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Surplus Facilities Management Program (SFMP)
Contract No. DE-AC05-81OR20722

NIAGARA FALLS STORAGE SITE
ANNUAL SITE ENVIRONMENTAL REPORT

Lewiston, New York

Calendar Year 1986

June 1987

Bechtel National, Inc.

DOE/OR/20722-150

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JUNE 1987

Prepared for

UNITED STATES DEPARTMENT OF ENERGY

OAK RIDGE OPERATIONS OFFICE

Under Contract No. DE-AC05-81OR20722

By

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ABSTRACT

During 1986, 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 1986 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 1986. 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. Two remaining water treatment ponds will be 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.

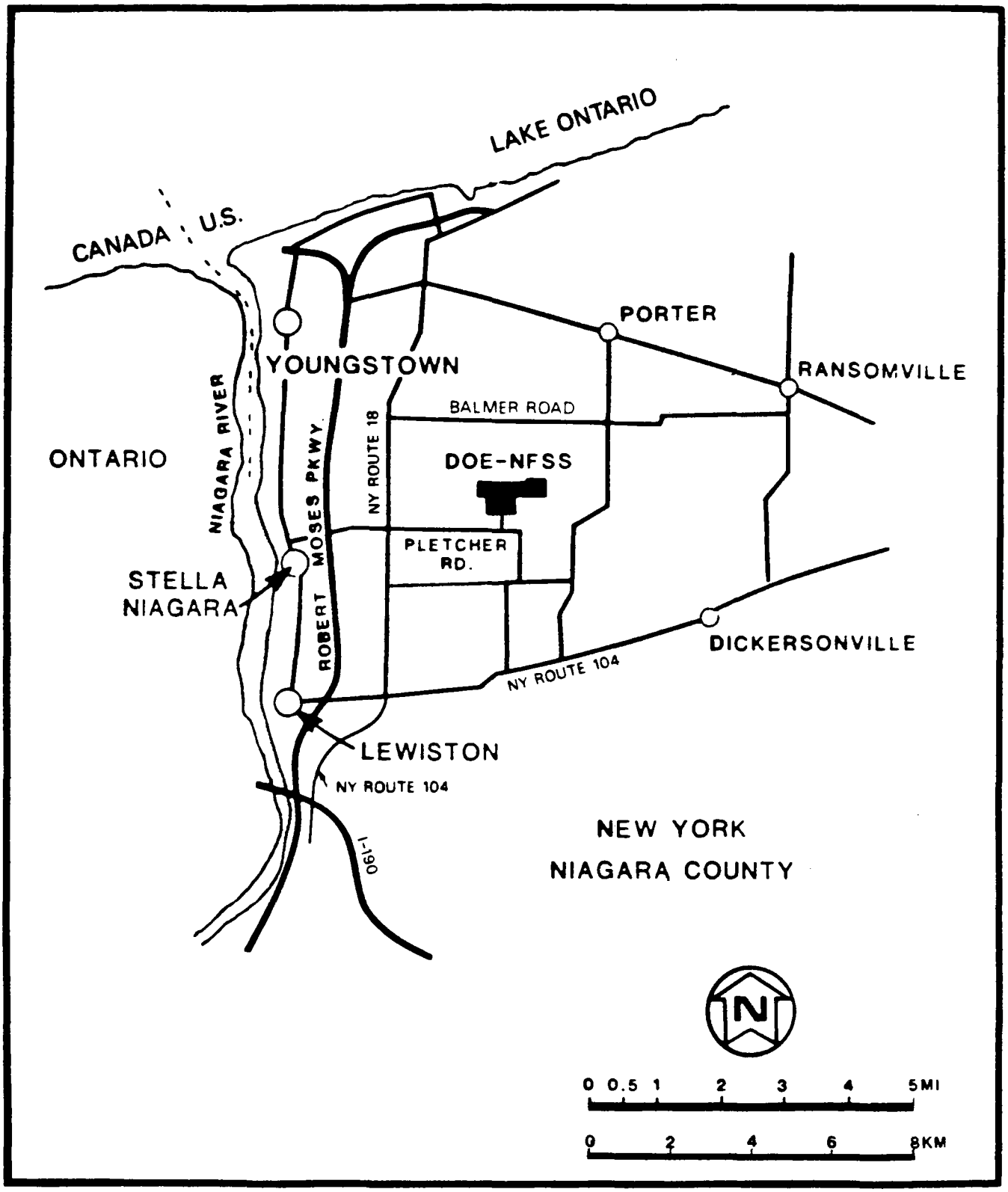


FIGURE 1-1 LOCATION OF THE NFSS

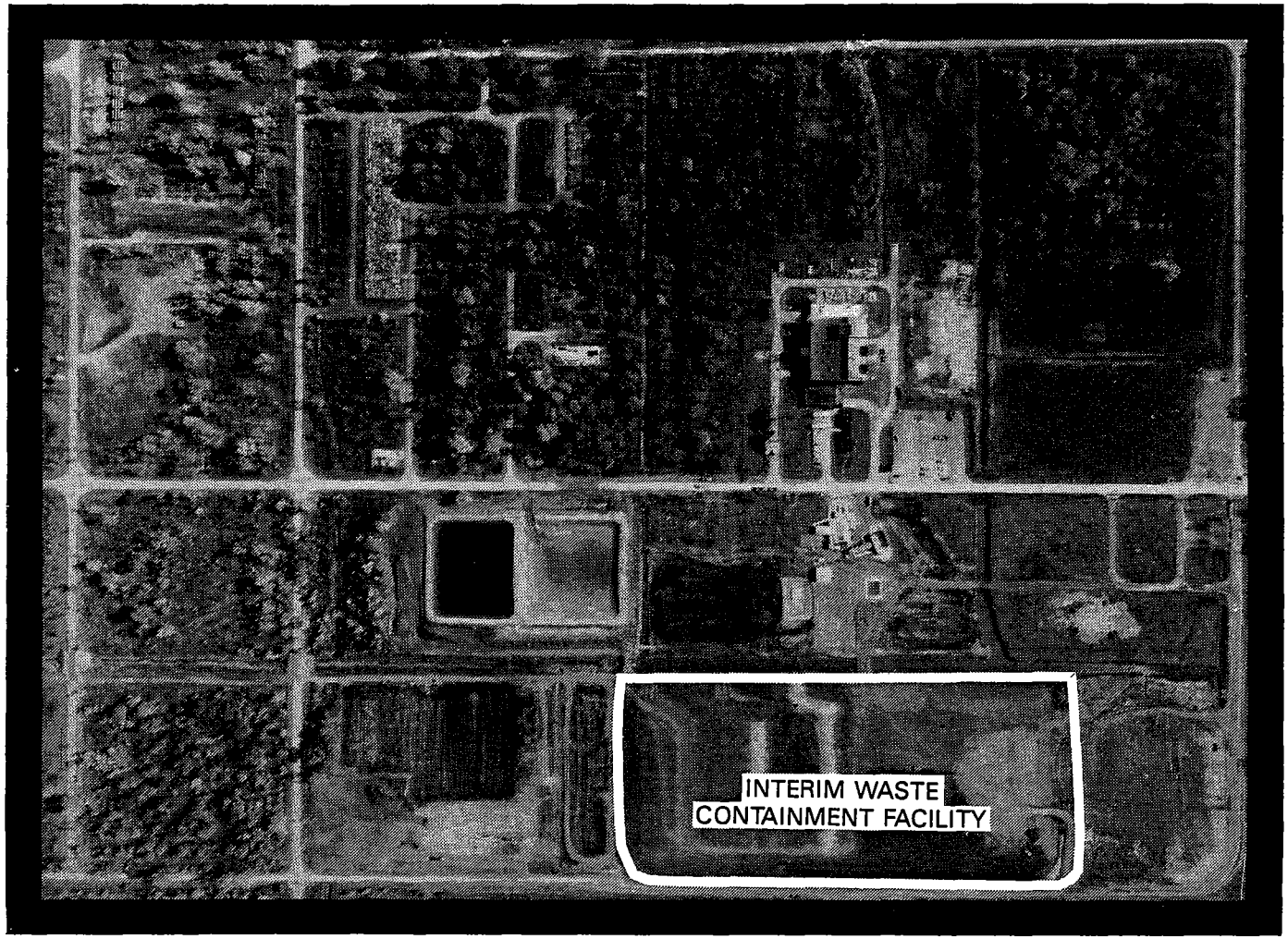


FIGURE 1-2 AERIAL VIEW OF THE NFSS

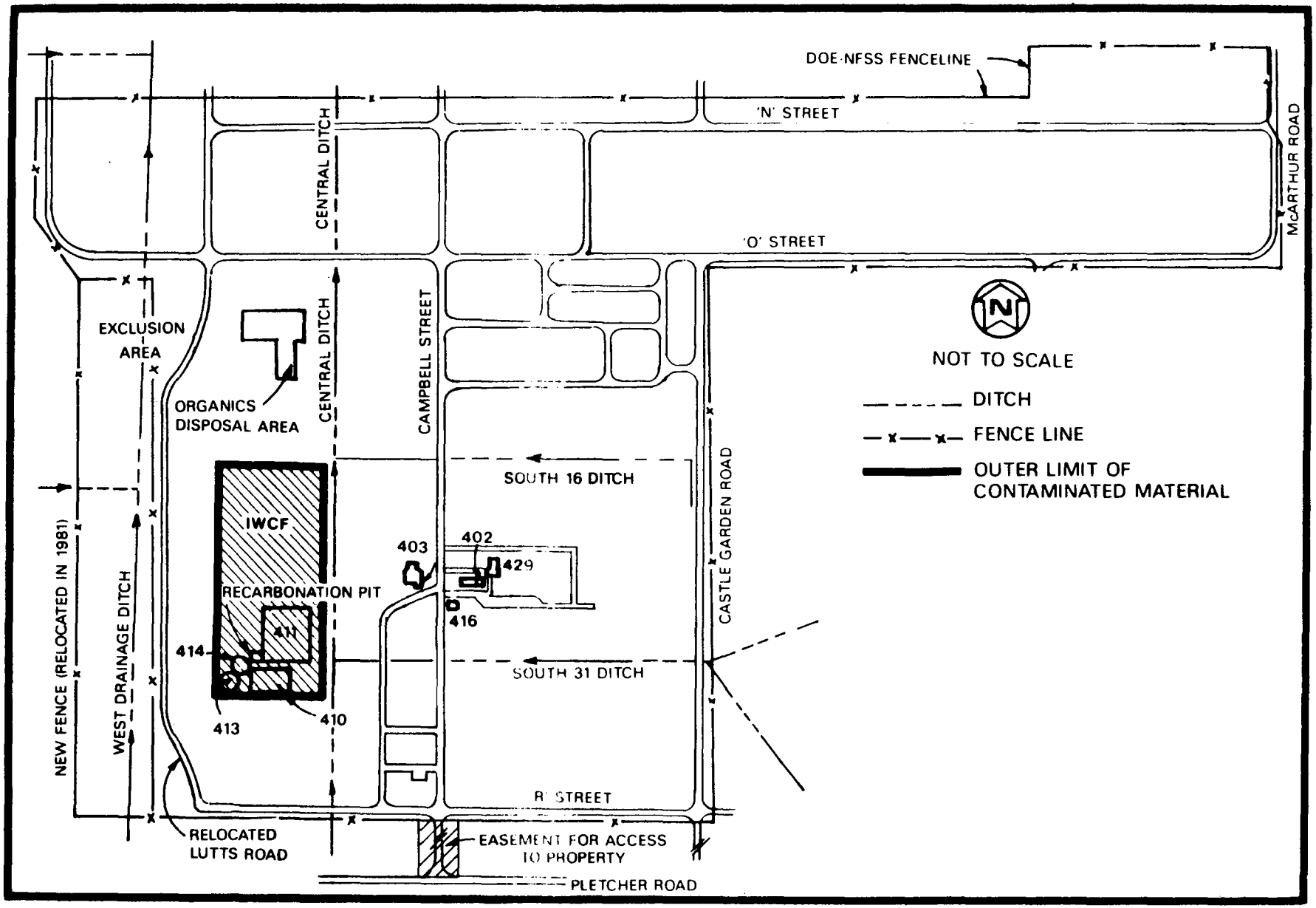


FIGURE 1-3 PRESENT CONFIGURATION OF THE NFSS

