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Formerly Utilized Sites Remedial Action Program (FUSRAP)

ADMINISTRATIVE RECORD

for

Niagara Falls Storage Site

U.S. Department of Energy

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Department of Energy
Field Office, Oak Ridge
P.O. Box 2001
Oak Ridge, Tennessee 37831—8723

October 1, 1992

Distribution

SITE ENVIRONMENTAL REPORT - NIAGARA FALLS STORAGE SITE

Enclosed for your information is a copy of the 1991 Site Environmental Report for the U.S. Department of Energy's Niagara Falls Storage Site located in Lewiston, New York. This report is prepared and published annually for distribution to interested local, state, and federal agencies and members of the public.

If you have any questions on the contents of this report or desire additional information, please contact me directly at (615) 576-7477 or by calling toll-free (800) 253-9759.

Sincerely,

Ronald E. Kirk

Ronald E. Kirk, Site Manager
Former Sites Restoration Division

Enclosure

095170

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DOE/OR/21949-343

Formerly Utilized Sites Remedial Action Program (FUSRAP)
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NIAGARA FALLS STORAGE SITE ANNUAL ENVIRONMENTAL REPORT FOR CALENDAR YEAR 1991

Lewiston, New York

September 1992

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NIAGARA FALLS STORAGE SITE

ANNUAL ENVIRONMENTAL REPORT

FOR CALENDAR YEAR 1991

LEWISTON, NEW YORK

SEPTEMBER 1992

Prepared for

United States Department of Energy

Oak Ridge Field Office

Under Contract No. DE-AC05-91OR21949

By

Bechtel National, Inc.

Oak Ridge, Tennessee

Bechtel Job No. 14501

EXECUTIVE SUMMARY

This document describes the environmental monitoring program at the Niagara Falls Storage Site (NFSS) and surrounding area, implementation of the program, and monitoring results for 1991. Environmental monitoring at NFSS began in 1981. The site is owned by the U.S. Department of Energy (DOE) and is assigned to the DOE Formerly Utilized Sites Remedial Action Program (FUSRAP). FUSRAP is a 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.

The environmental monitoring program at NFSS includes 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 including seven metals are routinely measured in groundwater.

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

Results of environmental monitoring during 1991 indicate that concentrations of contaminants of concern were below applicable standards and DCGs. Concentrations of some chemical contaminants in groundwater were above the New York State Department of Environmental Conservation (Class GA) and EPA guidelines for drinking water. These guidelines were included for comparison purposes only; groundwater at NFSS is not used for drinking water.

The potential radiation dose calculated for a hypothetical maximally exposed individual is 0.3 mrem (milliroentgen equivalent man) per year, less than an individual would receive while traveling in an airplane at 12,000 meters (39,000 feet) for one hour.

During 1991, site activities included remediating one localized onsite area [approximately 100 square meters (1,100 square feet)] and consolidating two small interim storage piles and 60 drums of radioactively contaminated material into the waste containment structure. NFSS was in compliance with all applicable DOE orders and federal and state regulations.

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

CONTENTS

CONTENTS

(continued)

FIGURES

FIGURES

(continued)

TABLES

TABLES

(continued)

ACRONYMS

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 guide
DOE	Department of Energy
DQO	data quality objective
EIS	environmental impact statement
EPA	Environmental Protection Agency
FUSRAP	Formerly Utilized Sites Remedial Action Program
LOOW	Lake Ontario Ordnance Works
MSD	matrix spike duplicate
MSL	mean sea level
NEPA	National Environmental Policy Act
NESHAPs	National Emission Standards for Hazardous Air Pollutants
NFSS	Niagara Falls Storage Site
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NYCRR	New York Compilation of Rules and Regulations
NYSDEC	New York State Department of Environmental Conservation
PARCC	precision, accuracy, representativeness, comparability, and completeness
PCB	polychlorinated biphenyl

ACRONYMS
(continued)

QA	quality assurance
QAPmP	quality assurance program plan
QC	quality control
RCRA	Resource Conservation and Recovery Act
ROD	record of decision
RPD	relative percent difference
SARA	Superfund Amendments and Reauthorization Act
SRM	standard reference material
TETLD	tissue-equivalent thermoluminescent dosimeter
TOC	total organic carbon
TOX	total organic halides
TPQ	threshold planning quantity
TSCA	Toxic Substances Control Act
UST	underground storage tank
WCS	waste containment structure

UNITS OF MEASURE

Bq	becquerel
C	Celsius
cm	centimeter
F	Fahrenheit
ft	foot
g	gram
h	hour
ha	hectare
in.	inch
km	kilometer
L	liter
m	meter
µCi	microcurie
µg	microgram
mg	milligram
mi	mile
ml	milliliter
µmhos	micromhos
mph	miles per hour
mR	milliroentgen
mrem	millirem
mSv	millisievert
pCi	picocurie
rem	roentgen equivalent man
s	second
Sv	sievert
yd	yard
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, implementation of the program, monitoring results for 1991, and special occurrences (if any) during 1991 and the first quarter of 1992.

1.1 DOE INVOLVEMENT

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 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, a small storage shed, and four abandoned buildings (Figure 1-2). No process effluents are generated at the site. The waste containment structure (WCS), a clay-lined, clay-capped, and grass-covered storage pile, covers approximately 4 ha (10 acres) (Figure 1-3). The routine maintenance of the WCS is described in an instruction guide. The property is entirely fenced, and public access is restricted.

1.3 SITE HISTORY

The history of NFSS goes back to World War II, when the Manhattan Engineer District, predecessor to the Atomic Energy Commission, used part of the Army's Lake Ontario Ordnance Works (LOOW) as a transshipment and storage site for radioactive

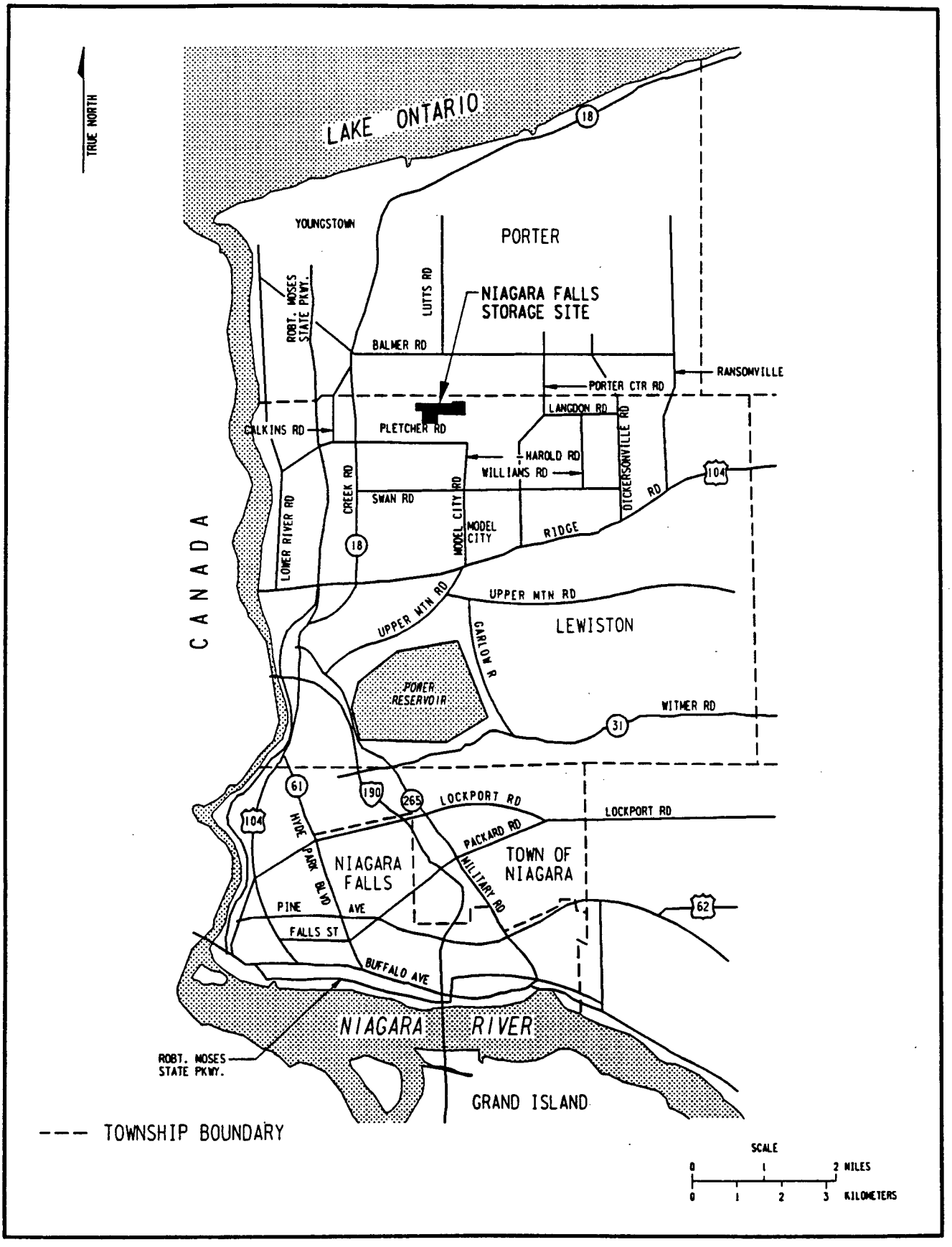

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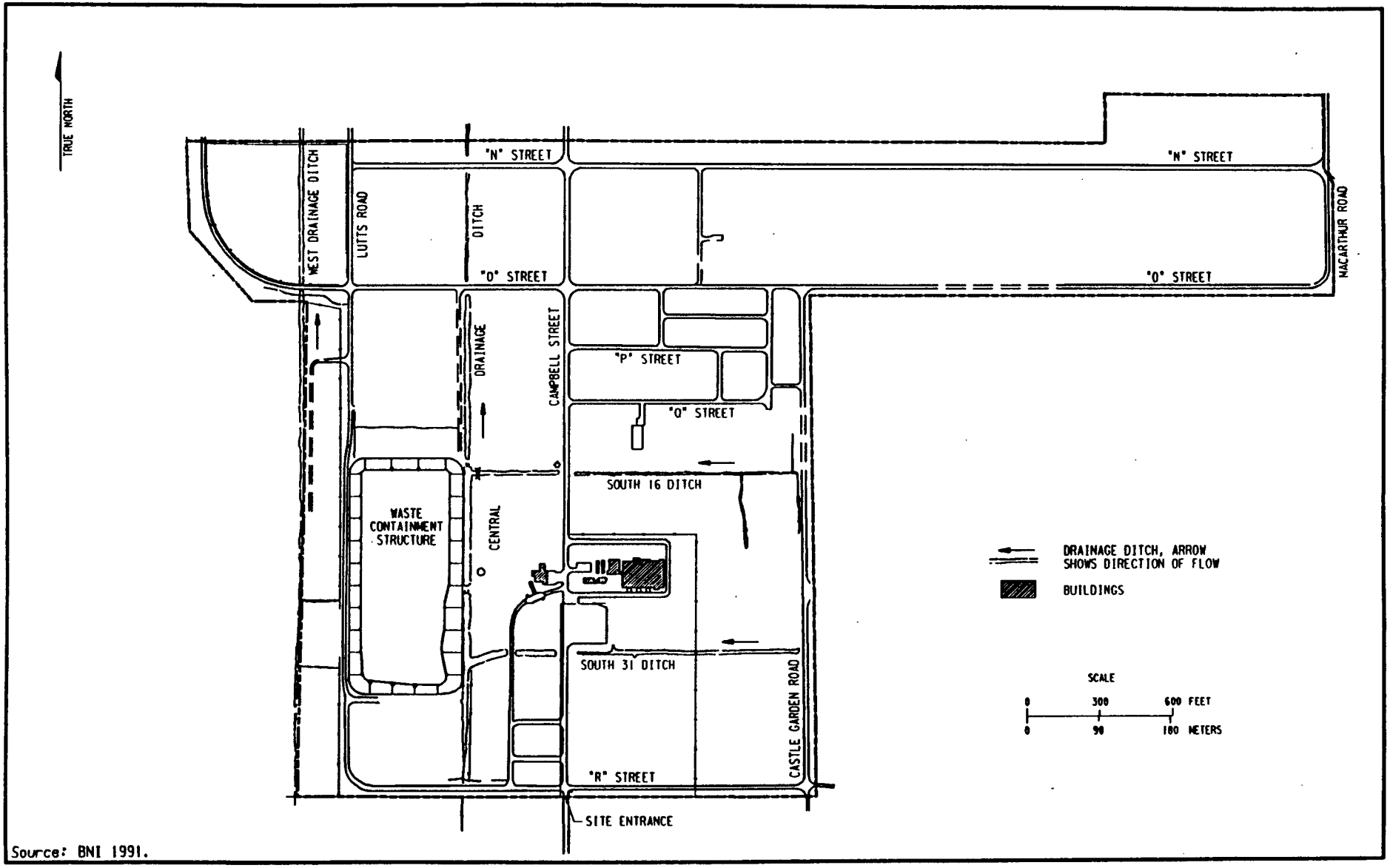
Figure 1-1
Location of NFSS



Source: BNI 1991.

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Figure 1-2
Present Configuration of NFSS

Figure 1-3
Aerial View of the NFSS Waste Containment Structure

materials. The site was also used for enriching nonradioactive boron-10 (1954 through 1958 and 1964 through 1971). However, the primary use of the site (1944 to present) has been for storage of radioactive residues produced as a by-product of uranium production. 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 3,060 ha (7,570 acres). Radiological surveys and characterizations of NFSS were performed in 1979 and 1980 (Battelle 1991), and radiological surveys of vicinity properties were conducted from 1981 to 1985. Remediation of 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 pitchblende processing for uranium extraction) were stored in the WCS. One localized onsite area [approximately 100 m^2 (1,100 ft^2)] was remediated in mid-1991. In addition, two small interim storage piles of contaminated materials generated during additional remediation of onsite isolated areas in 1989 and 60 drums of radioactively contaminated material were consolidated into the WCS. All onsite areas of residual radioactivity above guidelines have now been remediated; materials generated during remedial actions are stored in the WCS [approximately 195,000 m^3 (255,000 yd^3)].

A chemical characterization of the site was conducted in 1990. A soil gas survey identified moderately elevated levels of volatile organic compounds near Building 401. An investigation will be conducted to determine whether volatile organic compounds are also present in the groundwater.

1.4 LAND USE

As shown in Figure 1-4, land in the vicinity of the site is predominantly rural. The site is bordered by a chemical waste

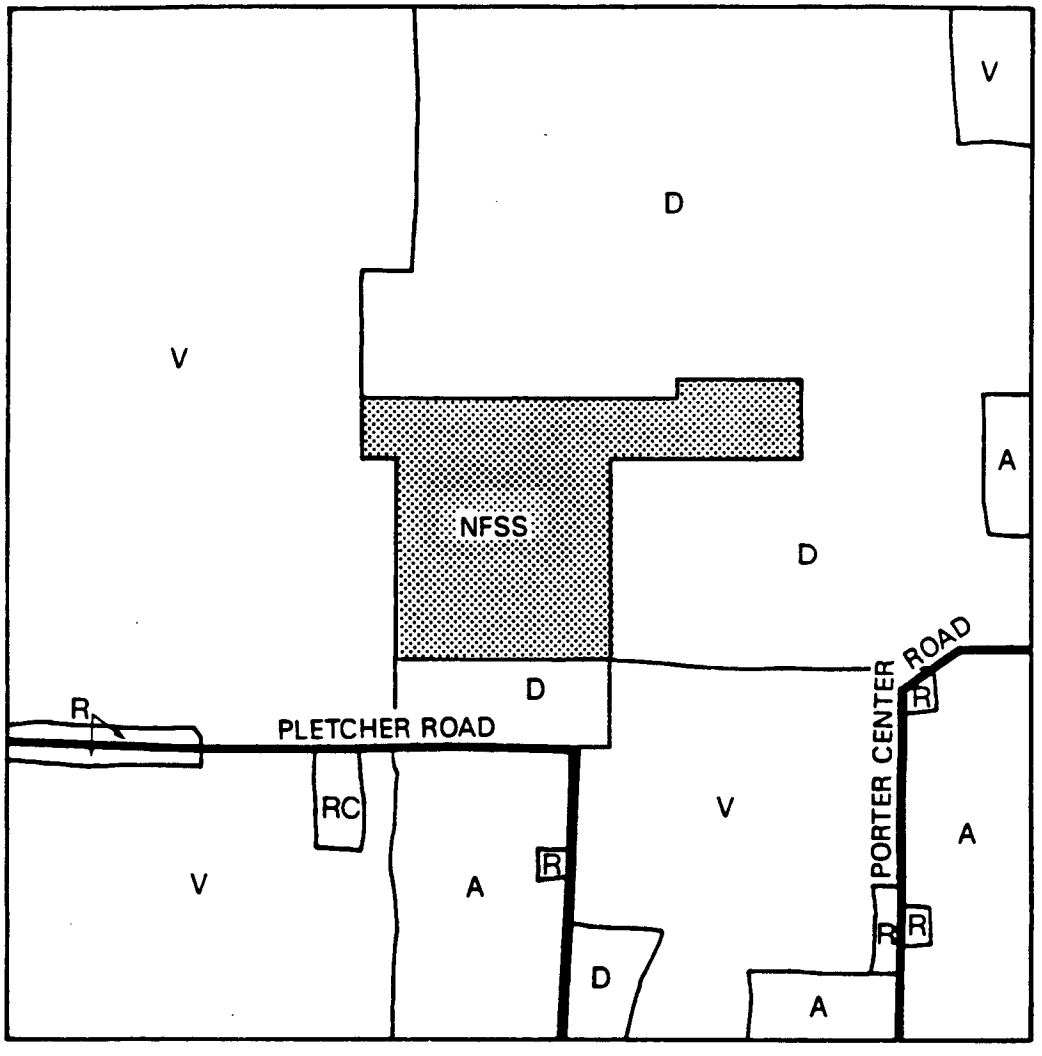


Figure 1-4
Generalized Land Use in the Vicinity of NFSS

disposal facility (CWM Chemical Services, Inc.) to the north, a solid waste disposal facility (Modern Disposal, Inc.) to the east and south, and a Niagara Mohawk Power Corporation right-of-way to the west.

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 and the West Drainage Ditch, which empty 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 within an 80-km (50-mi) radius of NFSS is in excess of 250,000; according to the 1990 census (Economic Development Board at the Lockport County Court House, County Seat), the population of Niagara County is 220,756.

1.5 CLIMATE

Table 1-1 is a summary of 1991 climatological data from the National Oceanic and Atmospheric Administration (NOAA) for the Buffalo/Niagara Falls area; it includes site precipitation data for 1991 and NOAA normal precipitation data from 1951 to 1980. Monthly site precipitation ranged from 1.8 to 20 cm (0.71 to 7.9 in.). Temperature extremes ranged from -17 to 32°C (1.4 to 90°F). Average wind speed ranged from 15 to 21 km/h (9.3 to 13 mph), predominantly from the west.

Table 1-1

Summary of Climatological Data for 1991

for Buffalo, New York, and Vicinity

Month	Temperature (°F) Min	Max	Avg	Total Precip (in.)	Total Site[a] Precip (in.)	Total Normal[b] Precip (in.)	Wind Avg Speed (mph)	Wind Resultant Direction
January	3	45	26	2.1	~5	3.0	13	W
February	3	57	31	2.1	~2.4	2.4	13	W
March	18	70	38	6.0	~7.9	3.0	12	W
April	26	78	51	5.8	4.8	3.1	12	SW
May	36	90	64	3.1	2.6	2.9	11	SW
June	46	88	69	0.9	0.7	2.7	9.6	W
July	52	88	72	3.3	2.6	3.0	9.8	W
August	52	89	71	2.8	2.3	4.2	9.3	W
September	32	89	62	3.2	1.3	3.4	9.5	W
October	30	79	53	3.1	1.4	2.9	9.8	SW
November	18	70	39	4.0	1.6	3.6	11.4	W
December	2	59	31	3.4	~3.9	3.4	13.4	W

Source: NOAA Local Climatological Data, Greater Buffalo Int. Airport, Buffalo, NY.

[a]Results from rain gauge at the site. Values with ~ include snow. Values for snow have been converted to water equivalent values by multiplying by 0.10.

[b]Source: Climates of the States, Third Edition, Volume 2, NOAA Normals for Greater Buffalo International Airport, Buffalo, N.Y. Based on records from 1951 to 1980.

2.0 SUMMARY OF ENVIRONMENTAL COMPLIANCE

The primary regulatory guidelines and limits are given in the DOE orders and 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 1991 and first quarter 1992, as well as anticipated regulatory requirements that could affect the site in the future.

2.1 PRIMARY REGULATORY GUIDELINES

DOE Orders for Radionuclide Releases

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

Environmental monitoring results for calendar year 1991 show 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 radioactive contaminants.

Clean Air Act and National Emission Standards for Hazardous Air Pollutants

The primary federal statute governing air emissions is the CAA. NFSS is not an operating facility, has no point sources (e.g.,

stacks, vents, or effluent streams) for radionuclide air emissions, and does not require any state or federal air permits. NFSS was subject to Subparts H and Q of the National Emission Standards for Hazardous Air Pollutants (NESHAPs) in 1991. Beginning in July 1991, NFSS was also subject to the general provisions of NESHAPs found in Subpart A when two small piles of radioactively contaminated soil were excavated and consolidated into the existing WCS. However, calculations showed that all radionuclide emissions resulting from the pile consolidation work would cause an effective dose equivalent of less than 1 percent of the Subpart H standard. Thus, the pile consolidation work was exempted from any of the notification or reporting requirements found in Subpart A.

Compliance with the non-radon radionuclide standard in Subpart H of NESHAPs has been determined by evaluating the site using the computer model AIRDOS (Version 3.0) approved by EPA. Results from the model indicate that NFSS is in compliance with Subpart H (see Appendix E, p. E-2).

The national standard for radon emissions, Subpart Q, 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 maintained in 1991. Radon flux rates measured to demonstrate compliance with Subpart Q are provided in Subsection 4.1.1.

Subpart Q was not applicable while the pile consolidation work was being conducted because the storage facility was considered to be in an "uncompleted" status. As presented in the preamble of the Federal Register dated December 15, 1989, Subpart Q applies only to "completed" interim storage facilities at DOE sites where radon is present. Upon completion of the pile consolidation work, radon flux was monitored for compliance with Subpart Q.

NESHAPs Subpart M contains the National Asbestos Emission Standards. Asbestos from the roof of Building 410 (which has been demolished) is buried in an onsite 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 and in siding on other buildings.

In the summer of 1990, windows and broken siding in Building 401 were boarded up to prevent animal intrusion. Subpart M will be applicable for all asbestos removal activities.

Clean Water Act

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

On November 16, 1990, EPA promulgated changes to its stormwater regulation provisions. Although these provisions did not affect reporting obligations for 1991, significant changes in compliance reporting and monitoring will be implemented in 1992. As a result of the changes to the stormwater regulations, DOE has determined that a stormwater discharge permit will be required for NFSS. A plan will be developed and implemented to meet the regulatory deadline of October 1, 1992, set for submittal of stormwater discharge permit applications. The plan will include data collection methodology for all applicable regulatory parameters referenced in the regulation.

Resource Conservation and Recovery Act

RCRA is the principal federal statute governing the management of hazardous waste. Neither RCRA-regulated wastes nor radioactive wastes containing RCRA-regulated wastes have been detected at NFSS.

Toxic Substances Control Act

The most common toxic substances regulated by TSCA are polychlorinated biphenyls (PCBs) and asbestos. As noted earlier, asbestos is present at NFSS. Building 401 is not scheduled for renovation or demolition. Asbestos is also present in an onsite landfill, but long-term storage of it is planned. Provisions regulating asbestos are anticipated to remain limited to the notification of any future owner of the property that asbestos is present. PCB disposal was in accordance with applicable requirements.

Comprehensive Environmental Response, Compensation, and Liability Act

CERCLA, as amended by SARA, is the primary source of statutory authority for the remediation of sites contaminated with hazardous substances. However, any further remedial action activities at NFSS 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.

In response to a request from EPA, a preliminary assessment, which is an evaluation to determine the severity of the threat that a hazardous waste site poses to human health and the environment, was completed in 1990. Because insufficient chemical data were included in the preliminary assessment, a site investigation is being performed, and results should be available in fiscal year 1992.

National Environmental Policy Act

Compliance with NEPA 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 the waste pile. 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 cleanup decision was based on NEPA. It was designed to meet the goal of protecting human health and the environment.

In 1991, documentation to justify a proposed action as a categorical exclusion (CX) for removal of four underground storage tanks (USTs) was submitted to and approved by DOE Headquarters. The USTs discovered during the first quarter of 1991 were sampled and removed in accordance with 6 NYCRR Section 613.9. In addition, a site assessment was performed as required under 40 CFR Subpart G. The federal regulations were applicable to the removal operation because the USTs were not registered with the New York State

Department of Environmental Conservation (NYSDEC) as required under 6 NYCRR Part 612. The federal and state regulations are similar except for the federal requirement of conducting a site assessment.

A CX covering environmental monitoring activities was also approved by DOE Headquarters.

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 NFSS. 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 all applicable environmental statutes, regulations, and executive orders.

2.2 APPLICABLE ENVIRONMENTAL PERMITS

DOE has determined that a stormwater discharge permit application must be submitted pursuant to the National Pollutant Discharge Elimination System (NPDES) regulations by the regulatory deadline of October 1, 1992.

2.3 ENVIRONMENTAL IMPACT STATEMENTS AND ENVIRONMENTAL ASSESSMENTS

As stated, an EIS evaluating long-term disposition of the waste pile was completed and incorporated into the Administrative Record in 1986.

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

Except for chemical contaminants that exceed EPA and/or NYSDEC drinking water guidelines, NFSS is currently in compliance with all applicable environmental regulations. During the first quarter of 1992, environmental monitoring continued, as did review of potentially applicable regulations for their input on the site.

3.0 ENVIRONMENTAL PROGRAM INFORMATION

Routine monitoring for radiation, radioactive materials, and chemical substances at 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 mitigating environmental impacts.

The objectives of this report are to:

- Describe efforts to control stored pollutants until future remediation
- Describe the environmental monitoring program
- Report the radiological and nonradiological conditions of the site and surrounding areas during 1991
- Provide comparison of monitoring results and applicable regulatory standards (Appendix A)
- Provide trend analyses, where applicable, to indicate increases or decreases in environmental impact

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

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

3.1 SUMMARY OF ENVIRONMENTAL MONITORING PROGRAM

3.1.1 Environmental Monitoring Requirements

Requirements for environmental monitoring of radioactive materials 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 (radon and other radionuclides) are found in NESHAPs. Requirements for environmental monitoring of nonradiological parameters are found in DOE Order 5400.1 (DOE 1988b). Nonradiological parameters were monitored to obtain information on groundwater quality.

3.1.2 Monitoring Networks

The environmental monitoring networks at NFSS are as follows:

- There are 46 radon and external gamma radiation monitoring stations (18 onsite, 19 property-line, and 9 offsite). All stations, except background stations, are onsite and accessible only to employees and authorized visitors. Some stations are located on or near the property line to allow determination of exposure at the "fenceline" as required by DOE orders.

- There are five surface water and sediment monitoring locations [three onsite (one upstream) and two offsite, downstream].

- NFSS has 47 groundwater monitoring locations; monitoring the WCS is the overriding consideration. The two groundwater systems beneath the WCS are independent of each other and flow in different directions.

- Background stations are located offsite in areas considered to be uncontaminated; measured background values are compared with site values to determine compliance with DOE orders.

Details on the monitoring networks are provided in Sections 4.0 and 5.0.

3.2 SUMMARY OF SPECIAL ENVIRONMENTAL ACTIVITIES

During 1991, the environmental activities at NFSS consisted of performing the environmental monitoring described in Sections 4.0 and 5.0, remediating one localized onsite area, and incorporating two small storage piles and 60 drums containing radioactively contaminated material into the WCS.

In 1990, a one-time sampling event was conducted to study gross alpha and beta concentrations in 20 percent of the surface water, sediment, and groundwater samples. This study was designed to evaluate the isotopic analyses currently performed by comparing the sum of the radionuclide results (total uranium and radium) with the gross alpha and beta results (Table 3-1). There were some large discrepancies between the gross alpha and beta results and the isotopic results for the sediment and groundwater sampling locations (especially well OW-15A). Because this well is located in the lower groundwater system, the source of contamination was thought to be potassium-40 and/or natural thorium. Therefore, in the second quarter of 1991, samples were collected from the sediment and groundwater locations with elevated gross alpha and beta results and were analyzed for potassium-40 and isotopic thorium. Results (Table 3-2) indicate that potassium-40 and isotopic thorium are not causing the elevated levels. However, it is reasonable to assume that contamination is not migrating from the WCS because (1) results for the primary radionuclides in the WCS (total uranium and radium) are very low, and (2) the presence of contamination in the lower groundwater system but not in the upper groundwater system is not probable. In addition, the high

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
Surface Water (10^{-9} μCi/ml)[b]			
11	26	16	18
Sediment (pCi/g)[c]			
11	26	24	5.6
Groundwater (10^{-9} μCi/ml)[b]			
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

[a]Sampling locations are shown in Subsection 4.1.

[b]1 x 10^{-9} μCi/ml is equivalent to 0.037 Bq/L and 1 pCi/L.

[c]1 pCi/g is equivalent to 0.037 Bq/g.

Table 3-2

Summary of Potassium-40 and Isotopic Thorium Results for NFSS, 1991

Sampling Location[a]	Potassium-40	Thorium-232	Thorium-230	Thorium-228
Sediment (pCi/g)[b]				
11	21	1.4	1.01	0.96
Groundwater (10^{-9} µCi/ml)[c]				
OW-3A	10	0.4	0.6	0.4
OW-5A	10	0.2	0.3	0.2
OW-15A	17	0.9	0.9	0.9
OW-15B	3.4	0.1	0.2	0.1

[a]Sampling locations are shown in Subsection 4.1.

[b]1 pCi/g is equivalent to 0.037 Bq/g.

[c]1 x 10^{-9} µCi/ml is equivalent to 0.037 Bq/L and 1 pCi/L.

readings could be anomolies. In 1992, samples from well OW-15A will be analyzed for beta-emitting radionuclides in the uranium decay series.

3.3 SELF-ASSESSMENTS

During 1991, Bechtel National, Inc. (BNI), the project management contractor for FUSRAP, conducted two self-assessments at NFSS. The first focused on environmental monitoring and sampling activities; three nonconformance reports and a "lessons learned" document were issued. All findings have been resolved. The second focused on requirements and regulations for:

- Environmental monitoring and reporting
- CERCLA
- Radioactive waste management
- Radiation protection of public health and the environment
- NEPA
- Emergency response and community right-to-know
- PCB management
- Water discharge
- Air discharge
- Hazardous and mixed waste management

Results indicate that FUSRAP was in compliance with 98 percent of the requirements and regulations evaluated. Corrective actions are being implemented in response to the 2-percent variance. Findings were in the areas of compliance with controlling documents or situations where an alternate approach is consistent with good industry practices or best management practices. There were no findings that represented an imminent threat to public health, safety, or the environment.

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

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

4.0 RADIOLOGICAL ENVIRONMENTAL PROGRAM

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 in 1991 at NFSS included sampling for:

- Radon concentrations in air
- External gamma radiation exposure
- Radium-226 and total uranium concentrations in surface water, sediment, and groundwater

The monitoring systems include onsite, property-line, and offsite sampling locations to provide sufficient information on potential effects of the site on human health and the environment. The analytical methods performed on each matrix are presented in Appendix B.

This section of the report contains 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 C. All quarterly data are reported as received from the laboratory; however, the averages 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). Where appropriate, data are presented using powers of ten (e.g., $0.32 = 3.2 \times 10^{-1}$).

Some of the quarterly results are reported using a "less than" (<) sign. This notation is used to denote specific sample 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.

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

indicated by the results. Concentration trends are also shown in graphical representations, which include up to six of the highest values for each analyte and matrix sampled during the past five years. The scales for these graphs are set to a percentage of the appropriate guideline based on the values of the samples to ensure maximum resolution. Background values are also displayed when appropriate.

4.1 ENVIRONMENTAL MONITORING FOR RADIOACTIVE CONTAMINANTS

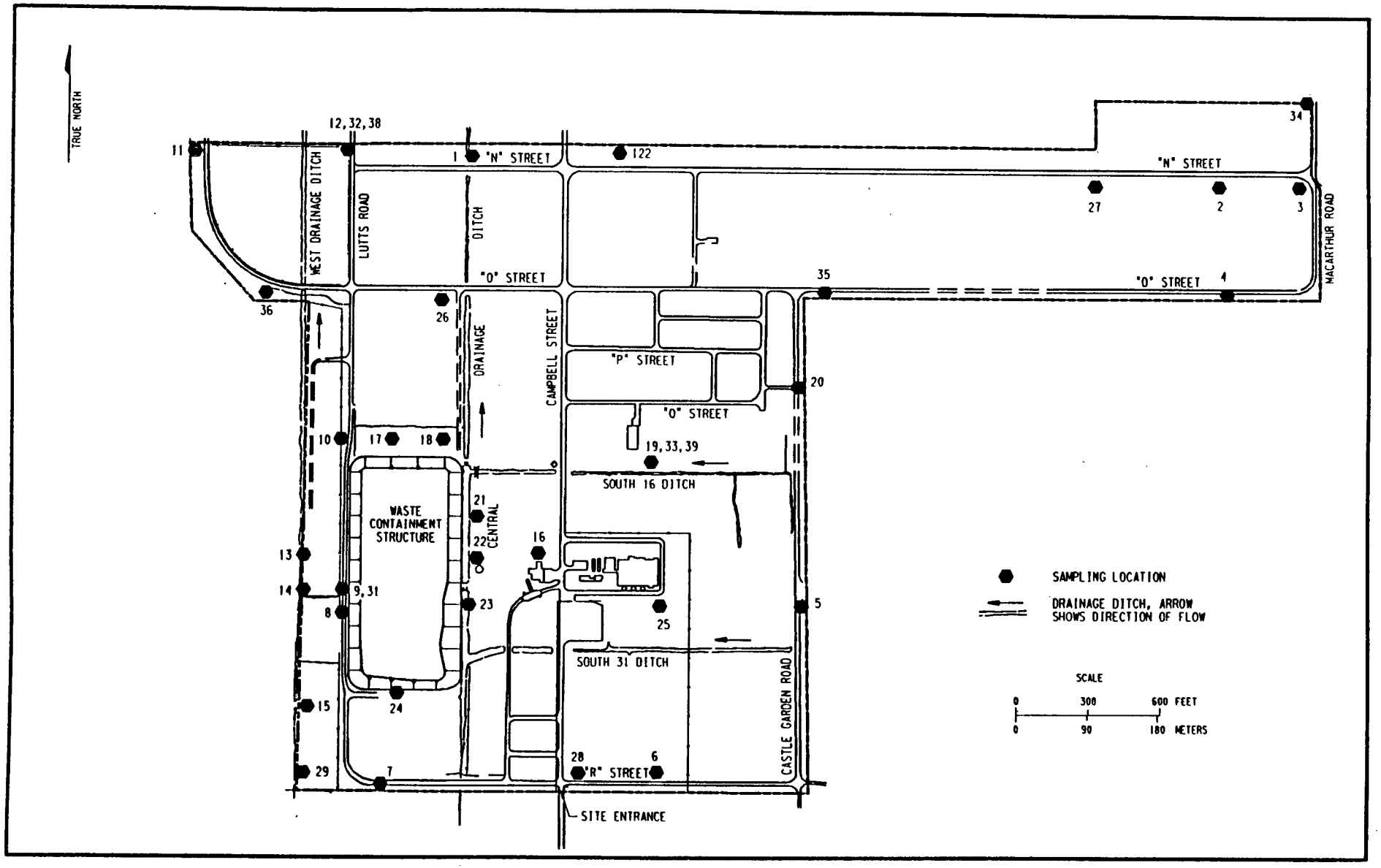
4.1.1 Radon Monitoring

At NFSS the major radiation exposure pathway from the uranium-238 series is inhalation of the short-lived radionuclides, radon (half-life of 3.8 days) and radon daughter products. Radon is an alpha-particle-emitting gas that is very mobile in air. Radon monitoring is conducted to confirm that NFSS is not significantly adding to the natural background radon levels and to ensure compliance with environmental regulations. Radon monitoring locations are shown in Figures 4-1 and 4-2.

