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NIAGARA FALLS STORAGE SITE
ANNUAL SITE ENVIRONMENTAL REPORT
CALENDAR YEAR 1987

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By

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DISCLAIMER

ABSTRACT

During 1987, the environmental monitoring program was continued at the Niagara Falls Storage Site (NFSS), a United States Department of Energy (DOE) surplus facility located in Niagara County, New York, presently used for the interim storage of radioactive residues and contaminated soils and rubble. The monitoring program is being conducted by Bechtel National, Inc.

The monitoring program at the NFSS measures radon gas concentrations in air; external gamma radiation levels; and uranium and radium concentrations in surface water, groundwater, and sediment. To verify that the site is in compliance with the DOE radiation protection standard and to assess its potential effect on public health, the radiation dose was calculated for the maximally exposed individual. Based on the conservative scenario described in the report, this individual would receive an annual external exposure approximately equivalent to 6 percent of the DOE radiation protection standard of 100 mrem/yr. By comparison, the incremental dose received from living in a brick house versus a wooden house is 10 mrem/yr above background. The cumulative dose to the population within an 80-km (50-mi) radius of the NFSS that would result from radioactive materials present at the site would be indistinguishable from the dose that the same population would receive from naturally occurring radioactive sources.

Results of the 1987 monitoring show that the NFSS is in compliance with the DOE radiation protection standard.

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1.0 INTRODUCTION

This report presents the findings of the environmental monitoring conducted at the Niagara Falls Storage Site (NFSS) during calendar year 1987. Environmental monitoring has been conducted at the NFSS since 1981. The NFSS is part of the United States Department of Energy (DOE) Surplus Facilities Management Program.

1.1 LOCATION AND DESCRIPTION

The NFSS occupies approximately 77.4 ha (191 acres) located in northwestern New York within the Township of Lewiston (Niagara County). The site is approximately 6.4 km (4 mi) south of Lake Ontario, 16 km (10 mi) north of the City of Niagara Falls, and is in a generally rural setting. The NFSS and its regional setting are shown in Figure 1-1; Figure 1-2 is an aerial photograph of the site.

The NFSS has been developed as an interim waste storage area for radioactive residues from pitchblende processing and radium-contaminated sand, soil, and building rubble. Work on the interim waste containment facility (IWCF) was completed in late 1986. The two remaining water treatment ponds were removed during 1987.

The dominant feature of NFSS as presented in Figure 1-3 is the 4-ha (10-acre) IWCF. The IWCF is enclosed within a dike and cutoff wall, each constructed of compacted clay. The cutoff wall extends a minimum of 45 cm (18 in.) into an underlying gray clay unit. The dike and cutoff wall, in conjunction with the engineered earthen drainage cover or cap, enclose the wastes in a clay envelope that provides a barrier to migration of radionuclides into both groundwater and surface water. More detailed information on the design of the IWCF is provided in Reference 1.

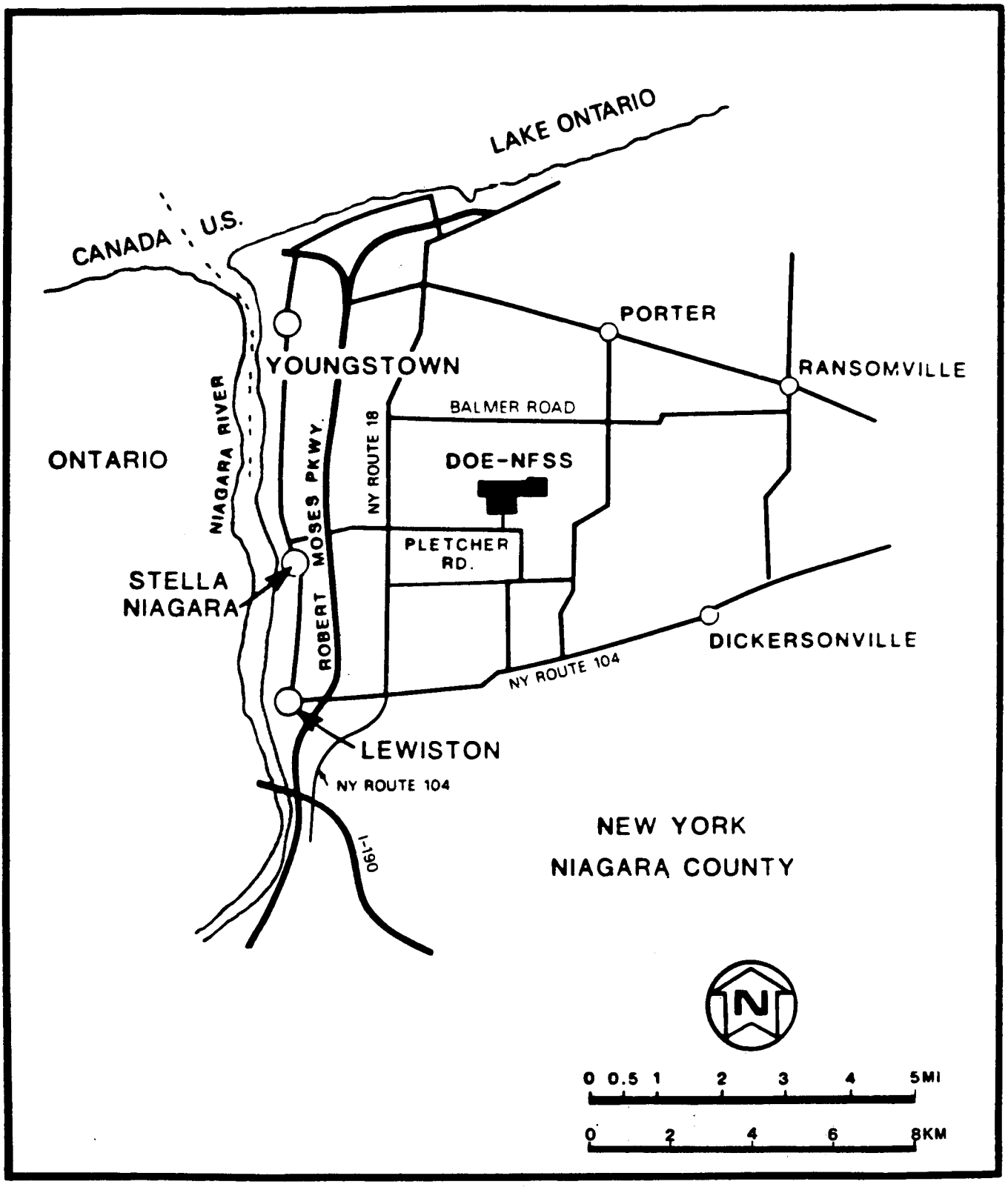


FIGURE 1-1 LOCATION OF THE NFSS

FIGURE 1-2 AERIAL VIEW OF THE NFSS

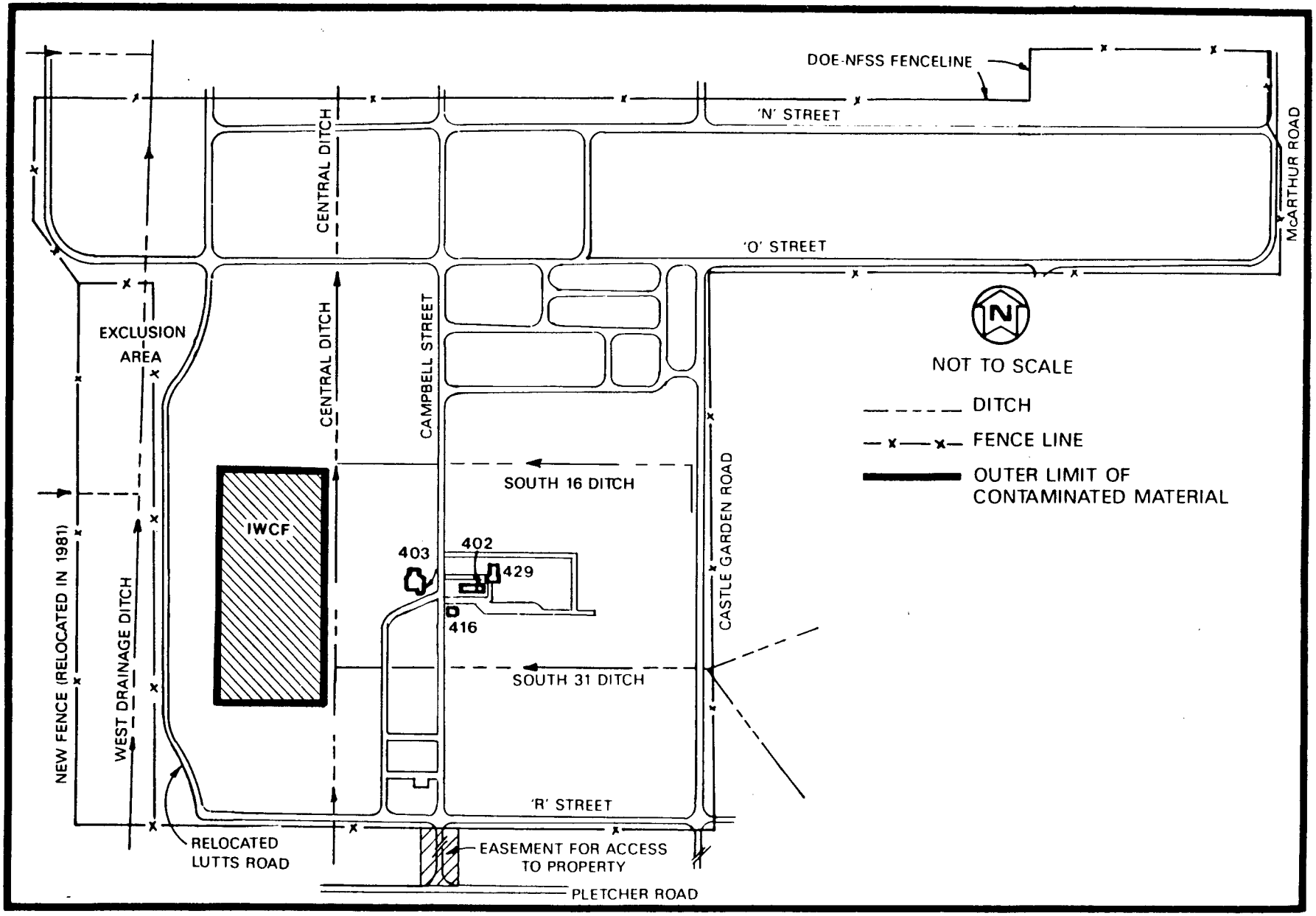


FIGURE 1-3 PRESENT CONFIGURATION OF THE NFSS

During construction, pollution control measures included the use of prudent engineering controls, e.g., use of sedimentation barriers in excavation areas and batch discharges of treated, impounded surface water in accordance with New York State Department of Environmental Conservation (NYSDEC) requirements.

The site is generally level, but slopes gently to the northwest at elevations between 96.9 and 97.8 m (318 and 321 ft) above m.s.l. The site drains poorly because of soil characteristics and the flatness of the terrain. Soils at the NFSS are predominantly silt loams underlain by a clayey glacial till and a lacustrine clay. Sand-gravel inclusions are frequent. Bedrock lies 9.1 to 15.2 m (30 to 50 ft) beneath the surface and consists of Queenston shale.

All surface water from the site discharges via the Central Drainage Ditch and its tributary ditches into Fourmile Creek, located northwest of the site. Groundwater is present in an aquifer at the bedrock surface (the primary aquifer beneath the site), in sand-gravel lenses, and in saturated clay zones at depths of 1.5 to 6.1 m (5 to 20 ft). Groundwater level contours indicate a slope of the primary aquifer to the north-northwest of approximately 3 m/km (10 ft/mi). The groundwater most likely discharges into the northern reaches of the Niagara River close to Lake Ontario (Ref. 2).

Lake water and river water are the predominant sources of potable water in the area surrounding the NFSS; approximately 90 percent of the population in Niagara and Erie Counties uses these sources. Water from Lake Erie serves 65 percent of the population, and water from the upper Niagara River serves 25 percent of the population (Ref. 3). Communities north of the Niagara Escarpment, including Lewiston and Porter Townships, receive much of their water from these sources.

Groundwater is used to supply approximately 10 percent of the population in Niagara and Erie Counties. The primary uses are for

small domestic and farm supplies in rural sections. The dominant source of this water, the Lockport dolomite aquifer, is absent north of the Niagara Escarpment where the NFSS is located. Wells in the vicinity of the NFSS are generally of low yield and supply water of poor quality. The upper aquifers in the glacial deposits near the NFSS are sometimes capable of supplying adequate groundwater for domestic use, although these sources may be depleted during dry seasons (Ref. 3).

The climate of the NFSS is classified as humid continental, with a considerable moderating influence from Lake Ontario. The normal temperature range is -3.9 to 24.4°C (25 to 76°F), with a mean annual temperature of 8.9°C (48°F). Mean annual precipitation is 80 cm (32 in.). Snowfall averages 140 cm/yr (56 in./yr), accounting for about 10 percent of the annual total precipitation (Ref. 4).

Wind speeds and directions recorded in the vicinity of the NFSS are given in Figure 1-4. The data show that the wind originates predominantly from the southwest. The average monthly wind speed ranges from 15.9 to 23 km/h (9.9 to 14.3 mph) (Ref. 4).

The primary areas of population near the NFSS are the towns of Lewiston (population: 16,200), Niagara (population: 9,650), Porter (population: 7,250), and Niagara Falls City (population: 71,400) (Ref. 3). Almost three-fourths of the 227,000 people residing in Niagara County live in urban areas. Population density in Niagara County in 1980 was about 168 persons/km^2 (430 persons/mi^2) (Ref. 3). Land uses immediately adjacent to the site are varied and are presented in Figure 1-5. The site is bordered by a hazardous waste disposal site, a sanitary landfill, and land that is currently vacant.

Land in the vicinity is also used for truck farms, orchards, and rural single-family dwellings. Lewiston-Porter Central Schools are located 3.1 km (1.5 mi) west of the site on Blairville/Creek Road. The nearest permanent residence is 1.1 km (0.7 mi) southwest of the site.