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 the flatness of the terrain and soil characteristics. 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 and river water is the predominant source 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 uses beyond those presented in Figure 1-5 are dominated by 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, while the nearest permanent residence is 1.1 km (0.7 mi) southwest of the site.

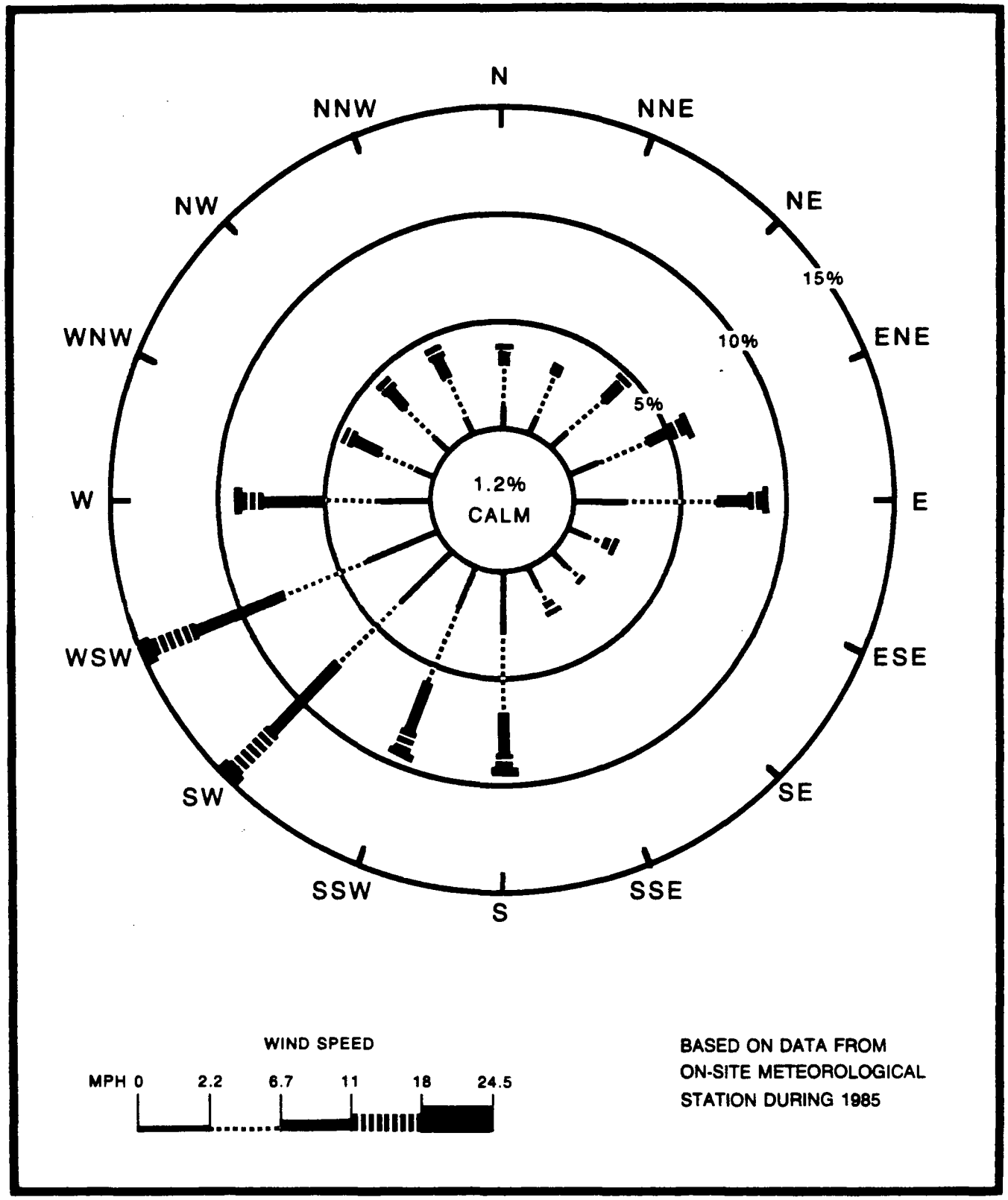


FIGURE 1-4 ANNUAL WIND ROSE FOR THE NFSS

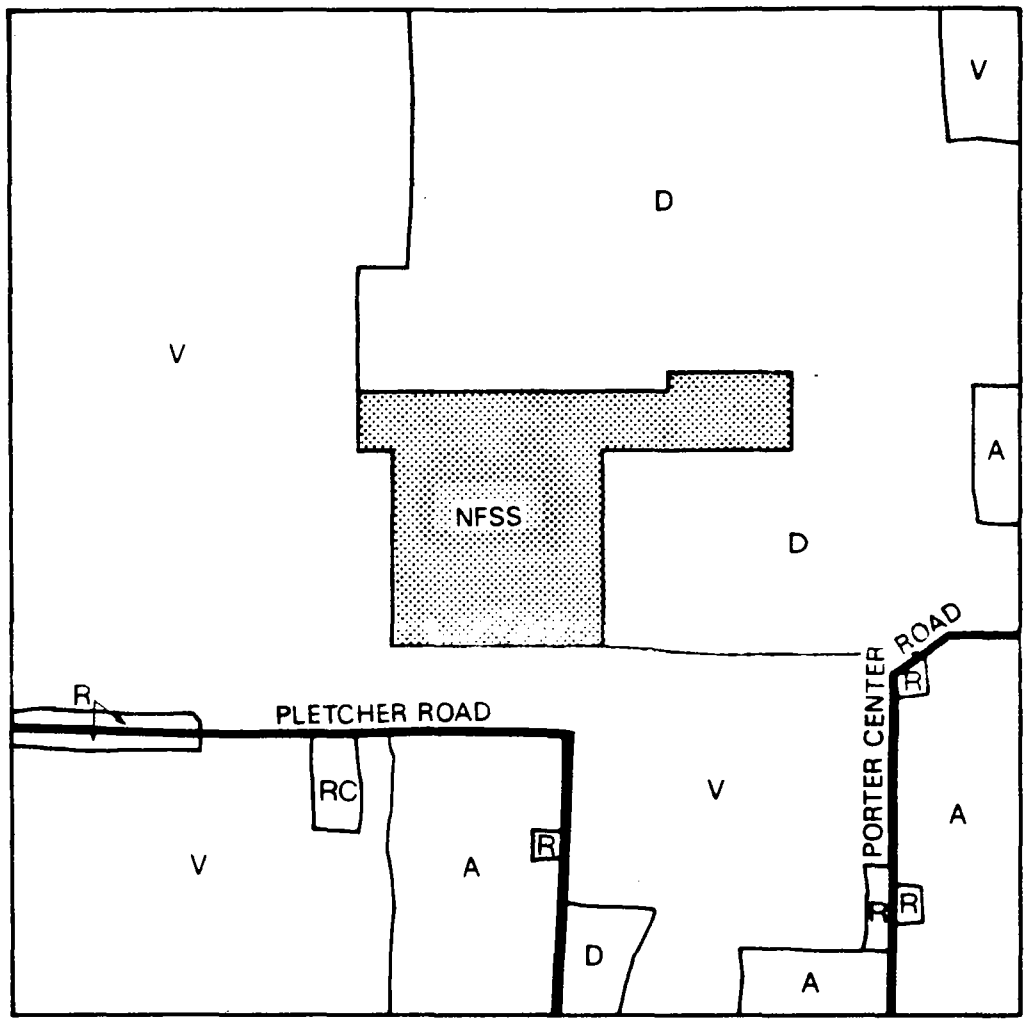


FIGURE 1-5 GENERALIZED LAND USE IN THE VICINITY OF THE NFSS

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, as well as associated iron cake, were stored in an open area north of Building 411. These residues were subject to environmental processes, which transported contaminants into the soil and drainageways, resulting in the contamination of other portions of the site and off-site drainageways. The small quantity of Middlesex Sands resulting from decontamination activities at the Middlesex Sampling Plant were 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 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).

