1.5.8

RADIOLOGICAL AND NON-RADIOLOGICAL CONTAMINANT

DESCRIPTION FOR THE NIAGARA FALLS STORAGE SITE

by

Bechtel National, Inc.

1.0 RESIDUE DESCRIPTION

Six varieties of pitchblende residues resulting from uranium extraction during and after World War II are currently found within the NFSS. The residues found in the NFSS include R-10 and Middlesex Sands which were obtained from U.S. owned ores, and K-65, L-30, L-50, and F-32 residues which were obtained from African owned ores and are the property of the Afrimet Indussa, African Metals Corporation (Afrimet). The Afrimet residues K-65, L-30, and L-50, were retained primarily for the predicted future economic value of the residual uranium. These residues also contain significant concentrations of potentially recoverable metals including: lead, cobalt, copper, nickel, gold, platinum, palladium, and silver. The F-32 residue is of low grade and is not believed to contain metals in concentrations capable of being economically recovered.

Knowledge of the physical and chemical characteristics of the individual residues will aid in the identification of the site contaminants and the assessment of migration potential. For this reason, inventory records, radiological and chemical analyses, and extraction processing techniques were examined for all the residues found within the NFSS (Anderson et al., 1981). In addition, trace element analysis, lead isotope analysis, and optical and crystallographic analysis were performed on the L-30, L-50, and K-65 residues. Residue ownership, storage location, weight and volume is presented in Table 1.1. Site structures are identified in Figure 1.1. The following is a general residue description. A more detailed presentation may be found in Anderson et al. (1981).

TABLE 1.1

SUMMARY OF THE MAJOR PITCHBLENDE RESIDUES
STORED AT THE DOE-NIAGARA FALLS STORAGE SITE

Residue[1]	Ownership	Storage Location	Weight kg 10^6 (tons)	Volume, m^3 (ft^3)
K-65	Afrimet[2]	Building 434	3.53 (3,891)	3,080 (110,000)
L-30	Afrimet	Building 411	7.46 (8,227)	6,020 (215,000)[3]
L-50	Afrimet	Buildings 413-414	1.70 (1,878)	1,624 (58,000)
F-32	Afrimet	Recarbonation Pit	0.13 (138)	110-336 (3,950-12,000)
Middlesex Sands	United States	Building 410	0.002 (2)	175 (6,180)
R-10	United States	North of Building 411	7.47 (8,235)	7,084 (235,800)[4]

(1) Source: Anderson et al. (1981)
(2) Afrimet Indussa, African Metals Corporation
(3) This residue is also covered by approximately 2,940 m^3 (105,000 ft^3) water.
(4) Approximate volume at time of disposal; total volume and weight of R-10 contaminated material found to be greatly in excess of this number, i.e., 11,340 m^3 (405,000 ft^3) of overburden and 35,000 m^3 (1,235,990 ft^3) of R-10 contaminated underlying soil.

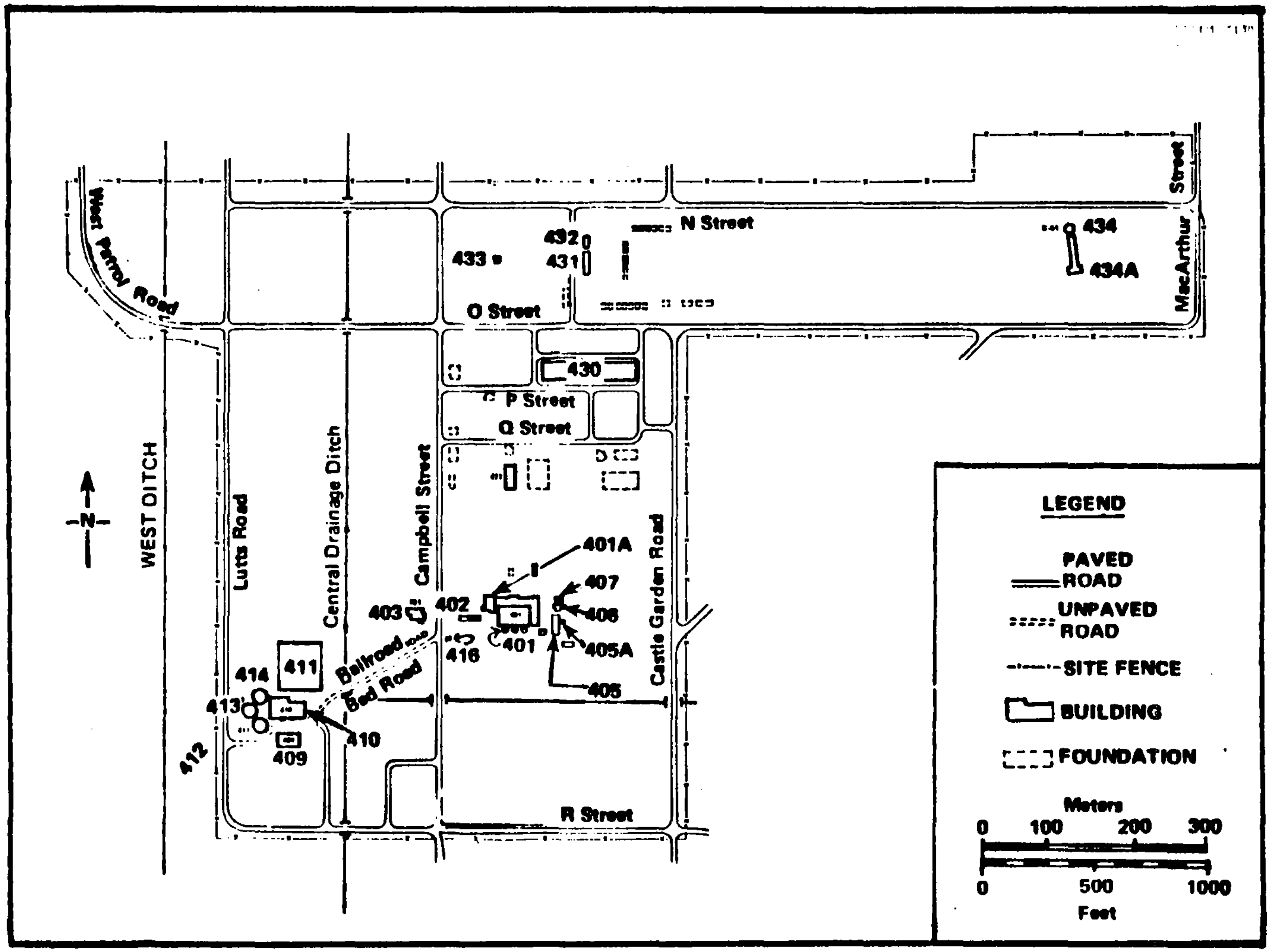


FIGURE 1.1 DIAGRAM OF THE DOE-NIAGARA FALLS STORAGE SITE SHOWING STRUCTURES AND FEATURES OF THE SITE

Source: Anderson et al. (1981)

1.1 K-65 Residue (Afrimet)

The K-65 residue resulted from the processing of high grade African pitchblende (35-60 percent U_3O_8) by the Mallinckrodt Chemical Works, St. Louis, Missouri. The residues are composed of two fractions: (1) a slimes fraction (passes through a 400u mesh) containing solubilized recrystallized fractions including radium contaminated barium sulfate and (2) a sand fraction (does not pass through a 400u mesh) containing undissolved ore particles and soluble silicate secondary minerals. Based on the best available data the K-65 residues have a uranium concentration of 1410-1965 ppm and a radium concentration of approximately 220 ppb.

The physical form of the residue is a wet muscovite clay (approximately 30 percent water) with an appreciable alpha quartz fraction. Chemically the K-65 residues are mixtures of oxides, carbonates, and sulfates with uranium primarily in the form of sodium uranyl carbonate. The metal concentrations of the K-65 residue is shown in Table 1.2.

1.2 L-30 Residue (Afrimet)

The L-30 residue resulted from the processing of low grade pitchblende (approximately 10 percent U_3O_8) by the Linde Ceramics Plant, Tonawanda, New York. The Linde process was a H_2SO_4 leach followed by Na_2CO_3 neutralization of the slurry and filtration of the uranyl carbonate slurry. The filter cake (residue L-30) is stored at the NFSS. The data available suggest uranium concentrations ranging from 830-5000 ppm and radium concentrations from 2-12 ppb. The wide range of values are indicative of the heterogeneity of these residues.

TABLE 1.2

METAL CONCENTRATIONS OF THE K-65 RESIDUES STORED IN BUILDING 434 OF THE DOE-NIAGARA FALLS STORAGE SITE

METAL	CONCENTRATION BCL (a)	CONCENTRATION NLO (b)
Uranium, ppm	500(c) 18,240(d) 30,000(e) 1,410-1,961(f)	500
Lead, ppm	35,000	95,000
Radium, ppb	217	180
Barium, ppm	30,000	-
Iron, ppm	5,000	-
Gold, ppm	<0.2	-
Platinum, ppm	<0.5	-
Palladium, ppm	20	-
Silver, ppm	<3	-
Copper, ppm	500	-
Cobalt, ppm	2,000	-
Nickel, ppm	3,000	-

(a) Battelle Columbus Laboratories.
(b) National Lead of Ohio (Currently National Lead, Inc.).
(c) Direct gamma spectroscopy of the residue.
(d) X-ray diffraction of the residue.
(e) Spark source mass spectroscopy.
(f) Calculated U from Ra measurements.

The L-30 residue is composed primarily of chamosite clay (70 percent) with smaller quantities of alpha quartz (20 percent), barite ($BaSO_4$) and sodium uranyl carbonate $Na_2UO_2(CO_3)_3$). Metal concentrations of the L-30 residue as measured by a number of authors is presented in Table 1.3.

1.3 <u>L-50 Residue (Afrimet)</u>

The L-50 residue resulted from uranium extraction of African pitchblende ores consisting of approximately 7 percent U_3O_8. Uranium and radium concentrations range from 1000-2100 ppm and 7-12 ppb, respectively. The L-50 residue is composed primarily of the clays antigorite (60 percent) and alpha quartz (33 percent). No sodium uranyl carbonate was detected. Metal concentrations of the L-30 residue are presented in Table 1.4

1.4 <u>F-32 Residue (Afrimet)</u>

This residue is the result of uranium extraction of a pitchblende ore obtained from the Belgium Congo area. Inventory data indicates that the uranium concentration in this ore ranged from 4000-6500 ppm. Radium activities of 800 pCi/g have been reported (calculated from ore values).

1.5 <u>Middlesex Sands (U.S.)</u>

These sands are the result of uranium sampling operations at the Middlesex Sampling Plant in Middlesex, New Jersey. This plant was used for the sampling, weighing, assaying, and storage of uranium and thorium ores. The original concentration of uranium was reported to be three percent but measurements made during the Battelle Memorial Institute site characterization (Anderson et al. 1981) indicate current levels of less than 100 ppm uranium and less than 0.01 ppb ^{226}Ra.

TABLE 1.3

METAL CONCENTRATIONS OF THE L-30 RESIDUES
STORED IN BUILDING 411 OF THE DOE-NIAGARA FALLS STORAGE SITE

Metal	BCL[a]	NLO[a]	Vitro[b]	Litz[d]
Uranium, ppm	5,000	1,800	1,950	830
Lead, ppm	7,500-23,500	-	-	7,600
Radium, ppb	12[c]	8	-	2
Barium, ppm	10,000-20,000	-	-	1,900
Iron, ppm	10,000-20,000	-	-	66,000
Gold, ppm	<0.2	-	-	0.7
Platinum, ppm	<0.5	-	-	0.2
Palladium, ppm	2	-	-	6.2
Silver, ppm	<2	-	-	6.2
Copper, ppm	1,500-5,000	2,000	-	1,100
Cobalt, ppm	5,000-10,000	6,200	-	2,600
Nickel, ppm	30,000-50,000	20,000	-	6,200

(a) Source: NLO, Inc., and Battelle Columbus Laboratories, 1980.

(b) Source: Vitro Corp., 1952.

(c) Source: Litz, 1974.

(d) Sample of west bay-stored residues only.

TABLE 1.4

METAL CONCENTRATIONS OF THE L-50 RESIDUES STORED AT THE DOE-NIAGARA FALLS STORAGE SITE

Metal	BCL[a]	NLO[a]
Uranium, ppm	1,000-2,100	1,200-1,300
Lead, ppm	7,000	7,600
Radium, ppb	8-12	7.8-9.3
Barium, ppm	20,000	-
Iron, ppm	20,000	-
Gold, ppm	<0.2	-
Platinum, ppm	<0.5	-
Palladium, ppm	2-3	-
Silver, ppm	<0.5	-
Copper, ppm	2,000-3,000	2,400
Cobalt, ppm	10,000	5,900
Nickel, ppm	20,000-30,000	19,100

(a) Source: NLO, Inc., and Battelle Columbus Laboratories, 1980.

1.6 R-10 Residue (U.S.)

The R-10 residue resulted from the processing of U.S. owned pitchblende ore (3.5 percent U_3O_8). The extraction process was similar to that used by Linde Ceramics which produced the L-30 and L-50 residues. The carbonate filter cake was stored on the soil surface north of Building 411 and the iron cake residue was placed in the same area on a discrete pile near Lutts Road (see Figure 1.1). The initial residue inventory suggested a uranium concentration of approximately 2300 ppm. The concentration of various nonradiological components of the R-10 residue are listed in Table 1.5.

2.0 RADIOLOGICAL AND NON RADIOLOGICAL CONTAMINANT DESCRIPTION AND MIGRATION

The major radiological and nonradiological contaminants found in the NFSS are produced by the radioactive decay of ^{238}U and the release of metals, each of which is contained in the stored residues.

The radioactive decay of ^{238}U, not including two minor branches in the decay scheme, supports 13 lineal radioactive decay products traditionally referred to as daughters (see Figure 2.1). The chain terminates in stable (nonradioactive) ^{206}Pb. In Figure 2.1 alpha decay is indicated by a line directed down and to the left at a 45° angle. The half lives of each member of the decay chain are indicated in the enclosed boxes.

