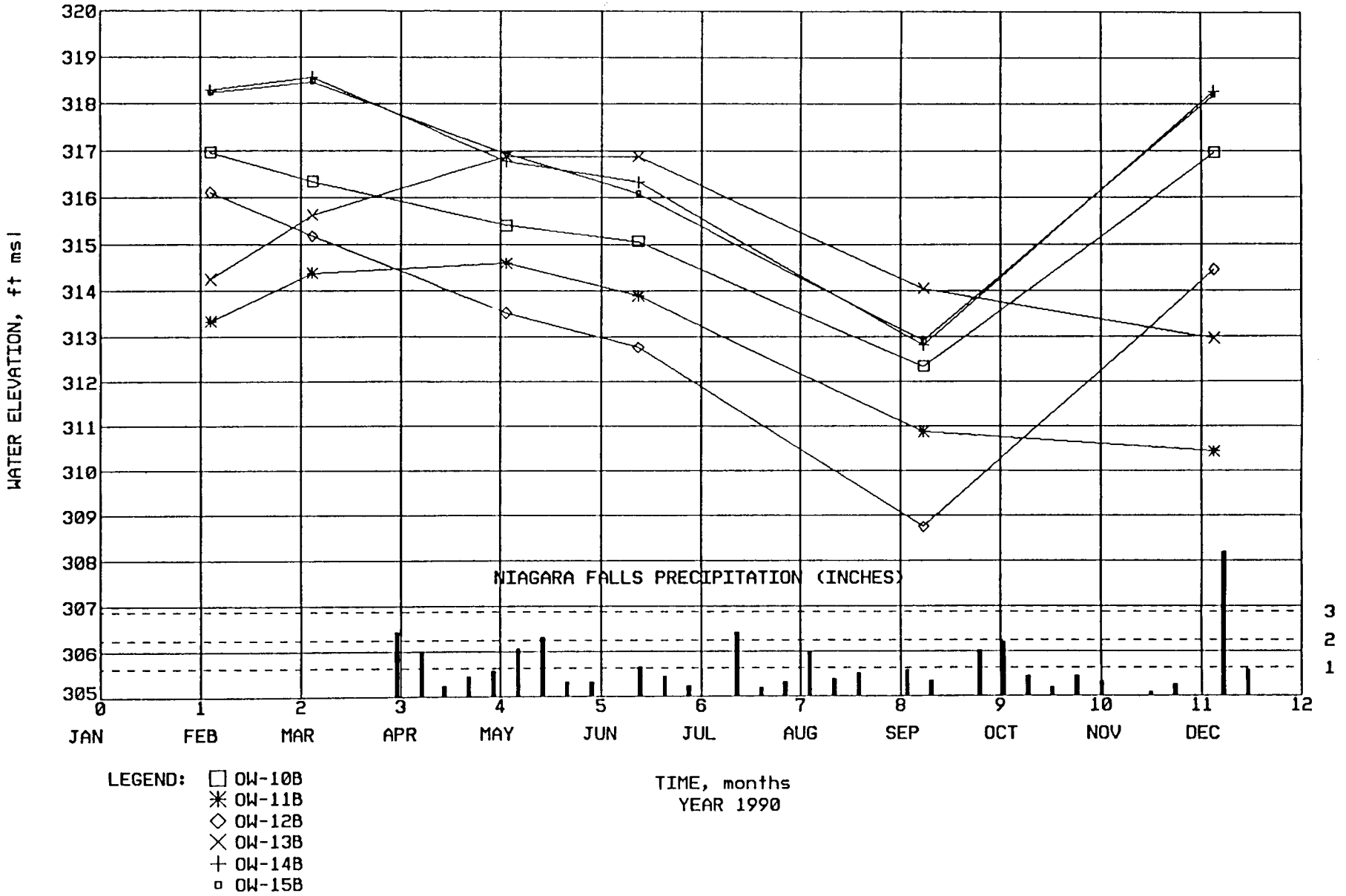
E-4



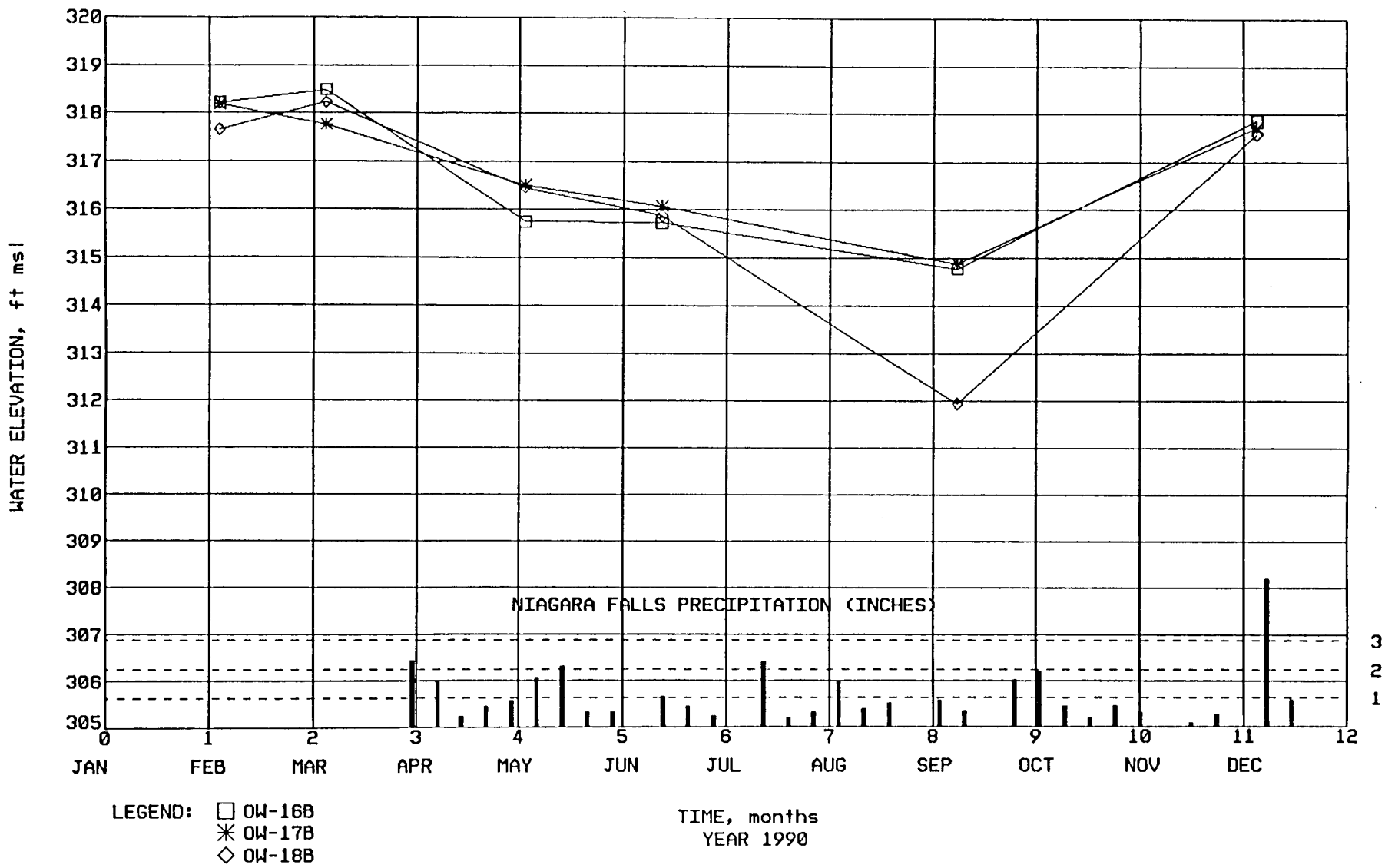