Data and discussion

The maximum quarterly ambient air radon concentration detected was 1.9×10^{-9} μCi/ml (0.07 Bq/L) at location 13. The annual average radon concentrations onsite and at the property line were less than the average background concentration (see Table 4-1). No quarterly or annual average level was higher than the DOE guideline of 3.0×10^{-9} μCi/ml.

The radon results for the WCS show an average flux rate of 0.05 pCi/m^2/s (0.002 Bq/m^2/s) with minimum and maximum levels of 0.04 and 3.3 pCi/m^2/s (1×10^3 and 0.12 Bq/m^2/s), respectively. These results demonstrate that the WCS is in compliance with the limit of 20 pCi/m^2/s (an averaged value) set forth in 40 CFR Part 61, Subpart Q.



158 R10F003.DGN

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

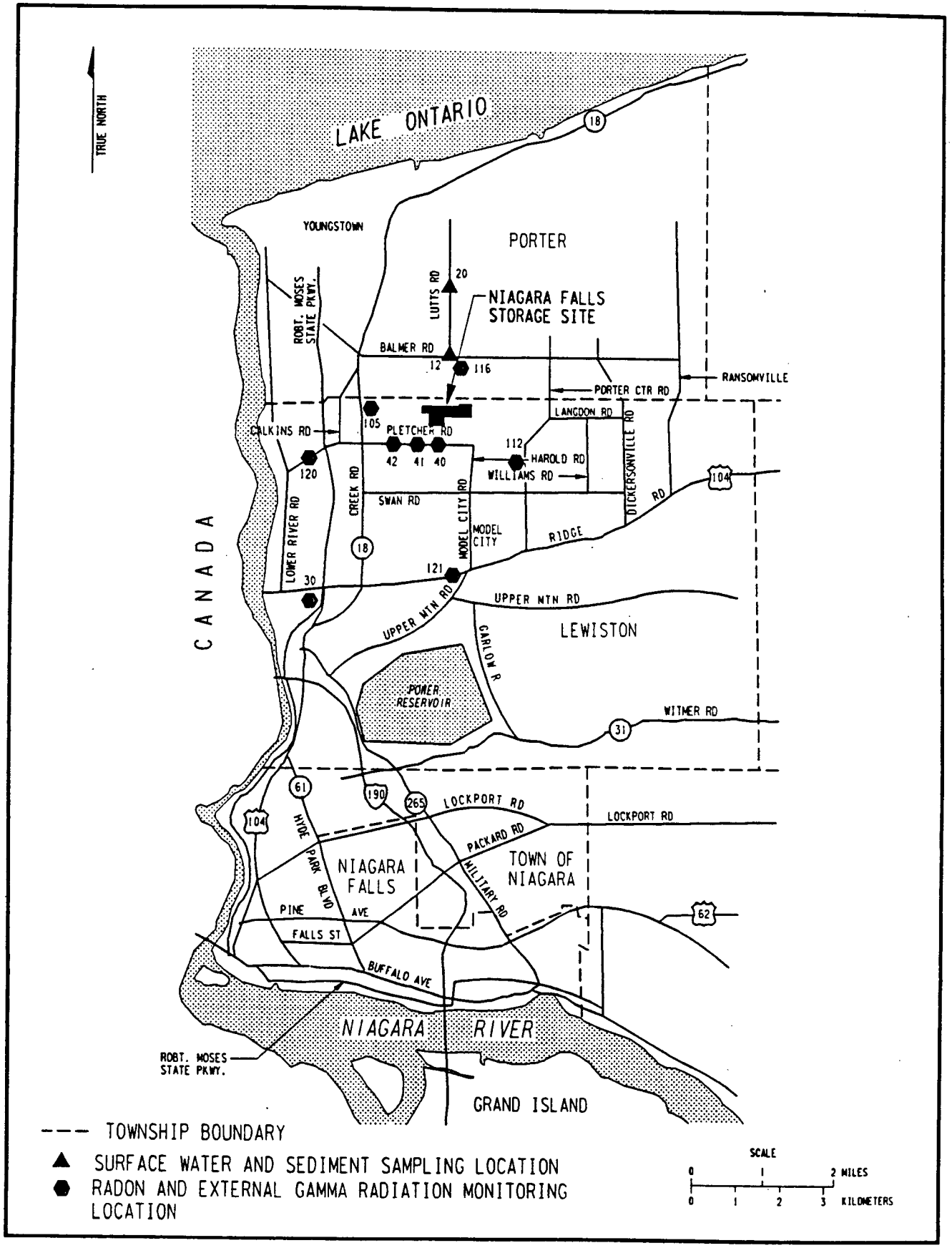


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Figure 4-2
Offsite Radon, External Gamma Radiation, Surface Water, and Sediment Monitoring Locations

Table 4-1
Average Radon Concentrations[a,b]
at NFSS, 1991

Sampling Location[c]	Quarter 1[d]	2	3	4	Avg
	(Concentrations are in 10^{-9} µCi/ml)				
Property Line					
1	0.5	<0.4	<0.3	<0.3	0.4
3	0.6	0.4	<0.3	<0.3	0.4
4	1.8	<0.4	<0.3	<0.4	0.7
5	1.1	<0.4	<0.3	<0.3	0.5
6	0.7	0.4	<0.3	<0.3	0.4
7	<0.4	<0.4	<0.3	<0.3	0.4
11	1.2	<0.4	<0.3	<0.3	0.6
12	<0.4	<0.4	<0.3	<0.3	0.4
13	1.9	<0.4	<0.3	0.7	0.8
14	0.5	<0.4	<0.3	0.4	0.4
15	0.7	<0.4	0.3	0.5	0.5
20	0.8	<0.4	<0.3	<0.3	0.5
28	1.4	<0.4	<0.3	<0.3	0.6
29	0.8	<0.4	<0.3	0.7	0.6
34	1.1	<0.4	<0.3	<0.3	0.5
35	1.3	<0.4	<0.3	<0.3	0.6
36	0.8	<0.4	<0.3	<0.3	0.5
38	1.1	<0.4	<0.3	<0.3	0.5
				Average	0.5
Onsite					
2	1.4	<0.4	<0.3	<0.3	0.6
8	1.2	<0.4	0.3	<0.3	0.6
9	1	<0.4	0.4	<0.3	0.5
10	0.8	<0.4	0.3	0.4	0.5
16	1.4	0.6	0.6	0.5	0.8
17	1.1	<0.4	0.4	0.3	0.6
18	1.1	<0.4	0.3	<0.3	0.5
19	1.1	<0.4	<0.3	<0.3	0.5
21	1.1	<0.4	0.4	<0.3	0.6
22	0.8	<0.4	1.1	0.8	0.8
23	1	<0.4	0.3	0.6	0.6
24	<0.4	<0.4	0.3	<0.3	0.4
25	1.1	<0.4	<0.3	<0.3	0.5

Table 4-1

(continued)

Sampling Location[c]	Quarter 1[d]	2	3	4	Avg
Onsite (cont'd)					
26	1.4	<0.4	<0.3	<0.3	0.6
27	0.9	<0.4	<0.3	<0.3	0.5
39	0.6	<0.4	0.4	<0.3	0.4
			Average		0.6
Quality Control					
31[e]	0.4	<0.4	0.3	0.6	0.4
32[f]	1.2	<0.4	<0.3	<0.3	0.6
33[g]	1.2	<0.4	<0.3	<0.3	0.6
			Average		0.5
Background					
30	0.4	0.5	<0.3	<0.3	0.4
40	0.8	<0.4	0.4	0.4	0.5
41	0.5	<0.4	0.4	0.4	0.4
42	1.3	<0.4	<0.3	0.3	0.6
105	<0.4	<0.4	<0.3	<0.3	0.4
112	0.7	0.8	4.5	11.8	4
116	1.1	<0.4	<0.3	0.5	0.6
120	1	<0.4	<0.3	<0.3	0.5
121	1.8	<0.4	<0.3	<0.3	0.7
			Average		1.0

[a]1 x 10^{-9} μCi/ml is equivalent to 0.037 Bq/L and 1 pCi/L. The DOE guideline is 3.0 x 10^{-9} μCi/ml.

[b]Background has not been subtracted from the reported values. Note: Concentrations at some stations were below values at background stations.

[c]Sampling locations are shown in Figures 4-1 and 4-2.

[d]First quarter dosimeters analyzed by Radon Environmental Monitoring, Inc.; dosimeters in subsequent quarters analyzed by Landauer, Inc.

[e]Quality control for station 12.

[f]Quality control for station 9.

[g]Quality control for station 19.

Trends

Trends in radon concentrations measured from 1986 through 1991 are presented in Table 4-2 and shown in Figure 4-3. 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. As Table 4-2 shows, radon concentrations at these locations are low, have not fluctuated notably, and approximate background levels for the area.

4.1.2 External Gamma Radiation Exposure Monitoring

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

Although tissue-equivalent thermoluminescent dosimeters are state-of-the-art, the dosimeter accuracy is approximately ±10 percent at radiation levels between 100 and 1,000 mR/yr and ±25 percent at levels between 0 and 70 mR/yr. Therefore, for the low levels that are being monitored at NFSS (below 70 mR/yr), there can be seemingly large differences resulting from inaccuracies of detection and the processing system.

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

Table 4-2

Trend Analysis for Radon Concentrations[a,b] at NFSS, 1986-1991

Sampling Location[c]	Average Annual Concentration 1986	1987	1988	1989	1990	Expected Range[d] ($\bar{x} \pm 2s$)	Average Annual Concentration 1991
	(Concentrations are in 10^{-9} µCi/ml)						
1	0.3	0.2	0.5	0.4	0.3	0.1 - 0.6	0.4
3	0.3	0.3	0.2	0.4	0.3	0.2 - 0.4	0.4
4	0.3	0.4	0.2	0.4	0.3	0.2 - 0.5	0.7
5	0.3	0.2	0.5	0.7	0.3	0 - 0.8	0.5
6	0.2	0.2	0.4	0.4	0.4	0.1 - 0.5	0.4
7	0.2	0.3	0.4	0.8	0.3	0 - 0.9	0.4
11	0.4	0.2	0.2	0.4	0.4	0.1 - 0.5	0.6
12	0.2	0.3	0.3	0.5	0.3	0.1 - 0.5	0.4
13	0.4	0.1	0.5	0.7	0.3	0 - 0.8	0.8
14	0.8	0.4	0.3	0.5	0.4	0.1 - 0.9	0.4
15	0.3	0.2	0.3	0.4	0.4	0.2 - 0.5	0.5
20	0.2	0.2	0.5	0.4	0.3	0.1 - 0.6	0.5
28	0.3	0.2	0.3	0.5	0.4	0.1 - 0.6	0.6
29	0.4	0.3	0.3	0.8	0.7	0 - 1	0.6
32	0.3	0.3	0.3	0.6	0.3	0.1 - 0.6	0.6
34	0.3	0.8	0.2	0.5	0.3	0 - 0.9	0.5
35	0.2	0.2	0.5	0.4	0.4	0.1 - 0.6	0.6
36	0.3	0.2	0.3	0.4	0.3	0.2 - 0.4	0.5
Background							
30	0.3	0.3	0.6	1.4	0.4	0 - 2	0.4
120[e]	--	--	0.5	0.5	0.3	0.2 - 0.7	0.3
121[e]	--	--	0.5	0.4	0.3	0.2 - 0.6	0.3

NOTE: Sources for 1986-1990 data are the annual site environmental reports for those years (BNI 1987, 1988, 1989, 1990, 1991).

[a]1 x 10^{-9} µCi/ml is equivalent to 0.037 Bq/L and 1 pCi/L. The DOE guideline is 3.0 x 10^{-9} µCi/ml.

[b]Measured background has not been subtracted.

[c]Sampling locations are shown in Figures 4-1 and 4-2.

[d]Average value ±2 standard deviations (95 percent confidence level).

[e]Station established in April 1988.

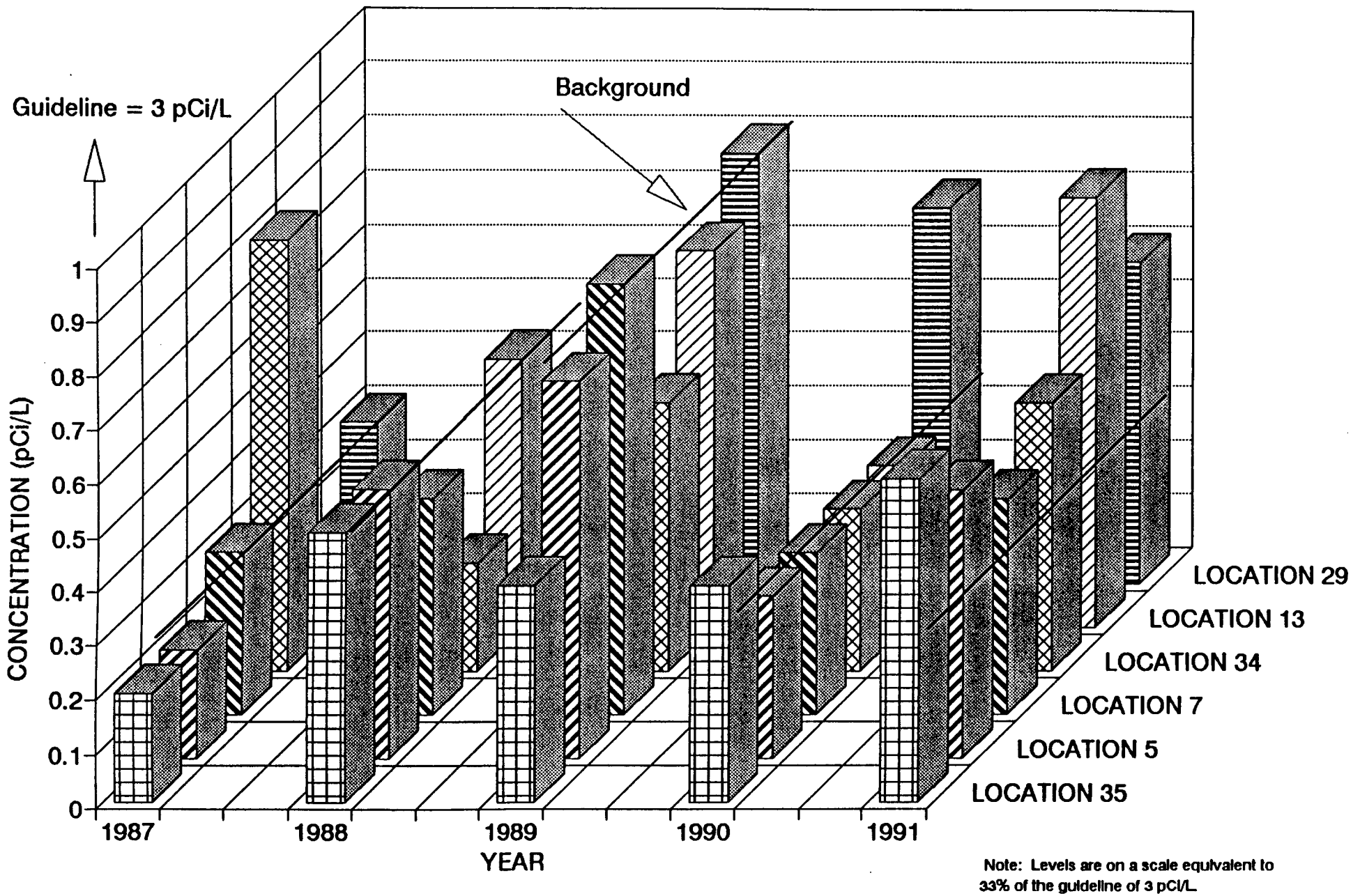


Figure 4-3
Average Annual Radon Levels at NFSS

Data and discussion

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.

For comparison, Figure 4-4 shows the average annual external gamma radiation exposure rates for locations onsite, at the site boundary, offsite, and across the nation. Based on these data, the radioactive waste at NFSS does not present a threat to the public from external gamma radiation exposure because the rates are so low, the waste is buried, and access to the waste is restricted.

Trends

Trends in average external gamma radiation exposure rates measured at the property-line and background locations from 1986 through 1991 are presented in Table 4-4. Trends for locations with the highest concentrations are shown in Figure 4-5. External gamma radiation exposure rates have not changed noticeably over the last five years. However, the dosimeter accuracy limits (±25 percent) at these low rates do not permit a more accurate determination.

4.1.3 Surface Water Monitoring

Surface water monitoring is conducted to determine whether onsite surface water is contaminated, to determine whether runoff from NFSS contributes to surface water contamination in the area, and to ensure compliance with environmental regulations. Onsite sampling locations for surface water (9, 10, and 11) are shown in Figure 4-6; offsite 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

Table 4-3

Average External Gamma Radiation Exposure Rates[a] at NFSS, 1991

Sampling Location[b]	Quarter 1	2	3	4	Avg
			(Rates are in mR/yr)		
Property Line (measured background subtracted)[c]					
1	1	7	7	5	5
3	0[d]	3	3	2	2
4	0	7	5	10	6
5	8	17	22	4	10
6	6	2	3	1	3
7	2	4	10	7	6
11	0	0	1	0	0
12	0	5	5	11	5
13	0	0	7	3	3
14	6	12	2	9	7
15	10	0	12	20	10
20	10	13	19	10	13
28	0	16	8	15	10
29	1	1	4	8	3
34	3	0	5	5	3
35	0	7	5	12	6
36	0	9	10	3	5
38	0	2	0	5	2
				Average	6
Onsite (measured background subtracted)[c]					
2	7	10	12	8	9
8	20	29	26	33	27
9	0	7	8	5	5
10	0	2	1	6	3
16	0	0	0	0	0
17	9	6	13	10	9
18	10	12	16	25	16
19	0	5	8	3	4
21	7	14	12	16	10
22	0	--[e]	14	10	8
23	0	10	13	18	10
24	0	8	3	4	4
25	0	0	5	0	1
26	3	8	8	0	5
27	0	4	1	6	3
39	0	3	7	3	3
				Average	7

Table 4-3

(continued)

Sampling Location[b]	Quarter 1	2	3	4	Avg
Quality Control					
31[f]	0	7	3	8	5
32[g]	0	4	0	0	1
33[h]	0	3	9	3	4
Background					
30	68	60	57	60	61
40	70	69	70	76	71
41	72	68	68	84	73
42	74	72	70	86	75
105	73	62	62	69	67
112	76	74	70	88	77
116	60	70	66	71	67
120	92	84	88	91	89
121	97	93	83	108	95
				Average	75

[a]Dosimeters evaluated each quarter have been in place for 1 yr. The DOE guideline is 100 mrem/yr above background. 1 mrem is approximately equivalent to 1 mR.

[b]Sampling locations are shown in Figures 4-1 and 4-2.

[c]Average annual measured background of 75 mR/yr has been subtracted from the property-line and onsite readings.

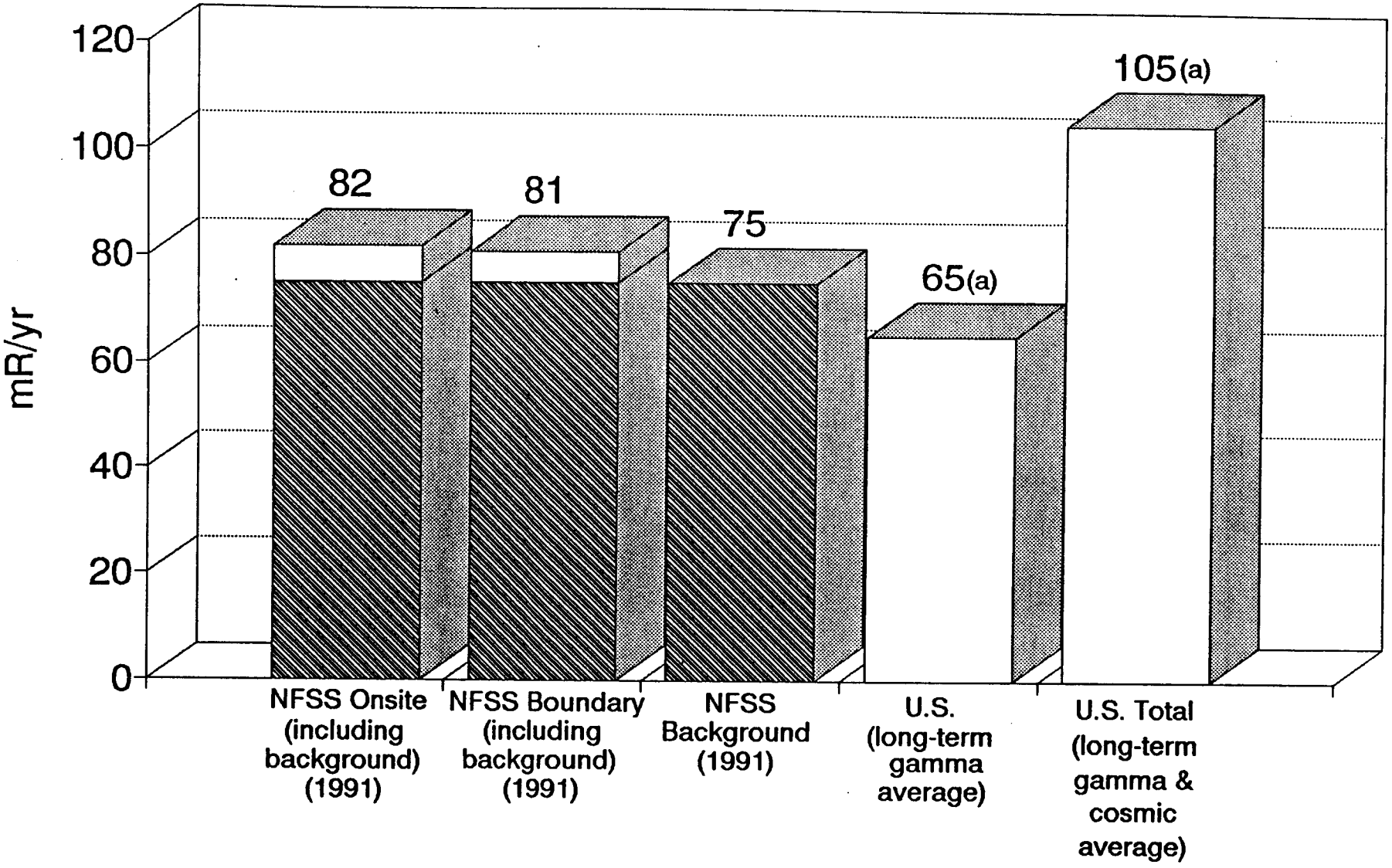
[d]A zero value indicates that the rate was equal to background at this location.

[e]Reading not taken because the dosimeter was vandalized.

[f]Quality control for station 9.

[g]Quality control for station 12.

[h]Quality control for station 19.



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

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

Figure 4-4
External Gamma Radiation Exposure Rates

Table 4-4

Trend Analysis for External Gamma Radiation Exposure Rates[a] at NFSS, 1986-1991

Sampling Location[b]	Average Annual Rate 1986	1987	1988	1989	1990	Expected Range[c] ($\bar{x} \pm 2s$)	Average Annual Rate 1991
				(Rates are in mR/yr)			
Property Line (measured background subtracted)[d]							
1	16	11	11	0[e]	1	0 - 20	5
3	4	11	9	0	1	0 - 10	2
4	14	13	7	0	1	0 - 20	6
5	14	16	22	2	7	0 - 30	13
6	8	3	16	0	0	0 - 20	3
7	8	11	7	2	2	0 - 10	6
11	4	2	5	0	0	0 - 7	0
12	2	6	8	0	0	0 - 10	5
13	0	0	6	1	0	0 - 7	3
14	3	7	14	0	4	0 - 20	7
15	6	6	14	3	2	0 - 20	11
20	26	24	23	8	6	0 - 40	13
28	14	14	10	2	4	0 - 20	10
29	0	0	10	0	1	0 - 10	3
32[f]	6	5	8	0	1	0 - 10	1
34	6	8	3	0	0	0 - 10	3
35	15	14	14	1	3	0 - 20	6
36	5	16	10	0	1	0 - 20	5
Background							
30	69	64	71	61	54	50 - 77	61
120[g]	--	--	--	83	80	77 - 86	89
121[g]	--	--	--	87	83	79 - 91	95

NOTE: Sources for 1986-1990 data are the annual site environmental reports for those years (BNI 1987, 1988, 1989, 1990, 1991).

[a]The DOE guideline is 100 mrem/yr above background. 1 mrem is approximately equivalent to 1 mR.

[b]Sampling locations are shown in Figures 4-1 and 4-2.

[c]Average value ±2 standard deviations (95 percent confidence level).

[d]Average annual measured background has been subtracted from property-line readings.

[e]A zero value indicates that the level was equal to background at this location.

[f]Quality control for station 12.

[g]Station established in April 1988.

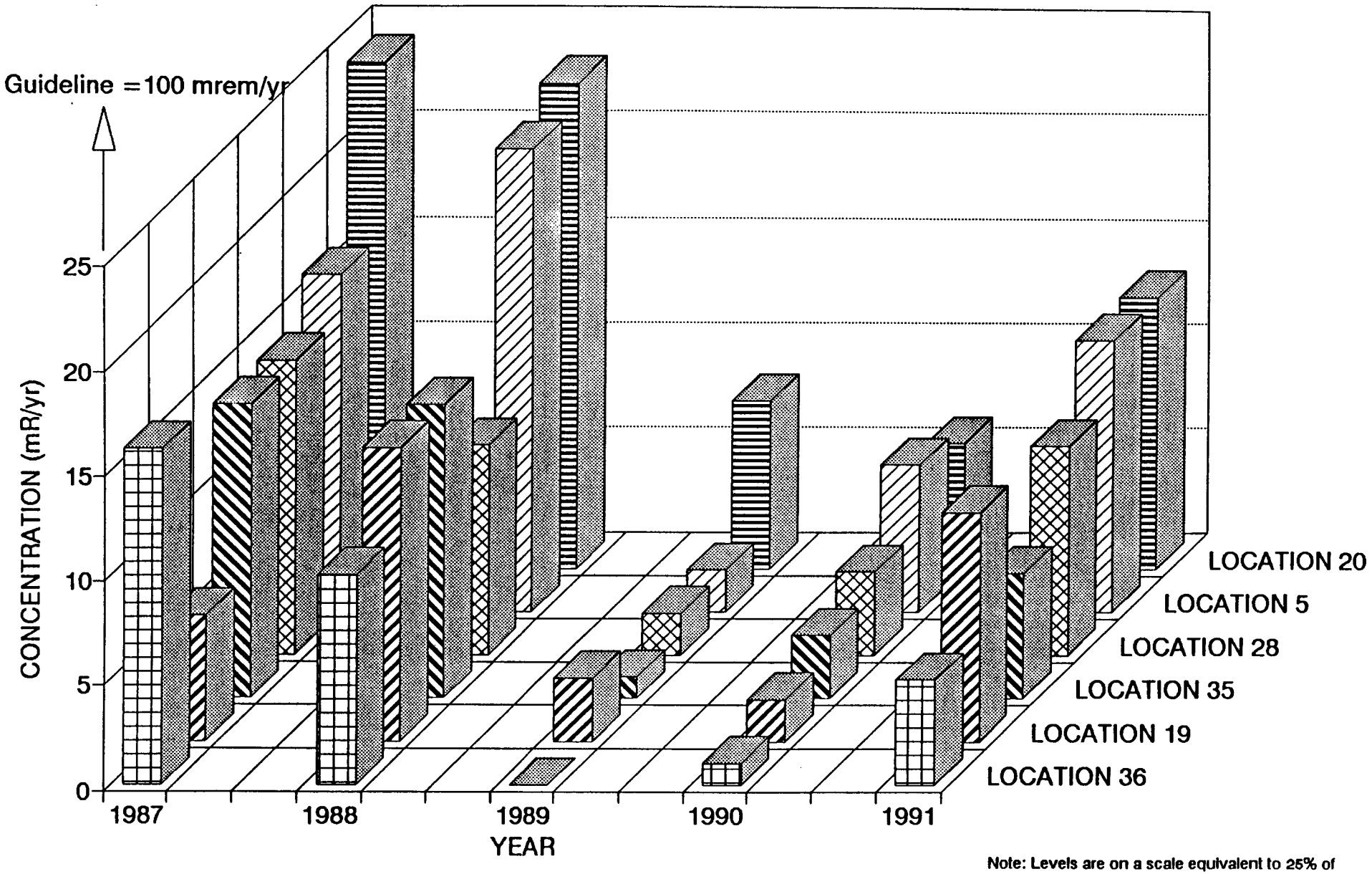


Figure 4-5
Average Annual External Gamma Radiation Levels Above Background at NFSS

Table 4-5

Concentrations[a,b] of Total Uranium and Radium-226 in Surface Water at NFSS, 1991

Sampling Location[c]	Quarter 1[d]	2	3	4	Avg
	(Concentrations are in 1 x 10^{-9} µCi/ml)				
	Total Uranium[d]				
9[e]	7	4	--[f]	4	5
10	11	7	--[f]	7	8
11	13	9	--[f]	16	13
12[g]	3	4	<4	3	4
20[g]	4	4	<4	4	4
	Radium-226[h]				
9[e]	2.3	0.1	--[f]	0.9	1
10	0.3	0.3	--[f]	1.5	0.7
11	3.3	0.5	--[f]	0.7	2
12[g]	0.2	0.1	0.9	1.0	0.6
20[g]	0.3	0.4	0.4	0.5	0.4

[a]1 x 10^{-9} µCi/ml is equivalent to 0.037 Bq/L and 1 pCi/L. The DCGs for total uranium and radium-226 are 600 x 10^{-9} and 100 x 10^{-9} µCi/ml, respectively.

[b]Measured background has not been subtracted.

[c]Sampling locations are shown in Figures 4-2 and 4-6.

[d]Total uranium concentrations were determined by using fluorometric analysis during the first three quarters and by kinetic phosphorescence analysis during the fourth quarter.

[e]Background, upstream sampling location.

[f]Because of drought conditions, the ditch was dry and could not be sampled.

[g]Offsite, downstream sampling location.

[h]Radium-226 concentrations were determined by emanation during the first three quarters and by alpha spectroscopy during the fourth quarter.

Table 4-6

Trend Analysis for Total Uranium and Radium-226 Concentrations[a,b] in Surface Water at NFSS, 1986-1991

Sampling Location[c]	Average Annual Concentration 1986	1987	1988	1989	1990	Expected Range[d] ($\bar{X} \pm 2s$)	Average Annual Concentration 1991
(Concentrations are in 10^{-9} µCi/ml)							
Total Uranium[e]							
9[f]	--	--	8	9	7	6 - 10	5
10	8	6	7	21	5	0 - 20	8
11	5	14	10	16	9	2 - 20	13
12[g]	4	5	6	10	9	2 - 10	4
20[g]	5	6	7	4	8	3 - 9	4
Radium-226[h]							
9[f]	--	--	0.2	1.5	0.5	0 - 2	1
10	0.2	0.2	0.2	0.6	0.5	0 - 0.7	0.7
11	0.3	0.3	1	2.5	0.4	0 - 3	2
12[g]	0.3	0.3	0.3	0.6	0.9	0.1 - 1	0.6
20[g]	0.4	0.4	1	0.5	0.7	0.1 - 1	0.4

NOTE: Sources for 1986-1990 data are the annual site environmental reports for those years (BNI 1987, 1988, 1989, 1990, 1991).

[a]1 x 10^{-9} µCi/ml is equivalent to 0.037 Bq/L and 1 pCi/L. The DCGs for total uranium and radium-226 are 600 x 10^{-9} and 100 x 10^{-9} µCi/ml, respectively.

[b]Measured background has not been subtracted.

[c]Sampling locations are shown in Figures 4-2 and 4-6.

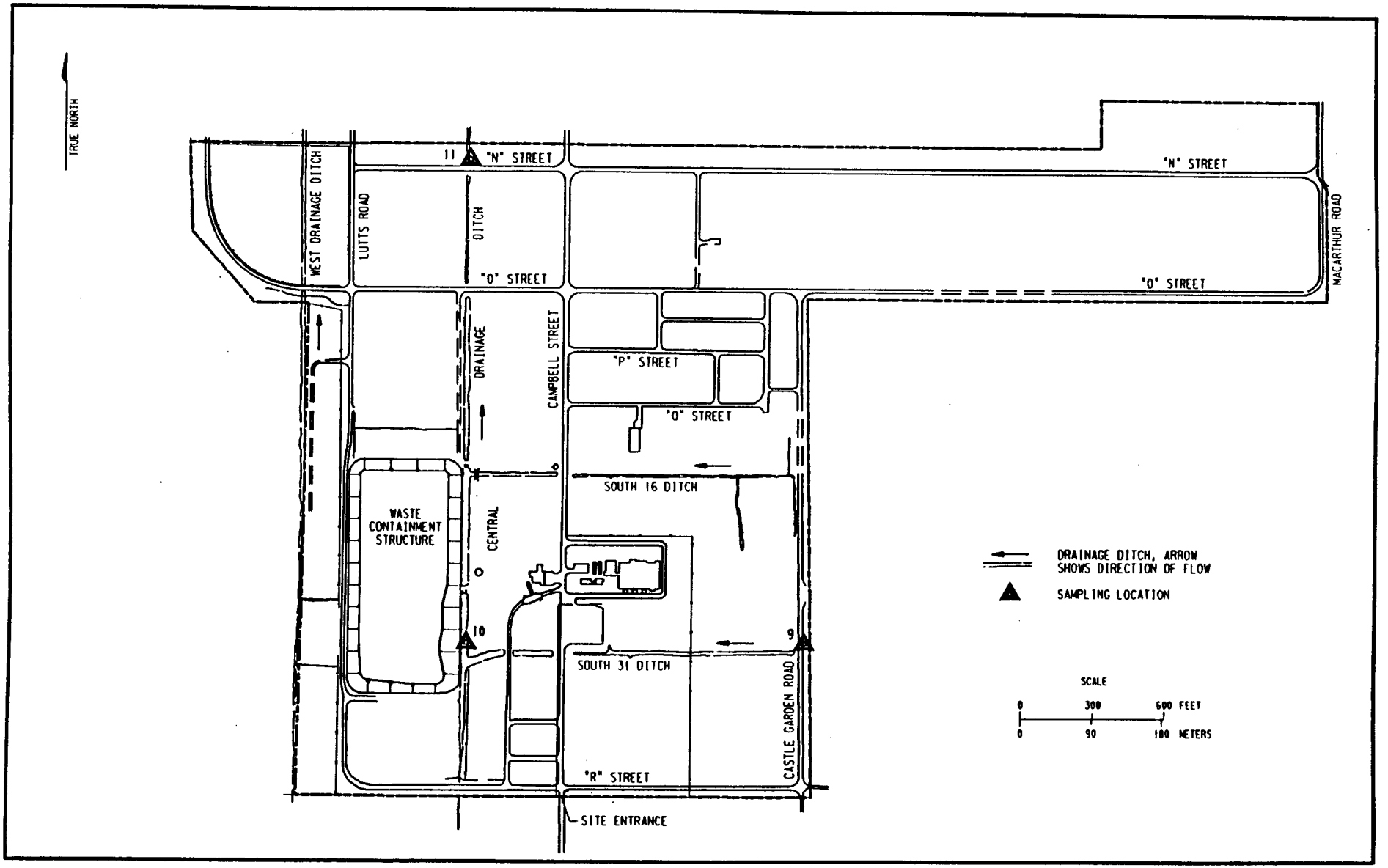
[d]Average value ±2 standard deviations (95 percent confidence level).