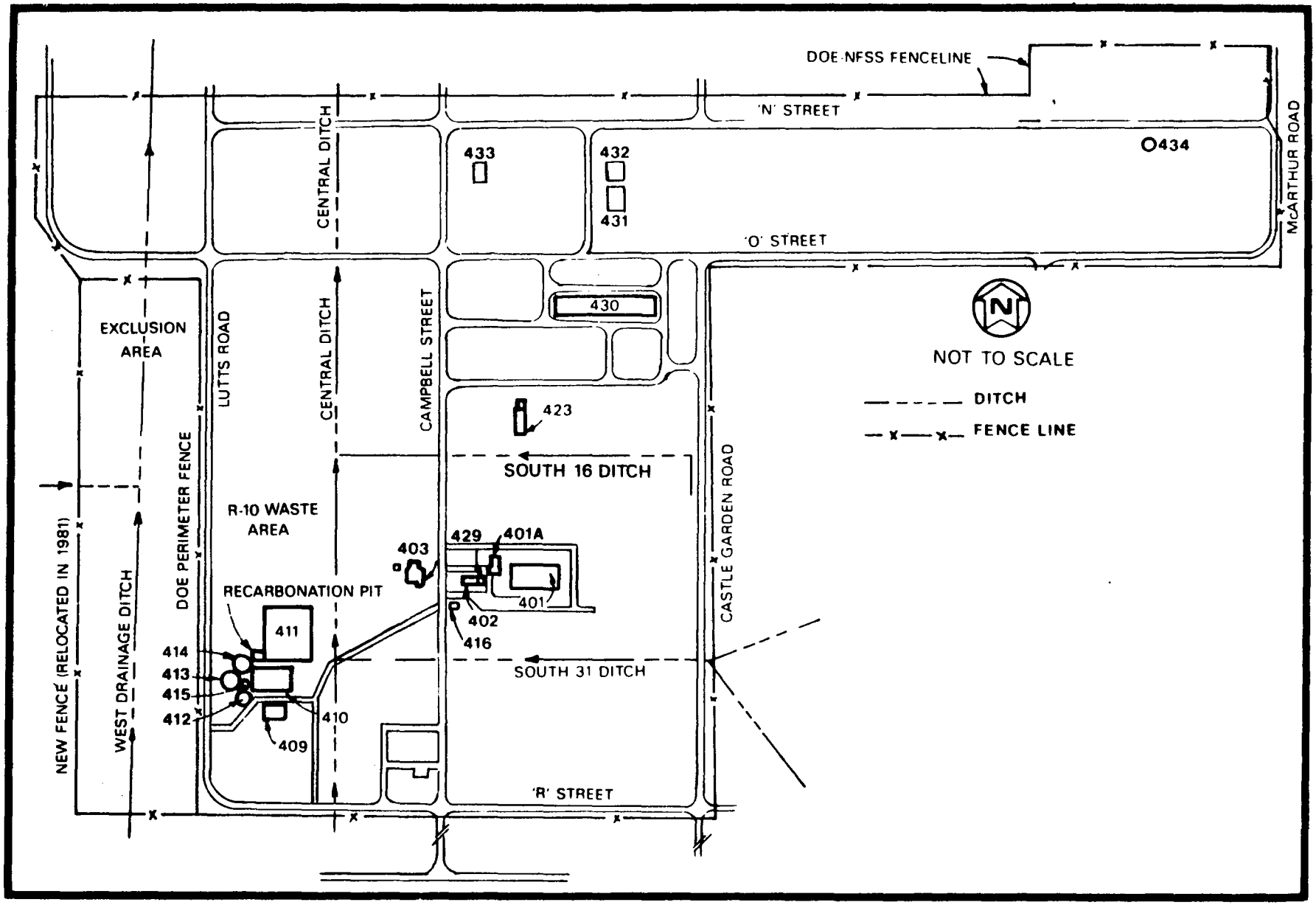


FIGURE 1-6 THE NFSS PRIOR TO INTERIM REMEDIAL ACTIONS

In 1979, Battelle Columbus Laboratories performed a radiological survey of the NFSS. Battelle published its findings in June 1981 (Ref. 5), and the report served as the basis for initial interim remedial action planning at the site. Bechtel National, Inc. (BNI) was chosen by DOE as the Project Management Contractor (PMC) for the NFSS project in 1981. As part of its duties as PMC, BNI maintains the security of the site, performs maintenance as required, carries out the environmental monitoring program, and helped plan and execute the interim remedial action program for the site. 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 located just off the NFSS in an area 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 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. Another 25.8 million liters (6.8 million gal) of contaminated water were treated and released, and four of the six water treatment ponds were reduced to grade. The remaining two will be removed in 1987 after the last of the impounded water has been treated and released.

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 1986, the environmental monitoring program at the NFSS continued to sample air, water, and sediments, 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 or not the site was in compliance with the radiation protection standard.

Annual average radon gas 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 3.1×10^{-10} uCi/ml (0.31 pCi/l). Radon concentrations have decreased noticeably from 1982 to 1986 (see Subsection 3.6.1) (Refs. 7, 8, 9, and 10).

Annual average gamma radiation levels recorded at the NFSS boundary ranged from background levels to 26 mR/yr above background (Table 3-2). These rates may be compared to the radiation level from naturally occurring background radiation in the vicinity of the NFSS, which averaged 69 mR/yr. 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, 8, 9, and 10).

In surface waters (Subsection 3.3.1), annual average concentrations of uranium ranged from 4×10^{-9} uCi/ml to 8×10^{-9} uCi/ml (4 pCi/l to 8 pCi/l); radium-226 concentrations ranged from 2×10^{-10} uCi/ml to 4×10^{-10} uCi/ml (0.2 pCi/l to 0.4 pCi/l). (See Tables 3-3 and 3-4). Average concentrations of both radionuclides have decreased steadily over the 1982-1986 monitoring period (see Subsection 3.6.3) (Refs. 7, 8, 9, and 10).

In groundwater (Subsection 3.3.2), the highest annual average concentration of uranium in an on-site well was 7.1×10^{-8} uCi/ml (71 pCi/l) (Table 3-3). In off-site wells, the maximum uranium concentration was less than 3×10^{-9} uCi/ml (less than 3 pCi/l). For radium-226, the maximum annual average concentration measured in both on- and off-site wells was 6×10^{-10} uCi/ml (0.6 pCi/l). Over the 5-year period from 1982-1986, concentrations of uranium and radium-226 have remained basically stable (see Subsection 3.6.4) (Refs. 7, 8, 9, and 10).

Concentrations of radionuclides in surface water and groundwater may 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 1.9 pCi/g for uranium and 1.1 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 1986 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 1986 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 1986 environmental monitoring at the NFSS (Ref. 11). 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 1986, 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).

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, 1983, 1984, 1985, and 1986 to allow for comparisons of data and identification of trends in monitoring results (see Subsection 3.6).

3.1 RADON MONITORING

Thirty-five radon gas 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. The locations of the radon monitors are shown in Figure 3-1.

Detectors are spaced along the site boundary to ensure adequate detection capability under most atmospheric conditions. Around the IWCF, where the potential for release is higher, detectors are more concentrated.

The radon gas 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 measured concentrations of radon gas (including background) in the air recorded at site boundary monitoring locations and the background level location. Annual average concentrations at the site boundary ranged from 1.7×10^{-10} to 3.6×10^{-10} uCi/ml (0.17 to 0.36 pCi/l). The annual average of background measurements was 3.1×10^{-10} uCi/ml (0.31 pCi/l). For comparisons of radon concentrations measured from 1982-1986, see Subsection 3.6.1.

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), it is not feasible to accurately determine the total quantity of radon released per year. 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.

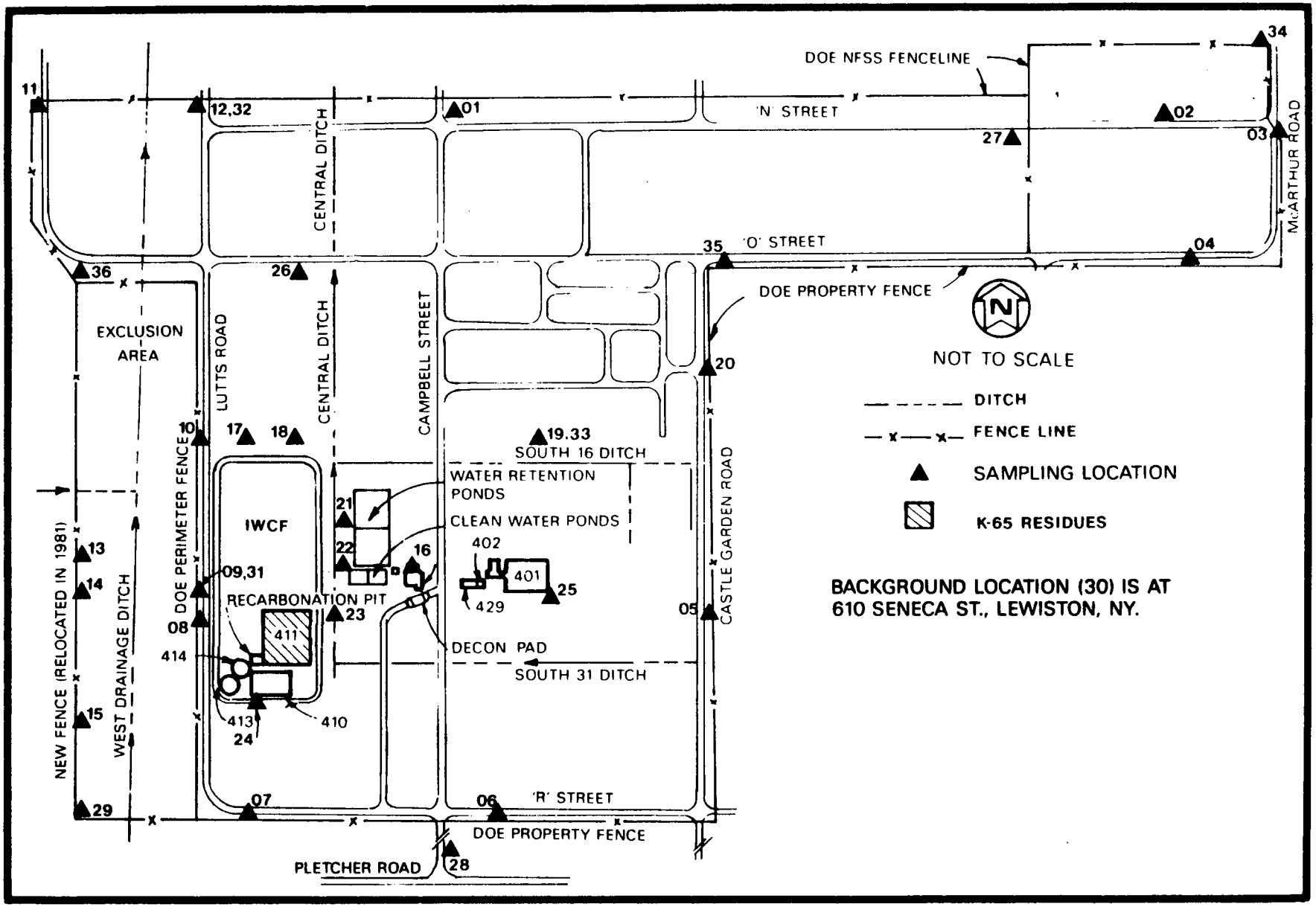


FIGURE 3-1 RADON AND EXTERNAL GAMMA RADIATION MONITORING LOCATIONS AT THE NFSS

TABLE 3-1

CONCENTRATIONS OF RADON-222

MEASURED BY TERRADEX MONITORS AT THE NFSS BOUNDARY, 1986

Sampling Location[a]	Number of Samples[b]	Concentration (10^{-9} uCi/ml)[c,d] Minimum	Maximum	Average
1	11	0.07	0.65	0.26
3	11	0.09	1.04	0.27
4	11	0.10	0.50	0.26
5	10[e]	0.00[f]	1.28	0.26
6	11	0.00[f]	0.35	0.17
7	11	0.07	0.65	0.24
11	11	0.00[f]	0.90	0.36
12	11	0.03	0.72	0.23
13	1[g]	0.40	0.40	-
14	1[g]	0.80	0.80	-
15	1[g]	0.30	0.30	-
20	11	0.05	0.79	0.20
28	11	0.00[f]	0.60	0.32
29	1[g]	0.40	0.40	-
32[h]	10[i]	0.00[f]	0.99	0.25
34	11	0.10	1.33	0.33
35	11	0.00[f]	0.56	0.19
36	11	0.00[f]	0.97	0.25
30[j]	11	0.00[f]	0.80	0.31

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

[b]Detectors were not exchanged in February.