3
2
1

E-5

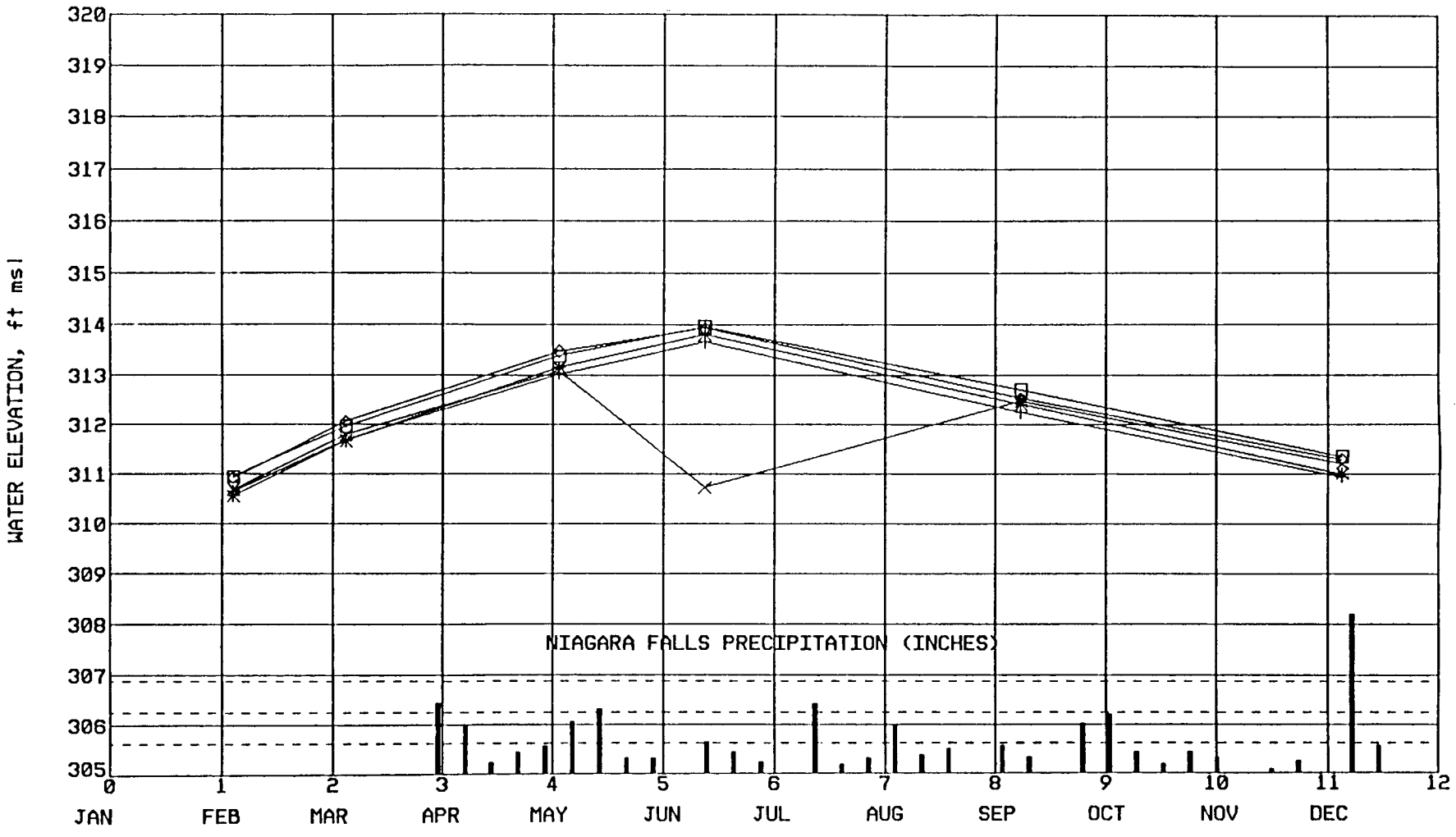




E-7