The principal environmental radiological implications and associated health effects of the uranium ore residues stored at the NFSS are related primarily to the following members of the ^{238}U decay chain: ^{230}Th, ^{226}Ra, ^{222}Rn, and ^{222}Rn progeny. The major potential routes of exposure to man are:

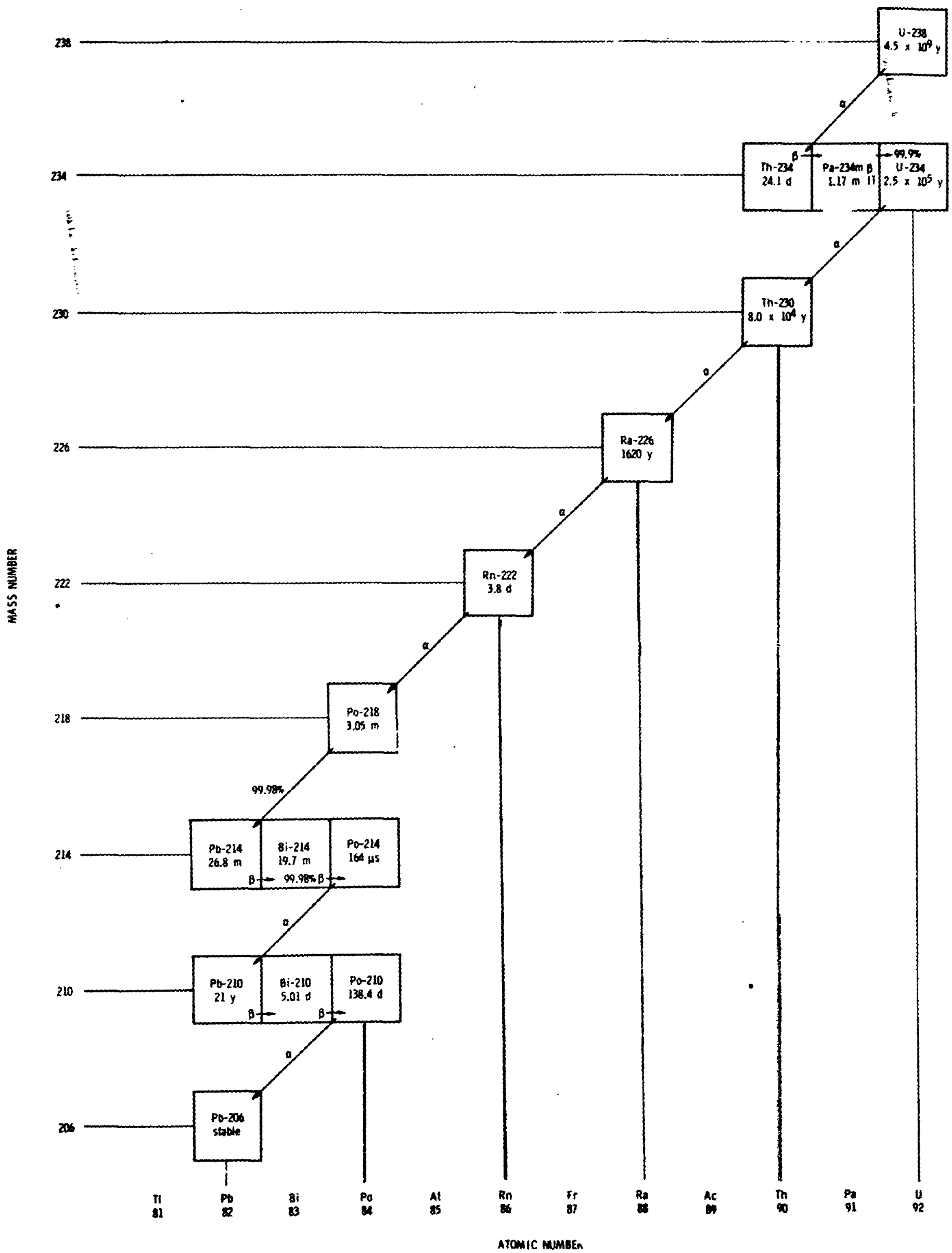


Fig. 2.1 The Uranium-238 Decay Series.

Source: U.S. Nuclear Regulatory Commission (1979)

TABLE 1.5

METAL CONCENTRATIONS AND ACTIVITIES
OF THE R-10 RESIDUE AND SPOILS PILE

Metal	Concentration	
Lead (Pb)	3-650	ppm
Arsenic (As)	0.5-5	ppm
Chromium (Cr)	20-30	ppm
Cerium (Ce	5-100	ppm
Fluorine (F)	3-100	ppm
Strontium (Sr)	50-200	ppm
Barium (Ba)	100-500	ppm
Zirconium (Zr)	10-1000	ppm
Copper (Cu)	20-3000	ppm
Nickel (Ni)	20-5000	ppm
Cobalt (Co)	50-5000	ppm
Vanadium (V)	30-1000	ppm
Titanium (Ti)	1000-3000	ppm
Uranium (U)	1-145	mg/g
Radium (Ra)-Surface	4-9400	pCi/g

SOURCE: Anderson et al. (1981)

(1) Inhalation of windblown residues or contaminated soils with the primary hazard related to the alpha emitters ^{230}Th and ^{226}Ra, each of which causes exposure to both the bone and the lung.

(2) Inhalation of the ^{222}Rn progeny, which decay from the escape of ^{222}Ra.

(3) External whole-body gamma exposure directly from the radionuclides in the residues and R-10 spoils pile.

(4) Ingestion by man of ground or surface water contaminated by radiological components (primarily from ^{226}Ra) leached from the residues or spoils pile and/or from solids physically transported into surface water.

(5) Ingestion by man of terrestrial or aquatic organisms which have ingested and bioaccumulated radioactively contaminated materials.

(6) Erosion and removal of residue or spoils pile material by flood waters.

Elevated concentrations of lead, copper, nickel, cobalt, and vanadium, relative to naturally occurring concentrations (See Table 2.2) have been observed at a number of exposed locations within the NFSS. An excellent discussion of the environmental implications of metals (including absorption, excretion, and toxicity) may be found in Doull et al. (1980).

The following is a discussion of the contaminants which have been found within the NFSS, at the site periphery and at various locations offsite. Contaminant migration resulting from surface runoff through site drainage ditches (Central Drainage Ditch, West Ditch, and the South-31 Ditch) may be found in the Geologic and Hydrologic Data Compilation for the NFSS (see Section 2.0). This document has previously been submitted to Argonne (Dec 1982).

2.1 Onsite Contamination

2.1.1 Identification of Onsite Contaminated Areas

Radiological and non-radiological contamination at the NFSS was characterized by Anderson et al.(1981) through the use of aerial surveys, historical records, and an extensive site survey. Using a 15x15m (50x50 ft) grid system (see Anderson et al. 1981 - pg 5-2) the entire site was surveyed for gamma radiation (at a height of 1m) and beta-gamma radiation (at a height of 1cm). The results of the beta-gamma survey were compared with an established set of background values for the NFSS (Table 2.1) to identify contaminated areas. Gamma instrumental surveys were not used for the identification of contaminated areas because of the shine (detected gamma irradiation attributable to a source other than that from the surface of the soil at the sampling location). Nine contaminated areas were identified through this procedure and are indicated in Figure 2.2. These areas were further evaluated to assess the nature and extent of contamination. Evaluations included screening analysis and alpha/gamma spectroscopy of surface soils and soil cores, vegetation sampling, animal sampling, selected soil analysis for metals and rare earths, and determination of radon emanation rates and air concentrations of radon and suspended particulates. This detailed information may be found in Anderson et al. (1981-Appendix H). A brief summary of each of the contaminated areas follows:

Area 1: R-10 Residue Storage and Spoil Pile

Area 1 can be characterized as 1) radiologically and chemically heterogenous, 2) the major source of radon emanation and off-site sediment contamination, and 3) containing the largest volume of low specific activity waste of each of the

TABLE 2.1

CHARACTERIZATION OF BACKGROUND CONDITIONS

BACKGROUND VALUES FOR RADIOLOGICAL CHARACTERIZATION OF THE DOE-NIAGARA FALLS STORAGE SITE

Parameter	Background Value
Gamma	
Radiation (1 m) (Industrial)	13 uR/hr[a]
Gamma/X-Ray	13 uR/hr[b]
Radiation (1 m)	
(TLDs)	22 uR/hr[c]
Beta-Gamma	60 uR/hr[d]
Radiation (1 cm)	
Surface Soil	
Alpha contamination	3.4 dpm/g[e]
Beta contamination	36 dpm/g
Radon(l)	
Terradex traps (on-site)	9 pCi/l[f]
Alpha scintillation (on-site)	1.4 pCi/l[g]
Detection device not stated (off-site)	0.04-0.50 pCi/l[h]
PERM [m] (off-site)	0.23 pCi/l[i]
Soil Radionuclides	
U (total)	6.9 pCi/g[j]
^{226}Ra	1.89 pCi/g
^{214}Bi	1.58 pCi/g
^{210}Pb	3.19 pCi/g
^{137}Cs	0.27 pCi/g
Sediment Radionuclides	
^{226}Ra	0.5 pC/g[k]

(a) Determined in specific area of southeast quadrant of site with a Ludlum R meter (see Appendix E).

(Cont'd)

Table 2.1 (Cont'd)

(b) Determined off-site in the Niagara Frontier using thermoluminescent dosimeters.

(c Determined in specific area of southeast quadrant of site using thermoluminescent dosimeters.

(d) Determined in a specific area of southeast quadrant of site using an Eberline E-120 with HP 260 probe.

(e) Determined on specified surface soil samples from southeast quadrant of site using a Beckman Wide-Beta II.

(f) Determined using Terradex cups.

(g) Determined on selected soil and air samples from southeast quadrant of site using Randam alpha scintillation detector and Eberline RGMI.

(h) Background values reported for various locations in New York State. Source: National Council on Radiation Protection and Measurements (1975).

(i) Background value obtained from 3 offsite locations (maximum distance to NFSS = 1370m) sampled weekly for a period of 1 year. Source: Humphrey (1980).

(j) Determined on soil core profiles in periphery wells split-spoon sampled using gamma spectroscopy.

(k) Determined on sediment samples from a branch of Twelvemile Creek never receiving drainage from the NFSS.

(l) Maximum Permissable Concentration of ^{222}Rn adopted by the Department of Energy and New York State = 3.0 pCi/l for uncontrolled sites.

(m) Passive Environmental Radon Monitor.

Source: Anderson et al. (1981) except for (h) and (i).

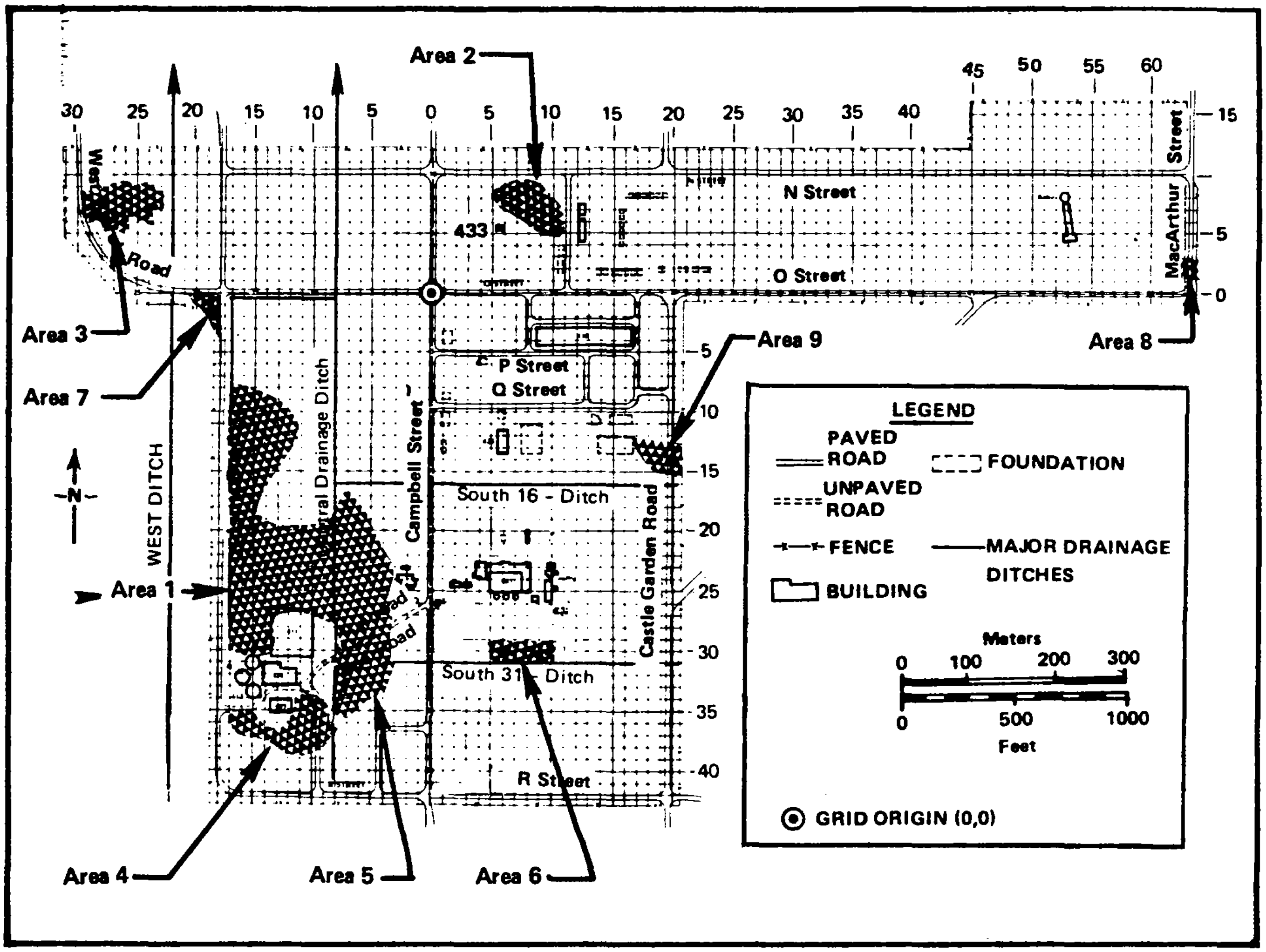


FIGURE 2.2 MAP OF CONTAMINATED AREAS OF THE DOE-NIAGARA FALLS STORAGE SITE

Source: Anderson et al. (1981)

contaminated areas. This area contains significant concentrations of uranium decay chain products (including radium, radon, and radon daughters) and metal contaminants. A summary of the radiological and non-radiological characteristics of the R-10 storage area is shown in Table 2.2.