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

[d]Background has not been subtracted.

[e]Detector was missing in April.

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

[g]Detector was inaccessible for 11 months because of the high water level in this area.

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

[i]Detector was missing in September.

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

Until the end of September 1986, a supplemental radon monitoring program for the NFSS area was conducted by Mound Laboratories, operated for DOE by Monsanto Research Corporation, Miamisburg, Ohio. The results are presented in Subsection 4.1.1.

3.2 EXTERNAL GAMMA RADIATION LEVELS

External gamma radiation levels were measured at 33 monitoring locations, 17 of which are on the site boundary and 3 on the perimeter of the exclusion area. One of the monitoring locations is off-site to measure the background radiation level. All locations correspond to radon (Terradex) detector locations as shown in Figure 3-1. The locations of the detectors are selected to ensure adequate measurement of radiation levels.

The external gamma radiation levels are measured using lithium fluoride (LiF) thermoluminescent dosimeters (TLDs), exchanged quarterly. Each monitor contains five TLD chips, the responses of which are averaged. Analysis is performed by Thermo Analytical/Eberline (TMA/E).

The results for the 17 site boundary, one background, and one quality control external gamma radiation monitoring locations are presented in Table 3-2. External radiation data for the first quarter of 1986 were invalidated because the dosimeters were exposed to radiation during shipment to the laboratory. The magnitude and nonuniformity of the exposure prevented a correction of the data. In the fourth quarter of 1986 procedures were implemented to reduce the probability of such in-transit exposures occurring in the future.

The annual average background radiation level for the NFSS area (69 mR) has been subtracted from the measured levels in Table 3-2 to provide an estimate of the effect the site has had on measured levels at the site boundary. The highest levels were measured at two locations adjacent to a sanitary landfill where access is controlled by the owner. At these locations, the maximum annual

TABLE 3-2

EXTERNAL GAMMA RADIATION LEVELS FOR THE NFSS, 1986

Sampling Location[a]	Number of Measurements[b]	Radiation Level (mR/yr)[c,d] Minimum	Maximum	Average
Site Boundary				
1	3	10	24	16
3	3	1	10	4
4	3	9	22	14
5	3	11	18	14
6	3	3	10	8
7	3	3	11	8
11	3	0[e]	6	4
12	3	0[e]	5	2
13	1[f]	0[e]	0[e]	-
14	1[f]	3	3	-
15	1[f]	6	6	-
20	3	24	28	26
28	3	8	20	14
29	1[f]	0[e]	0[e]	-
32[g]	3	0[e]	15	6
34	3	0[e]	15	6
35	3	9	22	15
36	3	3	6	5
Background[h]	3	61	81	69

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

[b]First quarter data invalidated by in-transit exposure.

[c]Background has been subtracted.

[d]Divide by 4 to compare with 1985 mrem/quarter values.

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

[f]Detector was inaccessible for three quarters because of high water levels in this area.

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

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

average level was 26 mR/yr above the average background level of 69 mR/yr. Based on a very conservative 40-h/week occupancy factor, the exposure to workers in this area of the landfill would be a maximum of 6 mR/yr.

To compare the 1986 external gamma radiation levels reported in Table 3-2 with those measured in 1985 (Ref. 10), the 1986 values for minimum, maximum, and average should be divided by 4 since they are expressed as annual values, whereas the 1985 values are expressed as quarterly values.

For comparisons of external gamma radiation levels measured from 1982 through 1986, see Subsection 3.6.2.

3.3 WATER SAMPLING

During 1986, 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 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.