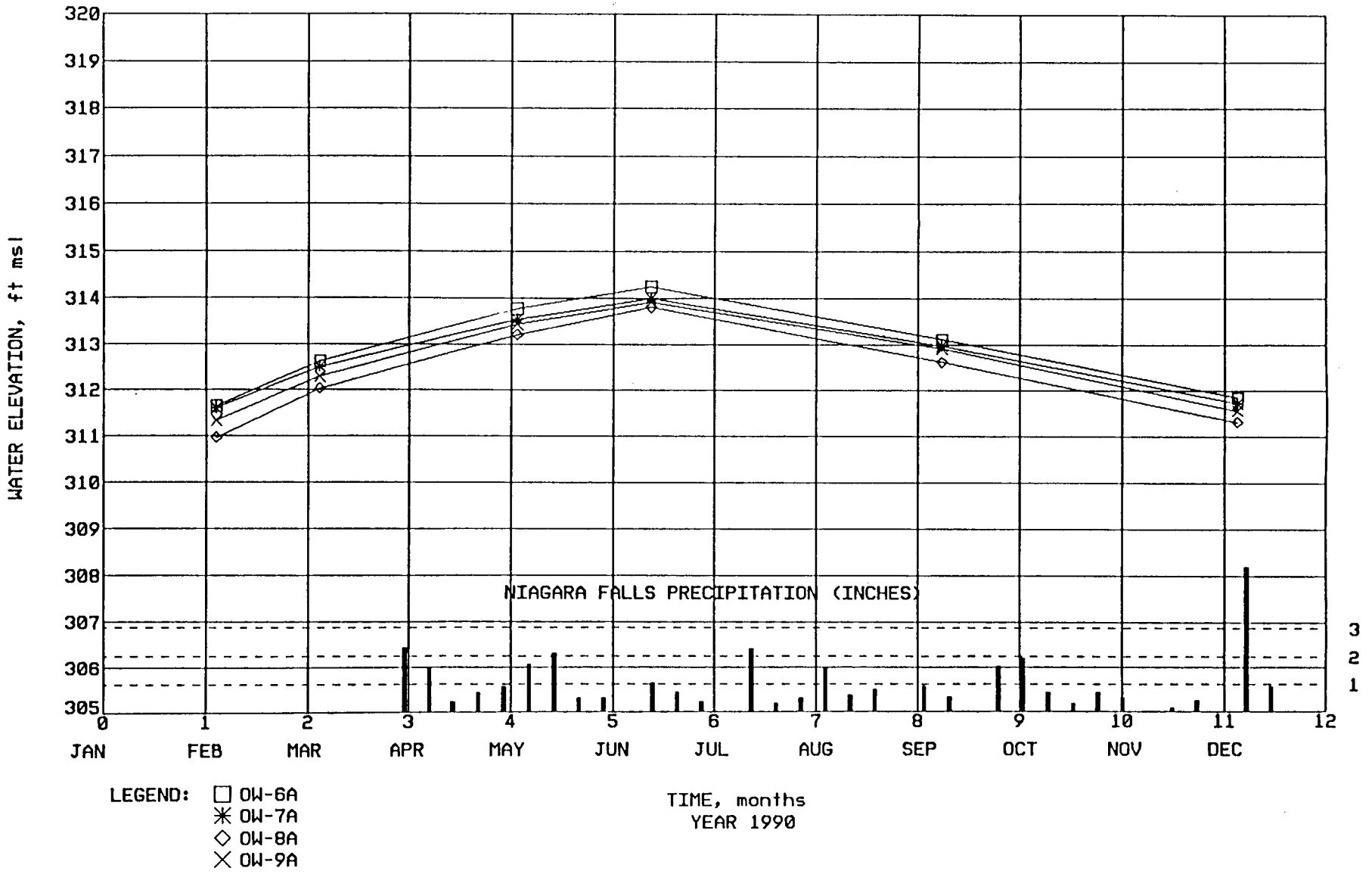
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