[e]Total uranium concentrations were determined by using fluorometric analysis during 1986 through 1990 and the first three quarters of 1991 and by kinetic phosphorescence analysis during the fourth quarter of 1991.

[f]Background, upstream sampling location established in October 1988 at the South 31 Ditch; thus, data for 1988 represent one quarter's results, not average annual results.

[g]Offsite, downstream sampling location.

[h]Radium-226 concentrations were determined by emanation during 1986 through 1990 and the first three quarters of 1991 and by alpha spectroscopy during the fourth quarter of 1991.



158 R10F004.DGN

Figure 4-6
Onsite Surface Water and Sediment Sampling Locations

discharges via the Central Drainage Ditch, all sampling locations except location 9 were placed along that ditch.

Table 4-5 presents 1991 concentrations of total uranium and radium-226 in surface water, which were well below the DCGs of 600 x 10^{-9} and 100 x 10^{-9} μCi/ml, respectively.

Trends

Trends in average annual radionuclide concentrations measured in surface water from 1986 through 1991 are presented in Table 4-6 and shown in Figures 4-7 and 4-8. As shown in the table, results for 1991 are within the expected range of values. Concentrations of total uranium and radium-226 remain fairly consistent and close to background levels.

4.1.4 Sediment Monitoring

Sediment monitoring is conducted to determine whether contaminants are collecting in onsite and/or offsite sediments and to ensure compliance with environmental regulations.

Sediment samples were collected quarterly at surface water sampling locations where sediment is present. Onsite sampling locations (9, 10, and 11) are shown in Figure 4-6; downstream, offsite locations (12 and 20) are shown in Figure 4-2.

Data and discussion

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

Table 4-7 presents 1991 concentrations of total uranium and radium-226 in sediment at NFSS. The higher concentration of total uranium at location 9 (the upstream location) probably results from 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 guideline of 90 pCi/g established for NFSS. Radium-226 levels

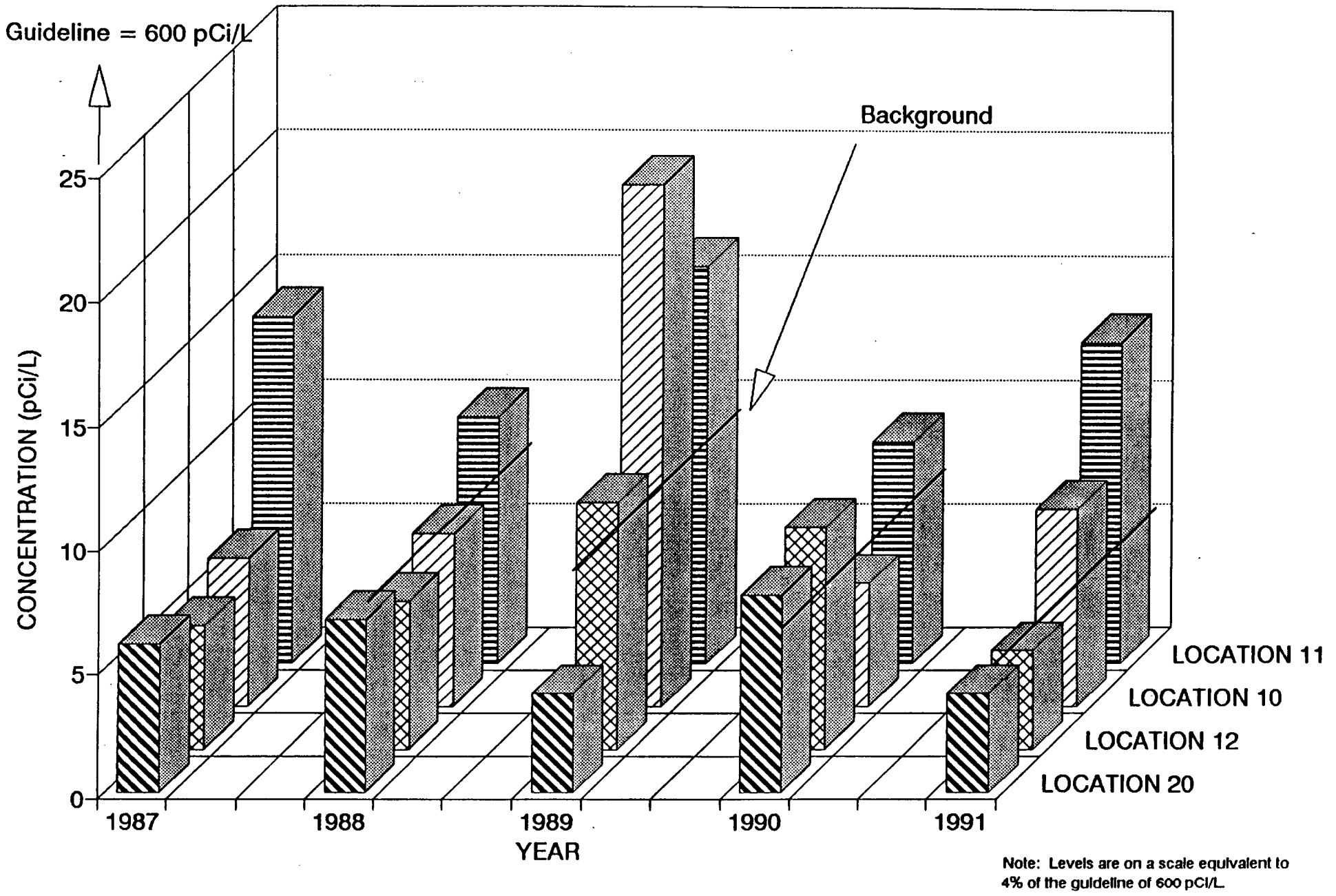


Figure 4-7
Average Annual Total Uranium Levels in Surface Water at NFSS

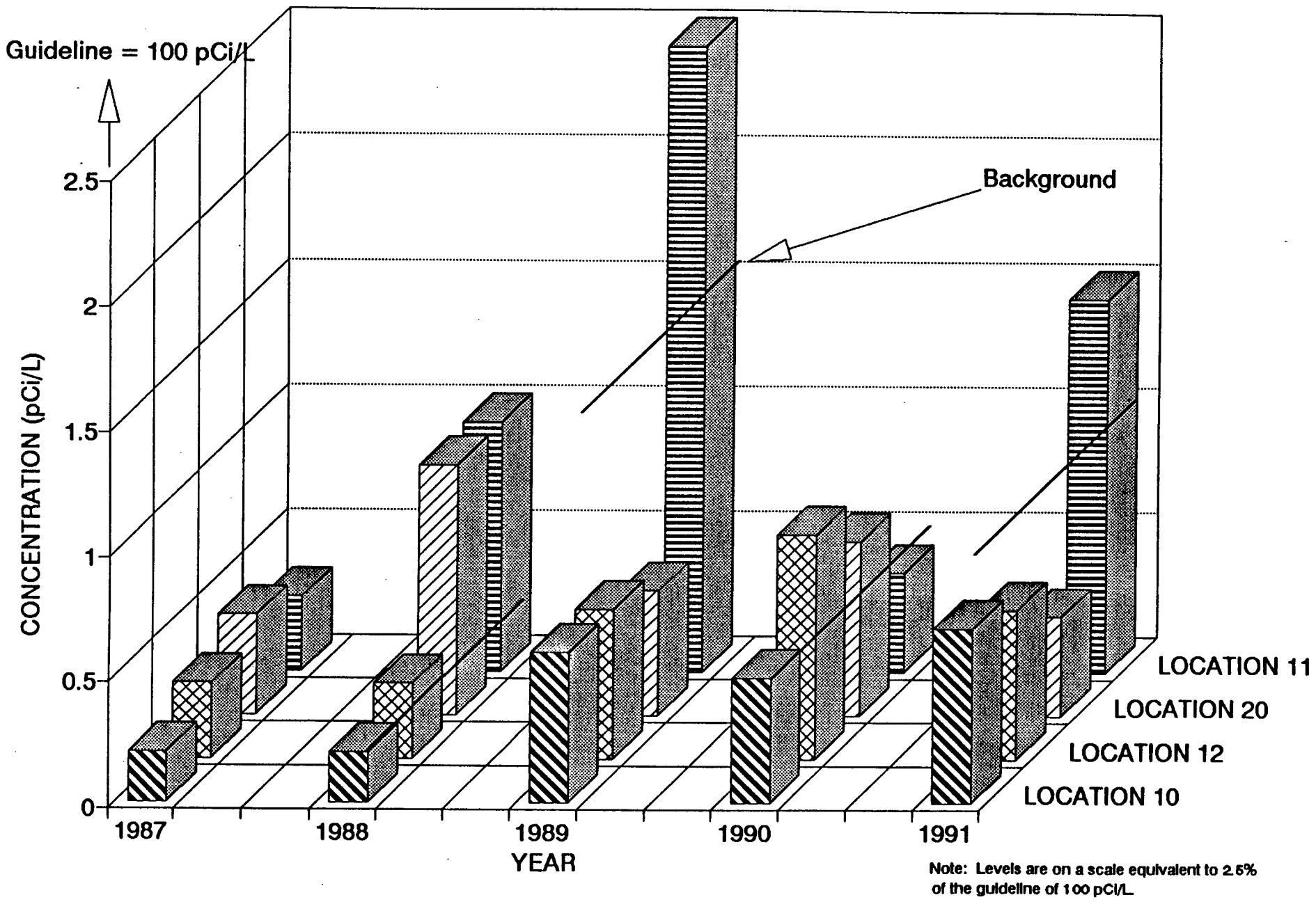


Figure 4-8
Average Annual Radium-226 Levels in Surface Water at NFSS

Table 4-7

Concentrations[a,b] of Total Uranium and Radium-226 in Sediment at NFSS, 1991

Sampling Location[c]	Quarter 1	2	3	4	Avg
	(Concentrations are in pCi/g)				
	Total Uranium				
9[d]	10.7	<9	--[e]	2.1	7
10	4.7	<4	--[e]	3.7	4
11	3.9	<4	--[e]	3.3	4
12[f]	1.6	<4	1.7	6.8	3
20[f]	1.8	<4	1.8	2.1	3
	Radium-226				
9[d]	2.1	1.0	--[e]	<1	2
10	0.6	1.1	--[e]	<0	0.8
11	1.9	0.9	--[e]	<1	1
12[f]	0.8	0.6	0.2	<1	0.7
20[f]	1.1	0.7	0.7	<2	1

[a]1 pCi/g is equivalent to 0.037 Bq/g. The FUSRAP soil guideline for total uranium is 90 pCi/g, and for radium-226 is 5 pCi/g.

[b]Measured background has not been subtracted.

[c]Sampling locations are shown in Figures 4-2 and 4-6.

[d]Background, upstream sampling location.

[e]Because of drought conditions, the ditch was dry and could not be sampled.

[f]Offsite, downstream sampling location.

remained close to background throughout the year and below the FUSRAP soil guidelines listed in Appendix A.

Trends

Trends in average annual radionuclide concentrations measured in sediment from 1986 through 1991 are presented in Table 4-8 and shown in Figures 4-9 and 4-10. Total uranium and radium-226 concentrations in sediment 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.

The monitoring well system is designed to provide sufficient coverage of both upgradient and downgradient conditions. Sampling locations (Figure 4-11) were selected based on the areas of known radioactive contamination and available hydrogeological data. Well BH-48 monitors background conditions in the lower groundwater system, including bedrock (see Section 6.0), and well 20S monitors background conditions in the upper groundwater system. 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. Most of the monitoring wells are located near the WCS. In 1987, 36 wells ("OW" wells in Figure 4-11) were added to the environmental monitoring program to closely monitor groundwater near the WCS to detect possible contaminant movement from the pile. Generally, "OW" wells with the suffix "A" are in the lower groundwater system; those with the suffix "B" are in the upper system.

Because of elevated uranium values in well A-42, chemical, radiological, and hydrogeological conditions in the well were investigated in December 1988; results indicate that the sand lens through which the well was driven is not in good hydraulic connection with the zones of completion of adjacent wells.

Table 4-8

Trend Analysis for Total Uranium and Radium-226 Concentrations[a,b] in Sediment at NFSS, 1986-1991

Sampling Location[c]	Average Annual Concentration 1986	1987	1988	1989	1990	Expected Range[d] ($\bar{x} \pm 2s$)	Average Annual Concentration[e] 1991
				(Concentrations are in pCi/g)			
				Total Uranium			
9[e]	--	--	2	2.6	3.7	1 - 5	7
10	--[f]	1.8	2.7	8.8	1.8	0 - 11	4
11	1.4	2	1.5	2.1	2.5	1 - 3	4
12[g]	1.9	1.3	1.9	1.4	1.7	1.1 - 2.2	3
20[g]	1.4	1.5	1.8	1.5	1.6	1.3 - 1.9	3
				Radium-226			
9[e]	--	--	1.3	1	1	0.8 - 1	2
10	--[f]	0.8	0.8	1.8	0.8	0.1 - 2	0.8
11	1.1	1.3	1	1.7	1	0.6 - 2	1
12[g]	1	0.5	1.3	0.8	0.8	0.3 - 2	0.7
20[g]	1.6	0.8	0.9	0.8	1	0.4 - 2	1

NOTE: Sources for 1986-1990 data are the annual site environmental reports for those years (BNI 1987, 1988a, 1989, 1990, 1991).

[a]1 pCi/g is equivalent to 0.037 Bq/g. The FUSRAP soil guideline for total uranium is 90 pCi/g, and for radium-226 is 5 pCi/g.

[b]Measured background has not been subtracted.

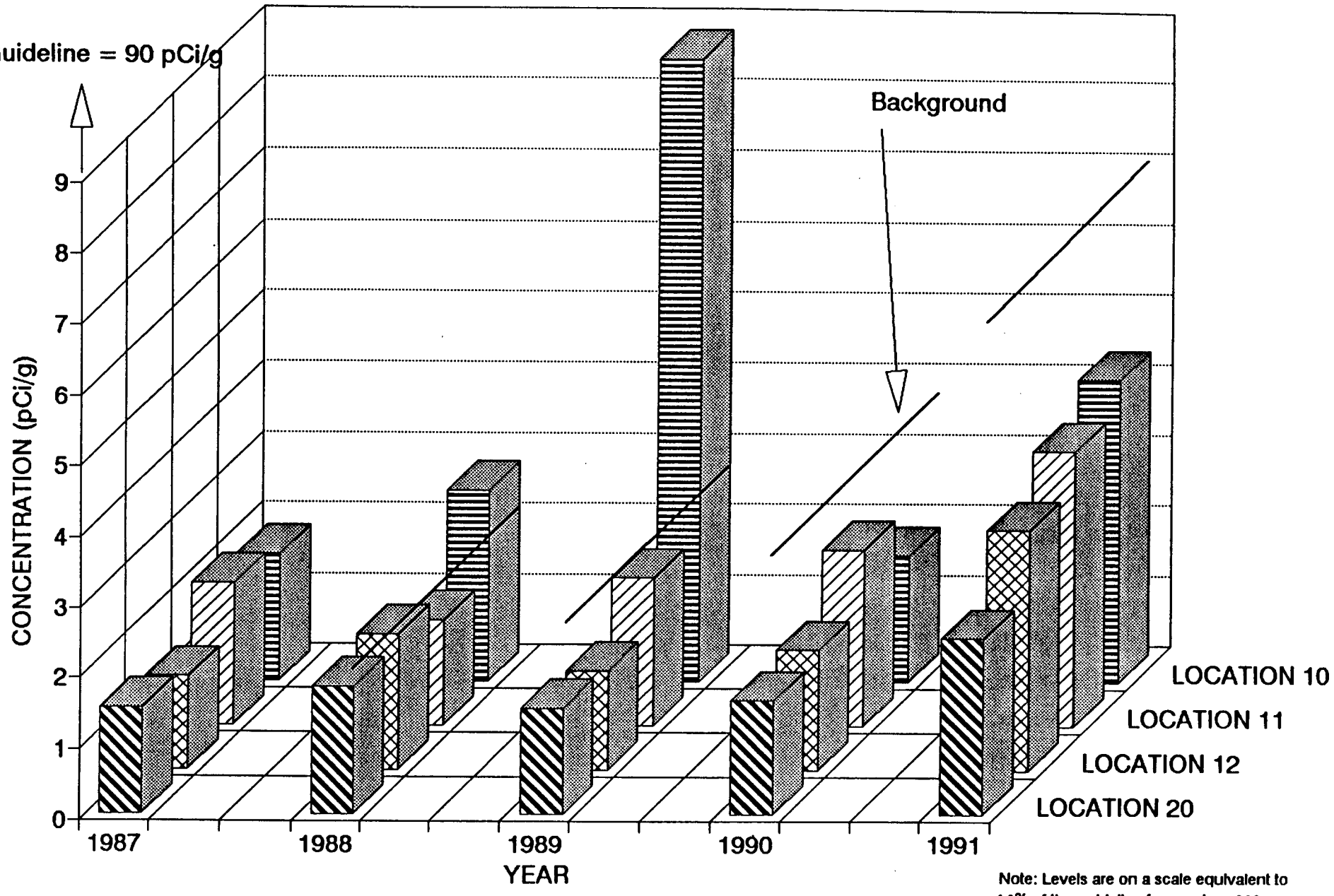
[c]Sampling locations are shown in Figures 4-2 and 4-6.

[d]Average value ±2 standard deviations (95 percent confidence level).

[e]Background, upstream sampling location established in October 1988 at the South 31 Ditch; thus, data for 1988 represent one quarter's results, not average annual results.

[f]Not enough sediment was available for sample.

[g]Offsite, downstream sampling location.



Note: Levels are on a scale equivalent to 10% of the guideline for uranium-238 of 90 pCi/g. Background values were not collected in 1987.

Figure 4-9
Average Annual Total Uranium Levels in Sediment at NFSS

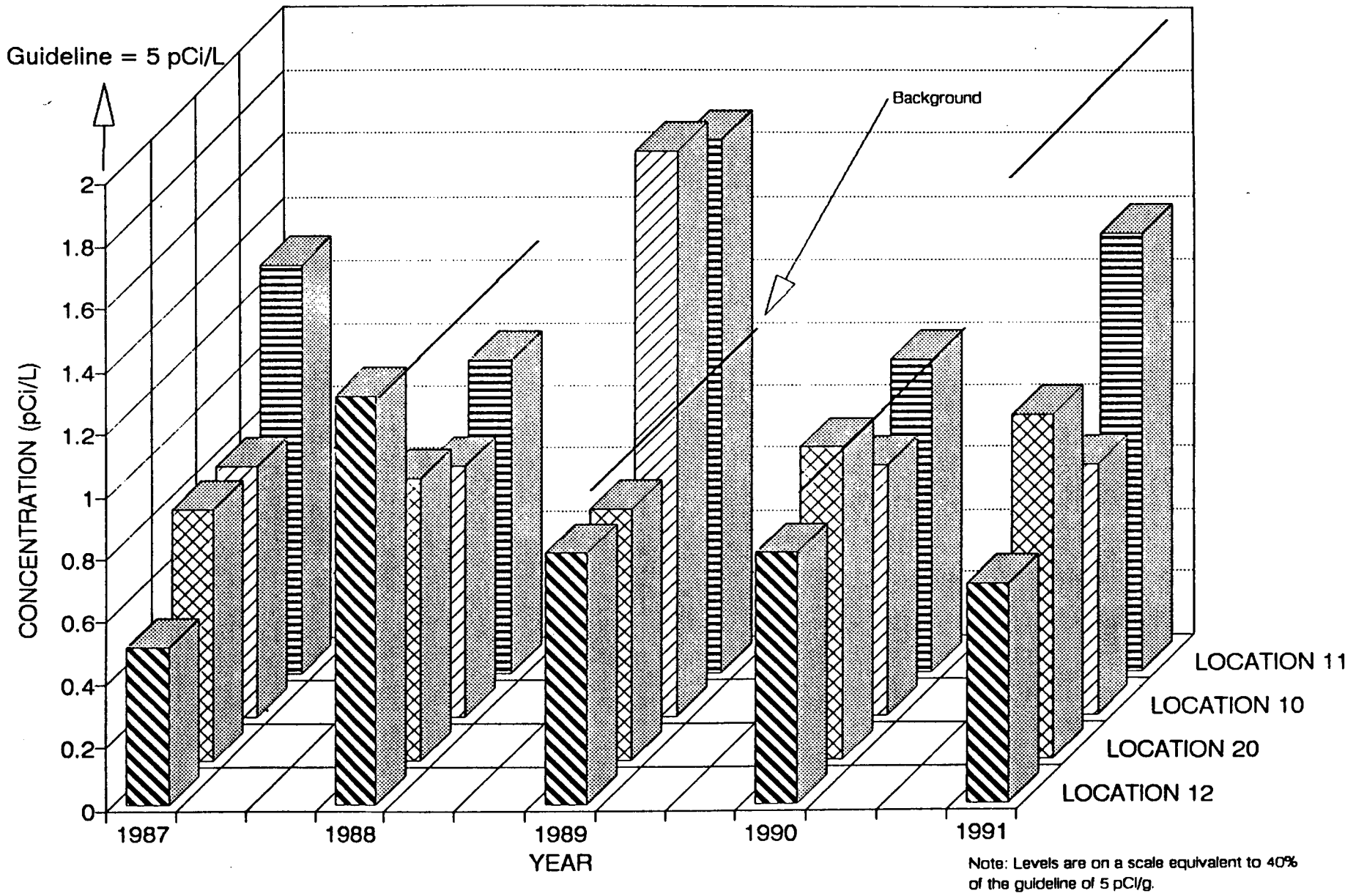


Figure 4-10
Average Annual Radium-226 Levels in Sediment at NFSS

Additionally, results of subsequent sampling conducted in 1989 indicate that radioactive contamination in well A-42 is probably associated with contaminated soils in or near the well and not with leakage from the WCS.

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

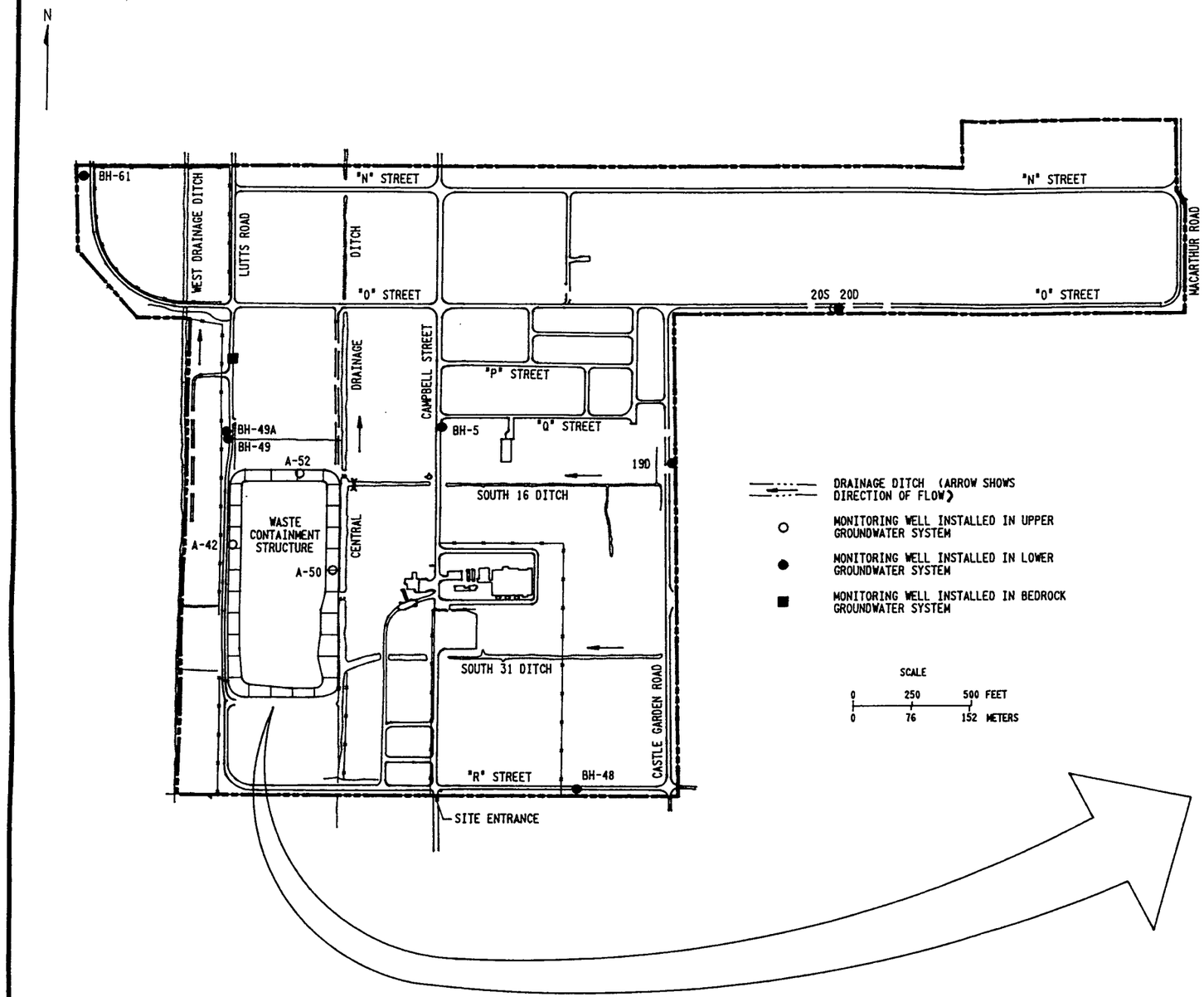
Quarterly groundwater samples were analyzed for radium-226 and total uranium.

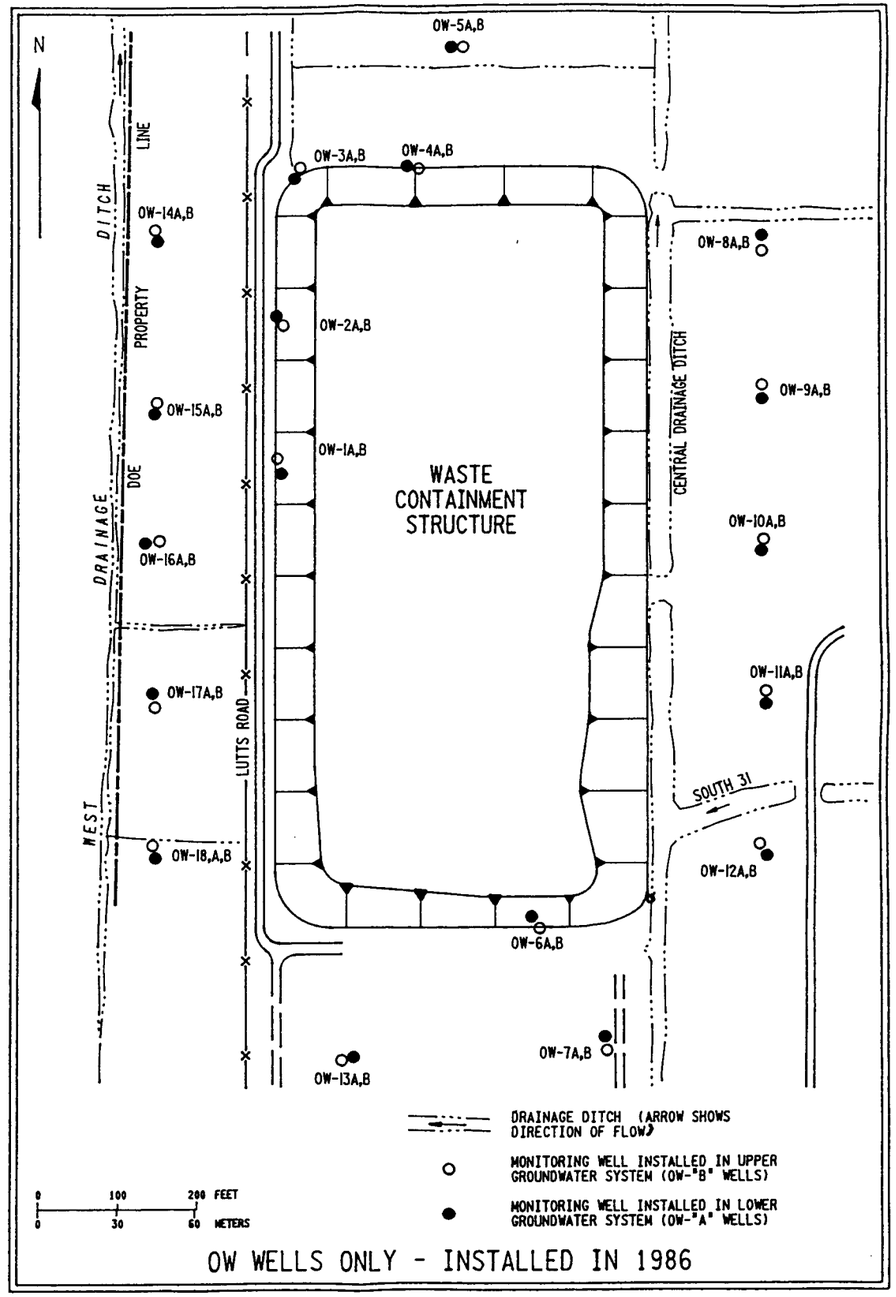
Data and discussion

Radium-226 concentrations in groundwater samples are presented in Table 4-9. Drought conditions in 1991 affected the elevation of water levels in the upper groundwater system; Wells OW-1B, OW-3B, OW-5B, OW-7B, OW-8B, OW-9B, OW-11B, OW-12B, OW-15B, OW-17B, OW-18B, A-50, and 20-S (Figure 4-11) did not refill with water after purging. Therefore, samples were not collected from some of these wells during the fourth quarter if the amount of water was insufficient. Samples were also not collected from OW-5B during the third quarter because there was a wasp nest in the well. Samples were not collected from OW-4A during the third quarter because the bailer was stuck in the well and could not be removed. Data available for the first, second, and third quarters for most of the wells in the upper groundwater system are presented in tables; the average levels for these quarters are compared with average background levels in well 20S.

There were no major differences in upgradient and downgradient radionuclide concentrations in the upper or lower groundwater systems for WCS area wells. All radium-226 concentrations were below the DCG of 100×10^{-9} μCi/ml.

Total uranium concentrations in groundwater samples are presented in Table 4-10. There were no significant differences in radionuclide concentrations between the background and downgradient wells in the lower groundwater system. The average concentration in downgradient wells in the upper groundwater system was two times greater than the average background concentration. As can be seen





158 R10F005.DGN

Figure 4-11
Groundwater Sampling Locations at NFSS

Table 4-9

Concentrations[a,b] of Radium-226[c] in Groundwater at NFSS, 1991

Sampling Location[d]	Quarter 1	2	3	4	Avg
(Concentrations are in 10^{-9} µCi/ml)					
Upper Groundwater System					
OW-1B	--[e]	0.4	0.4	--[f]	0.4
OW-2B	0.1	0.1	0.1	0.7	0.3
OW-3B	0.2	0.4	0.2	0.2	0.3
OW-4B	0.2	0.2	0.6	3.1	1
OW-5B	--[e]	0.3	--[g]	--[f]	0.3
OW-6B	0.1	0.3	0.2	0.1	0.2
OW-7B	0.3	0.4	0.3	--[f]	0.3
OW-8B	0.1	0.1	0.3	--[f]	0.2
OW-9B	0.3	0.3	0.1	--[f]	0.2
OW-10B	0.1	0.3	1.7	0.6	0.7
OW-11B	0.2	0.1	0.3	--[f]	0.2
OW-12B	0.4	0.1	--[f]	--[f]	0.3
OW-13B	0.8	0.1	0.4	0.7	0.5
OW-14B	0.2	0.1	0.7	2.2	0.8
OW-15B	0.2	0.1	0.5	--[f]	0.3
OW-16B	0.5	0.2	0.8	2.4	1
OW-17B	0.4	0.4	0.1	0.2	0.3
OW-18B	0.4	0.8	0.5	--[f]	0.6
A-42	0.8	0.3	0.2	0.5	0.5
A-50	0.2	0.4	0.5	--[f]	0.4
A-52	0.7	0.5	0.5	2.7	1
BH-49A	0.7	0.5	3.1	2.7	1
20-S[h]	0.3	0.5	0.4	--[f]	0.4
Lower Groundwater System					
OW-1A	0.5	0.2	0.4	0.8	0.5
OW-2A	0.7	0.4	0.4	0.3	0.5
OW-3A	0.3	0.4	0.3	0.7	0.4
OW-4A	0.2	0.7	--[i]	0.2	0.4
OW-5A	0.3	0.2	0.5	0.9	0.5
OW-6A	0.2	0.6	0.5	1.7	0.8
OW-7A	0.3	0.2	0.1	2.1	0.7
OW-8A	0.8	0.6	0.9	1.4	0.9
OW-9A	0.5	0.4	0.3	2.3	0.9

Table 4-9

(continued)

Sampling Location[d]	Quarter 1	2	3	4	Avg
	(Concentrations in 10^{-9} µCi/ml)				
	Lower Groundwater System (cont'd)				
OW-10A	0.2	0.2	0.3	1.5	0.6
OW-11A	0.2	0.1	0.6	4.1	1
OW-12A	0.3	0.1	0.4	0.4	0.3
OW-13A	0.4	0.1	0.5	0.4	0.4
OW-14A	0.5	0.1	0.3	0.5	0.4
OW-15A	1.3	0.1	0.5	1	0.7
OW-16A	0.9	0.1	0.5	0.4	0.5
OW-17A	0.2	0.5	0.3	3.6	1
OW-18A	0.6	0.4	0.2	0.4	0.4
BH-5	0.2	0.4	0.4	1.9	0.7
BH-49	0.6	0.5	0.4	0.9	0.6
BH-61[j]	0.2	0.5	0.7	0.2	0.4
19-D	0.3	0.4	0.1	0.7	0.4
20-D	0.5	0.6	0.7	1.1	0.7
BH-48[h]	2.5	1.1	1	2.8	2

[a]1 x 10^{-9} µCi/ml is equivalent to 0.037 Bq/L and 1 pCi/L. The DCG is 100 x 10^{-9} µCi/ml.