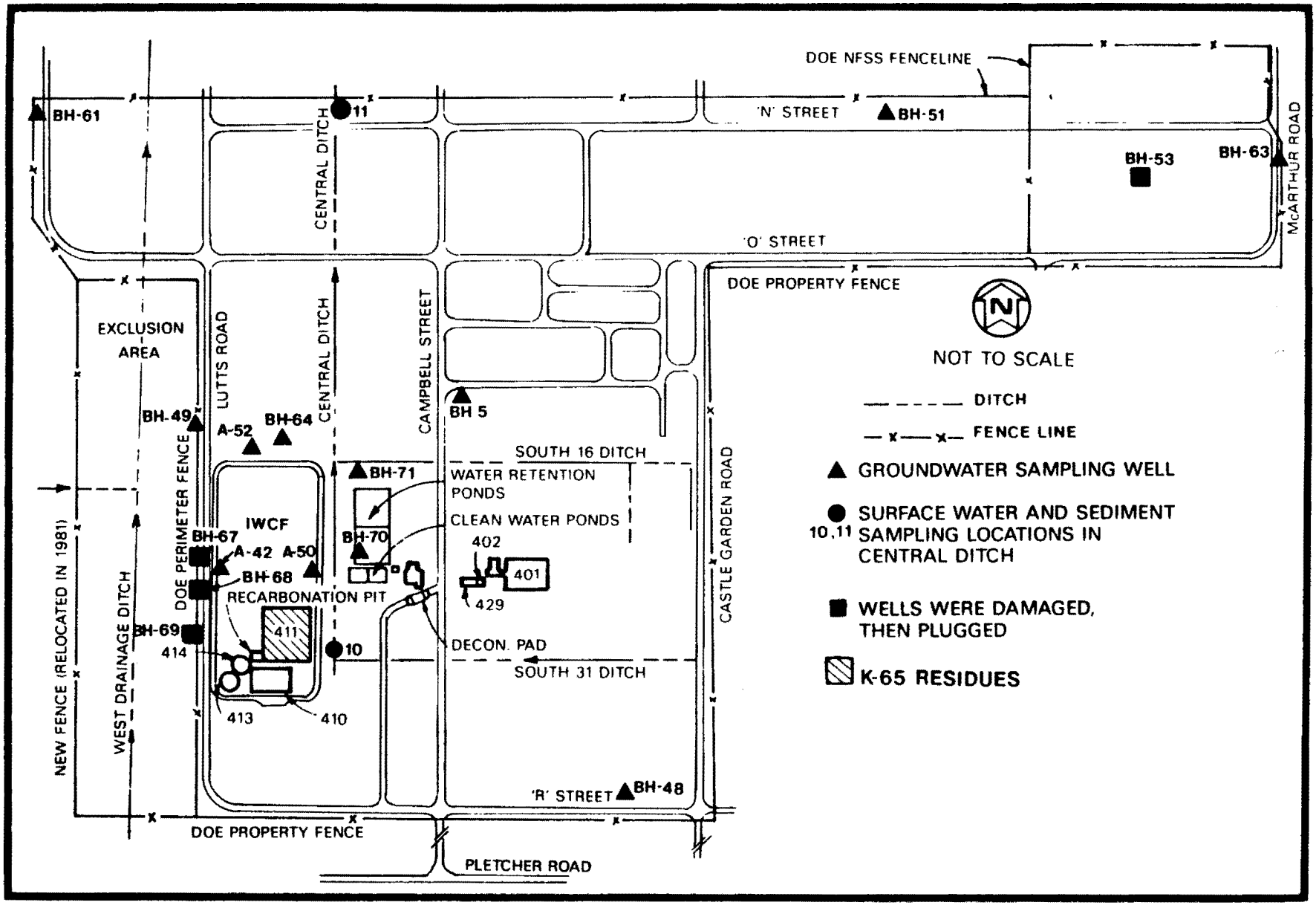


FIGURE 3-2 SURFACE WATER, GROUNDWATER, AND SEDIMENT SAMPLING LOCATIONS AT THE NFSS

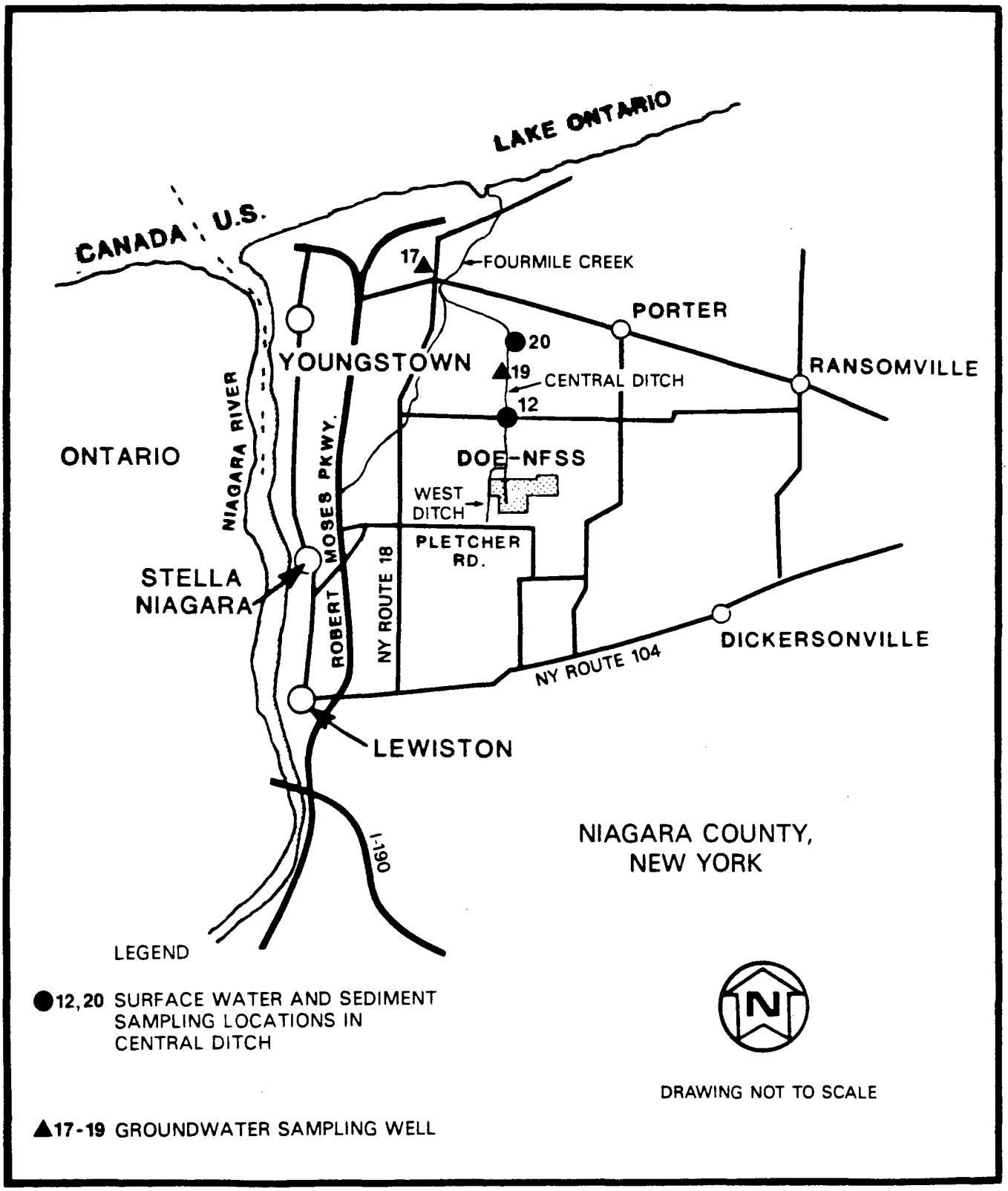


FIGURE 3-3 SURFACE WATER, GROUNDWATER, AND SEDIMENT SAMPLING LOCATIONS IN THE VICINITY OF THE NFSS

TABLE 3-3

CONCENTRATIONS OF URANIUM IN NFSS WATER SAMPLES, 1986

Sampling Location[a]	Number of Samples	Concentration (10^{-9} uCi/ml)[b] Minimum	Maximum	Average
Surface Water				
On-Site				
10	3[c]	<3	11	8
11	4	<3	9	5
Off-Site				
12	3[d]	<3	5	4
20	3[d]	<3	9	5
Groundwater				
On-Site				
BH-5	4	<3	<3	<3
BH-48	4	<3	6	5
BH-61	4	<3	<3	<3
A-42	3[e]	65	73	71
A-50	4	<3	5	4
BH-49	3[f]	<3	<3	<3
BH-51	4	<3	9	7
BH-63	4	<3	<3	<3
A-52	3[f]	13	19	17
BH-64	4	11	15	13
BH-70	4	<3	4	<3
BH-71	4	<3	<3	<3
Off-Site				
17	2[g]	<3	<3	<3
19	2[g]	<3	<3	<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]Location was dry in the second quarter.
[d]Location was dry in the first quarter.
[e]Well casing was damaged; well was not sampled in the second quarter.
[f]Well casing was damaged; well was not sampled in the first quarter.
[g]Periodic sampling only; samples were drawn in the first and fourth quarters.

TABLE 3-4

CONCENTRATIONS OF RADIUM-226 IN NFSS WATER SAMPLES, 1986

Sampling Location[a]	Number of Samples	Concentration (10^{-9} uCi/ml)[b] Minimum	Maximum	Average
Surface Water				
On-Site				
10	3[c]	0.1	0.3	0.2
11	4	0.2	0.4	0.3
Off-Site				
12	3[d]	0.1	0.5	0.3
20	3[d]	0.2	0.6	0.4
Groundwater				
On-Site				
BH-5	4	0.3	0.7	0.5
BH-48	4	0.4	0.7	0.5
BH-61	4	0.2	0.5	0.3
A-42	3[e]	0.1	1.5	0.6
A-50	4	0.2	0.9	0.5
BH-49	3[f]	0.1	0.5	0.2
BH-51	4	0.1	0.5	0.3
BH-63	4	0.2	1.0	0.5
A-52	3[f]	0.2	0.3	0.3
BH-64	4	0.3	0.5	0.4
BH-70	4	0.3	0.6	0.5
BH-71	4	0.2	0.8	0.4
Off-Site				
17	2[g]	0.2	0.4	0.3
19	2[g]	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]Location was dry in the second quarter.
[d]Location was dry in the first quarter.
[e]Well casing was damaged; well was not sampled in the second quarter.
[f]Well casing was damaged; well was not sampled in the first quarter.
[g]Periodic sampling only; samples were drawn in the first and fourth quarters.

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.

Annual average uranium concentrations in on-site surface water ranged from 5 to 8 x 10^{-9} uCi/ml (5 to 8 pCi/l); in off-site surface water, concentrations ranged from 4 to 5 x 10^{-9} uCi/ml (4 to 5 pCi/l). The highest annual average concentration of radium-226 in surface water was 4 x 10^{-10} uCi/ml (0.4 pCi/l). These values 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 1986, see Subsection 3.6.3.

3.3.2 Groundwater

During 1986, groundwater samples were collected quarterly from 12 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, an additional 36 new wells were installed to monitor the performance of the IWCF (Ref. 12). These wells will be sampled as part of the 1987 environmental monitoring program; data from them will be reported in future environmental monitoring reports.

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. Well BH-48 is an upgradient (background) monitoring location and Well BH-61 is a downgradient monitoring location.

Groundwater samples were collected after the wells had been bailed dry or two 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.

Results of analyses for uranium concentrations in groundwater are listed in Table 3-3, and radium results are given in Table 3-4. Annual average concentrations of uranium in groundwater from on-site wells ranged from less than 3×10^{-9} to 7.1×10^{-8} uCi/ml (less than 3 to 71 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 6×10^{-10} uCi/ml (0.2 to 0.6 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 in groundwater measured from 1982 through 1986, see Subsection 3.6.4.

3.4 SEDIMENT SAMPLING

During 1986, sediment samples consisting of composites weighing approximately 500 g (1.1 lb) were collected on-site and off-site at 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 for uranium, based on dry weight, and radium are presented in Table 3-5. 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

TABLE 3-5

URANIUM AND RADIUM-226 CONCENTRATIONS

IN NFSS SEDIMENT SAMPLES, 1986

Sampling Location[a]	Number of Samples	Concentration [pCi/g (dry)] Minimum	Maximum	Average
Uranium				
On-Site				
10	-b-	-	-	-
11	4	0.9	2.4	1.4
Off-Site				
12	4	1.1	3.7	1.9
20	1[c]	1.4	1.4	-
Radium-226				
On-Site				
10	-b-	-	-	-
11	4	0.1	2.9	1.1
Off-Site				
12	4	0.3	1.9	1.0
20	1[c]	0.6	0.6	-

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

[b]The water level in the Central Drainage Ditch was too high for a sample to be collected in the first, third, and fourth quarters. In the second quarter the location was dry.

[c]Location was dry during the first quarter; samples were not taken in the second and third quarters.

unrealistic to assume that ingestion of this water would occur. The NFSS is fenced and locked, and security is well maintained. Since the NFSS is fenced and locked, a member of the public could only consume water on the site by trespassing on the property every day to gain access to the 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, 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, 26 mR/yr, was recorded at TLD Location 20. As presented 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 versus a wooden house is 10 mrem/yr (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 comparisons from year to year, and permit detection of trends over time. In the following subsections, 1986 annual averages for each monitoring location for radon, external gamma radiation, surface water, and groundwater are compared with results for 1982, 1983, 1984, and 1985.

In some cases, sampling locations that existed in past years no longer exist due to malfunctions, adjustments to the monitoring program, or changes caused by 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 the monitoring locations presently existing; 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 3-6 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 during the years. In summary, however, 1986 concentrations overall are lower than in 1982 and are at approximately background levels.

TABLE 3-6

ANNUAL AVERAGE CONCENTRATIONS OF RADON-222 MEASURED BY TERRADEX MONITORS AT THE NFSS BOUNDARY, 1982-1986*

Sampling Location[a]	Concentration (10^{-9} uCi/ml)[b,c]				
	1982	1983	1984	1985	1986
Site Boundary					
1	1.15	0.80	0.89	0.40	0.26
3	0.60	0.54	0.66	0.45	0.27
4	0.71	0.58	0.57	0.36	0.26
5	0.62	0.40	0.51	0.23	0.26
6	0.65	0.47	0.49	0.35	0.17
7	1.02	0.54	0.35	0.58	0.24
11	0.89	0.47	0.34	0.39	0.36
12	0.83	0.55	0.44	0.37	0.23
13	0.88	0.37	0.71	0.54	0.40
14	0.68	0.44	0.47	0.29	0.80
15	0.76	0.54	0.49	0.33	0.30
20	0.74	0.53	0.45	0.53	0.20
28	0.74	0.37	0.53	0.38	0.32
29	-[d]	0.64	0.42	0.57	0.40
32	0.99	0.38	1.04	0.35	0.25
34	0.36	0.58	0.46	0.54	0.33
35	-[e]	-[e]	-[e]	0.31	0.19
36	-[e]	-[e]	-[e]	0.41	0.25
Background					
30	-[f]	-[g]	1.02	0.38	0.31

[a]Sampling locations are shown in Figure 3-1.
[b]1 x 10^{-9} uCi/ml is equivalent to 1 pCi/l.
[c]Background has not been subtracted.
[d]Sampling Location 29 was relocated to its present location in the fourth quarter of 1982. Data for 1982, therefore, are not directly comparable to other years' data.
[e]Sampling Locations 35 and 36 were added to the monitoring program in January 1985.
[f]Background monitoring location was added to the monitoring program in January 1983.
[g]Background detector was improperly exposed during one sampling period. Annual average background, therefore, was invalid.
*Sources for 1982, 1983, 1984, and 1985 data are the Annual Site Environmental Reports for those years (Refs. 7, 8, 9, and 10). In some cases, previous years' data have been reported in different units of measurement. For ease of comparison, all data in trend tables are reported in the units used in the 1986 report. Applicable conversion factors are listed in Appendix B of this report.