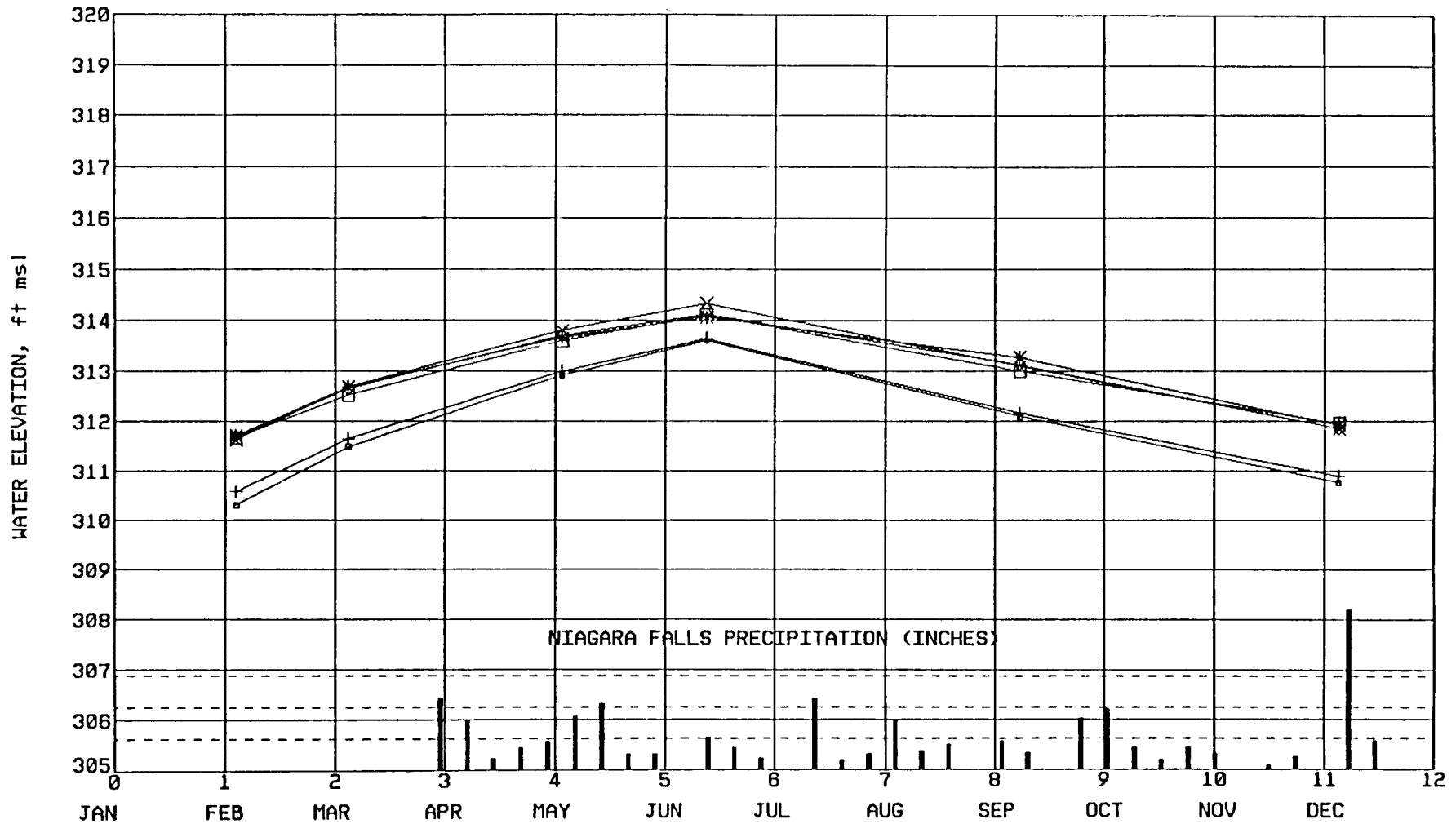
LEGEND: □ OW-1A
* OW-2A
◇ OW-3A
× OW-4A
+ OW-5A