[b]Measured background has not been subtracted.

[c]Radium-226 concentrations were determined by emanation during the first three quarters and by alpha spectroscopy during the fourth quarter.

[d]Sampling locations are shown in Figure 4-11.

[e]Not enough water for sample.

[f]Well did not recover after purging.

[g]Wasp nest in well; could not sample.

[h]Background well.

[i]Bailer stuck in well; could not sample.

[j]Downgradient well.

Table 4-10

Concentrations[a,b] of Total Uranium[c] in Groundwater at NFSS, 1991

Sampling Location[d]	Quarter 1	2	3	4	Avg
(Concentrations are in 10^{-9} µCi/ml)					
Upper Groundwater System					
OW-1B	--[e]	3	3	--[f]	3
OW-2B	8	7	11	6.6	8
OW-3B	14	15	13	10.8	13
OW-4B	4	5	8	5.5	6
OW-5B	--[e]	10	--[g]	--[f]	10
OW-6B	30	6	19	16.2	20
OW-7B	10	12	13	--[f]	12
OW-8B	9	5	26	--[f]	10
OW-9B	18	22	20	--[f]	20
OW-10B	7	14	28	5.8	10
OW-11B	15	28	27	--[f]	23
OW-12B	12	14	--[f]	--[f]	13
OW-13B	19	18	17	18	18
OW-14B	5	4	13	5.1	7
OW-15B	7.4	31.8	12.2	--[f]	17
OW-16B	5	14	3	4.9	7
OW-17B	5	9	3	6	6
OW-18B	14	17	12	--[f]	14
A-42	63	56	47	60.9	57
A-50	6	10	4	--[f]	7
A-52	15	19	13	16.6	16
BH-49A	6	11	14	9.9	10
20-S[h]	5	8	4	--[f]	6
Lower Groundwater System					
OW-1A	3	3	3	0.8	3
OW-2A	11	3	3	0.3	4
OW-3A	6	4	4	6.4	5
OW-4A	3	3	--[i]	2.3	3
OW-5A	3	7	3	1	4
OW-6A	3	9	5	1.7	5

Table 4-10

(continued)

Sampling Location[d]	Quarter 1	2	3	4	Avg
Lower Groundwater System (cont'd)					
OW-7A	3	6	5	2.8	4
OW-8A	3	12	4	2.6	5
OW-9A	3	13	5	3	6
OW-10A	3	3	10	2.3	5
OW-11A	3	5	7	1.8	4
OW-12A	3	3	7	0.2	3
OW-13A	3	5	14	2.5	6
OW-14A	3	3	3	0.2	2
OW-15A	3	3	4	0.9	3
OW-16A	3	3	4	0.7	3
OW-17A	3	5	22	1.4	8
OW-18A	3	6	5	0.9	4
BH-5	3	3	3	0.1	3
BH-49	3	3	18	0.1	6
BH-61[j]	3	3	3	0.5	2
19-D	4	4	4	0.1	3
20-D	3	3	3	0.4	3
BH-48[h]	3	3	3	1.7	3

[a]1 x 10^{-9} μCi/ml is equivalent to 0.037 Bq/L and 1 pCi/L. The DCG is 600 x 10^{-9} μCi/ml.

[b]Measured background has not been subtracted.

[c]Total uranium concentrations were determined by using fluorometric analysis during the first three quarters and by kinetic phosphorescence analysis during the fourth quarter.

[d]Sampling locations are shown in Figure 4-11.

[e]Well did not recover after purging.

[f]Not enough water for sample.

[g]Wasp nest in well; could not sample.

[h]Background well.

[i]Bailer stuck in well; could not sample.

[j]Downgradient well.

in the trend section, the concentrations have remained steady since before the WCS was constructed; therefore, the WCS does not appear to be the source of the elevated uranium levels. Total uranium concentrations were well below the DCG of 600 x 10^{-9} μCi/ml.

Trends

Trends in average annual radionuclide concentrations measured in groundwater from 1986 through 1991 are presented in Tables 4-11 and 4-12; trends in wells with the highest concentrations are shown in Figures 4-12 and 4-13. The expected range is based on calculation of the standard deviation of the yearly mean and provides a rough check on the presence of any trends.

Concentrations of radium-226 and total uranium in groundwater at NFSS have remained basically stable, as can be seen by the narrow ranges. The total uranium concentrations in well A-42 have been consistently above those measured in the other wells because this well was installed in a radioactively contaminated area.

4.2 UNPLANNED RADIOACTIVE RELEASES

No unplanned radioactive releases occurred in 1991.

4.3 POTENTIAL DOSE TO THE PUBLIC

This section contains information on potential radiation exposures calculated for a hypothetical maximally exposed individual and the general public from radioactive materials at NFSS. As expected for a stable site like NFSS, all calculated doses were well below the DOE guideline.

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 radionuclides, but

Table 4-11
Trend Analysis for Radium-226 Concentrations[a,b] in Groundwater at NFSS, 1986-1991

Sampling Location[c]	Average Annual Concentration[d] 1986	1987	1988	1989	1990	Expected Range[e] ($\bar{x} \pm 2s$)	Average Annual Concentration[d] 1991
			(Concentrations are in 10^{-9} µCi/ml)				
			Upper Groundwater System				
OW-1B	--[f]	0.2	0.4	0.7	0.3	0 - 0.8	0.4
OW-2B	--	0.2	0.4	0.3	0.2	0.1 - 0.5	0.3
OW-3B	--	0.1	0.5	0.7	0.3	0 - 0.9	0.3
OW-4B	--	0.2	0.3	0.5	0.3	0.1 - 0.6	1
OW-5B	--	0.2	0.7	0.7	0.5	0.1 - 1	0.3
OW-6B	--	0.2	0.5	0.5	0.2	0 - 0.7	0.2
OW-7B	--	0.2	0.4	0.5	0.3	0.1 - 0.6	0.3
OW-8B	--	0.2	0.8	0.6	0.3	0 - 1	0.2
OW-9B	--	0.2	0.7	0.9	0.3	0 - 1	0.2
OW-10B	--	0.2	0.3	0.3	0.3	0.2 - 0.4	0.7
OW-11B	--	0.1	0.5	0.4	0.3	0 - 0.7	0.2
OW-12B	--	0.2	0.6	0.5	0.4	0.1 - 0.8	0.3
OW-13B	--	0.2	0.7	0.7	0.8	0.1 - 1	0.5
OW-14B	--	0.5	0.8	1.0	0.5	0.2 - 1	0.8
OW-15B	--	0.2	0.6	0.8	0.4	0 - 1	0.3
OW-16B	--	0.2	0.8	0.7	0.6	0 - 1	1
OW-17B	--	0.2	0.3	0.4	0.4	0.1 - 0.5	0.3
OW-18B	--	0.4	0.4	0.8	0.4	0.1 - 0.9	0.6
A-42	0.6	0.2	0.5	0.6	0.9	0.1 - 1	0.5
A-50	0.5	0.3	0.3	0.5	0.5	0.2 - 0.6	0.4
A-52	0.3	0.2	0.3	0.6	0.4	0.1 - 0.7	1
			Lower Groundwater System				
OW-1A	--	0.4	0.4	0.6	0.3	0.2 - 0.7	0.5
OW-2A	--	0.2	0.4	0.4	0.3	0.1 - 0.5	0.5
OW-3A	--	0.1	0.4	0.5	0.3	0 - 0.7	0.4
OW-4A	--	0.2	0.4	0.5	0.3	0.1 - 0.6	0.4
OW-5A	--	0.2	0.4	0.4	0.6	0.1 - 0.7	0.5
OW-6A	--	0.2	0.4	0.5	0.3	0.1 - 0.6	0.8
OW-7A	--	0.2	0.5	1.0	0.4	0 - 1	0.7
OW-8A	--	0.2	0.5	0.6	0.5	0.1 - 0.8	0.9
OW-9A	--	0.2	0.4	0.5	0.3	0.1 - 0.6	0.9
OW-10A	--	0.3	0.3	0.4	0.2	0.1 - 0.5	0.6
OW-11A	--	0.2	0.6	0.8	0.4	0 - 1	1
OW-12A	--	0.2	0.5	0.5	0.4	0.1 - 0.7	0.3
OW-13A	--	0.2	0.5	0.6	0.4	0.1 - 0.8	0.4
OW-14A	--	0.2	0.5	0.3	0.2	0 - 0.6	0.4
OW-15A	--	0.3	0.5	0.4	0.5	0.2 - 0.6	0.7
OW-16A	--	0.2	0.4	0.5	0.4	0.1 - 0.6	0.5
OW-17A	--	0.2	0.5	0.3	0.3	0.1 - 0.6	1
OW-18A	--	0.3	0.5	0.3	0.5	0.2 - 0.6	0.4
BH-5	0.5	0.4	0.3	0.4	0.4	0.3 - 0.5	0.7
BH-48[g]	0.5	0.5	0.7	0.7	0.7	0.4 - 0.8	2
BH-61[h]	0.3	0.3	0.3	0.4	0.4	0.2 - 0.4	0.4

Table 4-11

(continued)

NOTE: Sources for 1986-1990 data are the annual site environmental reports for those years (BNI 1987, 1988, 1989, 1990, 1991).

[a]1 x 10^{-9} μCi/ml is equivalent to 0.037 Bq/L and 1 pCi/L. The DCG is 100 x 10^{-9} μCi/ml.

[b]Measured background has not been subtracted.

[c]Sampling locations are shown in Figure 4-11. Sampling locations that no longer exist because of adjustments in the monitoring program or changes resulting from remedial actions are not reported in trend tables. Data from these locations would not be valid for comparison or trends.

[d]Radium-226 concentrations were determined by emanation during 1986 through 1990 and the first three quarters of 1991 and by alpha spectroscopy during the fourth quarter of 1991.

[e]Average value ±2 standard deviations (95 percent confidence level).

[f](--) indicates that well was not established and sampled until 1987.

[g]Background well.

[h]Downgradient well.

Table 4-12

Trend Analysis for Total Uranium Concentrations[a,b] in Groundwater at NFSS, 1986-1991

Sampling Location[c]	Average Annual Concentration[d] 1986	1987	1988	1989	1990	Expected Range[e] ($\bar{X} \pm 2s$)	Average Annual Concentration[d] 1991
			(Concentrations are in 10^{-9} μCi/ml)				
			Upper Groundwater System				
OW-1B	--[f]	4	5	8	4	2 - 9	3
OW-2B	--	5	8	9	7	4 - 10	8
OW-3B	--	10	14	17	10	6 - 20	13
OW-4B	--	6	7	7	6	5 - 8	6
OW-5B	--	11	10	12	8	7 - 10	10
OW-6B	--	15	14	13	15	12 - 16	20
OW-7B	--	3	5	3	9	0 - 10	12
OW-8B	--	17	20	20	14	12 - 24	10
OW-9B	--	14	20	20	10	6 - 26	20
OW-10B	--	3	6	7	7	2 - 10	10
OW-11B	--	36	28	32	31	25 - 38	23
OW-12B	--	15	14	10	10	7 - 18	13
OW-13B	--	14	17	17	19	13 - 21	18
OW-14B	--	5	7	6	4	3 - 8	7
OW-15B	--	6	7	14	7	1 - 20	17
OW-16B	--	6	7	11	5	2 - 10	7
OW-17B	--	7	8	8	6	5 - 9	6
OW-18B	--	14	18	19	19	13 - 22	14
A-42	71	78	55	67	76	51 - 88	57
A-50	4	4	3	7	8	1 - 10	7
A-52	17	18	19	13	15	12 - 21	16
			Lower Groundwater System				
OW-1A	--	4	3	4	3	2 - 5	3
OW-2A	--	3	3	4	4	2 - 5	4
OW-3A	--	3	4	8	5	1 - 9	5
OW-4A	--	3	3	3	3	3 - 3	3
OW-5A	--	3	4	4	4	3 - 5	4
OW-6A	--	3	3	3	3	3 - 3	5
OW-7A	--	8	10	10	3	1 - 10	4
OW-8A	--	3	3	5	3	2 - 6	5
OW-9A	--	3	4	5	3	2 - 6	6
OW-10A	--	5	4	3	3	2 - 6	5
OW-11A	--	3	4	3	3	2 - 4	4
OW-12A	--	3	5	7	3	1 - 8	3
OW-13A	--	3	4	3	3	2 - 4	6
OW-14A	--	4	4	3	3	2 - 5	2
OW-15A	--	3	4	3	3	2 - 4	3
OW-16A	--	3	5	3	3	2 - 6	3
OW-17A	--	3	4	4	3	2 - 5	8
OW-18A	--	3	4	5	3	2 - 6	4
BH-5	3	3	3	7	3	0 - 7	3
BH-48[g]	5	4	3	5	3	2 - 6	3
BH-61[h]	3	3	3	3	3	3 - 3	2

Table 4-12

(continued)

NOTE: Sources for 1986-1990 data are the annual site environmental reports for those years (BNI 1987, 1988, 1989, 1990, 1991).

[a]1 x 10^{-9} μCi/ml is equivalent to 0.037 Bq/L and 1 pCi/L. The DCG is 600 x 10^{-9} μCi/ml.

[b]Measured background has not been subtracted.

[c]Sampling locations are shown in Figure 4-11. Sampling locations that no longer exist because of adjustments in the monitoring program or changes resulting from remedial actions are not reported in trend tables. Data from these locations would not be valid for comparison or trends.

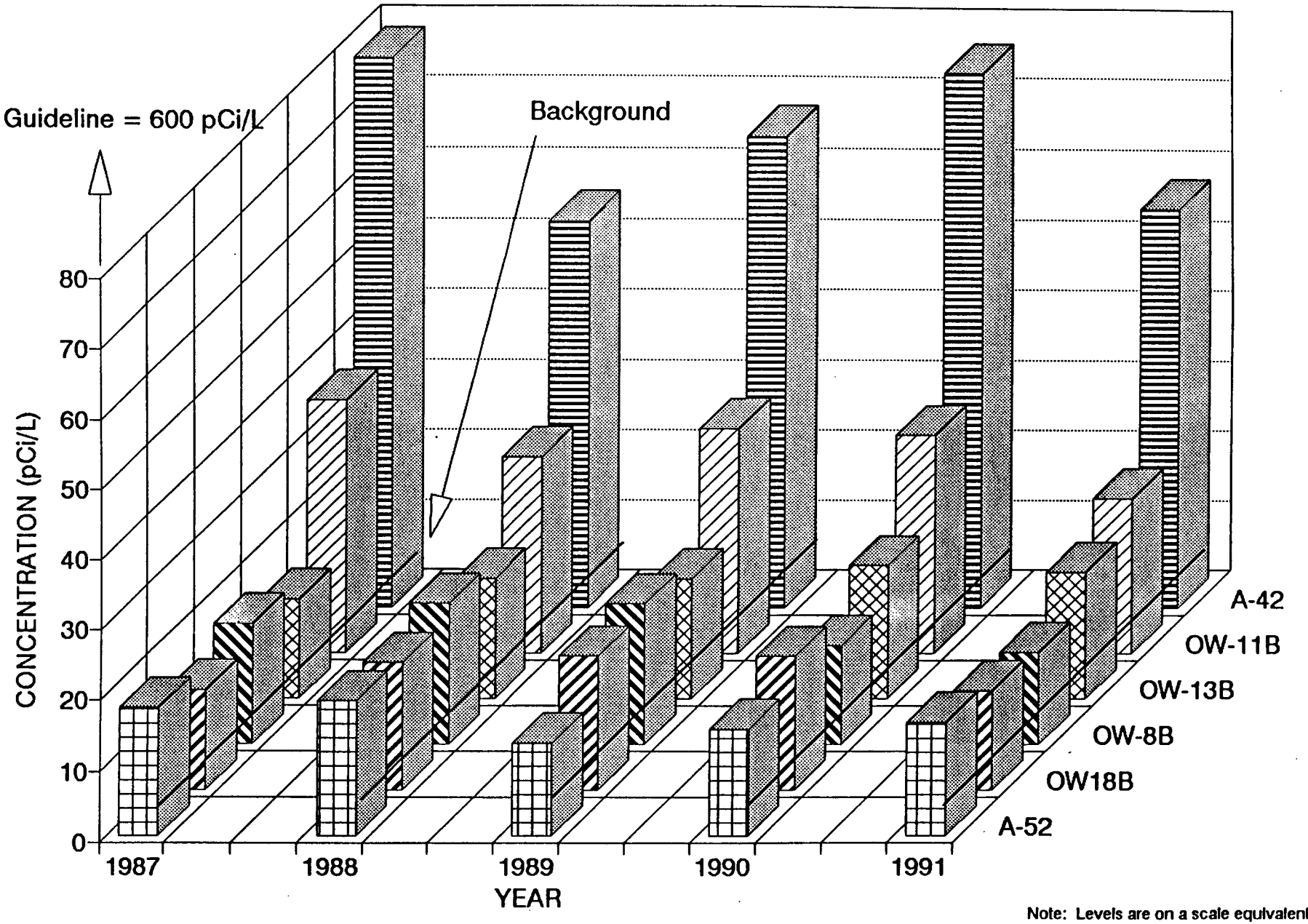
[d]Total uranium concentrations were determined by using fluorometric analysis during 1986 through 1990 and the first three quarters of 1991 and by kinetic phosphorescence analysis during the fourth quarter of 1991.

[e]Average value ±2 standard deviations (95 percent confidence level).

[f](--) indicates that well was not established and sampled until 1987.

[g]Background well.

[h]Downgradient well.



Note: Levels are on a scale equivalent to 13% of the guideline of 600 pCi/L.

Figure 4-12
Average Annual Total Uranium Levels in Groundwater at NFSS

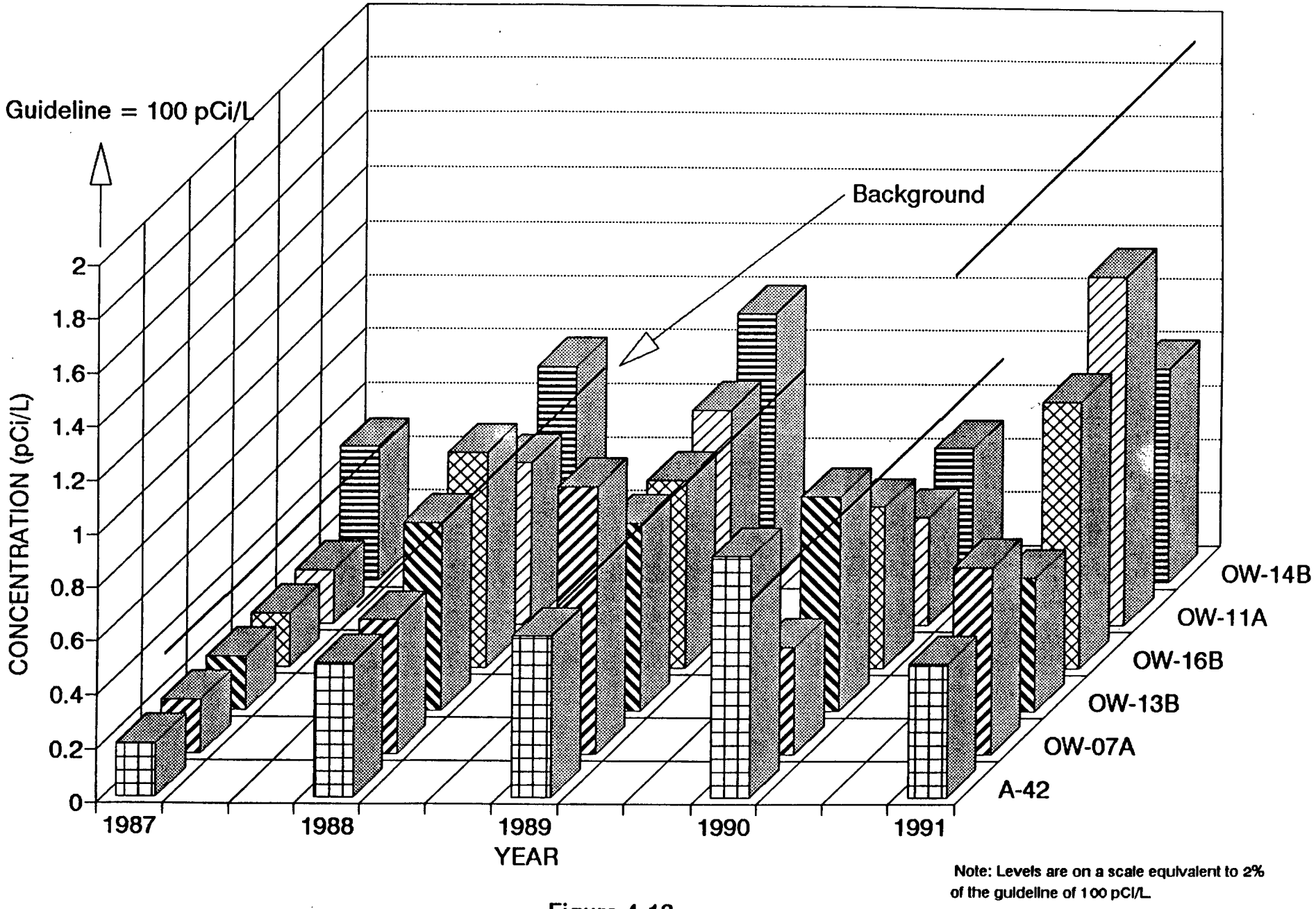


Figure 4-13
Average Annual Radium-226 Levels in Groundwater at NFSS

internal exposures continue as long as radionuclides reside in the body.

To assess the potential health effects of the materials 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 was then compared with the DOE guideline. 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 in compliance with boundary concentration requirements (Appendix D). All doses presented in this section are estimates and do not represent actual doses. A summary is provided in Table 4-13.

4.3.1 Hypothetical Maximally Exposed Individual

The hypothetical maximally exposed individual is assumed to live near the site and work at the Modern Disposal landfill adjacent to the eastern side of the site. For dose calculation purposes, this individual's average distance from the site was 300 m (980 ft), except for direct exposure, which was 10 m (30 ft) from the fenceline.

Direct gamma radiation pathway

The calculated yearly dose to the hypothetical worker at the landfill, calculated by using the equation in Appendix D for direct exposure, is 0.3 mrem/yr (0.003 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 site for an entire year.

Drinking water pathway

Only one water pathway, either groundwater or surface water, is considered to determine the committed dose to the hypothetical

Table 4-13

Summary of Calculated Doses[a] for NFSS, 1991

Exposure Pathway	Dose to Hypothetical Maximally Exposed Individual (mrem/yr)[b]	Collective Dose for Population Within 80 km of Site (person-rem/yr)[b]
Direct gamma radiation[c]	0.3	--[d]
Drinking water	--[d]	--[d]
Ingestion[e]	--[d]	--[d]
Air immersion[e]	--[d]	--[d]
Inhalation[e]	0.0002	5.7×10^{-4} [f]
Total	0.3[g]	5.7×10^{-4}
Background[h]	75	1.9×10^{4} [i]

[a]Does not include radon.

[b]1 mrem/yr = 0.01 mSv/yr; 1 person-rem/yr = 0.01 person-Sv/yr.

[c]Does not include contribution from background.

[d]Contribution to the total dose is negligible.

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

[f]Derived from Table 4-10.

[g]DOE guideline for total exposure to an individual is 100 mrem (DOE 1990b).

[h]Direct gamma radiation exposure only.

[i]Calculated by the following: (75 mrem/yr) (2.5×10^5 people).

maximally exposed individual. This individual would obtain 100 percent of his/her drinking water from either surface water or groundwater in the vicinity of the site. Because of the low radionuclide concentrations (near or below background) found in groundwater monitoring wells in the vicinity of the site and because no known drinking water wells are located within a 1.6-km (1-mi) radius of NFSS, the dose commitment to a hypothetical maximally exposed individual would be negligible and was not calculated. The dose from surface water to this individual was also not calculated because of the very low concentrations of radionuclides in the surface water.

Air pathway (ingestion, air immersion, inhalation)

The effective dose equivalent to the hypothetical maximally exposed individual, determined using EPA's AIRDOS model, Version 3.0, is negligible (5×10^{-4} mrem/yr). The 1991 AIRDOS compliance report generated from the AIRDOS computer model is provided in Appendix E.

Total dose

The total dose for the hypothetical maximally exposed individual is the sum of the 50-yr committed effective dose equivalent and the external effective dose equivalent, based on the total estimated radioactive particulates released in 1991 and the effective dose equivalent due to total external gamma radiation measured at the fenceline in 1991. When these doses are added together, the total effective dose equivalent is 0.3 mrem/yr (0.003 mSv/yr) for the hypothetical maximally exposed individual. This dose is less than the dose a person would receive while traveling in an airplane at 12,000 m (39,000 ft) for one hour because of greater amounts of cosmic radiation at higher altitudes (Appendix F).

4.3.2 General Population

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

Direct gamma radiation pathway

Distance from the site to the nearest residential areas and the presence of intervening structures reduce direct gamma exposure from NFSS (see Table 4-14). 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 would receive no significant dose commitment from radionuclides in drinking water, it is reasonable to assume that the general public would not receive a committed dose either.

Air pathway (ingestion, air immersion, inhalation)

The EPA AIRDOS model provides an effective dose equivalent for contaminants transported via the atmospheric pathway at different distances from the site (Table 4-14). 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 5.7×10^{-4} person-rem/yr (5.7×10^{-6} person-Sv/yr) (Table 4-14).

Table 4-14

Maximum Effective Dose to the General Public from NFSS, 1991

Distance from the Site (m) (inner radius)	(outer radius)	Effective Dose Equivalent (mrem/yr)[a,b]	Population Dose (person-rem/yr)[c,d]
0 -	1,000	5×10^{-4} *	1.9×10^{-5}
1,000 -	3,000	6.5×10^{-5}	2×10^{-5}
3,000 -	10,000	1.1×10^{-5}	3.9×10^{-5}
10,000 -	80,000	2×10^{-6}	4.9×10^{-4}
		Total Dose	5.7×10^{-4}

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

[b]Values were obtained using AIRDOS, Version 3.0 (Appendix E).

[c]Based on the 1990 census, a population density of 1.24×10^{-5} person/m^2 was used in the calculation.

[d]Calculated using: Population dose = [population density] [π (outer radius)^2 - π (inner radius)^2] [effective dose equivalent].

*Effective dose equivalent for 300 m.

Total population dose

The total population dose is the sum of the doses from all exposure pathways. Because air is the only pathway with a potential major contribution to the collective population dose, the total population dose (Table 4-14) is equal to that calculated for the air pathway [5.7×10^{-4} person-rem/yr (5.7×10^{-6} person-Sv/yr)]. This dose is extremely small when compared with the collective population dose caused by natural background gamma radiation (Table 4-13).

5.0 NONRADIOLOGICAL ENVIRONMENTAL PROGRAM

The environmental monitoring program at NFSS includes groundwater monitoring for nonradiological parameters. Downgradient, upgradient, and onsite wells provide information on the potential effects of the site on human health and the environment.

NFSS is not an operating site; therefore, the only "effluents" would be contaminants that migrate. Based on site characterization, nonradiological contamination 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).

5.1 GROUNDWATER MONITORING

Groundwater samples for chemical analyses were collected from the same locations as those for radiological analyses (Figure 4-11). Samples were analyzed for indicator parameters and metals. Laboratory detection limits for metals are given in Table 5-1. Table 5-2 lists the EPA and NYSDEC (Class GA) drinking water guidelines.

Indicator parameters monitored in groundwater at NFSS include specific conductivity, pH, total organic carbon (TOC), and total organic halides (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 conductivity and pH indicate changes in the inorganic composition of groundwater. Specific conductivity 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.

Table 5-1

Laboratory Detection Limits for Metal Analyses at NFSS, 1991

Metal	Detection Limit (µg/L)
Aluminum	200
Copper	25
Iron	100
Lead	3/90[a]
Manganese	15
Mercury	0.2
Vanadium	50

[a]The detection limit for lead was either 3 or 90 µg/L, depending on the analytical technique used.

Table 5-2

EPA and NYSDEC Guidelines as Action Levels for Water Media

Constituent	EPA[a] Concentration (µg/L)	NYSDEC[b] (Class GA) Standard Concentration (µg/L)
Copper	1,300[c]	2,000
Iron	--[d]	300[e]
Lead	15[c]	25
Manganese	--[d]	300[e]
Mercury	2[f]	2

[a]EPA, 1990. "Corrective Action for Solid Waste Management Units (SWMUs) at Hazardous Waste Management Facilities (EPA/SW-530-90-012); Proposed Rule," 40 CFR Part 264, 265, 270, 271 (July 27).

[b]NYSDEC, 1991. "Water Quality Regulations for Surface Waters and Groundwaters," 6 NYCRR Parts 700-705 (September 1).

[c]EPA, 1991. "Maximum Contaminant Level Goals and National Primary Drinking Water Regulations for Lead and Copper; Final Rule," 40 CFR Parts 141 and 142, pp. 26460-26479 (June 7).

[d]No standards available.

[e]Combined concentration standard for iron and manganese is 500 µg/L.

[f]Maximum contaminant level.

Data and discussion

Indicator parameters (Tables 5-3 and 5-4) indicate that groundwater is of somewhat poor quality. In general, slight variations were observed in both upgradient and downgradient wells.

Table 5-5 gives analytical results for metals detected in groundwater. Groundwater samples were not filtered before analyses; therefore, results include both dissolved and suspended metals.

Average concentrations of lead were above background levels in OW-17A and OW-18A; concentrations in these wells and the background well (BH-48) exceeded the EPA and NYSDEC (Class GA) guidelines (Table 5-2). Except in these wells and OW-16B, lead was not detected above the detection limits. However, the detection limit used by the laboratory was above the EPA and NYSDEC water guidelines; therefore, whether these values actually exceed guidelines cannot be determined. The laboratory has been informed of the detection limit requirements and will provide appropriate detection limits for 1992 samples.

Average concentrations of copper were above background levels in some wells; however, mercury was not detected above the detection limits in any wells. Concentrations of these metals are below the EPA and NYSDEC (Class GA) guidelines. Vanadium was not detected above the detection limit in most wells.

Average concentrations of aluminum, iron, and manganese exceeded background levels in most wells in the upper groundwater system and in well OW-6A in the lower groundwater system. Combined concentrations of iron and manganese in most wells [including background wells (20-S, BH-48)] exceeded NYSDEC (Class GA) guidelines.

Trends

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

Table 5-3

Specific Conductivity and pH in Groundwater at NFSS, 1991

Sampling Location[a]	Quarter 1	2	3	4	Avg
Specific Conductivity (µmhos/cm)					
Upper Groundwater System					
OW-1B	1,131	1,270	1,340	--[b]	1,250
OW-2B	1,675	1,728	1,750	1,650	1,700
OW-3B	2,270	2,330	2,400	2,210	2,300
OW-4B	1,455	1,580	1,510	1,390	1,480
OW-5B	1,680	1,624	--[c]	--[b]	1,650
OW-6B	2,300	2,340	2,410	2,350	2,350
OW-7B	1,295	1,916	2,050	--[b]	1,750
OW-8B	1,860	2,610	2,640	--[b]	2,370
OW-9B	2,370	2,530	2,450	--[b]	2,450
OW-10B	863	1,384	1,300	1,340	1,220
OW-11B	1,553	1,657	1,770	--[b]	1,660
OW-12B	1,065	1,736	1,540	--[b]	1,450
OW-13B	2,420	2,370	2,580	2,320	2,420
OW-14B	1,370	1,485	1,410	1,280	1,390
OW-15B	1,728	1,914	1,890	--[b]	1,840
OW-16B	1,209	1,409	1,320	1,290	1,310
OW-17B	1,640	1,820	1,850	1,600	1,730
OW-18B	3,410	3,640	3,560	--[b]	3,540
BH-49A	1,595	1,717	1,740	1,710	1,690
A-42	1,388	1,444	1,500	1,440	1,440
A-50	1,688	1,785	1,810	--[b]	1,760
A-52	1,400	1,426	1,390	1,310	1,380
20-S[d]	1,285	3,400	1,370	--[b]	2,020
Lower Groundwater System					
OW-1A	2,070	2,280	2,320	1,910	2,150
OW-2A	2,000	2,100	2,190	2,100	2,100
OW-3A	2,250	2,310	2,340	2,260	2,290
OW-4A	1,490	1,444	--[e]	1,450	1,460
OW-5A	1,450	1,509	1,500	1,480	1,490
OW-6A	2,020	2,240	2,430	2,060	2,190
OW-7A	2,040	2,180	2,320	2,290	2,210
OW-8A	2,520	1,788	1,960	2,530	2,200
OW-9A	2,180	2,430	2,560	2,140	2,330
OW-10A	1,410	1,491	1,480	1,520	1,480
OW-11A	1,670	1,766	1,650	1,750	1,710
OW-12A	1,770	1,917	1,740	2,050	1,870
OW-13A	1,920	2,000	2,120	2,050	2,020

Table 5-3

(continued)

Sampling Location[a]	Quarter 1	2	3	4	Avg
		Lower Groundwater System (cont'd)			
OW-15A	2,370	2,570	2,540	2,470	2,490
OW-16A	2,560	2,840	2,850	2,620	2,720
OW-17A	2,930	3,200	3,010	2,990	3,030
OW-18A	2,430	2,650	2,460	2,390	2,480
BH-5	1,450	2,020	1,560	1,600	1,660
BH-49	1,550	1,892	1,857	1,950	1,810
BH-61[f]	2,460	3,400	2,830	2,620	2,830
19-D	2,320	3,610	2,900	2,690	2,880
20-D	2,490	1,751	2,450	2,590	2,320
BH-48[d]	5,010	6,820	5,520	5,640	5,750
		pH (standard units)			
		Upper Groundwater System			
OW-1B	7.3	7.7	7.2	--[b]	7.4
OW-2B	6.4	7.2	7.1	7.1	7
OW-3B	7.2	7.5	7.2	7.3	7.3
OW-4B	7.5	7.5	7.2	7.5	7.4
OW-5B	7.1	7.5	--[c]	--[b]	7.3
OW-6B	7.1	7.1	6.9	7.2	7.1
OW-7B	7.5	7.7	7.1	--[b]	7.4
OW-8B	7.2	7.6	7.6	--[b]	7.5
OW-9B	7.5	7.4	7.6	--[b]	7.5
OW-10B	7.4	7.4	7	7.5	7.3
OW-11B	7.4	7.4	6.9	--[b]	7.2
OW-12B	7.4	7.5	7.1	--[b]	7.3
OW-13B	7.5	7.3	7	7.4	7
OW-14B	7.2	7.3	7.2	7.4	7.3
OW-15B	7.4	7.4	7.3	--[b]	7.4
OW-16B	7.2	7.4	7.2	7.4	7.3
OW-17B	7.5	7.4	7.5	7.6	7.5
BH-49A	7.3	7.2	6.9	7.3	7.2
A-42	7.1	7.2	6.8	7.2	7.1
A-50	7.3	7.1	7.1	--[b]	7.2
A-52	7.1	7	6.8	6.8	7
20-S[d]	7.5	7.9	7.3	--[b]	7.2

Table 5-3

(continued)

Sampling Location[a]	Quarter 1	2	3	4	Avg
Lower Groundwater System					
OW-1A	8.3	8.1	7.9	8.7	8.3
OW-2A	7.8	7.8	7.6	8	8
OW-3A	7.3	7.4	7.1	7.6	7.4
OW-4A	8.3	8.4	--[e]	8.4	8.4
OW-5A	7.9	8	7.9	7.7	8
OW-6A	7.7	7.7	7.4	7.9	7.7
OW-7A	7.6	7.5	7.3	7.8	7.6
OW-8A	7.8	7.1	7	7.6	7
OW-9A	7.8	7.6	7.3	7.6	7.6
OW-10A	8.2	8.1	7.6	8	8
OW-11A	7.7	7.7	7.2	7.7	7.6
OW-12A	7.5	7.5	7.1	7.6	7.4
OW-13A	8.4	7.5	7.4	7.7	7.8
OW-14A	7.9	7.8	7.7	8.1	7.9
OW-15A	7.8	7.7	7.5	7.7	7.7
OW-16A	7.7	7.7	7.6	7.8	7.7
OW-17A	8	7.5	7.7	7.8	8
OW-18A	7.5	7.8	7.5	8.1	7.7
BH-5	10.4	9.8	9.1	9.6	9.7
BH-49	9.7	9.3	9	8.1	9
BH-61[f]	7.9	7.6	7.5	7.6	7.7
BH-48[d]	7.7	7.5	7.4	7.5	7.5

[a]Sampling locations are shown in Figure 4-11.