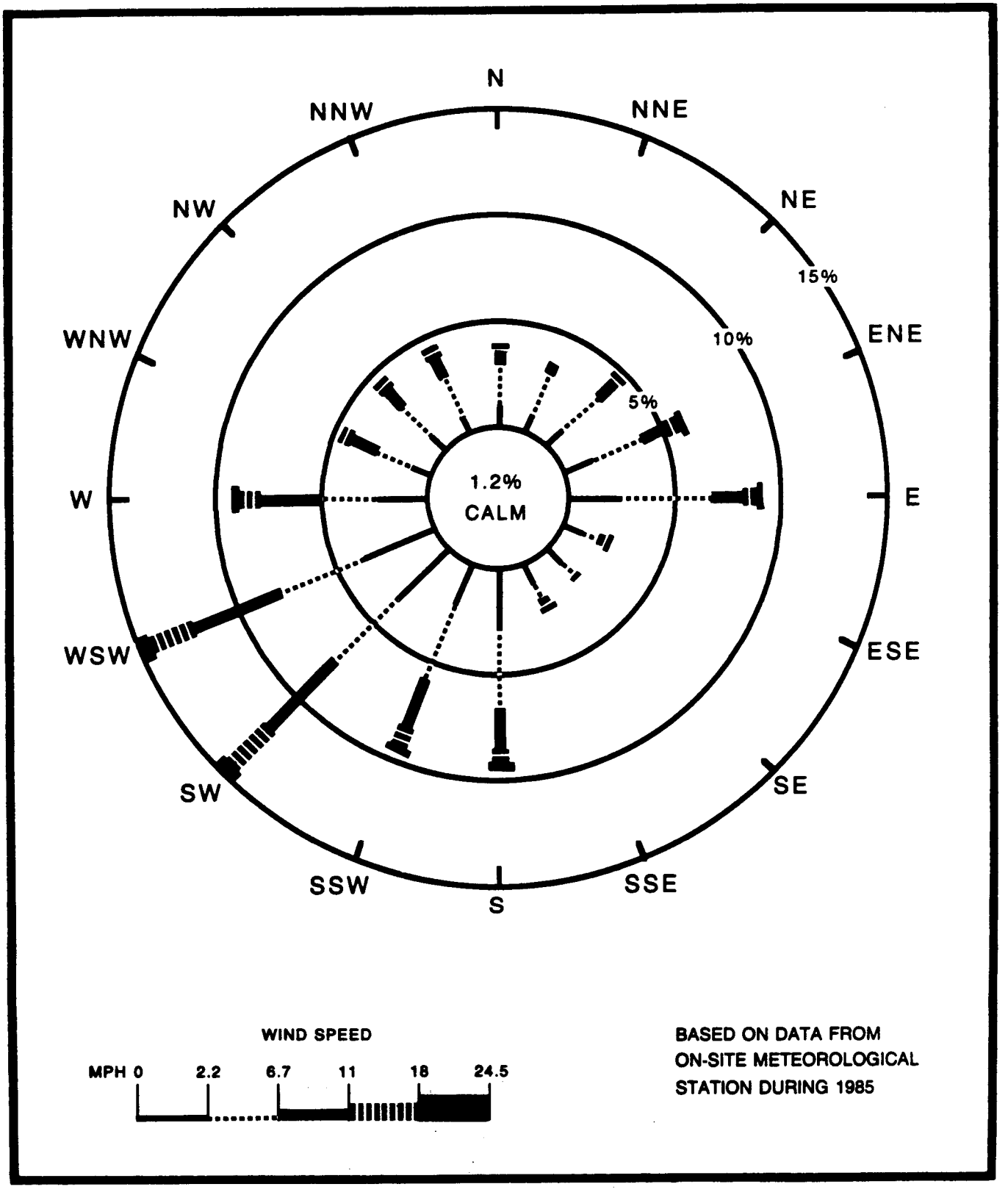
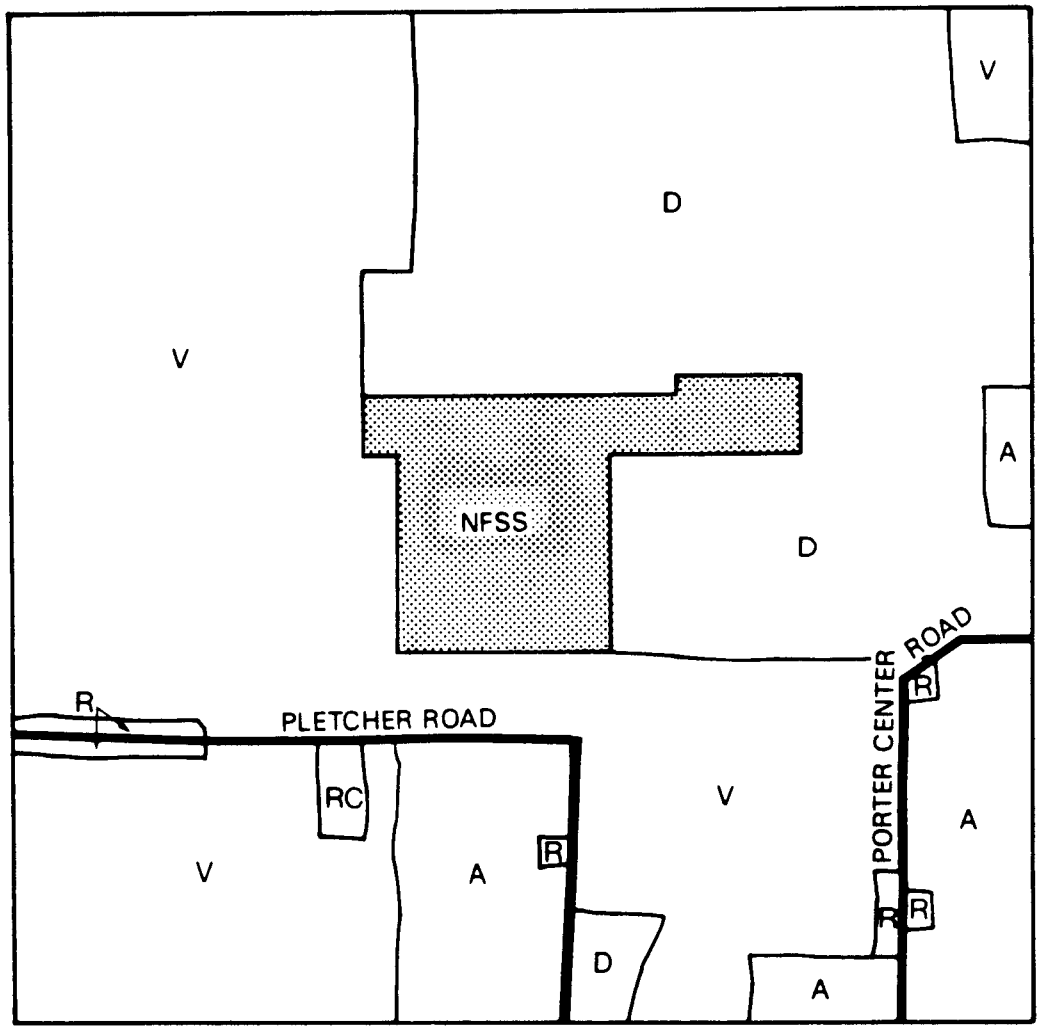


FIGURE 1-4 ANNUAL WIND ROSE FOR THE NFSS



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

R RESIDENTIAL
RC RECREATIONAL
A AGRICULTURAL
D WASTE DISPOSAL
V VACANT

N

0 0.5 MI
0 0.8 KM

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

1.2 SITE HISTORY

The NFSS is a remnant of the original 612-ha (1511-acre) site that was used during World War II by the Manhattan Engineer District (MED) project and was a portion of the Department of the Army's Lake Ontario Ordnance Works (LOOW). Except for nonradioactive boron-10 enriching operations during the periods 1954 to 1958 and 1964 to 1971, the site's major use from 1944 to the present has been for the storage of radioactive residues produced as by-products of uranium production during the MED project and subsequent Atomic Energy Commission (AEC) projects.

The first materials to arrive at the site were low-grade residues and by-products from the Linde Air Products Division in Tonawanda, New York, (the L-30, L-50, and R-10 residues) and from the Middlesex Sampling Plant in Middlesex, New Jersey, (the F-32 residues). The L-30 and L-50 residues were stored in Buildings 411, 413, and 414, while the F-32 residues were stored in the Recarbonation Pit directly west of Building 411. The R-10 residues and associated iron cake were stored in an open area north of Building 411. These residues were subject to environmental processes that transported contaminants into the soil and drainage pathways, resulting in the contamination of other portions of the site and of off-site drainage pathways. The small quantity of Middlesex sands resulting from decontamination activities at the Middlesex Sampling Plant was stored in Building 410. In 1949 pitchblende residues (the K-65 residues) resulting from uranium extraction conducted at a St. Louis plant were transported to the LOOW in drums. Some of these were stored outdoors along existing roads and rail lines; others were stored in Building 410. From 1950 to 1952, the K-65 residues were transferred to a renovated concrete water tower (Building 434).

The weight and volume of the residues and sands stored at the NFSS are summarized in Table 1-1. Buildings and other features of the NFSS before recent interim remedial actions are illustrated in Figure 1-6.

TABLE 1-1

RESIDUES AND MIDDLESEX SANDS STORED AT THE NFSS[a]

Residue	Weight (tons)	Volume [m^3 (yd^3)]
K-65	3891	3101 (4080)
L-30	8227	6050 (7960)
L-50	1878	1634 (2150)
F-32	138	334 (440)
R-10	8235	7144 (9400)
Middlesex Sands	2	174 (229)

[a]Battelle, 1981 (Ref. 5).

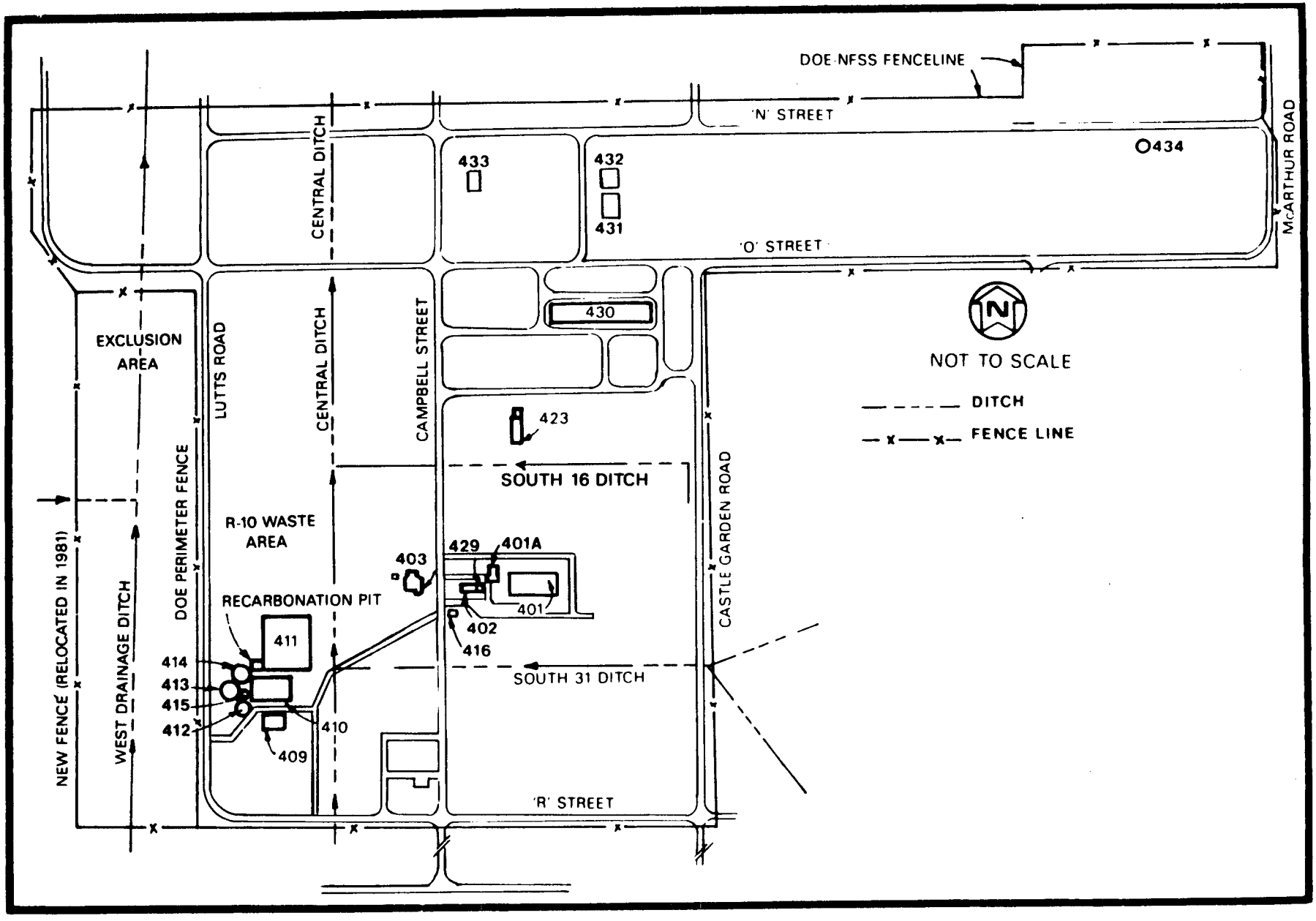


FIGURE 1-6 THE NFSS PRIOR TO INTERIM REMEDIAL ACTIONS

In 1979, Battelle Columbus Laboratories performed a radiological survey of the NFSS. The survey report published by Battelle in June 1981 served as the basis for initial interim remedial action planning for the site (Ref. 5). Bechtel National, Inc. (BNI) was chosen by DOE as the Project Management Contractor (PMC) for the NFSS project in 1981. As PMC, BNI helped plan and execute interim remedial action at the site. BNI also maintains site security, performs maintenance as required, and carries out the environmental monitoring program. Access to the site is controlled by a 2.1-m-(7-ft-) high fence that encloses the DOE property.

Since 1980, various steps have been taken at the NFSS to minimize potential radiological risks and prevent migration of residues. In the fall of 1980, the vent at the top of Building 434 (the former water tower in which the K-65 residues were stored) was capped to reduce radon emissions to the environment. Also during 1980, pipes penetrating the walls of the residue storage buildings were sealed or resealed as necessary to prevent radionuclide migration.

Because radon levels at the site's western boundary were exceeding DOE limits, the site fence was relocated approximately 152.4 m (500 ft) to the west in mid-1981, creating an exclusion area to protect the public from exposure to the higher radon levels. Radon levels at the new boundary were well below applicable guidelines. In 1981, remedial action was performed on a triangular-shaped area adjacent to the NFSS, bounded by Vine and O Streets and Castle Garden Road. Approximately 342 m^3 (450 yd^3) of contaminated material were excavated from this vicinity property and were relocated to the R-10 waste storage area.

To further reduce the levels of radon emanating from the site, Buildings 413 and 414 (used for storing the L-50 residues) were upgraded and sealed in 1982. Also in 1982, to prevent further migration of residues, contaminated soil near the R-10 pile was moved onto the pile, and a dike and cutoff wall were constructed around the R-10 area. The R-10 pile was then covered with an

ethylene propylene diene monomer (EPDM) liner, which markedly reduced radon emanation from the R-10 area. This action effectively reduced radon concentrations at the old site boundary (along Lutts Road) to levels that are below DOE guidelines.

In 1983 and 1984 the EPDM liner was removed, additional contaminated soils and rubble from on- and off-site areas were placed on the pile, and the pile was covered with the first layer of the interim clay cap. In 1984, 93 percent of the K-65 residues were transferred from Building 434 to Building 411.

Construction activities during 1985 included completion of the transfer of K-65 residues from Building 434 to the IWCF, demolition of Building 434, completion of remedial action on vicinity properties near the site, and continuation of installation of the cap over the wastes in the IWCF. These activities involved excavating approximately 10,640 m^3 (14,000 yd^3) of contaminated materials from on- and off-site areas, transferring 1102 m^3 (1450 yd^3) of building rubble to the IWCF, and discharging 12,047,691 liters (3,183,000 gal) of treated, impounded water in accordance with NYSDEC permit requirements.

During 1986, the cap over the IWCF was completed and geotechnical instrumentation installed in it to monitor the effectiveness of the facility. Also in 1986, another 25.8 million liters (6.8 million gal) of contaminated water was treated and released, and four of the six water treatment ponds were reduced to grade. In 1987 the impounded water in the remaining two ponds was treated and released [an additional 38.8 million liters (10.2 million gal)]. These two ponds were reduced to grade, and the NFSS was closed.

The DOE Record of Decision on the long-term disposition of the NFSS was issued in August 1986. For the radioactive wastes, DOE has selected long-term, in-place management consistent with the guidance provided in the U.S. Environmental Protection Agency (EPA) regulations governing uranium mill tailings. For the radioactive

residues, it is the DOE intent to provide for long-term, in-place management consistent with future applicable EPA guidance. If future analyses show that in-place management cannot meet EPA guidance, another option will be selected that meets EPA guidance and is environmentally acceptable.

2.0 SUMMARY OF MONITORING RESULTS

During 1987, the environmental monitoring program at the NFSS continued. Air, water, and sediments were sampled, and gamma radiation levels were monitored to verify compliance with the DOE radiation protection standard of 100 mrem/yr (Ref. 6). The potential radiation dose that might be received by the maximally exposed individual was calculated to determine whether the site was in compliance with the radiation protection standard.