TIME, months
YEAR 1990

3
2
1



E-10

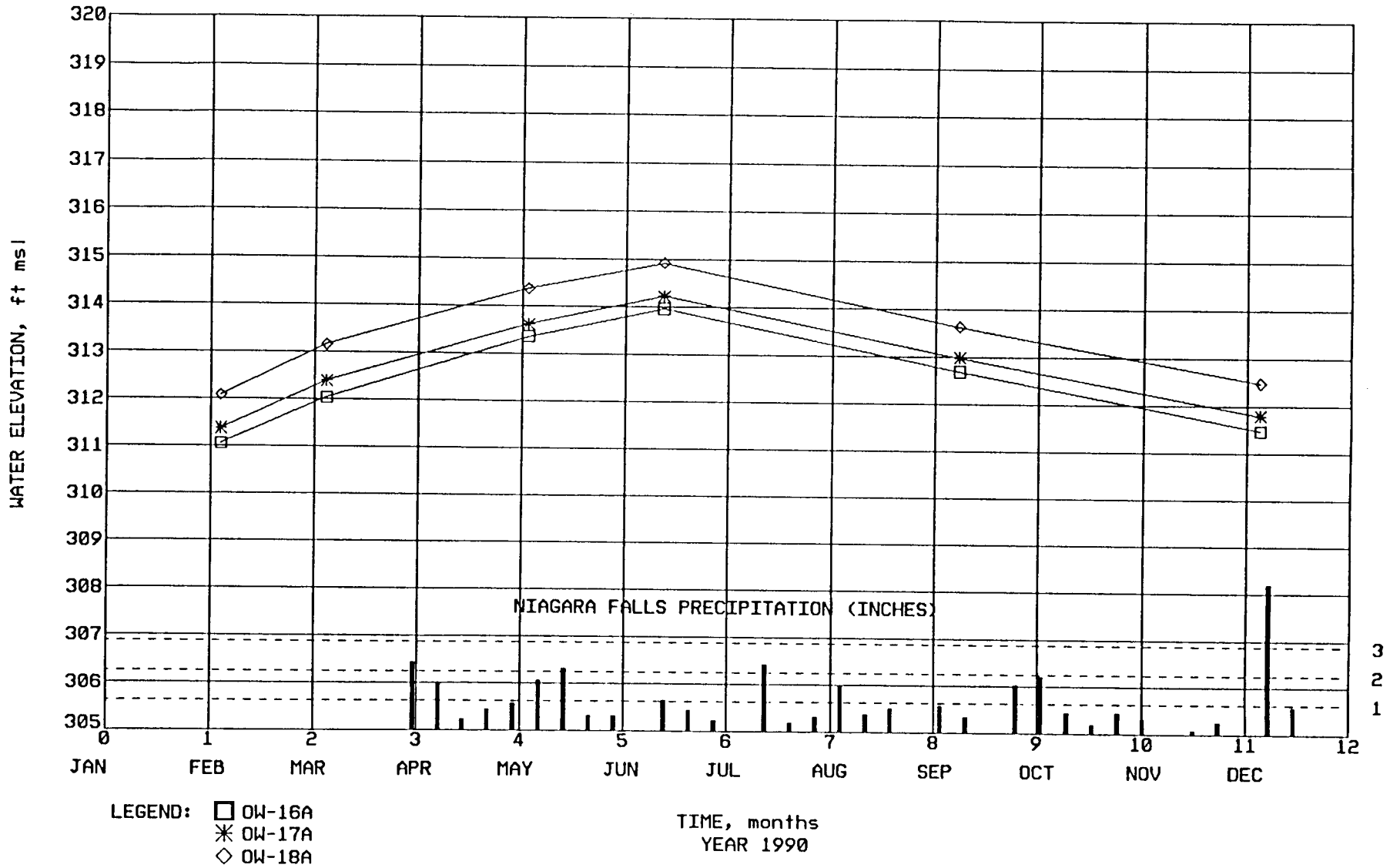


LEGEND: □ OW-10A
* OW-11A
◇ OW-12A
× OW-13A
+ OW-14A
□ OW-15A

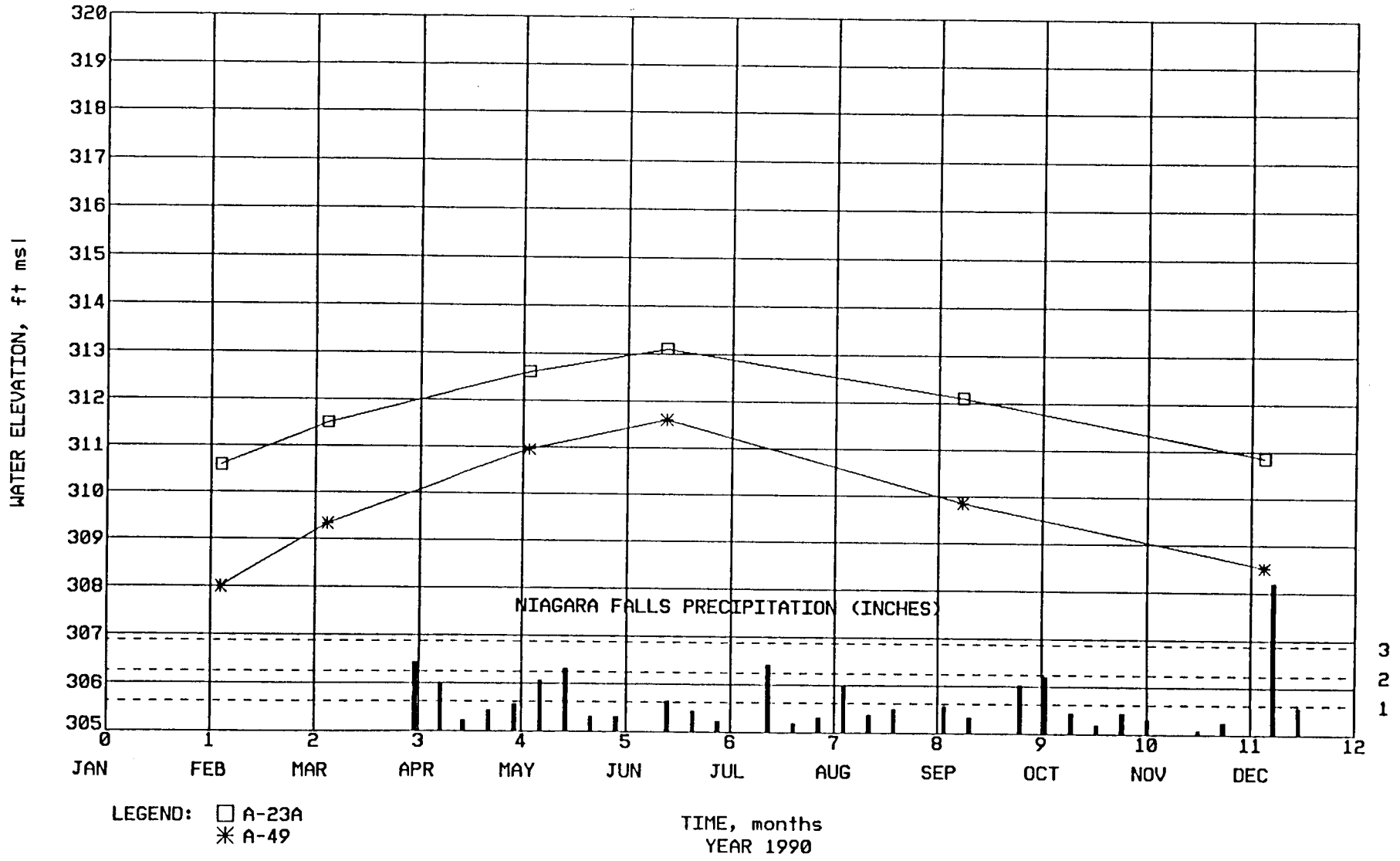
TIME, months
YEAR 1990

3
2
1

E-11



E-12

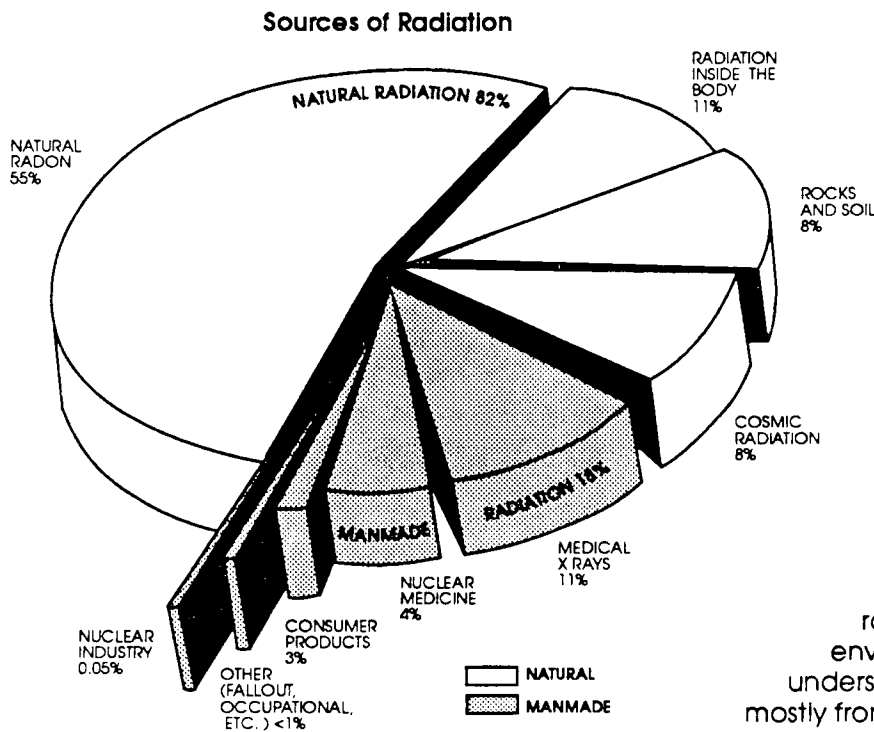


APPENDIX F
RADIATION IN THE ENVIRONMENT

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

Cosmic Radiation

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

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

Terrestrial Radiation

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

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

Buildings

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

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

Radon

Radon levels in buildings vary, depending on geographic location, from 0.1 to 200 pCi/liter. Average Indoor Radon Level 1.5 pCi/liter
Occupational Working Limit 100.0 pCi/liter