[b]Well did not recover after purging.

[c]Wasp nest in well; could not sample.

[d]Background well.

[e]Bailer stuck in well; could not sample.

[f]Downgradient well.

Table 5-4

Concentrations of Total Organic Carbon and Total Organic Halides in Groundwater at NFSS, 1991

Sampling Location[a]	Quarter 1	2	3	4	Avg
Total Organic Carbon (mg/L)					
Upper Groundwater System					
OW-1B	6	2.2	1.3	--[b]	3
OW-2B	2.1	1.7	18.1	1.2	5.8
OW-3B	1.8	2.1	1.7	--[b]	1.9
OW-4B	1.4	1.8	2.2	1.6	1.8
OW-5B	1.2	1.4	--[c]	--[b]	1.3
OW-6B	5.1	2.6	2	3.4	3
OW-7B	1.1	4.7	1	--[b]	2
OW-8B	1.9	1.9	4.5	--[b]	2.8
OW-9B	1.6	3.6	1.5	--[b]	2.2
OW-10B	1.6	2.1	5.2	3.2	3.0
OW-11B	1.5	1.5	1.6	--[b]	1.5
OW-12B	3.8	1.9	2.3	--[b]	2.7
OW-13B	17.8	12.4	3.4	2.3	9.0
OW-14B	7.3	11	1.9	1.6	5.5
OW-15B	2.2	2.4	2.1	--[b]	2.2
OW-16B	1.3	1.8	1.5	1.9	1.6
OW-17B	1.8	2.4	1.4	--[b]	1.9
OW-18B	3.7	3.1	2.9	--[b]	3.2
BH-49A	1.6	2.5	2.4	2.9	2.4
A-42	3.1	2.2	3.3	2.3	2.7
A-50	2.4	2.7	7.2	--[b]	4.1
A-52	3.4	4.8	2.1	2.2	3.1
20-S[d]	1.7	2.1	2.7	--[b]	2.2
Lower Groundwater System					
OW-1A	2.5	1.8	1.5	3.4	2.3
OW-2A	2.1	2	1.5	4.9	3
OW-3A	15.8	1.5	2	1.5	5
OW-4A	1.4	6.4	--[e]	1.5	3.1
OW-5A	5.2	1.6	1.5	1.7	3
OW-6A	2	1.7	1.5	2.4	1.9
OW-7A	2.3	1.3	2.1	1.4	1.8
OW-8A	1.8	2.1	2.2	3	2
OW-9A	2.9	1.8	2.3	2.9	2.5
OW-10A	2	1.8	3.8	1.8	2
OW-11A	1.3	3.1	4.8	0.98	2.5
OW-12A	1.6	1.7	2.6	1.7	1.9

Table 5-4

(continued)

Sampling Location[a]	Quarter 1	2	3	4	Avg
Lower Groundwater System (cont'd)					
OW-14A	1.3	2.3	1.6	1.6	1.7
OW-15A	2.8	2.8	2.3	2	3
OW-16A	2.5	2.3	2	1.9	2
OW-17A	1.5	2.2	1.6	2.1	1.9
OW-18A	1.7	2.6	1.8	1.7	2.0
BH-5	2.8	2.4	5.6	5	4
BH-49	1.4	1.2	2.3	1.6	1.6
BH-61[f]	1.5	1.6	2.7	1.4	1.8
BH-48[d]	7.7	0.94	2.1	0.78	2.9
Total Organic Halides (µg/L)					
Upper Groundwater System					
OW-1B	39	100	<20[g]	--[b]	50
OW-2B	33	<20	52	<20	30
OW-3B	23	46	<20	--[b]	30
OW-4B	96	91	20	<20	60
OW-5B	46	41	--[c]	--[b]	44
OW-6B	60	21	<20	<20	30
OW-7B	<20	29	<20	--[b]	20
OW-8B	27	<20	<20	--[b]	20
OW-9B	46	26	<20	--[b]	30
OW-10B	22	37	<20	<20	30
OW-11B	22	30	21	--[b]	20
OW-12B	<20	<20	<20	--[b]	20
OW-13B	22	76	93	<20	50
OW-14B	22	27	<20	<20	20
OW-15B	<20	<20	<20	--[b]	20
OW-16B	<20	69	24	<27	40
OW-17B	<20	67	<20	--[b]	40
OW-18B	23	92	110	--[b]	80
BH-5	<20	26	<20	<20	20
BH-49	86	130	160	<20	100
BH-61	84	88	69	<20	70
BH-49A	26	<20	<20	<20	20
A-42	60	<20	45	<20	40
A-50	88	<20	<20	--[b]	40
A-52	<20	<20	<20	<27	20
20-S[d]	52	<20	<20	--[b]	30

Table 5-4

(continued)

Sampling Location[a]	Quarter 1	2	3	4	Avg
		Lower Groundwater System			
OW-1A	73	140	26	29	67
OW-2A	110	<20	46	<20	50
OW-3A	33	38	<20	<20	30
OW-4A	40	42	--[e]	<20	30
OW-5A	<20	77	110	<20	60
OW-6A	<20	100	49	<20	50
OW-7A	27	39	40	83	50
OW-8A	94	81	27	69	68
OW-9A	22	50	<20	<20	30
OW-10A	<20	68	30	<20	40
OW-11A	55	65	36	20	40
OW-12A	73	97	<20	20	50
OW-13A	33	35	<20	<20	30
OW-14A	70	120	41	<27	70
OW-15A	100	310	74	83	140
OW-16A	110	<20	<20	38	50
OW-17A	63	57	91	67	70
OW-18A	50	39	<20	90	50
BH-5	<20	26	<20	<20	20
BH-49	86	130	160	<20	100
BH-61[f]	84	88	69	<20	70
BH-49A	26	<20	<20	<20	20
19-D	81	130	<20	<20	60
20-D	83	55	<20	<20	50
BH-48[d]	33	620	<20	<27	180

[a]Sampling locations are shown in Figure 4-11.

[b]Well did not recover after purging.

[c]Wasp nest in well; could not sample.

[d]Background well.

[e]Bailer stuck in well; could not sample.

[f]Downgradient well.

[g]The detection limit for TOX was 20 µg/L.

Table 5-5
Concentrations[a] of Metals in Groundwater at NFSS, 1991

Sampling Location[a]	Quarter 1	2	3	4	Avg
	(Concentrations are in µg/L)				
	Upper Groundwater System				
OW-1B					
Aluminum	345	4,390	3,820	--[b]	2,850
Copper	<25	<25	<25	--	25
Iron	622	6,610	4,740	--	3,990
Manganese	19.7	164	166	--	117
Lead	<90	<90	<90	--	90
Vanadium	<50	<50	<50	--	50
Mercury	--[c]	<0.2	<0.2	--	0.2
OW-2B					
Aluminum	<200	252	<200	<200	200
Copper	41.7	<25	<25	<25	29
Iron	430	512	<100	311	340
Manganese	55.8	129	144	160	120
Lead	<90	<90	<90	<90	90
Vanadium	<50	<50	<50	<50	50
Mercury	<0.2	<0.2	<0.2	<0.2	0.2
OW-3B					
Aluminum	296	3,190	988	--[b]	1,490
Copper	<25	34.5	<25	--	28
Iron	1,030	17,400	2,960	--	7,130
Manganese	42.1	213	74.4	--	110
Lead	<90	<90	<90	--	90
Vanadium	<50	135	51.9	--	80
Mercury	<0.2	<0.2	<0.2	--	0.2
OW-4B					
Aluminum	1,260	2,250	19,200	1,750	6,120
Copper	<25	<25	45.9	<25	30
Iron	2,420	3,940	31,800	3,060	10,300
Manganese	140	175	894	159	342
Lead	<90	<90	<90	<90	90
Vanadium	<50	<50	<50	<50	50
Mercury	<0.2	<0.2	<0.2	<0.2	0.2
OW-5B					
Aluminum	5,660	5,790	--[d]	--[b]	5,730
Copper	37.5	25.3	--	--	31
Iron	9,420	9,520	--	--	9,470
Manganese	331	271	--	--	301
Lead	<90	<90	--	--	90
Vanadium	<50	<50	--	--	50
Mercury	<0.2	<0.2	--	--	0.2

Table 5-5

(continued)

Sampling Location[a]	Quarter 1	2	3	4	Avg
		Upper Groundwater System (cont'd)			
OW-6B					
Aluminum	<200	674	2,170	738	950
Copper	<25	<25	26	28.5	26
Iron	430	1,330	4,170	1,380	1,830
Manganese	70.6	183	195	77.1	131
Lead	<90	<90	<90	<90	90
Vanadium	<50	<50	<50	<50	50
Mercury	<0.2	<0.2	<0.2	<0.2	0.2
OW-7B					
Aluminum	2,770	12,400	4,940	--[b]	6,700
Copper	<25	54.8	<25	--	35
Iron	4,980	22,000	8,930	--	12,000
Manganese	162	746	327	--	412
Lead	<90	<90	<90	--	90
Vanadium	<50	<50	<50	--	50
Mercury	<0.2	<0.2	<0.2	--	0.2
OW-8B					
Aluminum	1,680	1,220	5,990	--[b]	2,960
Copper	<25	<25	29.7	--	27
Iron	2,740	2,050	9,830	--	4,870
Manganese	71.3	57	321	--	150
Lead	<90	<90	<90	--	90
Vanadium	<50	<50	<50	--	50
Mercury	<0.2	<0.2	<0.2	--	0.2
OW-9B					
Aluminum	6,120	11,800	3,140	--[b]	7,020
Copper	27.4	38.1	<25	--	30
Iron	10,500	19,400	4,890	--	11,600
Manganese	256	476	151	--	294
Lead	<90	<90	<90	--	90
Vanadium	<50	<50	<50	--	50
Mercury	<0.2	<0.2	<0.2	--	0.2
OW-10B					
Aluminum	1,530	5,020	31,400	17,300	13,800
Copper	<25	31.7	120	73.1	63
Iron	3,020	9,520	58,500	34,400	26,400
Manganese	225	581	4140	2,050	1,750
Lead	<90	<90	<90	<90	90
Vanadium	<50	<50	96	63	70
Mercury	<0.2	<0.2	<0.2	<0.2	0.2
OW-11B					
Aluminum	6,170	2,800	5,240	--[b]	4,740
Copper	38.9	<25	26	--	30
Iron	11,700	5,500	10,200	--	9,130

Table 5-5

(continued)

Sampling Location[a]	Quarter 1	2	3	4	Avg
OW-11B (cont'd)	**Upper Groundwater System (cont'd)**				
Manganese	609	354	564	--[b]	509
Lead	<90	<90	<90	--	90
Vanadium	<50	<50	<50	--	50
Mercury	<0.2	<0.2	<0.2	--	0.2
OW-12B					
Aluminum	1,240	6,050	4,990	--[b]	7,810
Copper	35.3	<25	<25	--	28
Iron	19,500	9,190	7,730	--	12,100
Manganese	443	212	221	--	292
Lead	<90	<90	<90	--	90
Vanadium	<50	<50	<50	--	50
Mercury	<0.2	<0.2	<0.2	--	0.2
OW-13B					
Aluminum	9,510	8,810	15,600	26,500	15,100
Copper	43.1	37.2	55.4	79.7	54
Iron	16,800	15,800	26,700	47,100	26,600
Manganese	553	578	798	1,270	800
Lead	<3	<90	<90	<90	70
Vanadium	52.4	<50	61.7	82.9	60
Mercury	<0.2	<0.2	<0.2	<0.2	0.2
OW-14B					
Aluminum	1,610	2,050	7,310	29,400	10,100
Copper	<25	<25	30.7	96	44
Iron	2,770	3,460	12,300	47,900	16,600
Manganese	100	174	353	1,170	450
Lead	<3	<90	<90	<90	70
Vanadium	<50	<50	<50	<58.5	50
Mercury	<0.2	<0.2	<0.2	<0.2	0.2
OW-15B					
Aluminum	1,110	1,080	24,100	--[b]	8,760
Copper	<25	<25	74.6	--	42
Iron	1,940	1,880	40,400	--	14,700
Manganese	60.3	57.6	1,040	--	386
Lead	<3	<90	<90	--	60
Vanadium	<50	<50	59.7	--	50
Mercury	<0.2	<0.2	<0.2	--	0.2
OW-16B					
Aluminum	7,140	11,900	11,800	35,900	16,700
Copper	40.2	70.4	61.5	214	97
Iron	12,300	20,300	21,300	65,400	29,800
Manganese	636	920	831	2,280	1,170

Table 5-5

(continued)

Sampling Location[a]	Quarter 1	2	3	4	Avg
OW-16B (cont'd)	**Upper Groundwater System (cont'd)**				
Lead	4.9	<90	<90	263	110
Vanadium	<50	<50	<50	54.8	50
Mercury	<0.2	<0.2	<0.2	<0.2	0.2
OW-17B					
Aluminum	213	4,190	2,200	--[b]	2,200
Copper	<25	<25	<25	--	25
Iron	403	6,560	3,350	--	3,440
Manganese	15.2	160	98.5	--	91
Lead	<3	<90	<90	--	60
Vanadium	<50	<50	<50	--	50
Mercury	<0.2	<0.2	<0.2	--	0.2
OW-18B					
Aluminum	952	21,700	10,300	--[b]	11,000
Copper	<25	83.4	48.3	--	52
Iron	1,930	37,900	16,700	--	18,800
Manganese	94.1	1,300	558	--	650
Lead	<3	<90	<90	--	60
Vanadium	<50	79	67.6	--	70
Mercury	<0.2	<0.2	<0.2	--	0.2
BH-49A					
Aluminum	481	6,830	35,600	31,600	18,600
Copper	<25	25.5	123	110	71
Iron	1,230	12,200	63,600	56,800	33,500
Manganese	193	473	1,650	1,900	1,050
Lead	<3	<90	<90	<90	70
Vanadium	<50	<50	72.9	76	60
Mercury	<0.2	<0.2	<0.2	0.2	0.2
A-42					
Aluminum	200	248	<200	<200	200
Copper	<25	<25	<25	<25	25
Iron	278	510	279	138	301
Manganese	452	452	518	1,370	698
Lead	<3	<90	<90	<90	70
Vanadium	<50	<50	<50	<50	50
Mercury	<0.2	<0.2	<0.2	<0.2	0.2
A-50					
Aluminum	<200	3,070	6,210	--[b]	3,160
Copper	<25	<25	26.5	--	26
Iron	445	4,880	10,500	--	5,280
Manganese	85.7	244	522	--	284
Lead	<3	<90	<90	--	60
Vanadium	<50	<50	<50	--	50
Mercury	<0.2	<0.2	<0.2	--	0.2

Table 5-5
(continued)

Sampling Location[a]	Quarter 1	2	3	4	Avg
		Upper Groundwater System (cont'd)			
A-52					
Aluminum	1,480	9,170	9,960	15,500	9,030
Copper	82.2	81.9	89.8	96.7	89
Iron	3,090	15,400	16,200	26,800	15,400
Manganese	1,040	1,260	1,270	1,650	1,310
Lead	3.4	<90	<90	<90	70
Vanadium	<50	<50	<50	52.6	50
Mercury	<0.2	<0.2	<0.2	<0.2	0.2
20-S[c]					
Aluminum	490	5,370	7,610	--[b]	4,490
Copper	<25	<25	<25	--	25
Iron	939	9,000	11,500	--	7,150
Manganese	128	264	350	--	250
Lead	<3	<90	<90	--	60
Vanadium	<50	<50	<50	--	50
Mercury	<0.2	<0.2	<0.2	--	0.2
		Lower Groundwater System			
OW-1A					
Aluminum	15,100	1,860	10,400	956	7,080
Copper	45.5	<25	29.4	<25	31
Iron	26,600	3,270	16,800	1,670	12,100
Manganese	1,250	257	816	181	626
Lead	<90	<90	<90	<90	90
Vanadium	<50	<50	<50	<50	50
Mercury	--[c]	<0.2	<0.2	<0.2	0.2
OW-2A					
Aluminum	3,620	3,270	1,050	756	2,170
Copper	<25	<25	<25	<25	25
Iron	6,480	5,870	2,270	1,740	4,090
Manganese	326	277	154	155	228
Lead	<90	90	90	<90	90
Vanadium	<50	50	50	<50	50
Mercury	<0.2	0.2	0.2	<0.2	0.2
OW-3A					
Aluminum	1,500	6,120	1,440	6430	3,870
Copper	<25	35.1	<25	33	30
Iron	2,950	11,600	2,950	12,000	7,380
Manganese	255	610	221	652	435
Lead	<3	<90	<90	<90	70
Vanadium	<50	135	<50	<50	70
Mercury	<0.2	<0.2	<0.2	<0.2	0.2

Table 5-5
(continued)

Sampling Location[a]	Quarter 1	2	3	4	Avg
		Lower Groundwater System (cont'd)			
OW-4A					
Aluminum	1,480	15,100	--[f]	9,960	8,850
Copper	<25	71.9	--	63.8	54
Iron	3,120	29,700	--	18,700	17,200
Manganese	237	1,460	--	963	887
Lead	<3	<90	--	<90	60
Vanadium	<50	<50	--	<50	50
Mercury	<0.2	<0.2	--	<0.2	0.2
OW-5A					
Aluminum	2,590	2,190	13,800	760	4,840
Copper	<25	<25	34.2	<25	27
Iron	4,670	3,890	26,000	1,600	9,040
Manganese	233	173	1,380	110	474
Lead	<3	<90	<90	<90	70
Vanadium	<50	<50	<50	<50	50
Mercury	<0.2	<0.2	<0.2	<0.2	0.2
OW-6A					
Aluminum	2,560	46,300	59,300	14,200	30,600
Copper	62.8	165	105	85.5	105
Iron	6,680	81,300	99,500	27,000	53,600
Manganese	283	3,620	3,540	1,080	2,130
Lead	<90	<90	<90	<90	90
Vanadium	<50	76.3	102	51.8	70
Mercury	<0.2	0.21	<0.2	<0.2	0.2
OW-7A					
Aluminum	4,150	2,560	800	17,000	6,100
Copper	<25	<25	<25	58.9	34
Iron	7,020	4,610	1,590	29,900	10,800
Manganese	338	288	124	2,110	715
Lead	<3	<90	<90	<90	70
Vanadium	<50	<50	<50	67	50
Mercury	<0.2	<0.2	<0.2	<0.2	0.2
OW-8A					
Aluminum	7,870	4,720	4,390	6,390	5,840
Copper	34.1	28.7	34.5	37.8	34
Iron	13,500	7,600	7,730	11,000	9,960
Manganese	693	414	552	846	626
Lead	<3	<90	<90	<90	70
Vanadium	<50	<50	<50	52.56	50
Mercury	<0.2	<0.2	<0.2	<0.2	0.2

Table 5-5
(continued)

Sampling Location[a]	Quarter 1	2	3	4	Avg
	Lower Groundwater System (cont'd)				
OW-9A					
Aluminum	5,090	3,390	2,740	14,500	6,430
Copper	<25	<25	<25	65.5	35
Iron	8,670	6,030	4,650	27,600	11,700
Manganese	651	499	450	3,360	1,240
Lead	<3	<90	<90	<90	70
Vanadium	<50	<50	<50	72.9	60
Mercury	<0.2	<0.2	<0.2	<0.2	0.2
OW-10A					
Aluminum	1,340	564	7,020	6,380	3,830
Copper	26.6	<25	34.3	40	32
Iron	2,250	992	11,100	10,700	6,260
Manganese	98.7	55.6	370	534	264
Lead	3.6	<90	<90	<90	70
Vanadium	<50	<50	<50	<50	50
Mercury	<0.2	<0.2	<0.2	<0.2	0.2
OW-11A					
Aluminum	976	2,210	18,800	3,890	6,470
Copper	<25	<25	49.2	<25	31
Iron	1,800	3,820	30,800	7,070	10,900
Manganese	142	224	1,740	410	629
Lead	<3	<90	<90	<90	70
Vanadium	<50	<50	65.8	<50	50
Mercury	<0.2	<0.2	<0.2	<0.2	0.2
OW-12A					
Aluminum	606	948	687	458	675
Copper	<25	<25	<25	<25	25
Iron	3,360	3,680	3,630	3,000	3,420
Manganese	189	204	170	166	182
Lead	<3	<90	<90	<90	70
Vanadium	<50	<50	<50	<50	50
Mercury	<0.2	<0.2	<0.2	<0.2	0.2
OW-13A					
Aluminum	1,100	4,460	4,890	1,060	2,880
Copper	<25	<25	<25	<25	25
Iron	2,130	8,070	8,880	1,980	5,270
Manganese	104	318	327	82.1	208
Lead	<3	<90	<90	<90	70
Vanadium	<50	<50	<50	<50	50
Mercury	<0.2	<0.2	<0.2	<0.2	0.2

Table 5-5

(continued)

Sampling Location[a]	Quarter 1	2	3	4	Avg
	Lower Groundwater System (cont'd)				
OW-14A					
Aluminum	1,850	1,590	1,690	1,210	1,590
Copper	<25	<25	<25	<25	25
Iron	3,510	2,920	3,060	2,830	3,080
Manganese	363	345	333	257	325
Lead	<3	<90	<90	<90	70
Vanadium	<50	<50	<50	<50	50
Mercury	<0.2	<0.2	<0.2	<0.2	0.2
OW-15A					
Aluminum	12,700	6,480	10,600	1,730	7,880
Copper	33.6	26.1	<25	<25	27
Iron	22,600	12,500	19,500	3,450	14,500
Manganese	1,010	703	872	313	725
Lead	5.5	<90	<90	<90	70
Vanadium	<50	<50	<50	<50	50
Mercury	<0.2	<0.2	<0.2	<0.2	0.2
OW-16A					
Aluminum	1,030	1,790	3,250	994	1,770
Copper	<25	<25	<25	<25	25
Iron	2,390	4,040	6,380	3,210	4,010
Manganese	131	244	300	167	211
Lead	<3	<90	<90	<90	70
Vanadium	<50	<50	<50	<50	50
Mercury	<0.2	<0.2	<0.2	<0.2	0.2
OW-17A					
Aluminum	931	6,040	17,700	18,500	10,800
Copper	<25	39.6	33.1	54.3	38
Iron	1,830	10,800	31,500	37,500	20,400
Manganese	282	726	1,710	1,820	1,140
Lead	<3	<90	<90	579	200
Vanadium	<50	50.8	61.4	<50	50
Mercury	<0.2	<0.2	<0.2	<0.2	0.2
OW-18A					
Aluminum	7,860	1,900	727	1,050	2,880
Copper	36.6	<25	<25	<25	28
Iron	14,000	3,160	1,330	2,280	5,190
Manganese	633	252	172	226	321
Lead	7.3	<90	<90	905	270
Vanadium	<50	<50	<50	<50	50
Mercury	<0.2	<0.2	<0.2	<0.2	<0.2

Table 5-5
(continued)

Sampling Location[a]	Quarter 1	2	3	4	Avg
Lower Groundwater System (cont'd)					
19-D					
Aluminum	216	<200	40,800	1,000	10,600
Copper	<25	<25	61.6	<25	34
Iron	484	566	61,100	1,800	16,000
Manganese	316	338	2,160	330	790
Lead	<3	<90	<90	<90	70
Vanadium	<50	<50	85.9	<50	60
Mercury	<0.2	<0.2	<0.2	<0.2	0.2
20-D					
Aluminum	954	583	361	1,300	800
Copper	<25	<25	<25	<25	25
Iron	1,790	1,070	601	2,100	1,390
Manganese	337	283	220	380	310
Lead	<3	<90	<90	<90	70
Vanadium	<50	<50	<50	<50	50
Mercury	<0.2	<0.2	<0.2	<0.2	0.2
BH-5					
Aluminum	<200	<200	1,040	465	480
Copper	<25	<25	<25	<25	25
Iron	129	133	106	160	130
Manganese	<15	<15	<15	<15	15
Lead	<3	<90	19.9	<90	50
Vanadium	<50	<50	<50	<50	50
Mercury	<0.2	<0.2	<0.2	<0.2	0.2
BH-49					
Aluminum	6,450	1,380	782	1,000	2,400
Copper	<25	<25	<25	<25	25
Iron	11,000	2,330	1,380	1,800	4,100
Manganese	408	117	74.5	110	177
Lead	7.3	<90	<90	<90	70
Vanadium	<50	<50	<50	<50	50
Mercury	<0.2	<0.2	<0.2	<0.2	0.2
BH-61[g]					
Aluminum	580	1,850	1,850	570	1,200
Copper	<25	<25	<25	<25	25
Iron	1,980	4,250	3,390	1,700	2,830
Manganese	230	295	224	170	230
Lead	<3	<90	<90	<90	70
Vanadium	<50	<50	<50	<50	50
Mercury	<0.2	<0.2	<0.2	<0.2	0.2

Table 5-5

(continued)

Sampling Location[a]	Quarter 1	2	3	4	Avg
	Lower Groundwater System (cont'd)				
BH-48					
Aluminum	24,300	8,600	6,890	9,900	12,400
Copper	53.6	<25	25.2	34	35
Iron	48,100	17,000	11,600	20,000	24,000
Manganese	3,550	1,590	1,150	2,100	2,100
Lead	17.5	<90	<90	<90	70
Vanadium	71.2	<50	58.9	62	60
Mercury	<0.2	<0.2	<0.2	<0.2	0.2

[a]Sampling locations are shown in Figure 4-11.

[b]Well did not recover after purging.

[c]Not analyzed first quarter.

[d]Wasp nest in well; could not sample.

[e]Background well.

[f]Bailer stuck in well; could not sample.

[g]Downgradient well.

indicate the need for broader organic contaminant screening because of sustained elevated levels above 200 mg/L for TOC and 200 μg/L for TOX for several quarters, an individual organic contaminant analysis will be performed.

Analysis for metals was initiated in 1987; however, samples collected during 1987, 1988, 1989, and the first three quarters of 1990 were analyzed for filtered (dissolved) metals. Samples collected during the fourth quarter of 1990 and during 1991 were not filtered before analysis; therefore, some values are higher than in previous years because they include both dissolved and suspended metals. Samples were not collected from some of the wells during the fourth quarter of 1991 because the wells did not recover after purging. Therefore, sufficient data on total metals are not available to indicate a trend.

5.2 NATIONAL POLLUTANT DISCHARGE ELIMINATION SYSTEM

A permit application will be completed in 1992 to comply with the EPA NPDES requirements. Stormwater discharges will be sampled in the third quarter of 1992 to meet the application requirements.

5.3 OTHER EMISSIONS MONITORING

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

5.4 ENVIRONMENTAL OCCURRENCES

No unplanned releases occurred in 1991.

5.5 SARA TITLE III REPORTING

No reports under Section 313 of the Emergency Preparedness and Community Right-to-Know Act were filed during 1991. FUSRAP sites were not subject to toxic chemical release reporting provisions under 40 CFR 372.22 in 1991. However, in accordance with the spirit and language of DOE Order 5400.1, FUSRAP evaluates and

inventories toxic chemicals used onsite to ensure that no threshold planning quantities (TPQs) are exceeded.

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

6.0 GROUNDWATER PROTECTION PROGRAM

6.1 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 terrains 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 the 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. The elevation of ground surface is generally 98 m (320 ft) above mean sea level (MSL). Wells in bedrock are screened at depths ranging from 12.2 to 27.5 m (40 to 90 ft). The potentiometric surface 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) above MSL 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) above 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 potentiometric surface in this zone occurs at depths 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 this system are screened at depths of 6.1 to 14.4 m (20 to 47.2 ft), and the potentiometric surface 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 system in the glacial deposits near NFSS is capable of supplying adequate groundwater for domestic use, although this source 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 water 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 the Niagara River.

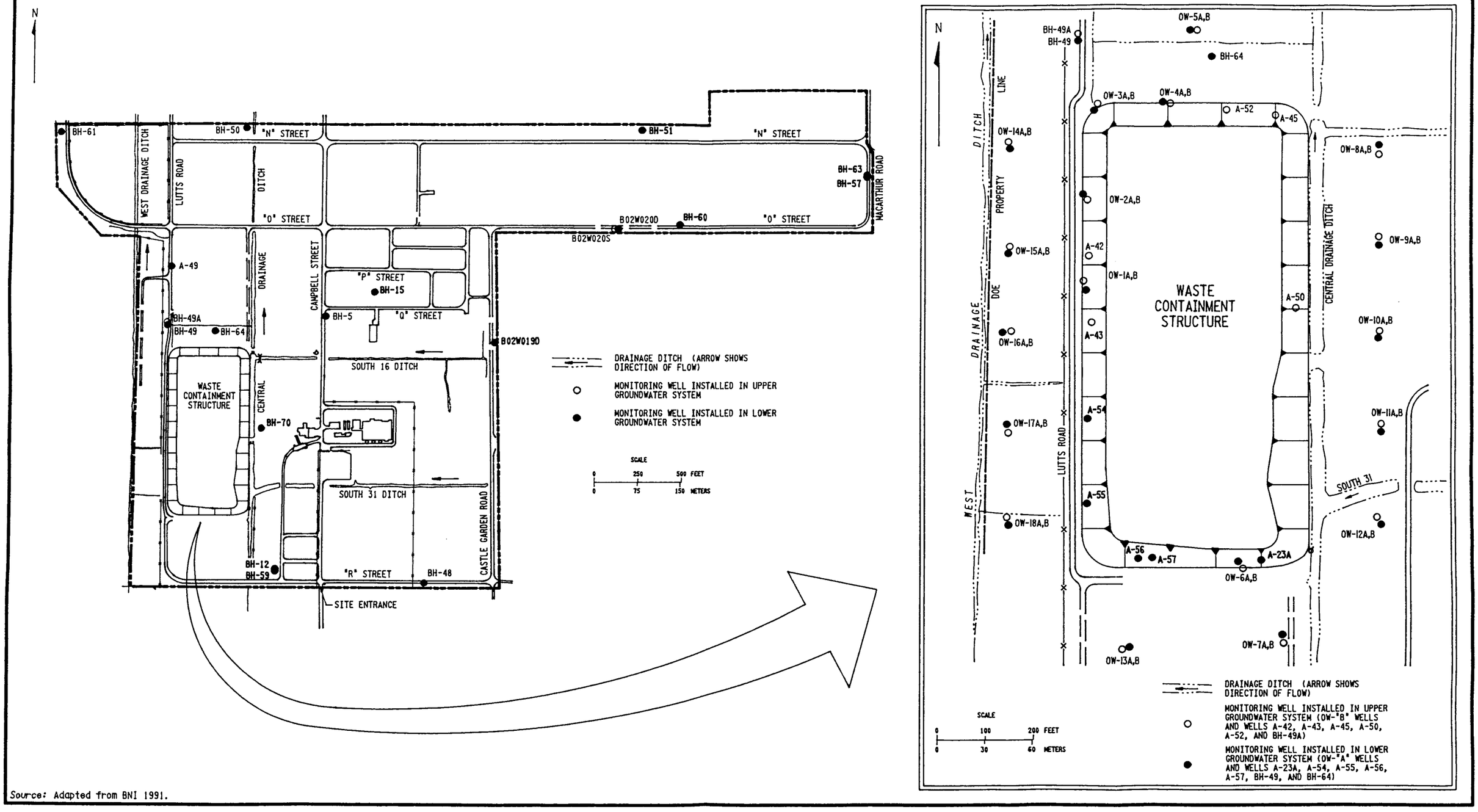
6.2 GROUNDWATER MONITORING

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 WCS during calendar year 1991 (Figure 6-1). Groundwater levels were measured biweekly using an electric downhole probe water level indicator. Well construction details are summarized in Table 6-1. An example of well construction details is provided in Appendix G. Further information on site geology, hydrogeology, and well installation methods can be found in an instruction guide, in BNI 1984 and 1986, and in 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 G). The NFSS hydrographs also include bar graphs of site precipitation records 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, fall, and winter) on base maps and contouring the values.



Source: Adapted from BNI 1991.

158 R10F006.DGN F2

Figure 6-1
Monitoring Wells Used for Water Level Measurements at NFSS

Table 6-1

NFSS Monitoring Well Construction Summary

Well Number[a]	Completion Date	Total Depth [m (ft)]	Monitoring or Screened Interval Below Ground [m-m (ft-ft)]	Construction Material
Upper Groundwater System				
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
Lower Groundwater System				
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
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

Table 6-1

(continued)

Well Number[a]	Completion Date	Total Depth [m (ft)]	Monitoring or Screened Interval Below Ground [m-m (ft-ft)]	Construction Material
Bedrock				
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

[a]Well locations are shown in Figure 6-1.

[b]PVC - polyvinyl chloride.

NOTE: Water level elevations for wells monitored in 1991 are shown as hydrographs in Appendix G.

6.2.2 Results and Conclusions

The hydrographs prepared for the water levels measured in 1991 are shown in Appendix G. Conclusions derived from these hydrographs and from the potentiometric surface maps are presented in the following subsections.