In 1987, a change was initiated in the quarterly monitoring schedule for all FUSRAP sites. Whereas monitoring operations were previously conducted in December, March, June, and September, sampling is now conducted in January, April, July, and October. The new schedule facilitates timely compliance with quarterly permitting requirements and allows sufficient time for more complete analysis activities. In order to initiate this change in the monitoring schedule, data from the last quarter of 1986 were carried over to the first quarter of 1987. Any bias resulting from the use of 1986 data is considered negligible.

Annual average radon concentrations (including background) at all monitoring locations were within the normal variation associated with background measurements for this area (see Subsection 3.1). The average background concentration of radon was 3.0×10^{-10} uCi/ml (0.3 pCi/l). Radon concentrations decreased noticeably from 1982 to 1986 and have remained stable since 1986 (see Subsection 3.6.1) (Refs. 7-11).

Annual average gamma radiation levels recorded at the NFSS boundary ranged from background levels to 24 mR/yr above background (Table 3-2). These levels may be compared to naturally occurring background radiation levels in the vicinity of the NFSS, which averaged 64 mR/yr in 1987. External radiation levels are discussed in Subsection 3.2. Annual average radiation levels generally have decreased sharply since 1982 (see Subsection 3.6.2) (Refs. 7-11).

In surface waters (Subsection 3.3.1), annual average concentrations of uranium ranged from 5×10^{-9} uCi/ml to 1.4×10^{-8} uCi/ml (5 to 14 pCi/l); radium-226 concentrations ranged from 2×10^{-10} uCi/ml to $1.8\ 10^{-9}$ uCi/ml (0.2 pCi/l to 1.8×10^{-9} pCi/l) (see Tables 3-3 and 3-4). Although uranium and radium-226 concentrations increased sharply in April 1987 when sampling of the Central Drainage Ditch coincided with a planned discharge of water from the ditch, average concentrations of both radionuclides have decreased steadily since 1982 (see Subsection 3.6.3) (Refs. 7-11).

In groundwater (Subsection 3.3.2), the highest annual average concentration of uranium in an on-site well was 7.8×10^{-8} uCi/ml (78 pCi/l), measured at on-site location A-42 (Table 3-3). Well A-42 is located in a sand lense of unknown extent. For radium-226, the maximum annual average concentration was 5×10^{-10} uCi/ml (0.5 pCi/l), measured at on-site location B-48 (Table 3-4). Over the 5-year period from 1982-1987, concentrations of uranium and radium-226 have remained basically stable (see Subsection 3.6.4) (Refs. 7-11). Concentrations of radionuclides in surface water and groundwater at the NFSS can be compared with the levels of radioactivity in the commonly consumed liquids listed in Appendix D, Radiation in the Environment.

In stream sediments (Subsection 3.4), the highest annual average concentration was 2.0 pCi/g for uranium and 1.3 pCi/g for radium-226. These concentrations may be compared with the levels of environmental radioactivity in phosphate fertilizers listed in Appendix D.

Releases of radioactive materials to the environment during 1987 included releases of radon during construction activities and small concentrations of uranium and radium-226 in waters released under the New York State Pollutant Discharge Elimination System Permit. All releases were below applicable guideline values as determined by site and vicinity monitoring data for radon, and measured

concentrations of uranium and radium-226 in waters discharged from on-site retention ponds.

Calculations were made of radiological doses received by the maximally exposed individual (Subsection 3.5.1). This individual is one who is assumed to be adjacent to the site and who would, when all potential routes of exposure are considered, receive the greatest dose. Exposure to external gamma radiation was the exposure pathway quantified.

The exposure to the maximally exposed individual from external gamma radiation was 6 mR/yr above background. Since 1 mR is approximately equivalent to 1 mrem, this exposure is approximately equivalent to 6 percent of the DOE radiation protection standard. The cumulative dose to the population within an 80-km (50-mi) radius of the NFSS that would result from radioactive materials present at the site would be indistinguishable from the dose that the same population would receive from naturally occurring radioactive sources.

Results of the 1987 monitoring show that the NFSS is in compliance with the DOE radiation protection standard.

3.0 DATA COLLECTION, ANALYSIS, AND EVALUATION

This section provides the results of 1987 environmental monitoring at the NFSS (Ref. 12). A description is also given of the sampling, monitoring, and analytical procedures used. Calculations were made to determine the estimated maximum possible radiation dose based on environmental conditions, measurements recorded, and evaluation of potential exposure pathways.

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

During 1987, the routine environmental monitoring program for NFSS included radon gas monitoring, external gamma radiation measurements, surface water and sediment sampling, and groundwater sampling of monitoring wells off-site and within the site boundary (which is a fenced and posted area).

In 1987, a change was initiated in the schedule for quarterly monitoring of all FUSRAP sites, such that sampling is conducted at each site in January, April, July, and October. Previously, quarterly sampling was conducted in March, June, September, and December. This change was implemented to allow sufficient time for more complete analysis activities. In order to implement this change in the monitoring schedule, data from the last quarter of

1986 were carried over to the first quarter of 1987 for purposes of environmental monitoring. Any bias resulting from the use of 1986 data is considered negligible.

Trend tables are provided for radon, external gamma radiation levels, surface water, and groundwater. These tables list annual averages for each monitoring location for 1982 through 1987 to allow for comparisons of data and identification of trends in monitoring results (see Subsection 3.6).

3.1 RADON MONITORING

Thirty-five radon detectors are maintained on-site and at site boundary locations, with three of the detectors (31, 32, and 33) designated as quality controls. One detector (30) is maintained some distance off-site to measure the natural background level. Detectors are placed along the site boundary at intervals designed to ensure adequate detection capability under most atmospheric conditions. Detectors are more closely spaced along the perimeter of the IWCF, where the potential for release of contaminants is greater. In April of 1987, monitoring stations 13, 14, 15, and 29 were moved approximately 220 m (200 yd) eastward to make them more accessible and thereby facilitate routine exchange of detectors. The locations of the radon monitors are shown in Figure 3-1.

The radon monitors are Terradex Type-F Track-Etch detectors. Detectors are obtained from the Terradex Corporation, placed at the sampling locations, collected and exchanged monthly by site personnel, and then returned to Terradex for analysis.

Table 3-1 reports the radon concentrations (including background) measured in the air at site boundary monitoring locations and the background location. Annual average concentrations at the site boundary ranged from 1.0×10^{-10} to 8.0×10^{-10} uCi/ml (0.10 to 0.80 pCi/l). The annual average of background measurements was 3.0×10^{-10} uCi/ml (0.3 pCi/l). For a comparison of radon concentrations measured from 1982-1987, see Subsection 3.6.1.

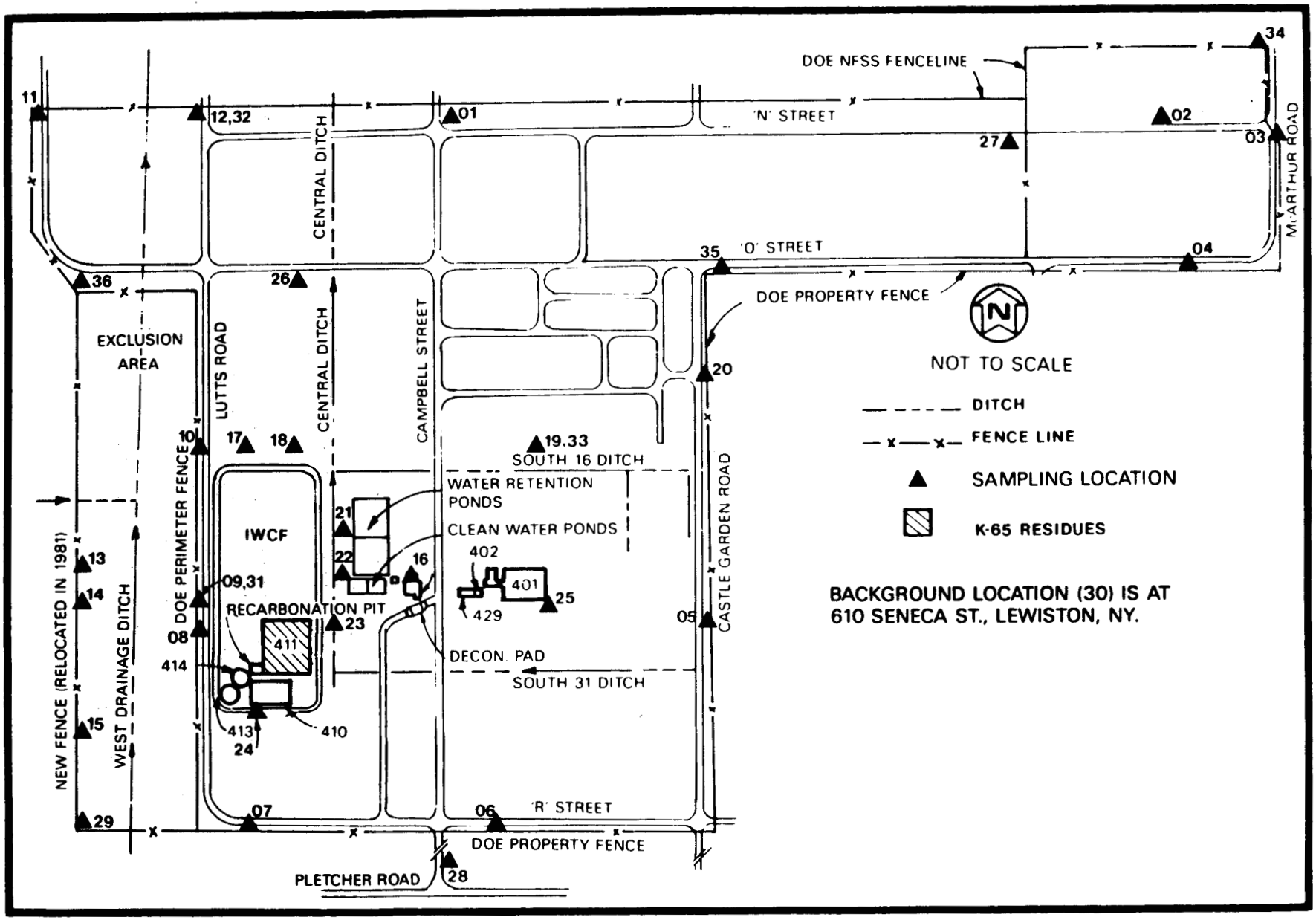


FIGURE 3-1 RADON AND EXTERNAL GAMMA RADIATION MONITORING LOCATIONS AT THE NFSS

TABLE 3-1

CONCENTRATIONS OF RADON-222

MEASURED BY TERRADEX MONITORS AT THE NFSS BOUNDARY, 1987

Sampling Location[a]	Number of Samples[b]	Concentration (10^{-9} uCi/ml)[c]		
		Minimum	Maximum	Average
1	4	0.0[d]	0.5	0.2
3	4	0.0[d]	1.0	0.3
4	4	0.1	0.6	0.4
5	4	0.1	0.3	0.2
6	4	0.1	0.4	0.2
7	4	0.1	0.5	0.3
11	4	0.0[d]	0.2	0.2
12	4	0.1	0.4	0.3
13	3[e]	0.0[d]	0.2	0.1
14	3[e]	0.1	0.8	0.4
15	3[e]	0.2	0.2	0.2
20	4	0.1	0.2	0.2
28	4	0.2	0.3	0.2
29	4	0.1	0.6	0.3
32[f]	4	0.2	0.3	0.3
34	4	0.1	1.8	0.8
35	4	0.1	0.3	0.2
36	4	0.1	0.3	0.2
30[g]	4	0.2	0.4	0.3

[a]Sampling locations are shown in Figure 3-1. Only site boundary locations are reported.

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

[c]Background has not been subtracted.

[d]Measurement was less than or equal to the limit of sensitivity of the detector and was reported as a zero value by the laboratory.

[e]Detector was inaccessible for the first quarter because of the high water level in this area.

[f]Location 32 is a quality control for Location 12.

[g]Background sampling location, located at 610 Seneca St., Lewiston, NY.

Because of the nature of the radon source (i.e., large surface areas emanating radon at rates that vary widely with changes in climatic/atmospheric conditions), accurate determination of the annual radon release rate is not feasible. Based on measured radon concentrations at the site boundary and in the environs, the on-site radon source makes a minimal contribution to natural radon concentrations in the area.

3.2 EXTERNAL GAMMA RADIATION LEVELS

External gamma radiation levels were measured at 33 monitoring locations; 17 of these are on the site boundary and 3 are on the perimeter of the former location of the tower that was used to store K-65 residues. One of the monitoring locations is off-site to measure the background radiation level. In April of 1987, monitoring stations 13, 14, 15, and 29 were moved approximately 220 m (200 yd) eastward to make them more accessible for the purpose of quarterly exchange of detectors. All locations correspond to the radon (Terradex) detector locations shown in Figure 3-1. The locations of the detectors are selected so as to ensure adequate measurement of radiation levels.

The external gamma radiation levels are measured using lithium fluoride (LiF) thermoluminescent dosimeters (TLDs), exchanged quarterly. In addition, an improved external gamma radiation monitoring system was introduced at the NFSS in April 1987 in conjunction with the current type of system. This system utilizes tissue-equivalent TLDs, which permit direct evaluation of the accumulated dose of gamma radiation to the deep tissue of the body (at a depth of 1 cm). In addition to providing values that are more realistic in terms of potential tissue dose than does the previously used system, the tissue-equivalent TLD system is more sensitive in detecting external gamma radiation. In both types of systems, each monitor contains five TLD chips, the responses of which are

averaged. Analysis is performed by Thermo Analytical/Eberline (TMA/E). Effective April 15, 1988, the tissue-equivalent TLD system will be used exclusively. Environmental reports for 1988 and subsequent years will present data generated by the new system.

Monitoring results for the 17 site boundary locations, the background location, and the quality control location are presented in Table 3-2. The annual average background radiation level for the NFSS area (64 mR) has been subtracted from the measured levels in Table 3-2 to provide an estimate of the effect of the site on measured external gamma radiation levels at the site boundary. The highest levels were measured at two locations adjacent to a sanitary landfill to which access is controlled by the owner. At these locations, the maximum annual average level was 24 mR/yr above the average background level of 64 mR/yr. Based on a very conservative 40-h/week occupancy factor, the maximum exposure to workers in this area of the landfill would be 6 mR/yr.

For comparisons of external gamma radiation levels measured from 1982 through 1987, see Subsection 3.6.2.

3.3 WATER SAMPLING

During 1987, sampling was performed to determine the concentrations of uranium and radium in surface water and groundwater at on-site and off-site locations. On-site sampling locations are shown in Figure 3-2, and off-site locations are shown in Figure 3-3. Results of uranium analyses for all sampling locations are presented in Table 3-3, and radium-226 results are presented in Table 3-4.

3.3.1 Surface Water

Surface water samples were collected quarterly from the Central Drainage Ditch at Locations 10, 11, 12, and 20. Locations 12 and 20

TABLE 3-2

EXTERNAL GAMMA RADIATION LEVELS FOR THE NFSS, 1987

Sampling Location[a]	Number of Measurements	Radiation Level (mR/yr)[b] Minimum	Maximum	Average
Site Boundary				
1	4	3	22	11
3	3[c]	1	17	11
4	4	3	24	13
5	4	7	21	16
6	4	0[d]	6	3
7	4	3	18	11
11	4	0[d]	8	2
12	4	0[d]	11	6
13	4	0[d]	5	0[d]
14	4	0[d]	20	7
15	4	0[d]	14	6
20	4	9	34	24
28	4	8	23	14
29	4	0[d]	0[d]	0[d]
32[e]	4	0[d]	8	5
34	4	0[d]	19	8
35	4	7	22	14
36	4	0[d]	11	16
Background[f]	4	51	81	64

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

[b]Measured background has been subtracted from measurements taken at site boundary locations. Measurements are obtained in mR/quarter, normalized to 1 year, and expressed in the table as mR/yr.