RADIATION IN THE ENVIRONMENT

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

mrem = millirem
pCi = picocurie

Food

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

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

Medical Treatment

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

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

Consumer Goods

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

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

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

Porcelain Dentures

(uranium)	1,500 mrem/year
Radoluminescent 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

References

- Effect of Ionizing Radiation on Human Health, The Arthur C. Upton. New York University Medical Center. Atomic Industrial Forum, 1984.
 Effects on Populations of Exposure to Low Levels of Ionizing Radiation: 1980 Committee on the Biological Effects of Ionizing Radiation. National Academy Press, 1984.
 Ionizing Radiation Exposure of the Population of the United States: Report Number 93. National Council on Radiation Protection and Measurements, 1987.
 Radiation Exposure of the U.S. Population from Consumer Products and Miscellaneous Sources: Report Number 95. National Council on Radiation Protection and Measurements, 1987.
 Radiation in Medicine and Industry. A.P. Jacobson and G.P. Sakolovsky, 1980
 Radioactivity in Consumer Products. U.S. Nuclear Regulatory Commission, 1978

PERSPECTIVE: How Big is a Picocurie?

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

The basis for the curie is the radioactivity of one gram of radium. Radium decays at a rate of about 2.2 trillion disintegrations (2.2×10^{12}) per minute. A *picocurie* is one trillionth of a curie. Thus, a picocurie represents 2.2 disintegrations per minute.

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

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

Millicurie =	$\frac{1}{1,000}$ (one thousandth) of a curie
Microcurie =	$\frac{1}{1,000,000}$ (one millionth) of a curie
Nanocurie =	$\frac{1}{1,000,000,000}$ (one billionth) of a curie
Picocurie =	$\frac{1}{1,000,000,000,000}$ (one trillionth) of a curie

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

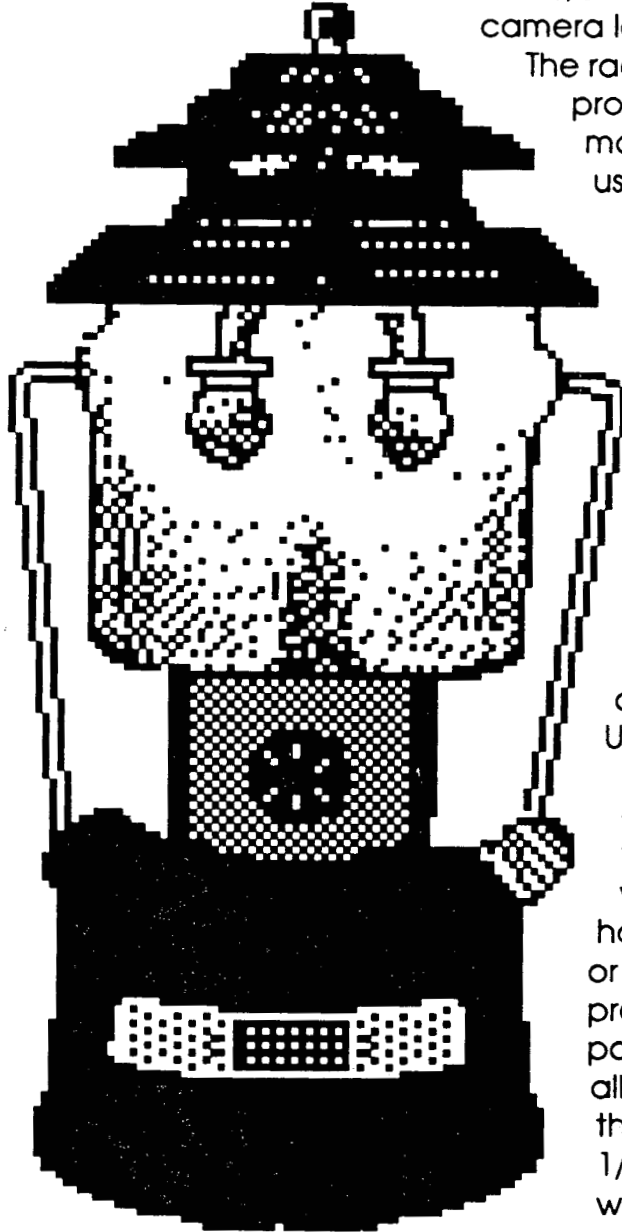
UNIT OF RADIOACTIVITY	SYMBOL	DISINTEGRATIONS PER MINUTE	DOLLAR ANALOGY	EXAMPLES OF RADIOACTIVE MATERIALS
1 Curie	Ci	2×10^{12} or 2 Trillion	2 Times the Annual Federal Budget	Nuclear Medicine Generator
1 Millicurie	mCi	2×10^9 or 2 Billion	Cost of a New Interstate Highway from Atlanta to San Francisco	Amount Used for a Brain or Liver Scan
1 Microcurie	μ Ci	2×10^6 or 2 Million	All-Star Baseball Player's Salary	Amount Used in Thyroid Tests
1 Nanocurie	nCi	2×10^3 or 2 Thousand	Annual Home Energy Costs	Consumer Products
1 Picocurie	pCi	2	Cost of a Hamburger and Coke	Background Environmental Levels