Maximum uranium concentrations (145 mg/g) in surface soils were found in the spoils pile immediately north of building 411. The greatest observed concentrations of ^{226}Ra in soils (9400 pCi/g) were also found north of building 411. Radon concentrations in air from this area ranged from 10-440 pCi/l during late summer. The average ^{222}Ra concentration at 1.5m above the soil surface for the August, September, October sampling period was 27 pCi/l. This valve is more than nine times the site background level presented in Table 2.1. Elevated (relative to the control area) airborne particulate radiation was observed north of building 411. The area south of building 409 did not show significant airborne particulate radiation (See Anderson et al. 1981, Appendix H, Table H4-11, H4-12).

Vegetation in the area showed ^{222}Ra concentrations up to 5.4 pCi/g and detectable concentrations of ^{214}Pb (2.9 pCi/g,) ^{214}Bi (2.6 pCi/g), and ^{210}Pb (9 pCi/g). No significant animal uptake was observed (See Anderson et al. 1981, Appendix H, Table H3-11, H3-12).

Metal concentrations found in soil samples from the R-10 residue storage and spoil pile area and a comparison with naturally occurring metal concentrations are presented in Table 2.2. Concentrations of vanadium (V), cobalt (Co), nickel (Ni), copper (Cu), and lead (Pb) at the NFSS exceeded the mean of naturally occurring metals. Anderson et al. (1981) states that the metals in this area of the site may present a potential source for on-site and off-site migration and potential hazard during current and proposed remedial action activities.

TABLE 2.2

SUMMARY OF RADIOLOGICAL AND NONRADIOLOGICAL CHARACTERISTICS OF THE R-10 RESIDUE STORAGE AND SPOIL PILE AREA

Characteristics	Range of Values
Radiological	
Gamma (1 m)	13-7000 R/hr
Beta-Gamma (1 cm)	0.06-4 mR/hr
Surface ^{226}Ra	4-9400 pCi/g
Total Uranium	1-145 pCi/g
Depth of ^{226}Ra	6 m (20 ft)
Total Volume >5pCi/g ^{226}Ra	53,340 m^3 (1.9 x 10^6 ft^3)[(a)]
Radon	
Concentration 1.5 m Above Surface	2-440 pCi/l
Concentration at Soil Surface	15-1200 pCi/l

Nonradiological	Naturally Occurring (ppm) (b)		On-Site (ppm)	
	Mean	(Range)	Mean	(Range)
Lead (Pb)	10	(2-200)	321	(3-650)
Arsenic (As)	6	(0.1-40)	2	(0.5-5)
Chromium (Cr)	100	(5-3000)	26	(20-30)
Cerium (Ce)	50	-	35	(5-100)
Fluorine (F)	200	(30-300)	26	(3-100)
Strontium (Sr)	300	(50-1000)	95	(50-200)
Barium (Ba)	500	(100-3000)	315	(100-500)
Zirconium (Zr)	300	(60-2000)	154	(10-1000)
Copper (Cu)	20	(2-100)	449	(20-3000)
Nickel (Ni)	40	(10-1000)	1634	(20-5000)
Cobalt (Co)	8	(1-40)	1030	(50-5000)
Vanadium (V)	100	(20-500)	196	(30-1000)
Titanium (Ti)	5000	(1000 - 10000)	1484	(1000-3000)
Bioconcentrations				
^{226}Ra in Vegetation				5.4 pCi/g

(a) Includes contaminated subsurface soil and spoil pile.
(b) Source: Bowen (1966). Note: Values refer to oven dried soils. Soils near mineral deposits have been omitted in computing ranges.

Area 2: New Naval Waste

Table 2.3 summarizes the radiological and nonradiological characteristics of the New Naval Waste area. Near the one drum of residues located in the area, beta-gamma measurements approached 70 mR/hr. The surface soils contained up to 7,140 pCi/g ^{226}Ra. Using the proposed federal standard (40 CFR 192) of 5.0 pCi ^{226}Ra/g of soil it was determined that soil to a depth of 4.9 m in this area exceeded the standard. The volume of soil exceeding the proposed standard was estimated to be 7,224 m^3 (258,000 ft^3) (Anderson et al. 1981 - See also Appendix H, Table H5-2 and Figure H5-1). The final federal standards (40 CFR 192) (5 pCi ^{226}Ra/g soil in the 15 cm surface layer and 15 pCi/g in any 15 cm layer below the surface layer) as compared to the proposed standard will result in a smaller volume of contaminated material exceeding this limit.

Uptake of ^{226}Ra by vegetation was detectable and was approximately 0.5 pCi/g (see Anderson et al, 1981, Appendix H, Table H3-11). Radon concentrations in air ranged from 350-450 pCi/l (see Anderson et al., 1981, Appendix H, Table H5-3).

Metals in this area were less than that found in the R-10 residue storage area. Only lead was found to exceed naturally occurring levels (see Table 2.2 and Anderson et al., 1981, Appendix H, Table H5-4).

Area 3: Northwest Pads

This area is located in the northwest portion of the site near two small concrete pads. A summary of the radiological and nonradiological characteristics of the area is given in Table 2.4.

TABLE 2.3

SUMMARY OF RADIOLOGICAL AND NONRADIOLOGICAL CHARACTERISTICS OF THE NEW NAVAL WASTE AREA

Characteristic	Range of Values
Radiological	
Gamma (1 m)	1.7-5 mR/hr
Beta-gamma (1 cm)	Background to 4 mR (70 mR near drum)
Surface ^{226}Ra Soil	3-7140 pCi/g
Vegetation ^{226}Ra	0.5 pCi/g
Depth ^{226}Ra >5 pCi/g ^{226}Ra	4.8 m (16 ft)
Total Volume >5 pCi/g ^{226}Ra	7224 m^3 (258,000 ft^3)
Radon concentration (at soil surface)	370-462 pCi/l
Nonradiological	
Lead (Pb)	<0.4-740 ppm
Arsenic (As)	1-3 ppm
Chromium (Cr)	5-50 ppm
Cerium (Ce)	1-30 ppm
Fluorine (F)	10-50 ppm
Strontium (Sr)	30-200 ppm
Barium (Ba)	20-500 ppm
Zirconium (Zr)	3-100 ppm
Copper (Cu)	3-50 ppm
Nickel (Ni)	5-30 ppm
Cobalt (Co)	2-20 ppm
Vanadium (V)	10-50 ppm
Titanium (Ti)	300-3000 ppm

Source: Anderson et al. (1981)

The primary contaminant is cesium 137 (^{137}Cs) (see Anderson et al. (1981), Appendix H, Table H6-1 and H6-2). The contamination is superficial extending to only 1.2 m (4 ft) in depth and covering an area of 1 m^2 (10.8 ft^2) (see Anderson et al. (1981), Appendix H, Figure H6-1). Other isotopes (e.g., ^{226}Ra) are only present in small amounts and may be associated with the slag used for a roadbed found in the area (see Appendix H, Table H6-1). No ^{90}Sr was detected in association with the ^{137}Cs contamination.

Several metals were detected in surface soil (see Table 2.4 and Anderson et al. 1981, Table H6-3). Copper levels exceeded those occurring naturally by an order of magnitude (see Table 2.2). The other observed metals in this area occurred at or below those occurring naturally.

Area 4: South of Building 409

The area south of Building 409 was used for surface storage of crucibles, saw blades, and other materials from metallurgical operations in the Niagara Falls region. This area has residual, superficial contamination remaining to a depth of 0.75 m (2.5 ft), over a 334 m^2 (3600 ft^2) area (see Anderson et al. (1981), Appendix H.7, Figure H7-1 and Table H7-1). Assuming that a 0.75 m depth of excavation would be required over the area, the volume of material exceeding the proposed 5 pCi/g ^{226}Ra standard is approximately 250 m^3 (8829 ft^3). Use of the final standard for ^{226}Ra in soils will result in a decreased volume of material requiring removal. Radon levels were elevated in this area (see Anderson et al. (1981), Appendix H, Tables H7-2 and H7-3).

TABLE 2.4 SUMMARY OF RADIOLOGICAL AND NONRADIOLOGICAL CHARACTERISTICS OF THE NORTHWEST CONTAMINATED AREA

Characteristic	Range of Values
Radiological	
Gamma (1 m)	0.3-2.2 mR/hr
Beta-gamma (1 cm)	Background to 70 mR/hr
Surface ^{226}Ra	1.7-6.9 pCi/g
^{137}Cs surface	1.17×10^3-5.9×10^4 pCi/g
2-4 ft	60.3 pCi/g
Volume above 5 pCi/g ^{226}Ra	NONE
Vegetation	
^{226}Ra	1 pCi/g
^{137}Cs	8.3 pCi/g
Nonradiological	
Chromium (Cr)	50 ppm
Strontium (Sr)	100 ppm
Barium (Ba)	300 ppm
Copper (Cu)	200 ppm
Nickel (Ni)	50 ppm
Titanium (Ti)	1000 ppm

Source ; Anderson et al. (1981)

Area 5: Railroad Bed Road

The railroad bed road area lies west of Campbell Street and east of the Central Drainage Ditch. The area consists of several scattered superficial spills of pitchblende residues near the old railroad bed used for the southwest building complex (see Anderson et al. (1981), Appendix H.8, Tables H8-1 and H8-2). Gamma and beta-gamma levels in these isolated areas were slightly above background levels (see Table 2.1).

Area 6: Slurry Pond

Area 9 is the fill the Boron-10 slurry pond and represents an area of approximately 2,090 m^2 (22,500 ft^2). This material was assumed to be clean fill when used but contains detectable levels of uranium decay products and coal slags. Beta-gamma levels ranged from 0.2-2 mR/hr at 1 cm above the surface (see Anderson et al. (1981), Appendix H, Table H9-1 and H9-2).

Area 7: South of West Patrol Road

Area 7 is presumed to be a spill. It covers an area of 743 m^2 (7500 ft^2) and was found through coring to be only superficial. Assuming a 0.6 m (2 ft) depth of ^{226}Ra contaminated soil exceeding the proposed 5 pCi/g standard, the volume of wastes would be approximately 420 m^3 (15,000 ft^3) (see Anderson et al. (1981), Appendix H, Table H, Table H3-3). The final standard will result in a decreased volume of soil requiring removal.

Area 8: East of McArthur Road

This contaminated location covers an area of 1 m^2 (10.8 ft^2) and is presumed to be a spill from the road. The contamination, however, is superficial, was largely removed in sampling, and is held within the NFSS sample archival system.

Area 9: West of Castle Garden Road

This area is adjacent to the railroad bed and may represent a spill (Anderson et al., 1981), Appendix H, Figs H3-13 and H3-14). The dominant contaminant is ^{137}Cs., averaging 50 pCi/g. The observed ^{226}Ra concentrations did not exceed the 5 pCi/g ^{226}Ra standard. The area was largely removed in sampling and is held within the NFSS sample archival system.

2.1.2 Radon Monitoring

Onsite ^{222}Rn concentrations in addition to those reported by Anderson et al. (1981) were monitored from May 1978 to February 1980 (Humphrey 1980). The two stations monitored (the first located at the intersection of Lutts Road and O Street and the second located south of Building 401) had average radon concentrations of 1.0 and 1.5 pCi/l, respectively. The range of values for these stations during this time period were 0.05 - 2.7 pCi/l and 0.1 -4.2 pCi/l, respectively.

The onsite radon monitoring program was expanded in July 1981. Onsite Terradex monitor locations may be found in Figure 2.3 for 1981 and Figure 2.4 for 1982. Average monthly radon concentrations for 1981 and 1982 are presented in Tables 2.5 and 2.6.

In general the onsite radon concentrations were greatest at the stations surrounding the R-10 residue and spoils pile (Stations 17, 18, 21, 22, 23 and 24). The average radon concentrations at these stations when compared monthly for July through November, however, were considerably lower (by a factor of 8.1) in 1982 than those values obtained for the same period in 1981. The observed reduction in radon concentrations in 1982 may be due in part to remedial action activities, most notably the interim stabilization of the R-10 residue and spoils pile area.

2.1.3 Gamma Radiation Exposure

The results of an on-site gamma survey using thermal luminescent dosimeters (TLD's) positioned at a height of 1m is presented in Anderson et al. (1981 - Appendix H, Table H3-9). The grid system used to collect this data is described in Anderson et al. (1981 - pg 5-2). The greatest gamma exposure was detected near the R-10 residue and spoils pile area (4535 uR/hr at S21.0/W14.0) and the K-65 tower (529 uR/hr at N8.0/E52.0).

A routine gamma exposure monitoring program was begun by Bechtel National, Inc. in the fourth quarter (October-December) of 1981. TLD locations onsite may be found in Figure 2.5. The quarterly results for gamma exposure at the onsite stations are presented in Table 2.7. The greatest gamma exposure was observed at stations 4 and 5 (near the R-10 residues and spoils pile and the L-30 and L-50 residue storage structures) and stations 12 and 14 (near the K-65 residue storage structure).