[c]Detector missing in second quarter.

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

[e]Location 32 is a quality control station for Location 12.

[f]Located at 610 Seneca St., Lewiston, NY.

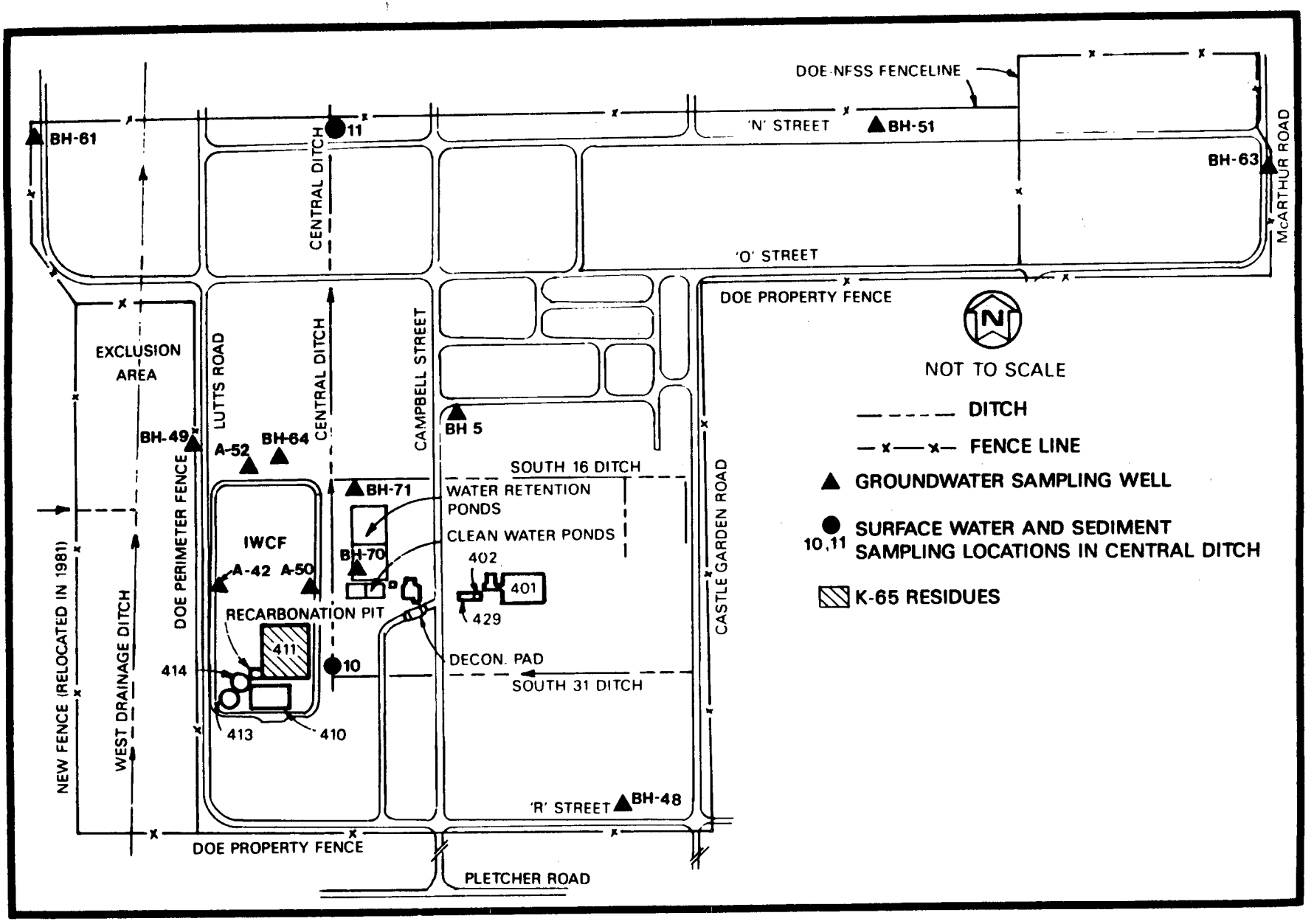


FIGURE 3-2 SURFACE WATER, GROUNDWATER, AND SEDIMENT SAMPLING LOCATIONS AT THE NFSS

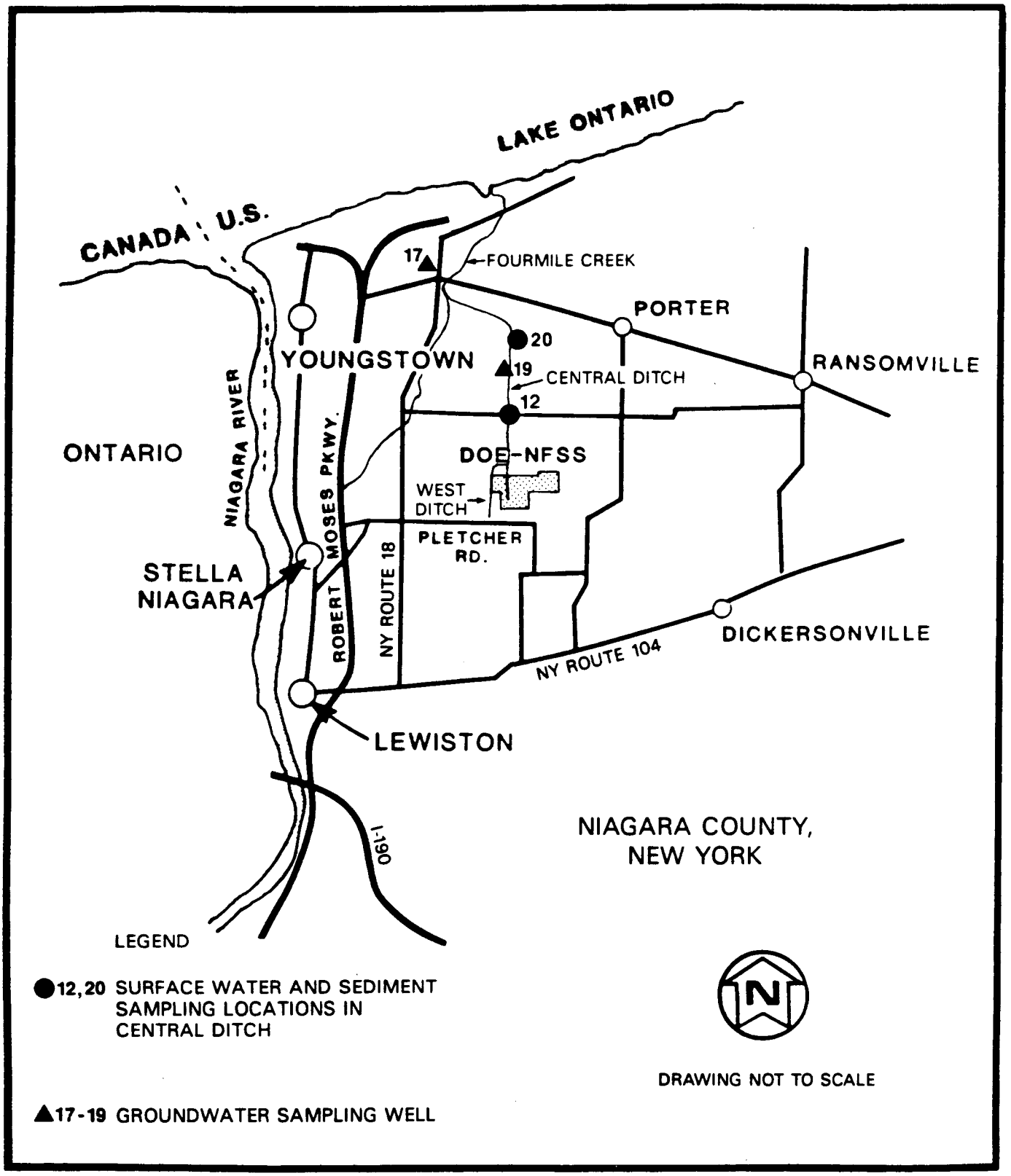


FIGURE 3-3 SURFACE WATER, GROUNDWATER, AND SEDIMENT SAMPLING LOCATIONS IN THE VICINITY OF THE NFSS

TABLE 3-3

CONCENTRATIONS OF URANIUM IN NFSS WATER SAMPLES, 1987

Sampling Location[a]	Number of Samples	Concentration (10^{-9} uCi/ml)[b, c] Minimum	Maximum	Average
Surface Water				
On-Site				
10	4	<3	10[d]	6
11	4	6	36[d]	14
Off-Site				
12	4	<3	5	5
20	3[e]	<3	12[d]	6
Groundwater				
On-Site				
BH-5	4	<3	<3	<3
BH-48	4	<3	5	4
BH-61	4	<3	<3	<3
A-42	4	73	93	78
A-50	4	4	5	4
BH-49	4	<3	<3	<3
BH-51	4	<3	9	6
BH-63	4	<3	4	3
A-52	4	19	17	18
BH-64	4	3	14	10
BH-70	4	<3	17	7
BH-71	4	<3	4	3
Off-Site				
17	1[f]	<3	<3	<3
19	1[f]	<3	<3	<3

[a]Sampling locations are shown in Figures 3-2 and 3-3.

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

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

[d]Concentrations were atypically high in April, when sampling of the Central Drainage Ditch coincided with a planned discharge of water from the ditch.

[e]Location was dry in the first quarter.

[f]Sampling of domestic water supply wells was terminated after first quarter results were obtained, since concentrations of uranium and radium in these wells have not exceeded 3.0×10^{-9} uCi/ml (3.0 pCi/l) and 3.0×10^{-10} uCi/ml (0.3 pCi/l), respectively, since 1983.

TABLE 3-4

CONCENTRATIONS OF RADIUM-226 IN NFSS WATER SAMPLES, 1987

Sampling Location[a]	Number of Samples	Concentration (10^{-9} uCi/ml)[b,c] Minimum	Maximum	Average
Surface Water				
On-Site				
10	4	0.1	0.3	0.2
11	4	0.2	6.2[d]	1.8
Off-Site				
12	4	<0.1	0.5	0.3
20	3[e]	0.2	0.5	0.3
Groundwater				
On-Site				
BH-5	4	0.3	0.5	0.4
BH-48	4	0.4	0.6	0.5
BH-61	4	0.3	0.4	0.3
A-42	4	0.1	0.3	0.2
A-50	4	0.1	0.4	0.3
BH-49	4	0.1	0.3	0.2
BH-51	4	0.2	0.4	0.3
BH-63	4	0.1	0.4	0.3
A-52	4	0.1	0.2	0.2
BH-64	4	0.1	0.4	0.2
BH-70	4	0.1	0.4	0.3
BH-71	4	0.1	0.5	0.3
Off-Site				
17	1[f]	0.2	0.4	0.3
19	1[f]	0.3	0.3	0.3

[a]Sampling locations are shown in Figures 3-2 and 3-3.
[b]1 x 10^{-9} uCi/ml is equivalent to 1 pCi/l.
[c]Where no more than one value is less than the limit of sensitivity of the analytical method, values are considered equal to the limit of sensitivity, and the average value is reported without the notation "less than."
[d]Concentrations were atypically high in April, when sampling of the Central Drainage Ditch coincided with a planned discharge of water from the ditch.
[e]Location was dry in the first quarter.
[f]Sampling of domestic water supply wells was terminated after first quarter results were obtained, since concentrations of uranium and radium in these wells have not exceeded 3.0 x 10^{-9} uCi/ml (3.0 pCi/l) and 3.0 x 10^{-10} uCi/ml (0.3 pCi/l), respectively, since 1983.

are 1.6 and 3.2 km (1 mi and 2 mi) downstream, respectively, from the northern boundary of the NFSS.

Surface water collection locations were selected on the basis of contaminant migration potential and discharge routes from the site. Because surface water runoff from the site discharges via the Central Drainage Ditch, all sampling locations have been placed along the ditch.

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

Results of the analysis of surface water for uranium content are given in Table 3-3; radium-226 results are given in Table 3-4. Annual average uranium concentrations in on-site surface water ranged from 6×10^{-9} to 1.4×10^{-8} uCi/ml (6 to 14 pCi/l); in off-site surface water, concentrations ranged from 5 to 6×10^{-9} uCi/ml (5 to 6 pCi/l). The highest annual average concentration of radium-226 in surface water was 1.8×10^{-9} uCi/ml (1.8 pCi/l). Concentrations of uranium and radium-226 were atypcially high in April of 1987, when sampling of the Central Drainage Ditch coincided with a planned discharge of water from the ditch. Radionuclide concentrations in surface water at the NFSS may be compared with the levels of radioactivity in the commonly consumed liquids listed in Appendix D.

The sampling of water supplied by a local municipal water system was suspended in 1986. This system draws water from the upper Niagara River approximately 16 km (10 mi) south of the NFSS. Sampling was suspended because the draw point of the system was upstream of the NFSS and because data from previous years indicated no significant uranium or radium-226 concentrations above background levels in these waters.

For comparisons of radionuclide concentrations in surface water measured at the site from 1982 through 1987, see Subsection 3.6.3.

3.3.2 Groundwater

During 1987, groundwater samples were collected quarterly from 48 on-site wells and periodically from two off-site wells. Sampling locations were selected based on the inventory of radioactive materials in various areas of the site and available geohydrological data. The majority of sample wells are located near the IWCF. Other wells are located both upgradient and downgradient to provide background data and to monitor any migration of contaminants off-site. In late 1986, 36 wells were installed along the perimeter of the IWCF to monitor its performance. These wells were added to the environmental monitoring program in April 1987. Their locations are shown in Figure 3-4.

In addition, to provide information as to the chemical substances present in the groundwater, programs were initiated to monitor baseline chemical constituents and to determine the identities and concentrations of various indicator parameters and heavy metals. A more detailed discussion of the chemical monitoring program is contained in Subsection 4.2.