Upper groundwater system

The 1991 water levels show a significant seasonal variation and groundwater deficit compared with the previous three years (Figure 6-2). Peak high water levels were recorded in March through May, and peak lows were recorded in most wells from November to December. Upper groundwater system hydrographs in Appendix G show a deep declining low period that began to recover at the end of the year. In the declining period, some wells show a leveling off, which is an indication that the water level was below the bottom of the well. Water levels below the bottom of the well could not be measured in the last quarter of 1991. This groundwater deficit is directly related to climatological conditions in the summer and fall. Lower-than-normal precipitation and higher-than-normal evaporation reduced the amount of recharge to the groundwater. The delayed response to climatological conditions reflects the local infiltration rates at each well, which is indicated by the different times that the peak low occurs.

The slope and flow direction of the upper groundwater system were determined from potentiometric surface maps (Figures 6-3, 6-4, 6-5, and 6-6). The dates plotted were representative of spring, summer, fall, and winter conditions. The general flow pattern at the WCS is from west to east, toward the central ditch that intersects the upper groundwater system. The flow gradient is nearly level under the pile and steepens beside the drainage ditch. The elevation of the pile is 85 m (329 ft) above MSL. The general flow direction away from the influence of the WCS is toward the northwest.

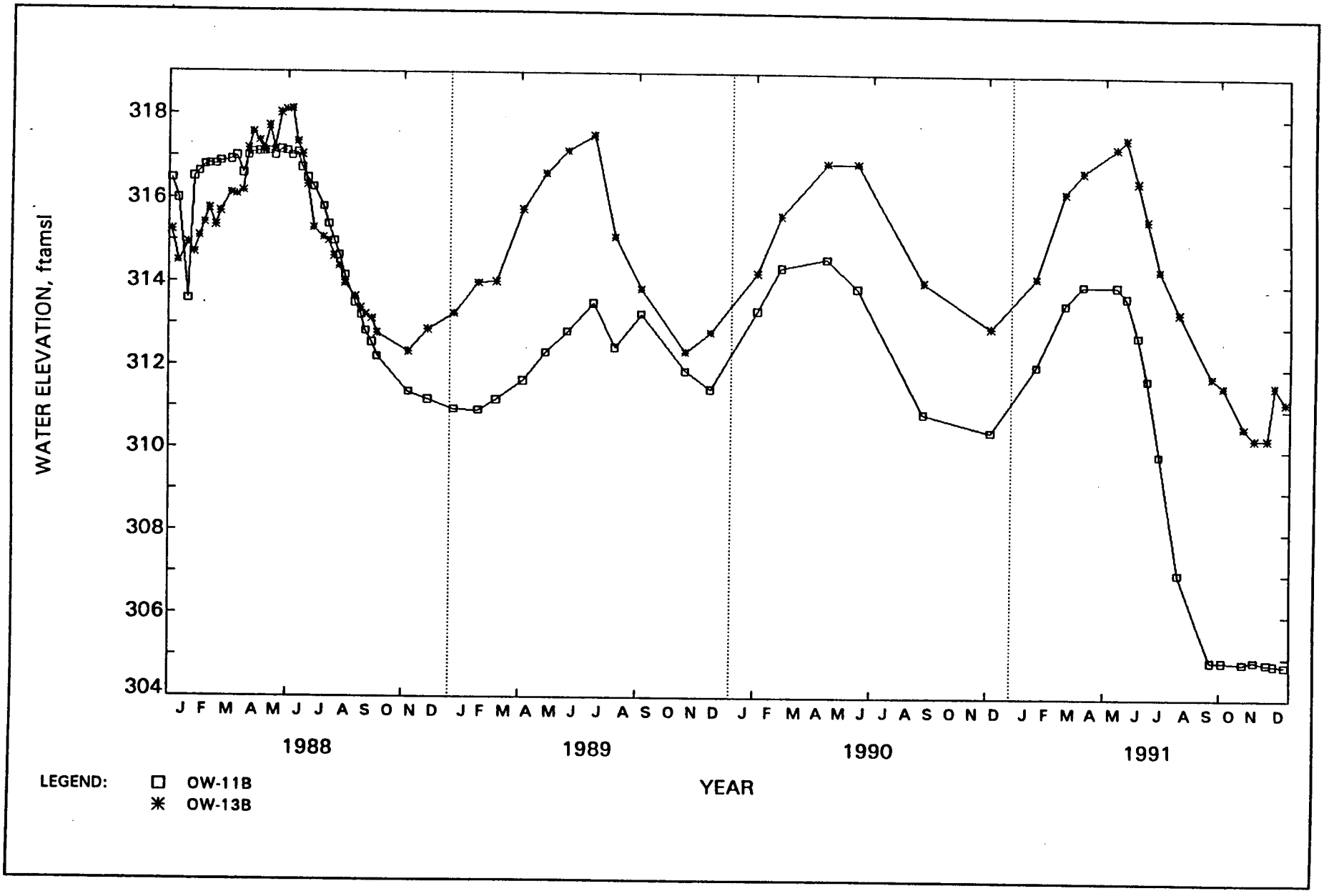


Figure 6-2
Four-year Hydrograph of Upper Groundwater System at NFSS

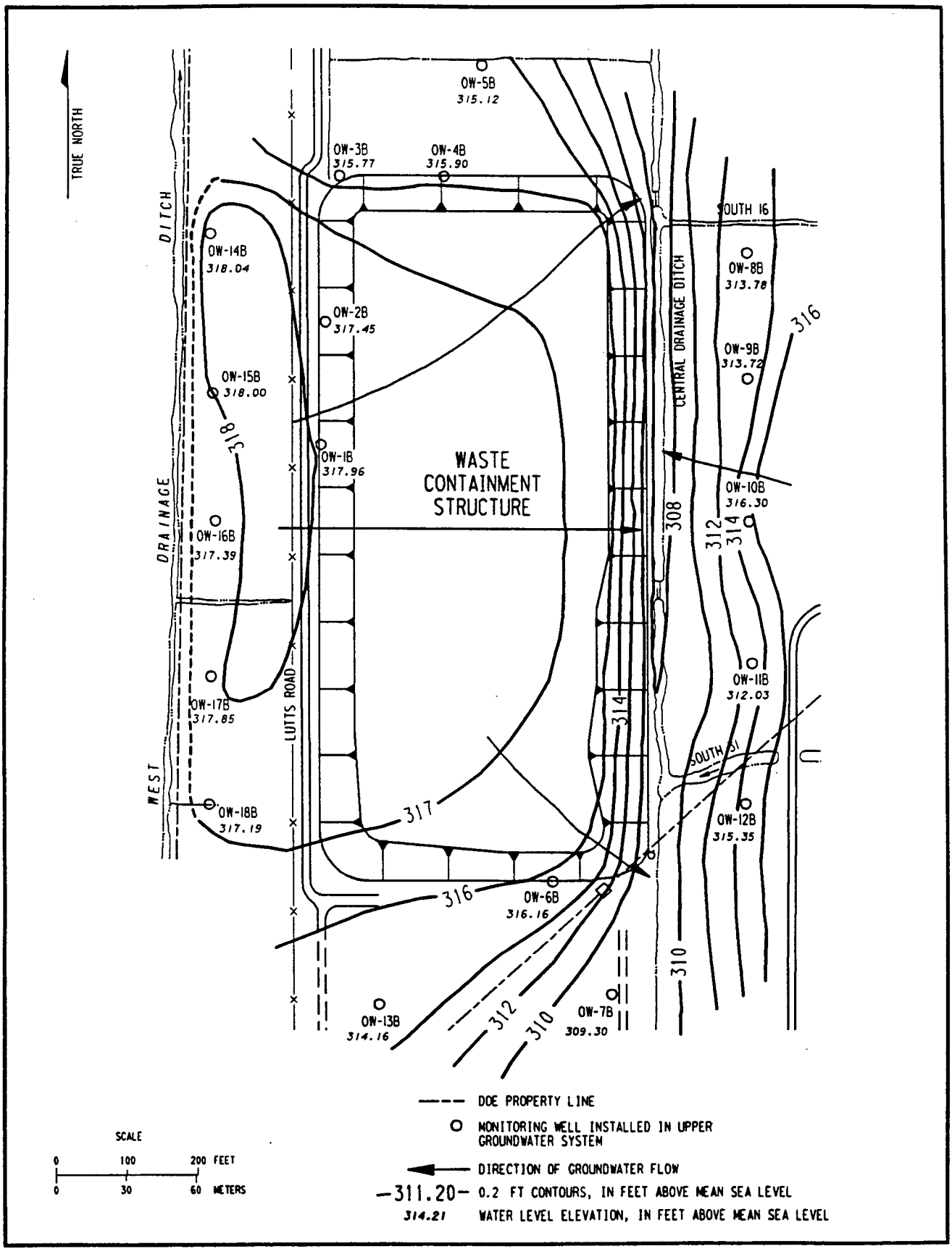


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Figure 6-3
Potentiometric Map of Upper Groundwater System (2/1/91)

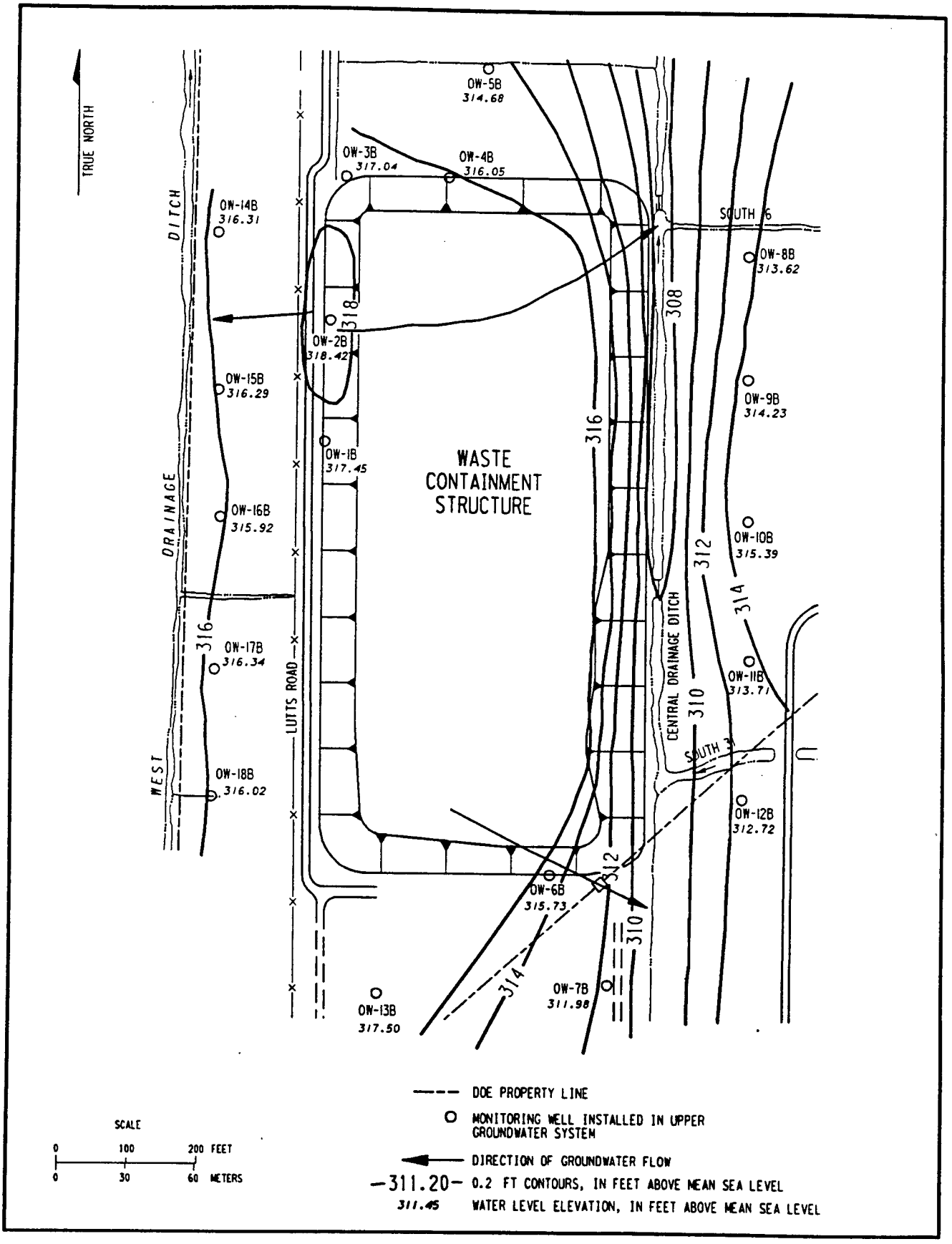

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Figure 6-4
Potentiometric Map of Upper Groundwater System (5/29/91)

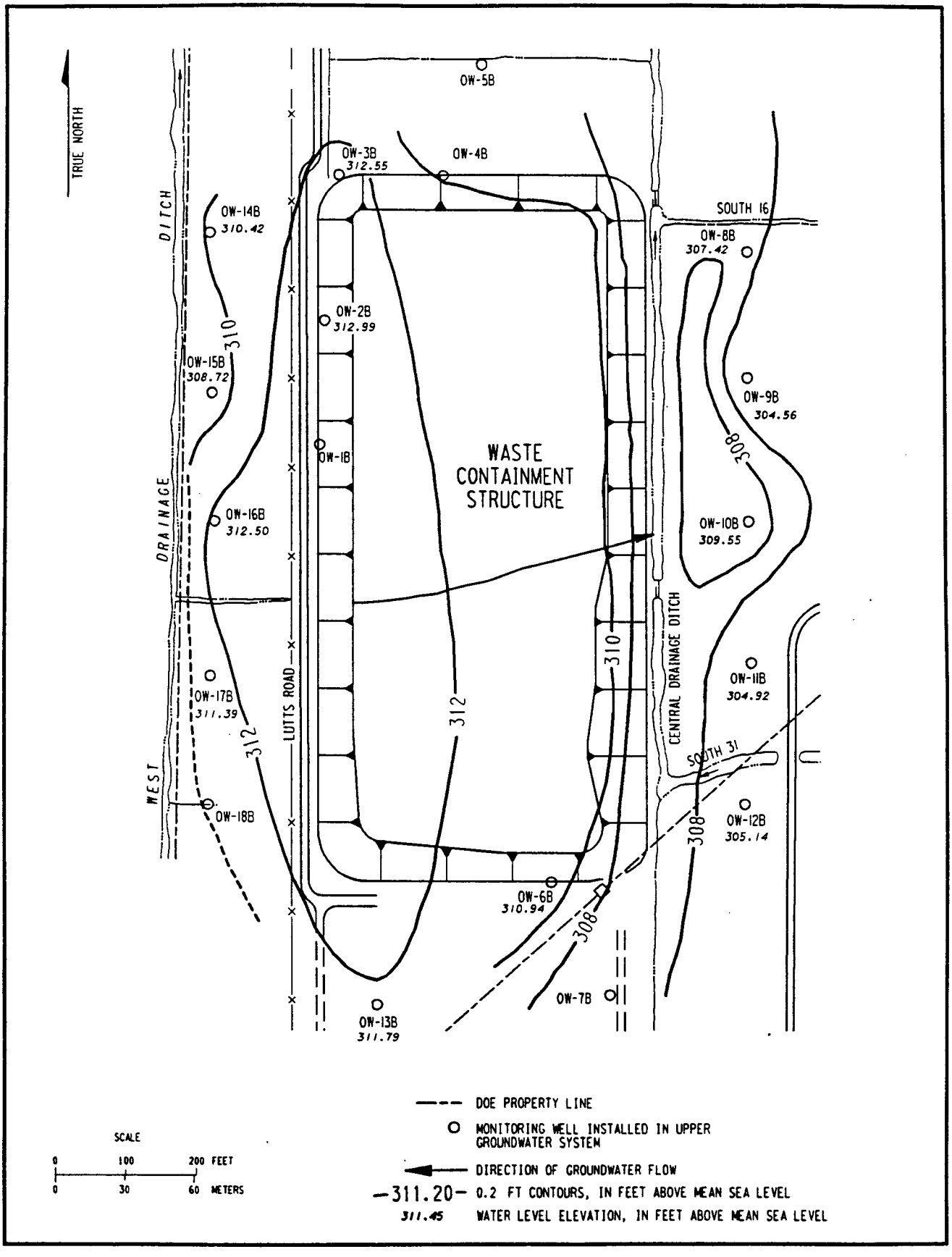

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Figure 6-5
Potentiometric Map of Upper Groundwater System (9/19/91)

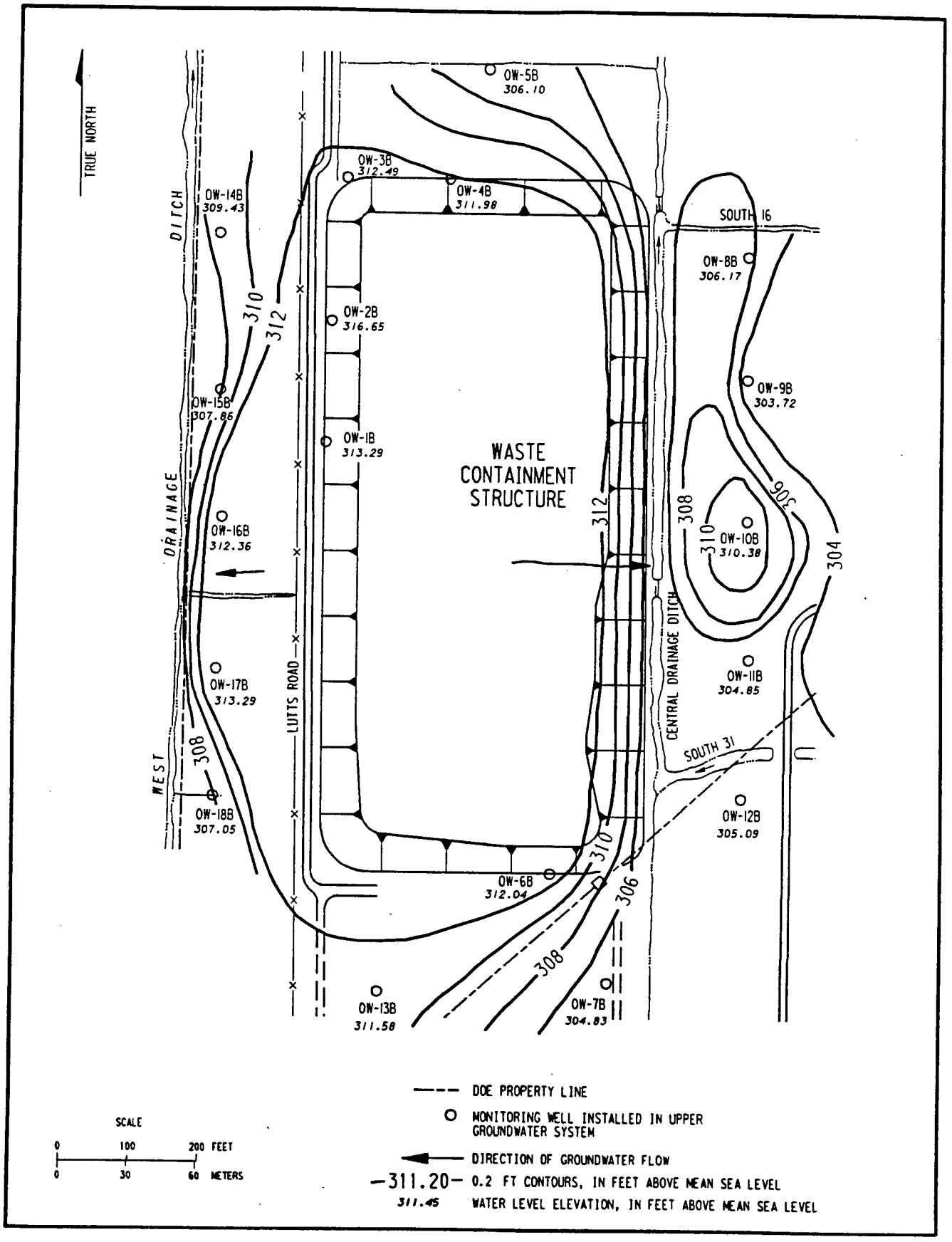

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Figure 6-6
Potentiometric Map of Upper Groundwater System (12/11/91)

Lower and bedrock groundwater systems

The lower and bedrock groundwater systems are discussed as a single unit in this section because they are hydraulically connected with similar flow gradient and direction (BNI 1990). Hydrographs of wells screened in these systems show a definite seasonal variation in water levels and groundwater deficit. For the lower system, water levels are highest in late May and lowest after December. Seasonal fluctuations in water levels had similar peak periods, but the peak low was significantly lower than in the three previous years (Figure 6-7). No response to individual precipitation events was indicated.

The slope and flow direction of the lower groundwater system were interpreted from seasonal potentiometric surface maps (Figures 6-8, 6-9, 6-10, and 6-11). The general flow direction is toward the northwest. Flow gradient was less than 0.0018 during 1991.

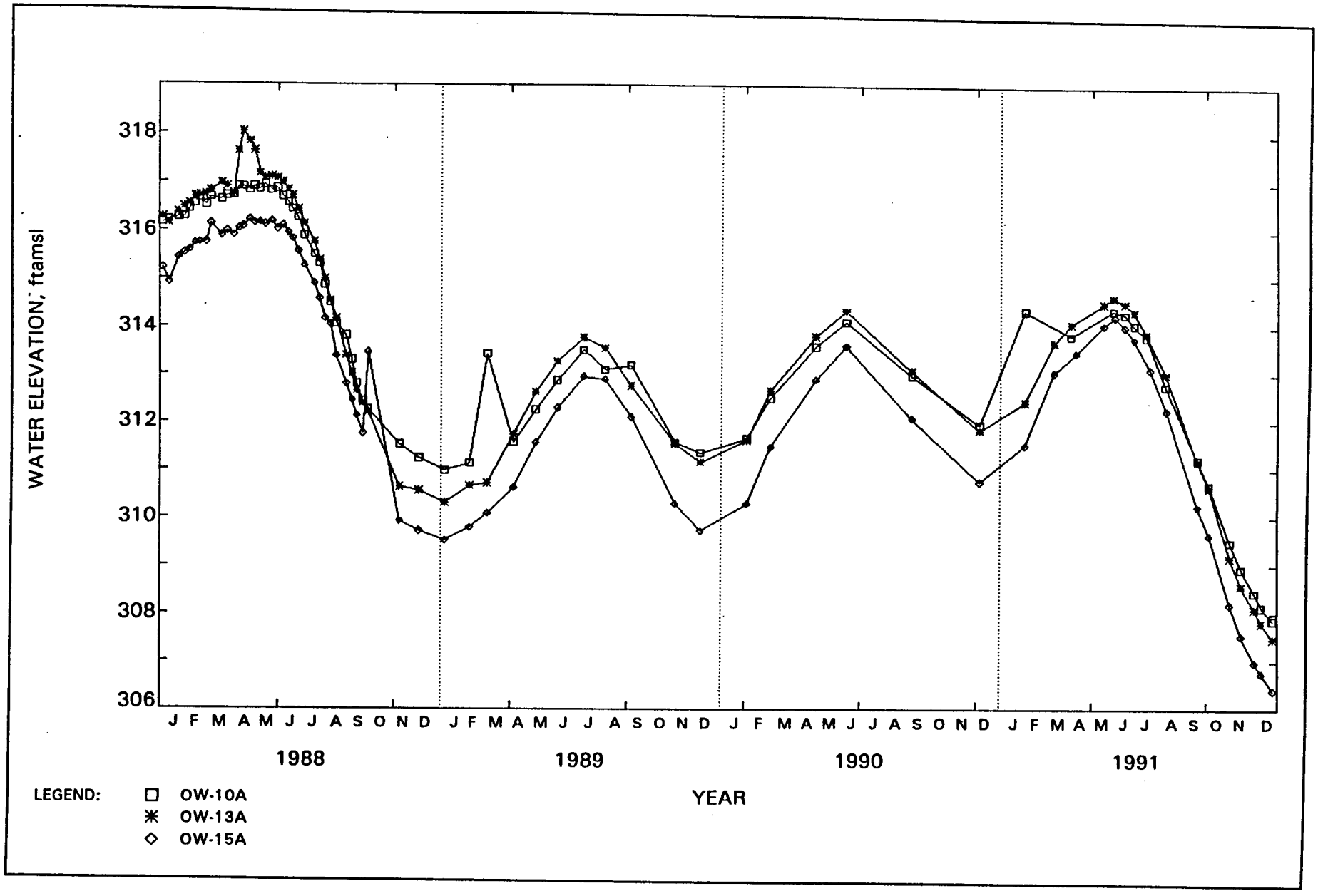
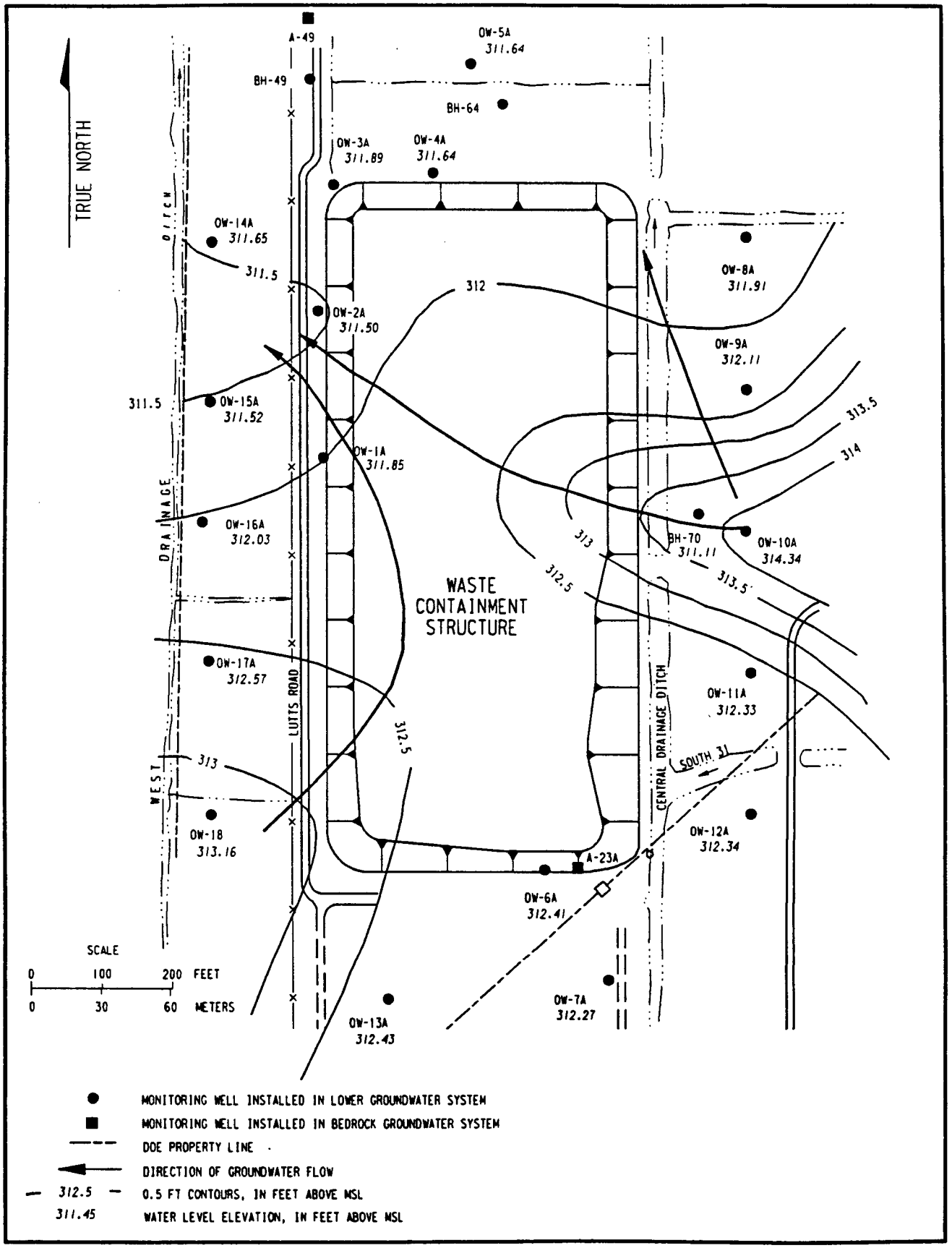


Figure 6-7
Four-year Hydrograph of Lower Groundwater System at NFSS



158 R10F011.DGN

Figure 6-8
Potentiometric Map of Lower Groundwater System (2/1/91)

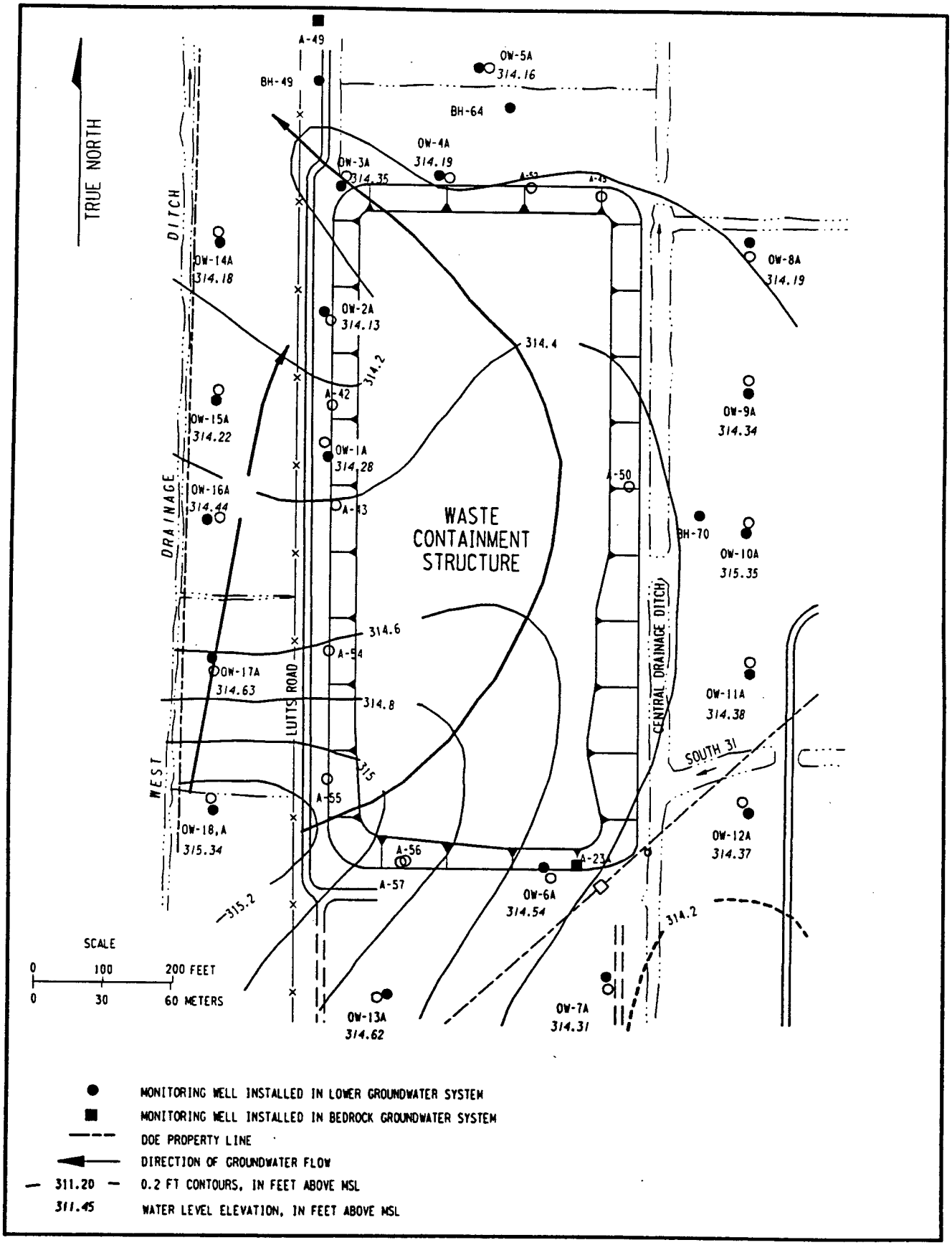


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Figure 6-9
Potentiometric Map of Lower Groundwater System (5/29/91)

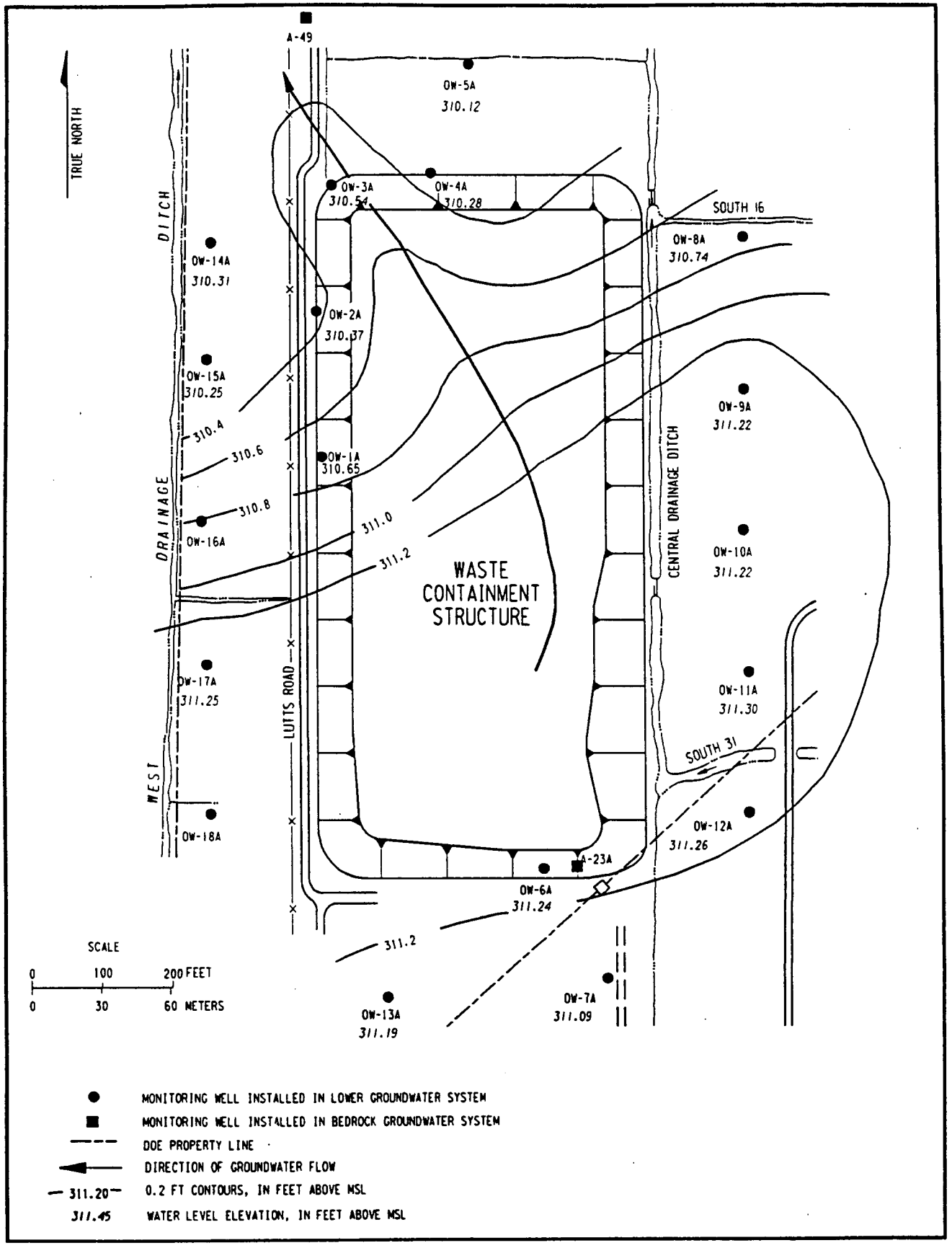

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Figure 6-10
Potentiometric Map of Lower Groundwater System (9/19/91)