2.2 Site Periphery Contamination

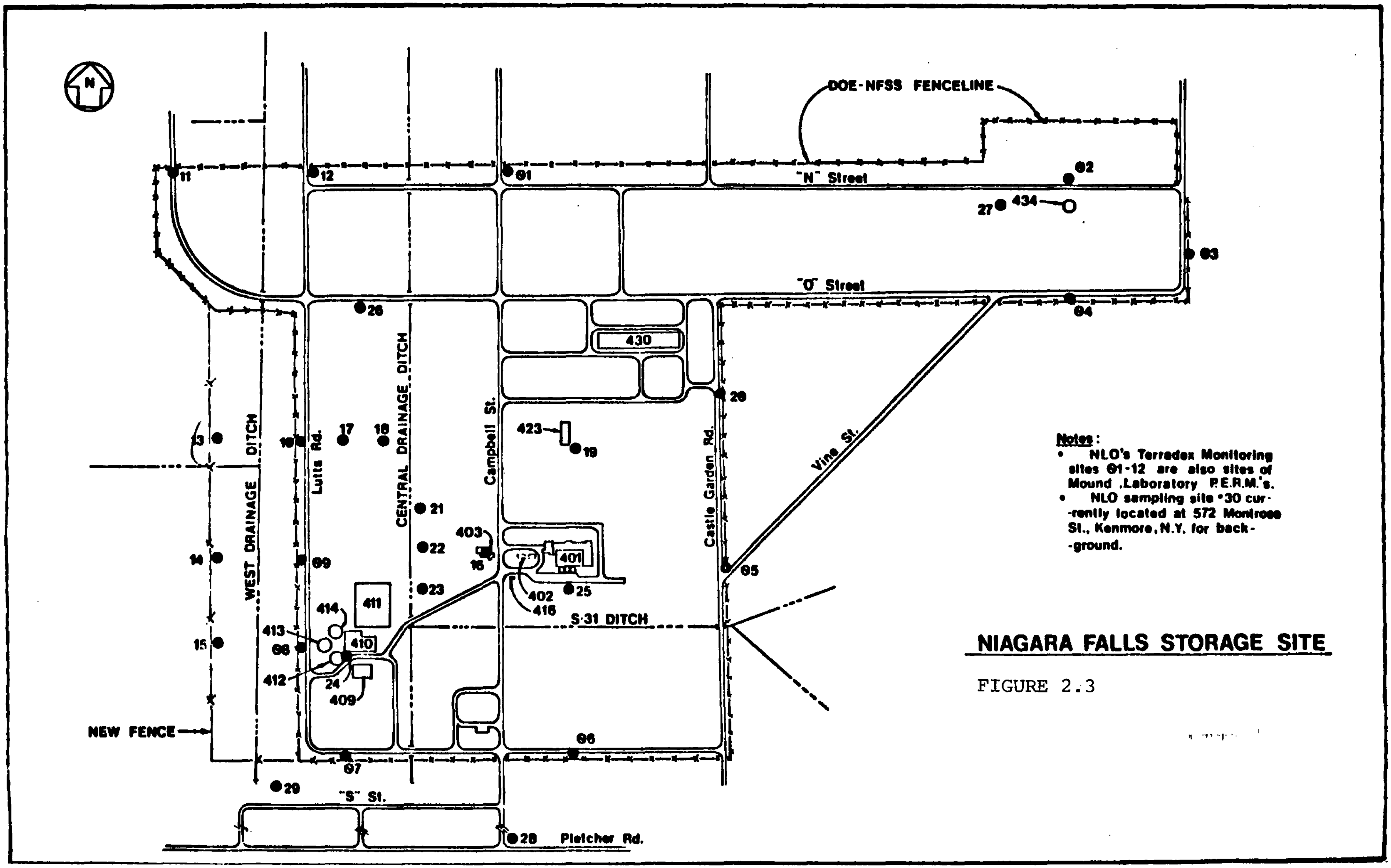
The NFSS is bordered by a hazardous landfill to the north (SCA), a sanitary landfill to the north (SCA), a sanitary landfill to the east (Modern Landfill), a utility right-of-way to the west (Niagara Mohawk) and New York State owned property to the south. The site perimeter, therefore, is not immediately bordered by privately owned residences or frequently used public land.

2.2.1 Core Drillings

Core drillings were performed along the site periphery. The location of these core drillings may be found in Anderson et al. (1981, Appendix H, Figure H2-1). The distribution of ^{226}Ra and ^{210}Pb in soil profiles (see Anderson et al. 1981, Appendix H, Figures H2-2 and H2-3) indicates that contamination is primarily confined to the surficial soils (0-1.2 m, 0-4 ft). The approximate average ^{226}Ra concentration within the northwest, northeast, southwest and southeast guadrants of the site are 3.2, 19.9, 14.1, and 4.5 pCi/g, respectively.

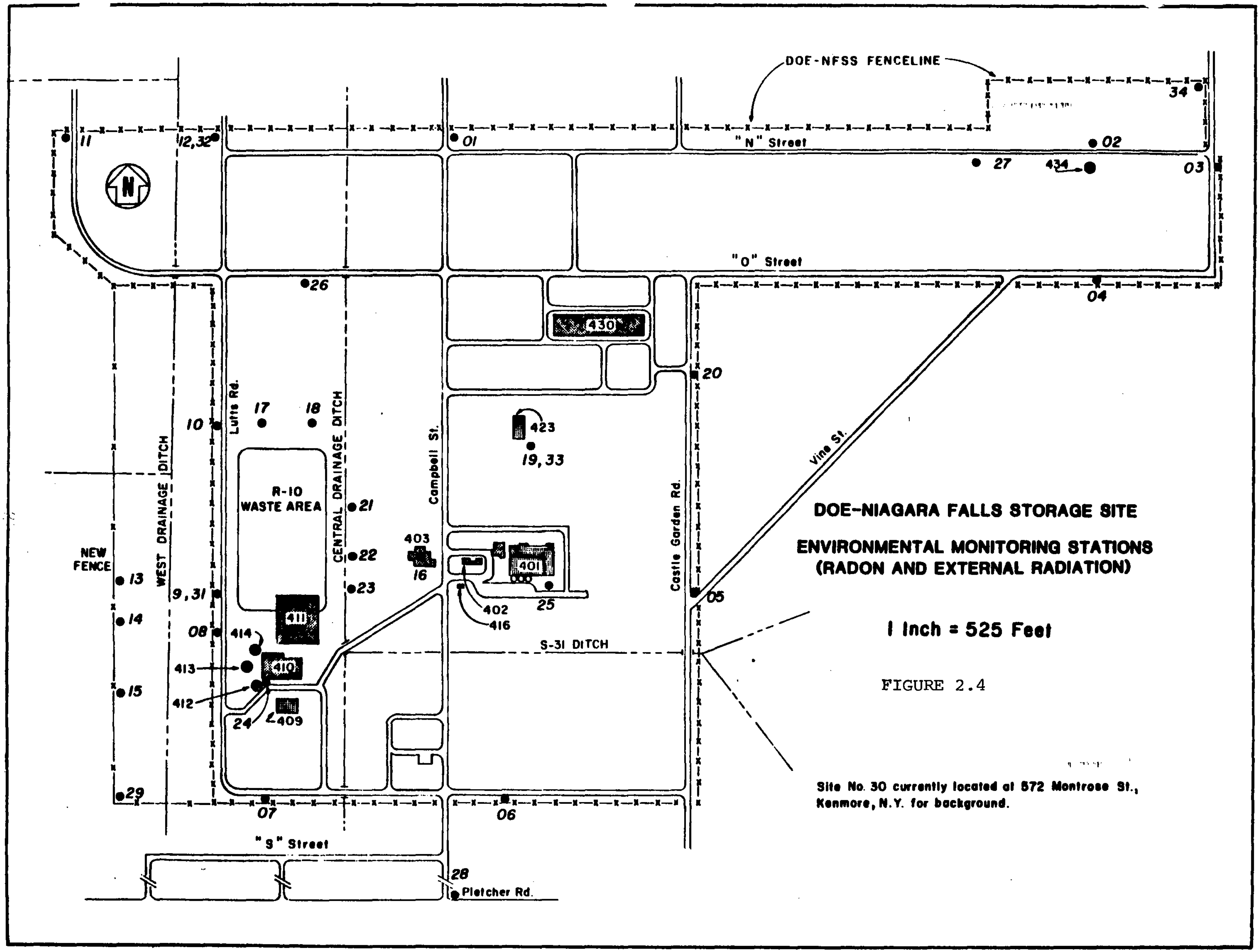
The approximate average ^{210}Pb concentration for the same quadrants listed above are 4.5, 199.5, 19.9, and 10.0 pCi/g, respectively. The concentrations of naturally occurring isotopes in site perimeter soils, including ^{226}Ra and ^{210}Pb, is listed in Anderson et al. (1981, Appendix H, Tables H2-1 and H2-2).

Contaminated areas close to the fence line include: Area 1 (the R-10 residue storage and spoil pile area, Area 8 east of MacArthur Street and Area 9 near Castle Garden Road (see Figure 2.2). Soil contamination was found off-site, west of Lutts Road, and near the R-10 residue storage and spoil



NIAGARA FALLS STORAGE SITE

FIGURE 2.3



DOE-NIAGARA FALLS STORAGE SITE

ENVIRONMENTAL MONITORING STATIONS (RADON AND EXTERNAL RADIATION)

1 Inch = 525 Feet

FIGURE 2.4

TABLE 2.5

RADON-222 CONCENTRATIONS WITHIN THE NFSS (1981)

Station No.	#16	#17	#18	#19	#21	
January						
February						
March						
April						
May						
June						
July	5.76	13.21	10.73	1.52	15.90	
August	6.18	27.13	34.31	1.14	17.34	
September	3.61	11.21	10.78	0.72	6.28	
October	1.25	7.64	7.92	1.34	4.32	
November	1.46	8.01	8.82	0.66	8.36	
December	1.52	4.63	4.32	0.59	3.28	
Yearly Average	3.29	11.97	12.81	0.99	9.24	
Station No.	**#22**	**#23**	**#24**	**#25**	**#26**	**#27**
January						
February						
March						
April						
May						
June						
July	28.94	24.08	9.28	1.94	2.14	1.00
August	56.23	50.41	7.44	1.14	3.14	1.04
September	15.06	10.24	4.68	0.40	2.86	0.72
October	8.74	10.93	4.90	0.70	1.25	0.52
November	15.72	8.36	4.90	0.77	2.61	0.20
December	4.42	3.07	3.70	1.00	1.11	1.00
Yearly Average	21.51	17.85	5.82	0.99	2.18	0.75

NOTE: For station location see Figure 2.3.

TABLE 2.6

RADON-222 CONCENTRATIONS WITHIN THE NFSS (1982)

Station No.	#16	#17	#18	#19	#21
January	-	-	-	-	-
February	1.16	0.86	0.56	0.07	0.36
March	1.37	2.67	1.77	0.67	1.67
April	2.11	5.21	5.02	1.14	3.27
May	1.79	4.25	3.61	2.11	4.68
June	2.37	4.22	2.56	1.36	1.54
July	1.55	2.05	2.84	1.06	1.75
August	1.60	2.83	3.23	1.03	2.58
September	1.44	3.72	2.09	1.82	1.93
October	0.68	2.10	1.48	0.48	1.12
November	0.47	1.37	0.55	0.39	0.55
December					
Yearly Average	1.45	2.93	2.37	1.01	1.94

Station No.	#22	#23	#24	#25	#26	#27
January	-	-	-	-	-	-
February	0.56	0.96	1.06	0.27	0.07	0.17
March	2.88	0.97	2.07	0.27	0.67	0.47
April	4.82	5.60	2.98	1.14	1.04	0.36
May	10.99	11.32	5.86	1.47	1.25	0.50
June	3.39	3.11	3.48	1.08	1.36	1.08
July	2.94	2.34	2.64	0.56	1.16	0.56
August	2.91	2.75	2.58	0.79	1.93	0.79
September	2.09	1.28	2.09	1.99	1.74	1.65
October	1.57	1.21	1.12	0.74	0.91	0.66
November	0.47	0.22	0.22	0.30	0.96	0.22
December						
Yearly Average	3.26	2.98	2.41	0.86	1.11	0.65

NOTE: For station location see Figure 2.4.

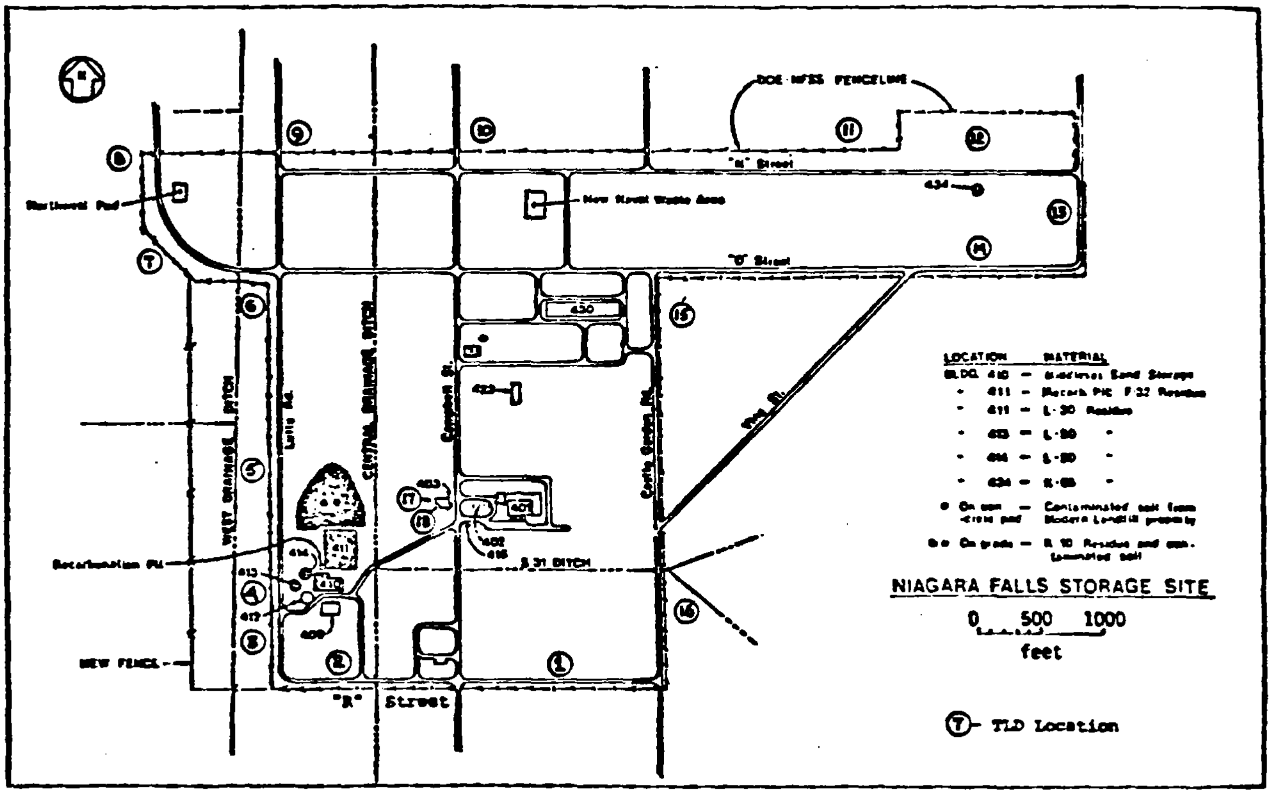


FIGURE 2.5 TLD Location at the NFSS

TABLE 2.7

GAMMA EXPOSURE (uR/hr) AT LOCATIONS WITHIN THE NFSS

	Average Response in uR/hr.			
Station	Oct-Dec 1981	Jan-Mar 1982	Apr-June 1982	July-Sept 1982
3	16	17.5	16.9	16.4
4	55	56.8	58.4	48.7
5	89	103.1	98.4	23.9
6	18	15.9	8.7	21.1
12	99	101.7	116.4	114.8
13	29	29.7	27.8	29.7
14	50	40.8	57.5	59.5

pile area. Soil samples taken west of the fence to the West Ditch were composited for screening. ^{226}Ra concentrations ranged from background to 85 pCi/g in these composites suggesting past erosion from the R-10 area (Anderson et al. 1981).