Wells BH-5, BH-48, BH-51, BH-64, and BH-70 monitor the lower aquifer. Well BH-71 monitors the bedrock aquifer. Wells A-42, A-50, and A-52 monitor the upper aquifer around the IWCF (but are not among the 36 new wells). Well A-42 is drilled into a sand lense of unknown extent. Well BH-48 is an upgradient (background)

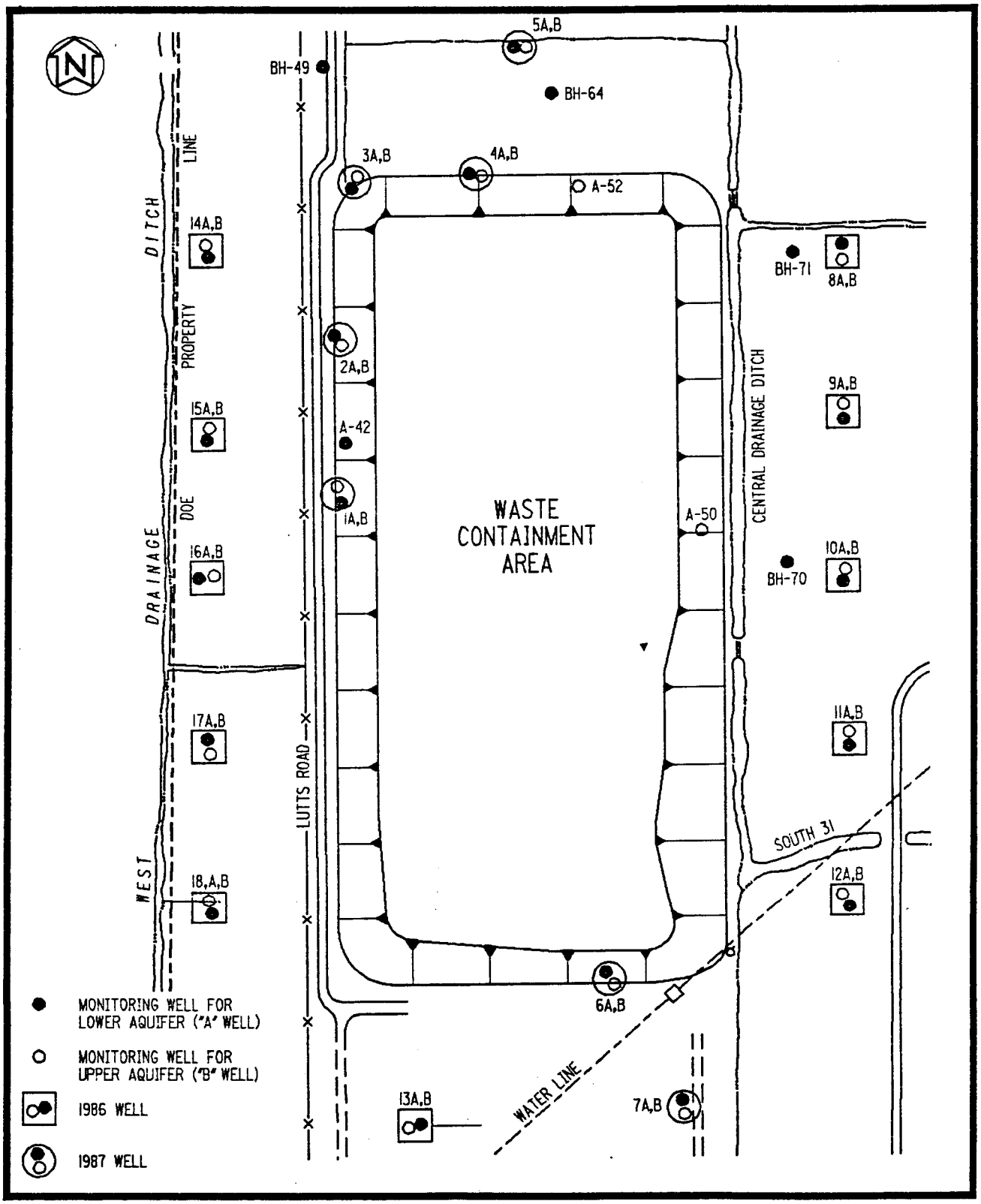


FIGURE 3-4 LOCATIONS OF GROUNDWATER MONITORING WELLS SURROUNDING WASTE CONTAINMENT AREA

monitoring location, and Well BH-61 is a downgradient monitoring location.

Groundwater samples were collected after the wells had been bailed dry or three casing volumes had been removed. Nominal 1-liter (0.26-gal) grab samples were collected using a bailer to fill a 4-liter (1-gal) container. Samples were analyzed by TMA/E for total uranium and dissolved radium-226 using the methods applied to surface water analyses.

Analysis results for uranium concentrations in groundwater are listed in Table 3-3; radium results are given in Table 3-4. Table 3-5 shows analysis results for uranium in the monitoring wells along the perimeter of the waste containment area; Table 3-6 shows the corresponding results for radium-226. Annual average concentrations of uranium in groundwater from on-site wells ranged from less than 3×10^{-9} to 7.8×10^{-8} uCi/ml (less than 3 to 78 pCi/l). The uranium concentration measured at the off-site wells was below the limit of detection. Annual average concentrations of radium-226 in groundwater from on-site and off-site wells ranged from 2×10^{-10} to 5×10^{-10} uCi/ml (0.2 to 0.5 pCi/l). Annual averages for total uranium in water in the wells monitoring the waste containment area ranged from less than 3.0×10^{-9} to 3.6×10^{-8} uCi/ml (3 to 36 pCi/l). Radium-226 annual average values ranged from 1.0×10^{-10} to 5.0×10^{-10} uCi/ml (0.1 to 0.5 pCi/l).

These values may be compared with the levels of radioactivity in the commonly consumed liquids listed in Appendix D.

For a comparison of radionuclide concentrations measured in groundwater at the NFSS from 1982 through 1987, see Subsection 3.6.4.

3.4 SEDIMENT SAMPLING

During 1987, sediment samples consisting of composites weighing approximately 500 g (1.1 lb) were collected on-site and off-site at

TABLE 3-5

CONCENTRATIONS OF URANIUM IN NFSS CONTAINMENT MONITORING WELLS, 1987

Sampling Location	Number of Samples[a]	Concentration (10^{-9} uCi/ml) Minimum	Maximum	Average
1A	3	3	5	4
1B	3	3	5	4
2A	3	3	4	3
2B	3	3	7	5
3A	2[b]	3	3	3
3B	3	5	13	10
4A	3	3	3	3
4B	3	5	7	6
5A	3	3	3	3
5B	3	10	12	11
6A	3	3	3	3
6B	3	11	20	15
7A	3	3	3	3
7B	3	7	11	8
8A	3	3	3	3
8B	3	9	23	17
9A	3	10	19	14
9B	3	3	3	3
10A	3	3	10	5
10B	3	3	4	3
11A	3	25	53	36
11B	3	3	3	3
12A	3	13	16	15
12B	3	3	3	3
13A	3	11	16	14
13B	3	3	3	3
14A	3	4	6	5
14B	3	3	4	4
15A	3	3	9	6
15B	3	3	3	3
16A	3	3	4	3
16B	3	4	9	6
17A	3	3	4	3
17B	3	3	9	7
18A	3	4	22	14
18B	3	3	3	3

[a]Since these wells were incorporated into the monitoring program in April 1987, no data were obtained for the first quarter.

[b]Well dry in the second quarter.

TABLE 3-6

CONCENTRATIONS OF RADIUM-226 IN NFSS CONTAINMENT MONITORING WELLS, 1987

Sampling Location	Number of Samples[a]	Concentration (10^{-9} uCi/ml) Minimum	Maximum	Average
1A	3	0.1	0.9	0.4
1B	3	0.2	0.3	0.2
2A	3	0.1	0.4	0.2
2B	3	0.1	0.4	0.2
3A	2[b]	<0.1	0.1	0.1
3B	3	0.1	0.2	0.1
4A	3	0.1	0.4	0.2
4B	3	0.1	0.3	0.2
5A	3	0.1	0.4	0.2
5B	3	0.1	0.4	0.2
6A	3	0.1	0.4	0.2
6B	3	0.1	0.3	0.2
7A	3	0.1	0.3	0.2
7B	3	0.1	0.3	0.2
8A	3	0.1	0.3	0.2
8B	3	0.1	0.3	0.2
9A	3	0.2	0.3	0.2
9B	3	0.1	0.5	0.3
10A	3	0.1	0.4	0.3
10B	3	0.1	0.3	0.2
11A	3	0.1	0.2	0.1
11B	3	0.1	0.2	0.2
12A	3	0.1	0.2	0.2
12B	3	0.1	0.3	0.2
13A	3	0.1	0.2	0.2
13B	3	0.1	0.4	0.2
14A	3	0.1	0.8	0.5
14B	3	0.1	0.3	0.2
15A	3	0.2	0.2	0.2
15B	3	0.2	0.3	0.3
16A	3	0.2	0.3	0.2
16B	3	0.2	0.3	0.2
17A	3	0.1	0.2	0.2
17B	3	0.1	0.2	0.2
18A	3	0.3	0.4	0.4
18B	3	0.3	0.4	0.3

[a]Since these wells were incorporated into the monitoring program in April 1987, no data were obtained for the first quarter.

[b]Well dry in the second quarter.

surface water sampling Locations 11, 12, and 20 (see Figures 3-2 and 3-3). The rationale for selecting sampling locations is as stated in Section 3.3.1.

TMA/E analyzed the samples for uranium and radium-226. The uranium concentration was obtained by summing the results from isotopic uranium analyses. Isotopic uranium was determined by alpha spectrometry, where the uranium has been leached and organically extracted and electroplated on a metal substrate. Radium-226 concentrations were determined by radon emanation.

The analysis results (based on dry weight) for uranium and radium are presented in Table 3-7. The average on-site and off-site concentrations are approximately the same and probably reflect background concentrations. These concentrations may be compared with the levels of radioactivity in phosphate fertilizers listed in Appendix D.

3.5 RADIATION DOSE

To assess the health effects of the radioactive materials stored at the NFSS, radiological exposure pathways were evaluated to calculate the dose to the maximally exposed individual. This individual is one who is assumed to be adjacent to the site and who would, when all potential routes of exposure are considered, receive the largest dose. An appraisal of potential pathways (exposure to external gamma radiation, ingestion of water, and inhalation of radon) suggested that exposure to external gamma radiation was the principal exposure mode.

The dose from ingesting groundwater or surface water from sources on the NFSS property was not calculated because it was considered unrealistic to assume that ingestion of this water would occur. The NFSS is fenced and locked, and security is well maintained. For this reason, a member of the public could consume water on the site only by trespassing on the property every day to gain access to the

TABLE 3-7

URANIUM AND RADIUM-226 CONCENTRATIONS

IN NFSS SEDIMENT SAMPLES, 1987

Sampling Location[a]	Number of Samples	Concentration [pCi/g (dry)] Minimum	Maximum	Average
Uranium				
On-Site				
10	2[b]	1.6	1.9	-
11	4	1.5	2.4	2.0
Off-Site				
12	4	0.9	1.6	1.3
20	3[c]	1.2	1.9	1.5
Radium-226				
On-Site				
10	2[b]	0.8	0.9	0.8
11	4	0.6	2.9	1.3
Off-Site				
12	4	0.3	0.7	0.5
20	3[c]	0.6	1.1	0.8

[a]Sampling locations are shown in Figures 3-2 and 3-3.

[b]No sample was collected in the first quarter. The Central Drainage Ditch was dry during the third quarter.

[c]There was no sediment at this location during the third quarter.

water. To consume groundwater from a well at the NFSS, the member of the public would also have to be equipped with a means of removing the well cap and would need a power source, a pump, and a hose.

Radon concentrations measured at the boundary of the NFSS were within the normal variation associated with background measurements for this area. Consequently, this pathway would not contribute additional dose to the maximally exposed individual.

3.5.1 Dose to Maximally Exposed Individual

To identify the individual in the vicinity of the NFSS who would receive the highest dose from on-site low-level radioactive materials, the exposure from external gamma radiation was calculated at various monitoring locations that could be accessible by the public. These exposures were then reviewed with regard to land use and occupancy factors for areas adjacent to the monitoring points. From these calculations, it was determined that the highest exposure would be received by an individual directly east of the site.

The highest measured radiation level above background, 24 mR/yr, was recorded at TLD Location 20. As shown in Figure 1-5, the area adjacent to TLD Location 20 is used as a sanitary landfill. Exposure to people in this area is therefore conservatively based on a 40-h work week, although it is highly unlikely that a worker would spend an entire 40-h work week near this sampling location. Applying a 40-h/week occupancy factor, the exposure to landfill workers would be a maximum of 6 mR/yr above background. Since 1 mR is approximately equivalent to 1 mrem, this exposure is approximately equivalent to 6 percent of the DOE radiation protection standard. By comparison, the incremental dose received from living in a brick house is 10 mrem/yr greater than the dose received by a person living in a wooden house (see Appendix D).

3.5.2 Dose to the Population in the Vicinity of the NFSS

The dose to the population represents the conceptual cumulative radiation dose to all residents within a 80-km (50-mi) radius of a given site. This calculated dose includes contributions from all potential pathways. For the NFSS, these pathways are: direct exposure to gamma radiation, inhalation of radon gas, and ingestion of water containing radioactivity.

The contribution to the population dose made by gamma radiation from on-site radioactive materials is too small to be measured since gamma radiation levels decrease rapidly as distance from the source of contamination increases. For example, if the gamma exposure rate at a distance of 0.9 m (3 ft) from a small-area radioactive source were 100 mR/yr, the exposure rate at a distance of 6.4 m (21 ft) from the source would be indistinguishable from naturally occurring background radiation.

Similarly, radon gas is known to dissipate rapidly as distance from the radon source increases (Ref. 10). Therefore, radon exposure does not contribute significantly to population dose.

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

Since the contributions to population dose via all three potential exposure pathways are inconsequential, calculation of dose to the population is not warranted. The cumulative dose to the population within an 80-km (50-mi) radius of the NFSS that would result from radioactive materials present at the site would be indistinguishable from the dose that the same population would receive from naturally occurring radioactive sources.

3.6 TRENDS

The environmental monitoring program at the NFSS has been established to allow an annual assessment of the environmental conditions at the site, provide a historical record for year-to-year comparisons, and permit detection of trends. In the following subsections, 1987 annual averages for each monitoring location for radon, external gamma radiation, and radionuclide concentrations in surface water and groundwater are compared with results for 1982-1986 for the corresponding locations.

In some cases, sampling locations monitored in prior years no longer exist (due to adjustments to the monitoring program or changes resulting from remedial action). Data from such locations would not be valid for comparisons or trends and therefore are not reported in the trend tables. Comparisons and trends are based on current monitoring locations; when there are gaps or anomalies in the data reported for these locations in past years, these are footnoted and explained in the tables. As the environmental monitoring program continues at the NFSS and more data are collected, comparisons and analyses of trends will become more valid.

3.6.1 Radon

As Table 3-8 shows, radon concentrations at the NFSS site boundary have decreased noticeably since 1982. The fluctuations in levels at some monitoring locations can be attributed to remedial action at the NFSS. Statistical analysis of radon data for the period 1982-87 indicates that significant decreases in radon concentrations at the NFSS began in late 1984 and continued into mid-1986. This period coincides with the period during which construction of the IWCF was begun and completed. Radon concentrations at the NFSS stabilized in late 1986 and have remained close to the background level for the area. Radon concentrations measured in 1987 do not differ significantly from 1986 levels.

TABLE 3-8

ANNUAL AVERAGE CONCENTRATIONS OF RADON-222 MEASURED BY TERRADEX MONITORS AT THE NFSS BOUNDARY, 1982-1987[a]

Sampling Location[b]	Concentration (10^{-9} uCi/ml)[c,d]					
	1982	1983	1984	1985	1986	1987
Site Boundary						
1	1.2	0.8	0.9	0.4	0.3	0.2
3	0.6	0.5	0.7	0.5	0.3	0.3
4	0.7	0.6	0.6	0.4	0.3	0.4
5	0.6	0.4	0.5	0.2	0.3	0.2
6	0.7	0.5	0.5	0.4	0.2	0.2
7	1.0	0.5	0.4	0.6	0.2	0.3
11	0.9	0.5	0.3	0.4	0.4	0.2
12	0.8	0.6	0.4	0.4	0.2	0.3
13	0.9	0.4	0.7	0.5	0.4	0.1
14	0.7	0.4	0.5	0.3	0.8	0.4
15	0.8	0.5	0.5	0.3	0.3	0.2
20	0.7	0.5	0.5	0.5	0.2	0.2
28	0.7	0.4	0.5	0.4	0.3	0.2
29	-[e]	0.6	0.4	0.6	0.4	0.3
32	1.0	0.4	1.0	0.4	0.3	0.3
34	0.4	0.5	0.5	0.5	0.3	0.8
35	-[f]	-[f]	-[f]	0.3	0.2	0.2
36	-[f]	-[f]	-[f]	0.4	0.3	0.2
Background						
30	-[g]	-[h]	1.0	0.4	0.3	0.3

[a]Data sources for previous years are the annual site environmental reports for those years (Refs. 7-11).

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

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

[d]Background has not been subtracted.

[e]Sampling Location 29 was moved to its present location in the fourth quarter of 1982. As such, 1982 data are not directly comparable to data for other years.

[f]Sampling Locations 35 and 36 were added to the monitoring program in January 1985.

[g]Background monitoring location was added to the monitoring program in January 1983.

[h]Background detector was improperly exposed during one sampling period. Annual average background, therefore, was invalid.