3.6.2 External Gamma Radiation Levels

As shown in Table 3-7, 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 are much lower than levels measured in 1982. This overall downward trend can be attributed to the effects of remedial action at the NFSS.

3.6.3 Surface Water

As shown in Tables 3-8 and 3-9, the concentrations of uranium and radium-226 in surface water have decreased since 1982. This decrease can be attributed to remedial action at the site. In some cases, the remedial action's construction activities contributed to transient increases in uranium concentrations at Location 10 from 1982 to 1983. However, 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.

3.6.4 Groundwater

As shown in Tables 3-8 and 3-9, there have been no noticeable trends in the concentrations of uranium or radium-226 in groundwater. Since the current monitoring wells were installed in 1983, most locations have reported concentrations that have remained basically stable.

TABLE 3-7

ANNUAL AVERAGE EXTERNAL GAMMA RADIATION LEVELS FOR THE NFSS, 1982-1986*

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

[a]Site boundary locations only. Sampling locations are shown in Figure 3-1.
[b]Background has been subtracted.
[c]External gamma radiation sampling locations as they presently exist were established in the fourth quarter of 1982. Therefore, 1982 data represents only one quarter's measurements.
[d]Detectors were missing from sampling location.
[e]Measurement was equal to or less than measured background value.
[f]Sampling Locations 35 and 36 were added to the monitoring program in January 1985.
[g]Background location was established in 1985.
*Sources for 1982, 1983, 1984, and 1985 data are the Annual Site Environmental Reports for those years (Refs. 7, 8, 9, and 10). In some cases, previous years' data have been reported in different units of measurement. For ease of comparison, all data in trend tables are reported in the units used in the 1986 report. Applicable conversion factors are listed in Appendix B of this report.

TABLE 3-8

ANNUAL AVERAGE CONCENTRATIONS OF URANIUM

IN NFSS WATER SAMPLES, 1982-1986*

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

[a]Sampling locations are shown in Figures 3-4 and 3-5. Sampling locations that have existed in previous years but that no longer exist due to malfunctions, 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. For specific information for a particular year, please consult that year's environmental monitoring report. See note below for references.

TABLE 3-8

(continued)

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

[c] On-site groundwater wells monitored in 1982 were replaced in mid-1983 with wells currently being monitored. Please see footnote a.

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

[e] Sampling performed annually, and sample was lost in shipment to the laboratory.

* Sources for 1982, 1983, 1984, and 1985 data are the Annual Site Environmental Reports for those years (Refs. 7, 8, 9, and 10). In some cases, previous years' data have been reported in different units of measurement. For ease of comparison, all data in trend tables are reported in the units used in the 1986 report. Applicable conversion factors are listed in Appendix B of this report.

TABLE 3-9

ANNUAL AVERAGE CONCENTRATIONS OF RADIUM-226

IN NFSS WATER SAMPLES, 1982-1986*

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

[a]Sampling locations are shown in Figures 3-4 and 3-5. Sampling locations that have existed in previous years but that no longer exist due to malfunctions, 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. For specific information for a particular year, please consult that year's environmental monitoring report. See note below for references.

TABLE 3-9
(continued)

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

[c] On-site groundwater wells monitored in 1982 were replaced in mid-1983 with wells currently being monitored. Please see footnote a.

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

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

[f] Sampling performed annually, and sample was lost in shipment to laboratory.

* Sources for 1982, 1983, 1984, and 1985 data are the Annual Site Environmental Reports for those years (Refs. 7, 8, 9, and 10). In some cases, previous years' data have been reported in different units of measurement. For ease of comparison, all data in trend tables are reported in the units used in the 1986 report. Applicable conversion factors are listed in Appendix B of this report.

4.0 RELATED ACTIVITIES AND SPECIAL STUDIES

4.1 RELATED ACTIVITIES

4.1.1 Supplemental Radon Monitoring

During the first 9 months of 1986, Mound Laboratories performed supplemental radon monitoring at 6 locations on the NFSS boundary and at 10 off-site locations using Passive Environmental Radon Monitors (PERMs) of the type developed by the DOE Environmental Measurements Laboratory. The samplers at each monitoring location were exposed continuously, with a typical sample being integrated over a 1-week period. This program was terminated in September 1986.

Figure 4-1 shows the locations of the 6 site boundary PERMs and 8 of the off-site locations. The data for the 6 site boundary locations are given in Table 4-1. Averages ranged from 2.1×10^{-10} to 3.1×10^{-10} uCi/ml (0.21 to 0.31 pCi/l).

The locations of the PERMs used to measure background radon levels are shown in Figure 4-2. Results from all off-site locations are presented in Table 4-2. Averages for off-site monitors ranged from 2×10^{-10} to 3×10^{-10} uCi/ml (0.20 to 0.35 pCi/l). The average natural background for the NFSS area that was measured by Mound Laboratories was 2.2×10^{-10} uCi/ml (0.22 pCi/l).

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

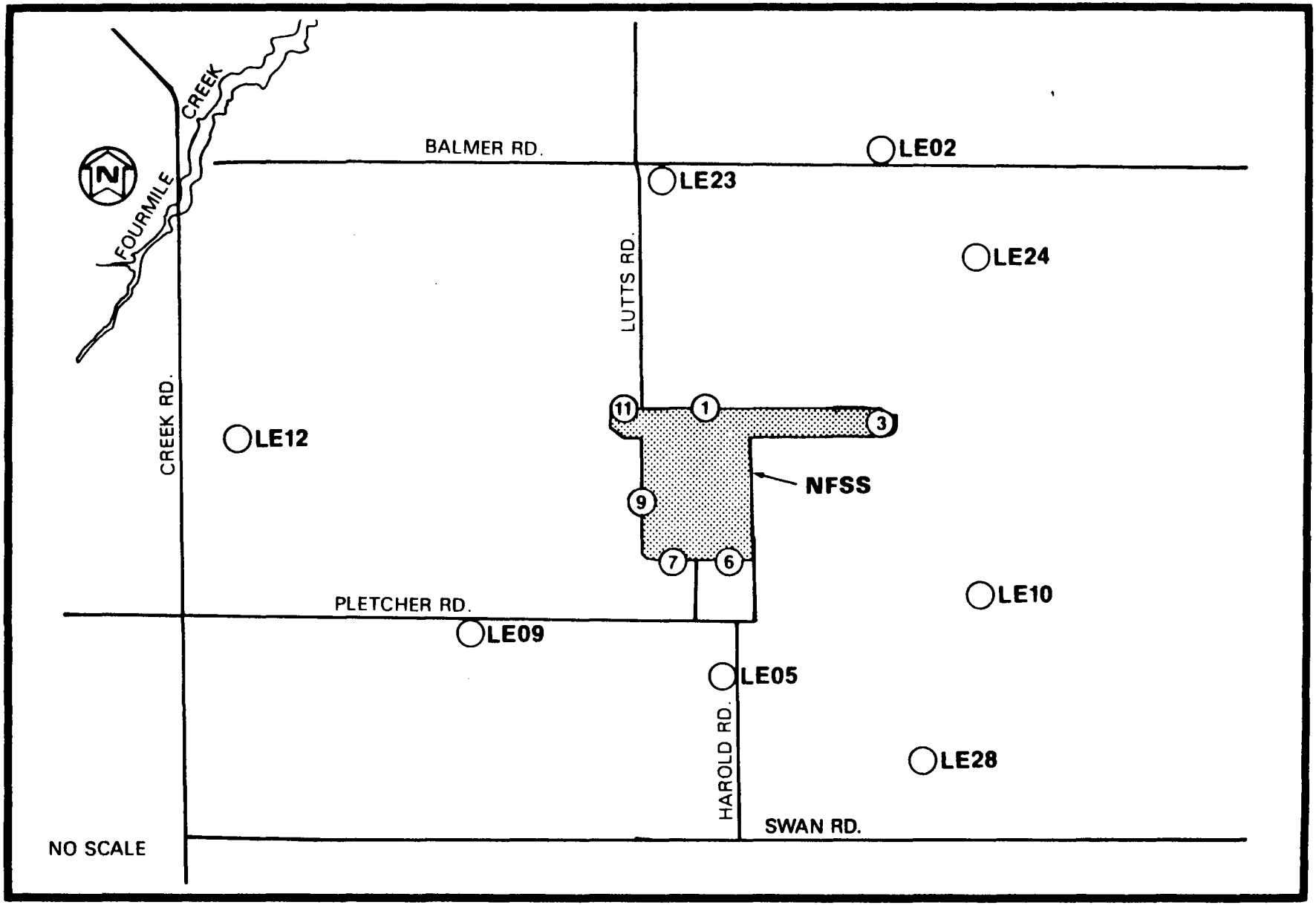


FIGURE 4-1 LOCATIONS OF PERMs AT THE NFSS BOUNDARY AND OFF-SITE

TABLE 4-1

RADON-222 MONITORING DATA FOR PERMs

AT THE NFSS BOUNDARY, 1986[a]

Sampling Location[b]	Concentration (10^{-9} uCi/ml)[c]					
	Quarterly Averages					
	1st	2nd	3rd	Minimum	Maximum	Average
1	0.19	0.28	0.43	0.19	0.43	0.30
3	0.13	0.29	0.22	0.13	0.29	0.21
6	0.15	0.30	0.49	0.15	0.49	0.31
7	0.18	0.37	0.35	0.18	0.37	0.30
9	0.11	0.24	0.29	0.11	0.29	0.21
11	0.17	0.29	0.37	0.17	0.37	0.27
Background[d]	0.15	0.22	0.29	0.15	0.29	0.22

[a]Measurements by Mound Laboratories, Monsanto Research Corporation. These measurements are total radon concentrations; background has not been subtracted.

[b]Sampling locations are shown in Figure 4-1.

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

[d]Averaged from measurements recorded at sampling locations LE13 and LE19 (see Figure 4-2 and Table 4-2).