2.2.2 Radon Monitoring

Radon monitoring along the site periphery has been conducted since April 1978. From April 1978 through August of 1980, nine ^{222}Rn monitors of the PERM (Passive Environmental Radon Monitor) design were located along the NFSS periphery. Three additional sampling locations were selected in September 1980. These monitoring locations are indicated in Figure 2.6. Radon concentrations at these stations were determined weekly through July 1981. During August 1981 the PERM's were replaced with Terradex Type F Track Etch detectors. Radon concentrations were determined monthly using these detectors. In September 1981 a new fence was placed approximately 145 m (475 ft) west of the existing fence along the western perimeter of the site and Terradex monitors (Stations 13, 14 and 15) were added to the sampling program. The radon monitor locations for 1981 and 1982 at the site periphery are indicated in Figures 2.3 and 2.4.

Weekly radon concentrations through February 1980 are presented in Table 2.8. Monthly averages for the PERM collected data and the monthly values for the Terradex collected data are found in Table 2.9.

In general the largest concentrations of ^{222}Rn are observed along the southwest perimeter (Stations 7, 8, 9, 10) of the NFSS. The elevated radon concentrations in this area relative to other monitoring locations along the site periphery is due in part to the R-10 residue and spoils

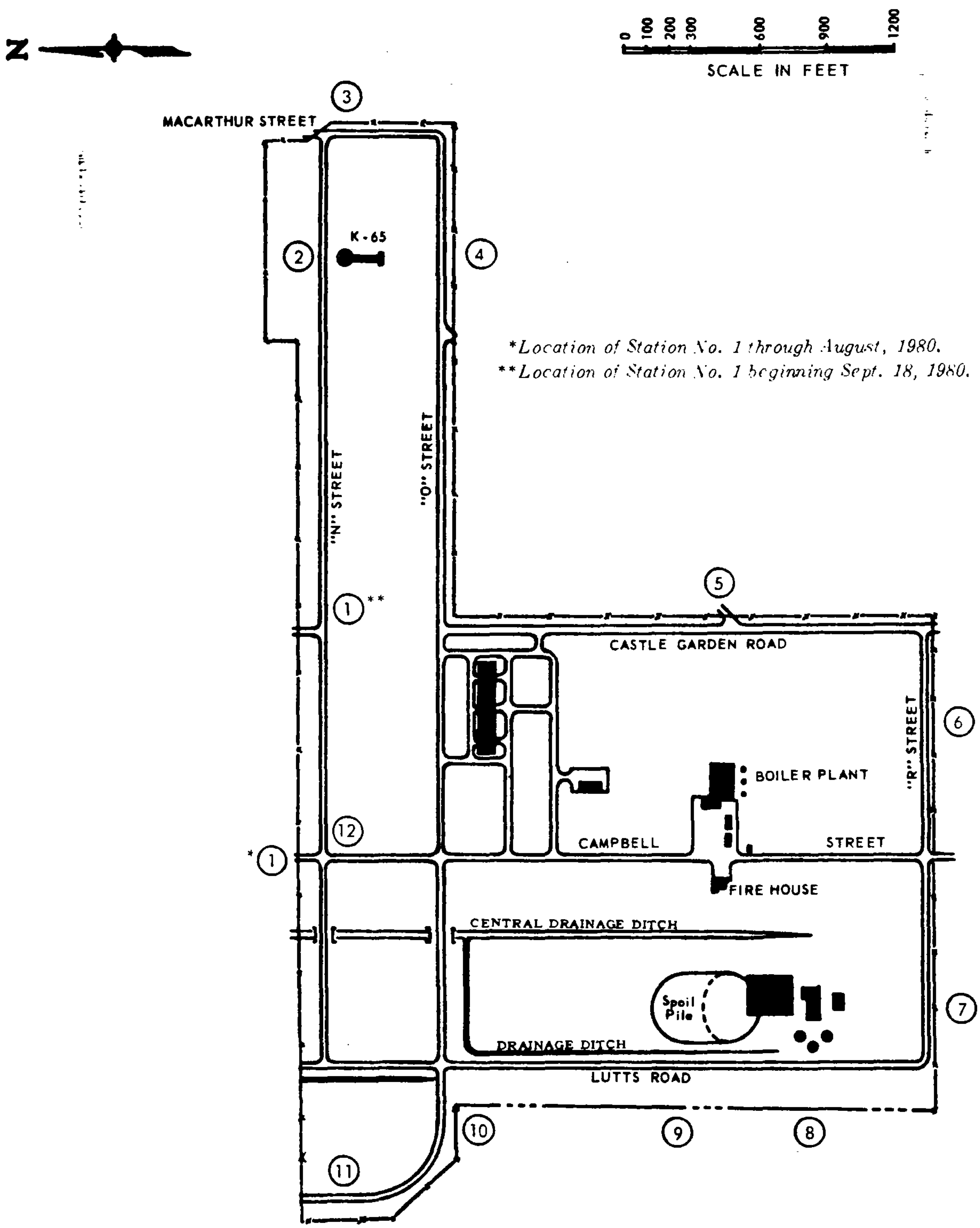


FIGURE 2.6 Boundary Radon Monitoring Locations 1980

TABLE 2.8

Weekly NFSS Radon Concentrations Along the Site Periphery (Aug. 1977-Feb. 1980)

Collection Period	On-Site Locations[1]									Comments
	1	2	3	4	5	6	7	8	9	
8/30 - 9/6/77	--	--	--	0.7	1.0	--	3.5	--	--	Original data; EML PERM's and readings.
5/25 - 6/1/78	0.67	<0.5	<0.5	0.31	<0.5	0.51	<0.5	0.19	--	NLO PERM's and readings.
6/ 1 - 6/15	(2)	0.11	0.42	0.15	0.20	0.32	0.76	2.92	--	
6/15 - 6/29	(2)	0.07	0.38	<0.5	0.54	0.37	<0.5	<0.5	--	
6/29 - 8/10	(2)	0.14	0.51	0.58	0.10	1.10	1.15	4.11	--	
8/10 - 8/17	2.04	1.03	1.08	0.82	0.60	1.39	4.05	14.36	--	
8/17 - 8/24	2.03	<0.5	1.05	<0.5	<0.5	1.60	4.66	14.23	--	
8/24 - 8/31	1.43	0.06	0.04	0.01	0.17	<0.5	0.79	3.82	--	
8/31 - 9/ 7	2.27	<0.5	<0.5	<0.5	(2)	1.04	(2)	(2)	--	
9/ 7 - 9/14	0.80	(2)	<0.5	0.19	0.32	1.40	0.74	13.82	--	
9/14 - 9/21	<0.5	<0.5	<0.5	<0.5	<0.5	0.50	14.85	2.81	--	
9/21 - 9/28	0.45	0.24	0.25	0.24	0.18	0.44	2.53	12.10	--	
9/28 - 10/ 5	(3)	(2)	(2)	(2)	0.48	0.81	1.00	4.30	--	NLO PERM's and EML readings.
10/ 5 - 10/12	0.23	<0.5	(2)	<0.5	<0.5	0.05	0.06	1.29	--	NLO PERM's and readings.
10/12 - 10/19	0.60	<0.5	0.04	<0.5	<0.5	0.46	4.81	22.79	--	NLO PERM's and readings.
10/19 - 10/26	--	--	--	--	--	--	--	1.19[4]	--	All 8 PERM's at #8 position; EML readings.
10/26 - 11/ 2	0.66	0.28	0.68	0.21	(2)	0.33	0.58	(2)	--	NLO PERM's and readings.
11/ 2 - 11/ 9	--	--	--	--	--	--	--	6.01[4]	--	All 8 PERM's at #8 position; EML readings.
11/ 9 - 11/16	0.45	<0.5	<0.5	0.63	<0.5	<0.5	2.04	14.32	--	NLO PERM's and readings.
11/16 - 11/22	1.18	0.70	0.82	0.14	0.74	0.29	<0.5	3.25	--	
11/22 - 11/30	0.27	0.63	0.59	0.58	0.21	0.35	(2)	0.22	--	
11/30 - 12/ 7	(2)	(2)	(2)	(2)	--	(2)	0.35	2.48	0.12	No. 5 PERM relocated at position #9.
12/ 7 - 12/15	--	--	--	--	--	--	--	0.71[4]	--	All 8 PERM's at #8 position; EML readings.
12/15 - 12/28	0.48	0.05	0.75	0.08	--	0.12	1.00	0.11	<0.5	NLO PERM's and readings.
12/28/78-1/4/79	--	--	--	--	--	--	--	3.36[4]	--	All 8 PERM's at #8 position; EML readings.
1/8/79	--	--	--	--	0.20	--	--	--	--	EML reported values.
1/22	0.50	0.05	0.80	0.08	--	0.30[4]	1.00	0.10	<0.5	
2/12	0.30	0.07	--	--	--	--	0.30	1.70	--	
2/26	--	0.15[4]	--	--	--	--	0.60[4]	1.85[4]	--	
3/12	--	0.40	0.20[4]	--	--	--	0.60	1.50	4.00	
4/ 2	--	0.25[4]	0.40	--	0.60	--	--	--	5.70	
4/16	--	0.30	0.30	--	--	--	1.00	3.90	1.10	
4/30	1.90	0.50	--	--	--	0.40	--	1.20	--	
5/21	2.50	0.30[4]	--	--	--	--	1.03[4]	4.05[4]	--	

Source: Humphry (1980)

--Continued - page 2--

TABLE 2.8 CONT'D

Collection Period	On-Site Locations(1) 1	2	3	4	5	6	7	8	9	Comments
5/17 - 5/24/79	1.00	0.20(5)	0.30	0.30(5)	--	0.80(5)	4.60(5)	9.50	--	NLO PERM's and readings.
5/24 - 5/31	0.60	0.20(5)	0.20	0.05	--	0.80	1.50(5)	3.30	2.70	
5/31 - 6/ 6	1.40	0.20	0.50	0.30	--	1.50	3.50	4.10	6.10	
6/ 6 - 6/13	2.00	0.20	0.90	0.50(4)	--	1.70	2.10	2.90	6.90	
6/13 - 6/20	1.60	<0.05	0.40	0.40	--	1.20	2.80	10.70	21.50	
6/20 - 6/27	0.80	0.20	0.30	<0.05	--	1.30	3.20	0.50	1.90	
6/27 - 7/ 5	0.90	0.50	0.60	0.60	0.50(5)	1.90	1.50	1.20	9.70	
7/ 5 - 7/11	3.00	0.20	0.70	<0.1	--	1.80	3.20	0.90	6.20	
7/11 - 7/18	2.90	0.30	0.50	0.20	--	3.10	5.40	8.00	7.30	
7/18 - 7/25	4.20	0.40	0.90	0.50	--	0.10	4.30	16.60	27.30	
7/25 - 8/ 2	2.40	0.30	0.70	0.30	--	1.80	3.50	9.60	6.60	
8/ 2 - 8/ 8	0.60	0.40	0.60	0.90	--	(2)	1.20	6.60	6.70	
8/ 8 - 8/15	1.80	0.30	0.80	0.50	--	0.50	0.50	1.40	6.90	
8/15 - 8/22	0.70	0.10	0.60	1.20	--	2.10	7.60	5.40	7.60	
8/22 - 8/29	0.20	0.20	0.10	0.40	--	1.50	3.00	4.90	6.70	
8/29 - 9/ 5	1.10	0.40	0.60	1.00	--	1.20	3.90	4.10	1.00	
9/ 5 - 9/12	1.50	0.70	0.70	0.70	--	1.70	6.10	9.60	2.80	
9/12 - 9/19	0.10	0.40	0.20	0.60	--	0.50	0.70	5.50	1.50	
9/19 - 9/26	1.80	0.60	0.40	0.90	--	1.10	5.90	45.40	25.30	^{222}Rn pumped from Bldgs.
9/26 - 10/ 3	2.10	0.30	0.70	0.70	--	2.50	4.80	10.50	80.20	^{222}Rn pumped from Bldgs.
10/ 3 - 10/10	0.20	1.50	0.10	0.60	--	0.20	0.40	0.30	0.90	NLO PERM's and readings.
10/10 - 10/17	0.80	0.60	0.30	0.40	--	0.50	2.70	13.30	1.20	
10/17 - 10/24	0.90	0.40	0.30	0.10	--	0.60	1.20	3.60	3.80	
10/24 - 10/31	0.40	0.40	0.50	0.20	--	0.50	0.60	0.60	0.80	
10/31 - 11/ 7	1.50	0.10	0.40	0.40	--	0.70	4.00	2.50	2.40	
11/ 7 - 11/14	0.70	<0.1	0.50	0.30	--	0.80	1.00	2.60	1.30	
11/14 - 11/21	1.30	0.40	0.50	1.00	--	0.80	2.10	3.10	1.80	
11/21 - 11/28	0.70	<0.1	0.40	--	--	0.50	1.30	2.60	4.90(4)	No. 4 PERM moved to #9 pos. + 3 EML PERM's.
11/28 - 12/ 4	0.10	0.20	0.20	--	--	0.20	0.20	0.20	2.17(4)	
12/ 4 - 12/12	0.40	<0.1	0.30	--	--	0.40	0.30	0.20	0.37(4)	
12/12 - 12/19	0.40	0.40	0.10	--	--	0.30	<0.1	0.60	1.20(4)	
12/19 - 12/26	1.20	<0.1	0.30	0.20	--	0.40	1.70	5.50	6.90	NLO PERM's and readings.
12/26 - 1/2/80	0.60	<0.1	0.30	0.10	--	0.40	0.30	0.50	0.20	
1/ 2 - 1/ 9	0.40	0.30	0.20	0.40	--	0.30	0.50	2.20	0.80	
1/ 9 - 1/16	0.40	0.30	0.30	0.10	--	0.10	1.20	1.80	1.60	EML PERM's and readings.
1/16 - 1/23	0.40	0.30	0.20	--	--	0.10	0.40	0.40	0.40	
1/23 - 1/30	0.40	--	--	--	--	--	0.20	0.20	0.30	
1/31 - 2/ 7	0.30	0.40	0.30	0.20	--	0.20	0.30	0.20	0.40	
2/ 8 - 2/15	0.40	0.30	0.60	0.20	--	0.20	0.30	0.80	3.00	