3.6.2 External Gamma Radiation Levels

As shown in Table 3-9, while there has been some fluctuation in external gamma radiation levels (especially during the years 1983 to 1985 when remedial activities were in full progress), 1986 levels in most cases were much lower than levels measured in 1982. This overall downward trend can be attributed to the effects of remedial action at the NFSS. External gamma radiation levels in 1987 were in slightly lower than those measured in 1986, but the difference is not statistically significant. External gamma radiation levels have stabilized at the NFSS at levels that are so close to background for the area as to be statistically insignificant.

3.6.3 Surface Water

As shown in Tables 3-10 and 3-11, the concentrations of uranium and radium-226 in surface water have decreased since 1982. This decrease can be attributed to remedial action conducted at the site, although construction activities during remedial action contributed to a sharp increase in uranium concentration at Location 10 from 1982 to 1983. A comparison of 1986 data with 1982 data shows the extent to which remedial action has been successful in reducing radionuclide concentrations in surface water at the NFSS.

Uranium and radium-226 levels were biased high in April 1987 at the on-site stations when sampling of the Central Drainage Ditch coincided with a planned discharge of water from the ditch (see Section 4.1.3). Significant decreases were measured at off-site locations from 1982 through 1986. Levels of both radionuclides remained low in 1987.

3.6.4 Groundwater

As shown in Tables 3-10 and 3-11, there have been no noticeable trends in the concentrations of uranium or radium-226 in groundwater

TABLE 3-9

ANNUAL AVERAGE EXTERNAL GAMMA RADIATION LEVELS AT THE NFSS, 1982-1987[a]

Sampling Location[b]	Radiation Level (mR/yr)[c]					
	1982[d]	1983	1984	1985	1986	1987
Site Boundary						
1	22	19	34	18	16	11
3	156	127	119	24	4	11
4	261	192	167	48	14	13
5	90	86	84	24	14	16
6	26	15	35	21	8	3
7	43	17	31	20	8	11
11	-[e]	12	17	12	4	2
12	-[e]	12	24	11	2	6
13	-[e]	14	42	14	0[f]	0[f]
14	8	8	13	6	3	7
15	22	0[f]	8	3	6	6
20	173	121	127	65	26	24
28	-[e]	8	26	14	14	14
29	5	12	31	14	0[f]	0
32	13	17	16	10	6	5
34	85	78	79	16	6	8
35	-[g]	-[g]	-[g]	16	15	14
36	-[g]	-[g]	-[g]	6	5	16
Background						
30	-[h]	-[g]	-[g]	91	69	64

[a]Data sources for previous years data are the annual site environmental reports for those years (Refs. 7-11).

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

[c]Measured background has been subtracted from readings taken at site boundary locations. Measurements are obtained in mR/quarter, normalized to 1 year, and expressed as mR/yr.

[d]Current external gamma radiation sampling locations were established in the fourth quarter of 1982. Therefore, 1982 data represent only one quarter's measurements.

[e]Detectors were missing from sampling location.

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

[g]Sampling Locations 35 and 36 were added to the monitoring program in January 1985.

[h]Background location was established in 1985.

TABLE 3-10

ANNUAL AVERAGE CONCENTRATIONS OF URANIUM IN NFSS WATER SAMPLES, 1982-1987[a]

Sampling Location[b]	Concentration (10^{-9} uCi/ml)[c] 1982	1983	1984	1985	1986	1987
Surface Water						
On-Site						
10	76	656	19	15	8	6
11	108	30	3	19	5	14
Off-Site						
12	36	23	8	9	4	5
20	39	22	10	4	5	6
Groundwater						
On-Site						
BH-5	-[d]	5[e]	3	3	<3	<3
BH-48	-[d]	5[e]	6	5	5	4
BH-61	-[d]	<3[e]	4	3	<3	<3
A-42	-[d]	56[e]	55	62	71	78
A-50	-[d]	8[e]	5	3	4	4
BH-49	-[d]	<3[e]	3	3	<3	<3
BH-51	-[d]	9[e]	7	11	7	6
BH-63	-[d]	9[e]	3	3	<3	<3
A-52	-[d]	8[e]	73	22	17	18
BH-64	-[d]	18[e]	13	15	13	10
BH-70	-[d]	5[e]	7	4	3	7
BH-71	-[d]	3[e]	4	3	<3	<3
Off-Site						
17	9	<3	<3	<3	<3	<3[g]
19	<3	<3	-[f]	<3	<3	<3[g]

[a]Data sources for prior years are the annual site environmental reports for those years (Refs. 7-11).

[b]Sampling locations are shown in Figures 3-2 and 3-3. Sampling locations that have existed in previous years but that no longer exist due to adjustments in the monitoring program or changes caused by remedial action are not reported in trend tables. Data from these locations would not be valid for comparisons or trends.

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

TABLE 3-10

(Continued)

[d]On-site groundwater wells monitored in 1982 were replaced in mid-1983 with wells currently being monitored (see footnote b).

[e]New on-site groundwater wells were installed in mid-1983. Data reported represent two quarters' measurements.

[f]Sampling performed annually; sample was lost during shipment to the laboratory.

[g]Sampling of domestic water supply wells was terminated after first quarter results were obtained, since concentrations of uranium and radium in these wells have not exceeded 3.0×10^{-9} uCi/ml (3.0 pCi/l) and 3.0×10^{-10} uCi/ml (0.3 pCi/l), respectively, since 1983.

TABLE 3-11

ANNUAL AVERAGE CONCENTRATIONS OF RADIUM-226

IN NFSS WATER SAMPLES, 1982-1987[a]

Sampling Location[b]	Concentration (10^{-9} uCi/ml)[c]					
	1982	1983	1984	1985	1986	1987
Surface Water						
On-Site						
10	0.6	0.4	0.2	0.4	0.2	0.2
11	1.5	1.2	0.1	0.7	0.3	1.8
Off-Site						
12	0.8	0.8	0.4	0.2	0.3	0.3
20	0.6	0.6	0.3	0.4	0.4	0.3
Groundwater						
On-Site						
BH-5	-[d]	0.1[e]	0.2	0.5	0.5	0.4
BH-48	-[d]	0.2[e]	0.4	0.6	0.5	0.5
BH-61	-[d]	0.1[e]	0.2	0.5	0.3	0.3
A-42	-[d]	0.2[e]	0.4	0.5	0.6	0.2
A-50	-[d]	0.3[e]	0.4	0.7	0.5	0.3
BH-49	-[d]	0.2[e]	0.2	0.4	0.2	0.2
BH-51	-[d]	0.3[e]	0.3	0.5	0.3	0.3
BH-63	-[d]	0.3[e]	0.4	0.4	0.5	0.3
A-52	-[d]	-[f]	0.1	0.2	0.3	0.2
BH-64	-[d]	0.2[e]	0.1	0.3	0.4	0.2
BH-70	-[d]	0.6[e]	0.2	0.6	0.5	0.3
BH-71	-[d]	0.4[e]	0.2	0.4	0.4	0.4
Off-Site						
17	0.3	0.1	0.3	0.2	0.3	0.3[h]
19	0.4	0.1	-[g]	0.1	0.3	0.3[h]

[a]Data sources for prior years are the annual site environmental reports for those years (Refs. 7-11).

[b]Sampling locations are shown in Figures 3-2 and 3-3. Sampling locations that have existed in previous years but that no longer exist due to adjustments in the monitoring program or changes caused by remedial action are not reported in trend tables. Data from these locations would not be valid for comparisons or trends.

TABLE 3-11

(Continued)

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

[d] On-site groundwater wells monitored in 1982 were replaced in mid-1983 with wells currently being monitored (see footnote b).

[e] New on-site groundwater wells were installed in mid-1983. Data reported represent two quarters' measurements.

[f] Well casing was damaged and no samples could be obtained.

[g] Sampling performed annually; sample was lost during shipment to laboratory.

[h] Sampling of domestic water supply wells was terminated after first quarter results were obtained, since concentrations of uranium and radium in these wells have not exceeded 3.0 x 10^{-9} uCi/ml (3.0 pCi/l) and 3.0 x 10^{-10} uCi/ml (0.3 pCi/l), respectively, since 1983.

at the NFSS. Since the current monitoring wells were installed in 1983, most locations have reported concentrations that have remained basically stable.

Uranium levels in A-42 exhibited a slight rising trend through the third quarter of 1986 and stabilized at 73 pCi/l until the third quarter of 1987, when a concentration of 93 pCi/l was measured. In the fourth quarter of 1987, the concentration of uranium in Well A-42 was again 73 pCi/l.

The uranium concentration in Well A-42 is consistently above that measured in the other wells. This well was installed during the early days of remedial action on the site; a review of historical records indicates that it was drilled in an area that had been radioactively contaminated. An investigation is under way in an effort to determine why data for Well A-42 are atypical.

Environmental monitoring for various chemical parameters was initiated in 1987. A discussion of analysis results is contained in Subsection 4.2 of this report.

4.0 RELATED ACTIVITIES AND SPECIAL STUDIES

4.1 RELATED ACTIVITIES

In 1987, a change was initiated in the schedule for quarterly monitoring of all FUSRAP sites, such that sampling is conducted at each site in January, April, July, and October. Previously, quarterly sampling was conducted in March, June, September, and December. This change was implemented to allow sufficient time for more complete analysis activities. In order to implement this change in the monitoring schedule, data from the last quarter of 1986 were carried over to the first quarter of 1987 for purposes of environmental monitoring. Any bias resulting from the use of 1986 data is considered negligible.

In addition, an improved external gamma radiation monitoring system was introduced at the NFSS in April 1987 in conjunction with the currently used type of system. This system utilizes tissue-equivalent TLDs, which permit a direct evaluation of the accumulated dose of gamma radiation to the deep tissue of the body (at a depth of 1 cm). Besides providing values that are more realistic in terms of potential tissue dose than does the other type of TLD, the tissue-equivalent TLD is more sensitive in detecting external gamma radiation. Effective April 15, 1988, tissue-equivalent TLDs will be used exclusively. Data collected from these new TLDs will be presented in the environmental reports for 1988 and subsequent years.

4.1.1 Water Discharges

Surface water discharges from the NFSS are regulated by the NYSDEC, under the New York State Pollutant Discharge Elimination System (SPDES). Permit No. NY-0110469 was issued on May 1, 1983, and is in effect for 5 years.

During 1987, the 10.2 million gal (38.8 million liters) of water in the remaining two water treatment ponds was treated and released. The ponds were subsequently reduced to grade and reseeded. Both prior to and during release, the water was sampled for the applicable parameters presented in Table 4-1. Each discharge request was reviewed and approved by the NYSDEC. All water released complied with the discharge limits for uranium and radium and with SPDES permit limits.

4.1.2 Cap Performance Monitoring

During the last quarter of 1986, 13 vibrating wire pressure transducers (VWPTs) were installed inside the waste containment facility to monitor its effectiveness. Pressure changes measured by these instruments occur as a result of changes in the height of saturation within the wastes. For example, a pressure increase occurring rapidly within the first year after completion of the facility might be indicative of a newly developing permeable condition nearby, whereas a slow increase in pressure at one or more stations with a steady decrease in pressure at others will indicate equalization of the water contained within the facility when it was closed. The former situation would indicate that an inspection of the integrity of the facility was required; the inspection would be conducted as part of maintenance and surveillance activities that will continue at the NFSS for at least 5 years. Three pneumatic pressure transducers were also installed to provide a means of checking the operation of the VWPTs. Further detail regarding the performance monitoring program is provided in Reference 13.

In late 1986, an additional 36 groundwater monitoring wells were installed around the IWCF to monitor its performance (Figure 3-4). These wells were sampled as part of the 1987 environmental monitoring program. Analysis results for uranium and radium are presented in Tables 3-5 and 3-6. Results of analyses for chemical parameters are presented below.

TABLE 4-1

1987 SPDES PERMIT PARAMETERS FOR THE NFSS[a]

Parameter	Unit	Permit Limits	
		BAT[b]	Water Quality
Arsenic	mg/l	0.33	0.05
Barium	mg/l	0.42	-
Cerium	mg/l	0.10	-
Chromium	mg/l	0.15	0.005
Cobalt	mg/l	0.10	0.005
Copper	mg/l	0.10	-
Cyanide	mg/l	-	0.10
Fluoride	mg/l	4.2	1.5
Iron	mg/l	0.42	0.3
Lanthanum	mg/l	0.10	-
Lead	mg/l	0.10	0.03
Lithium	mg/l	0.42	-
Manganese	mg/l	0.10	-
Mercury	mg/l	-	0.0004
Nickel	mg/l	0.10	0.03
Selenium	mg/l	4.00	-
Strontium	mg/l	0.42	-
Thallium	mg/l	-	0.02
Vanadium	mg/l	0.4	-
Zinc	mg/l	0.22	-
Zirconium	mg/l	0.10	-
Total Suspended Solids	mg/l	50	-
Settleable Solids	mg/l	0.30	-
pH	--[c]	6.0-9.0	-
Gross Alpha[d]			
(as uranium)	uCi/ml	-	6×10^{-7}
(as radium-226)	uCi/ml	-	3×10^{-8}

[a]Maximum discharge rate: 1,090,080 liters/day (288,000 gal/day).

[b]Best available technology.

[c]Unitless.

[d]Discharge limit.

4.2 SPECIAL STUDIES

4.2.1 Groundwater Chemical Investigation and Monitoring

In April 1987, the 36 monitoring wells installed around the IWCF to monitor its performance were incorporated into the environmental monitoring program. As part of the monitoring program, samples from these wells are analyzed for chemical constituents. The chemical monitoring program includes baseline monitoring for the chemical substances listed in Subsection 4.2.1 below; routine monitoring of the 36 new wells for heavy metals; and routine monitoring of all wells for "indicator" parameters [total organic carbon (TOC), total organic halogens (TOX), pH, and specific conductivity].

The results obtained in 1987 are summarized in the following subsections and tables. Based on the data currently available, it is not possible to draw conclusions or establish trends concerning chemical constituents in groundwater at the NFSS, except as to the presence or absence of individual chemical species.

4.2.2 Baseline Appendix IX Monitoring

In July 1987, 16 wells at the NFSS were selected for baseline chemical monitoring pursuant to 40 CFR 261, Appendix IX. Baseline quarterly monitoring began the same month and will be complete in July 1988. This program includes analysis for 54 volatile organic compounds (VOA); 65 semi-volatile compounds that are on the hazardous substances list; 64 semi-volatile compounds that are not on the hazardous substances list; basic, neutral, and acid extractable compounds; 26 pesticides and PCBs from the EPA Contract Laboratory Program list; 12 organophosphate pesticides, 4 herbicides; 24 toxic or potentially toxic metals; and sulfides, fluorides, and cyanides.

The concentrations of most of these compounds were below the limit of detectability of the respective analytical method. Tables 4-2 through 4-5 list the parameters for which analysis was conducted, but which were not detected.

Analysis results for indicator parameters and "Appendix IX" chemical constituents that were found to be present in detectable quantities are listed in Table 4-6. These findings cannot be interpreted until the baseline monitoring program is completed in July 1988.

4.2.3 Metals in Groundwater

In April 1987, the 36 IWCF monitoring wells installed in 1986 were incorporated into the groundwater monitoring program at the NFSS. As part of this program, quarterly analysis for dissolved metals in groundwater was initiated. Metal ions are normal constituents of groundwater; however, the presence of very high concentrations of toxic heavy metals associated with the materials stored in the IWCF, such as lead, nickel, vanadium, chromium, cobalt, or barium, would indicate an impact resulting from site activities. The well system is designed to provide sufficient wells to cover both upgradient and downgradient conditions.

Concentrations of ICP metals for the period of April 1987 to October 1987 are given in Table 4-7. Chemical contaminants not present in detectable concentrations are not listed in the table. Table 4-7 also lists analysis results for indicator parameters.

Well A-42 (which is located on the IWCF perimeter but is not one of the 36 "new" wells) is drilled into a sand lense of unknown exent. This well also exhibits metal ion concentrations within the ranges found in other on-site wells. Specific conductance values are moderate in comparison with those found in other on-site wells, and are generally similar to those for nearby Wells 2A and 2B, which do not exhibit high uranium values.