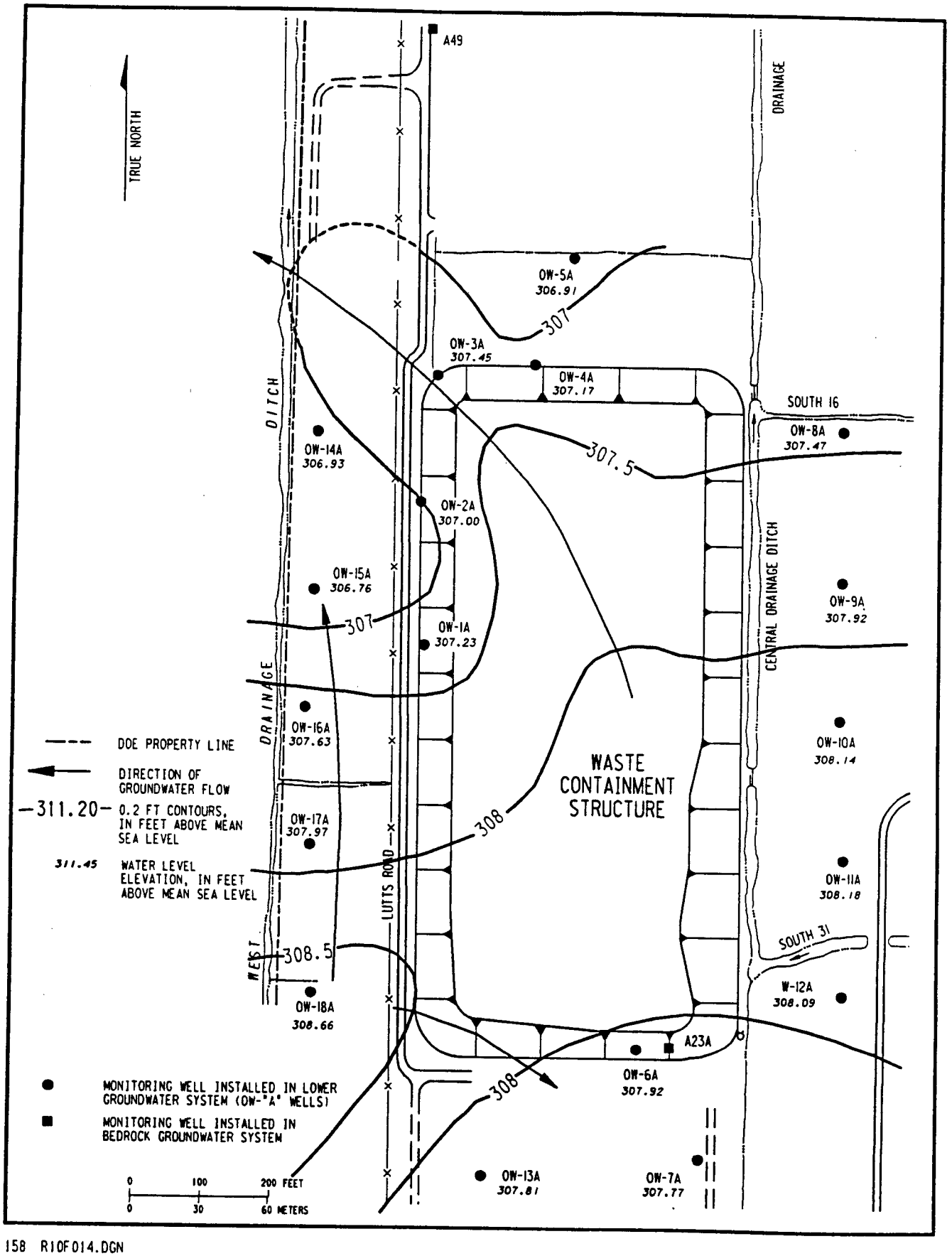

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Figure 6-11
Potentiometric Map of Lower Groundwater System (12/11/91)

7.0 QUALITY ASSURANCE

7.1 INTRODUCTION

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

7.2 PROCEDURES

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

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

7.3 QUALITY ASSURANCE SUMMARY

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

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

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

7.3.1 Data Usability

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

- Metals in groundwater
- TOC in groundwater
- TOX in groundwater
- Radium-226 in groundwater and sediments
- Total uranium in groundwater
- Uranium-238 in sediments
- External gamma radiation

Other analytes were also evaluated, and certain elements did not fully meet PARCC requirements or could not be completely evaluated because some QC data were not retrievable. Corrective actions were initiated for all identified data deficiencies and

Table 7-1

Data Usability Summary

ANALYTE	PRECISION	ACCURACY	REPRESENTATIVENESS	COMPLETENESS	COMPARABILITY	QUANTITATIVE	QUALITATIVE	DQO[1]
Metals	YES[2]	YES	YES	YES	YES	YES	YES	YES
Total organic carbon	YES	YES	YES	YES	YES	YES	YES	YES
Total organic halides	YES	YES	YES	YES	YES	YES	YES	YES
Radium-226	YES	YES	YES	YES	YES	YES	YES	YES
Total uranium	YES	YES	YES	YES	YES	YES	YES	YES
Uranium-233/234	3	4	5	YES	6	7	YES	YES
Uranium-234	3	4	5	YES	6	7	YES	YES
Uranium-235	3	4	5	YES	6	7	YES	YES
Uranium-238	YES	YES	YES	YES	YES	YES	YES	YES
External gamma radiation	YES	YES	YES	YES	YES	YES	YES	YES
Radon-222	YES	YES	8	YES	YES	YES	YES	YES

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

1 The data quality objective (DQO) for the environmental monitoring program is to detect and quantify any release from NFSS that could be potentially harmful to human health and environment.

2 The term "Yes" indicates that data are usable based on the analyses of the indicated PARCC parameters.

3 Laboratory duplicate information was not reported for this parameter.

4 Data on laboratory standard reference materials (SRMs) and blanks were incomplete or not reported for this parameter.

5 Representativeness goal was not met because laboratory blank data were incomplete or not reported for this parameter.

6 Comparability factor could not be calculated because precision and accuracy information was not available.

7 Data do not meet quantitative goals because the variation associated with those values could not be adequately assessed.

8 Representativeness could not be assigned a value because none of the elements used to define representativeness are assessed for this parameter.

nonconformances. As part of the ongoing FUSRAP QA program, appropriate actions have been implemented including root-cause analyses and procedure development and revision.

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

- Radium-226 in surface water
- Uranium-233/234 in sediments
- Uranium-234 in sediments
- Uranium-235 in sediments
- Radon in air

7.3.2 Precision

The precision goal of 80 percent, as measured by analytical results for matrix spike duplicates (MSDs) and field and laboratory duplicates, was met for all chemical parameters at NFSS. This goal indicates that a minimum of 80 percent of the QC results fell within acceptable ranges. Calculations indicate that minimal variability was introduced by field sampling. MSD samples are used to measure analytical variability. The established criteria for acceptable variation were exceeded for the following analytes: aluminum, iron, and lead (in the first quarter); iron, manganese, copper, mercury, and lead (in the second quarter); aluminum, iron, manganese, copper, mercury, and lead (in the third quarter); and aluminum and iron (in the fourth quarter). This indicates that a matrix effect may be present at the site, which would interfere with the analytical determination of variation. Nevertheless, evaluation of the data usability indicated that data had met their intended end use.

The precision goal of 80 percent was met for all radiological analytes of concern at NFSS with the exception of radium-226 in surface water and uranium-233/234 in sediments. Precision could

not be assessed for radium-226 for this matrix because field duplicate information was not available. Precision for the uranium isotope could not be calculated because laboratory duplicate information was not reported. This lack of precision information, however, does not affect the usability of the data.

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

Values for radiological sediment analyses are considered qualitative because no field duplicate samples were taken and, consequently, total variability could not be quantified. Qualitative data are useful for estimating the approximate concentration or activity of an analyte, but the amount of variation associated with the data remains unknown.

Data from the FUSRAP radiological laboratory's monthly QC reports indicate that all analytes met the overall laboratory duplicate requirements for precision, except for radium-226 and uranium-233/234. QC data are incomplete at this time for these analytes; should further information become available, it will be incorporated into future annual site environmental reports. Data for these analytes are considered qualitative; however, the program's DQOs for precision have been met.

7.3.3 Accuracy

The accuracy goal of 80 percent was met for all chemical analytes of concern at NFSS. This goal indicates that a minimum of 80 percent of the QC results fell within acceptable ranges. Control limits were statistically established from the data population for metals and TOC in groundwater. Blank contamination was detected in the first, second, and third quarter samples analyzed for metals and in the second quarter samples analyzed for TOC. Some associated concentrations could not be assessed to determine whether they had exceeded these limits.

Method blank analyses were reported for all chemical analytes in groundwater, and the accuracy objective was met for all four quarters.

The goal of 80 percent accuracy was met for all radiological analytes of concern at NFSS except for uranium-233/234, uranium-234, and uranium-235. Accuracy for these analytes could not be assessed because laboratory blank and standard reference material (SRM) information was incomplete. Nevertheless, the program has determined that the values associated with these uranium isotopes satisfied the intended end use of the data.

Evaluation of radiological accuracy was limited because it was based on the total reported results for all FUSRAP sites where environmental monitoring was conducted in 1991. Laboratory QC data were summarized in a monthly report that provided an overall assessment of the laboratory's performance for the period. Because of the summary nature of the reports, NFSS QC data may be more accurate than actually reported.

7.3.4 Representativeness

The program's required objective for representativeness was met for all chemical and radiological data with the exception of uranium isotopes in sediments and radon in air. Representativeness could not be assessed for the uranium isotopes because laboratory blank information was incomplete or not reported. Additionally, none of the elements used to evaluate representativeness are

assessed for radon; therefore, a value could not be assigned to this analyte. Lack of representativeness information for this analyte does not affect the usability of the data.

7.3.5 Completeness

At NFSS, the completeness goal of 80 percent was exceeded for all chemical and radiological groundwater, surface water, and sediment samples. Air monitoring was conducted for external gamma radiation and radon, and all required data were collected.

7.3.6 Comparability

All chemical and radiological methodologies satisfy the program's goals for comparability. In addition, NFSS data met the program's comparability objectives, as calculated from precision and accuracy values, for all chemical analytes and for all radiological analytes except radium-226 in surface water; uranium-233/234, uranium-234, and uranium-235 in sediments; and radon in air. As with the precision and accuracy parameters, a calculated value for comparability also cannot be assessed because of the unavailability of data.

7.4 PROGRAMMATIC FACTORS

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

7.5 DOE LABORATORY QUALITY ASSESSMENT PROGRAM FOR RADIOACTIVE MATERIAL

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

Table 7-2

Results of the Quality Assessment Program, 1991

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

Table 7-2

(continued)

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

[a]TMA/E - ThermoAnalytical/Eberline, the radiological analysis subcontractor for FUSRAP.

[b]EML - the DOE Environmental Measurements Laboratory.

[c]Corrective action request has been issued.

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APPENDIX A
ENVIRONMENTAL STANDARDS

ENVIRONMENTAL STANDARDS

The DOE long-term radiation protection standard of 100 mrem/yr 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 GUIDES

As referenced in Section 2.0, DOE orders provide the standards for radionuclide emissions from DOE facilities. DOE Order 5400.5, "Radiation Protection of the Public and the Environment," provides the procedures and requirements for radionuclide releases.

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

Radionuclide	F1 Value[a]	Ingested Water DCG (μCi/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

[a]F1 is defined as the gastrointestinal tract absorption factor. This measures the uptake fraction of ingestion of a radionuclide into the body.

[b]Inhaled 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).

[c]DOE 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.

Radionuclide	Soil Concentration (pCi/g) Above Background
Radium-226 Radium-228 Thorium-230 Thorium-232	5 pCi/g, averaged over the first 15 cm of soil below the surface; 15 pCi/g when averaged over any 15-cm-thick soil layer below the surface layer.
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.

APPENDIX B
PARAMETERS FOR ANALYSIS

Parameters for Analysis at NFSS, 1991

Medium[a]	Parameter	Technique
Groundwater	Total uranium	Fluorometric/kinetic phosphorescence analysis
	Radium-226	Emanation/alpha spectroscopy
	Total organic halides	Coulometric determination
	Total organic carbon	Carbonaceous analyzer
	Total metals: aluminum, copper, iron, manganese, lead, vanadium	Inductively coupled plasma atomic emission spectrophotometry
	Mercury	Atomic absorption/ Spectrophotometry
	Specific conductivity	Electrometric
	pH	Electrometric
Surface Water	Total uranium	Fluorometric/kinetic phosphorescence analysis
	Radium-226	Emanation/alpha spectroscopy
Sediment	Total uranium	Alpha spectrometry
	Radium-226	Gamma spectrometry
Air	Radon-222	Track-etch
	External gamma radiation	Thermoluminescence

[a]Air samples are cumulative; all others are grab samples.

APPENDIX C
METHODOLOGY FOR STATISTICAL ANALYSIS OF DATA

METHODOLOGY FOR STATISTICAL ANALYSIS OF DATA

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

Thorium-230 Results (pCi/L)

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

Average annual concentrations are calculated by adding the results for the year and dividing by the number of quarters for which data have been taken and reported (usually four). An example is given below.

First, results reported for the year are added.

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

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

$$37 \div 4 = 9.25$$

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

Thorium-230 Results (pCi/L)

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

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. If site conditions do not change, 95 percent of the data points would be expected to fall within this range. 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 xi, ..., xn 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	2	4
2	5	8	-3	9
3	14	8	6	36
4	8	8	0	0
5	5	8	-3	9

$$\sum (X_i - \bar{x})^2 = 58$$

$$S = \sqrt{\frac{58}{5 - 1}} = \sqrt{\frac{58}{4}} = \sqrt{14.5} = 3.807,$$

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 D

POPULATION EXPOSURE METHODOLOGY

POPULATION EXPOSURE METHODOLOGY

DOSE CALCULATION METHODOLOGY

DOE Order 5400.5 requires that the impacts of the site on both the hypothetical maximally exposed individual and the population within 80 km (50 mi) of the site be evaluated. For radioactive materials, this evaluation is usually conducted by calculating the dose received by a hypothetical maximally exposed individual and the general population and comparing this dose with DOE guidelines. This appendix describes the methodology used to calculate the doses given in Subsection 4.2.

PATHWAYS

The purpose of the dose calculation is to identify the potential routes or pathways that are available to transmit either radioactive material or ionizing radiation to the receptor. In general, the pathways are (1) direct exposure to gamma radiation, (2) atmospheric transport of radioactive material, (3) transport of radioactive material via surface water or groundwater, (4) bioaccumulation of radioactive materials in animals used as a food source, and (5) uptake of radioactive materials 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 decreases 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 in compliance with boundary concentration requirements.

Contamination is transported in surface water when runoff from a rainfall event or some other source of overland flow carries contamination from the site to the surface water system. This contamination poses an exposure problem only 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 of less than one year are included with the parent radionuclide. Table D-1 lists the pertinent radionuclides, their half-lives, and dose conversion factors for ingestion.

DOSE CALCULATION METHOD

Direct Exposure

As previously indicated, only direct exposure is 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 tissue-equivalent thermoluminescent dosimeter (TETLD) program (described in Section 4.0). These data provide a measure of the amount and energy (in units of mR/yr) of the ionizing radiation at 1 m (3 ft) above the ground. For the purposes of this report, it is assumed that the hypothetical maximally exposed individual works 40 hours per week at the Modern Disposal landfill southeast of the site at

Table D-1

Radionuclides of Interest

Radionuclide	Half-life[a]	Dose Conversion Factor[b] for Ingestion (mrem/pCi)
Uranium-238	4.51×10^{9} years	2.5×10^{-4}
Thorium-234	24.1 days	--[c]
Protactinium-234 m	1.17 minutes	--[c]
Protactinium-234	6.75 hours	--[c]
Uranium-234	2.47×10^{5} years	2.6×10^{-4}
Thorium-230	8.0×10^{4} years	5.3×10^{-4}
Radium-226	1602 years	1.1×10^{-3}
Uranium-235	7.1×10^{8} years	2.5×10^{-3}
Thorium-231	25.5 hours	--[d]
Thorium-232	1.4×10^{10} years	2.8×10^{-3}
Protactinium-231	3.25×10^{4} years	1.1×10^{-2}
Actinium-227	21.6 years	1.5×10^{-2}
Thorium-227	18.2 days	--[e]
Radium-223	11.43 days	--[e]

[a]Source: Radiological Health Handbook (HEW 1970).

[b]Source: Federal Guidance Report No. 11, Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion (EPA-520/1-88-020) and International Dose Conversion Factors for Calculation of Dose to the Public (DOE/EH-0071).

[c]Included in the uranium-238 dose conversion factor.

[d]Included in the uranium-235 dose conversion factor.

[e]Included in the actinium-227 dose conversion factor.

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 hypothetical 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 m (3 ft) from the fenceline, the exposure at 10 m (30 ft) from the fenceline can be calculated by using the following equation (Cember 1983).

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

where: h_1 = TETLD distance from the fenceline [1 m (3 ft)]
h_2 = Distance from the hypothetical maximally exposed individual to 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 m (3 ft) can be calculated by taking the average of the results from the two dosimeters along this portion of the fenceline (5 and 20 mR/yr). The average exposure rate for these dosimeters was 13 mR/yr. Using the formula above, the exposure rate at 10 m (30 ft) is approximately 1.3 mR/yr. Because 1 mR/yr is approximately equal to 1 mrem/yr, the resulting dose would be 1.3 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.

$$\textit{Dose} = (\textit{Dose at 10 m}) \times \frac{(40\ h/wk)}{(7\ days/wk \times 24\ h/day)} = 0.3\ mrem/yr$$

Therefore, the dose from direct gamma radiation to the hypothetical maximally exposed individual is 0.3 mrem/yr (0.003 mSv/yr). This exposure scenario should provide a very conservative estimate of the dose from direct gamma exposure to this individual.

Surface Water Pathway

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

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

where:
- D_s = Committed effective dose from surface water
- C_i = Concentration of the i^{th} radionuclide in surface water at the site
- F_s = Average annual flow of surface water 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 hypothetical 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 Pathway

Exposures from contaminants in groundwater are important in calculating the dose to both the hypothetical maximally exposed individual and the nearby population. The data used to support the groundwater dose calculations consist of measurements of the 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 this 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 hypothetical 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.

Air Pathway

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

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

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

APPENDIX E
CLEAN AIR ACT COMPLIANCE REPORT
FOR 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: Niagara Falls Storage Site
Address: 1397 Fletcher Road
Lewiston , NY. 14092
Annual Assessment for Year: 1991
Date Submitted: 4/14/92

Comments: Input data is taken from 158-CV-02

Prepared By:

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

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

CLEAN AIR ACT COMPLIANCE REPORT 4/14/92 4:38 PM

Facility: Niagara Falls Storage Site
Address: 1397 Fletcher Road City: Lewiston State: NY
Comments: Input data is taken from 158-CV-02
Year: 1991

	Dose Equivalent Rates to Nearby Individuals (mrem/year)
Effective Dose Equivalent	0.0005
Highest Organ Dose is to ENDOSTEUM	0.0060

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

Radio-nuclide	Class	Amad	Area #1 (Ci/y)
U-238	W	1.0	4.7E-08
U-234	W	1.0	5.1E-08
U-235	W	1.0	2.2E-09
RA-226	W	1.0	3.7E-06
Total Area (m**2)			4.5E+04

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

Wind Data	IAG0905.WND	Temperature (C)	10
Food Source	LOCAL	Rainfall (cm/y)	101
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	8.8E-05
BREAST	8.8E-05
RED MARROW	5.2E-04
LUNGS	1.5E-03
THYROID	8.8E-05
ENDOSTEUM	6.0E-03
REMAINDER	1.1E-04
EFFECTIVE	5.0E-04

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 ENDOSTEUM (mrem/y)
INGESTION	2.8E-04	5.3E-03
INHALATION	2.2E-04	6.7E-04
AIR IMMERSION	1.0E-10	1.2E-10
GROUND SURFACE	2.9E-06	3.6E-06
TOTAL:	5.0E-04	6.0E-03

Niagara 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 ENDOSTEUM (mrem/y)
U-238	4.9E-06	4.4E-05
U-234	5.9E-06	5.5E-05
U-235	2.8E-07	2.3E-06
RA-226	4.9E-04	5.9E-03
TOTAL :	5.0E-04	6.0E-03

Niagara 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	5.0E-04
1000	6.5E-05
3000	1.1E-05
10000	2.0E-06
80000	9.5E-08

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	3.1E-04	4.2E-04	5.0E-04	4.4E-04	4.0E-04	3.8E-04	3.5E-04	2.9E-04
1000	3.8E-05	4.2E-05	6.5E-05	4.4E-05	4.7E-05	3.9E-05	4.3E-05	2.7E-05
3000	6.6E-06	7.3E-06	1.1E-05	7.6E-06	8.1E-06	6.7E-06	7.5E-06	4.7E-06
10000	1.2E-06	1.3E-06	2.0E-06	1.4E-06	1.4E-06	1.2E-06	1.3E-06	8.3E-07
80000	4.7E-08	6.0E-08	9.5E-08	6.7E-08	6.3E-08	5.4E-08	5.7E-08	3.7E-08

	S	SSW	SW	WSW	W	WNW	NW	NNW
DISTANCE (METERS):								
300	2.5E-04	2.1E-04	2.4E-04	3.0E-04	3.6E-04	2.9E-04	1.9E-04	1.8E-04
1000	3.1E-05	1.9E-05	2.8E-05	2.8E-05	4.8E-05	2.7E-05	2.2E-05	1.2E-05
3000	5.3E-06	3.2E-06	4.9E-06	4.8E-06	8.2E-06	4.6E-06	3.7E-06	2.1E-06
10000	9.3E-07	5.7E-07	8.5E-07	8.4E-07	1.4E-06	7.8E-07	6.4E-07	3.6E-07
80000	3.8E-08	2.4E-08	3.5E-08	3.3E-08	5.0E-08	2.6E-08	2.4E-08	1.5E-08

Niagara Falls Storage Site

METEOROLOGICAL AND PLANT INFORMATION SUPPLIED TO PROGRAM----

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

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

PLUME DEPLETION AND DEPOSITION PARAMETERS

NUCLIDE	GRAVITATIONAL FALL VELOCITY (METERS/SEC)	DEPOSITION VELOCITY (METERS/SEC)	SCAVENGING COEFFICIENT (1/SEC)	EFFECTIVE DECAY CONSTANT IN PLUME (PER DAY)
U-238	0.000	0.00180	0.101E-04	0.000E+00
U-234	0.000	0.00180	0.101E-04	0.000E+00
U-235	0.000	0.00180	0.101E-04	0.000E+00
RA-226	0.000	0.00180	0.101E-04	0.000E+00

FREQUENCY OF ATMOSPHERIC STABILITY CLASSES FOR EACH DIRECTION

SECTOR	FRACTION OF TIME IN EACH STABILITY CLASS						
	A	B	C	D	E	F	G
N	0.0079	0.0409	0.0779	0.5319	0.3415	0.0000	0.0000
NNW	0.0147	0.0554	0.0918	0.5707	0.2674	0.0000	0.0000
NW	0.0170	0.0692	0.1091	0.4792	0.3255	0.0000	0.0000
WNW	0.0041	0.0373	0.0980	0.3984	0.4623	0.0000	0.0000
W	0.0047	0.0328	0.0830	0.4515	0.4279	0.0000	0.0000
WSW	0.0014	0.0324	0.0810	0.5340	0.3512	0.0000	0.0000
SW	0.0124	0.0431	0.1100	0.5178	0.3168	0.0000	0.0000
SSW	0.0136	0.0675	0.1204	0.5455	0.2529	0.0000	0.0000
S	0.0163	0.0764	0.1420	0.4611	0.3043	0.0000	0.0000
SSE	0.0125	0.0679	0.1253	0.5497	0.2447	0.0000	0.0000
SE	0.0168	0.0617	0.1110	0.5526	0.2579	0.0000	0.0000
ESE	0.0121	0.0392	0.1071	0.6021	0.2395	0.0000	0.0000
E	0.0085	0.0358	0.0543	0.6335	0.2680	0.0000	0.0000
ENE	0.0062	0.0291	0.0756	0.6710	0.2180	0.0000	0.0000
NE	0.0057	0.0270	0.0966	0.6236	0.2471	0.0000	0.0000
NNE	0.0054	0.0230	0.1024	0.6178	0.2514	0.0000	0.0000

FREQUENCIES OF WIND DIRECTIONS AND RECIPROCAL-AVERAGED WIND SPEEDS

WIND TOWARD	FREQUENCY	WIND SPEEDS FOR EACH STABILITY CLASS (METERS/SEC)						
		A	B	C	D	E	F	G
N	0.062	1.00	1.48	2.25	3.35	1.31	0.00	0.00
NNW	0.020	1.04	1.42	2.24	3.16	1.22	0.00	0.00
NW	0.029	0.96	1.45	1.44	2.20	1.16	0.00	0.00
WNW	0.032	1.06	1.42	1.92	2.27	1.11	0.00	0.00
W	0.063	1.04	1.50	2.00	2.83	1.18	0.00	0.00
WSW	0.043	1.01	1.53	2.34	3.03	1.27	0.00	0.00
SW	0.045	1.05	1.80	2.34	2.91	1.26	0.00	0.00
SSW	0.032	1.00	1.84	2.60	2.60	1.28	0.00	0.00
S	0.049	0.99	1.66	2.44	2.77	1.23	0.00	0.00
SSE	0.050	1.01	1.83	2.48	3.06	1.30	0.00	0.00
SE	0.077	0.99	1.64	2.39	3.03	1.30	0.00	0.00
ESE	0.077	1.00	2.02	2.58	3.60	1.34	0.00	0.00
E	0.087	1.01	1.39	2.14	3.48	1.39	0.00	0.00
ENE	0.100	1.04	1.46	2.71	4.29	1.47	0.00	0.00
NE	0.141	1.05	1.66	3.05	4.34	1.45	0.00	0.00
NNE	0.092	0.96	1.86	3.07	4.59	1.42	0.00	0.00

FREQUENCIES OF WIND DIRECTIONS AND TRUE-AVERAGE WIND SPEEDS

WIND TOWARD	FREQUENCY	WIND SPEEDS FOR EACH STABILITY CLASS (METERS/SEC)						
		A	B	C	D	E	F	G
N	0.062	1.36	2.33	3.46	5.13	1.99	0.00	0.00
NNW	0.020	1.43	2.40	3.43	4.82	1.84	0.00	0.00
NW	0.029	1.28	2.27	2.41	3.54	1.66	0.00	0.00
WNW	0.032	1.46	2.21	3.02	3.62	1.58	0.00	0.00
W	0.063	1.43	2.33	3.17	4.33	1.73	0.00	0.00
WSW	0.043	1.37	2.37	3.44	4.51	1.93	0.00	0.00
SW	0.045	1.45	2.77	3.44	4.38	1.91	0.00	0.00
SSW	0.032	1.36	2.78	3.72	4.17	1.93	0.00	0.00
S	0.049	1.33	2.47	3.61	4.25	1.84	0.00	0.00
SSE	0.050	1.38	2.81	3.59	4.71	1.98	0.00	0.00
SE	0.077	1.34	2.62	3.59	4.70	2.04	0.00	0.00
ESE	0.077	1.35	2.99	3.75	5.19	2.11	0.00	0.00
E	0.087	1.38	2.12	3.30	5.42	2.20	0.00	0.00
ENE	0.100	1.44	2.26	4.10	6.16	2.32	0.00	0.00
NE	0.141	1.45	2.59	4.46	6.03	2.29	0.00	0.00
NNE	0.092	1.28	2.89	4.44	6.16	2.20	0.00	0.00

APPENDIX F

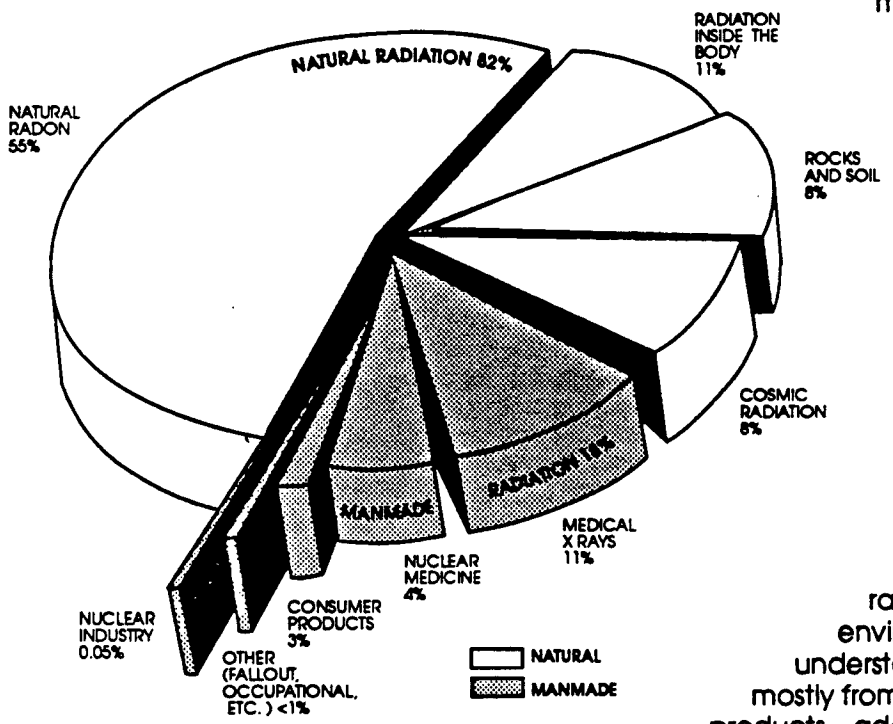
RADIATION IN THE ENVIRONMENT

Radiation in the Environment

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

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

Sources of Radiation



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

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

TYPES OF IONIZING RADIATION

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

Alpha

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

Beta

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

Gamma

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

Units of Measure

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

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

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

Cosmic Radiation

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

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

Terrestrial Radiation

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

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

Buildings

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

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

Radon

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

Average Indoor Radon Level ..... 1.5 pCi/liter
Occupational Working Limit ..... 100.0 pCi/liter

RADIATION IN THE ENVIRONMENT

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

mrem = millirem
pCi = picocurie

Food

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

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

Medical Treatment

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

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

Consumer Goods

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

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

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

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

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

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PERSPECTIVE: How Big is a Picocurie?

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

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

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

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

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

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

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

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

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

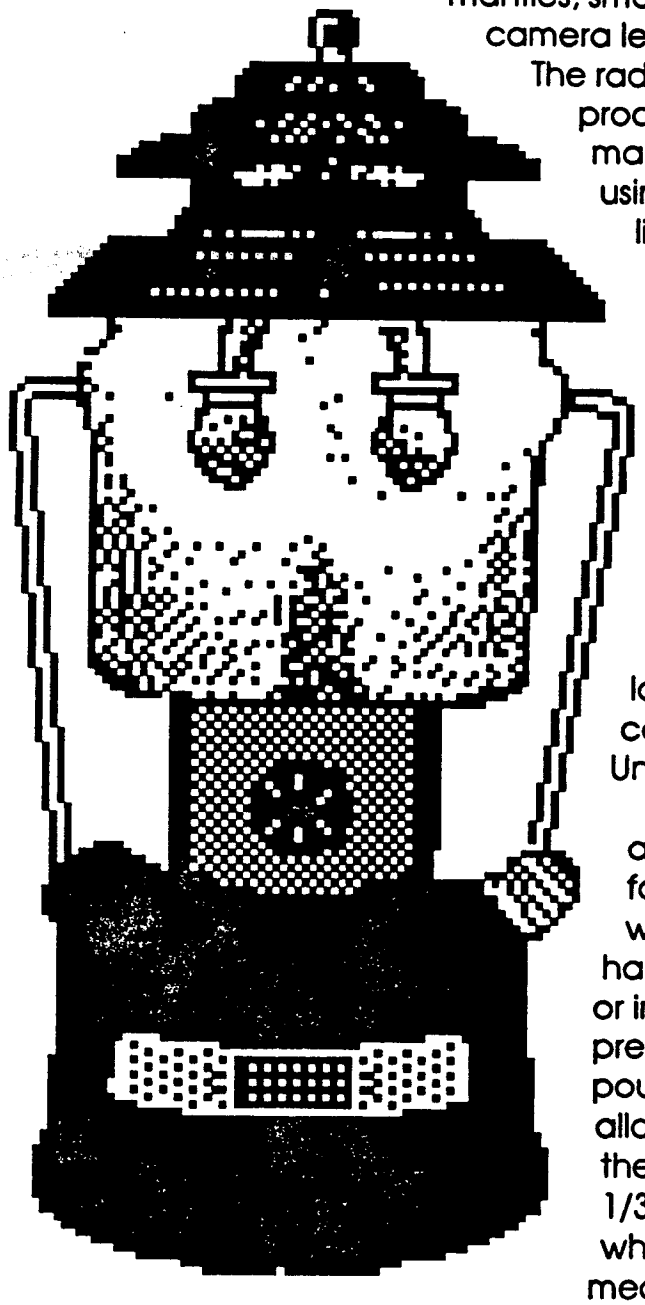
UNIT OF RADIOACTIVITY	SYMBOL	DISINTEGRATIONS PER MINUTE	DOLLAR ANALOGY	EXAMPLES OF RADIOACTIVE MATERIALS
1 Curie	Ci	$2x10^{12}$ or 2 Trillion	2 Times the Annual Federal Budget	Nuclear Medicine Generator
1 Millicurie	mCi	$2x10^{9}$ or 2 Billion	Cost of a New Interstate Highway from Atlanta to San Francisco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

Chart provided by W. L. Beck, R. obtel National, Inc.