TABLE 2.9

RADON-222 CONCENTRATIONS ALONG THE PERIPHERY OF THE NFSS (1978)

Station No.	#1	#2	#3	#4	#5	#6
January	-	-	-	-	-	-
February	-	-	-	-	-	-
March	-	-	-	-	-	-
April	-	-	-	-	-	-
May	0.67	<0.50	<0.50	0.31	0.50	0.51
June	-	0.09	0.40	0.08	0.37	0.35
July	-	0.14	0.51	0.58	0.10	1.10
August	1.83	0.36	0.72	0.28	0.26	1.00
September	1.01	0.08	0.06	0.11	0.13	0.85
October	0.50	0.09	0.37	0.07	0.16	0.41
November	0.63	0.44	0.47	0.45	0.32	0.21
December	0.48	0.05	0.75	0.08	-	0.12
Yearly Average	0.85	0.16	0.41	0.25	0.22	0.57

Station No.	#7	#8	#9	#10	#11	#12
January	-	-	-			
February	-	-	-			
March	-	-	-			
April	-	-	-			
May	-	0.19	-			
June	0.38	1.46	-			
July	1.15	4.11	-			
August	3.17	10.80	-			
September	6.04	9.58	-			
October	1.61	11.34	-			
November	1.02	5.95	-			
December	0.68	1.10	0.06			
Yearly Average	2.01	5.57	0.06			

NOTE: Date collected using Passive Environmental Radon Monitors (PERMS), station locations may be found in Figure 2.6.

TABLE 2.9 (Cont'd)

RADON-222 CONCENTRATIONS ALONG THE PERIPHERY OF THE NFSS (1979)

Station No.	#1	#2	#3	#4	#5	#6
January	0.50	0.05	0.08	0.08	0.20	0.30
February	0.30	0.12	-	-	-	-
March	-	0.40	0.20	-	-	-
April	1.90	0.33	0.35	-	0.60	0.40
May	1.37	0.27	0.25	0.18	-	0.80
June	1.45	0.15	0.53	0.34	-	1.43
July	2.68	0.34	0.68	0.03	0.50	1.74
August	0.83	0.25	0.53	0.75	-	1.37
September	1.32	0.53	0.48	0.80	-	1.13
October	0.58	0.64	0.38	0.40	-	0.86
November	1.05	0.13	0.45	0.57	-	0.70
December	0.54	0.12	0.24	0.15	-	0.34
Yearly Average	1.14	0.28	0.44	0.37	0.43	0.91

Station No.	#7	#8	#9	#10	#11	#12
January	1.00	1.73	-			
February	0.50	1.80	-			
March	0.60	1.50	4.00			
April	1.00	2.55	3.44			
May	1.84	4.83	2.70			
June	2.90	4.55	9.10			
July	3.58	7.26	11.42			
August	3.08	5.66	6.98			
September	4.15	15.02	22.16			
October	1.94	4.45	1.68			
November	2.10	2.70	3.37			
December	0.50	1.40	1.69			
Yearly Average	1.93	4.36	6.65			

NOTE: Date collected using Passive Environmental Radon Monitors (PERMS) Station locations may be found in Figure 2.6.

TABLE 2.9 (Cont'd)

RADON-222 CONCENTRATIONS ALONG THE PERIPHERY OF THE NFSS (1980)

Station No.	#1	#2	#3	#4	#5	#6
January	0.40	0.30	0.23	0.25	-	0.17
February	0.35	0.35	0.45	0.20	-	0.20
March	0.50	0.33	0.45	0.30	-	0.33
April	0.43	0.35	0.28	0.80	0.80	0.43
May	0.40	0.30	0.27	-	-	0.60
June	1.10	0.30	0.43	-	-	1.10
July	1.15	0.40	0.55	-	-	1.00
August	0.90	0.30	0.47	-	-	0.70
September	1.10	0.77	0.70	0.51	0.64	1.80
October	1.46	0.54	0.46	0.64	0.53	1.13
November	0.88	0.35	0.30	0.23	0.34	0.51
December	1.02	0.58	0.33	0.12	0.28	0.36
Yearly Average	0.81	0.41	0.41	0.38	0.52	0.69

Station No.	#7	#8	#9	#10	#11	#12
January	0.58	1.15	0.78	-	-	-
February	0.30	0.50	1.70	-	-	
March	0.43	1.73	1.50	-	-	-
April	0.85	3.45	4.58	-	-	-
May	0.98	2.50	3.57	-	-	-
June	1.17	4.03	6.70	-	-	-
July	2.35	7.15	8.20	-	-	-
August	1.23	5.60	6.07	-	-	-
September	4.10	16.15	19.00	9.50	3.00	1.70
October	2.95	13.20	14.38	11.68	1.88	1.75
November	0.81	3.98	6.05	4.71	0.89	1.45
December	1.05	5.40	4.57	3.75	0.81	1.05
Yearly Average	1.40	5.18	6.43	7.41	1.64	1.48

NOTE: Date collected using Passive Environmental Radon Monitors (PERMS) Station locations may be found in Figure 2.6.

TABLE 2.9 (Cont'd)

RADON-222 CONCENTRATIONS ALONG THE PERIPHERY OF THE NFSS (1981)

Station No.	#1	#2	#3	#4	#5	#6	#7	#8
January	0.74	0.33	0.25	0.12	0.14	0.21	0.77	4.58
February	0.52	0.20	0.23	0.08	0.16	0.20	0.58	2.55
March	0.53	0.17	0.23	0.08	0.25	0.20	0.40	1.38
April	0.41	0.16	0.20	0.06	0.18	0.16	0.40	1.45
May	0.87	0.33	0.33	0.33	0.32	0.69	1.14	3.56
June	1.05	0.40	0.35	0.33	0.25	0.49	1.10	2.60
July	2.87	1.83	1.83	1.52	2.04	2.35	2.04	4.42
August	1.04	0.36	0.65	0.26	1.14	1.04	4.34	13.07
September	1.36	0.40	0.50	0.61	0.29	0.40	0.61	3.07
October	0.80	0.70	0.89	0.61	0.80	0.80	2.53	13.76
November	0.66	0.43	0.08	0.31	0.43	0.54	1.12	5.95
December	1.42	0.90	0.18	0.49	0.80	1.32	0.59	4.32
Yearly Average	0.84	0.40	0.32	0.30	0.36	0.50		

Station No.	#9	#10	#11	#12	#20	#28	#29
January	4.72	3.01	0.74	0.46	-	-	-
February	2.09	1.52	0.44	0.49	-	-	-
March	1.33	1.90	0.80	0.42	-	-	-
April	1.71	1.82	0.50	0.57	-	-	-
May	2.74	4.61	1.90	0.97	-	-	-
June	3.15	4.81	1.52	0.75	-	-	-
July	6.28	6.28	1.42	1.32	1.00	2.04	2.04
August	15.98	28.49	1.62	1.33	0.94	0.75	2.69
September	5.11	10.03	0.50	0.50	0.50	0.29	0.83
October	21.34	7.28	1.43	1.34	0.52	0.61	-
November	12.96	9.62	3.30	2.15	0.43	0.20	0.66
December	6.07	3.07	1.00	0.90	0.28	0.59	0.80
Yearly Average	6.12	6.87	1.17	0.93	0.61	0.75	1.40

NOTE: July-Dec. data collected using Terradex Track Etch Detector, station locations may be found in Figure 2.3.

TABLE 2.9 (Cont'd)

RADON-222 CONCENTRATIONS ALONG THE PERIPHERY OF THE NFSS (1982)

Station No.	#1	#2	#3	#4	#5	#6	#7	#8
January	-	-	-	-	-	-	-	-
February	0.36	0.27	0.07	0.17	0.36	0.27	0.17	0.27
March	0.27	0.27	0.27	0.27	0.37	0.77	1.07	4.08
April	1.33	1.43	0.94	0.36	0.07	0.55	2.01	4.63
May	1.57	0.93	0.83	0.40	0.50	0.40	1.25	6.82
June	0.80	0.99	0.52	1.36	1.36	0.99	0.99	2.28
July	1.55	0.66	0.56	0.56	0.46	0.46	0.66	1.45
August	1.44	1.03	0.79	1.44	1.44	0.71	0.71	1.20
September	2.58	1.48	1.57	1.65	1.48	1.65	2.26	2.42
October	1.68	0.57	0.48	0.66	0.14	0.31	1.30	0.95
November	0.72	0.39	0.30	0.55	0.22	0.30	0.55	0.30
December								
Yearly Average	1.47	0.80	0.63	0.74	0.64	0.64	1.09	2.44

Station No.	#9	#10	#11	#12	#13	#14	#15	#20
January	-	-	-	-	-	-	-	-
February	0.86	0.76	0.17	0.27	0.17	0.07	0.17	0.46
March	5.18	2.67	0.67	1.17	0.77	-	-	0.47
April	4.92	4.24	0.85	1.14	0.55	-	-	1.04
May	13.78	4.46	1.36	0.83	0.83	-	-	0.61
June	2.00	1.08	0.16	0.34	0.62	-	-	0.89
July	1.25	0.80	0.46	0.56	0.46	-	-	1.25
August	0.71	0.38	0.95	-	0.46	0.38	0.14	1.28
September	2.09	2.09	3.33	2.66	2.42	1.28	3.07	0.98
October	0.95	1.48	1.08	-	2.27	0.77	0.50	0.66
November	0.55	2.61	0.22	0.47	0.14	1.21	0.30	0.22
December								
Yearly Average	3.22	2.14	0.92	0.92	0.86	0.74	0.83	0.79

NOTE: Data collected using Terradex Track Etch Detectors station locations may be found in Figure 2.4.

TABLE 2.9 (Cont'd)

RADON-222 CONCENTRATIONS ALONG THE PERIPHERY OF THE NFSS (1982)

Station No.	#28	#29
January	-	-
February	0.07	0.46
March	0.37	0.37
April	0.65	7.73
May	1.57	0.83
June	1.08	0.99
July	0.27	0.46
August	1.28	0.71
September	1.77	1.77
October	0.59	0.41
November	0.14	0.47
December		
Yearly Average	0.78	1.42

pile. The average radon concentrations at these stations when compared monthly for February through November, however, were lower (by a factor of 2.4) in 1982 than these values for the same period in 1981. This observed reduction in radon concentrations in 1982, as stated previously, may be due in part to remedial action activities conducted on the R-10 residue and spoils pile.

2.2.3 Gamma Radiation Exposure

Anderson et al. (1981) identified portions of the NFSS periphery which exceeded the gamma (1m) and/or beta-gamma (1cm) background instrument readings listed in Table 2.2. The three areas exceeding these background readings are (1) near Building 434 storing K-65 residues, (2) near the southwest storage complex (Buildings 411, 413, 414, and R-10 residue and spoils pile area) and (3) the area west of Castle Garden Road between the South-31 ditch and P Street (see Figure 2.7). The results of gamma and beta-gamma instrument surveys may be found in Anderson et al. (1981, Appendix H.3.) A description of the grid system used to collect this information may be found in Anderson et al. (1981, pg 5-2)

Results of the gamma exposure monitoring program conducted by Bechtel National, Inc. at the site periphery are presented in Table 2.10. TLD monitor locations may be found in Figure 2.5. Gamma exposure at the site periphery during the four quarter monitoring period was substantially lower than the gamma exposure detected at onsite locations during the same time period (See Table 2.7). The highest gamma exposure detected at the site periphery was 13.8 uR/hr (120.9 mR/yr).