TABLE 4-2

APPENDIX IX VOLATILE SUBSTANCES

NOT DETECTED AT THE NFSS, 1987

Chloromethane	Dichlorodifluoromethane
Bromomethane	Iodomethane
Vinyl Chloride	Methacrylonitrile
Chloroethane	Dibromomethane
Carbon Disulfide	Isobutanol
1,1-Dichloroethene	1,2-Dibromoethane
1,1-Dichloroethane	1,1,1,2-Tetrachloroethane
Trans-1,2-Dichloroethene	1,2,3-Trichloropropane
Chloroform	1,2-Dibromo-3-Chloropropane
1,2-Dichloroethane	Allyl Alcohol
1,1,1-Trichloroethane	2-Chloro-1,3-Butadiene
Carbon Tetrachloride	3-Chloropropene
Vinyl Acetate	Trans-1,4-Dichloro-2-Butene
Bromodichloromethane	Ethyl Cyanide
1,2-Dichloropropane	Ethylene Oxide
Trans-1,3-Dichloropropene	3-Chloropropionitrile
Trichloroethene	2-Propyn-1-01
Dibromochloromethane	Trichloromethanethiol
1,1,2-Trichloroethane	
Benzene	
Bis-1,3-Dichloropropene	
2-Chloroethylvinylether	
Bromoform	
4-Methyl-2-Pentanone	
2-Hexanone	
Tetrachloroethene	
1,1,2,2-Tetrachloroethane	
Toluene	
Chlorobenzene	
Ethylbenzene	
Styrene	
Total Xylenes	

TABLE 4-3

APPENDIX IX EXTRACTABLES

NOT DETECTED AT THE NFSS, 1987

Acetophenone
2-Acetylaminofluorene
4-Aminobiphenyl
Aniline
Aramite
Benzenethiol
Benzidine
P-Benzoquinone
2-Sec-Butyl-4,6-Dinitrophenol
Meta-Cresol
Chlorobenzilate
Diallate
2,6-Dichlorophenol
Dimethoate
P-(Dimethyl-amino)azobenzene
7-12 - Dimethylbenz(a)anthracene
3',3'-Dimethylbenzidine
3,3'-Dimethoxybenzidine
Dibenzo(a,e)Pyrene
Dibenz(a,h)Pyrene
Dibenz(a,i)Pyrene
Alpha, Alpha-Dimethylphenethylamine
1,4-Dioxane
Meta-Dinitrobenzene
1,2-Diphenyl hydrazine
Disulfoton
Ethyl Methacrylate
Ethyl Methanesulfonate
Isosafrole
Malononitrile
Methapyrilene
3-Methylcholanthrene
4,4'-Methylenebis (2-Chloroaniline)
Methyl Methacrylate
Methyl Methanesulfonate
Isodrin
Hexachlorophene
Hexachloropropene
Hexachlorodibenzo-p-Dioxins
2,3,7,8-TCDD
Tetrachlorodibenzo-p-Dioxins
Phenol
Bis(2-Chloroethyl)Ether
2 Chlorophenol
1,3-Dichlorobenzene
1,4-Dichlorobenzene
Benzyl Alcohol
Tetrachlorodibenzofurans
Pentachlorodibenzo-P-Dioxins
Pentachlorodibenzofurans
1,4-Naphthoquinone
1-Naphthalenamine
1-Napthylamine
2-Naphthylamine
4-Nitroquinoline-1-oxide
N-Nitrosodi-n-Butylamine
N-Nitrosodiethylamine
N-Nitrosodimethylamine
N-Nitrosomethylethylamine
N-Nitrosomorpholine
N-NitrosopiperidinepP-(Dimethylamino
Pronamide
Pyridine
Resorcinol
Safrole
1,2,4,5-Tetrachlorobenzene
2,3,4,6-Tetrachlorophenol
Tris(2,3-Dibromopropyl) Phosphate
N-Nitrosopyrrolidine
5-Nitro-o-Toluidine
Pentachlorobenzene
Pentachloroethane
Pentachloronitrobenzene
Phenacetin
P-Phenylenediamine
2-Picoline
Thionazin
Phorate
Famphur
O-Toluidine
O,O,O-Triethyl Phosphorothioate
Sym-Trinitrobenzene
Dibenzofuran
2,4-Dinitrotoluene
2,6-Dinitrotoluene
Diethyl Phthalate
4-Chlorophenyl-phenylether
Fluorene
4-Nitroaniline
4-6-Dinitro-2-methylphenol
N-Nitrosodiphenylamine
4-Bromophenyl-phenylether
Hexachlorobenzene
Pentachlorophenol

TABLE 4-3
(continued)

1,2-Dichlorobenzene	Phenanthrene
2-Methylphenol	Anthracene
Bis(2-Chlorisopropyl)Ether	Di-n-Butyl Phthalate
4 Methylphenol	Fluoranthene
N-Nitroso-Di-n-Propylamine	Pyrene
Hexachloroethane	Butyl Benzyl Phthalate
Nitrobenzene	3,3'-Dichlorobenzidine
Isophorone	Benzo(a)Anthracene
2-Nitrophenol	Chrysene
2,4-Dimethylphenol	Di-n-Octyl Phthalate
Benzoic Acid	Benzo(b)Fluoranthene
Bis(2-Chlorethoxy)Mcthane	Benzo(k)Fluoranthene
2 Methylnaphthalene	Benzo(a)Pyrene
Hexachlorocyclopentadiene	Indeno(1,2,3-cd)Pyrene
2,4,6-Trichlorophenol	Dibenz(a,h)Anthracene
2,4,5-Trichlorophenol	Benzo(g,h,i)Perylene
2-Chloronaphthalene	2-Nitroaniline
Dimethyl Phthalate	Acenaphthylene
3-Nitroaniline	Acenaphthene
2,4-Dinitrophenol	4-Nitrophenol
2,4-Dichlorophenol	1,2,4-Trichlorobenzene
Naphthalene	4 Chloraniline
Hexachlororbutadiene	4-Chloro-3-methylphenol

TABLE 4-4

APPENDIX IX PESTICIDES, PCBs,

AND HERBICIDES NOT DETECTED

AT THE NFSS, 1987

PESTICIDES	PCBs
Alpha-BHC	PCB-1013
Beta-BHC	PCB-1221
Delta-BHC	PCB-1242
Gamma-BHC	PCB-1232
Heptachlor	PCB-1254
Aldrin	PCB-1260
Heptachlor Epoxide	
Endosulfan I	HERBICIDES
Dieldrin	
4,4^{1}-DDE	2,4-D
Endrin	2,4,5-TP
4,4^{1}-DDD	2,4,5-T
Endosulfan Sulfate	
4,4^{1}-DDT	
Methoxychlor	
Endrin Ketone	
Chlorodane	
Toxaphene	
Phorate	
Dimethoate	
Delnar	
Diazinon	
Methyl Parathion	
Malathion	
Ethyl Parathion	
DEF	
Ethion	
Demetron	
Azinphos-Methyl	

TABLE 4-5

METALS NOT DETECTED

AT THE NFSS, 1987

APPENDIX IX METALS	ICP METALS
Aluminum	Arsenic
Arsenic	Barium
Barium	Beryllium
Beryllium	Cadmium
Cadmium	Cobalt
Cobalt	Potassium
Mercury	Antimony
Potassium	Thallium
Osmium	
Lead	
Antimony	
Selenium	
Thallium	
Vanadium	

TABLE 4-6

INDICATOR PARAMETERS AND CONCENTRATIONS OF APPENDIX IX CHEMICAL CONTAMINANTS IN GROUNDWATER AT THE NFSS, 1987

Parameter (Unit)	Range of Concentrations by Sampling Location (Monitoring Well Number)[a,b,c]					
	1A	1B	5A	5B[d]	7A	7B
pH (unitless)	7.4-11.0	7.5-8.3	7.6-8.2	8.0	7.5-7.7	7.3-7.7
Total Organic Carbon (mg/l)	1.8-65.9	1.6-9.2	1.1-40.8	5.8-9.4	1.4-3.0	1.6-2.4
Total Organic Halide (ug/l)	25-32	12-56	10-78	10-35	10-57	10-37
Specific Conductance (umhos/cm)	570-1220	1130-1720	575-1340	1350-1570	1000-2000	1550-1830
Silver (ug/l)	ND	13	11.8	20.7	21.9	21.5
Aluminum (ug/l)	ND	ND	ND	ND	ND	209
Calcium (ug/l x 1000)	72.1-93.8	73.6-111	42.4-43.1	102-108	108-112	106-116
Chromium (ug/l)	37.6	38.4	41.0	73.4	75	82.2
Copper (ug/l)	29.6-139	ND	ND	41.7	ND	53.4-77.6
Iron (ug/l)	ND	ND	ND	ND	ND	163
Potassium (ug/l)	ND	18700	8670	13500	13600	ND
Magnesium (ug/l x 1000)	75.2-81.7	53.2-74.5	77.1	80.3-135	115-127	151-158
Manganese (ug/l)	280-446	29.9-379	97-266	125-259	15-234	54-184
Sodium (ug/l x 1000)	56-57.3	111-127	93	50.9-91.8	125-126	63.0-64.6
Nickel (ug/l)	4.9-155	41.1-154	77.3	49.3-119	106	114-134
Tin (ug/l)	ND	ND	ND	ND	ND	160
Zinc (ug/l)	106	27.7-94	ND	ND	ND	34.5-82
Fluoride (ug/l)	0.26	0.42-0.52	0.41-0.44	0.32	0.37-0.38	0.37-0.41
Acetone (ug/l)	230	14-24	ND	19-50	ND	ND
Bis(2 ethylhexyl) phthalate (ug/l)	10	10	ND	20	52	ND
Diphenylamine (ug/l)	ND	ND	ND	ND	ND	ND
Methylene Chloride (ug/l)	5	ND	ND	ND	ND	ND
Acetonitrile (ug/l)	ND	26	ND	ND	ND	ND
2-Butanone (ug/l)	ND	ND	ND	ND	ND	ND
PCB-1248 (ug/l)	ND	ND	ND	ND	ND	ND

TABLE 4-6

(Continued)

Parameter (Unit)	Range of Concentrations by Sampling Location (Monitoring Well Number)[a,b,c]					
	12A	12B	13A	13B	14A	14B
pH (unitless)	7.2-7.6	7.3-7.4	7.1-7.2	7.8-9.4	7.1-8.0	7.4-7.9
Total Organic Carbon (mg/l)	2.0-2.4	1.3-2.9	3.5-5.4	2.0-3.0	3.4-4.6	1.2-2.4
Total Organic Halide (ug/l)	10-34	2.8-10	10-40	10-31	10-40	10-29
Specific Conductance (umhos/cm)	1430-1730	1030-1690	1850-2200	1050-1880	1250-1420	900-1910
Silver (ug/l)	27.2	39-258	ND	15.2	14.5	16.5
Aluminum (ug/l)	203	ND	313	256	ND	ND
Calcium (ug/l x 1000)	133-147	111-137	157-158	126-139	92.0-96.7	116-117
Chromium (ug/l)	91.6	10-66.2	91.0	66.7	ND	43.3
Copper (ug/l)	40-73.3	ND	32.2	ND	54.8	ND
Iron (ug/l)	150	ND	146	ND	ND	ND
Potassium (ug/l)	ND	11500	ND	11100	ND	10900
Magnesium (ug/l x 1000)	133-148	89.7-92.4	182-183	109-119	100-107	72.6-76.7
Manganese (ug/l)	45.6-207	ND	149-746	63.7-84.9	271-669	48-288
Sodium (ug/l x 1000)	48.9	.0219-104	.023-58	95-110	5.8-160	152
Nickel (ug/l)	221	107-117	62.2-213	84.7	84.2-148	53.1
Tin (ug/l)	105	ND	ND	ND	104	ND
Zinc (ug/l)	33.6	ND	62.3	28.8	21.5-93	66.7
Fluoride (ug/l)	0.37	0.42-0.44	0.41	0.38	0.33-0.38	0.42-0.44
Acetone (ug/l)	72	47	ND	ND	73	ND
Bis(2 ethylhexyl)phthalate (ug/l)	22	62	ND	ND	ND	0.15
Diphenylamine (ug/l)	ND	ND	ND	ND	10	18
Methylene Chloride (ug/l)	5	5	ND	ND	ND	ND
Acetonitrile (ug/l)	ND	ND	ND	ND	ND	ND
2-Butanone (ug/l)	10	15	ND	ND	ND	ND
PCB-1248 (ug/l)	ND	ND	ND	3	ND	ND

TABLE 4-6

(Continued)

Parameter (Unit)	Range of Concentrations by Sampling Location (Monitoring Well Number)[a,b,c]							
	A42	BH5	BH48	BH61	BH63	BH70	FB[e]	TB[f]
pH (unitless)	7.0-7.3	10.8-11.0	7.6-9.9	7.8-8.3	7.2-7.8	7.1-7.3	7.0	7.0
Total Organic Carbon (mg/l)	2.0-77.8	4.1-6.3	1.1-9.2	2.7-24.2	2.4-14.7	1.8-4.9	ND	ND
Total Organic Halide (ug/l)	10-31	10-97	10-280	10-54	10-100	10-57	ND	ND
Specific Conductance (umhos/cm)	1140-1330	1230-1420	3850-5700	2100-2570	2400-2570	2360-3130	ND	ND
Silver (ug/l)	11.4	ND	31.1	12.4	16.7	28.3	ND	ND
Aluminum (ug/l)	ND	ND	288	ND	ND	256	ND	ND
Calcium (ug/l x 1000)	148-151	102-109	518-544	106-152	189-198	254-315	ND	ND
Chromium (ug/l)	44.5	19.5	102	47.1	58.1	99.7	ND	ND
Copper (ug/l)	ND	ND	30.6	ND	ND	ND	ND	ND
Iron (ug/l)	192	ND	ND	ND	ND	536	ND	ND
Potassium (ug/l)	80	15600	28800	11400	11700	9000	ND	ND
Magnesium (ug/l x 1000)	57.8-58.9	5	103-104	77.7-106	67.2-75.3	156-160	ND	ND
Manganese (ug/l)	330-606	ND	674-783	21.3-76.8	148-183	282-355	ND	ND
Sodium (ug/l x 1000)	32.2	107-130	533-568	200-202	242-244	133-151	ND	ND
Nickel (ug/l)	41.2	ND	59.9	47.1	41.7	79.4	ND	ND
Tin (ug/l)	ND	ND	ND	ND	ND	ND	ND	ND
Zinc (ug/l)	80	32.2	58.1	52	33	29.5	ND	ND
Fluoride (ug/l)	0.13-0.14	0.32-0.36	0.47-0.48	0.25-0.28	0.28-0.30	0.27-0.28	0.14	ND
Acetone (ug/l)	240	63	43	ND	ND	ND	11	12
Bis(2 ethylhexyl)phthalate (ug/l)	ND	13	ND	17	15	10-15	11	ND
Diphenylamine (ug/l)	ND	ND	ND	ND	31	ND	ND	ND
Methylene Chloride (ug/l)	5	5	ND	ND	5	5	5	ND
Acetonitrile (ug/l)	ND	ND	ND	ND	ND	ND	ND	ND
2-Butanone (ug/l)	ND	15	ND	ND	ND	ND	ND	ND
PCB-1248 (ug/l)	ND	3.1	ND	0.43	ND	ND	ND	ND

[a]These wells monitored "Appendix IX" parameters for the third and fourth quarters.

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

[c]ND - No detectable concentration. Where only one value is listed, concentration ranged from ND to the value in the table.

[d]Well 5B is an extremely poor producer.

[e]FB - Field blank used to determine contamination resulting from sample collection.

[f]TB - Trip blank used to determine contamination during shipment.