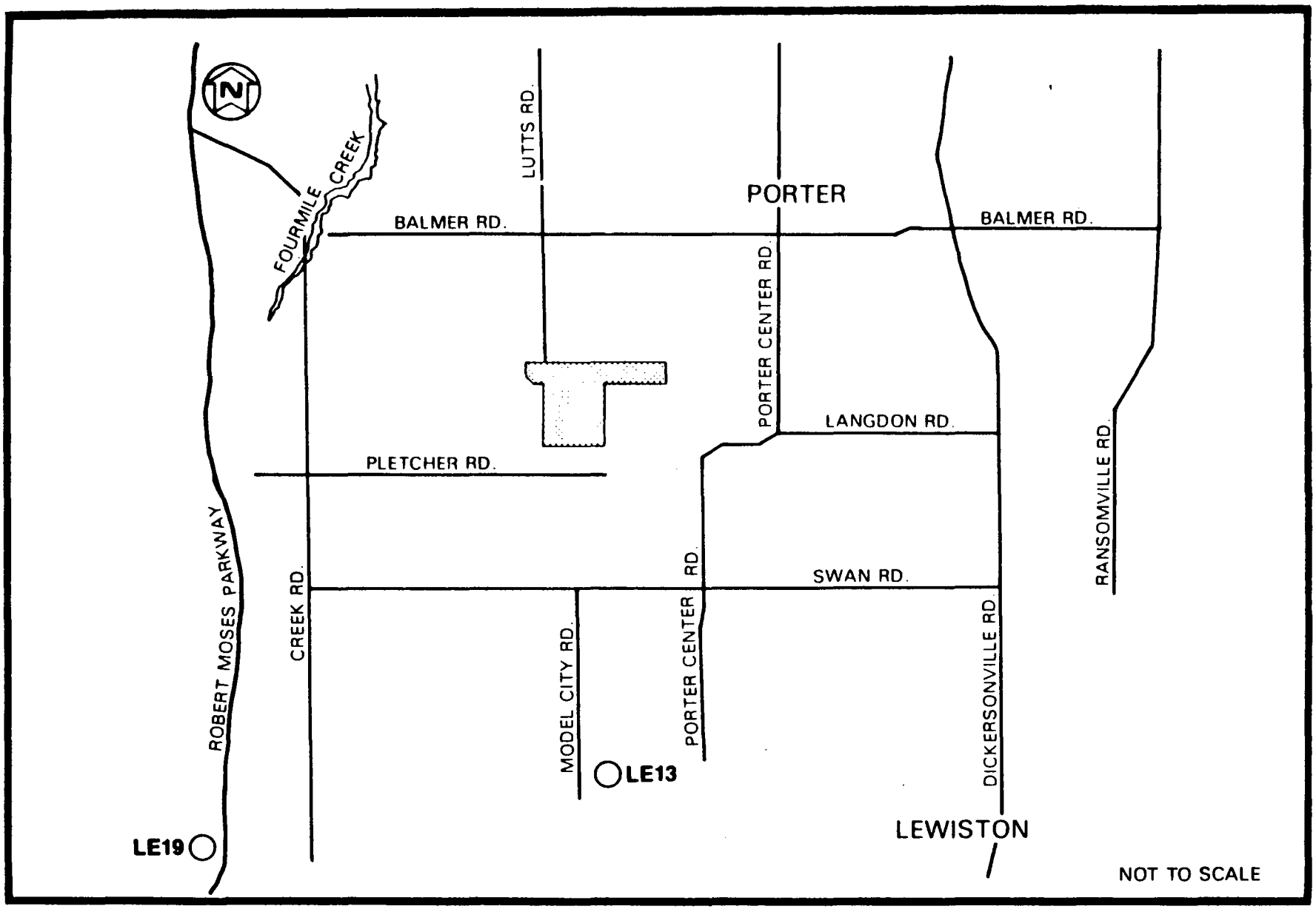


FIGURE 4-2 LOCATIONS OF BACKGROUND PERMs FOR THE NFSS

TABLE 4-2

RADON-222 MONITORING DATA FOR PERMs

IN THE VICINITY OF THE NFSS, 1986[a]

Sampling Location[b]	Concentration (10^{-9} uCi/ml)[c]					
	Quarterly Averages					
	1st	2nd	3rd	Minimum	Maximum	Average
LE02	0.15	0.29	0.25	0.15	0.29	0.23
LE05	0.13	0.25	0.32	0.13	0.32	0.23
LE09	0.13	0.29	0.34	0.13	0.34	0.25
LE10	0.18	0.34	0.55	0.18	0.55	0.35
LE12	0.11	0.27	0.32	0.11	0.32	0.23
LE13[d]	0.14	0.20	0.28	0.14	0.28	0.20
LE19[d]	0.15	0.23	0.31	0.15	0.31	0.23
LE23	0.14	0.30	0.52	0.14	0.52	0.32
LE24	0.16	0.28	0.33	0.16	0.33	0.25
LE28	0.10	0.28	0.42	0.10	0.42	0.26
Background[e]	0.15	0.22	0.29	0.15	0.29	0.22

[a]Measurements by Mound Laboratories, Monsanto Research Corporation. These measurements are total radon concentrations; background has not been subtracted.

[b]Sampling locations are shown in Figure 4-2.

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

[d]These locations form a control group for measuring background radon levels.

[e]Averaged from measurements recorded at sampling locations LE13 and LE19.

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 11.

In late 1986, an additional 36 groundwater monitoring wells were installed around the IWCF to monitor its performance (Ref. 12). These wells will be sampled as part of the 1987 environmental monitoring program; data from them will be reported in future environmental monitoring reports.

4.1.3 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 May 1, 1983, and is in effect for a period of 5 years.

During 1986, 25.8 million liters (6.8 million gal) of treated waste water were released from the site. Discharges consisted of runoff water from the IWCF, washwater from the vehicle decontamination facility, and construction waste water. Water was discharged to the Central Drainage Ditch, which is a tributary of Fourmile Creek. Each discharge request was reviewed and approved by the NYSDEC.

All water discharged was analyzed before and during release for the applicable permit parameters presented in Table 4-3. For radioactivity, discharge limits of 6×10^{-7} uCi/ml (600 pCi/l) for

TABLE 4-3

1986 SPDES PERMIT PARAMETERS FOR THE NFSS[a]

Measured Parameter	Units	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	ml/l	0.30	-
pH	standard unit	6.0-9.0	-
Gross Alpha[c]			
(as Uranium)	uCi/ml	-	6×10^{-7}
(as Radium-226)	uCi/ml	-	3×10^{-8}

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

[b]Best available technology.

[c]Discharge limit.

uranium and 3 x 10^{-8} uCi/ml (30 pCi/l) for radium-226 were applicable. All water released complied with the discharge limits and SPDES permit limits.

4.2 SPECIAL STUDIES

In April 1986 the **Final Environmental Impact Statement for Long-Term Management of the Existing Radioactive Wastes and Residues at the Niagara Falls Storage Site** (Ref. 3) was published. The Record of Decision was published on August 27, 1986, stating that DOE had selected in-place management of the wastes and residues, consistent with EPA guidance, as the long-term disposition of the site.

Listed below are the reports relevant to environmental considerations at the NFSS that were published in 1985 and 1986.

- **Design Report for the Waste Containment Facility at the Niagara Falls Storage Site** (Ref. 1)
- **Report on the Performance Monitoring System for the Interim Waste Containment at the Niagara Falls Storage Site** (Ref. 13)
- **Closure/Post-Closure Plan for the Interim Waste Containment Facility at the Niagara Falls Storage Site** (Ref. 14)
- **Environmental Monitoring Plan for the Niagara Falls Storage Site and the Interim Waste Containment Facility** (Ref. 12)

REFERENCES

1. Bechtel National, Inc. Design Report for the Waste Containment Facility at the Niagara Falls Storage Site, DOE/OR/20722-21, Oak Ridge, TN, May 1986.

2. Bechtel National, Inc. Geologic Report for the Niagara Falls Storage Site, DOE/OR/20722-8, Oak Ridge, TN, June 1984.

3. U. S. Department of Energy. Final Environmental Impact Statement: Long-Term Management of the Existing Radioactive Wastes and Residues at the Niagara Falls Storage Site, DOE/EIS-0109F, Washington, DC, April 1986.

4. Gale Research Company. Climate of the States, 3rd Edition, Vol. 1, Detroit, MI, 1985.

5. Battelle Columbus Laboratories. A Comprehensive Characterization and Hazard Assessment of the DOE Niagara Falls Storage Site, BNI-074, Columbus, OH, June 1981.

6. Memorandum, R.J. Stern, Department of Energy, to Distribution. "Preparation of Annual Site Environmental Reports for Calendar Year 1985" (Attachment: DOE-Derived Concentration Guides for Drinking Water and Breathing Air Contaminated With Radionuclides by Members of the Public), February 28, 1986.

7. Bechtel National, Inc. Niagara Falls Storage Site Environmental Monitoring Report Calendar Year 1982, Report No. 10-05-202-002, Oak Ridge, TN, May 1983.

8. Bechtel National, Inc. Niagara Falls Storage Site Environmental Monitoring Report Calendar Year 1983, DOE/OR/20722-18, Oak Ridge, TN, July 1984.

9. Bechtel National, Inc. Niagara Falls Storage Site Environmental Monitoring Report for Calendar Year 1984, DOE/OR/20722-55, Oak Ridge, TN, July 1985.

10. Bechtel National, Inc. Niagara Falls Storage Site Annual Site Environmental Report Calendar Year 1985, DOE/OR/20722-98, Oak Ridge, TN, April 1986.

11. Memorandum, R.W. Evers, Bechtel National, Inc., to File. "Environmental Monitoring Program - 1986 Environmental Monitoring Data," CCN 043490, March 4, 1987.

12. Bechtel National, Inc. Environmental Monitoring Plan for the Niagara Falls Storage Site and the Interim Waste Containment Facility, DOE/OR/20722-86, Oak Ridge, TN, April 1986.

13. Bechtel National, Inc. Report on the Performance Monitoring System for the Interim Waste Containment at the Niagara Falls Storage Site, DOE/OR/20722-71, Oak Ridge, TN, October 1985.

14. Bechtel National, Inc. Closure/Post-Closure Plan for the Interim Waste Containment Facility at the Niagara Falls Storage Site, DOE/OR/20722-85, Oak Ridge, TN, May 1986.

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 is 100 mrem/yr (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	$\cong$	1 mrem
1 mrem	$\cong$	1000 uR
1 mrem/yr	$\cong$	8.7 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

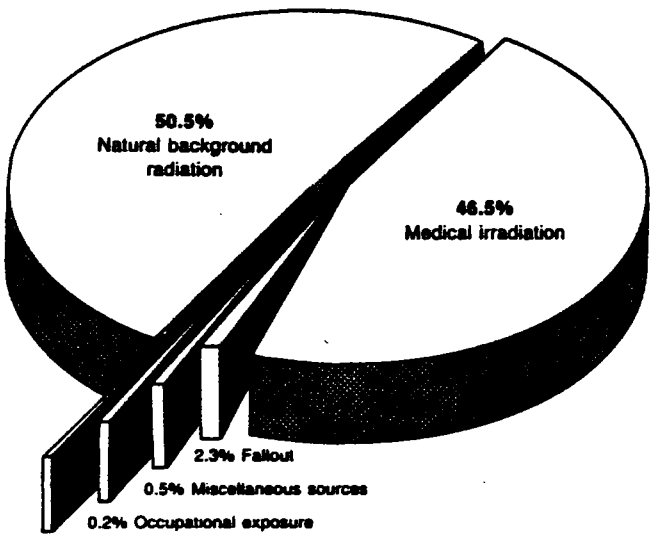
APPENDIX C
ABBREVIATIONS

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.