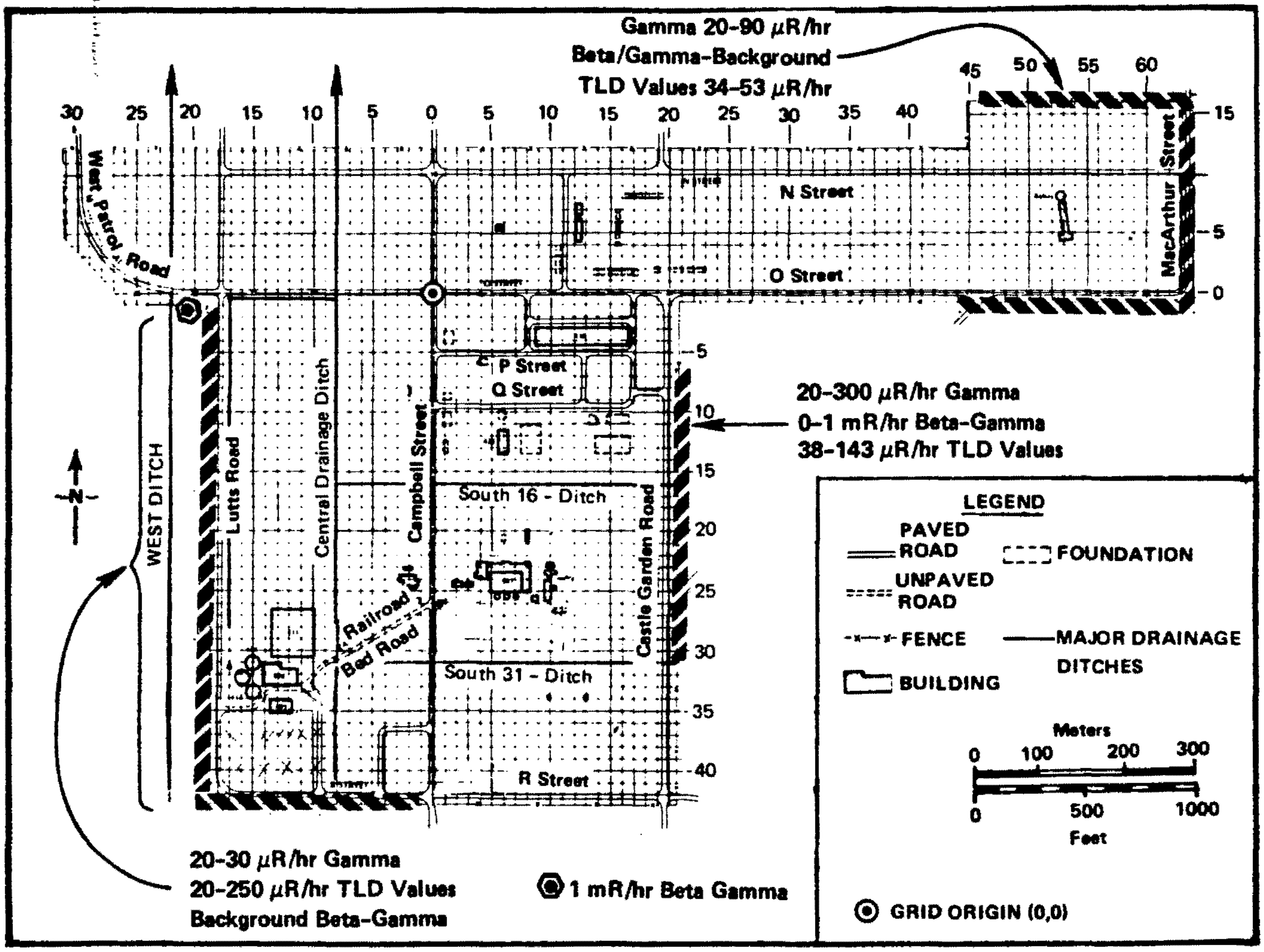


FIGURE 2.6. Periphery Areas of the Site which Exceeded Background Instrumental (1m Gamma, 1 cm Beta-Gamma) Readings

Source: Anderson et al. (1981)

TABLE 2.10

EXTERNAL RADIATION MONITORING AT THE NFSS PERIPHERY

Average Response in mR/hr

STATION	OCT-DEC 1981	JAN-MAR 1982	APR-JUNE 1982	JULY-SEPT 1982
1	-	8.8	8.3	9.3
2	14	12.8	-	13.8
7	11	9.4	10.4	11.8
8	9	8.8	9.4	11.8
9	8	8.0	9.2	11.2
10	9	9.8	10.2	12.5
11	11	10.8	10.8	12.5
15	9	11.9	12.6	13.7
16	11	-	10.5	11.9

2.3 Offsite Contamination

Contaminant migration from the NFSS to offsite areas via surface water and the groundwater drainage systems is described in detail in the Geological and Hydrological Data Compilation for the NFSS (See Sections 2.0 and 3.0) which has previously been submitted to Argonne (Dec. 1982).

In general the most rapid movement of radiological and non-radiological contaminants at the NFSS is via surface water drainage (Acres American, 1980). The migration of metals from the NFSS to offsite areas is lessened to a degree by the alkaline nature of the soils and clay adsorptivity (Anderson et al., 1981).

Using soil permeability data obtained from field and laboratory tests, Acres American (1980 - pg 74-79) estimated a slow vertical migration rate of 0.007 m (0.02 ft) per year between the ground surface and the lower soil aquifer (a distance of 10.4 m (3.4 ft.). Horizontal migration of groundwater was estimated to be 0.009 m (0.03 ft.) per year. Acres American (1980) concluded that the rate of groundwater flow in the soil overburden is slow and would significantly restrict the offsite migration of contaminants in groundwater.

2.3.1 Radon Monitoring

Offsite ^{222}Rn determinations were begun in August of 1978. Initially 20 offsite stations (see Figure 2.8) were monitored weekly for ^{222}Rn using PERM's. Results for August 1978 through May 1979 are presented in Table 2.11. Radon concentrations observed during all of 1979 and 1980 (January through August) are shown in Tables 2.12 and 2.13, respectively. In September 1980 a number of monitor locations were changed and an additional 10 PERM's were added to the sampling program. The current location of these stations is presented in Figure 2.9.

Seven remote monitors in addition to Station 18 and one monitor near Station 16 are not identified in Figure 2.9. Weekly values for these stations are averaged and presented quarterly from December 1980 through December 1981 in Table 2.14.

Radon concentrations for this time period were generally highest during the summer quarter (July - October) and at stations in the immediate vicinity of the NFSS (Stations 1, 2, 3, 4, 13 and 15). The results of radon monitoring from September - December 1980, the location of stations 23-30, and any updated radon data will be forwarded as soon as they become available.

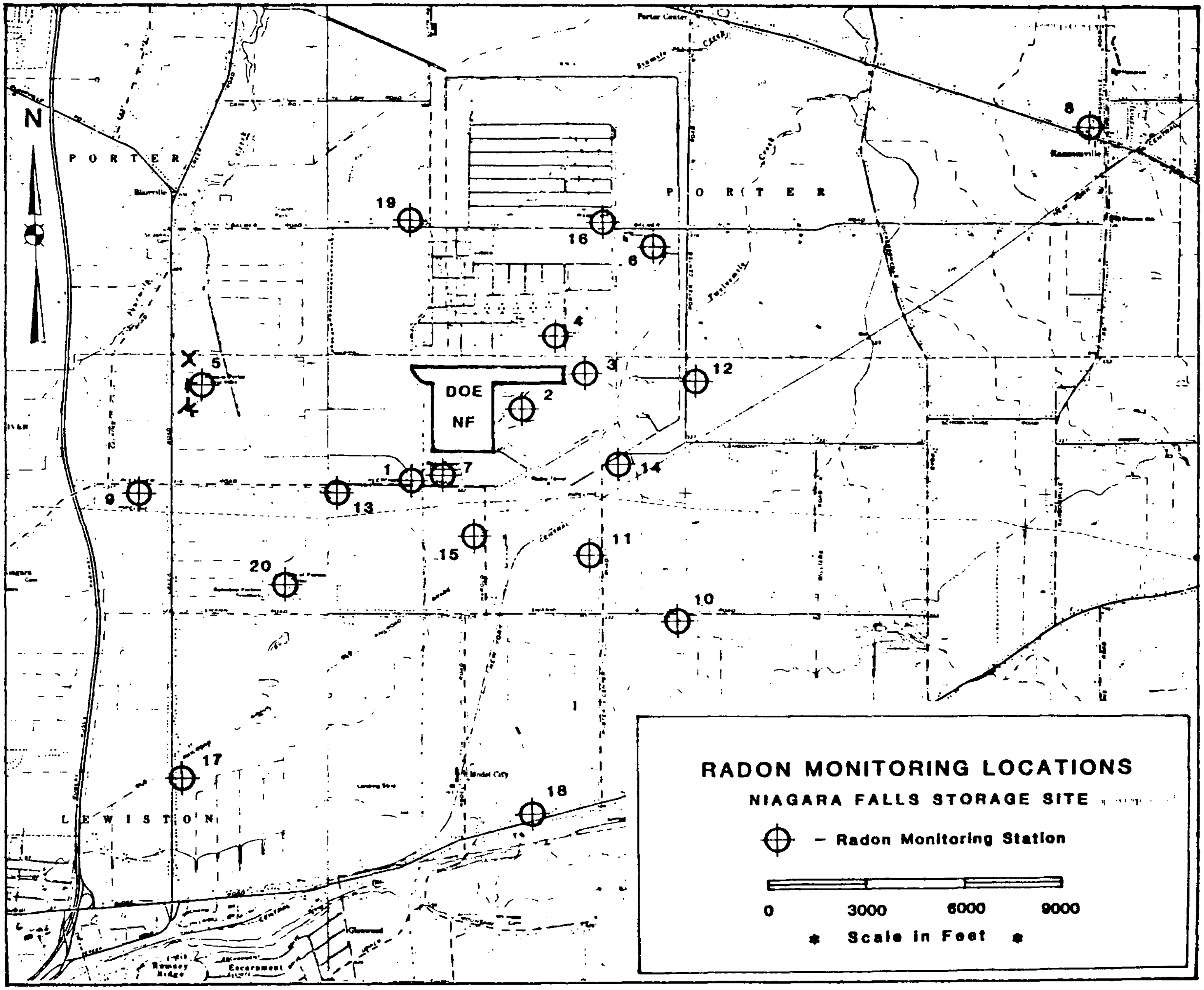


Figure 2.8 Offsite Radon Monitoring Locations1978 to 1980
Source: Weidner & Boback (1981)

TABLE 2.11

OFFSITE RADON CONCENTRATIONS (August 1978 - May 1979)

Station	Radon Concentration (pCi/l) Minimum	Maximum	Mean
1	0.1	0.6	0.3
2	0.03	0.8	0.4
3	<0.03	0.5	0.3
4	<0.03	0.8	0.2
5	0.1	0.4	0.2
6	0.1	0.4	0.2
7	0.2	1.6	0.6
8	0.1	0.6	0.2
9	0.1	0.3	0.2
10	0.07	0.4	0.2
11	0.1	0.5	0.2
12	0.1	0.6	0.2
13	0.08	0.4	0.2
14	0.2	0.4	0.3
15	0.1	0.3	0.2
16	0.09	0.4	0.3
17	0.09	0.2	0.1
18	0.08	0.3	0.1
19	0.1	0.4	0.2

SOURCE: NLCO-003EV (Special)

TABLE 2-12

OFFSITE RADON CONCENTRATIONS (January 1979 - December 1980)

Station	Number of Samples	Radon Concentration (pCi/l) Minimum	Maximum	Mean
1	14	0.1	2.4	0.7
2	12	0.3	0.6	0.4
3	15	0.2	0.6	0.3
4	16	0.1	0.6	0.3
5	18	0.1	0.4	0.2
6	12	0.1	0.5	0.2
7	10	0.2	2.5	0.8
8	13	0.08	0.4	0.2
9	13	0.08	0.5	0.3
10	12	0.07	0.4	0.2
11	15	0.1	0.4	0.2
12	14	0.1	0.4	0.2
13	15	0.08	0.4	0.2
14	12	0.1	0.6	0.3
15	10	0.1	0.4	0.2
16	13	0.07	0.6	0.3
17	19	0.06	0.2	0.1
18	21	0.08	0.3	0.1
19	16	0.1	0.8	0.4
20	13	0.09	0.4	0.2

SOURCE: NLCO-007 EV

TABLE 2-13

OFFSITE RADON CONCENTRATIONS (January 1980 - August 1980)

Station	Number of Samples	Radon Concentration (pCi/l) Minimum	Maximum	Mean
1	6	0.2	0.4	0.3
2	6	0.2	0.5	0.4
3	6	0.2	0.5	0.3
4	6	0.1	0.3	0.2
5	10	0.1	0.2	0.2
6	5	0.1	0.3	0.2
7	6	0.1	0.2	0.2
8	11	0.06	0.3	0.2
9	9	0.07	0.3	0.2
10	7	0.1	0.2	0.1
11	9	0.06	0.3	0.2
12	10	0.07	0.3	0.2
13	9	0.1	0.3	0.2
14	10	0.1	0.2	0.2
15	10	0.1	0.4	0.2
16	6	0.1	0.6	0.3
17	16	0.05	0.2	0.1
18	17	0.05	0.3	0.1
19	17	0.1	0.3	0.2
20	13	0.08	0.2	0.2