TABLE 4-7

INDICATOR PARAMETERS AND CONCENTRATIONS OF ICP CHEMICAL CONTAMINANTS IN GROUNDWATER AT THE NFSS, 1987[a]

Parameter (Unit)	Range of Concentrations by Sampling Location (Monitoring Well Number)[b]					
	2A	2B	3A	3B	4A	4B
pH (unitless)	7.4-7.8	7.1-7.2	7.5-7.6	7.5-8.5	7.2-8.8	7.2-7.5
Total Organic Carbon (mg/l)	1.4-1.9	1.2-2.3	1.3-5.2	2.3-3.7	1.2-3.4	1.5-3.9
Total Organic Halide (ug/l)	10-89	10-21	10-49	10-15	10-43	10-69
Specific Conductance (umhos/cm)	1700-1930	1500-1650	1740-1760	2130-2470	830-1260	1350-1550
Silver (ug/l)	ND	ND	ND	ND	14.6	ND
Aluminum (ug/l)	479	236	205	248	ND	821
Boron (ug/l)	825	133	202	166	359	131
Calcium (ug/l x 1000)	127-130	143-148	34.5-77.1	110-112	70-98.7	70.9-93.8
Chromium (ug/l)	ND	ND	ND	ND	ND	ND
Copper (ug/l)	28.1	30.2	ND	29.7	ND	ND
Iron (ug/l)	157	ND	ND	127	255	384
Mercury (ug/l)	ND	ND	0.39	ND	ND	ND
Potassium (ug/l x 1000)	8.74	ND	6.91-18.7	ND	ND	5.68
Magnesium (ug/l x 1000)	69.3-69.9	90.2-103	46.8-114	190-196	40.8-98	47.5-90.4
Manganese (ug/l)	104-132	122-144	117-262	66-415	21-135	37-103
Molybdenum (ug/l)	ND	ND	107	117	ND	ND
Sodium (ug/l x 1000)	150-198	62.8-69	67-111	95.7-150	43.5-116	58-97
Nickel (ug/l)	ND	ND	69.5-220	255	ND	43.8
Lead (ug/l)	ND	ND	ND	ND	ND	ND
Selenium (ug/l)	ND	ND	ND	ND	ND	23
Vanadium (ug/l)	ND	ND	ND	ND	ND	ND
Zinc (ug/l)	ND	ND	ND	ND	ND	ND

TABLE 4-7

(Continued)

Parameter (Unit)	Range of Concentrations by Sampling Location (Monitoring Well Number)[b]					
	6A	6B	8A	8B	9A	9B
pH (unitless)	7.4-9.0	7.2	7.5-10	7.2-7.5	7.1-7.3	8.0-10.0
Total Organic Carbon (mg/l)	1.6-3.9	2.0-3.1	1.7-2.7	2.5-3.5	1.8-3.0	1.7-3.7
Total Organic Halide (ug/l)	10-42	10-57	19-80	23-64	23-50	12-40
Specific Conductance (umhos/cm)	300-1300	2130-2370	630-2280	1770-2000	2100-2450	950-1850
Silver (ug/l)	ND	ND	ND	ND	ND	ND
Aluminum (ug/l)	ND	252	231	208-270	217-290	256
Boron (ug/l)	292	180	848	125	244	385
Calcium (ug/l x 1000)	86.7-97	136-139	139-157	142-147	170-176	122-134
Chromium (ug/l)	ND	ND	ND	10	ND	ND
Copper (ug/l)	ND	ND	ND	30.9	58.3-59.2	ND
Iron (ug/l)	ND	ND	ND	1530	382	123
Mercury (ug/l)	ND	ND	ND	ND	ND	ND
Potassium (ug/l x 1000)	13.6	5.34	14.4	ND	ND	12
Magnesium (ug/l x 1000)	50.7	207-218	80.5-84.2	155-163	204-212	28.3-48.8
Manganese (ug/l)	229-236	181-384	78.6-137	109-202	281-417	20.1
Molybdenum (ug/l)	ND	ND	ND	ND	102	ND
Sodium (ug/l x 1000)	52.1-84	68.4-81	166-200	56.8-63	57.2	109-117
Nickel (ug/l)	67.1-88.4	102-181	ND	41.6-213	82.9-564	ND
Lead (ug/l)	ND	ND	ND	ND	ND	ND
Selenium (ug/l)	8.2	ND	ND	ND	ND	ND
Vanadium (ug/l)	ND	50.7	ND	ND	54.4	ND
Zinc (ug/l)	ND	66	ND	34.1	112	27.6

TABLE 4-7

(Continued)

Parameter (Unit)	Range of Concentrations by Sampling Location (Monitoring Well Number)[b]					
	10A	10B	11A	11B	15A	15B
pH (unitless)	7.2-7.6	7.4-9.6	7.3-7.5	7.2-7.5	7.3-7.4	7.4-9.5
Total Organic Carbon (mg/l)	1.8-3.5	1.4-5.4	1.3-2.6	2.8-6.6	2.7-4.5	1.4-4.9
Total Organic Halide (ug/l)	10-30	10-37	10-33	10-28	10-50	10-26
Specific Conductance (umhos/cm)	1070-1250	1000-1250	1400-1670	1350-1640	1320-1620	265-2070
Silver (ug/l)	ND	ND	ND	14.1	ND	ND
Aluminum (ug/l)	202	237	203-216	265	250	264
Boron (ug/l)	142	266	ND	732	ND	557
Calcium (ug/l x 1000)	75.8-103	76.9-97.8	88.9-129	13.3-95.5	88.5-89.7	97.3-153
Chromium (ug/l)	ND	ND	ND	ND	ND	14
Copper (ug/l)	ND	103	51.7	50.7	80.7-115	ND
Iron (ug/l)	ND	ND	ND	ND	ND	ND
Mercury (ug/l)	ND	ND	ND	ND	ND	0.29
Potassium (ug/l x 1000)	11.5	5.21	13.1	ND	ND	10.1
Magnesium (ug/l x 1000)	96.5	32.2-92.6	97.4-128	103-130	118-124	50.8-78.3
Manganese (ug/l)	106-109	124-239	142-449	120-286	273-695	165-221
Molybdenum (ug/l)	ND	ND	126	ND	173	100
Sodium (ug/l x 1000)	42.7-67.4	31.8-78	73.8	36.8-94	64.9-79	128-147
Nickel (ug/l)	162	ND	433	ND	68.7-412	125
Lead (ug/l)	ND	ND	ND	ND	ND	ND
Selenium (ug/l)	ND	ND	ND	ND	ND	ND
Vanadium (ug/l)	ND	ND	ND	ND	ND	ND
Zinc (ug/l)	ND	227	44	121	22.0	ND

TABLE 4-7

(Continued)

Parameter (Unit)	Range of Concentrations by Sampling Location (Monitoring Well Number)[b]					
	16A	16B	17A	17B	18A	18B
pH (unitless)	7.4-9.0	7.3-9.4	7.2-8.8	7.3-7.4	7.3	7.5-8.6
Total Organic Carbon (mg/l)	2.2-4.4	1.5-2.2	1.5-3.0	2.0-17.5	3.5-7.0	1.4-3.2
Total Organic Halide (ug/l)	10-57	10-44	10-37	10-23	10-34	10-56
Specific Conductance (umhos/cm)	1400-2620	1200-1340	850-2440	1500-1650	2200-3160	1160-2150
Silver (ug/l)	ND	ND	ND	ND	ND	ND
Aluminum (ug/l)	320	234	279	246	352	302
Boron (ug/l)	732	ND	555	109	176	501
Calcium (ug/l x 1000)	143-144	98.4-107	123-144	90.6-95	140-164	103-121
Chromium (ug/l)	ND	ND	ND	ND	ND	ND
Copper (ug/l)	25.6	ND	ND	ND	41.4	ND
Iron (ug/l)	ND	ND	ND	2280	971	ND
Mercury (ug/l)	0.29	ND	ND	ND	ND	ND
Potassium (ug/l x 1000)	7.99	ND	16.5	ND	5.2	12.1
Magnesium (ug/l x 1000)	192-195	86.3-88.8	119-136	124-126	254-316	121-141
Manganese (ug/l)	77.4-88.8	189-467	183-189	213-565	413-583	206-320
Molybdenum (ug/l)	101	ND	ND	183	149	ND
Sodium (ug/l x 1000)	135-188	37.9	130-157	58.8-70	137-164	123-140
Nickel (ug/l)	ND	125-139	ND	139-463	49.3-450	ND
Lead (ug/l)	ND	ND	ND	ND	ND	ND
Selenium (ug/l)	ND	ND	ND	ND	ND	ND
Vanadium (ug/l)	ND	ND	ND	ND	52.2	ND
Zinc (ug/l)	61.4	56.3	ND	75.2	33.4-887	21.2

TABLE 4-7

(Continued)

Parameter (Unit)	Range of Concentrations by Sampling Location (Monitoring Well Number)[b]					
	A50[c]	A52[c]	BH49[c]	BH51[c]	BH64[c]	BH71[c]
pH (unitless)	7.4-9.7	6.9-7.0	10.0-11.0	7.4-7.9	7.2-7.3	7.4-7.5
Total Organic Carbon (mg/l)	1.6-3.2	2.2-3.3	2.9-5.9	1.2-1.9	1.2-1.7	1.5-2.1
Total Organic Halide (ug/l)	10-22	10-25	10-25	10-16	10-16	10-22
Specific Conductance (umhos/cm)	1920-2060	1390-1600	1270-1870	3040-3220	1720-1760	2260-2400

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

[b]ND - No detectable concentration. Where only one value is listed, the concentration ranged from ND to the value in the table.

[c]These wells were analyzed only for indicator parameters.

4.2.4 Indicator Parameters in Groundwater

Analysis for "indicator" parameters is conducted to determine groundwater quality and to identify the need for additional, more detailed and specific analyses. Indicator parameters for the NFSS are TOC, TOX, pH, and specific conductance. Results of 1987 monitoring for these parameters are shown in Tables 4-6 and 4-7.

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APPENDIX A
QUALITY ASSURANCE

APPENDIX A
QUALITY ASSURANCE

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

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

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

Interlaboratory comparison of the TLD results was provided by participation in the International Environmental Dosimeter Project sponsored jointly by the Department of Energy, the Nuclear Regulatory Commission, and the EPA.

Assurance of the quality of dose calculations was provided in several ways. First, comparisons were made against past calculated doses and significant differences, if any, were verified. Second, all computed doses were double-checked by the originator and by an independent third party who also checked all input data and assumptions used in the calculation.

APPENDIX B
ENVIRONMENTAL STANDARDS

APPENDIX B
ENVIRONMENTAL STANDARDS

The DOE long-term radiation protection standard of 100 mrem/yr includes exposure from all pathways except medical treatments (Ref. 6). Evaluation of exposure pathways and resulting dose calculations are based on assumptions such as occupancy factors in determining the dose from external gamma radiation; subtraction of background concentrations of radionuclides in air, water, and soil before calculating dose; closer review of water use, using the data that most closely represents actual exposure conditions rather than maximum values as applicable; and using average consumption rates of food and water per individual rather than maximums. Use of such assumptions will result in calculated doses that more accurately reflect the exposure potential from site activities.

TABLE B-1

CONVERSION FACTORS

1 year	=	8760 hours
1 liter	=	1000 ml
1 mR	$\simeq$	1 mrem
1 mrem	$\simeq$	1000 uR
100 mrem/yr	$\simeq$	11.4 uR/h (assuming 8760 hours of exposure per year)
1 uCi	=	1,000,000 pCi
1 pCi	=	0.000001 uCi
1 pCi/l	=	10^{-9} uCi/ml
1 pCi/l	=	0.000000001 uCi/ml
1 uCi/ml	=	1,000,000,000 pCi/l
10^{-6}	=	0.000001
10^{-7}	=	0.0000001
10^{-8}	=	0.00000001
10^{-9}	=	0.000000001
10^{-10}	=	0.0000000001
7×10^{-10}	=	0.0000000007

APPENDIX C
ABBREVIATIONS

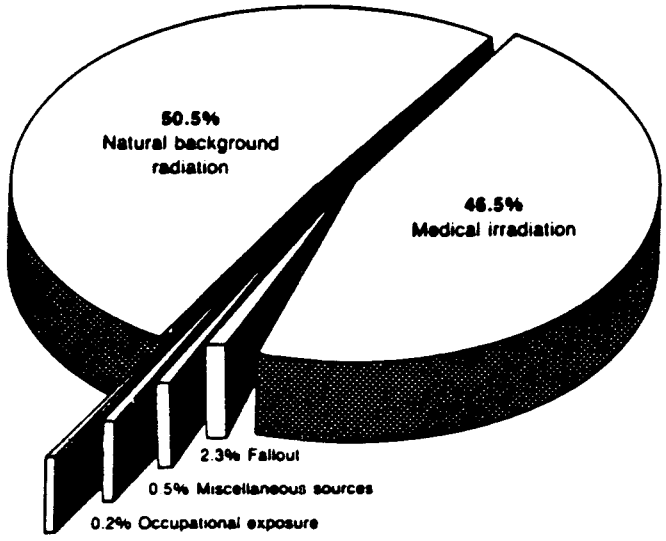
APPENDIX C
ABBREVIATIONS

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

APPENDIX D
RADIATION IN THE ENVIRONMENT

Radiation in the Environment

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



Source: National Academy of Sciences, 1980; National Council of Radiation Protection and Measurement

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

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

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 only move through the air 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 may 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 wall 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.

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Units of Measure

Radiation can be measured in a variety of ways. Typically, units of measure show either the total amount of radioactivity present in a substance, or 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 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. Quantities 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, or mrem (one-thousandth of a rem) range. On the average, people receive about 180 mrem of radiation a year. Most of this radiation is from natural radiation and medical exposure.

RADIATION IN THE ENVIRONMENT

Cosmic Radiation

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

Sea Level (add one for each additional 100 feet in elevation)	26 mrem/year
Atlanta, GA (1,050 feet)	37 mrem/year
Denver, CO (5,300 feet)	79 mrem/year
Minneapolis, MN (815 feet)	34 mrem/year
Salt Lake City, UT (4,400 feet)	70 mrem/year
Spokane, WA (1,890 feet)	45 mrem/year

Terrestrial Radiation

Terrestrial sources are naturally radioactive elements in the soil and water such as thorium, radium, uranium, and carbon.

United States (average)	26 mrem/year
Denver, Colorado	90 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

Based on occupancy 75 percent of the time.

Wood House	35 mrem/year
Brick House	45 mrem/year
Concrete House	45 mrem/year
Stone House	50 mrem/year

Specific Buildings

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.

Typical Radon Level	1.5 pCi/liter
Occupational Working Limit	100.0 pCi/liter

The numbers given here are approximate or represent an average since samples vary.

mrem = millirem

pCi = picocurie

Foods

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

Beer	390 pCi/liter
Domestic 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
Flour	0.14 pCi/g
Peanuts and 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	20 mrem
Dental X Ray, Whole Mouth	900 mrem

International Nuclear Weapons Test Fallout

Average for a U.S. citizen	1 mrem/year

Consumer Goods

Cigarettes (2 packs/day) (Polonium-210)	8,000 mrem/year
Color Television	1 mrem/year
Gas Lantern Mantle (thorium-232)	3 mrem/hour
Highways	4 mrem/year
Jet Airplane Travel/1,500 miles (cosmic)	1 mrem
Natural Gas Stove (radon-222)	6-9 mrem/year
Phosphate Fertilizers*	4 mrem/year
Porcelain Dentures (uranium salts)	1,500 mrem/year
Radioluminescent Clock (radium-226)	9 mrem/year
Smoke Detector (americium-241)	0.2 mrem/year

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

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

APPENDIX E

DISTRIBUTION LIST FOR NIAGARA FALLS STORAGE SITE ANNUAL SITE ENVIRONMENTAL REPORT

APPENDIX E

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