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
CONVERSION FACTORS

TABLE G-1
CONVERSION FACTORS

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 H
CLEAN AIR ACT COMPLIANCE REPORT
FOR NIAGARA FALLS STORAGE SITE

40 CFR Part 61
National Emission Standards
for Hazardous Air Pollutants

CLEAN AIR ACT COMPLIANCE REPORT
(Version 3.0 November 1989)

Facility: Naigara Falls Storage Site
Address: 1397 Pletcher Road
Lewistown, NY. 14092
Annual Assessment for Year: 1990
Date Submitted: 3/20/91

Comments:

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

Facility: Naigara Falls Storage Site

Address: 1397 Pletcher Road

City: Lewistown

State: NY

Comments:

Year: 1990

Dose Equivalent Rates to Nearby
Individuals (mrem/year)

Effective
Dose Equivalent

0.3400

Highest Organ
Dose is to
LUNGS

2.5

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

Radio-nuclide	Class	Amad	Area #1 (Ci/y)
U-238	Y	1.0	5.6E-06
U-234	Y	1.0	5.4E-06
U-235	Y	1.0	2.5E-07
RA-226	Y	1.0	3.4E-04
TH-232	Y	1.0	0.0E-01
TH-230	Y	1.0	0.0E-01
Total Area (m**2)			4.5E+04

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

Wind Data	IAG0905.WND	Temperature (C)	9
Food Source	LOCAL	Rainfall (cm/y)	114
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	1.7E-02
BREAST	1.7E-02
RED MARROW	5.3E-02
LUNGS	2.5E+00
THYROID	1.7E-02
ENDOSTEUM	5.4E-01
REMAINDER	2.1E-02
EFFECTIVE	3.4E-01

Niagara Falls Storage Site

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	2.6E-02	6.5E-03
INHALATION	3.1E-01	2.5E+00
AIR IMMERSION	9.2E-09	7.8E-09
GROUND SURFACE	2.7E-04	2.3E-04
	-----	-----
TOTAL:	3.4E-01	2.5E+00

Naigara Falls Storage Site

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	4.5E-03	3.5E-02
U-234	4.9E-03	3.8E-02
U-235	2.1E-04	1.6E-03
RA-226	3.3E-01	2.4E+00
TH-232	3.1E-28	1.6E-27
TH-230	2.2E-28	8.7E-28
TOTAL :	3.4E-01	2.5E+00

Naigara Falls Storage Site

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

DIRECTION : NORTHEAST

DISTANCE (meters)	EFFECTIVE DOSE EQUIVALENT (mrem/y)
300	3.4E-01
1000	4.1E-02
3000	6.5E-03
10000	1.0E-03
80000	3.7E-05

Naigara Falls Storage Site

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	2.1E-01	2.8E-01	3.4E-01	3.0E-01	2.7E-01	2.5E-01	2.4E-01	1.9E-01
1000	2.4E-02	2.7E-02	4.1E-02	2.8E-02	3.0E-02	2.5E-02	2.7E-02	1.7E-02
3000	3.8E-03	4.2E-03	6.5E-03	4.4E-03	4.7E-03	3.9E-03	4.2E-03	2.7E-03
10000	5.9E-04	6.7E-04	1.0E-03	7.0E-04	7.3E-04	6.0E-04	6.6E-04	4.1E-04
80000	1.8E-05	2.4E-05	3.7E-05	2.5E-05	2.4E-05	2.0E-05	2.1E-05	1.3E-05
	S	SSW	SW	WSW	W	WNW	NW	NNW
DISTANCE (METERS):								
300	1.7E-01	1.4E-01	1.6E-01	2.0E-01	2.4E-01	1.9E-01	1.3E-01	1.2E-01
1000	1.9E-02	1.2E-02	1.8E-02	1.8E-02	3.1E-02	1.7E-02	1.4E-02	7.5E-03
3000	3.0E-03	1.8E-03	2.8E-03	2.8E-03	4.8E-03	2.7E-03	2.1E-03	1.2E-03
10000	4.6E-04	2.8E-04	4.3E-04	4.3E-04	7.3E-04	4.1E-04	3.2E-04	1.8E-04
80000	1.4E-05	8.9E-06	1.3E-05	1.3E-05	2.0E-05	1.0E-05	8.7E-06	5.5E-06

Niagara Falls Storage Site

APPENDIX I
DISTRIBUTION LIST FOR NIAGARA FALLS INTERIM STORAGE SITE
ENVIRONMENTAL REPORT FOR CALENDAR YEAR 1990

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