SOURCE: NLCO-007 EV

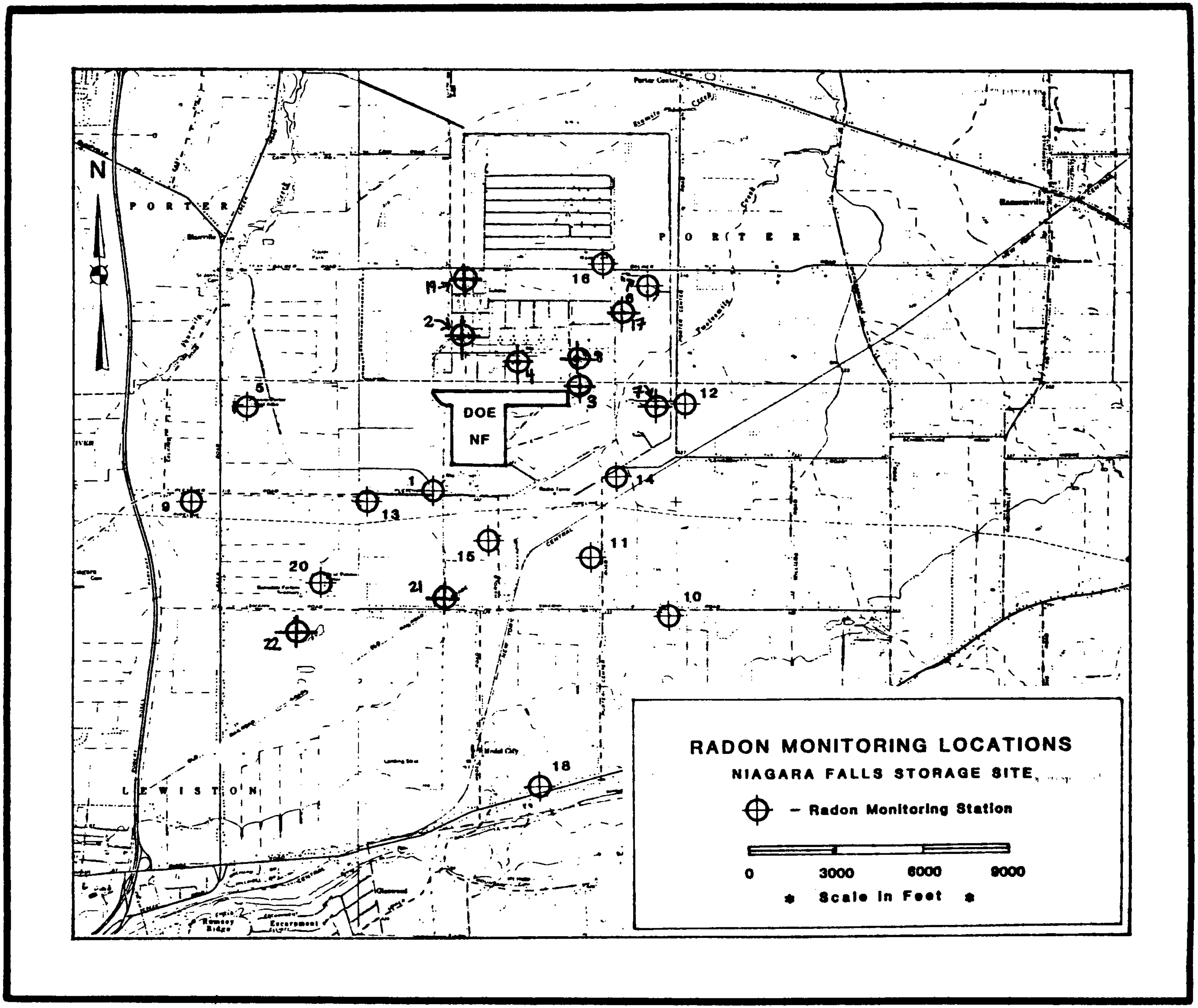


Figure 2.9. Offsite Radon Monitoring Locations 1980 to present
Source: Modified from Weidner and Boback (1981)

TABLE 2.14

OFFSITE RADON CONCENTRATIONS (DEC 1980 - DEC 1981)

Radon Concentration (pCi/l)

Station	DEC 30- APR 1	APR 1-JUL 2	JUL 1 - OCT 1	SEP 30 - DEC 31
1	0.26	0.28	0.89	0.74
2	0.27	0.39	0.72	0.51
3	0.26	0.33	0.56	0.39
4	0.23	0.27	0.49	0.28
5	0.15	0.17	0.27	0.25
6	0.17	0.18	0.30	0.18
7	0.19	0.22	0.37	0.22
8	0.15	0.16	0.32	0.19
9	0.15	0.17	0.26	0.19
10	0.14	0.16	0.25	0.15
11	0.18	0.21	0.30	0.16
12	0.20	0.24	0.41	0.22
13	0.18	0.22	0.56	0.37
14	0.14	0.15	0.35	0.23
15	0.18	0.22	0.46	0.28
16	0.11	0.14	0.26	0.18
17	0.18	0.19	0.39	0.26
18	0.14	0.16	0.29	0.15
19	0.22	0.24	0.43	0.31
20	0.13	0.14	0.25	0.17
21	0.16	0.17	0.35	0.31
22	0.14	0.16	0.26	0.20
23	0.17	0.19	0.41	0.28
24	0.19	0.22	0.28	0.16
25	0.17	0.20	0.31	0.20
26	0.16	0.18	0.31	0.22
27	0.16	0.17	0.33	0.20
28	0.14	0.16	0.26	0.19
29	0.13	0.15	0.23	0.15
30	0.11	0.14	0.22	0.16

2.3.2 Gamma Radiation Exposure

Anderson et al. (1981) measured offsite gamma radiation exposure using thermal luminescent dosimeters (TLD's). Offsite dosimeters were located at the mouths of Fourmile Creek and Sixmile Creek, at Fort Niagara and on streets north, south, east, and west of the NFSS. Station locations are identified in Figures 2.10 and 2.11. Exposure at these locations (in uR/hr) is indicated in Anderson et al. (1981, Appendix H, Table H3-10). The highest observed exposure (69 uR/hr) was observed at Station PL 4 located west of the southwest corner of the site. the lowest observed exposure (11 uR/hr) was observed at Station S-1 located south of the southwest corner of the site.

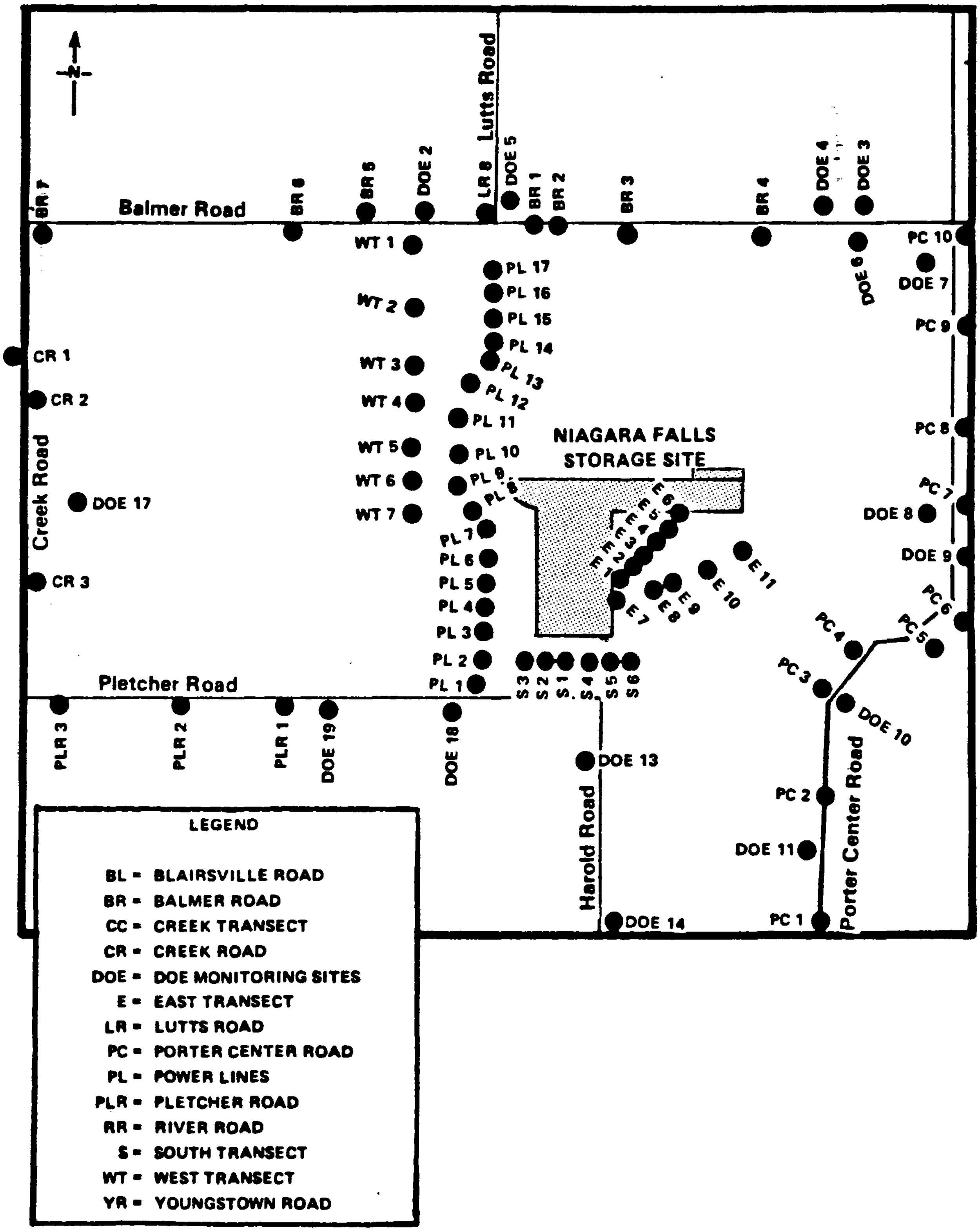


FIGURE 2.10 OFF-SITE TLD MONITORS LOCATED IN THE IMMEDIATE VICINITY OF THE DOE-NIAGARA FALLS STORAGE SITE

Source: Anderson et al. (1981)

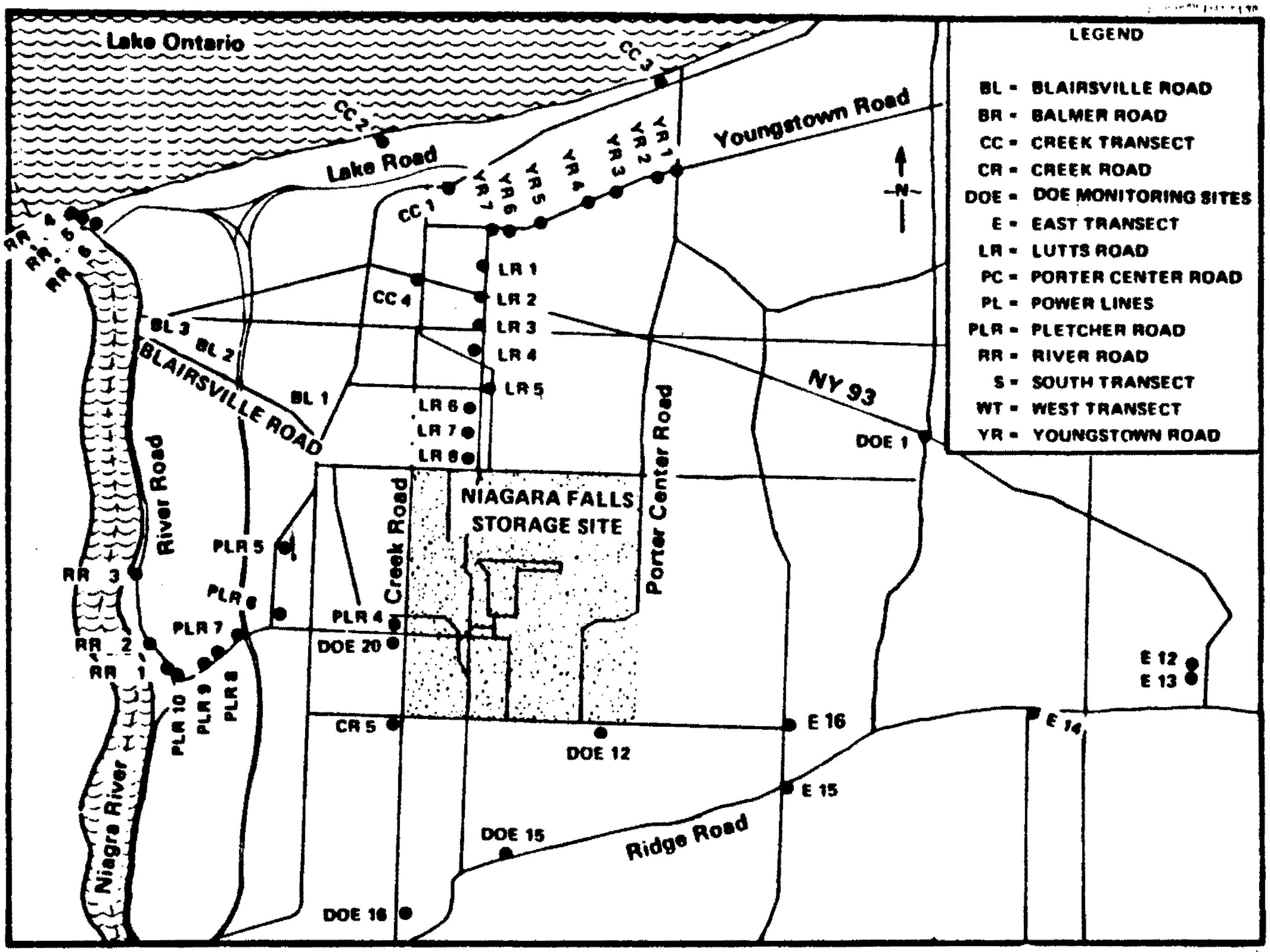


FIGURE 2.11 OFF-SITE TLD MONITORS LOCATED IN THE NIAGARA FRONTIER
(Stippled area is that shown in Figure 2.10)

Source: Anderson et al. (1981)

REFERENCES

Acres American, Inc. Hydrologic and Geologic Characterization of the DOE-Niagara Falls Storage Site, 1981.

Anderson, T. L., J. F. Dettorre, D. R. Jackson and B. S. Ausmus. A Comprehensive Characterization and Hazard Assessment of the DOE-Niagara Falls Storage Site. Battelle Columbus Laboratories 1981.

Doull, J., C. D. Klaassen, and M. O. Amdur, eds. Casarett and Doull's Toxicology - The Basic Science of Poisons. Macmillan Publishing Co., Inc., New York 1981.

Humphrey, H. W. Review of Radon Monitoring at the Niagara Falls Storage Site. National Lead Company of Ohio, 1980.

Litz, J. E. Treatment of Pitchblende Residues for Recovery of Metal Values. Hazen Research, Inc., for Cotter Corp., Canon City, Co. 1974.

NLO, Inc. and Battelle Columbus Laboratories. Scoping Investigations of Short-term and Long-term Storage Costs for Afrimet Residues-NFSS and FMPC. Report to the U. S. Department of Energy, Remedial Action Program Office, Washington, DC. 1980.

United States Environmental Protection Agency. Interim Cleanup Standards for Inactive Uranium Processing Sites. Fed. Reg. 45: 27366-27368.

United States, Nuclear Regulatory Commission. Generic Environmental Impact Statement on Uranium Milling

Vitro Corp. Summary Report: Recovery of Radium from K-65 Residue. U. S. Atomic Energy Commission, KLX-1222, Washington, DC. 1952.

Weidner, R. B. and M. W. Boback. Niagara Falls Storage Site Environmental Monitoring Report for 1979 and 1980. National Lead Company of Ohio, 1981.