PERSPECTIVE: Radioactivity in Gas Lantern Mantles

Around the House

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



Lanterns: In a New Light

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

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

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

APPENDIX G

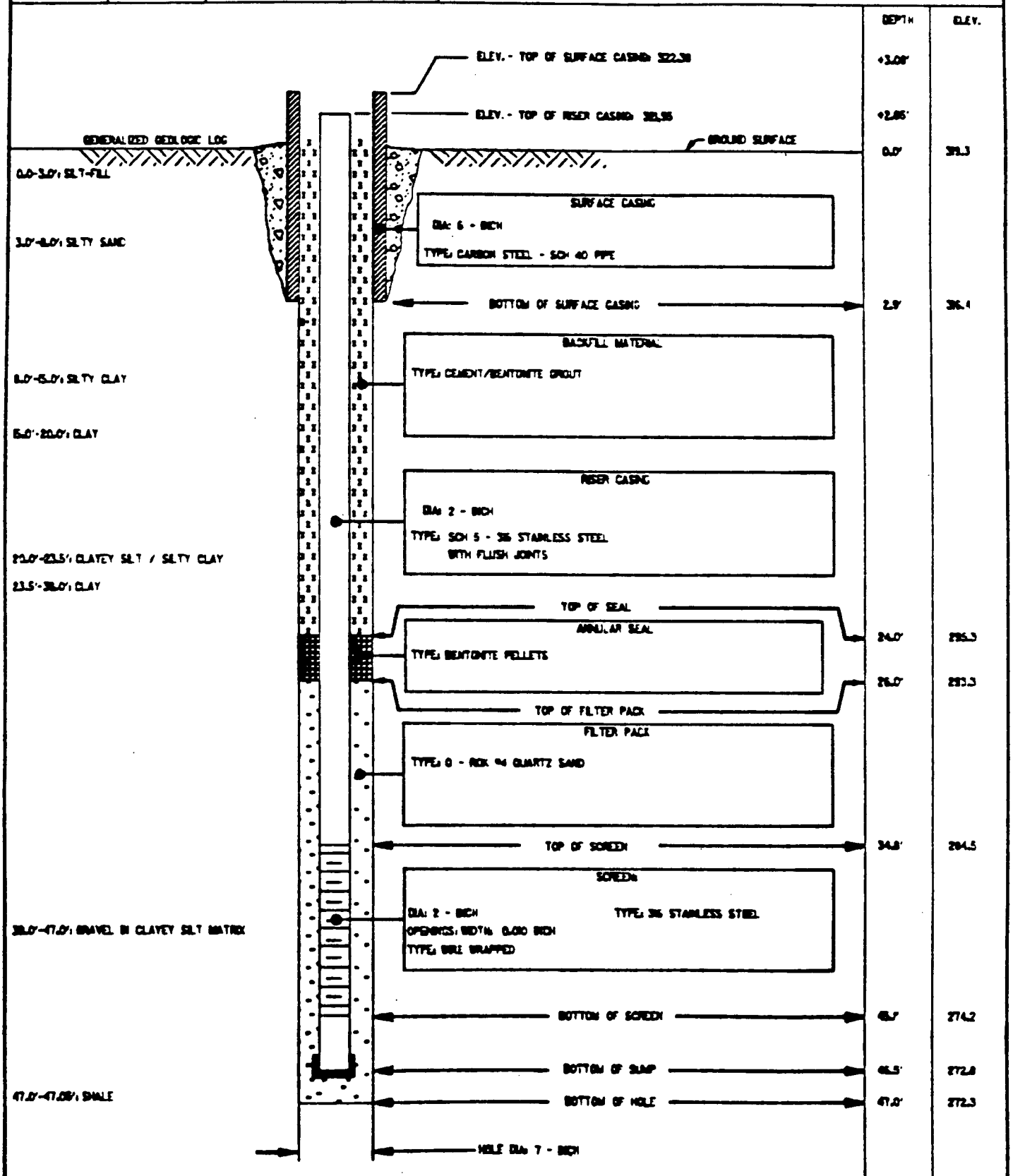
SAMPLE OBSERVATION WELL CONSTRUCTION LOG AND HYDROGRAPHS SHOWING WATER LEVEL ELEVATIONS

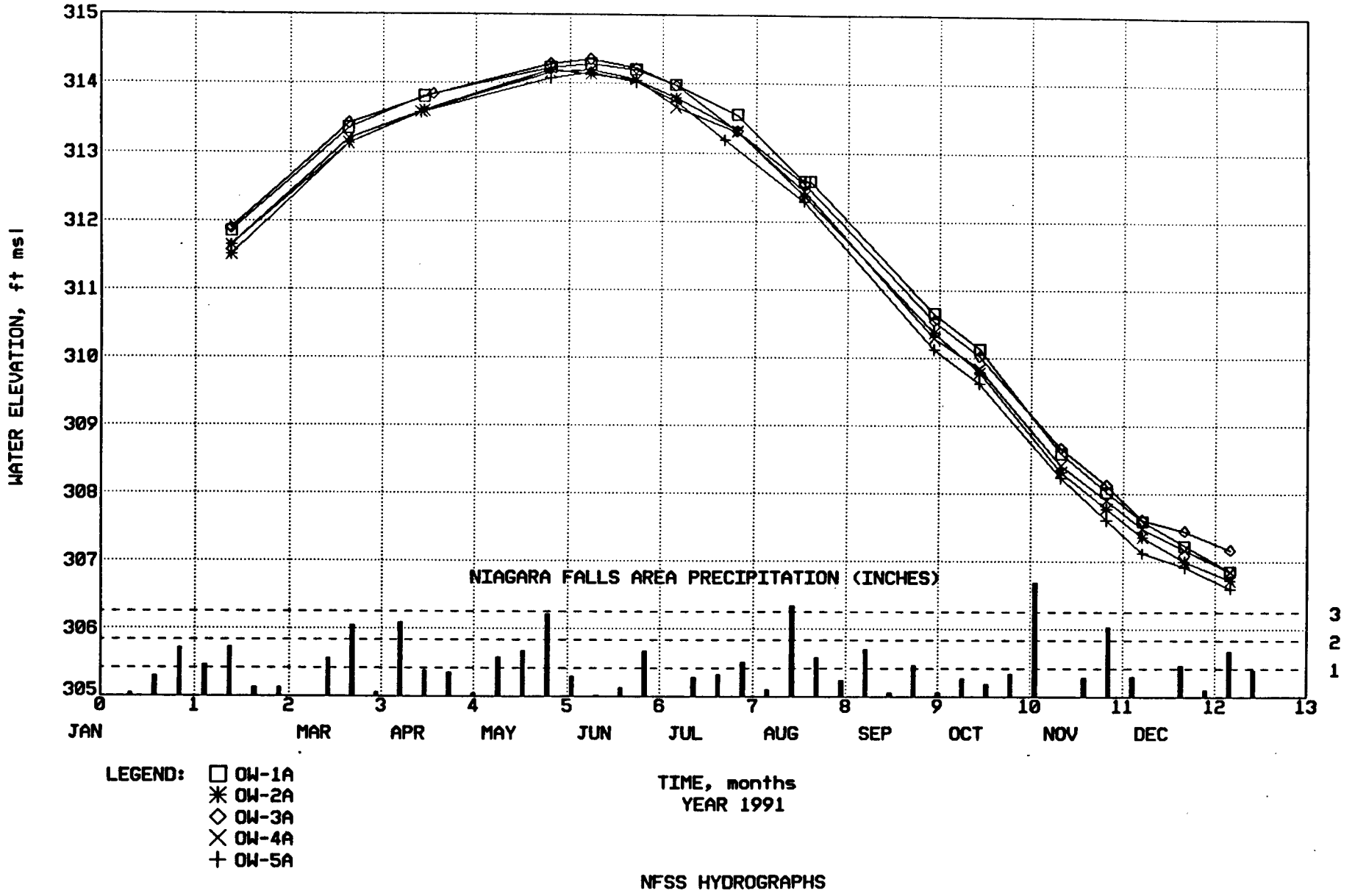
MONITORING WELL

PROJECT	WELL NO.
NIAGARA FALLS STORAGE SITE	OW-1A

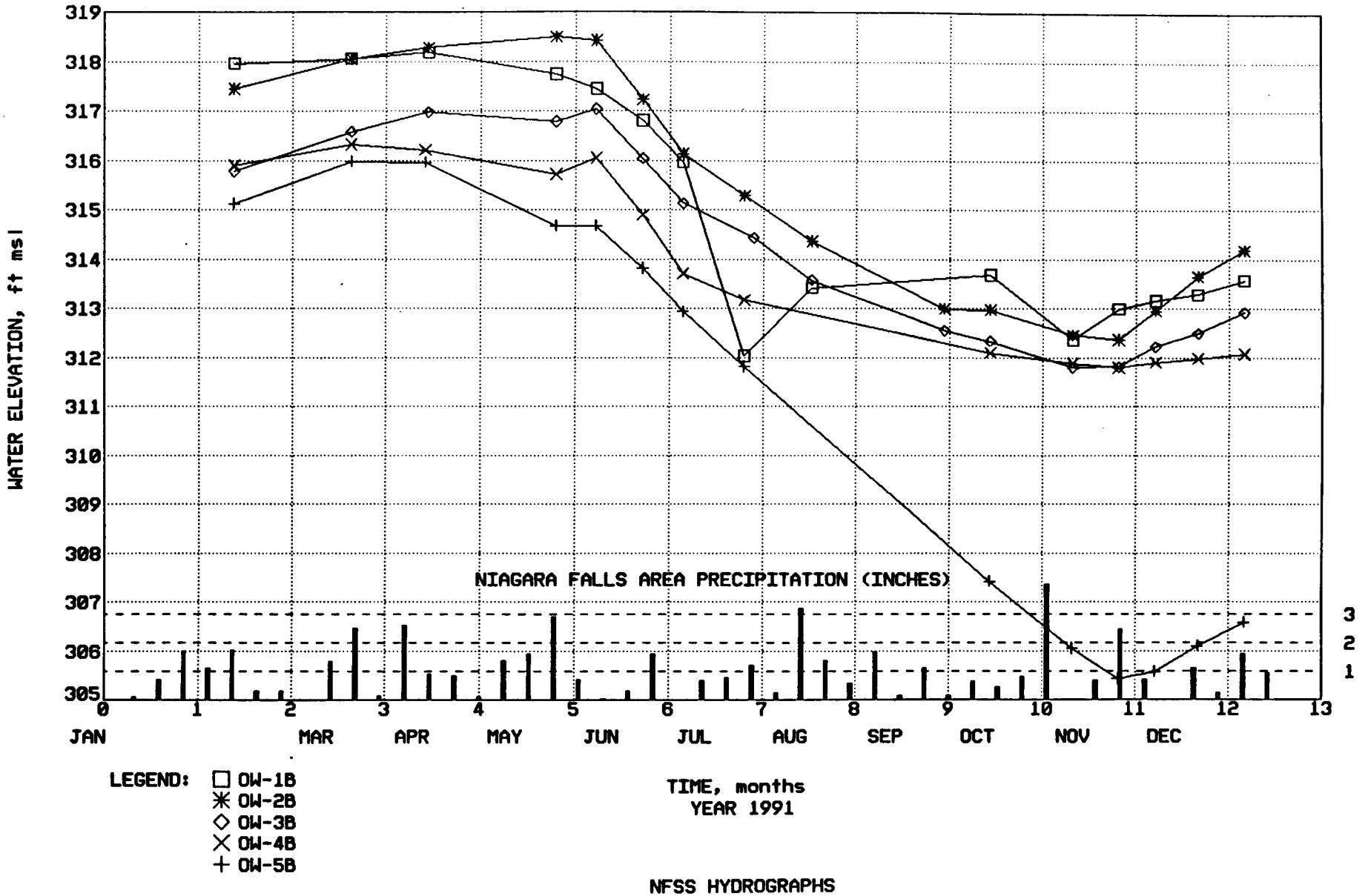
JOB NO.	SITE	COORDINATES
14501	WEST OF WASTE CONTAINMENT	S414 E006

BEGUN	COMPLETED	PREPARED BY	REFERENCE POINT FOR MEASUREMENTS
9/19/86	10/21/86	A.ATKINSON/D.MIDDLETON	TOP OF STAINLESS STEEL RISER PIPE

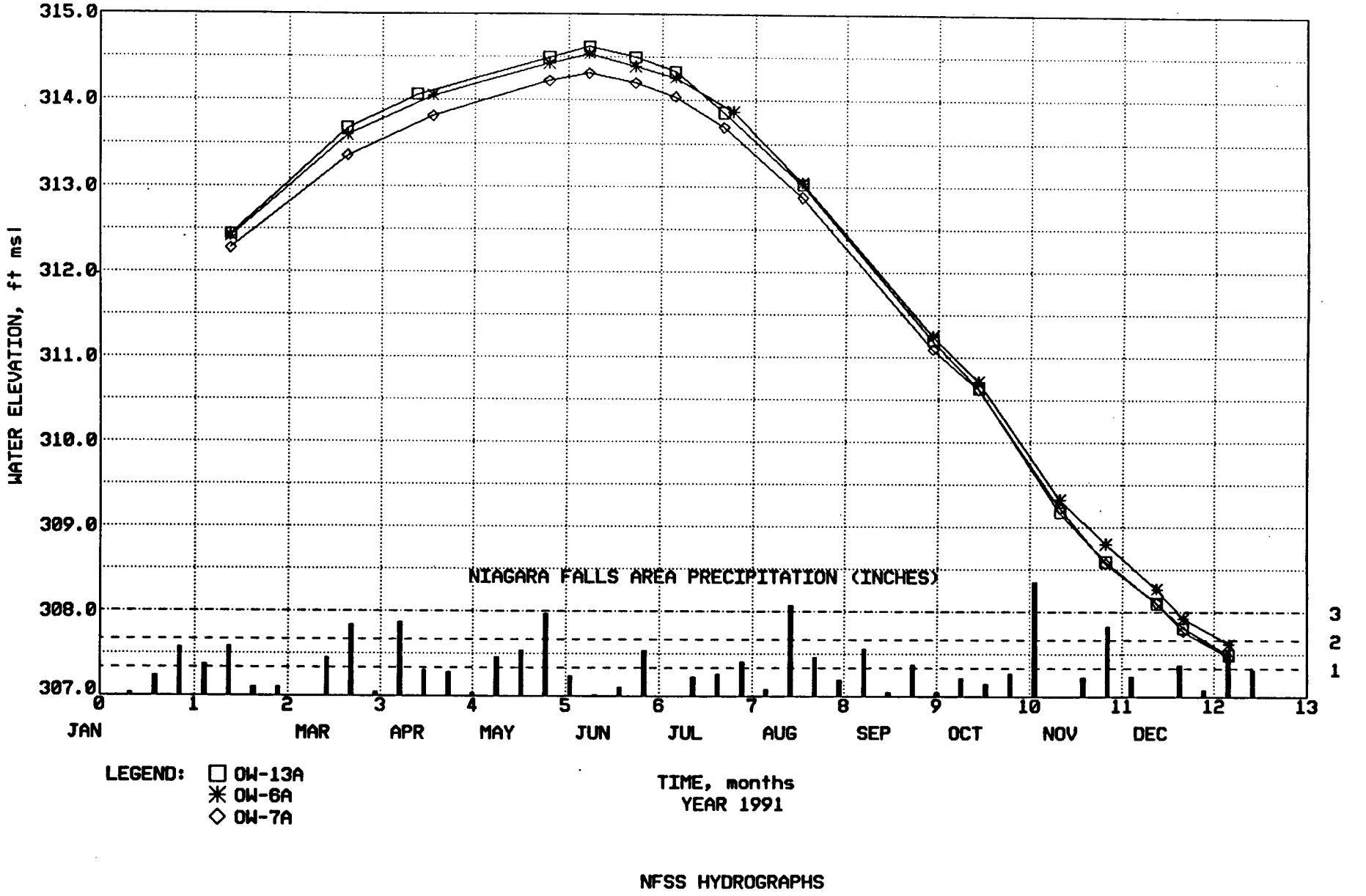




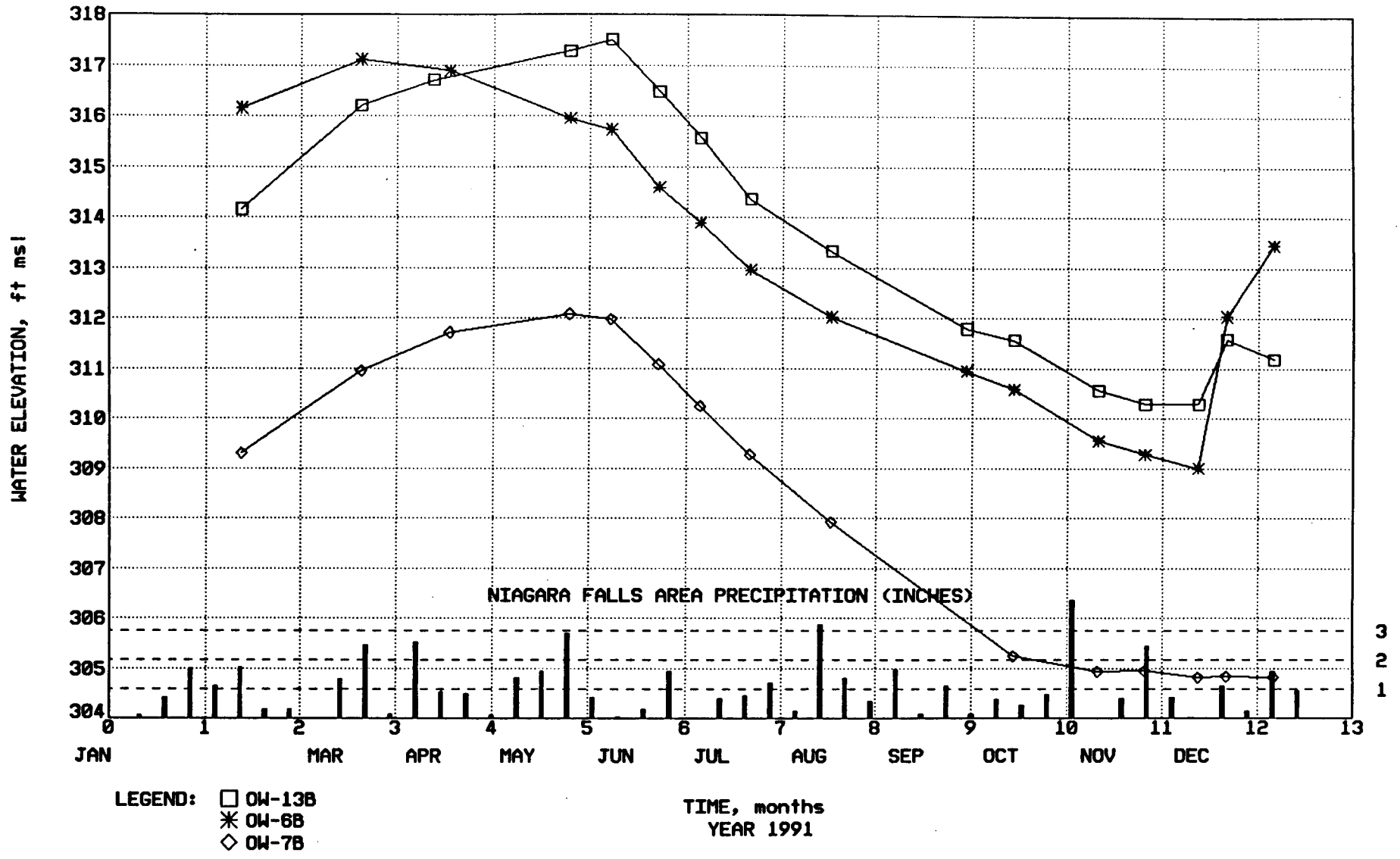
NFSS HYDROGRAPHS



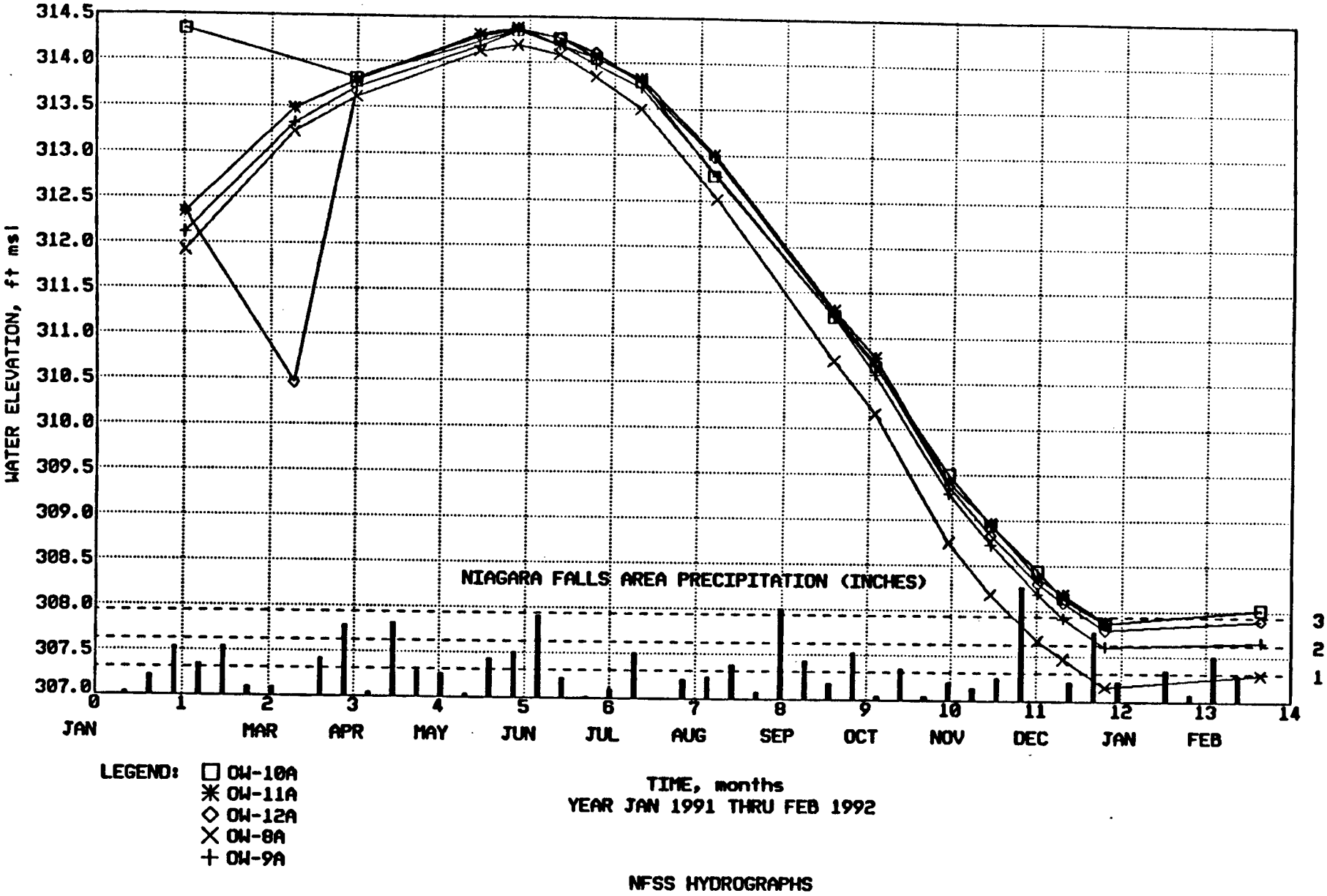
NFSS HYDROGRAPHS



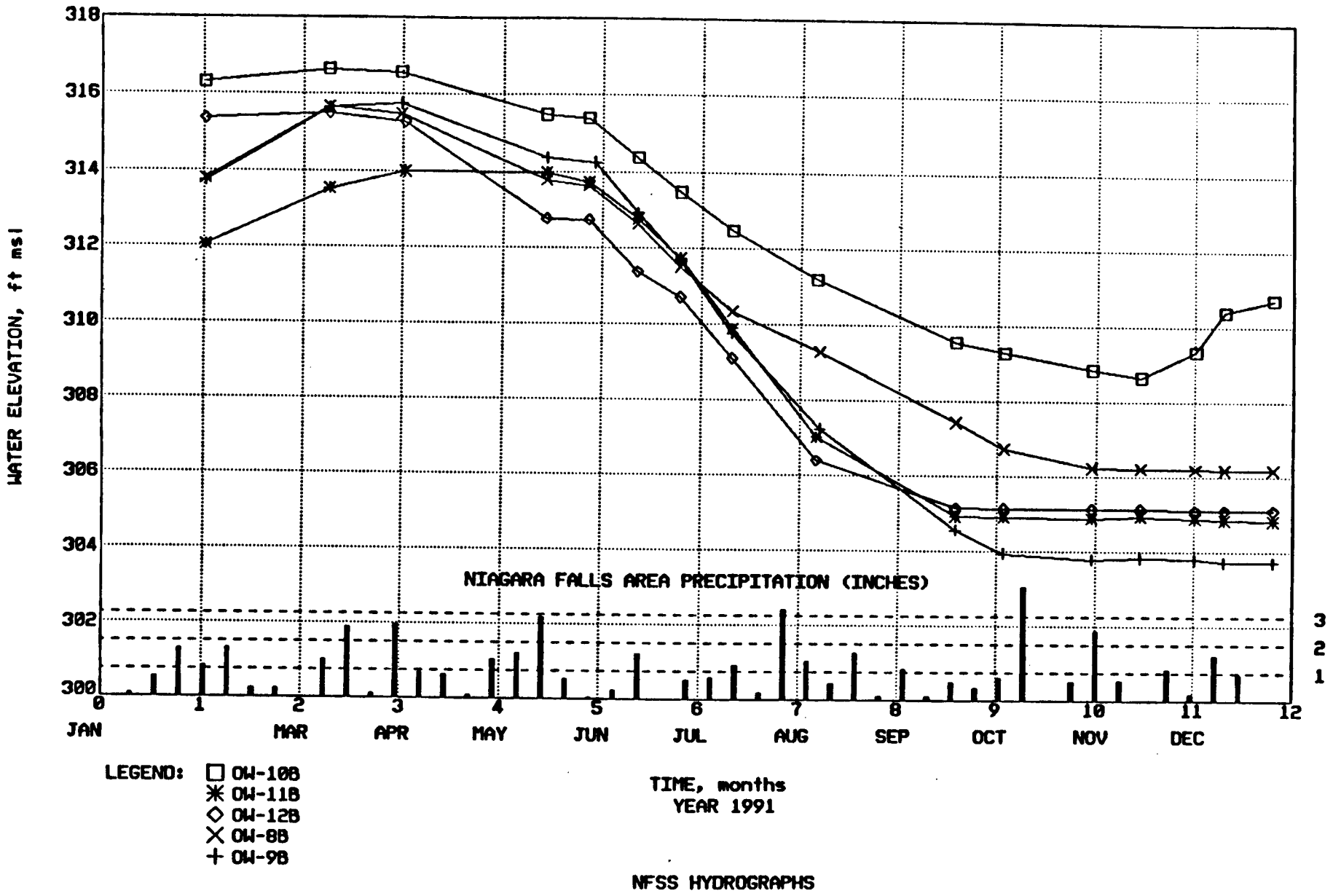
NFSS HYDROGRAPHS



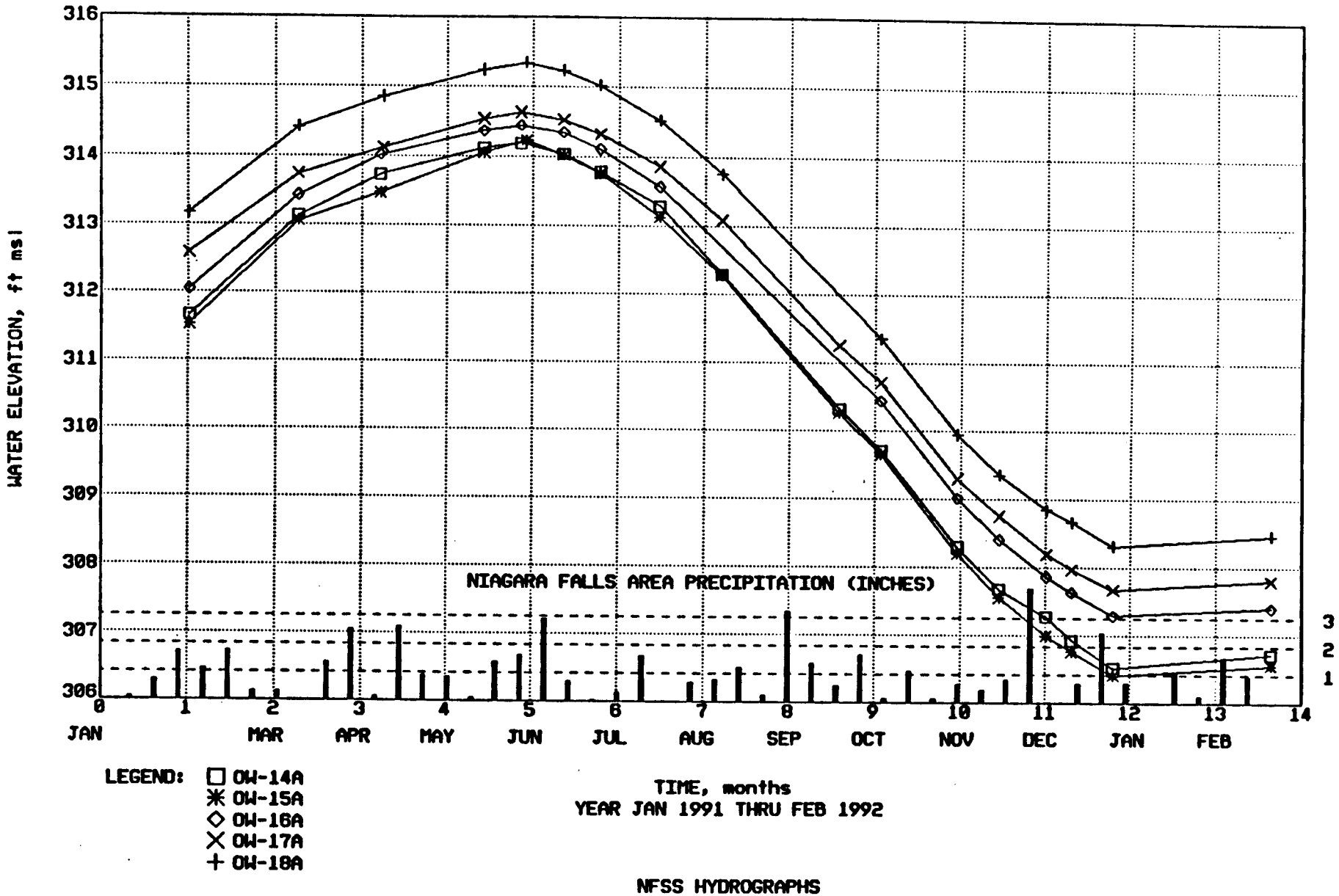
NFSS HYDROGRAPHS



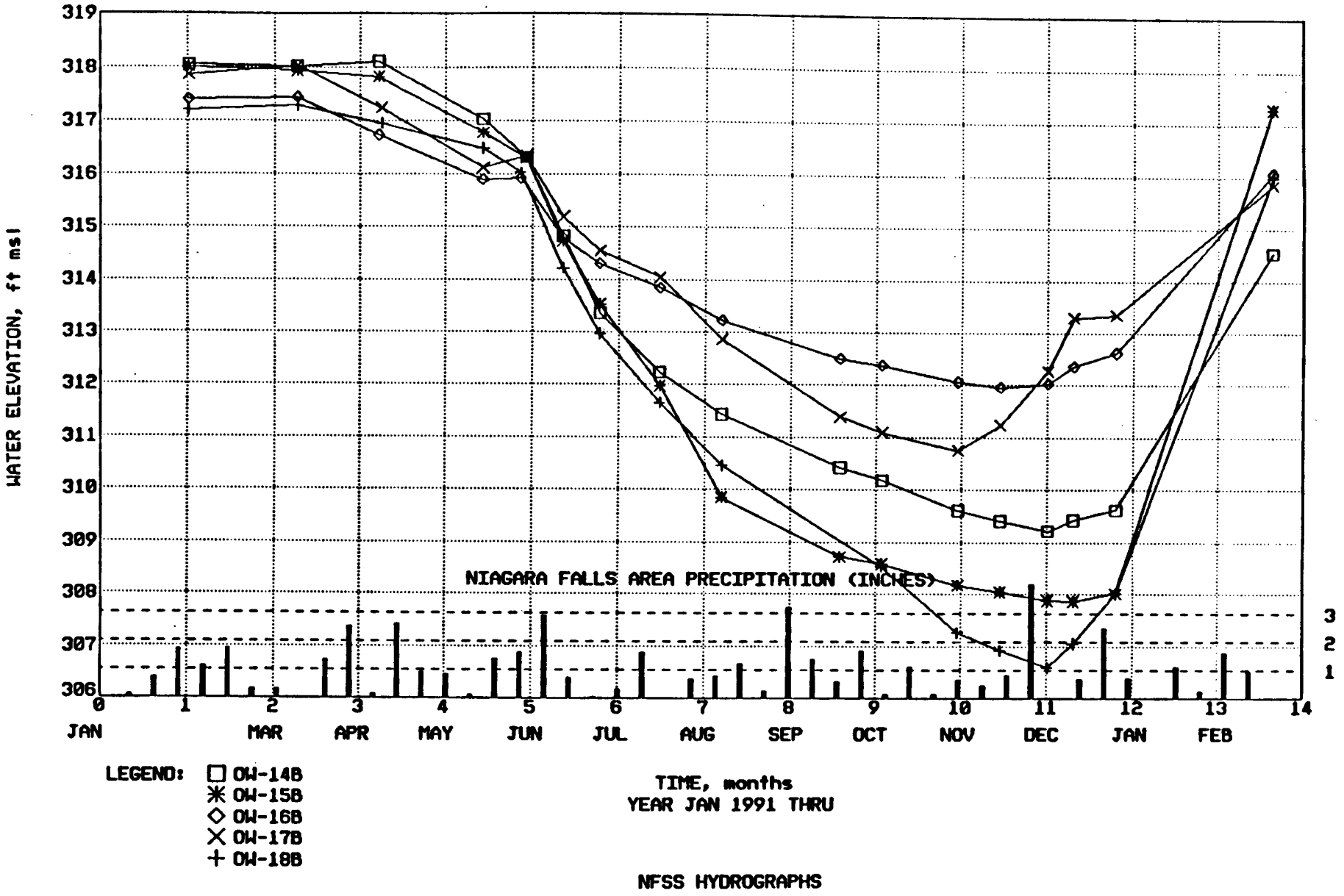
NFSS HYDROGRAPHS



NFSS HYDROGRAPHS



NFSS HYDROGRAPHS


WATER ELEVATION, ft msl
319
318
317
316
315
314
313
312
311
310
309
308
307
306
NIAGARA FALLS AREA PRECIPITATION (INCHES)
3
2
1
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
JAN
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
JAN
FEB
LEGEND:
OW-14B
OW-15B
OW-16B
OW-17B
OW-18B
TIME, months
YEAR JAN 1991 THRU
NFSS HYDROGRAPHS

APPENDIX H
CONVERSION FACTORS

Table H-1
Conversion Factors

1 yr	=	8,760 h
1 L	=	1,000 ml
1 μCi	=	1,000,000 pCi
1 pCi	=	0.000001 μCi
0.037 Bq/L	=	10^{-9} μCi/ml = 1 pCi/L
0.037 Bq/L	=	0.000000001 μCi/ml
1 μCi/ml	=	1,000,000,000 pCi/L
0.000001	=	1×10^{-6}
0.0000001	=	1×10^{-7}
0.00000001	=	1×10^{-8}
0.000000001	=	1×10^{-9}
0.0000000001	=	1×10^{-10}

APPENDIX I

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