References

Effect of Ionizing Radiation on Human Health, The. Arthur C. Upton. New York University Medical Center. Atomic Industrial Forum, 1984.

Effects on Populations of Exposure to Low Levels of Ionizing Radiation: 1980. Committee on the Biological Effects of Ionizing Radiations. National Academy Press, 1984.

Radiation Exposure from Consumer Products and Miscellaneous Sources: Report Number 56. National Council on Radiation Protection and Measurements, 1977.

Radiation in Medicine and Industry. A.P. Jacobson and G.P. Sakolosky, 1980.

Radioactivity in Consumer Products. U.S. Nuclear Regulatory Commission, 1978.

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.....26 mrem/year
(add one for each additional 100 feet in elevation)
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
McAlpe, 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)...8,000 mrem/year
(Polonium-210)
Color Television.....1 mrem/year
Gas Lantern Mantle.....3 mrem/hour
(thorium-232)
Highways.....4 mrem/year
Jet Airplane Travel/1,500 miles.....1 mrem
(cosmic)
Natural Gas Stove.....6-9 mrem/year
(radon-222)
Phosphate Fertilizers*.....4 mrem/year
Porcelain Dentures.....1,500 mrem/year
(uranium salts)
Radioluminescent Clock.....9 mrem/year
(radium-226)
Smoke Detector.....0.2 mrem/year
(americium-241)

* 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

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APPENDIX E

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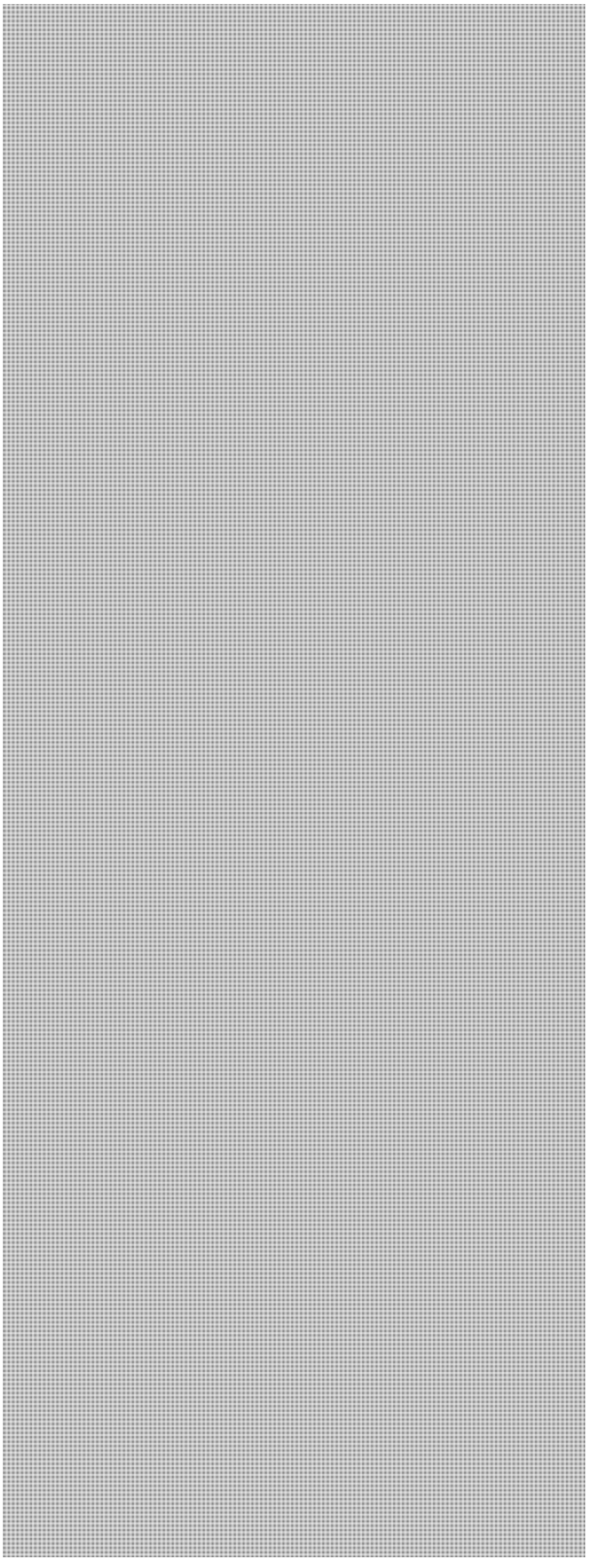

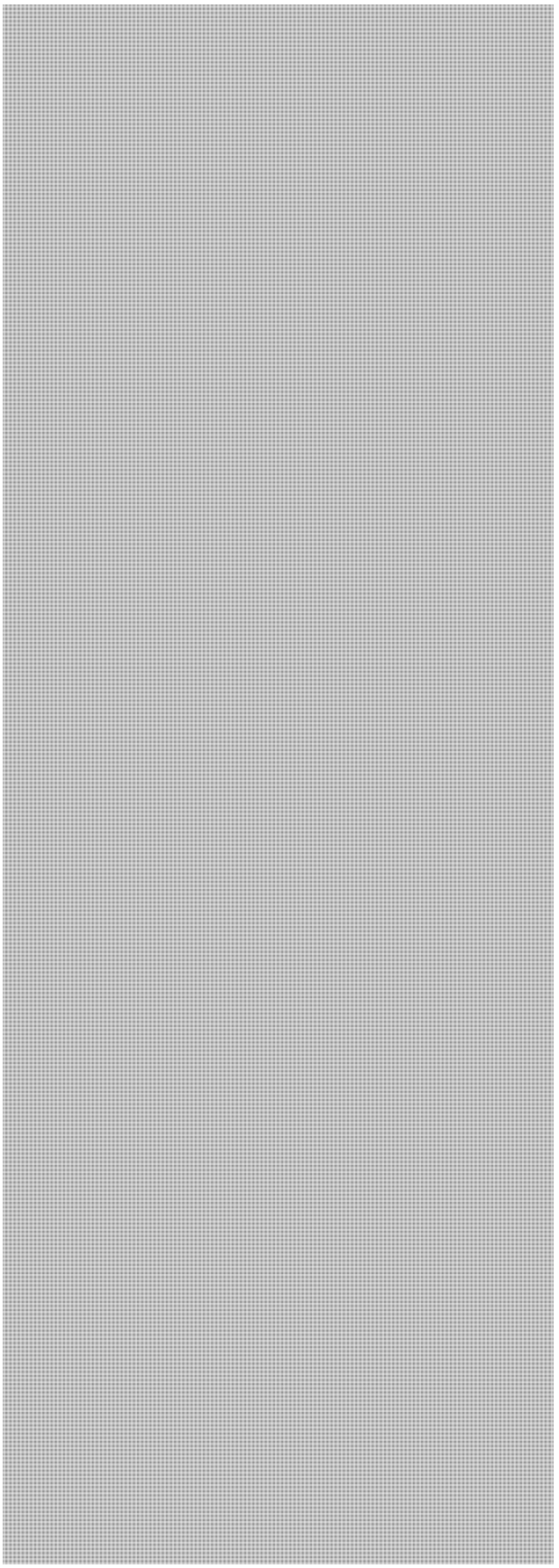

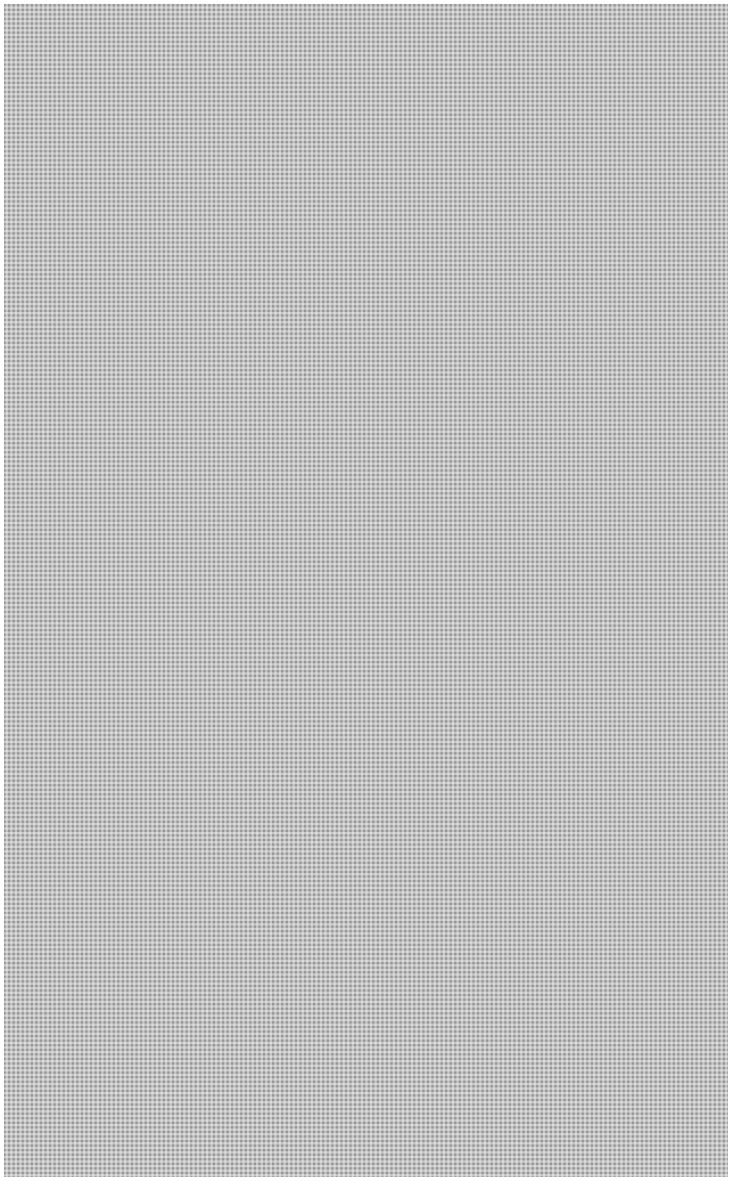

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